Central Rivers Power

Boott Hydropower, LLC
Subsidiary of Central Rivers Power US, LLC
670 N. Commercial Street, Suite 204
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Via eFiling September 30, 2020

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, D.C. 20426

Re: Lowell Hydroelectric Project (FERC No. 2790-072);
Revised Initial Study Report

Dear Secretary Bose:

Boott Hydropower, LLC (Boott), a subsidiary of Central Rivers Power US, LLC, is the Licensee, owner, and operator of the 20-megawatt Lowell Hydroelectric Project (Project) (FERC No. 2790). Boott operates and maintains the Project under license from the Federal Energy Regulatory Commission (FERC or Commission). The Project's existing license expires on April 30, 2023. Boott is pursuing a new license for the Project using the Commission's Integrated Licensing Process (ILP) as defined in 18 Code of Federal Regulations (C.F.R.) Part 5.

Boott has initiated studies and information gathering activities as provided in the Commission's March 13, 2019 Study Plan Determination for the Project. In accordance with 18 C.F.R. § 5.15(c), Boott filed the Initial Study Report (ISR) with the Commission on February 25, 2020. As described in the ISR, data collection and/or analyses are scheduled or in progress for all studies, several of which include data collection into the 2021 study year. Boott held the ISR Meeting with relicensing participants and FERC staff on March 11, 2020, and pursuant to 18 C.F.R. § 5.15(c)(3), Boott filed the ISR Meeting Summary on March 25, 2020.

On June 12, 2020 the Commission issued a *Revised Process Plan and Schedule and Determination on Requests for Study Modifications for the Lowell Hydroelectric Project* (Revised PPS). In accordance with the Revised PPS, Boott is filing the Revised ISR with the Commission, which contains the results of the following studies: Downstream American Eel Passage Assessment; Juvenile Alosine Downstream Passage Assessment; Upstream and Downstream Adult Alosine Passage Assessment; Fish Assemblage Study; and the Recreation and Aesthetics Study. The Revised ISR will be made available to resource agencies, Indian tribes, local governments, non-governmental organizations, and members of the public on the Project's distribution list. Electronic copies of the Revised ISR will be available on the Project's public relicensing website at www.lowellprojectrelicensing.com, or via FERC's online e-Library at http://www.ferc.gov/docs-filing/elibrary.asp by searching FERC Project No. 2790 (sub-docket 072).

The Commission's regulations at 18 C.F.R. § 5.15(c)(2) and the Revised PPS require Boott to hold a Revised ISR Meeting with relicensing participants and FERC staff within 15 days of filing the Revised ISR. Accordingly, Boott will hold a Revised ISR Meeting from 9:00 a.m. to 5:00 p.m. on

October 15, 2020. Boott will hold this meeting by a video conference call and will provide the meeting information to the distribution list several days beforehand.

To allow for adequate planning, Boott respectfully requests that those planning to attend the ISR Meeting RSVP by emailing Robert Quiggle with HDR at Robert.Quiggle@hdrinc.com on or before October 9, 2020.

Pursuant to 18 C.F.R. § 5.15(c)(3) and the Revised PPS, Boott will file a Revised ISR Meeting Summary with the Commission within 15 days of the ISR Meeting (on or before October 30, 2020). Within 30 days of the filing of the ISR Meeting Summary (i.e., November 29, 2020), stakeholders may file a disagreement with the summary and/or any proposals to modify ongoing studies or for new studies with the Commission.

Please do not hesitate to contact me at (978) 935-6039 or kwebb@centralriverspower.com if you have any questions concerning this submittal.

Sincerely,
Boott Hydropower, LLC

Kevin M. Webb
Licensing Manager

cc: M. Stanley, CRP
C. Mooney, CRP

Technical Report for the Upstream and Downstream Adult Alosine Passage Assessment

Lowell Hydroelectric Project (FERC No. 2790)

Prepared For
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September 30, 2020

Table of Contents

List of Tables

List of Figures

1 Introduction

A radio-telemetry assessment of the upstream and downstream passage success for adult alewife (*Alosa pseudoharengus*) and American shad (*Alosa sapidissima*) was conducted in support of the relicensing for the Lowell Hydroelectric Project (Lowell or Project), Federal Energy Regulatory Commission (FERC) No. 2790, as identified in the Revised Study Plan (RSP) submitted by Boott Hydropower, LLC (Boott) on January 28, 2019. The approach and methodology described in the RSP for the adult alosine telemetry study was approved with modifications by the FERC in its Study Plan Determination (SPD) letter dated March 13, 2019. In their SPD, FERC staff commented on several points related to the original resource agency study requests and the adult alosine passage study proposed by Boott as part of the PSP.

- Resource agency request for a HI-Z balloon tag turbine survival assessment.
    - FERC recommended no HI-Z balloon tag assessment be conducted during 2019. Information from the radio-telemetry and desktop analyses should provide adequate estimates of project survival. In the event these findings are inconclusive FERC would consider additional study requests.
- Resource agency request to increase the number of dual-tagged (i.e., PIT and radio transmitters) from 150 alewives to 200 alewives and from 180 American shad to 200 American shad.
    - FERC indicated there was no evidence that the originally proposed sample sizes of 150 dual-tagged alewives and 180 dual tagged American shad would be insufficient to meet the goals of the study.
- Resource agency request to release tagged alewives and American shad intended to evaluate upstream passage at Lowell at the Lawrence Project rather than transport by truck to a point further upstream.
    - FERC recommended fish be released at a point further upstream to reduce the potential for fallback downstream of Lawrence immediately following tagging and release.
- Resource agency request for one group of herring to be released after May 20 due to likelihood of blueback herring present at that point in the season.
    - FERC recommended at least one release event occur after May 20.
- Resource agency request to add additional monitoring stations into the bypassed reach to help assess passage effectiveness through the existing concrete weirs.

  - FERC recommended that the spatial layout of the monitoring stations as described in the RSP should provide sufficient information to assess passage through that reach.

- Resource agency request to add an additional stationary receiver along the eastern wall of the E.L. Field tailrace to provide data redundancy.
  - FERC recommended placement of an additional stationary receiver along the eastern wall of the E.L. Field tailrace.

- Resource agency requested that Boott either (1) adjust the detection zone of RSP Station M7 further downstream or (2) add an additional station to ensure detection of fish as they approach the confluence of the bypassed reach and tailrace.
  - FERC recommended that the proposed location for Station M7 described in the RSP be installed in a manner which adequately covered the bypassed reach and tailrace confluence area.

This technical report was prepared on behalf of Boott to provide a description of the objectives, methodologies and results of the 2020 radio-telemetry assessment to evaluate the upstream and downstream passage of adult alosines at the Lowell Project.

It is important to note that the timing of this field study (April – June 2020) coincided with the rapid onset of the COVID-19 pandemic throughout the United States and that both the States of New Hampshire and Massachusetts were operating under a "stay-at-home" order during that time. Every effort was made to conduct this evaluation as described in the RSP and as approved by FERC in their SPD while still maintaining the health and safety of all Normandeau project staff and Boott operations staff.

2 Objectives

The goal of this study was to assess the behavior, approach routes, passage success, survival, and residence duration of adult American shad and alewives as they encounter the Lowell Project during their upstream and downstream migrations to determine if Project operations negatively impact their survival and production.

Specific objectives focused on upstream passage included:

- Determining route selection and behavior of upstream migrating shad and alewives at the Project under varied operational conditions, including a range of spill conditions;
- Assessing the nearfield attraction to, and entrance efficiency of, the fish lift with the river-side entrance open;
- Evaluating residence or fallback associated with the Pawtucket Gatehouse at the upstream end of the Northern Canal;

- Assessing the nearfield attraction to, and entrance efficiency of, the Pawtucket Dam ladder;
- Evaluating the internal efficiency of the Pawtucket Dam ladder;
- Collection of ladder and lift efficiency data, to include rates of approach to fishway entrances, entry into fishways, and passage under varied operational conditions, including a range of spill conditions; and
- To assess the effects of Project operations on the timing, orientation, routes and migration rates of shad and alewives.

Specific objectives focused on downstream passage included:

- Determining the proportion of post-spawned adults that select the downtown canal system or E.L. Field power canal as a downstream passage route;
- Determining post-spawned adult downstream migration route selection, passage efficiency, and residence duration associated with the power canal under various operational conditions, including a range of spill conditions;
- Comparing rates and measures of residence duration and movement among Project areas and routes utilized (e.g., spill at dam versus power canal); and
- Evaluating mortality of adult alosines passed via each potential route.

3 Project Description and Study Area

The Lowell Project is located at River Mile (RM) 41 on the Merrimack River in the City of Lowell in Middlesex County, Massachusetts, with an impoundment extending approximately 23 miles upstream into Hillsborough County, New Hampshire. The existing Lowell Project consists of: (1) a 1,093-foot-long, 15-foot-high masonry gravity dam (Pawtucket dam) that includes a 982.5-foot-long spillway with a crest elevation of 87.2 feet National Geodetic Vertical Datum 1929 (NGVD 29) topped by 5-foot-high pneumatically-operated crest gates deployed in five independently-operable zones; (2) a 720-acre impoundment with a normal maximum water surface elevation of 92.2 feet NGVD 29; (3) a 5.5-mile-long canal system which includes several small dams and gatehouses; (4) a powerhouse (E.L. Field) which uses water from the Northern Canal and contains two turbine-generator units with a total installed capacity of 15.0 megawatts (MW); (5) a 440-foot-long tailrace channel; (6) four powerhouses (Assets, Bridge Street, Hamilton, and John Street) housed in nineteenth century mill buildings along the Northern and Pawtucket Canal System containing 15 turbine-generator units with a total installed capacity of approximately 5.1 MW; (7) a 4.5-mile long, 13.8-kilovolt transmission line connecting the powerhouses to the regional distribution grid; (8) upstream and downstream fish passage facilities including a fish elevator and downstream fish bypass at the E.L. Field powerhouse, and a vertical-slot fish ladder at the Pawtucket dam; and (9) appurtenant facilities.

At the normal pond elevation of 92.2 feet NGVD 1929 (crest of the pneumatic flashboards), the surface area of the impoundment encompasses an area of approximately 720 acres. The gross storage capacity between the normal surface elevation of 92.2 feet and the minimum pond level of 87.2 feet is approximately 3,600 acre-feet. The Project operates essentially in a run-of-river (ROR) mode using automatic pond level control, and has no usable storage capacity.

The study area for the upstream and downstream adult alosine passage assessment included the mainstem Merrimack River from the upper extent of the Project's impoundment located approximately 23 river miles upstream from the Pawtucket Dam in Litchfield, New Hampshire, to the Lawrence Hydroelectric Project (FERC No. 2800), located approximately 11 river miles downstream of the Pawtucket Dam (Figure 3-1). The Project's downtown canal system and the Hamilton, Assets, Bridge Street and John Street Power Stations were also considered as part of the study area.

Figure 3–1. Merrimack River study reach considered during the spring 2020 adult alosine upstream and downstream passage assessment.

4 Methods

The upstream and downstream passage of adult alewives and American shad at the Lowell Project was evaluated using radio-telemetry during the spring of 2020. Following the release of radio-tagged individuals into the Merrimack River both upstream and downstream of the Lowell facility, their movements were monitored using a series of stationary radio-telemetry receivers in place at the Project as well as at several additional stationary monitoring receivers installed at bank-side locations upstream and downstream of the Project to inform on general movements, distribution among available passage routes and Project passage success.

4.1 Telemetry Equipment

Movements of radio-tagged individuals during the 2020 study were recorded via a series of stationary PIT[1] and radio-telemetry receivers. Telemetry equipment used during the evaluation of adult alosine passage at Lowell included Orion radio-telemetry receivers, manufactured by Sigma Eight, as well as SRX radio receivers manufactured by Lotek Wireless. Each radio-telemetry receiver was paired with either an aerial or underwater antenna (dropper antenna). Aerial antennas (four or six element Yagi) were utilized to detect radio-tagged individuals within the larger, more open sections of river, such as within the tailrace or at locations downriver of Lowell. Dropper antennas were fixed at downstream passage locations (e.g., downstream bypass). Dropper antennas were custom built by stripping the shielded ends of RG-58 coaxial cables.

Adult American shad and alewives were tagged using transmitters manufactured by Sigma-Eight (model TX-PSC-I-80 or TX-PSC-I-80D) and operating on one of five unique frequencies (149.440, 149.460, 149.480, 149.760, or 149.800 MHz). The TX-PSC-I-80 transmitters measured approximately 10 x 10 x 27 mm, weighed 4.2 g, and had an estimated battery life of 64 days when set at a 2.0 second burst rate. The TX-PSC-I-80D transmitters measured approximately 10 x 10 x 22 mm, weighed 3.3 g and had an estimated battery life of 64 days when set at a 2.0 second burst rate. Each transmitter was coded to emit a unique identifying signal so that individual shad and alewives could be identified by a receiver.

A series of PIT receivers were installed to complement the radio-telemetry array and were placed at locations intended to allow for precise tracking of shad and herring within the Project fishways. The PIT receivers and tags used during 2020 were half-duplex (HDX) and were manufactured by Oregon RFID. Each antenna loop was customized per monitoring site specifics, and equipped with a set of capacitors to properly tune the antenna loop inductance. The HDX PIT tags were encoded by the manufacturer and read only with a 64 bit unique ID. Each cylindrical PIT tag measured 3.65 mm in diameter, 32 mm long, and weighed 0.8g.

4.2 Monitoring Stations

The RSP identified monitoring stations to be set up at Lowell for the spring 2020 adult alosine passage assessment. Each monitoring location identified in the RSP was installed and consisted

[1] Passive Integrated Transponder

of a data-logging receiver, antenna, and power source[2]. Receivers were configured to receive transmitter signals from a designated area continuously throughout the study period. During installation of each station, range testing was conducted to configure the antennas and receivers in a manner which maximized detection efficiencies at each location. The operation of receivers was initially established during installation, then confirmed throughout the study period by using beacon tags. A number of beacon tags were stationed at strategic locations within the detection range of either multiple or single antennas, and they emitted signals at programmed time intervals. These signals were detected and logged by the receivers and used to record the functionality of the system throughout the study period.

The locations of monitoring stations installed for the 2020 Lowell adult alosine passage study are outlined here and presented in Figures 4-1 through 4-4.

Monitoring Station 04: Station 04 was installed within the Lowell Project impoundment and was intended to detect radio-tagged adult alosines (1) originally released downstream of Lowell and following successful passage via the fish lift or ladder at the Project, or (2) during their initial movement downstream and away from the upstream release location. Station 04 consisted of a single Lotek SRX radio-receiver and aerial antenna oriented perpendicular to the river channel. It was located approximately 2.1 miles upstream of the Pawtucket Gatehouse and approximately 5.1 miles downstream of the upper release location.

Monitoring Station 05: This station consisted of a single Lotek SRX radio-receiver and an aerial antenna calibrated to provide detection information for radio-tagged alosines (1) originally released downstream of Lowell and following successful passage via the fish lift or ladder at the Project, or (2) originally released upstream as they approached the upstream face of Pawtucket Dam.

Monitoring Station 06: Station 06 consisted of a single Orion radio-receiver and aerial antenna. It was calibrated to provide coverage of the upstream side of the Pawtucket Gatehouse and to inform on (1) radio-tagged alosines originally released downstream of Lowell which had ascended the Project fish lift and successfully exited the Northern Canal via the Pawtucket Gatehouse, or (2) radio-tagged alosines which following a period of residence upstream of the Project had approached the upstream side of the Pawtucket Gatehouse.

Monitoring Station 07: Station 07 consisted of a single Orion radio-receiver and aerial antenna calibrated to provide coverage of the downstream side of the Pawtucket Gatehouse. Station 07 was installed to inform on (1) radio-tagged adult alosines originally released downstream which had ascended the Project fish lift and approached the Pawtucket Gatehouse in an attempt to exit the Northern Canal, or (2) radio-tagged adult alosines which following a period of residence

[2] Note that three stations identified in the RSP were either modified or eliminated due to logistical issues identified during install, as discussed below. RSP Station M20 was eliminated and replaced with Station M21. RSP Stations C3 and C7 were changed from PIT to radio-telemetry receivers as noted during the ISR meeting in March, 2020.

upstream of the Project had successfully passed through the Pawtucket Gatehouse and entered the Northern Canal.

Monitoring Station 08: Station 08 consisted of a single Lotek SRX radio-receiver and aerial antenna installed to provide detection information for radio-tagged adult alosines which were (1) successfully ascended via the fish lift following release downstream, or (2) following a period of residence upstream of the Project had successfully passed through the Pawtucket Gatehouse, entered the Northern Canal and forebay and were in the vicinity of the entrances to the downstream bypass and E.L. Field turbine intake racks.

Monitoring Station 09: Station 09 consisted of a single Orion radio-receiver and underwater drop antenna. It was installed and calibrated to provide detection information for radio-tagged adult alosines which following a period of residence upstream of the Project had successfully passed through the Pawtucket Gatehouse, entered the Northern Canal and forebay, and passed downstream via the downstream bypass.

Monitoring Station 10: This station consisted of a single Lotek SRX radio-receiver and aerial antenna and was installed at a location overlooking the Project tailrace. Detections at this location were used to identify radio-tagged adult alosines which were (1) originally released downstream and subsequently ascended into the Project tailrace and were within the nearfield area of the upstream fish lift, or (2) passed downstream through the turbine units at the E.L. Field Powerhouse following a period of residence upstream of the Pawtucket Dam and within the Northern Canal upstream of the intakes. As stated in the SPD, the installation of an additional stationary receiver along the eastern wall of the E.L. Field tailrace to provide data redundancy was recommended. During the spring installation period, the installation of an additional receiver along the eastern tailrace wall was not conducted due to a lack of safe access during spring flow conditions. Detections from the receiver installed on the backside of the E.L. Field Powerhouse was used for determining presence in the Lowell tailrace.

Monitoring Station 11: Station 11 consisted of a single Lotek SRX radio-receiver and aerial antenna and was installed to scan across the bypassed reach at a point downstream of where the surge gate enters from the power canal and upstream from the downstream bypass. Detections at this location were used to (1) confirm the downstream passage of radio-tagged adult alosines which following a period of residence upstream of the Project passed downstream using the spillway or surge gate, or (2) identify radio-tagged adult alosines released at Lawrence which had initiated an ascent upstream into the bypassed reach. The detection field for Station 11 was centered at a point in the bypassed reach approximately 15% of the distance upstream from the downstream confluence with the tailrace (when considering the full length of the bypassed reach from the entrance to the Pawtucket Dam fish ladder downstream to the confluence with the tailrace).

Monitoring Station 12: Station 12 consisted of a single Lotek SRX radio-receiver and aerial antenna installed to scan across the bypassed reach at a location near to the midpoint of that section. Detections at this location were used to identify radio-tagged adult alosines which had ascended upstream within the bypassed reach. The detection field for Station 12 was centered at a point in the bypassed reach approximately 53% of the distance upstream from the downstream confluence with the tailrace (when considering the full length of the bypassed reach from the entrance to the Pawtucket Dam fish ladder downstream to the confluence with the tailrace).

Monitoring Station 13: Station 13 consist of a single Lotek SRX radio-receiver and aerial antenna installed to scan the upper section of the bypassed reach in close proximity to the entrance to the upstream fishway. Detections at this location were used to identify radio-tagged adult alosines which have ascended the full length of the bypassed reach, were upstream of the concrete weirs and within the nearfield area of the upstream fishway.

Monitoring Stations 14/15: Stations 14 and 15 each consisted of a single half-duplex PIT reader and antenna installed at the first weir upstream from the entrance to the Project fish ladder. These two readers provided fine scale detection information for PIT-tagged adult alosines which had ascended the Project bypassed reach and entered the upstream fishway. The use of two independent PIT readers at this location permitted the install of a pair of smaller loop antennas to monitor each of the two slot openings rather than a single large antenna to try to monitor the full cross section of the fish ladder.

Monitoring Station 16**:** Station 16 was not described in the RSP but was added as a supplement to Stations 14 and 15 during the installation of stationary receivers prior to the spring 2020 study. Station 16 consisted of a single Orion radio-telemetry receiver coupled to an underwater drop antenna positioned inside of the entrance to the Pawtucket Dam fish ladder. This receiver was intended to provide redundant detection information for dual-tagged adult alosines in fish ladder entrance. The drop antenna was positioned upstream of the entrance weir and immediately downstream of the first concrete weir within the lower leg of the fishway.

Monitoring Stations 17/18: Stations 17 and 18 each consisted of a single half-duplex PIT reader and antenna installed at the first weir upstream from the turn pool within the Project fish ladder. These two readers provided fine scale detection information for PIT-tagged adult alosines which had ascended the lower leg of the fishway and were beginning their ascent through the upper leg. Similar to Stations 14/15, the use of two independent PIT readers at this location permitted the install of a pair of smaller loop antennas to monitor each of the two slot openings rather than a single large antenna to try to monitor the full cross section of the fish ladder.

Monitoring Station 19: Station 19 consisted of a single half-duplex PIT reader and antenna. The antenna was installed at the upstream side of the window crowder just downstream from the exit gate at the top of the Pawtucket Dam fish ladder. Installation of the antenna at this position allowed for the usage of a smaller loop antenna than would be required to attempt to monitor the full cross section of the fish ladder. Station 19 was intended to provide fine scale detection information for PIT-tagged adult alosines which had ascended the Project bypassed reach, entered and successfully navigated the upstream fishway structure.

Monitoring Station 20: Station 20 consisted of a single half-duplex PIT reader and antenna installed to provide detection information for adult alosines which had entered the Lowell fish lift via the river-side entrance. Site conditions prior to the 2020 lift operational season were characterized by high tailwater elevations which prevented the dewatering of the lower entrance flume. As a result, options for installation of the single antenna in the lift entrance were limited. The antenna frame was sized to slide into an existing slot in the wall of the entrance flume just upstream of the riverside entrance weir and was of a size to span the full cross section of the fish lift entrance flume. The watered conditions in the exit flume eliminated the ability to move the antenna frame back and forth within the entrance flume to position at the “sweet spot” for detection range. Construction of two smaller antennas to cover the entrance was not considered due to concerns with a vertical pipe at the center of the entrance flume water column and the potential impact on upstream migrants.

Monitoring Station 21: Station 21 was not described in the RSP but was added during the installation of stationary receivers prior to the spring 2020 study, as a supplement for Monitoring Station 20. Station 21 consisted of a single Orion radio-telemetry receiver coupled to an underwater drop antenna positioned inside of the entrance to the E.L. Field fish lift. This receiver was intended to provide redundant detection information for dual-tagged adult alosines in the lift entrance. The drop antenna was positioned midway between the entrance weir the fish crowder when in its “fishing” position.

Monitoring Stations 22/23: Stations 22 and 23 each consisted of a single half-duplex PIT reader and antenna installed at the upstream end of E.L. Field fish lift exit flume. These two readers provided detection information for PIT-tagged adult alosines which had ascended upstream via the lift and were exiting into the Northern Canal. A pair of independent PIT readers were installed at this location rather than a single large antenna to monitor the full cross section of exit flume to maximize detection probability. Antennas were positioned side by side in the exit flume. During installation the exit flume was dewatered and project staff were able to move the antennas to multiple locations within the channel to identify the location where background interference was minimal.

Monitoring Station 24: Station 24 was installed at a point just downstream of the convergence of flow from the bypassed reach and E.L. Field powerhouse tailrace channel and consisted of a Lotek SRX receiver and aerial antenna. This station provided detection information for radio-tagged adult alosines (1) released at the Lawrence Project as they approach the Lowell Project, and (2) following downstream passage or a period of residence within the tailrace or bypassed reach at the Lowell Project.

Monitoring Station 25: This station was installed at a point along the mainstem of the Merrimack River downstream of both the E.L. Field Powerhouse tailrace and the confluence with the Concord River. Station 25 consisted of a single Lotek SRX receiver and aerial antenna oriented perpendicular to the river channel. This station provided detection information for radio-tagged adult alosines released (1) at the Lawrence Project as they approach the Lowell Project, and (2) following downstream passage or a period of residence within the tailrace or bypassed reach at the Lowell Project. Station 25 was installed at the Lowell Waste Water Treatment Plant, approximately 2.1 miles downstream of the tailrace.

Monitoring Station 26: Station 26 was installed at a commercial business near the midpoint between the Lowell and Lawrence projects and consisted of a single Lotek SRX receiver and aerial antenna oriented perpendicular to the river channel. This station provided detection information for radio-tagged adult alosines released (1) at the Lawrence Project as they approach the Lowell Project, and (2) following downstream passage or a period of residence within the tailrace or bypassed reach at the Lowell Project. Station 26 was located approximately 6.0 miles downstream of the tailrace.

Monitoring Station 27: This station consisted of a single Lotek SRX radio-receiver and an aerial antenna and was installed and calibrated in a manner to provide detection information for radio-tagged adult alosines as they approached the upstream face of Essex Dam (approximately 10.75 miles downstream of the Lowell tailrace).

Monitoring Stations 04 through 27 were installed and maintained throughout the duration of the spring 2020 adult alosine study to inform on the upstream and downstream passage of tagged alewives and American shad at Lowell and within the mainstem of the Merrimack River. An additional seven receivers were described in the RSP and were installed at locations within the Pawtucket Canal system (or “downtown canal” system) as part of this study. Outmigrating adult alosines can potentially enter the Pawtucket Canal system, the entrance of which sits at a point upstream of the Pawtucket Dam and the Northern Canal.

Outmigrating adult alosines entering the Pawtucket Canal first encounter the Guard Locks at a point approximately 1,700 ft downstream from the confluence with the mainstem Merrimack River. Following passage by the Guard Locks, radio-tagged adult alosines are free to move downstream through the Pawtucket Canal until flow diverges and continued passage is possible into either the Western, Merrimack, or Hamilton Canals or the individual can continue downstream in the Pawtucket Canal (via the Swamp Locks). The Western and Merrimack Canals are no longer in use and are essentially deadwater areas and the Assets Power Station (located on the Merrimack Canal) is non-functional and is planned to be eliminated from the new project license. Individuals passing into the Hamilton Canal subsequently enter the Lower Pawtucket Canal via the turbine intakes at the Hamilton Power Station or through the Hamilton Wasteway. From the lower Pawtucket Canal individuals enter into the Eastern Canal. From the Eastern Canal fish can pass into the Concord River via the Bridge Street Power Station or into the Merrimack River via the John Street Power Station or Boott Gate. The Lower Locks is rarely used to pass flow from the Eastern Canal other than for lockage. Monitoring Stations installed and operated within the downtown canal system during the 2020 adult alosine study consisted of:

Monitoring Station 28: Station 28 was installed to detect outmigrating radio-tagged adult alosines which entered the Pawtucket Canal system rather than pass the Lowell Project via one of the mainstem passage routes. The entrance to the Pawtucket Canal sits at a point upstream of the Pawtucket Dam and the Northern Canal. Station 28 was located at the Guard Locks, approximately 1,700 ft downstream from the entrance to the canal. The monitoring zone for Station 28 was focused downstream of the Guard Locks facility to ensure any detections recorded at that location were of fish which had definitively entered the Pawtucket Canal system. Monitoring Station 28 consisted of a single Orion receiver and aerial antenna.

Monitoring Station 29: Station 29 was installed to detect radio-tagged adult alosines which have moved from the Pawtucket Canal to the Hamilton Canal and reached the Hamilton Power Station. It consisted of a single Orion receiver and antenna coverage at the Hamilton Power Station intake area upstream of the intake for Hamilton Unit 1.

Monitoring Station 30: As described in the RSP, Station 30 was to consist of a single half-duplex PIT reader and antenna and installed at the Hamilton Wasteway located at the downstream end of the Hamilton Canal. During the initial site reconnaissance it was determined that the installation of a PIT antenna was not feasible at this site due to the potential flow volume and the size of the opening and as a result coverage of this route was modified to a single Orion receiver and aerial antenna.

Monitoring Station 31: This station was installed to detect radio-tagged adult alosines which had entered the Eastern Canal and reached the Bridge Street Power Station (a.k.a. “Section 8”). It consisted of a single Lotek receiver and antenna coverage of the Bridge Street Power Station discharge area. Adult alosines successfully passing here had the potential to be subsequently detected downstream at Monitoring Stations 25, 26, and 27.

Monitoring Station 32: Station 32 was installed to detect radio-tagged adult alosines which had entered the Eastern Canal and reached the John Street Power Station. It consisted of a single Orion receiver and antenna coverage at the John Street Power Station intake area.

Monitoring Station 33: Station 33 consisted of a single Orion radio receiver and antenna coverage of the John Street Power Station discharge. Adult alosines successfully passing here had the potential to be subsequently detected downstream at Monitoring Stations 25, 26, and 27.

Monitoring Station 34: As described in the RSP, Station 34 was to consist of a single half-duplex PIT reader and antenna installed at the sluice gate located at Boott Dam. During the initial site reconnaissance it was determined that the installation of a PIT antenna was not feasible at this site due to the potential flow volume and the size of the opening and as a result coverage of this route was modified to a single Orion receiver and aerial antenna. This location provided coverage to detect any fish departing the Eastern Canal for the Merrimack River during periods of gate operation to flush debris from the lower canal system.

4.3 Tagging and Release Procedures

The majority of adult American shad and alewives were collected for tagging at the Essex Dam fish lift at the Lawrence Hydroelectric Project[3]. Following collection methodology from a previous evaluation of shad movement in the lower Merrimack River (Sprankle, 2005), adult alosines were collected from a net pen placed in the exit flume of the lift which received fish directly from the hopper bucket. Following capture in the net pen, fish were dip-netted out and visually assessed to ascertain their suitability for tagging. Any individuals exhibiting excessive scale loss or other signs of significant stress were not considered for tagging and were released directly into the fish lift exit flume. Individuals deemed acceptable for tagging were quickly measured (total length, nearest mm), and gender was determined (when possible) by gently expressing eggs or milt from running-ripe fish. Radio transmitters were inserted gastrically. To facilitate gastric implantation, transmitters were affixed to a flexible tube with their trailing antenna running through the hollow center. The transmitter and leading edge of the flexible tube were pushed through the mouth and down to the stomach. Once in place, the tube was removed leaving the transmitter antenna trailing from the mouth. PIT tags were implanted into the peritoneal cavity through a small incision on the ventral side of the fish. Adult alosines during this study were either tagged with a radio transmitter (i.e., “radio-tagged”), a PIT tag (i.e., “PIT-tagged”) or both a radio and PIT tag (i.e., “dual-tagged”).

4.3.1 Upstream Release Procedures

Dual and PIT-tagged adult alosines intended to assess upstream passage effectiveness were released over six dates for alewives and five dates for American shad. All dual and PIT-tagged adult alosines were released directly into the exit flume of the upstream fishway at Lawrence following tagging.

4.3.2 Downstream Release Procedures

Radio-tagged adult alosines intended to assess downstream passage effectiveness were released over four dates for alewives and three dates for American shad. All radio-tagged adult alosines were trucked upstream and released into the Merrimack River at the Tyngsboro Riverfront Park, approximately 7.25 miles upstream of the dam. As described in the RSP, a total of 100 adult alewives and 100 adult American shad were to be radio-tagged and released upstream of the Pawtucket Dam for the purposes of evaluating downstream passage. The RSP had described an additional 50 adult alewives and 50 adult American shad which were to be radio-tagged and released directly into the downtown canal system downstream of the Guard Locks to assess passage through those facilities. Due to overriding safety concerns, Boott had ceased operation of the turbine units within the downtown canal system prior to the study period. Following consultation with the resource agencies, Boott elected to reallocate the transmitters originally purchased for the downtown canal assessment to increase the number

[3] Note that a subset of adult river herring required for the downstream passage evaluation were collected at Amoskeag fishways. Boott consulted with the resource agencies prior to tagging fish from Amoskeag. Additional details are provided in Section 5.6.

of individuals evaluated for downstream passage at the Pawtucket Dam and E.L. Field Powerhouse.

4.4 Data Collection

4.4.1 Stationary Telemetry Data

Receiver downloads occurred three to four times weekly during the period from the initial tag and release event until the end of June, 2020. Backup copies of all telemetry data were made prior to receiver initialization. Field tests at the time of download to ensure data integrity and receiver performance included confirmation of file integrity, confirmation that the last record was consistent with the downloaded data (beacon tags were critical to this step), and lastly, confirmation that the receiver was operational upon restart and actively collecting data post download. Within a data file, transmitter detections were stored as a single event (i.e., single data line). Each event included the date and time of detection, frequency, ID code, and signal strength.

4.4.2 Manual Telemetry Data

To provide supplemental detection information to the stationary receiver data set, manual tracking was conducted on a number of occasions from the time of initial release through the end of June, 2020. Manual effort was exerted in the vicinity of the Lowell Project (i.e., tailrace and headpond immediately upstream of Pawtucket Dam) on most dates when stationary telemetry equipment was checked. In addition, a number of boat or truck-based efforts were conducted to look for radio-tagged alosines within the Lowell impoundment and the reach of the Merrimack downstream to Lawrence.

4.4.3 Operational and Environmental Data

Hourly records for operations data were provided by Boott for the 2020 evaluation period and included:

- Headpond elevation (ft);
- Power canal elevation (ft);
- Headpond-power canal differential (ft);
- Tailrace elevation (ft);
- Head differential for E.L. Field turbines (ft);
- Total inflow (cfs);
- Unit 1 discharge (cfs) and output (KW);
- Unit 2 discharge (cfs) and output (KW);
- Downstream bypass discharge (cfs);
- Upstream fishway discharge (cfs);
- Downtown canal flow (cfs); and
- Spill flow through the bypassed reach.

4.4.4 Downstream Drift Assessment

Ten freshly dead adult alewives and ten American shad were radio-tagged and released downstream of Lowell during the 2020 study period. Two individuals were released on each date that a group of live test fish was released upstream of the Pawtucket Dam. Dead, radio-tagged adult alosines were released directly into the discharge of an active turbine unit at the E.L. Field powerhouse. The downstream progression of these known mortalities was recorded by the downstream stationary receivers.

4.5 Data Analysis – Upstream Passage

4.5.1 Fish Movement and Project Area Usage

The tagging, telemetry and Project operations data sets collected as part of this effort were examined and used to evaluate a number of metrics related to upstream passage success and movement through the Project area. These metrics included:

Approach Duration: This value was calculated as the duration of time from release into the Merrimack River at the Lawrence fish lift facility until the initial detection at Monitoring Station 24, the convergence area of the Pawtucket Dam bypassed reach and the E.L. Field tailrace discharge. The duration and rates of upstream ascent for tagged adult alosines from the Lawrence fish lift were further broken down to the discrete sections as bounded by Monitoring Stations 27 to 26, 26 to 25, and 25 to 24. This value was calculated for only dual-tagged individuals.

Time at Large: This value was calculated as the duration of time from the initial detection at Monitoring Station 24 until (1) upstream passage at the Project fish lift or fish ladder, or (2) movement downstream and permanently away from the project area. Final departure times were determined by the last detection at the lift or ladder structures for fish passing upstream or the last detection at Monitoring Station 24 for fish failing to pass and departing downstream. This value was calculated for only dual-tagged individuals.

Foray Events: Foray events were defined for dual-tagged individuals which moved from the convergence area (i.e., the detection zone of Station 24) upstream towards the fish lift or fish ladder as evidenced by detections on one or more receivers along those two routes leading towards possible upstream passage into the headpond above the Pawtucket Dam. Each event was initiated by a detection at either Station 10 (i.e., E.L. Field tailrace and access to the fish lift) or Station 11 (i.e., the Pawtucket Dam bypassed reach and access to the fish ladder). The duration and magnitude (i.e., most upstream station) of each foray was determined. For individuals which initiated a foray in the direction of the fish lift, each unique event could potentially encompass a sequence of detections at:

- Station 10 – E.L. Field tailrace;
- Stations 20/21 – fish lift entrance;
- Stations 22/23 – fish lift exit flume;
- Station 08 – E.L. Field forebay;

- Station 07 – downstream side of the Pawtucket Gatehouse;
- Station 06 – upstream side of the Pawtucket Gatehouse;
- Station 05 – Merrimack River immediately upstream of the Pawtucket Dam; and
- Station 04 – Merrimack River approximately 2.0 miles upstream of the Pawtucket Dam.

For individuals which initiated a foray in the direction of the fish ladder, each unique event could potentially encompass a sequence of detections at:

- Station 11 – lower portion of the Pawtucket Dam bypassed reach;
- Stations 12 – mid-point of the Pawtucket Dam bypassed reach;
- Stations 13 – upstream end of the Pawtucket Dam bypassed reach;
- Station 14/15/16 – fish ladder entrance;
- Station 17/18 – fish ladder turn pool;
- Station 19 – fish ladder exit;
- Station 05 – Merrimack River immediately upstream of the Pawtucket Dam; and
- Station 04 – Merrimack River approximately 2.0 miles upstream of the Pawtucket Dam.

Entrance Events: The total number of unique entrance events within each defined foray event for a dual-tagged adult alosines approaching either the lift or fish ladder was determined. This process relied on the ability to identify the breaks in the detection time series for a particular individual to indicate when that fish was or was not present in the vicinity of an entrance receiver. Initial attempts to determine the appropriate threshold interval for coverage of the two entrances (i.e., lift or ladder), the intervals between all successive detections at those two locations were calculated by individual and foray event. A threshold interval for determining continued presence was identified as the 97th percentile of the observed set of interval durations. However, due to overlap in receiver coverage, tagged individuals had the opportunity to be detected by both the entrance receiver and the adjacent receiver above or below. This resulted in entrance detection intervals that were heavily inflated by rapid, alternating detections between sites skewing the 97th percentile threshold and overestimating the number of entrance events. To remove the impact of double coverage and alternating site detections and more accurately capture unique entrance events, an individual needed to exhibit at least three successive detections at either entrance before moving up or downstream in order to be considered an entry event. It should be noted that the receivers at the lift and ladder entrances do not provide directional data. As a result, the reported number of "entrance events" calculated for an individual does not necessarily represent the precise number of individual entries at each structure. However, it does provide some insight into how often a tagged fish was in the vicinity of the entrance (either entering or exiting the structure).

4.5.2 Parameter Estimates for Evaluation of Upstream Passage Effectiveness

Upstream passage effectiveness for adult herring and shad at the Project fish lift and fish ladder was estimated using a standard Cormack-Jolly-Seber (CJS) model run for the set of individual encounter histories developed for each dual-tagged individual which was determined to have initiated a foray towards either passage facility. For dual-tagged individuals this approach provided a series of reach-specific "survival" or passage success estimates at the fish lift for:

- Station 10 to Stations 20/21 (tailrace to lift entrance);
- Stations 20/21 to Stations 22/23 (lift entrance to lift exit);
- Stations 22/23 to Station 08 (lift exit to E.L. Field forebay);
- Station 08 to Station 07 (E.L. Field forebay to downstream of Pawtucket Gatehouse); and
- Station 07 to Station 06 (downstream to upstream of Pawtucket Gatehouse).

This approach provided a series of reach-specific "survival" or passage success estimates at the fish ladder for:

- Station 11 to Station 12 (lower to middle of Pawtucket Dam bypassed reach);
- Station 12 to Station 13 (middle to upper Pawtucket Dam bypassed reach);
- Station 13 to Stations 14/15/16 (upper Pawtucket Dam bypassed reach to ladder entrance);
- Stations 14/15/16 to Stations 17/18 (ladder entrance to turn pool); and
- Stations 17/18 to Station 19 (ladder turn pool to exit).

Standard error and confidence bounds for each estimate were generated and those reach-specific estimates or the product of adjacent reach-specific estimates were used to evaluate upstream passage success. At the fish lift, nearfield effectiveness was estimated as the probability of a fish detected at Station 10 (E.L. Field tailrace) to move to Stations 20/21 (fish lift entrance). Internal effectiveness was estimated as the probability of a fish detected at the lift entrance to move to the lift exit (i.e., from Stations 20/21 to Stations 22/23). Total effectiveness for the Lowell fish lift was estimated as the joint probability to move from the E.L. Field tailrace to the lift exit (i.e., (Stn10 to Stn20/21)*(Stn20/21 to Stn22/23)). Additionally, the probability of successful departure from the Northern Canal (i.e., passage upstream and through the Pawtucket Gatehouse) was estimated as the probability to move from Station 07 to Station 06.

At the fish ladder, nearfield effectiveness was estimated as the probability of a fish detected at Station 13 (upper Pawtucket Dam bypassed reach) to move to Stations 14/15/16 (fish ladder entrance). Internal effectiveness was estimated as the joint probability of a fish detected at the ladder entrance to move to the ladder exit (i.e., (Stn14/15/16 to Stn17/18)*(Stn17/18 to Stn19)). Total effectiveness for the Lowell fish ladder was estimated as the joint probability to move from the upper Pawtucket Dam bypassed reach to the ladder exit (i.e., (Stn13 to Stn14/15/16)*(Stn14/15/16 to Stn17/18)*(Stn17/18 to Stn19)).

To evaluate upstream passage effectiveness using the CJS models, a suite of candidate models were developed in Program MARK (White and Burnham 1999) based on whether survival (i.e., passage success), recapture (i.e., detection), or both vary or are constant among stations. Models developed during this study included:

- Phi(t)p(t): survival and recapture may vary between receiver stations;
- Phi(t)p(.): survival may vary between stations; recapture is constant between stations;
- Phi(.)p(t): survival is constant between stations; recapture may vary between stations;
- Phi(.)p(.): survival and recapture are constant between stations;

Where;

- Phi = probability of survival
- p = probability of detection
- (t) = parameter varies
- (.) = parameter is constant

To evaluate the fit of the CJS model, goodness of fit testing was conducted for the "starting model" (i.e., the fully parameterized model) using the function RELEASE within Program MARK. Akaike's Information Criterion (AIC) was used to rank the models as to how well they fit the observed mark-recapture data. Lower AIC values denote a more explanatory yet parsimonious fit than higher AIC values. The model with the lowest AIC value was selected for the purposes of generating passage effectiveness estimates.

4.6 Data Analysis – Downstream Passage

A complete record of all valid stationary receiver detections for each radio-tagged adult alosine was generated. The pattern and timing of detections in these individual records were reviewed, and a route of passage as well as project arrival and passage times were assigned to each radio-tagged individual. In the instance that a downstream route could not be clearly determined from the collected data, the passage event for that particular fish was classified as 'unknown'.

Where data were available, the approach duration and project residence times were calculated. Values for approach duration were calculated as the duration of time from release until detection at Station 05. Upstream project residence time was defined as the duration of time from the initial detection at Station 05 until the determined time of downstream passage. Time spent immediately upstream of the dam was further evaluated using initial detection times for adult alosines at Monitoring Stations 06 and 07 to provide an understanding of passage times associated with moving through the Pawtucket Gatehouse and entering into the Northern Canal approach to the E.L. Field powerhouse.

4.6.1 Parameter Estimates for Evaluation of Downstream Passage

Downstream passage success at the Project was estimated for adult alosines using a standard Cormack-Jolly-Seber (CJS) model run for the set of individual encounter histories (i.e., the series of detection/no detection through the linear sequence of receivers from upstream to downstream). This approach provided a series of reach-specific "survival" or passage success estimates for:

- Monitoring Station 04 to Monitoring Station 05 (i.e., lower impoundment);
- Monitoring Station 05 (i.e., upstream approach) to downstream passage;
- Downstream passage to Monitoring Station 25 (i.e., first downstream receiver);
- Monitoring Station 25 (i.e., first downstream receiver) to Monitoring Station 26 (i.e., second downstream receiver); and
- Station 26 to Lawrence.

Standard error and confidence bounds for each estimate were generated. The joint probability of three reach survival estimates (i.e., (Lowell to Station 25)*(Station 25 to Station 26)*(Station 26 to Lawrence)) was used as the estimate of total passage survival for the Project. This approach resulted in a mortality estimate that included both background mortality (i.e., natural mortality such as predation) and mortality due to Project effects in the reach extending from Lowell downstream to Lawrence. Thus, the results presented in this report reflect a minimum estimate of survival attributable to Project effects for adult alosines.

To evaluate passage success using the CJS models, a suite of candidate models were developed in Program MARK based on whether survival (i.e., passage success), recapture (i.e., detection), or both vary or are constant among stations. Models developed during this study included:

- *Phi(t)p(t)*: survival and recapture may vary between receiver stations;
- *Phi(t)p(.)*: survival may vary between stations; recapture is constant between stations;
- *Phi(.)p(t)*: survival is constant between stations; recapture may vary between stations;
- *Phi(.)p(.)*: survival and recapture are constant between stations;

Where;

- *Phi* = probability of survival
- *p* = probability of detection
- *(t)* = parameter varies
- *(.)* = parameter is constant

To evaluate the fit of the CJS model, goodness of fit testing was conducted for the “starting model” (i.e., the fully parameterized model) using the function RELEASE within Program MARK. Akaike’s Information Criterion (AIC) was used to rank the models as to how well they fit the observed mark-recapture data. Lower AIC values denote a more explanatory yet parsimonious fit than higher AIC values. The model with the lowest AIC value was selected for the purposes of generating passage effectiveness estimates.

Models were prepared which evaluated downstream passage success of adult alosines at Lowell as follows:

- All adult alosines (separated as alewife or shad) – based on detection at Station 37, Station 39 and Lawrence; and

- All adult alosines (separated as alewife or shad) – adjusted for median “travel time” for freshly dead adult alosines released in Lowell tailrace to reach Lawrence (i.e., test fish with downstream travel times in excess of median drift duration manually adjusted to reflect a mortality at the Project).

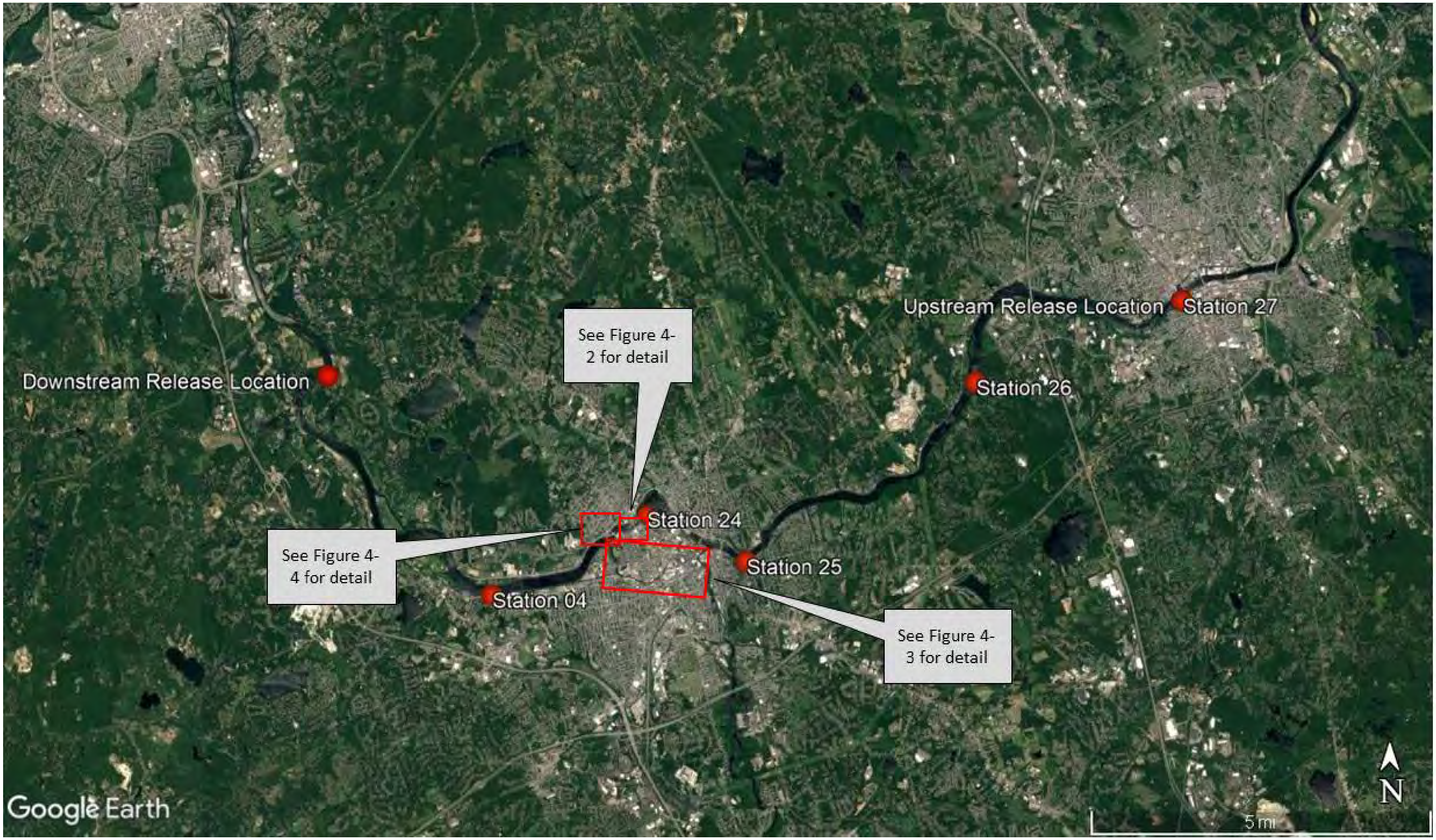

Figure 4–1. Locations of remote stationary radio-telemetry receivers installed during the 2020 adult alosine passage assessment at Lowell.

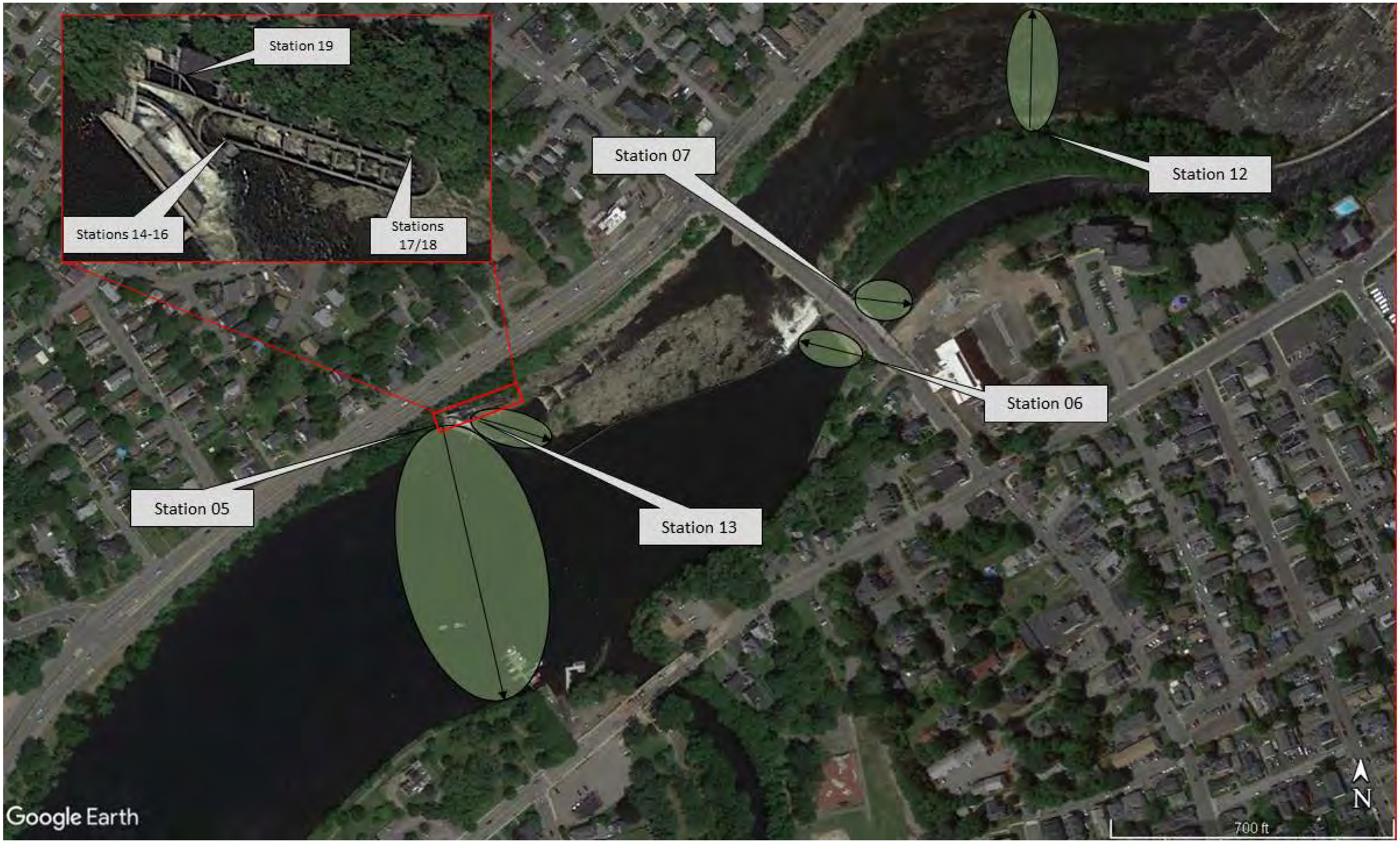

Figure 4–2. Locations and approximate detection areas for stationary radio-telemetry receivers installed upstream of Pawtucket Dam, fish ladder and Northern Gatehouse during the 2020 adult alosine passage assessment at Lowell.

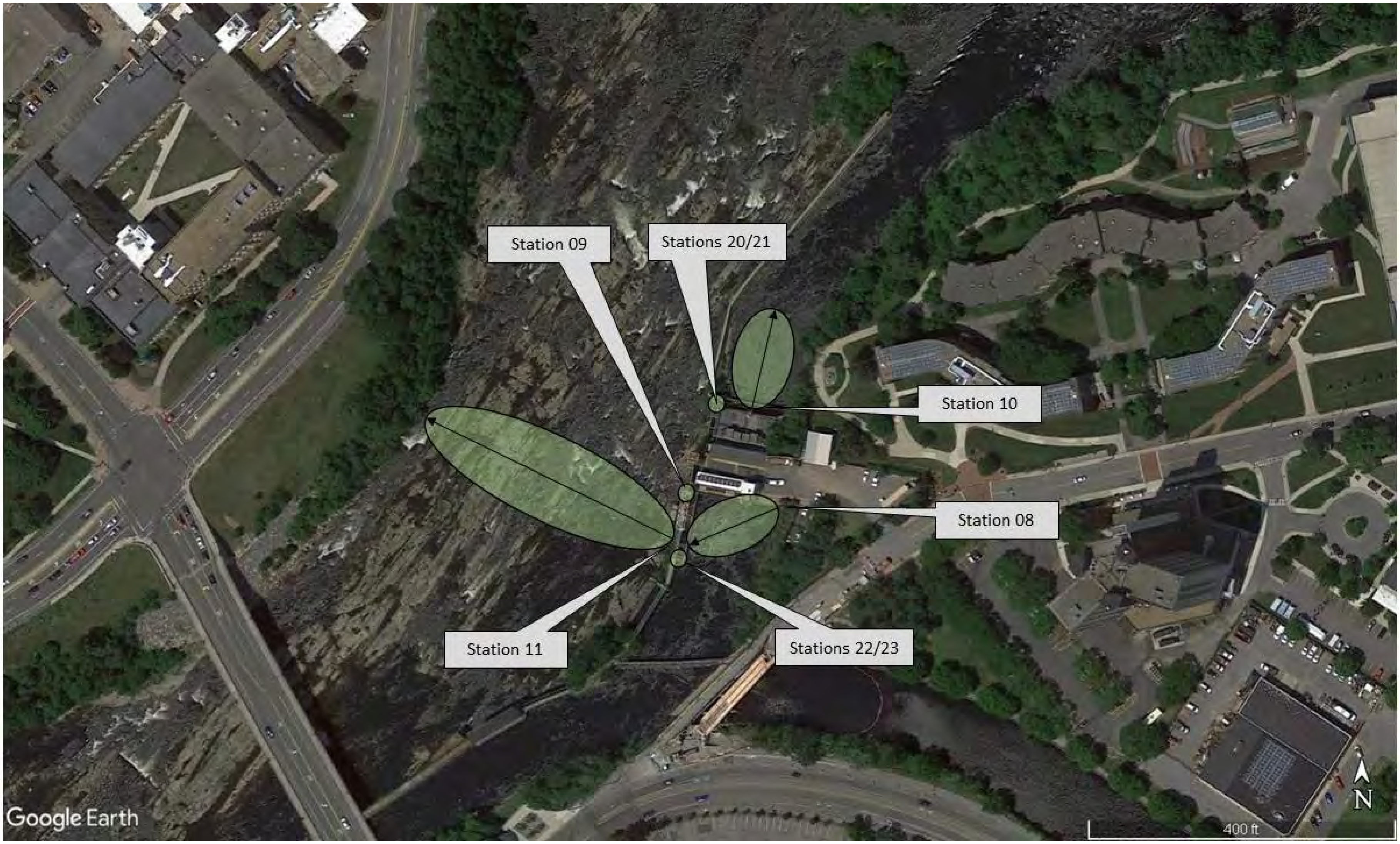

Figure 4–3. Locations and approximate detection areas for stationary radio-telemetry receivers installed in the vicinity of the E.L. Field Powerhouse during the 2020 adult alosine passage assessment at Lowell.

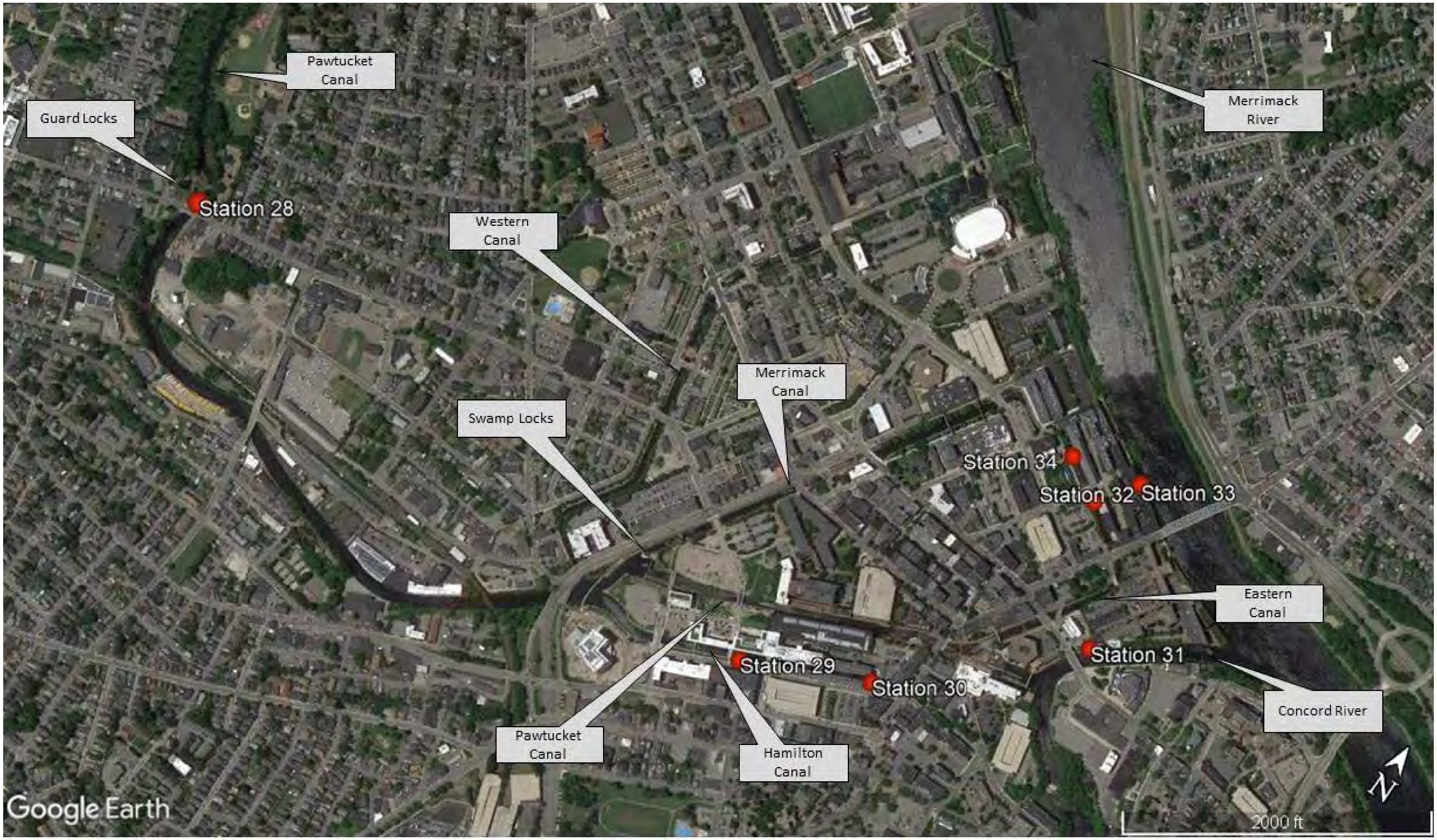

Figure 4–4. Locations and approximate detection areas for stationary radio-telemetry receivers installed within the downtown canal system during the 2020 adult alosine passage assessment at Lowell.

5 Results

5.1 Merrimack River Conditions and Lowell Project Operations

Daily water temperature at Lowell ranged from 8.0-21.1 °C over the course of the monitoring period. Figure 5-1 presents the Merrimack River inflow as recorded at the Lowell Project for the period of time from the first release of tagged adult alosines at Lawrence on May 7 until the end of the monitoring period on June 30, 2020. Merrimack River flow at Lowell ranged between 1,150 and 13,200 cfs during the nearly two month spring study period. Figure 5-2 presents the monthly flow duration curves prepared for the Lowell Project during the development of the Preliminary Application Document. The median flow condition at the Project is approximately 8,900 cfs during May and 4,900 cfs during June. Merrimack River conditions have a ~55% probability during May and a ~25% probability during June to exceed the ~8,000 cfs capacity of the E.L. Field powerhouse.

Table 5-1 summarizes the percentage of inflow records from the 2019 study period categorized by volume (to the nearest 1,000 cfs) as well as the percentage of time that each volume category is historically exceeded[4]. To help characterize the 2020 passage season, monthly exceedance probabilities less than 0.35 were classified as “high” flow conditions, 0.35 to 0.65 were classified as “normal” flow conditions, and greater than 0.65 were classified as “low” flow conditions. Inflows at the Project for the period May 7 through 31 were representative of high flow conditions (i.e., those with a probability of exceedance of less than 0.35) for 6% of the period, normal flow conditions (i.e., those with a probability of exceedance of 0.35-0.65) for 59% of the time and low flow conditions (i.e., those with a probability of exceedance of greater than 0.65) for 35% of the time. For the month of June, inflows were representative of normal flow conditions 7% of the time and low flow conditions 93% of the time.

Figure 5-3 summarizes the allocation of water among the E.L. Field powerhouse, bypassed reach, E.L. Field fish passage facility, Pawtucket Dam fish ladder and the downtown canal system at Lowell. Turbine units were in operation at the E.L. Field powerhouse for the duration of the study period with a brief exception on June 11. The E.L. Field fish passage facilities were operated throughout the study period, passing approximately 100 cfs between the hours of approximately 0600 to 1500 and 160 cfs from approximately 1500 to 0600. Two major spill events, associated with increases in river flows, occurred during the early portion of the monitoring period. Peaks for these two high flow events occurred on May 7 and May 18. Flows to the downstream canal system represented between 27-26% of the 2,000 cfs capacity during May and 27% of the 2,000 cfs capacity during June. Due to overriding safety concerns, Boott ceased operation of the turbine units within the downtown canal system prior to the study period. To the extent possible, Boott’s operations staff attempted to operate the canal system as if there were canal units available, by opening gates when river flows exceeded the hydraulic

[4] Estimates of monthly exceedance estimated from monthly flow duration curves provided in Appendix H of the PAD.

capacity of the E.L. Field turbines (7,000 to 8,000 cfs). As a result, flows through the downtown canal system were limited to passage via open gates. Manual gate manipulations during the study period were limited to two dates. A summary of the downtown canal gate operations and discharge is provided in Table 5-2.

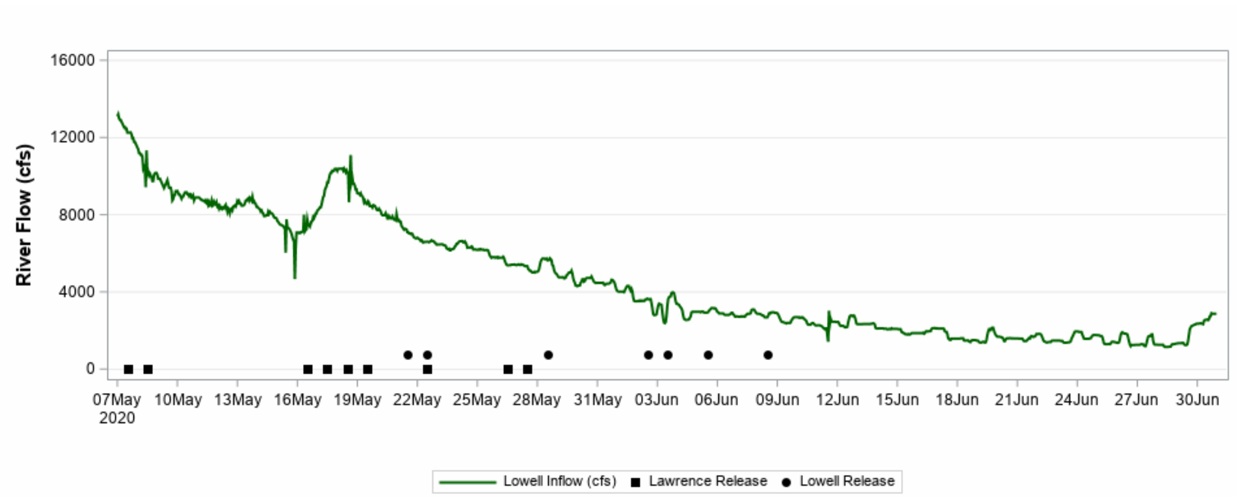

Figure 5–1. Merrimack River flow at Lowell for the period May 7 to June 30, 2020.

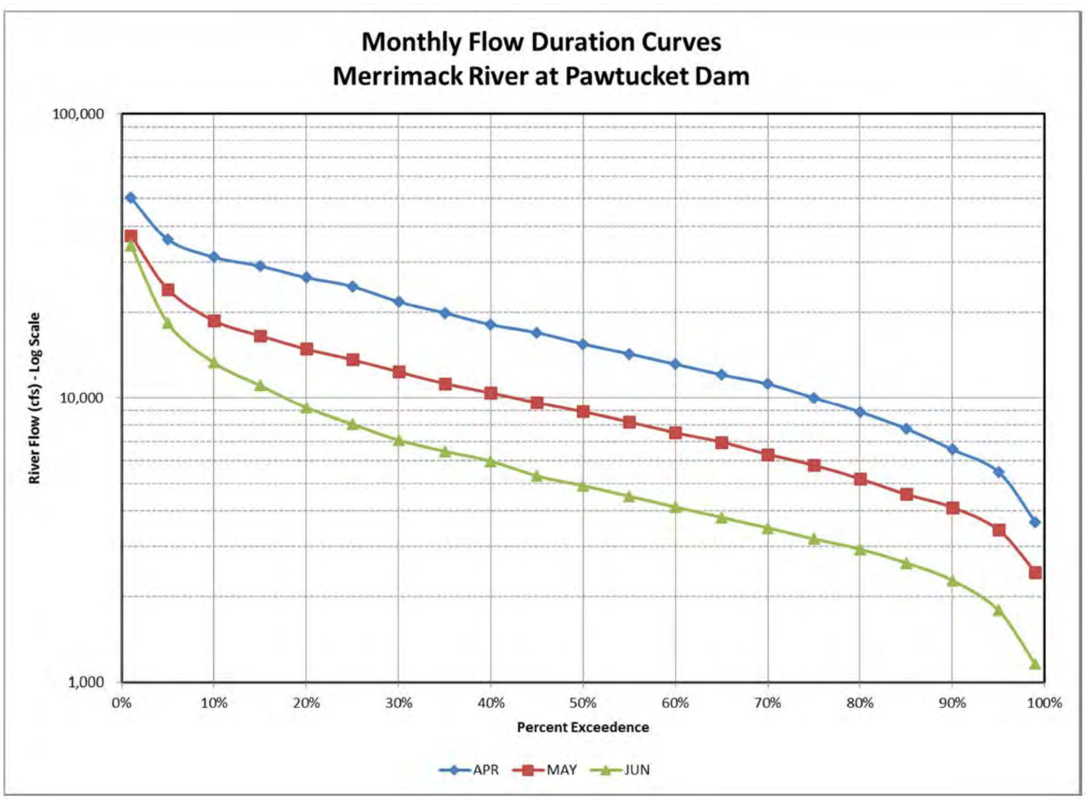

Figure 5–2. Flow duration curves for the months of April, May, and June at the Lowell hydroelectric project.

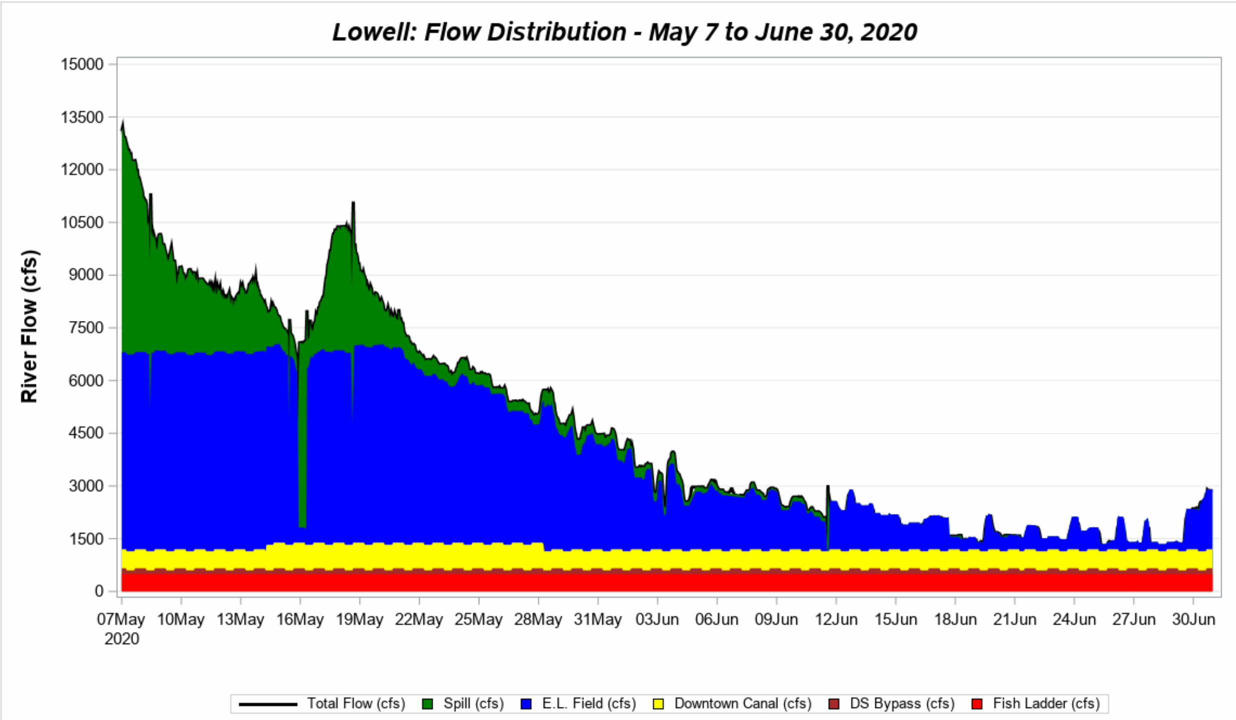

Figure 5–3. Total, spill, E.L. Field, fish ladder, downstream bypass and downtown canal system flow (cfs) for the period May 7 to June 30, 2020.

Table 5–1. Frequency of occurrence of river inflow at Lowell (to nearest 1,000 cfs) during 2020 adult alosine passage assessment and corresponding percentage of time flows are historically exceeded.

	May 7-31, 2020		June 1-30, 2020	
River Flow (nearest 1k)	Percentage of Month	Percentage of Time Historically Exceeded	Percentage of Month	Percentage of Time Historically Exceeded
1000	0.0%	100	20.6%	99
2000	0.0%	100	46.4%	94
3000	0.0%	96	26.0%	80
4000	5.2%	90	7.1%	62
5000	15.0%	82	-	-
6000	14.8%	74	-	-
7000	13.7%	65	-	-
8000	18.5%	56	-	-
9000	17.7%	48	-	-
10000	9.5%	42	-	-
11000	1.7%	9	-	-
12000	2.3%	6	-	-
13000	1.7%	LT 5	-	-

Table 5–2. Summary of downtown canal gate settings and estimated discharge values during the spring 2020 adult alosine telemetry study at Lowell.

Date	Gate	Setting	Estimated Discharge (cfs)
7-May	Guard Locks	open	542
	Swamp Locks Deep Gate	open	542
	Hamilton Wasteway	closed	0
	Lower Locks Gates	open	542
	Boott Gate	closed	0
14-May	Guard Locks	open	729
	Swamp Locks Deep Gate	open	0
	Hamilton Wasteway	open	729
	Lower Locks Gates	open	542
	Boott Gate	open	190
28-May	Guard Locks	open	542
	Swamp Locks Deep Gate	open	542
	Hamilton Wasteway	closed	0
	Lower Locks Gates	open	542
	Boott Gate	closed	0

5.2 Monitoring Station Functionality

Radio-tagged adult alosines were released into the Merrimack River beginning in early May, and the RSP called for continuous monitoring at each stationary receiver location through the end of June, 2020. An overview of system continuity for stationary receivers along the mainstem of the Merrimack and at the E.L. Field Powerhouse is provided in Figure 5-4, for receivers associated with the fish lift and ladder is provided in Figure 5-5, and for receivers positioned at locations in the downtown power canal in Figure 5-6. The majority of the radio-telemetry monitoring stations installed to evaluate passage at Lowell during the spring study operated without issue for the full period.

Interruptions in continuous coverage were observed at two locations among the mainstem and E.L. Field receivers. Station 05 (approach area immediately upstream of Pawtucket Dam) was offline from 1000 on June 4 to 1000 on June 8 due to an internal error in the receiver. To adjust for this outage detection data recorded at Station 06 was reviewed and was used as an approximate for "first detection" of outmigrants approaching the Pawtucket Dam during this period. Station 24 (convergence area of the tailrace and bypassed reach) was offline for three periods during the latter part of May (1500 on May 19 – 1100 on May 20, 1200 on May 20 – 0900 on May 22, and 1300 on May 26 – 1000 on May 27). All components at Station 24 were evaluated after the second interruption (with no obvious cause). The receiver was replaced with a new unit on May 27 and operated without issue for the remainder of the study. To adjust for this outage, detection data from Stations 10 and 11 were used as a surrogate to represent "first detection" downstream of the Project for dual-tagged fish migrating upstream. Neither outage had an impact on the ability to estimate effectiveness of the upstream fishway facilities or downstream passage survival for adult alosines.

All radio and PIT-readers installed in the E.L. Field fish lift and Pawtucket Dam fish ladder operated without issue for the duration of the study. Over the course of the study there were several minor outages at receiver stations related to the generating units within the downtown canal system. As there was no generation at any of the downtown canal turbine units over the course of the study the overall impact of these short duration outages had no impact on study results.

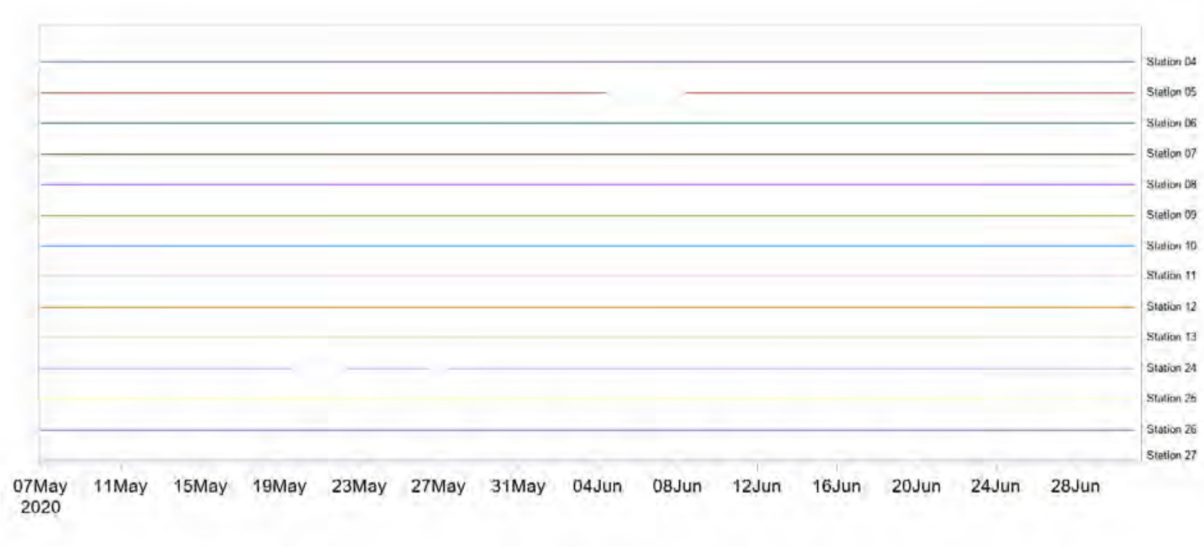

Figure 5–4. Operational coverage for telemetry receivers along the mainstem Merrimack River and vicinity of the E.L. Field Powerhouse during the adult alosine passage assessment, May 7 to June 30, 2020.

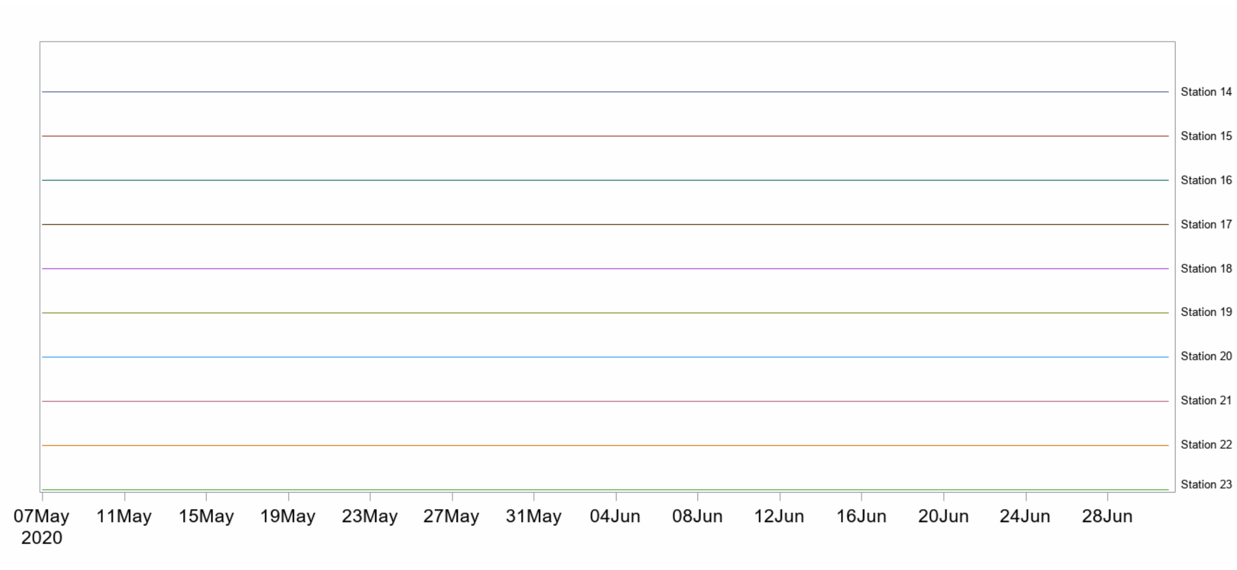

Figure 5–5. Operational coverage for telemetry receivers at the E.L. Field fish lift and Pawtucket Dam fish ladder during the adult alosine passage assessment, May 7 to June 30, 2020.

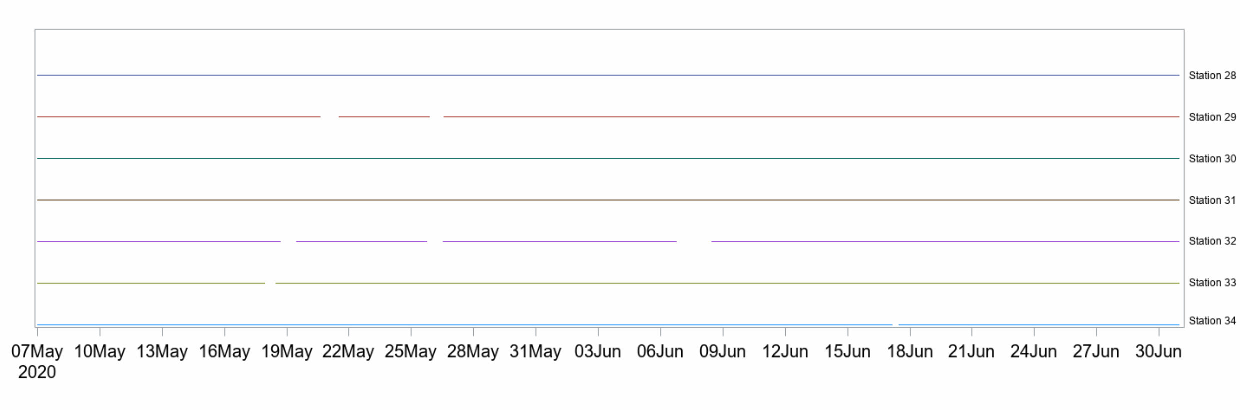

Figure 5–6. Operational coverage for telemetry receivers within the downtown canal system at the Lowell Project during the adult alosine passage assessment, May 7 to June 30, 2020.

5.3 Downstream Drift Assessment

Freshly dead, radio-tagged adult alewives (n = 10) and American shad (n =10) were released directly into the discharge of an active turbine unit at the Lowell Project during the 2020 downstream passage assessment. A total of two individuals were released in the tailrace on each date when 20 live radio-tagged adult alewives or American shad were released upstream of the Project. Table 5-3 provides a summary of the body size, tag information, release schedule and flow conditions at the time of release. These individuals were radio-tagged using a unique frequency (149.360 MHz) and a set of independent receivers were positioned at Monitoring Stations 25, 26, and 27 to scan for the approach and passage of these fish. There were no detections for any of the 20 drift individuals at Stations 25 (2.1 miles), 26 (6.0 miles) or 27 (10.75 miles) downstream of the Lowell tailrace.

Table 5–3. Summary of tagging and release information for the downstream drift assessment of adult alewives and American shad released in the Lowell tailrace during the downstream passage assessment, May 7 to June 30, 2020.

Species	Release Date	River Condition (cfs)		Frequency (ID)	Total Length (mm)
		Inflow	ELF Discharge		
Herring	21-May	7027	5127	149.360(10)	294
				149.360(11)	303
				149.360(12)	313
				149.360(13)	328
				149.360(14)	305
				149.360(15)	306
	22-May	6594	4808	149.360(16)	283
				149.360(17)	250
	28-May	5730	4188	149.360(18)	300
				149.360(19)	296
Shad	3-Jun	3278	2069	149.360(190)	452
				149.360(191)	475
				149.360(192)	438
				149.360(193)	472
				149.360(194)	438
	5-Jun	2927	1699	149.360(30)	464
				149.360(31)	499
				149.360(32)	451
				149.360(33)	487
				149.360(34)	506

5.4 Upstream Passage Effectiveness – Adult Alewives

A total of 354 adult alewives were tagged following collection at the Lawrence fish lift during May 2020 and were released for the purposes of evaluating upstream passage at Lowell (Table 5-4). Tagging was conducted over a total of six dates starting on May 7 and ending on May 19. Annual returns for river herring at Lawrence commenced on April 22 and ended on June 15 with significant daily peaks on May 17 and May 28 (Figure 5-7). Looking retrospectively, tagging dates carried out during the 2020 study were conducted during the 5th to 40th percentiles of the annual return. Of the fish tagged, 150 individuals carried both a PIT and radio-transmitter[5] and 204 carried only a PIT tag. Adult alewives tagged for evaluation of upstream passage at Lowell had a sex ratio of nearly 1:1 (51% male, 48% female; 1% undetermined). Total length of individuals tagged ranged from 260-335 mm (mean = 302 mm). A full listing of tagged individuals released at Lawrence during the spring of 2020 is provided in Appendix A.

5.4.1 Post-Release Movements

Adult alewives released downstream of Lowell were free to (1) move upstream and enter into the monitored section of the Merrimack River immediately downstream of the Project, (2) utilize the section of the Merrimack River between Lawrence and Lowell, or (3) fail to move upstream and depart the study reach to downstream of Lawrence. Each dual-tagged individual was classified into a unique post-release movement category based on their pattern of detections among the various monitoring stations. Individuals that were determined to have moved upstream to the project (based on detection at Monitoring Station 24) were classified as "Approached". Individuals that were limited to detections at the monitoring stations downstream of Lowell (i.e., Stations 25 and 26) were classified as "Lower River." Individuals that moved downstream immediately following release (as indicated by a lack of detections at any receivers upstream of Station 27 were classified as "Fallback").

As presented in Table 5-5, the majority of dual-tagged adult alewives were determined to have successfully moved upstream and into the area immediately downstream of the Lowell Project following their release. Of the 150 dual-tagged alewives released, 85% (128 of the 150) were determined to have approached Lowell. A total of 16 dual-tagged adult alewives (11% of all dual-tagged individuals) partially ascended the reach between Lowell and Lawrence but failed to approach the Project. Of those individuals, 50% ascended as far upstream as Station 26 and 50% ascended as far upstream as Station 25. Six dual-tagged individuals were undetected at any of the monitoring stations upstream of Lawrence following their release into the river.

5.4.2 Approach Duration and Time at Large

Adult alewives dual-tagged and released at Lawrence approached Lowell over a range of dates from May 7 (i.e., the first date of downstream releases) until May 23 (Figure 5-8). The median approach duration for dual-tagged adult alewives (i.e., the duration of time from release at Lawrence until initial detection at Station 24) was 19.6 hours (range = 7.7 hours to 11.9 days;

[5] All alewives that were tagged with a radio-tag and a PIT transmitter are referred to as "dual-tagged" in this report.

Table 5-6). When examined by release date, the median approach duration to Lowell was lowest for adult alewives released on May 16 and 17 and highest for those released on May 7 and 8 (Figure 5-9). The minimum, maximum, and quartile transit times through defined sections of the Merrimack River between the release location at Lawrence and the approach receiver (i.e., Station 24) at Lowell are provided in Table 5-7. Transit times calculated using the first detections for each dual-tagged fish at Stations 26, 25, and 24 resulted in median swim times of 5.9 hours from Lawrence to Station 26 (approximately 4.75 miles), 3.5 hours from Station 26 to Station 25 (approximately 3.9 miles) and 2.9 hours from Station 25 to Station 24 (approximately 2.0 miles). Table 5-8 provides the minimum, maximum, and quartile transit times through defined sections of the Merrimack River between the release location at Lawrence and Station 24 as a rate (i.e., miles per hour (mph)).

The duration of time at large following the initial detection at Station 24 for each dual-tagged individual ranged from 1.2 hours to 18.6 days (median = 1.9 days; Table 5-9). For an individual herring, the calculated value for time at large represented time from initial Station 24 detection until either (1) upstream passage out of the study area at the E.L. Field fish lift or the Pawtucket Dam fish ladder, or (2) the final movement downstream and away from the project area. When examined by eventual passage fate (i.e., passed or failed), the median duration of time at large for adult herring successfully passing upstream was less than one half that observed for adult herring which failed to pass upstream (1.7 days vs. 3.9 days, respectively).

5.4.3 Foray and Entrance Events

The full time series of recorded detections for each dual-tagged adult alewife was reviewed and each unique foray upstream towards either the E.L. Field fish lift or Pawtucket Dam fish ladder was identified based on the approach described in Section 4.5. Of the 128 dual-tagged alewives which were determined to have approached Lowell (based on detection at a minimum of Station 24) 95% (121 of the 128) made at least one upstream foray towards either the fish lift or ladder during their time at large in the Project area. Of those dual-tagged alewives, 82 individuals made one or more foray event towards the fish lift and 86 individuals made one or more foray towards the fish ladder. Fifty of the 128 dual-tagged adult alewives were determined to have made at least one foray in the direction of both the fish lift and fish ladder during their time at large in the project area.

5.4.3.1 E.L. Field Fish Lift

The 82 dual-tagged adult alewives determined to have approached the E.L. Field fish lift produced a combined total of 134 unique foray events. When considered on an individual basis, the number of unique lift forays ranged between one and five (mean = 1.6 events). Figure 5-10 summarizes the upstream magnitude for the full set of observed foray events at the fish lift for dual-tagged adult alewives. Approximately 66% of the set of upstream foray events towards the E.L. Field fish lift resulted in detection of the dual-tagged alewife at the lift entrance. Approximately 23% of upstream foray events resulted in dual-tagged adult alewives reaching the downstream side of the Pawtucket Gatehouse. Finally, 17% of the total number of 134 upstream forays in the direction of the E.L. Field fish lift resulting in dual-tagged alewives reached the upstream side of the Pawtucket Gatehouse.

Table 5-10 provides the minimum, maximum and quartile transit times for dual-tagged adult alewives moving upstream during fish lift forays. Upon entering the tailrace detection zone, the median duration of time to locate the fish lift entrance was 0.7 hours (range <0.1 hours to 13.4 hours). The median time to move from the entrance to the exit of the upstream fish lift was 10.4 hours and may be a function of a number of influences including timing of the lift schedule. Upon entering the E.L. Field Power Canal dual-tagged adult alewives proceed quickly upstream to the downstream face of the Pawtucket Gatehouse (median duration = 0.7 hours). The median duration of time for dual-tagged adult alewives to pass the Pawtucket Gatehouse was 25.7 hours (range 0.8 hours to 5.0 days).

Dual-tagged adult alewives were free to be detected at the E.L. Field fish lift entrance multiple times within a single foray event. As noted earlier, approximately 66% of upstream foray events resulted in detection at the fish lift entrance on at least one occasion. The total number of these entrance events were defined for each unique foray event and ranged from one to five (mean = 1.6; Table 5-11). Fish lift entrances were recorded over a range of dates from May 8 through May 30, 2020 (Figure 5-11). The percentage of entrance events peaked during mid-May (approximately May 17 through May 21). The diel distribution of entrance events at the E.L. Field fish lift is presented in Figure 5-12 and indicated dual-tagged alewives present at the lift entrance throughout the day with peaks during midday, evening and overnight.

5.4.3.2 Pawtucket Dam Fish Ladder

The 86 dual-tagged adult alewives determined to have approached the Pawtucket Dam fish ladder produced a combined total of 105 unique foray events. When considered on an individual basis, the number of unique fish ladder forays ranged between one and three (mean = 1.2 events). Figure 5-13 summarizes the upstream magnitude for the full set of observed foray events at the fish ladder for dual-tagged adult alewives. The majority of upstream foray events terminated between the lower and upper bypassed reach detection locations (i.e., Stations 11 and 13) with approximately 55% of upstream foray events resulting in detection of the dual-tagged alewife at the upstream end of the bypassed reach. Upon reaching the upstream end of the bypassed reach, the rate of foray failure decreased. Finally, 41% of the total number of 105 upstream forays in the direction of the Pawtucket Dam fish ladder resulted in dual-tagged alewives reaching the ladder exit.

Table 5-12 provides the minimum, maximum and quartile transit times for dual-tagged adult alewives moving upstream during fish ladder forays. Following detection at the lower bypassed reach receiver, the median duration of time to ascend the bypassed reach was 23.6 hours (range = 2.7 hours to 11.7 days). Upon detection at the upper end of the bypassed reach the median duration of time to locate the fish lift entrance was 4.0 hours. Time from initial detection at the fish ladder entrance until exit at the top of the structure ranged from 0.8 hours to 2.0 days (median = 2.9 hours). The median time for dual-tagged adult alewives to transit the lower leg of the fish ladder was 2.1 hours and to transit the upper leg of the fish ladder was 1.1 hours.

Dual-tagged adult alewives were free to be detected at the Pawtucket Dam fish ladder entrance multiple times within a single foray event. Approximately 51% of upstream foray events resulted in detection at the fish ladder entrance on at least one occasion. The total number of these entrance events were defined for each unique foray event and ranged from one to three (mean = 1.2; Table 5-13). The average number of entrance detections during a single foray was higher for the earlier release groups of dual-tagged adult alewives. Fish ladder entrances for dual-tagged adult alewives were recorded over a range of dates from May 7 through May 23, 2020 (Figure 5-14). Similar to the fish lift, the percentage of entrance events peaked during mid-May (approximately May 17 through May 21). The diel distribution of entrance events at the Pawtucket Dam fish ladder is presented in Figure 5-15 and indicated dual-tagged alewives were present at the ladder entrance throughout the day.

5.4.4 PIT-Tagged Individuals

5.4.4.1 E.L. Field Fish Lift

Limitations detailed for the installation of Monitoring Station 20 in Section 4.2 precluded effective monitoring of PIT-tagged fish at that location. As a result, detection potential for the 204 PIT-tagged adult alewives at the E.L. Field fish lift was limited to the upper exit flume (Stations 22 and 23). PIT-tagged adult alewives were detected at the upper exit flume over a range of dates from May 10 through June 14, 2020 (Figure 5-16). The majority of PIT detections for tagged adult alewives at the lift entrance occurred between 0800 and 1800 with a pronounced peak at 1500 (Figure 5-17). Of the possible 204 PIT-tagged adult alewives, 88 (43%) were determined to have been present in the E.L. Field fish lift exit flume over the course of the study (Table 5-14).

5.4.4.2 Pawtucket Dam Fish Ladder

A total of 204 PIT-tagged adult alewives were released at Lawrence (Table 5-4) and 101 (49.5%) of those individuals were detected at the PIT reader stations installed within the Pawtucket Dam fish ladder (Table 5-15). PIT-tagged adult alewives were detected at the entrance to the Pawtucket Dam fish ladder over a range of dates from May 9 to May 27, 2020 (Figure 5-18). The majority of PIT detections for tagged adult alewives at the fish ladder entrance occurred between 0900 and 1800 (Figure 5-19). Of the 101 PIT-tagged adult alewives detected at the entrance reader, 94% (95 of the 101) were subsequently detected at the turn pool reader and 68% of those (65 of the 95) were subsequently detected at the exit reader. Table 5-16 provides the transit durations for PIT-tagged adult alewives based on initial detections at the entrance, turn pool and exit readers. The median duration to transit the lower leg of the fish ladder was 1.6 hours and to transit the upper leg of the fish ladder was 1.2 hours. The median duration for a PIT-tagged alewife to move from the Pawtucket Dam fish ladder entrance to the exit was 3.8 hours.

5.4.5 Upstream Passage Effectiveness – Lowell Fish Lift

The CJS model *Phi*(t)*p*(t) provided the best fit for the observed mark-recapture data associated with upstream movements of dual-tagged adult alewives approaching the E.L. Field fish lift (Table 5-17). Specific passage success estimates at Lowell ranged between 0.527- 1.0 among discretely monitored river sections from the tailrace to the point upstream of the Pawtucket

Gatehouse (Table 5-18). The detection efficiency for receivers associated with upstream passage of dual-tagged adult alewives at the fish lift ranged from 0.724-1.0 (Table 5-19). The lowest detection value was associated with the two PIT readers positioned in the exit flume of the upstream fishway.

As defined in Section 4.5.2, the specific passage success estimates obtained from the CJS model for dual-tagged adult alewives approaching the E.L. field fish lift were used to estimate (1) near field attraction, (2) fish lift internal efficiency, and (3) overall fish lift effectiveness. As stated earlier the nearfield attraction rate is the probability of an adult herring to move from the nearfield/tailrace region into the downstream entrance of the lift, the internal efficiency is the probability of an adult herring to move from the lift entrance to the lift exit and the overall efficiency is the probability of an adult herring to move from the tailrace/nearfield region to the upstream exit from the fish lift. Upstream passage effectiveness estimates for dual-tagged adult alewives at the Lowell fish lift during 2020 are as follows:

- Nearfield attraction effectiveness:
  - 83.3% (75% CI = 77.4-88.0%)
- Fish lift internal efficiency:
  - 52.7% (75% CI = 45.0-60.3%)
- Overall fish lift effectiveness:
  - 43.9% (75% CI = 39.3-51.4%)

5.4.6 Upstream Passage Effectiveness – Lowell Fish Ladder

The CJS model *Phi*(t)*p*(t) provided the best fit for the observed mark-recapture data associated with upstream movements of dual-tagged adult alewives approaching the Pawtucket Dam fish ladder (Table 5-20). Specific passage success estimates at Lowell ranged between 0.722-0.930 among discretely monitored river sections from Station 11 in the lower bypassed reach to the exit of the fish ladder upstream of the Pawtucket Dam (Table 5-21). The detection efficiency for receivers associated with upstream passage of dual-tagged adult alewives at the fish ladder ranged from 0.905-1.0 (Table 5-22).

As defined in Section 4.5.2, the specific passage success estimates obtained from the CJS model for dual-tagged adult alewives approaching the Pawtucket Dam fish ladder were used to estimate (1) near field attraction, (2) fish ladder internal efficiency, and (3) overall fish ladder effectiveness. As stated earlier the nearfield attraction rate is the probability of an adult herring to move from the nearfield/upper bypass region into the downstream entrance of the ladder, the internal efficiency is the probability of an adult herring to move from the ladder entrance to the ladder exit and the overall efficiency is the probability of an adult herring to move from the nearfield/upper bypass region to the upstream exit from the fish ladder. Upstream passage effectiveness estimates for dual-tagged adult alewives at the Pawtucket Dam fish ladder during 2020 are as follows:

- Nearfield attraction effectiveness:
  - 93.0% (75% CI = 87.9-96.0%)

- Fish ladder internal efficiency:
    - 81.3% (75% CI = 75.1-87.5%)
- Overall fish ladder effectiveness:
    - 75.6% (75% CI = 69.2-82.2%)

Table 5–4. Summary of tagging and release information for adult alewives released at Lawrence during the Lowell upstream passage assessment, May 7 to June 30, 2020.

Date	Type	Number
7-May	Dual	25
	PIT	34
8-May	Dual	25
	PIT	34
16-May	Dual	14
	PIT	-
17-May	Dual	36
	PIT	68
18-May	Dual	25
	PIT	34
19-May	Dual	25
	PIT	34
Total	Dual	150
	PIT	204

Table 5–5. Summary of post-release movement for adult alewives tagged and released downstream of Lowell during spring 2020.

Post-release Movement	Release Group						
	7-May	8-May	16-May	17-May	18-May	19-May	All
Approach	20	21	12	30	22	23	128
Downstream							0
Stn 26	2	2	1	3	0	0	8
Stn 25	2	2	0	2	1	1	8
Fallback	1	0	1	1	2	1	6
Total	25	25	14	36	25	25	150

Table 5–6. Minimum, maximum, and quartile values of approach duration (hours) for dual-tagged adult alewives released downstream of Lowell during the spring 2020 upstream passage assessment.

Alewife - Approach Duration (hrs)					
Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
7-May	8.3	286.1	12.5	27.5	39.4
8-May	12.4	223.7	20.2	28.1	29.9
16-May	8.9	31.1	10.0	10.4	12.9
17-May	7.7	48.5	9.0	11.2	22.2
18-May	9.3	55.9	10.6	16.1	22.0
19-May	11.1	78.5	18.8	24.1	28.6
All	**7.7**	**286.1**	**11.0**	**19.6**	**28.6**

Table 5–7. Minimum, maximum, and quartile values of upstream transit durations (hours) for dual-tagged adult alewives released downstream of Lowell during the spring 2020 upstream passage assessment.

Alewife - Upstream Transit Times (hrs)						
Downstream Reach	Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
Lawrence to Station 26 (4.75 miles)	7-May	3.3	36.6	5.3	8.25	14.6
	8-May	3.9	8.6	5.6	6.6	7.1
	16-May	4.1	14	5.25	5.7	7.4
	17-May	3.1	74.9	4.4	5.4	6.1
	18-May	3.7	13.5	4.5	5.45	7.3
	19-May	5.5	25.5	5.8	5.9	6.4
	All	**3.1**	**74.9**	**4.7**	**5.9**	**7.1**
Station 26 to Station 25 (3.9 miles)	7-May	2.9	139.7	3.4	4.7	25.9
	8-May	3.8	27.3	7	19.5	21.1
	16-May	2.6	11.7	2.6	2.6	3.1
	17-May	2.4	40.7	2.7	3.2	12.4
	18-May	2.6	13.8	3.2	3.65	8.9
	19-May	2.1	6.1	2.2	2.6	3.4
	All	**2.1**	**139.7**	**2.7**	**3.5**	**11.7**
Station 25 to Station 24 (2.0 miles)	7-May	1.9	186.3	2.4	4	13.3
	8-May	2	12.4	2.65	2.95	7.3
	16-May	2.1	11.7	2.15	2.2	2.4
	17-May	1.4	13.3	1.6	2.1	3.8
	18-May	1.9	97	2.4	2.9	6.2
	19-May	14.5	70.4	15.4	16.2	47
	All	**1.4**	**186.3**	**2.2**	**2.9**	**8.4**

Table 5–8. Minimum, maximum, and quartile values of upstream transit rates (mph) for dual-tagged adult alewives released downstream of Lowell during the spring 2020 upstream passage assessment.

Alewife - Upstream Transit Rates (mph)						
Downstream Reach	Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
Lawrence to Station 26 (4.75 miles)	7-May	0.13	1.44	0.33	0.58	0.90
	8-May	0.55	1.22	0.67	0.72	0.85
	16-May	0.34	1.16	0.64	0.83	0.91
	17-May	0.06	1.53	0.78	0.88	1.08
	18-May	0.35	1.28	0.65	0.87	1.06
	19-May	0.19	0.86	0.74	0.81	0.82
	All	**0.06**	**1.53**	**0.67**	**0.81**	**1.01**
Station 26 to Station 25 (3.9 miles)	7-May	0.03	1.34	0.15	0.83	1.15
	8-May	0.14	1.03	0.18	0.20	0.56
	16-May	0.33	1.50	1.26	1.50	1.50
	17-May	0.10	1.63	0.31	1.22	1.44
	18-May	0.28	1.50	0.44	1.07	1.22
	19-May	0.64	1.86	1.15	1.50	1.77
	All	**0.03**	**1.86**	**0.33**	**1.11**	**1.44**
Station 25 to Station 24 (2.0 miles)	7-May	0.01	1.05	0.15	0.50	0.83
	8-May	0.16	1.00	0.27	0.68	0.76
	16-May	0.17	0.95	0.84	0.91	0.93
	17-May	0.15	1.43	0.53	0.95	1.25
	18-May	0.02	1.05	0.32	0.69	0.83
	19-May	0.03	0.14	0.04	0.12	0.13
	All	**0.01**	**1.43**	**0.24**	**0.69**	**0.91**

Table 5–9. Minimum, maximum, and quartile values of time at large (hours) for dual-tagged adult alewives released downstream of Lowell during the spring 2020 upstream passage assessment.

Alewife - Time at Large (hrs)					
Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
7-May	16.0	333.6	91.6	171.3	234.9
8-May	3.1	411.4	43.7	161.9	206.6
16-May	20.2	97.9	38.8	46.6	67.5
17-May	1.2	192.5	22.4	41.6	54.7
18-May	12.1	445.6	28.8	58.4	83.3
19-May	2.0	148.5	6.0	26.2	39.5
All	**1.2**	**445.6**	**23.1**	**46.9**	**134.9**
Fate	**Minimum**	**Maximum**	**Q25**	**Q50 (Median)**	**Q75**
Failed	1.2	445.6	22.5	94.8	181.1
Passed	2.1	254.8	24.4	41.5	67.4

Table 5–10. Minimum, maximum, and quartile values of transit durations (hours) for dual-tagged adult alewives during fish lift forays recorded during the spring 2020 upstream passage assessment.

Alewife - Fish Lift Foray Durations (hrs)					
Lift Foray Segment	Minimum	Maximum	Q25	Q50 (Median)	Q75
Tailrace to Entrance	<0.1	13.4	0.4	0.7	1.7
Entrance to Exit	0.2	46.9	1.5	10.4	19.1
Exit to Forebay	<0.1	<0.1	<0.1	<0.1	<0.1
Forebay to Pawtucket Gatehouse	0.2	1.5	0.5	0.7	0.8
Pawtucket Gatehouse to Upstream	0.8	120.2	4.9	25.7	47.4

Table 5–11. Minimum, maximum, and mean number of fish lift entrance events per upstream foray for dual-tagged adult alewives recorded during the spring 2020 upstream passage assessment.

Alewife - Number of Lift Entrance Detection Events			
Release Date	Minimum	Maximum	Mean
7-May	1	2	1.3
8-May	1	3	1.4
16-May	1	2	1.1
17-May	1	2	1.2
18-May	1	2	1.2
19-May	1	2	1.1
All	**1**	**3**	**1.2**

Table 5–12. Minimum, maximum, and quartile values of transit durations (hours) for radio-tagged adult alewives during fish ladder forays recorded during the spring 2020 upstream passage assessment.

Alewife - Fish Ladder Foray Durations (hrs)					
Ladder Foray Segment	Minimum	Maximum	Q25	Q50 (Median)	Q75
Lower Bypass to Mid Bypass	0.8	236.3	3.2	10.0	16.9
Mid Bypass to Upper Bypass	0.5	30.4	1.0	2.1	9.6
Lower Bypass to Upper Bypass	2.7	281.9	16.3	23.6	35.9
Upper Bypass to Entrance	0.3	258.7	1.0	4.0	19.0
Entrance to Turn Pool	0.3	102.4	1.3	2.1	4.1
Turn Pool to Exit	0.2	47.4	0.6	1.1	3.2
Entrance to Exit	0.8	49.1	2.2	2.9	14.7

Table 5–13. Minimum, maximum, and mean number of fish lift entrance events per upstream foray for dual-tagged adult alewives recorded during the spring 2020 upstream passage assessment.

Alewife - Number of Ladder Entrance Detection Events			
Release Date	Minimum	Maximum	Mean
7-May	1	5	2.6
8-May	1	5	2.1
16-May	1	3	1.6
17-May	1	3	1.6
18-May	1	4	1.4
19-May	1	2	1.1
All	**1**	**5**	**1.6**

Table 5–14. Number of PIT-tagged adult alewives released at Lawrence and recorded at in the exit channel of the E.L. Field Powerhouse fish lift during the spring 2020 upstream passage assessment.

Alewife - PIT Reader Counts	
Release Date	Fish Lift Exit
7-May	12
8-May	13
16-May	46
17-May	17
18-May	0
All	**88**

Table 5–15. Number of PIT-tagged adult alewives released at Lawrence and recorded at in the entrance, turn pool and exit of the Pawtucket Dam fish ladder during the spring 2020 upstream passage assessment.

Alewife - PIT Reader Counts			
Release Date	Entrance	Turn Pool	Exit
7-May	18	17	7
8-May	18	16	5
16-May	51	48	41
17-May	13	13	12
18-May	1	1	0
All	**101**	**95**	**65**

Table 5–16. Minimum, maximum, and quartile values for PIT-tagged adult alewives moving within the Pawtucket Dam fish ladder during the spring 2020 upstream passage assessment.

PIT-Tagged Alewife - Fish Ladder Durations (hours)					
Ladder Foray Segment	Minimum	Maximum	Q25	Q50 (Median)	Q75
Entrance to Turn Pool	0.2	196	0.8	1.6	4.9
Turn Pool to Exit	0.2	56	0.7	1.2	2.9
Entrance to Exit*	0.4	69.4	1.9	3.8	17.1

*Entrance to Exit duration calculated for individuals which ascended full length of ladder. Entrance to turn pool durations include individuals which may have ascended only as far upstream as the turn pool (i.e., did not pass full length of structure)

Table 5–17. CJS model selection criteria for upstream passage effectiveness of the E.L. Field fish lift for adult alewives at Lowell during spring 2020.

Model	AICc	Delta AICc	AICc Weight	Model Likelihood	No. Parameters	Deviance
Phi(t)p(t)	375.79	0.00	1.00	1.00	10	37.83
Phi(t)p(.)	466.96	91.18	0.00	0.00	6	137.30
Phi(.)p(t)	478.19	102.40	0.00	0.00	8	144.40
Phi(.)p(.)	589.86	214.07	0.00	0.00	2	268.35

Table 5–18. Passage success probability estimates (*Phi)*, standard errors, and likelihood 75 and 95% confidence intervals for dual-tagged adult alewives approaching the E.L. Field fish lift during 2020.

Reach	*Phi*	SE	95% CI		75% CI	
Tailrace to Entrance	0.833	0.046	0.724	0.905	0.774	0.880
Entrance to Exit	0.527	0.067	0.396	0.654	0.450	0.603
Exit to Forebay	1.000	0.000	-	-	-	-
Forebay to Pawtucket Gatehouse	1.000	0.000	-	-	-	-
Pawtucket Gatehouse to Upstream	0.793	0.075	0.610	0.904	0.694	0.867

Table 5–19. Detection efficiency estimates (*p)*, for monitoring stations installed to detect dual-tagged adult alewives approaching the E.L. Field fish lift during 2020.

Location	S	SE	95% CI	
Station 21	1.000	0.000	-	-
Station 22/23	0.724	0.083	0.538	0.856
Station 08	0.828	0.070	0.647	0.926
Station 07	1.000	0.000	-	-
Station 06	1.000	0.000	-	-

Table 5–20. CJS model selection criteria for upstream passage effectiveness of the Pawtucket Dam fish ladder for adult alewives at Lowell during spring 2020.

Model	AICc	Delta AICc	AICc Weight	Model Likelihood	No. Parameters	Deviance
Phi(t)p(t)	502.57	0.00	1.00	1.00	13	59.49
Phi(t)p(.)	520.06	17.49	0.00	0.00	7	89.34
Phi(.)p(t)	578.38	75.81	0.00	0.00	8	145.61
Phi(.)p(.)	648.23	145.66	0.00	0.00	2	227.65

Table 5–21. Passage success probability estimates (*Phi)*, standard errors, and likelihood 75 and 95% confidence intervals for dual-tagged adult alewives approaching the Pawtucket Dam fish ladder during 2020.

Reach	*Phi*	SE	95% CI		75% CI	
Lower Bypass to Mid Bypass	0.722	0.048	0.618	0.806	0.663	0.774
Mid Bypass to Upper Bypass	0.918	0.035	0.818	0.965	0.868	0.950
Upper Bypass to Entrance	0.930	0.034	0.827	0.973	0.879	0.960
Entrance to Turn Pool	0.913	0.041	0.793	0.966	0.853	0.950
Turn Pool to Exit	0.891	0.047	0.760	0.955	0.824	0.935

Table 5–22. Detection efficiency estimates (*p)*, for monitoring stations installed to detect dual-tagged adult alewives approaching the Pawtucket Dam fish ladder during 2020.

Location	S	SE	95% CI	
Station 11	1.000	0.000	1.000	1.000
Station 12	0.982	0.017	0.886	0.998
Station 13	1.000	0.000	1.000	1.000
Station 14/15/16	1.000	0.000	1.000	1.000
Station 17/18	0.930	0.039	0.805	0.977
Station 19	0.905	0.045	0.772	0.964

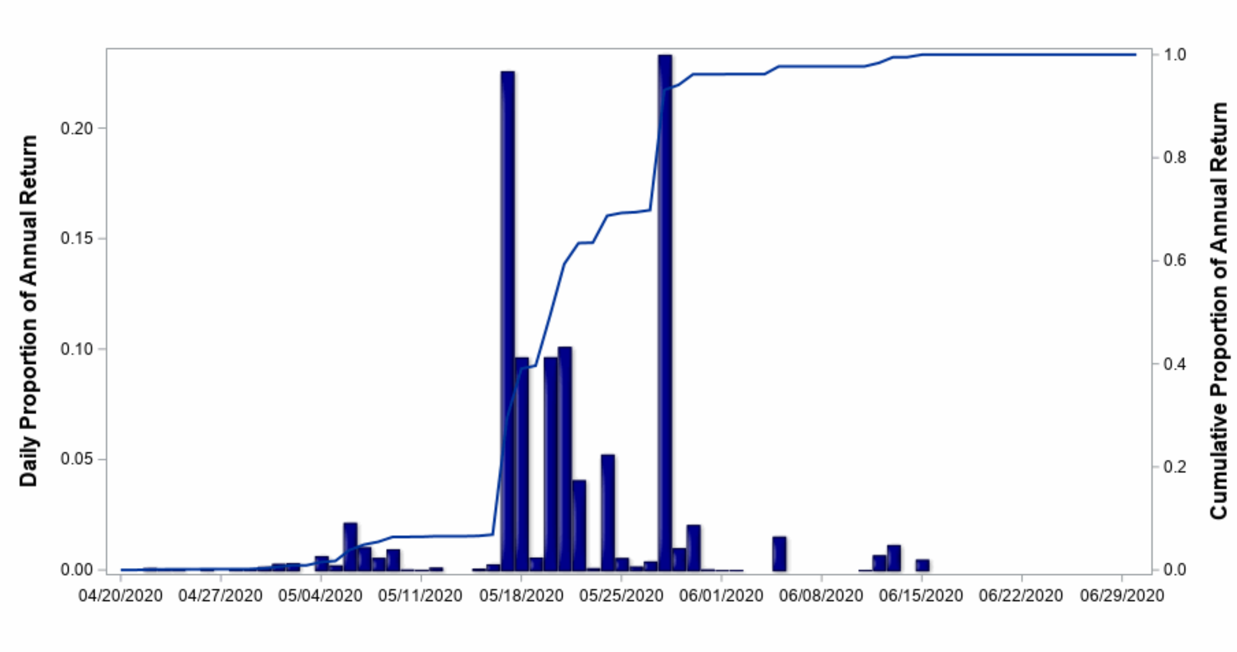

Figure 5–7. Daily (bars) and cumulative (line) percentage of adult river herring returns at the Lawrence fishway as enumerated by Salmonsoft recording for the 2020 passage season.

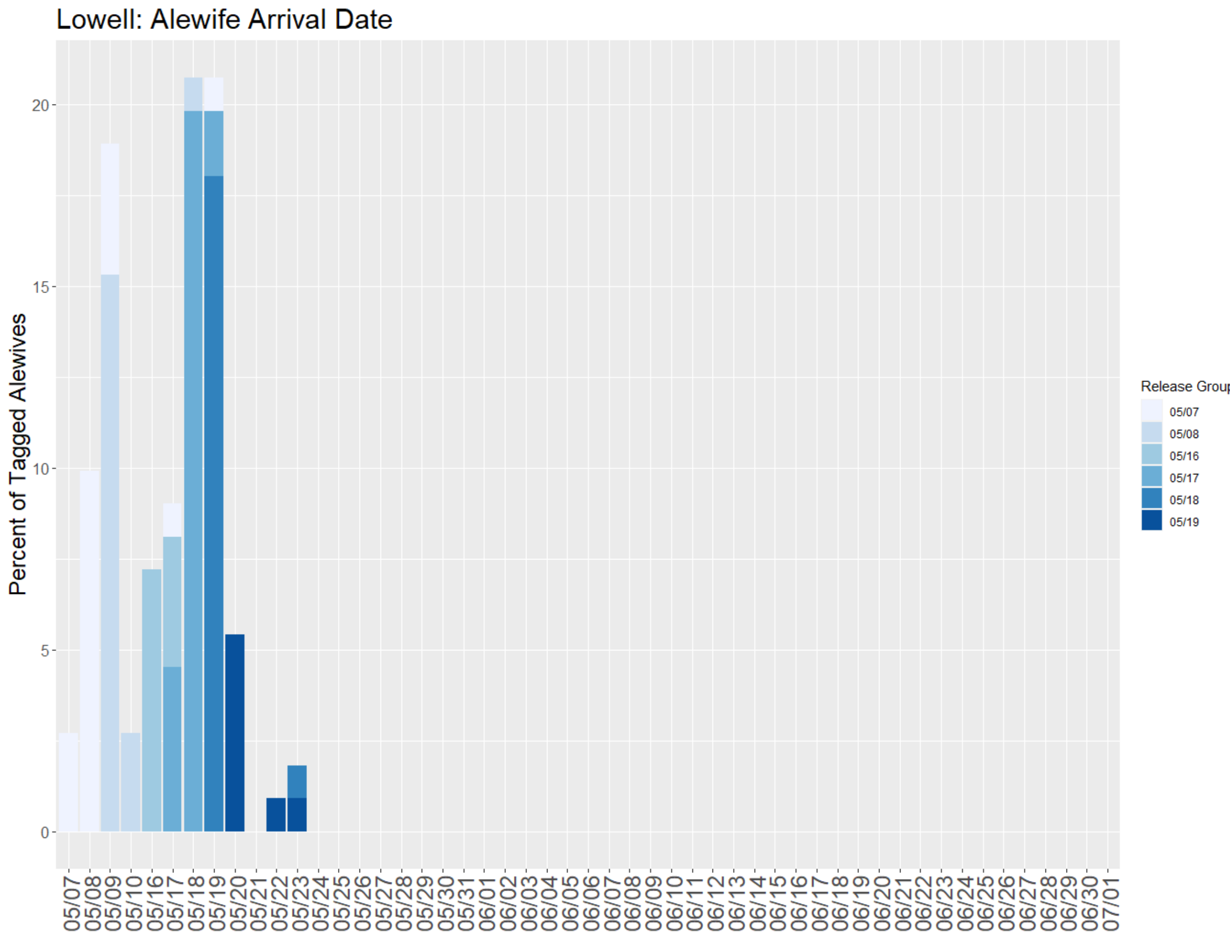

Figure 5–8. Distribution of arrival dates for dual-tagged adult alewives originally released downstream of Lowell at the Lawrence Project as part of the spring 2020 upstream passage assessment.

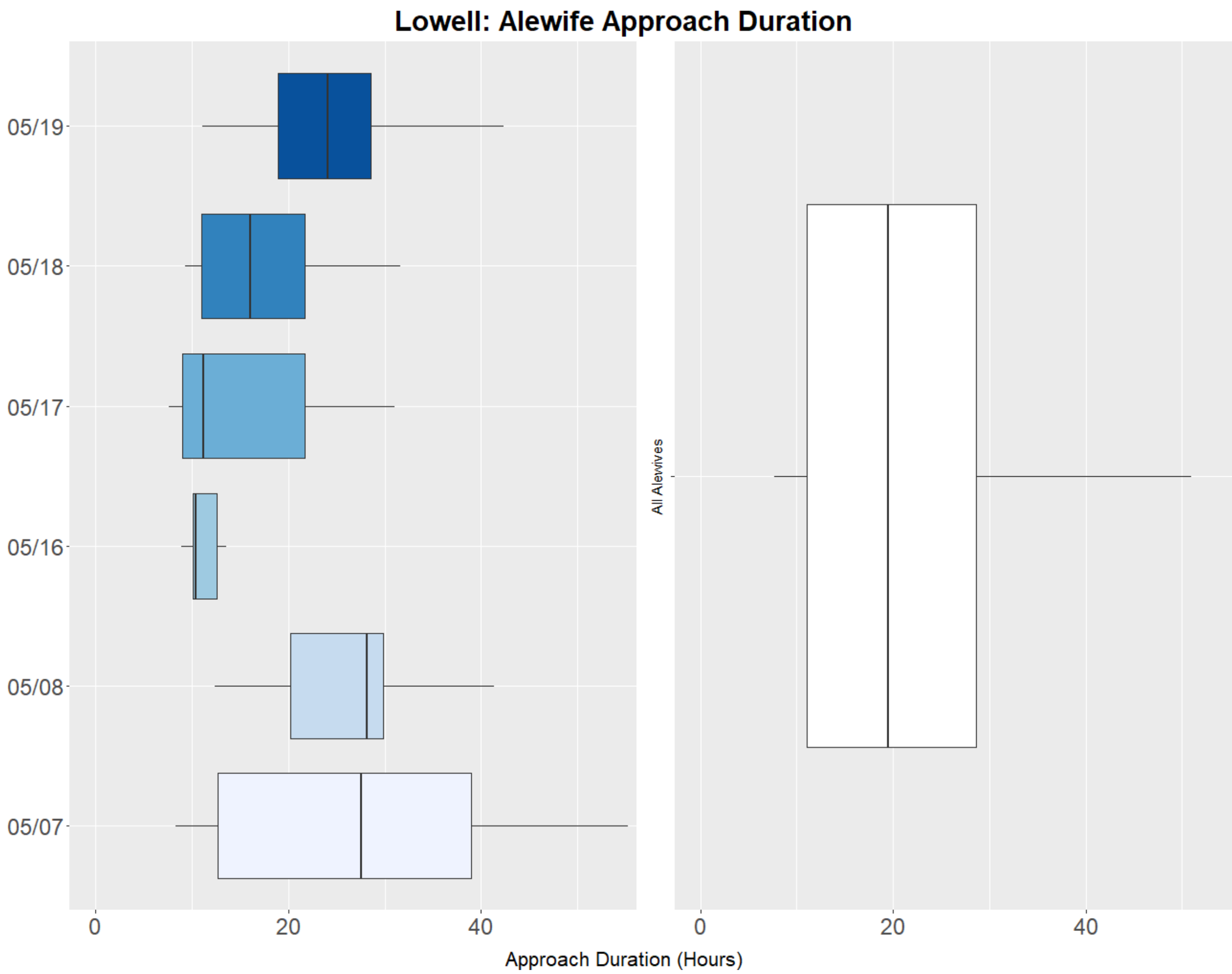

Figure 5–9. Boxplot of the approach duration for all dual-tagged adult alewives released downstream of Lowell during the spring 2020 upstream passage assessment. [6]

[6] The solid line represents the median while left and right portions of the box represent the first and third quartiles, respectively. Whiskers extend to the range of the data within the interquartile range (quartile*1.05) such that outliers outside of this range are not displayed.

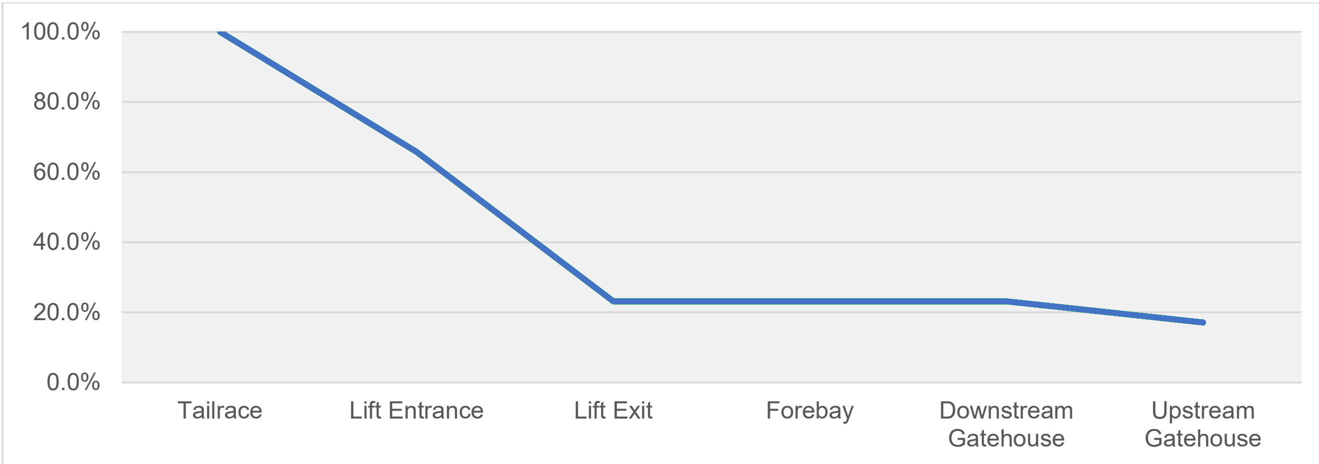

Figure 5–10. Magnitude of upstream progress for dual-tagged adult alewife forays at the E.L. Field fish lift during the spring 2020 upstream passage assessment.

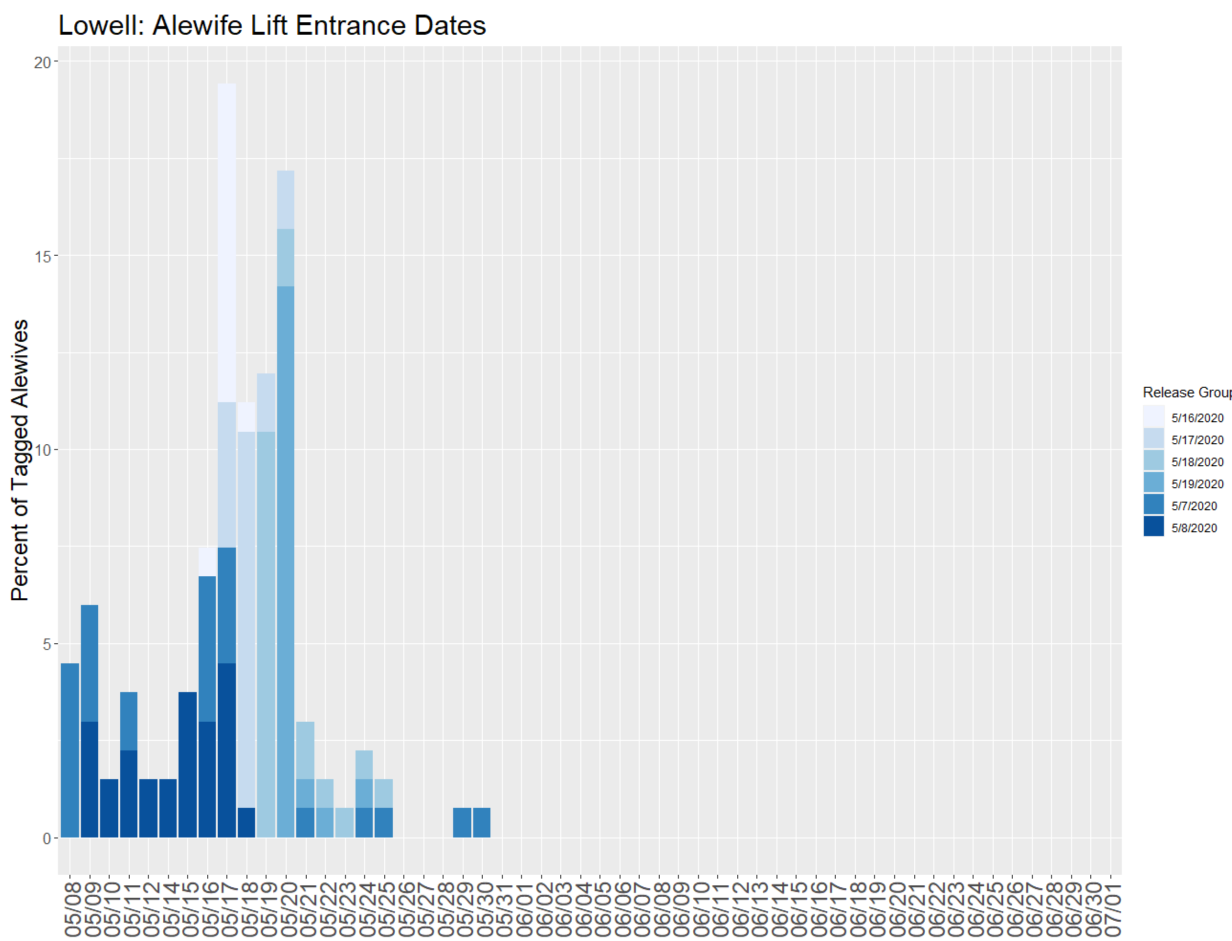

Figure 5–11. Distribution of entrance dates for dual-tagged adult alewives at the E.L. Field fish lift during the spring 2020 upstream passage assessment.

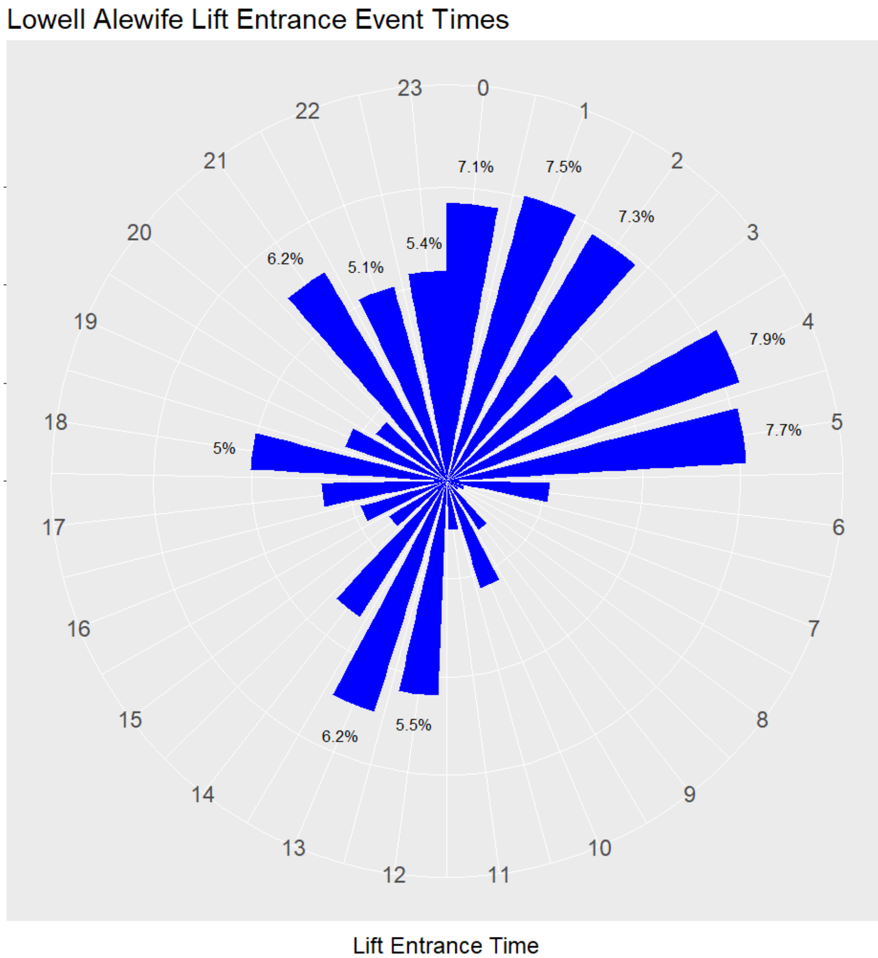

Figure 5–12. Distribution of entrance times for dual-tagged adult alewives at the E.L. Field fish lift during the spring 2020 upstream passage assessment.

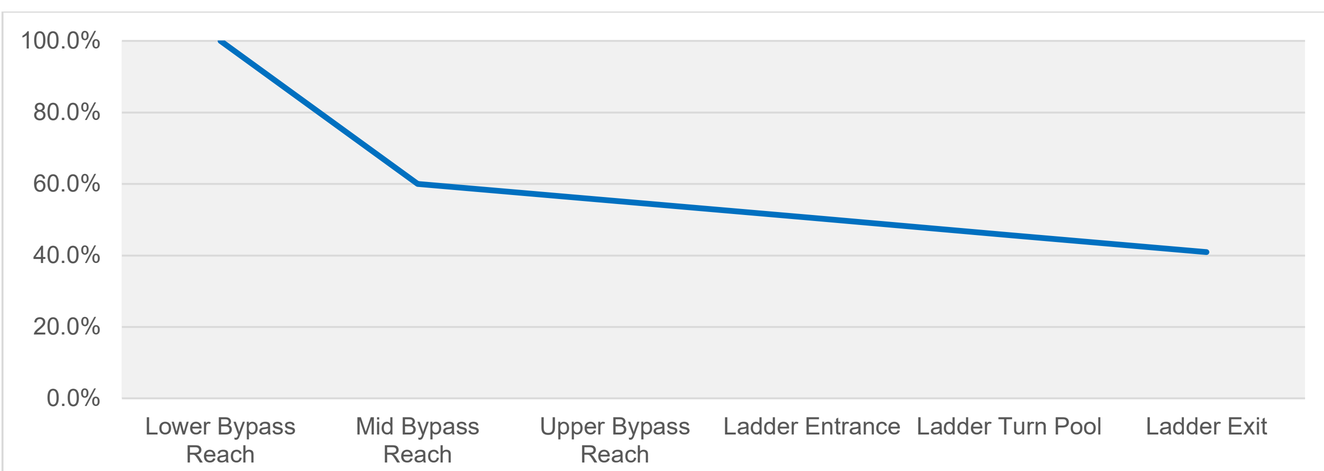

Figure 5–13. Magnitude of upstream progress for dual-tagged adult alewife forays at the Pawtucket Dam fish ladder during the spring 2020 upstream passage assessment.

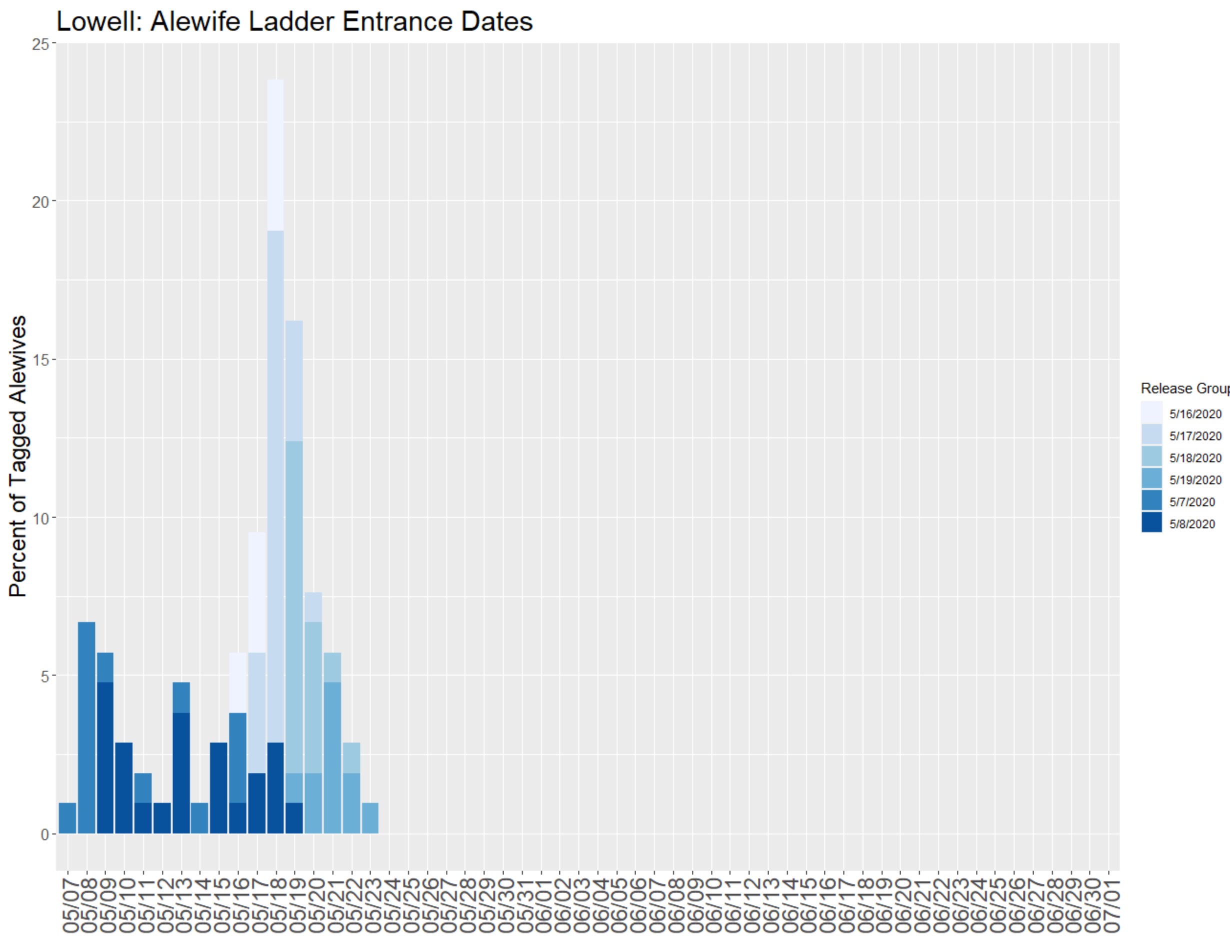

Figure 5–14. Distribution of entrance dates for dual-tagged adult alewives at the Pawtucket Dam fish ladder during the spring 2020 upstream passage assessment.

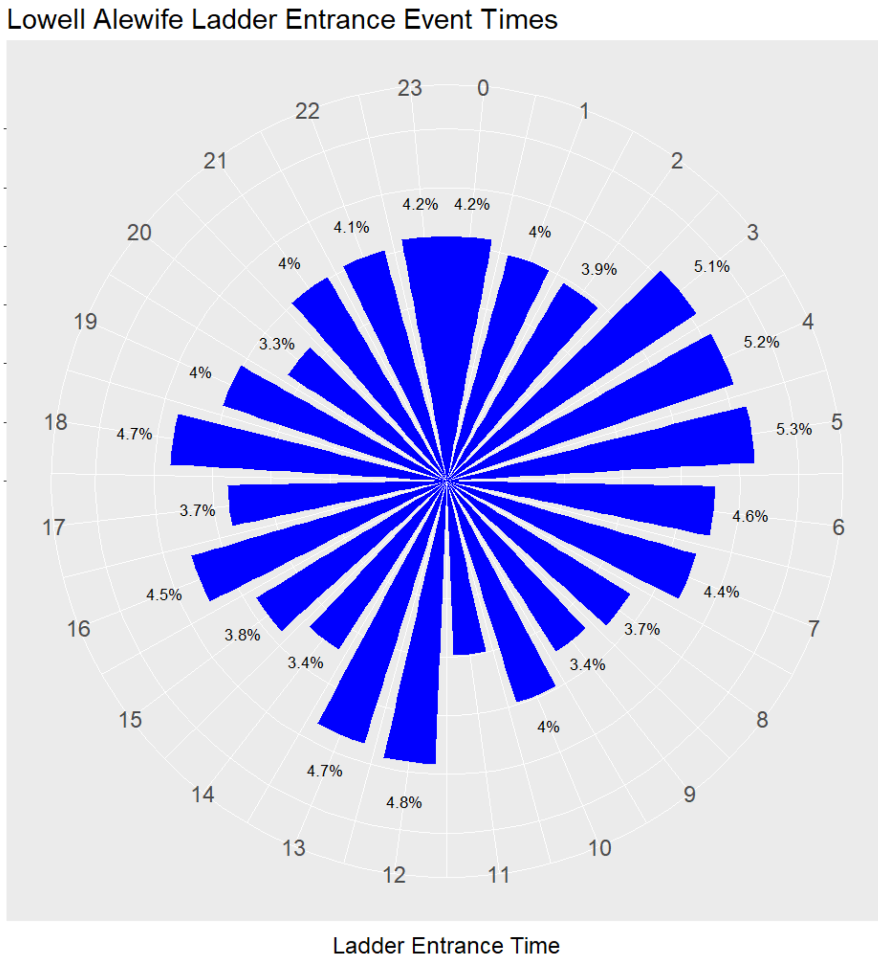

Figure 5–15. Distribution of entrance times for dual-tagged adult alewives at the Pawtucket Dam fish ladder during the spring 2020 upstream passage assessment.

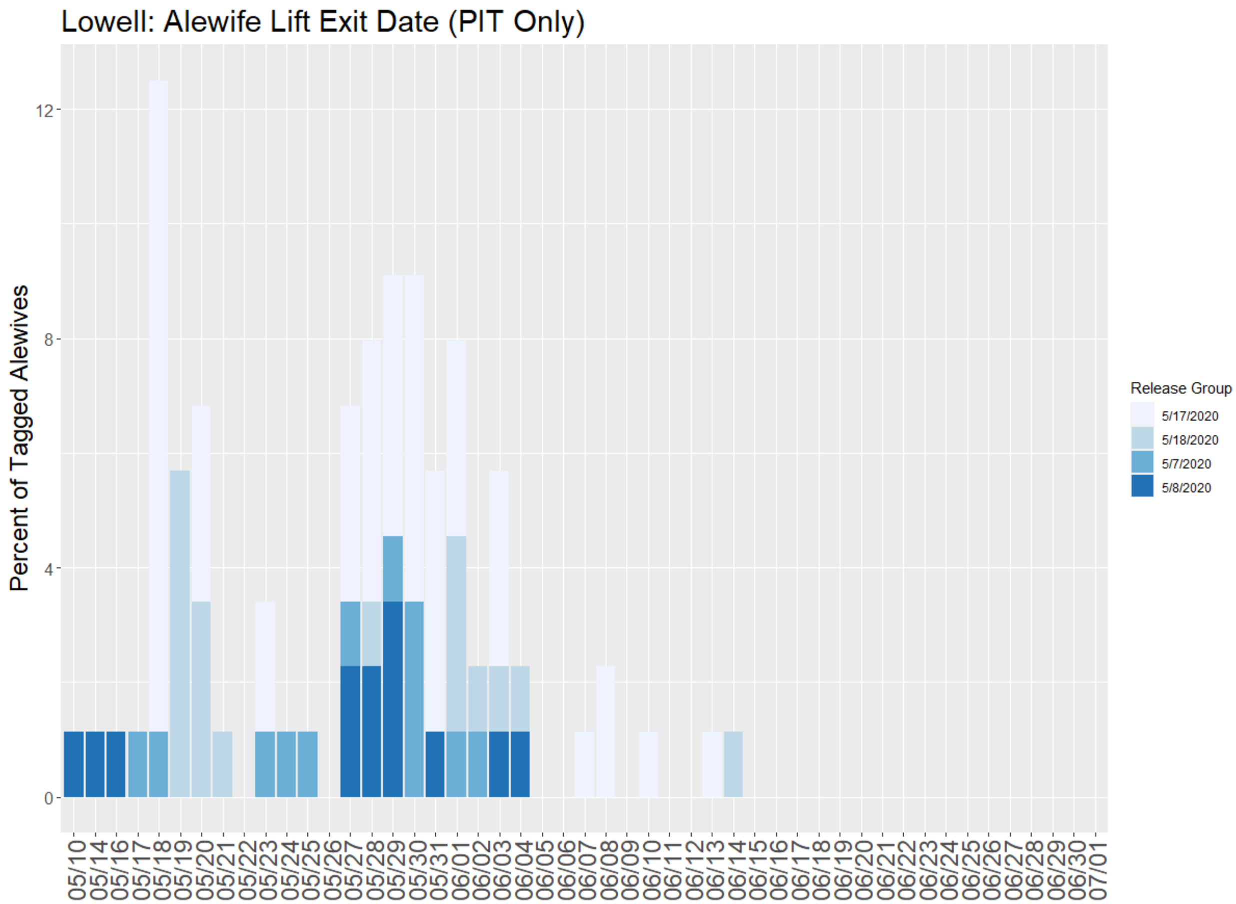

Figure 5–16. Distribution of exit flume dates for PIT-tagged adult alewives at the E.L Field Powerhouse fish lift during the spring 2020 upstream passage assessment.

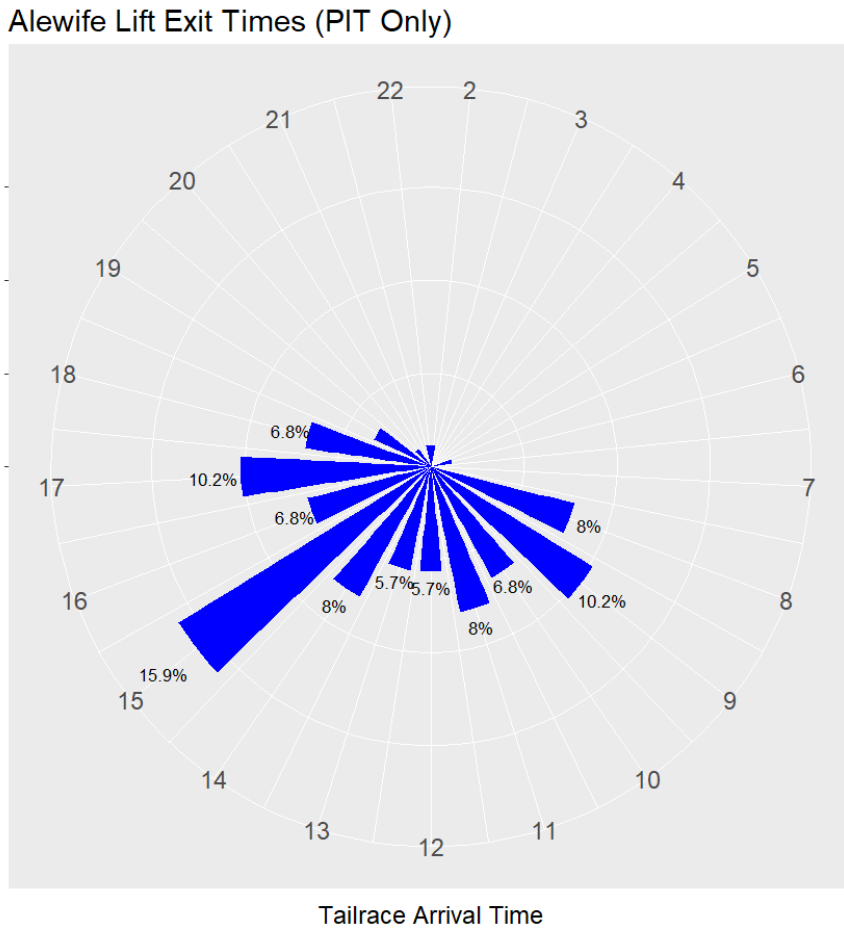

Figure 5–17. Distribution of entrance times for PIT-tagged adult alewives at the Pawtucket Dam fish ladder during the spring 2020 upstream passage assessment.

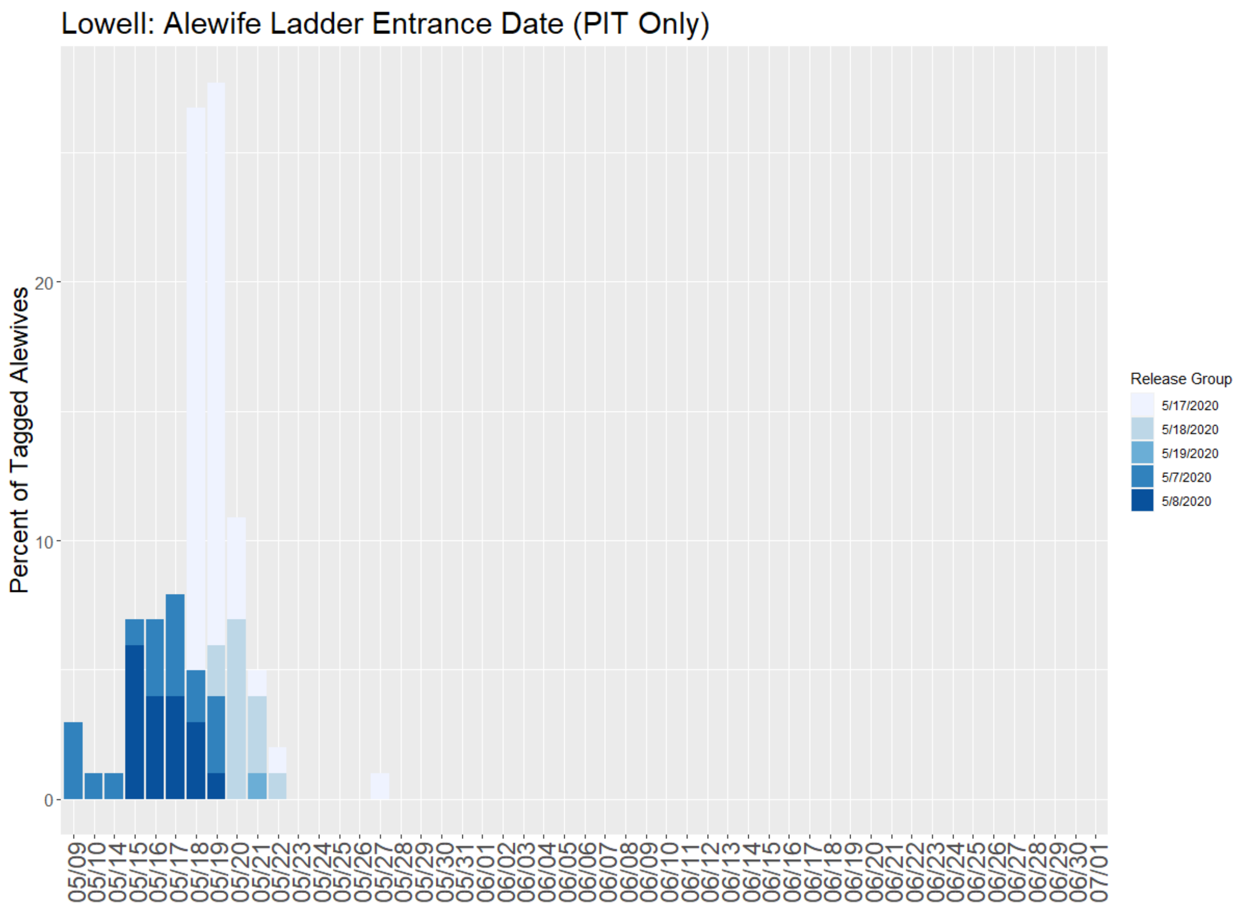

Figure 5–18. Distribution of entrance dates for PIT-tagged adult alewives at the Pawtucket Dam fish ladder during the spring 2020 upstream passage assessment.

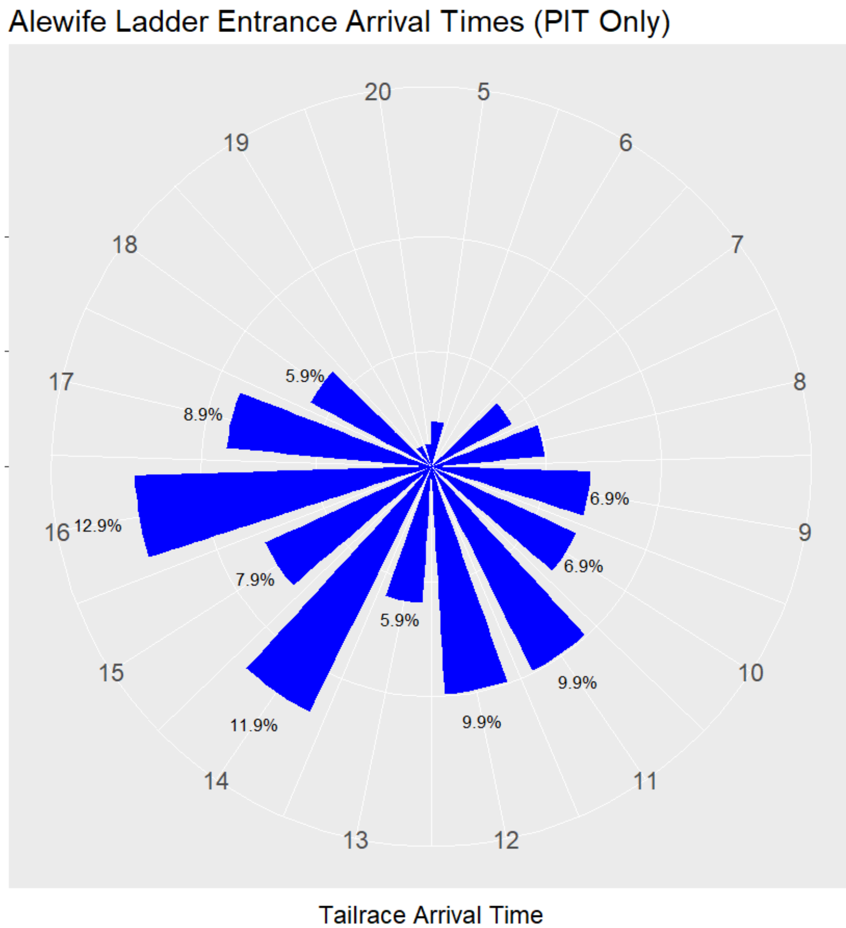

Figure 5–19. Distribution of entrance times for PIT-tagged adult alewives at the Pawtucket Dam fish ladder during the spring 2020 upstream passage assessment.

5.5 Upstream Passage Effectiveness – Adult American Shad

A total of 384 adult American shad were tagged following collection at the Lawrence fish lift during May 2020 and were released for the purposes of evaluating upstream passage at Lowell (Table 5-23). Tagging was conducted over a total of five dates starting on May 16 and ending on May 27. Annual returns for American shad at Lawrence commenced on May 5 and ended on June 25 with the peak daily returns occurring during the last week of May (Figure 5-20). Looking retrospectively, tagging dates carried out during the 2020 study were conducted during the 2^{nd} to 32^{nd} percentiles of the annual return. Of the adult shad tagged, 180 individuals carried both a PIT and radio-transmitter and 204 carried only a PIT tag[7]. Adult American shad tagged for evaluation of upstream passage at Lowell were 73% male, 21% female, and 6% undetermined. Total length of individuals tagged ranged from 400-573 mm (mean = 480 mm).

5.5.1 Post-Release Movements

Similar to adult alewives, the American shad tagged and released downstream of Lowell were free to (1) move upstream and enter into the monitored section of the Merrimack River immediately downstream of the Project, (2) utilize the section of the Merrimack River between Lawrence and Lowell, or (3) fail to move upstream and depart the study reach to downstream of Lawrence. Each dual-tagged individual was classified into a unique post-release movement category based on their pattern of detections among the various monitoring stations. Individuals which were determined to have moved upstream to the project (based on detection at Monitoring Station 24) were classified as “Approached”. Individuals which were limited to detections at the monitoring stations downstream of Lowell (i.e., Stations 25 and 26) were classified as “Lower River”. Individuals which moved downstream immediately following release (as indicated by a lack of detections at any receivers upstream of Station 27 were classified as “Fallback”).

As presented in Table 5-24, nearly 40% of dual-tagged adult shad (70 out of 180 individuals) were determined to have successfully moved upstream and into the area immediately downstream of the Lowell Project following their release. The percentage of dual-tagged shad to ascend upstream to the Project was consistent between the sexes (39% of dual-tagged males and 39% of dual-tagged females). The majority of individuals (47% of all dual-tagged individuals) partially ascended the reach between Lowell and Lawrence but failed to approach the Project. Of those individuals, 48% ascended as far upstream as Station 26 (4.75 miles upstream of Lawrence) and 52% ascended as far upstream as Station 25 (8.7 miles upstream of Lawrence). Twenty-five dual-tagged individuals (14% of the total) were undetected at any of the monitoring stations upstream of Lawrence following their release into the river. A portion of a tagged group of adult shad exhibiting fallback behavior immediately following handling and tagging is not unexpected.

[7] All shad that were tagged with a radio-tag and a PIT transmitter are referred to as “dual-tagged” in this report.

5.5.2 Approach Duration and Time at Large

Adult American shad dual-tagged and released at Lawrence approached Lowell over a range of dates from May 17 until June 6 (Figure 5-21). The median approach duration for dual-tagged adult shad (i.e., the duration of time from release at Lawrence until initial detection at Station 24) was 2.7 days (range = 8.4 hours to 29.3 days; Table 5-25). When examined by release date, the median approach duration to Lowell was lowest for adult shad released on May 22 and 26 and highest for those released on May 18 (Figure 5-22). The minimum, maximum, and quartile transit times through defined sections of the Merrimack River between the release location at Lawrence and the approach receiver (i.e., Station 24) at Lowell are provided in Table 5-26. Transit times calculated using the first detections for each dual-tagged fish at Stations 26, 25, and 24 resulted in median swim times of 14.0 hours from Lawrence to Station 26 (approximately 4.75 miles), 23.4 hours from Station 26 to Station 25 (approximately 3.9 miles) and 22.3 hours from Station 25 to Station 24 (approximately 2.0 miles). Table 5-27 provides the minimum, maximum, and quartile transit times through defined sections of the Merrimack River between the release location at Lawrence and Station 24 as a rate (i.e., miles per hour (mph)).

The duration of time at large following the initial detection at Station 24 for each dual-tagged American shad ranged from 0.3 hours to 24.1 days (median = 2.1 days; Table 5-28). For an individual adult shad, the calculated value for time at large represented time from initial Station 24 detection until either (1) upstream passage out of the study area at the E.L. Field fish lift or the Pawtucket Dam fish ladder, or (2) the final movement downstream and away from the project area. When examined by eventual passage fate (i.e., passed or failed), the median duration of time at large for adult American shad successfully passing upstream was nearly equal to that observed for adult shad which failed to pass upstream (2.3 days vs. 1.9 days, respectively).

5.5.3 Foray and Entrance Events

The full time series of recorded detections for each dual-tagged adult American shad was reviewed and each unique foray upstream towards either the E.L. Field fish lift or Pawtucket Dam fish ladder was identified based on the approach described in Section 4.5. Of the 70 dual-tagged shad which were determined to have approached Lowell (based on detection at a minimum of Station 24) 63% (44 of the 70) made at least one upstream foray towards either the fish lift or ladder during their time at large in the Project area. Of those dual-tagged shad, 43 individuals made one or more foray event towards the fish lift and only a single individual made a foray towards the fish ladder.

5.5.3.1 E.L. Field Fish Lift

The 43 dual-tagged adult shad determined to have approached the E.L. Field fish lift produced a combined total of 201 unique foray events. When considered on an individual basis, the number of unique lift forays ranged between one and 20 (mean = 4.7 events). Figure 5-23 summarizes the upstream magnitude for the full set of observed foray events at the fish lift for dual-tagged adult American shad. Approximately 37% of the set of upstream foray events towards the E.L. Field fish lift resulted in detection of the dual-tagged shad at the lift entrance.

Approximately 6% of upstream foray events resulted in dual-tagged adult American shad reaching the downstream side of the Pawtucket Gatehouse. Finally, 3% of the total number of 201 upstream forays in the direction of the E.L. Field fish lift resulted in dual-tagged shad reaching the upstream side of the Pawtucket Gatehouse.

Table 5-29 provides the minimum, maximum and quartile transit times for dual-tagged adult American shad moving upstream during fish lift forays. Upon entering the tailrace detection zone, the median duration of time to locate the fish lift entrance was 1.1 hours (range 0.1 hours to 1.8 days). Upon entering the E.L. Field Power Canal dual-tagged adult shad proceeded quickly upstream to the downstream face of the Pawtucket Gatehouse (median duration = 0.8 hours). The median duration of time for dual-tagged adult shad to pass the Pawtucket Gatehouse was 5.4 days (range 3.3 days to 9.0 days).

Dual-tagged adult shad were free to be detected at the E.L. Field fish lift entrance multiple times within a single foray event. As noted earlier, approximately 37% of upstream foray events resulted in detection at the fish lift entrance on at least one occasion. The total number of these entrance events were defined for each unique foray event and ranged from one to twenty (mean = 4.6; Table 5-30). Fish lift entrances were recorded over a range of dates from May 18 through June 15, 2020 (Figure 5-24). The percentage of entrance events peaked during late-May (approximately May 28 through May 30). The diel distribution of entrance events at the E.L. Field fish lift is presented in Figure 5-25 and indicated dual-tagged shad present at the lift entrance peaked during the mid-morning and early afternoon hours.

5.5.3.2 Pawtucket Dam Fish Ladder

Foray events for dual-tagged adult American shad up the Lowell bypassed reach and towards the Pawtucket Dam fish ladder were limited to a single event. A dual-tagged shad from the May 16 release group was detected at Station 11 in the lower bypassed reach on May 17th. It did not enter the fish ladder.

5.5.4 PIT-Tagged Individuals

5.5.4.1 E.L. Field Fish Lift

Limitations detailed for the installation of Monitoring Station 20 in Section 4.2 precluded effective monitoring of PIT-tagged fish at that location. As a result, detection potential for the 204 PIT-tagged adult American shad at the E.L. Field fish lift was limited to the upper exit flume (Stations 21 and 22). PIT-tagged adult shad were detected at the upper exit flume over a range of dates from May 19 through June 14, 2020 (Figure 5-26). Of the possible 204 PIT-tagged adult shad, 16 (8%) were determined to have been present in the E.L. Field fish lift exit flume over the course of the study.

5.5.4.2 Pawtucket Dam Fish Ladder

Detections at PIT readers within the Pawtucket Dam fish ladder for the 204 PIT-tagged adult shad released at Lawrence were limited to just two individuals. One PIT-tagged adult shad released at Lawrence on May 18 was detected at the fish ladder entrance on May 24 and ascended as far upstream as the turn pool (travel time = 0.8 hours). A second individual (released at Lawrence on May 26) was detected at the fish ladder entrance reader on June 11 but was not subsequently detected at the turn pool or the ladder exit.

5.5.5 Upstream Passage Effectiveness – Lowell Fish Lift

The CJS model *Phi*(t)*p*(t) provided the best fit for the observed mark-recapture data associated with upstream movements of dual-tagged adult American shad approaching the E.L. Field fish lift (Table 5-31). Specific passage success estimates at Lowell ranged between 0.451- 1.0 among discretely monitored river sections from the tailrace to the point upstream of the Pawtucket Gatehouse (Table 5-32). The detection efficiency for receivers associated with upstream passage of dual-tagged adult American shad at the fish lift ranged from 0.612-1.0 (Table 5-33). Similar to that observed for dual-tagged adult alewives, the lowest detection value was associated with the two PIT readers positioned in the exit flume of the upstream fishway.

As defined in Section 4.5.2, the specific passage success estimates obtained from the CJS model for dual-tagged adult shad approaching the E.L. field fish lift were used to estimate (1) near field attraction, (2) fish lift internal efficiency, and (3) overall fish lift effectiveness. As stated earlier the nearfield attraction rate is the probability of an adult shad to move from the nearfield/tailrace region into the downstream entrance of the lift, the internal efficiency is the probability of an adult shad to move from the lift entrance to the lift exit and the overall efficiency is the probability of an adult shad to move from the tailrace/nearfield region to the upstream exit from the fish lift. Upstream passage effectiveness estimates for dual-tagged adult shad at the Lowell fish lift during 2020 are as follows:

- Nearfield attraction effectiveness:
    - 67.4% (75% CI = 58.8-75.1%)
- Fish lift internal efficiency:
    - 45.1% (75% CI = 34.8-55.8%)
- Overall fish lift effectiveness:
    - 30.4% (75% CI = 22.1-39.5%)

5.5.6 Upstream Passage Effectiveness – Lowell Fish Ladder

Limited number of returns for dual-tagged American shad (see Section 5.5.3.2) prevented the usage of a CJS model to evaluate upstream passage effectiveness of the Pawtucket Dam fish ladder for that species during spring, 2020.

Table 5–23. Summary of tagging and release information for adult American shad released at Lawrence during the Lowell upstream passage assessment, May 7 to June 30, 2020.

Date	Type	Number
16-May	Dual	30
	PIT	20
18-May	Dual	30
	PIT	48
22-May	Dual	30
	PIT	34
26-May	Dual	59
	PIT	68
27-May	Dual	31
	PIT	34
Total	Dual	180
	PIT	204

Table 5–24. Summary of post-release movement for adult American shad tagged and released downstream of Lowell during spring 2020.

Post-release Movement	Release Group					
	16-May	18-May	22-May	26-May	27-May	All
Approach	16	13	10	18	13	70
Downstream						0
Stn 26	4	7	6	17	7	41
Stn 25	5	8	11	14	6	44
Fallback	5	2	3	10	5	25
Total	30	30	30	59	31	180

Table 5–25. Minimum, maximum, and quartile values of approach duration (hours) for dual-tagged adult American shad released downstream of Lowell during the spring 2020 upstream passage assessment.

Shad - Approach Duration (hrs)					
Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
16-May	31.0	703.2	46.7	64.5	163.3
18-May	8.4	223.8	76.1	111.9	123.8
22-May	10.5	85.4	27.1	40.0	67.7
26-May	28.4	288.3	31.1	41.7	70.1
27-May	18.6	186.4	43.0	70.5	82.7
All	**8.4**	**703.2**	**37.7**	**64.5**	**94.5**

Table 5–26. Minimum, maximum, and quartile values of upstream transit durations (hours) for dual-tagged adult American shad released downstream of Lowell during the spring 2020 upstream passage assessment.

Shad - Upstream Transit Times (hr)						
Downstream Reach	Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
Lawrence to Station 26 (4.75 miles)	16-May	3.8	141.0	5.5	8.5	17.9
	18-May	4.5	220.1	7.9	10.3	27.6
	22-May	3.8	239.7	4.5	9.4	67.8
	26-May	2.2	194.4	7.8	15.0	26.2
	27-May	5.8	225.4	9.7	16.3	27.7
	All	**2.2**	**239.7**	**7.4**	**14.0**	**27.6**
Station 26 to Station 25 (3.9 miles)	16-May	4.1	49.1	15.6	20.7	34.7
	18-May	2.1	37.6	2.5	23.1	27.2
	22-May	2.1	138.4	13.4	18.2	74.7
	26-May	11.3	480.2	18.2	27.2	50.2
	27-May	5.0	235.6	7.2	25.9	32.1
	All	**2.1**	**480.2**	**15.2**	**23.4**	**37.3**
Station 25 to Station 24 (2.0 miles)	16-May	2.3	166.6	14.6	36.4	61.0
	18-May	1.8	194.7	49.4	88.5	94.0
	22-May	2.7	54.9	4.0	7.9	24.9
	26-May	2.3	197.9	8.6	11.3	21.2
	27-May	2.0	99.2	3.2	13.2	75.4
	All	**1.8**	**197.9**	**5.9**	**22.3**	**75.4**

Table 5–27. Minimum, maximum, and quartile values of upstream transit rates (mph) for dual-tagged adult American shad released downstream of Lowell during the spring 2020 upstream passage assessment.

Shad - Upstream Transit Rates (mph)						
Downstream Reach	Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
Lawrence to Station 26 (4.75 miles)	16-May	0.03	1.25	0.27	0.56	0.86
	18-May	0.02	1.06	0.17	0.47	0.60
	22-May	0.02	1.25	0.07	0.51	1.06
	26-May	0.02	2.16	0.18	0.32	0.61
	27-May	0.02	0.82	0.17	0.30	0.50
	All	**0.02**	**2.16**	**0.17**	**0.34**	**0.64**
Station 26 to Station 25 (3.9 miles)	16-May	0.08	0.95	0.11	0.19	0.25
	18-May	0.10	1.86	0.14	0.17	1.56
	22-May	0.03	1.86	0.06	0.22	0.30
	26-May	0.01	0.35	0.08	0.14	0.21
	27-May	0.02	0.78	0.12	0.15	0.54
	All	**0.01**	**1.86**	**0.10**	**0.17**	**0.26**
Station 25 to Station 24 (2.0 miles)	16-May	0.01	0.87	0.03	0.05	0.14
	18-May	0.01	1.11	0.02	0.02	0.04
	22-May	0.04	0.74	0.08	0.25	0.50
	26-May	0.01	0.87	0.09	0.18	0.23
	27-May	0.02	1.00	0.03	0.15	0.63
	All	**0.01**	**1.11**	**0.03**	**0.09**	**0.34**

Table 5–28. Minimum, maximum, and quartile values of time at large (hours) for dual-tagged adult American shad released downstream of Lowell during the spring 2020 upstream passage assessment.

Shad - Time at Large (hrs)					
Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
16-May	1.3	578.2	43.5	190.6	260.1
18-May	0.9	424.6	31.8	76.6	312.1
22-May	97.0	499.5	121.3	184.1	243.9
26-May	0.3	49.7	12.2	31.0	45.1
27-May	0.5	145.6	9.7	43.2	58.6
All	**0.3**	**578.2**	**24.0**	**49.7**	**165.5**
Fate	Minimum	Maximum	Q25	Q50 (Median)	Q75
Failed	0.3	578.2	11.8	46.8	215.3
Passed	28.5	424.6	43.9	54.5	136.4

Table 5–29. Minimum, maximum, and quartile values of transit durations (hours) for dual-tagged adult American shad during fish lift forays recorded during the spring 2020 upstream passage assessment.

Shad - Fish Lift Foray Durations (hr)					
Lift Foray Segment	Minimum	Maximum	Q25	Q50 (Median)	Q75
Tailrace to Entrance	0.1	43.6	0.6	1.1	1.8
Entrance to Exit	1.0	23.5	1.2	2.4	11.5
Exit to Forebay	<0.1	0.4	<0.1	<0.1	0.1
Forebay to Pawtucket Gatehouse	0.3	1.5	0.5	0.8	1.1
Pawtucket Gatehouse to Upstream	79.7	216.2	80.6	129.5	197.6

Table 5–30. Minimum, maximum, and mean number of fish lift entrance events per upstream foray for dual-tagged adult American shad recorded during the spring 2020 upstream passage assessment.

Shad - Number of Lift Entrance Detection Events			
Release Date	Minimum	Maximum	Mean
16-May	1	20	5.6
18-May	1	10	4.8
22-May	1	10	3.9
26-May	1	9	3.4
27-May	1	18	5.2
All	**1**	**20**	**4.6**

Table 5–31. CJS model selection criteria for upstream passage effectiveness of the E.L. Field fish lift for adult American shad at Lowell during spring 2020.

Model	AICc	Delta AICc	AICc Weight	Model Likelihood	No. Parameters	Deviance
Phi(t)p(t)	254.77	0.00	1.00	1.00	10	32.13
Phi(t)p(.)	315.05	60.28	0.00	0.00	5	103.05
Phi(.)p(t)	336.50	81.73	0.00	0.00	7	120.30
Phi(.)p(.)	410.43	155.66	0.00	0.00	2	204.63

Table 5–32. Passage success probability estimates (*Phi*), standard errors, and likelihood 75 and 95% confidence intervals for dual-tagged adult American shad approaching the E.L. Field fish lift during 2020.

Reach	*Phi*	SE	95% CI		75% CI	
Tailrace to Entrance	0.674	0.071	0.523	0.797	0.588	0.751
Entrance to Exit	0.451	0.093	0.282	0.631	0.348	0.558
Exit to Forebay	1.000	0.000	-	-	-	-
Forebay to Pawtucket Gatehouse	0.918	0.078	0.594	0.989	0.773	0.974
Pawtucket Gatehouse to Upstream	0.500	0.144	0.244	0.756	0.340	0.660

Table 5–33. Detection efficiency estimates (*p*), for monitoring stations installed to detect dual-tagged adult American shad approaching the E.L. Field fish lift during 2020.

Location	S	SE	95% CI	
Station 21	1.000	0.000	1.000	1.000
Station 22/23	0.612	0.135	0.341	0.828
Station 08	0.842	0.102	0.541	0.960
Station 07	1.000	0.000	1.000	1.000
Station 06	0.833	0.152	0.369	0.977

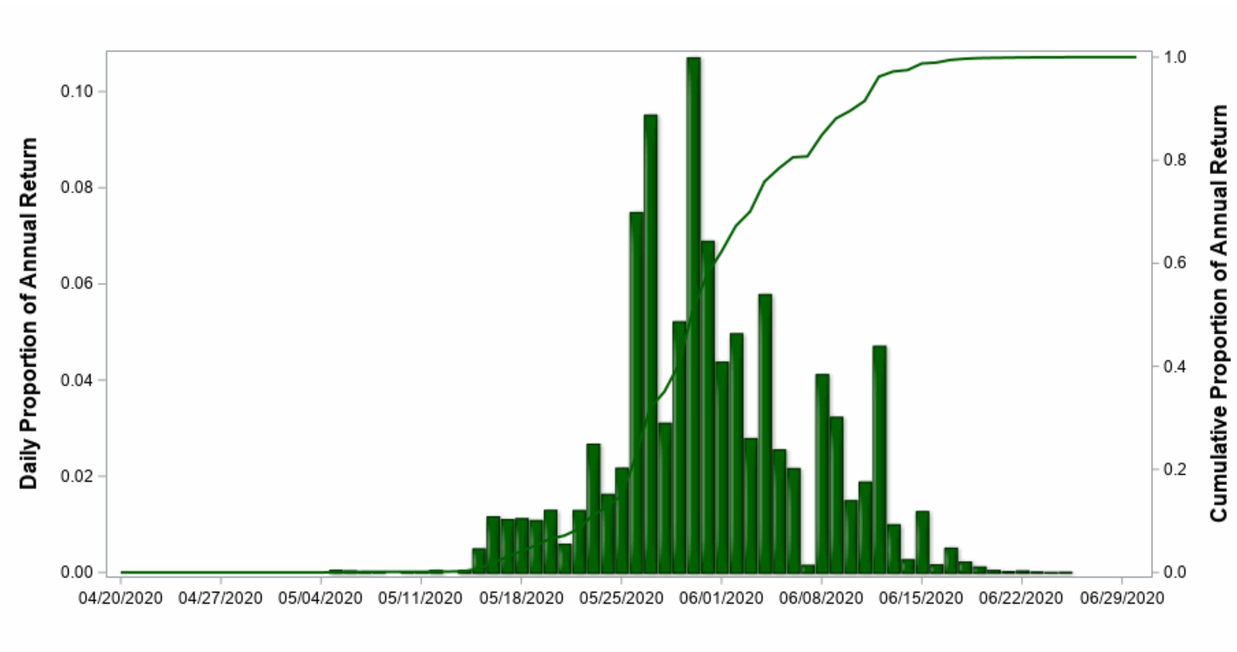

Figure 5–20. Daily (bars) and cumulative (line) proportion of annual adult American shad returns at the Lawrence fishway as enumerated by Salmonsoft recording for the 2020 passage season.

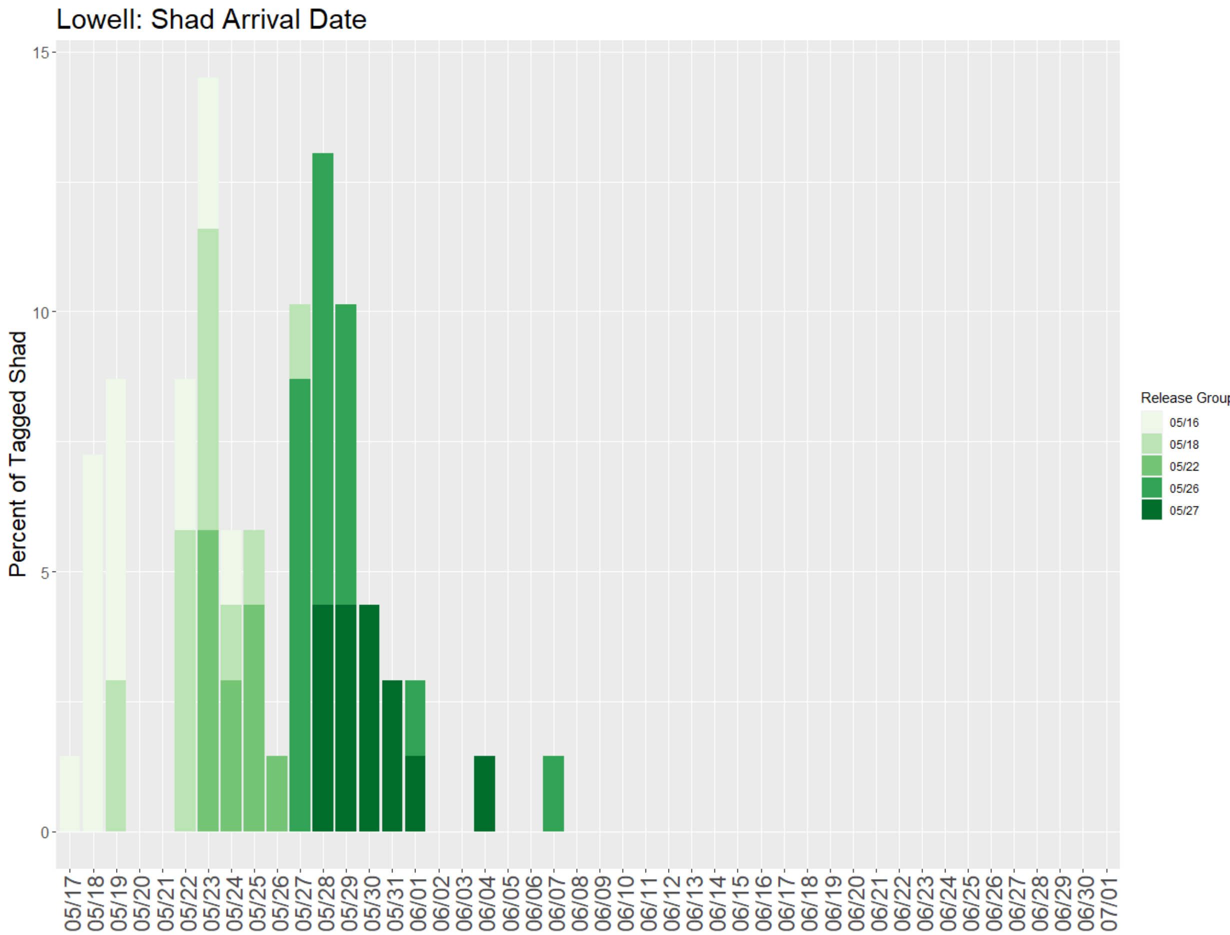

Figure 5–21. Distribution of arrival dates for dual-tagged adult American shad originally released downstream of Lowell at the Lawrence Project as part of the spring 2020 upstream passage assessment.

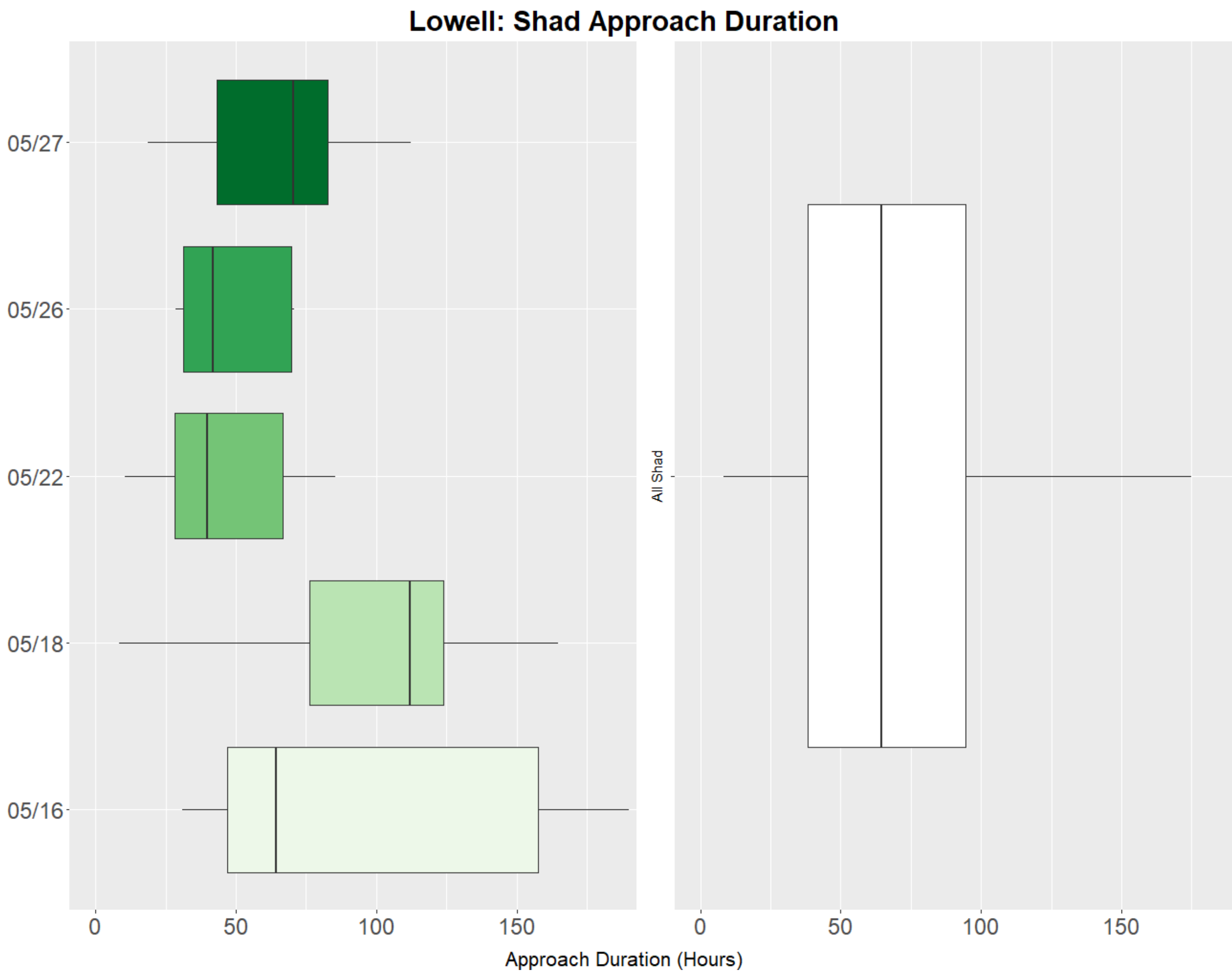

Figure 5–22. Boxplot of the approach duration for all dual-tagged adult American shad released downstream of Lowell during the spring 2020 upstream passage assessment. [8]

[8] The solid line represents the median while left and right portions of the box represent the first and third quartiles, respectively. Whiskers extend to the range of the data within the interquartile range (quartile*1.05) such that outliers outside of this range are not displayed.

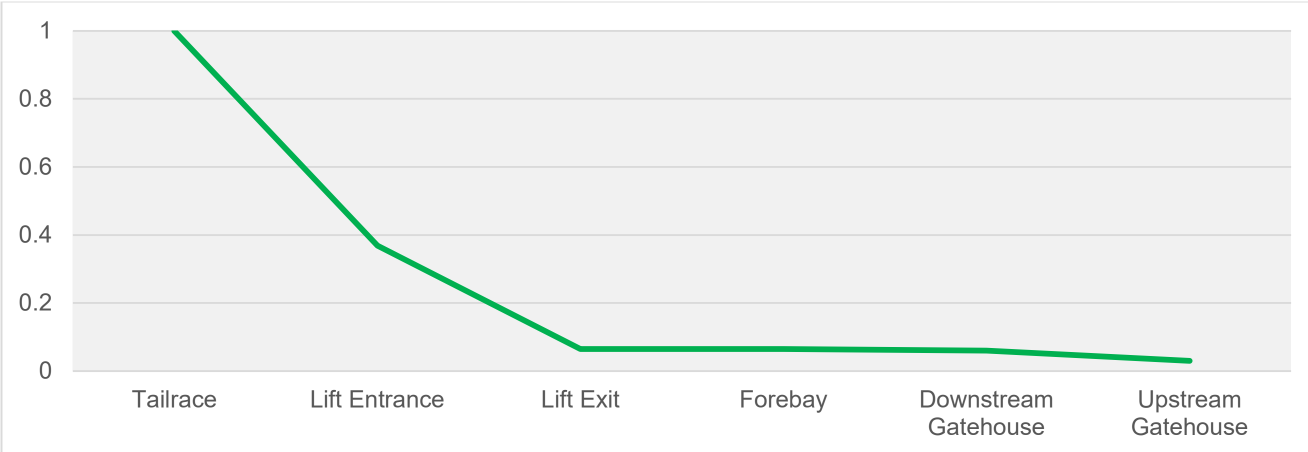

Figure 5–23. Magnitude of upstream progress for dual-tagged adult American shad forays at the E.L. Field fish lift during the spring 2020 upstream passage assessment.

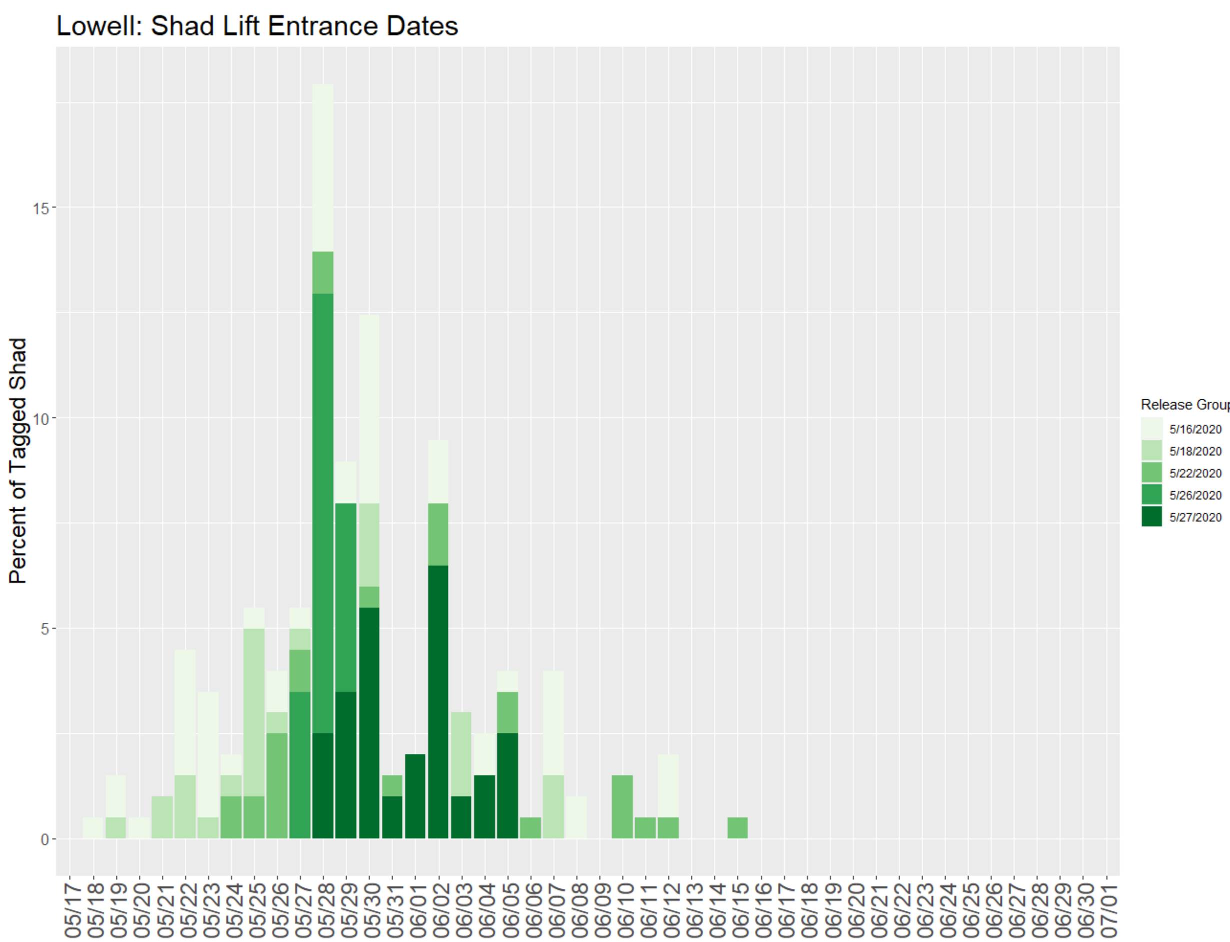

Figure 5–24. Distribution of entrance dates for dual-tagged adult American shad at the E.L. Field fish lift during the spring 2020 upstream passage assessment.

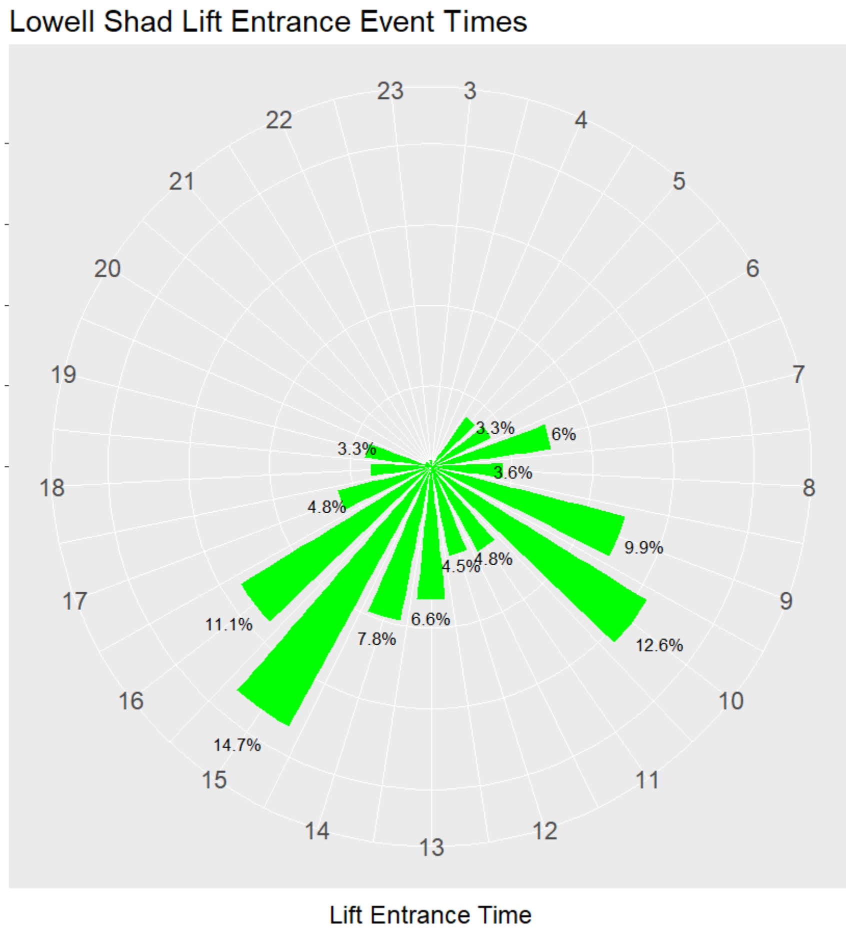

Figure 5–25. Distribution of entrance times for dual-tagged adult American shad at the E.L. Field fish lift during the spring 2020 upstream passage assessment.

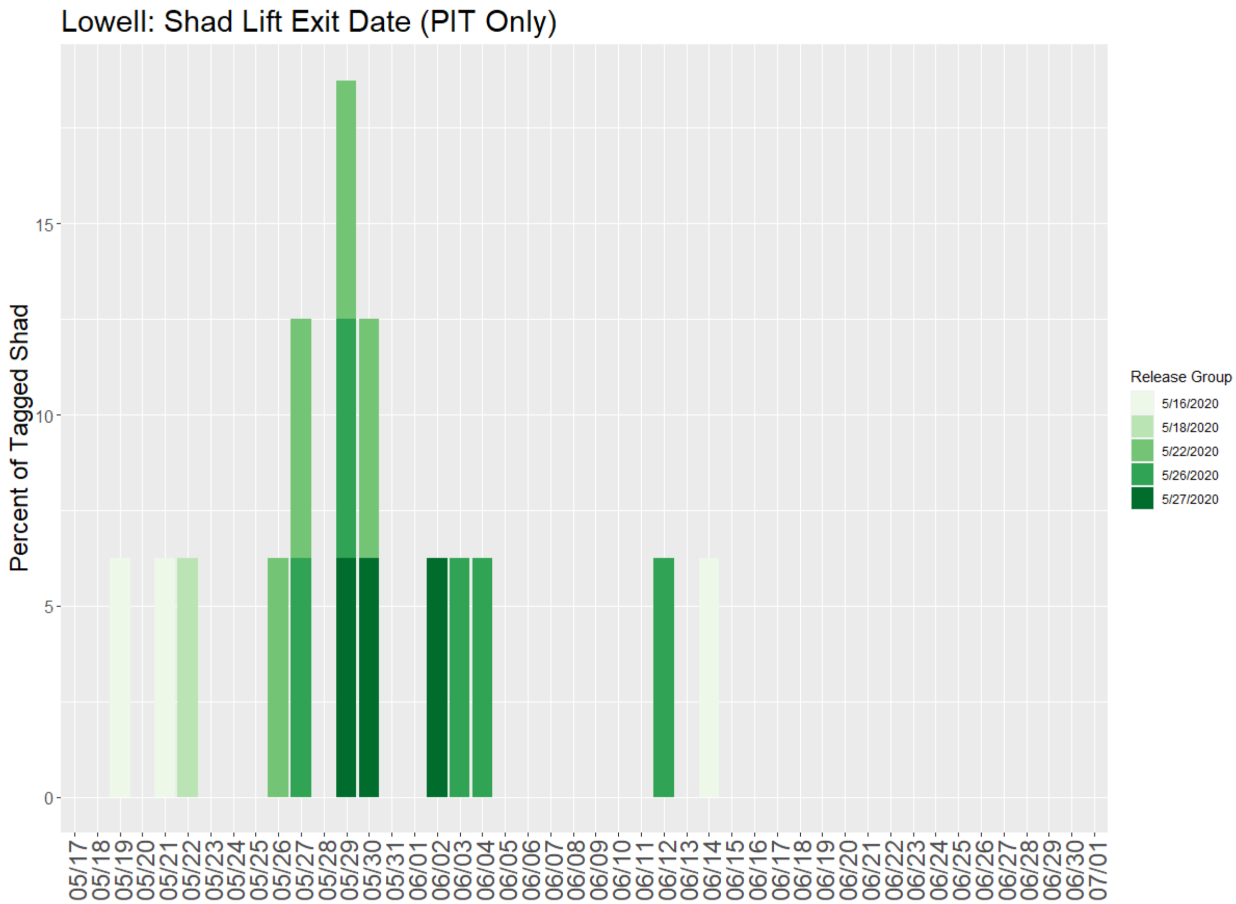

Figure 5–26. Distribution of exit flume dates for PIT-tagged adult American shad at the E.L Field Powerhouse fish lift during the spring 2020 upstream passage assessment.

5.6 Downstream Passage Effectiveness – Adult Alewives

A total of 150 adult alewives were radio-tagged and released during late-May and early-June 2020 for the purposes of evaluating downstream passage at Lowell (Table 5-34). Tagging was conducted on a total of four dates starting on May 21 and ending on June 2. Due to observations of reduced daily returns of river herring to the Lawrence Project over the days following the second release group (May 22) adult herring for the last two releases were obtained at the Amoskeag fishway located upstream of the Lowell Project in Manchester, NH. Adult alewives tagged for evaluation of downstream passage at Lowell were comprised of 43% female, 56% male and 1% undetermined. Total length of individuals tagged ranged from 220-330 mm (mean = 294 mm). The mean body length for fish obtained at Lawrence and Amoskeag was similar (295 mm and 292 mm, respectively). A full listing of tagged individuals released upstream of Lowell during the spring of 2020 is provided in Appendix A.

5.6.1 Project Arrival and Upstream Residence Duration

Releases of radio-tagged adult alewives were initiated upstream of Lowell at the Tyngsborough Riverfront Park on May 21, 2020. Figure 5-27 presents the distribution of arrival dates for those individual radio-tagged herring at the Pawtucket Dam as indicated by detection at Stations 05 and 06. Initial detections for radio-tagged alewives were recorded over a range of dates from May 21 through June 17 with a peak in arrivals on June 3, 2020. The duration of time from release until arrival at Lowell (i.e., the approach duration) ranged from 6.7 hours to 13.5 days (median = 2.4 days; Table 5-35).

The duration of time radio-tagged individuals were present upstream of the Pawtucket Dam was determined for all individuals which approached and eventually passed downstream and was calculated as the duration of time from initial detection immediately upstream of the dam until confirmed downstream passage via one of the available routes. When all individuals are considered, the upstream residence duration prior to downstream passage ranged between 0.7 hours to 8.8 days (Table 5-36; Figure 5-28). The median duration of time spent immediately upstream of the dam structure was 2.0 days and did not appear to differ greatly by release date for radio-tagged adult alewives released upstream of Lowell (range = 1.8 – 3.2 days). Of the radio-tagged alewives which approached Pawtucket Dam, 23% passed in less than 24 hours and 77% passed in less than 96 hours after initial detection.

Outmigrating adult alosines encountering the Pawtucket Dam can (1) pass through the Pawtucket Gatehouse and enter the power canal, (2) pass downstream over Pawtucket Dam via spill, or (3) enter the Pawtucket Canal and navigate downstream via the downtown canal system. During the 2020 evaluation only two radio-tagged adult alewives were detected at Monitoring Station 28 indicating those individuals passed downstream through the downtown canal system rather than remaining in the mainstem Merrimack. The majority of radio-tagged alewives were determined to have passed through the Pawtucket Gatehouse and entered the Northern Canal to approach the E.L. Field powerhouse. The duration of time to pass through the Pawtucket Gatehouse was determined based on the initial detection for each individual adult at Stations 06 and 07 which independently monitored the upstream and downstream sides of that structure. The median duration of time for radio-tagged adult alewives to initially encounter and then pass through the Pawtucket Gatehouse was 1.8 hours (range <0.1 hours to 4.1 days; Table 5-37). The majority (68%) of radio-tagged adult alewives passing through the Pawtucket Gatehouse did so in 12 hours or less following their initial detection at the structure.

Radio-tagged adult alewives which entered the Northern Canal and passed downstream of E.L. Field powerhouse did so relatively quickly. Of those individuals, 84% were resident in the power canal upstream of E.L. Field for 12 hours or less. The median residence duration in the Northern Canal was 0.5 hours (range = 0.2 hours to 1.8 days; Table 5-38). Five radio-tagged individuals were present in the Northern Canal for greater than 24 hours prior to downstream passage.

5.6.2 Downstream Passage

A total of 150 radio-tagged adult alewives were released upstream of Lowell during the spring of 2020. Of that total, 124 were determined to have approached the Pawtucket Dam and were available for the evaluation of downstream passage route (Table 5-39). The majority of radio-tagged individuals passed through the Pawtucket Gatehouse and approached the E.L. Field powerhouse (97% of approaching fish). Most individuals passed downstream of Lowell via the E.L. Field turbine units (52% of radio-tagged alewives) or utilized the downstream bypass (45% of radio-tagged alewives). Use of the bypassed reach (i.e., spill) was limited to a single individual. Two adult radio-tagged adult alewives (2% of all fish approaching Pawtucket Dam) utilized the downtown canal system for downstream passage. The first of two individuals entering the downtown canal system moved through the Pawtucket Canal (i.e., Guard Locks and Swamp Locks) to the Eastern Canal. It was detected at Station 32 in the intake area of the John St. Station prior to passing downstream via the Boott Dam and subsequent detection downstream at Lawrence. The second individual moved through the Pawtucket Canal to Hamilton Canal and passed via the Hamilton Wasteway. It was detected at Station 32 in the intake area of the John St. Station prior to arrival at the receiver monitoring Boott Dam (i.e., Station 34). There were no detections at any downriver locations for this individual. The single individual which passed Lowell via spill was initially detected at Station 06 (i.e., immediately upstream of the Pawtucket Gatehouse) but did not pass that structure and enter the Northern Canal.

Radio-tagged adult alewives were observed passing downstream of Lowell between the dates of May 21 through June 17 (Figure 5-29). Downstream passage of radio-tagged adult alosines at Lowell peaked during the early part of June with nearly half of all passage events occurring between June 3 and June 6, 2020. Figure 5-30 presents the timing distribution of downstream passage events for radio-tagged adult alewives at Lowell. The majority of individuals passed downstream during the mid-afternoon through early evening hours (i.e., 1400-1900).

5.6.3 Downstream Transit

Three monitoring stations were installed downstream of Lowell for the purpose of detecting radio-tagged adult alosines following passage at the Project during the spring of 2020. Those receivers were located approximately 2.1 (Monitoring Station 25), 6.0 (Monitoring Station 26), and 10.75 (Monitoring Station 27) miles downstream of the project. The minimum, maximum, and quartile transit times through those three reaches are presented in Table 5-40. The median transit time durations for tagged adult alewives moving downstream of Lowell were 5.0, 2.6, and 19.0 hours for the 2.1 mile, 3.9 mile and 4.75 mile downstream reaches, respectively. Table 5-41 provides the minimum, maximum, and quartile transit times through defined sections of the Merrimack River between Lowell and Lawrence as a rate (i.e., miles per hour (mph)).

Table 5-42 and Figure 5-31 present the minimum, maximum and quartile transit times for radio-tagged adult alewives to cover the full reach from immediately downstream of Lowell to the upstream face of the Essex Dam in Lawrence (i.e., Station 27). The median travel time for those individuals to approach Lawrence following downstream passage at Lowell was 1.1 days (range = 8.0 hours to 7.7 days).

5.6.4 Passage Survival

The CJS model *Phi(t)p(t)* provided the best fit for the observed mark-recapture data associated with downstream movements of radio-tagged adult alewives approaching and passing at Lowell during 2020 (Table 5-43). The detection efficiency for telemetry receivers recording passage of adult herring for monitoring stations at Lowell and downstream of Lowell ranged from 1.000 to 0.845 (Table 5-44). The reach-specific survival estimates for the Merrimack River from the Lowell impoundment receiver to detection immediately upstream of Lawrence are presented in Table 5-45. Passage success for downstream passage of adult alewives at Lowell was calculated as the joint probability of the three reach-specific survival estimates which encompasses the full section of the Merrimack River from Lowell downstream to Lawrence (i.e., Lowell to Station 25, Station 25 to Station 26, and Station 26 to Lawrence). This resulted in an estimated downstream passage survival for adult alewives at Lowell of 76.5% (75% CI = 71.5%-80.5%). No adjustments were made to encounter histories for adult alewives passing Lowell to reflect the duration of time to detection at Lawrence following downstream passage since there were no documented events for radio-tagged "drift" alewives at the downstream receiver stations indicating that the magnitude of downstream travel for that species following dead release into the tailrace was negligible.

Radio-tagged adult alewives which approached and passed downstream at Lowell during the 2020 evaluation did so via a variety or passage routes (Table 5-39). When examined by passage route, detection at Station 27 (i.e., Lawrence Dam) occurred for 77% of individuals passing Lowell via the downstream bypass and 61% of individuals passing via the E.L. Field turbine units. The single adult alewife passing Lowell via spill and one of the two passing Lowell via the downtown canal system were also subsequently detected at Lawrence.

Table 5–34. Summary of tagging and release information for adult alewives released upstream of Lowell during the spring 2020 downstream passage assessment.

Date	Source	Type	Number
21-May	Lawrence	Radio	60
22-May	Lawrence	Radio	20
28-May	Amoskeag	Radio	20
2-Jun	Amoskeag	Radio	50
Total		Radio	150

Table 5–35. Minimum, maximum, and quartile values of approach duration (hours) for radio-tagged alewives released upstream of Lowell during the spring 2020 adult alosine passage assessment.

Alewife - Approach Duration (hrs)					
Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
21-May	6.7	323.6	154.2	181.0	234.1
22-May	58.5	299.4	115.8	147.9	258.7
28-May	11.8	155.1	25.4	37.8	54.7
2-Jun	11.5	75.9	27.6	32.7	38.3
All	**6.7**	**323.6**	**32.7**	**58.5**	**178.0**

Table 5–36. Minimum, maximum, and quartile values of upstream residence duration (hours) for radio-tagged alewives released upstream of Lowell during the spring 2020 adult alosine passage assessment.

Alewife - Upstream Residence (hrs)					
Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
21-May	0.8	198.6	22.3	44.3	89.2
22-May	16.0	210.1	34.9	51.5	83.6
28-May	0.7	181.7	51.6	77.5	106.0
2-Jun	2.1	134.4	22.3	42.6	72.5
All	**0.7**	**210.1**	**25.1**	**48.2**	**89.3**

Table 5–37. Minimum, maximum, and quartile values of time to pass the Pawtucket Gatehouse and enter Northern Canal (hours) for radio-tagged alewives released upstream of Lowell during the spring 2020 adult alosine passage assessment.

Alewife - Pawtucket Gatehouse Passage (hrs)					
Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
21-May	<0.1	99.3	0.2	0.5	7.9
22-May	0.1	9.9	0.2	0.8	4.6
28-May	<0.1	94.2	0.1	2.2	17.8
2-Jun	<0.1	65.6	0.6	2.6	25.1
All	**<0.1**	**99.3**	**0.2**	**1.8**	**15.4**

Table 5–38. Minimum, maximum, and quartile values of Northern Canal residence duration (hours) for radio-tagged alewives released upstream of Lowell during the spring 2020 adult alosine passage assessment.

Alewife - Northern Canal Residence (hrs)					
Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
21-May	0.2	38.2	0.3	0.4	6.1
22-May	0.2	27.2	0.3	0.4	0.5
28-May	0.2	33.3	0.3	0.5	4.6
2-Jun	0.2	42.3	0.4	0.7	5.7
All	**0.2**	**42.3**	**0.3**	**0.5**	**5.5**

Table 5–39. Downstream passage route selection for radio-tagged alewives released upstream of Lowell during the spring 2020 adult alosine passage assessment.

Release Date	Alewife - Lowell Downstream Passage Route					
	No Detect	No Pass	Downtown	Turbine	Spill	Bypass
21-May	16	0	0	24	1	19
22-May	7	0	0	7	0	6
28-May	0	0	0	11	0	9
2-Jun	3	1	2	22	0	22
All	26	1	2	64	1	56
% of Total Detected		1%	2%	52%	1%	45%

Table 5–40. Minimum, maximum, and quartile values of travel time (hours) through three separate downstream reaches for radio-tagged alewives following downstream passage at Lowell during the spring 2020 adult alosine passage assessment.

Alewife - Downstream Transit Duration (hrs)						
Downstream Reach	Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
Downstream of Lowell to Station 37 (2.1 miles)	21-May	1.1	50.8	3.2	5.2	11.9
	22-May	2.6	17.0	4.5	6.2	10.0
	28-May	1.7	18.7	3.6	5.5	10.1
	2-Jun	1.5	28.5	2.6	4.6	7.1
	All	**1.1**	**50.8**	**3.0**	**5.0**	**9.2**
Station 37 to Station 39 (3.9 miles)	21-May	1.7	4.2	1.9	2.2	2.9
	22-May	1.8	4.5	2.0	2.1	2.5
	28-May	1.9	16.5	2.3	2.7	3.3
	2-Jun	2.2	13.7	2.6	3.0	3.9
	All	**1.7**	**16.5**	**2.1**	**2.6**	**3.1**
Station 39 to Lawrence (Station 40; 4.75 miles)	21-May	2.6	138.9	14.6	19.0	21.0
	22-May	4.5	8.5	4.5	5.8	8.5
	28-May	13.4	51.5	17.8	19.6	21.5
	2-Jun	4.1	68.2	16.8	18.7	20.5
	All	**2.6**	**138.9**	**16.1**	**19.0**	**21.1**

Table 5–41. Minimum, maximum, and quartile values of rate of travel (mph) through three separate downstream reaches for radio-tagged alewives following downstream passage at Lowell during the spring 2020 adult alosine passage assessment.

Alewife - Downstream Transit Rate (mph)						
Downstream Reach	Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
Downstream of Lowell to Station 37 (2.1 miles)	21-May	0.43	1.06	0.62	0.82	0.95
	22-May	0.40	1.00	0.74	0.88	0.92
	28-May	0.11	0.95	0.55	0.67	0.78
	2-Jun	0.13	0.82	0.46	0.61	0.71
	All	**0.11**	**1.06**	**0.58**	**0.71**	**0.86**
Station 37 to Station 39 (3.9 miles)	21-May	0.93	2.29	1.34	1.77	2.05
	22-May	0.87	2.17	1.60	1.90	2.00
	28-May	0.24	2.05	1.18	1.44	1.70
	2-Jun	0.28	1.77	1.00	1.32	1.53
	All	**0.24**	**2.29**	**1.26**	**1.53**	**1.86**
Station 39 to Lawrence (Station 40; 4.75 miles)	21-May	0.03	1.83	0.23	0.25	0.33
	22-May	0.56	1.06	0.56	0.82	1.06
	28-May	0.09	0.35	0.22	0.24	0.27
	2-Jun	0.07	1.16	0.23	0.25	0.28
	All	**0.03**	**1.83**	**0.23**	**0.25**	**0.30**

Table 5–42. Minimum, maximum, and quartile values for downstream travel duration from Lowell to Lawrence (hours) for radio-tagged alewives released upstream of Lowell during the spring 2020 adult alosine passage assessment.

Alewife - Downstream Travel: Lowell to Lawrence (hrs)					
Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
21-May	8.0	143.4	23.7	26.5	29.9
22-May	15.0	23.4	15.0	15.3	23.4
28-May	21.1	61.6	25.6	28.5	38.7
2-Jun	10.6	184.6	23.9	26.2	34.0
All	**8.0**	**184.6**	**23.8**	**26.6**	**33.3**

Table 5–43. CJS model selection criteria for survival of alewives at Lowell during the spring 2020 adult alosine passage assessment.

Model	AICc	Delta AICc	AICc Weight	Model Likelihood	No. Parameters	Deviance
Phi(t)p(t)	671.00	0.00	1.00	1.00	11	23.25
Phi(t)p(.)	698.84	27.84	0.00	0.00	7	59.29
Phi(.)p(t)	722.83	51.83	0.00	0.00	8	81.24
Phi(.)p(.)	868.37	197.37	0.00	0.00	2	238.95

Where *phi* = survival; *p* = detection probability; t = parameter is allowed to vary with time; and “.” = parameter is fixed with time.

Table 5–44. Detection efficiency estimates (p) for monitoring locations installed to detect radio-tagged alewives at Lowell during the spring 2020 adult alosine passage assessment.

Location	S	SE	95% CI	
Station 04	0.992	0.008	0.945	0.999
Lowell	1.000	0.000	1.000	1.000
Station 25	0.967	0.019	0.904	0.989
Station 26	0.855	0.039	0.762	0.916
Station 27	0.845	0.040	0.751	0.907

Table 5–45. Reach-specific survival probability estimates (*phi)*, standard errors, and likelihood 75% and 95% confidence intervals for radio-tagged alewives at Lowell during the spring 2020 adult alosine passage assessment.

Reach	*Phi*	SE	95% CI		75% CI	
Station 04 to Project	0.976	0.014	0.929	0.992	0.955	0.988
Project to Passage	0.992	0.008	0.944	0.999	0.974	0.997
Passage to Station 25	0.782	0.037	0.700	0.846	0.736	0.822
Station 25 to Station 26	0.973	0.022	0.872	0.995	0.931	0.990
Station 26 to Lawrence	1.000	0.000	-	-	-	-

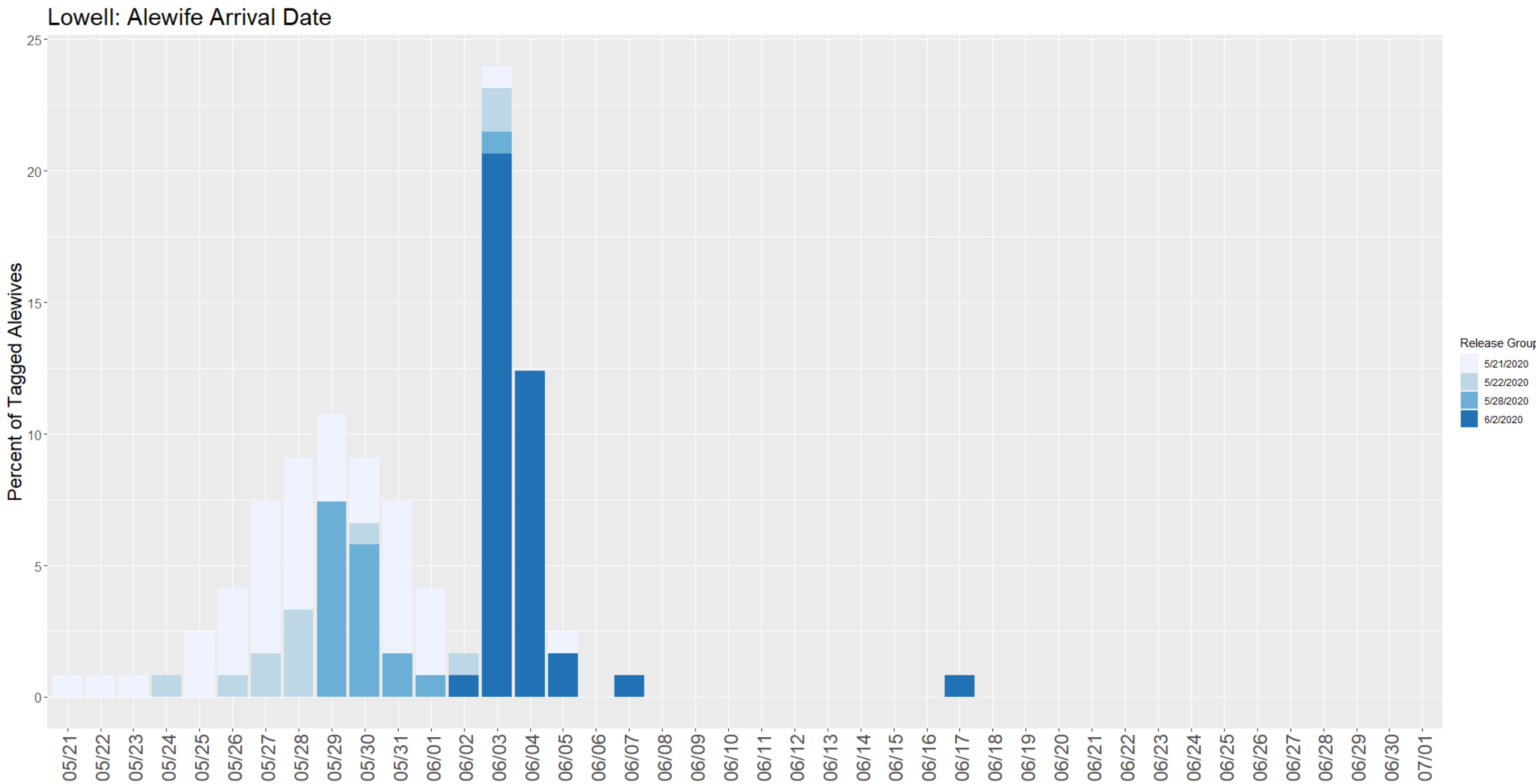

Figure 5–27. Distribution of Pawtucket Dam arrival dates for radio-tagged alewives at Lowell during the spring 2020 adult alosine passage assessment.

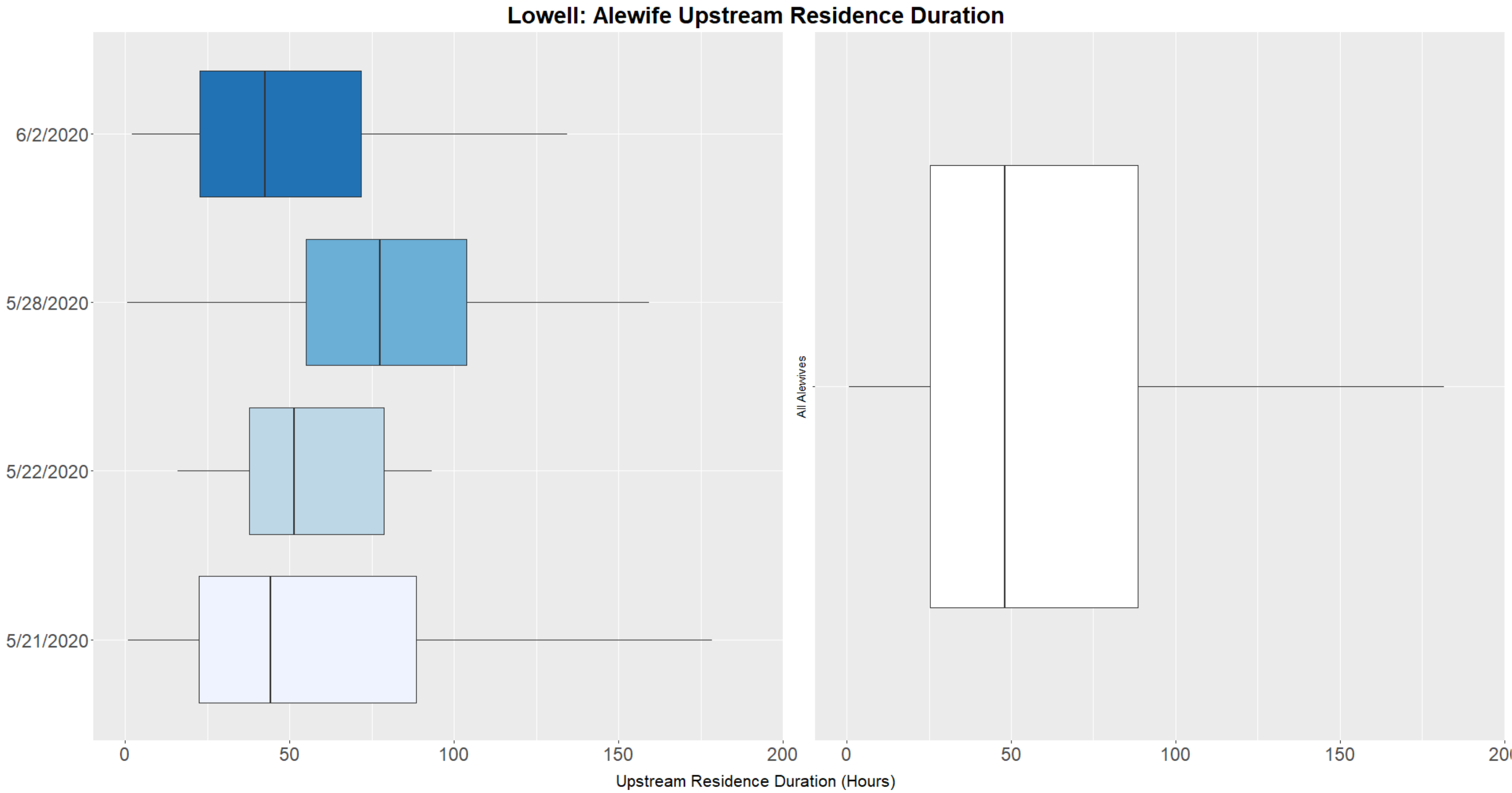

Figure 5–28. Boxplot of the Lowell upstream residence duration for radio-tagged alewives at Lowell during the spring 2020 adult alosine passage assessment. [9]

[9] The solid line represents the median while left and right portions of the box represent the first and third quartiles, respectively. Whiskers extend to the range of the data within the interquartile range (quartile*1.05) such that outliers outside of this range are not displayed.

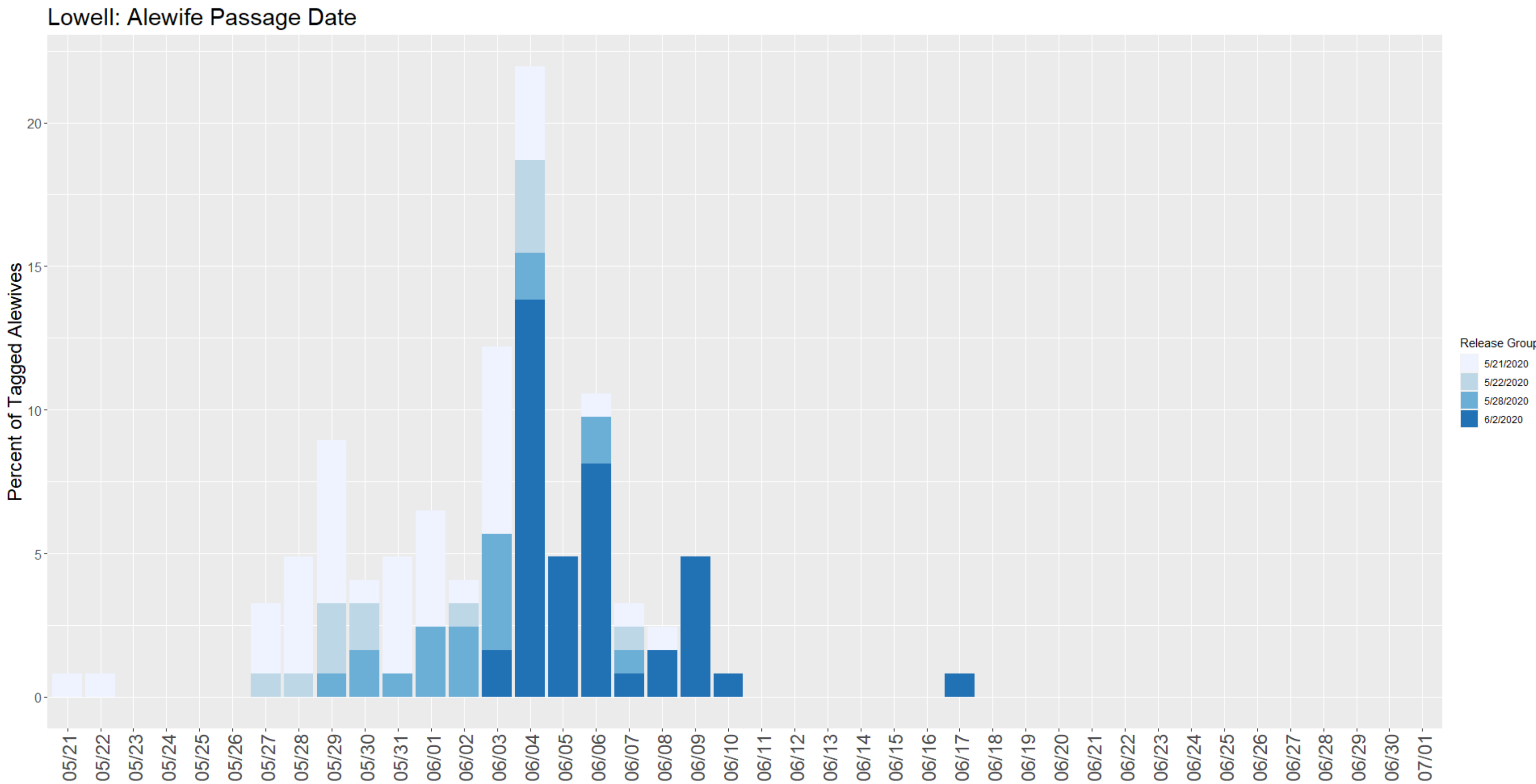

Figure 5–29. Distribution of Pawtucket Dam downstream passage dates for radio-tagged alewives at Lowell during the spring 2020 adult alosine passage assessment.

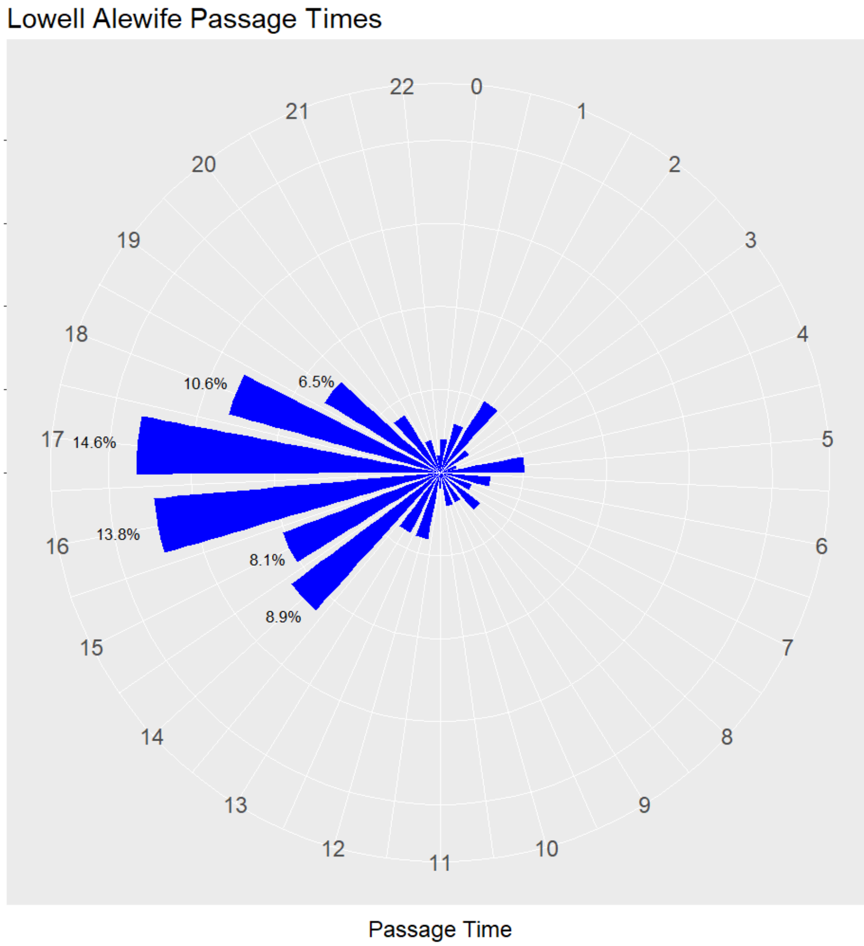

Figure 5–30. Distribution of downstream passage time for all radio-tagged alewives at Lowell during the spring 2020 adult alosine passage assessment.

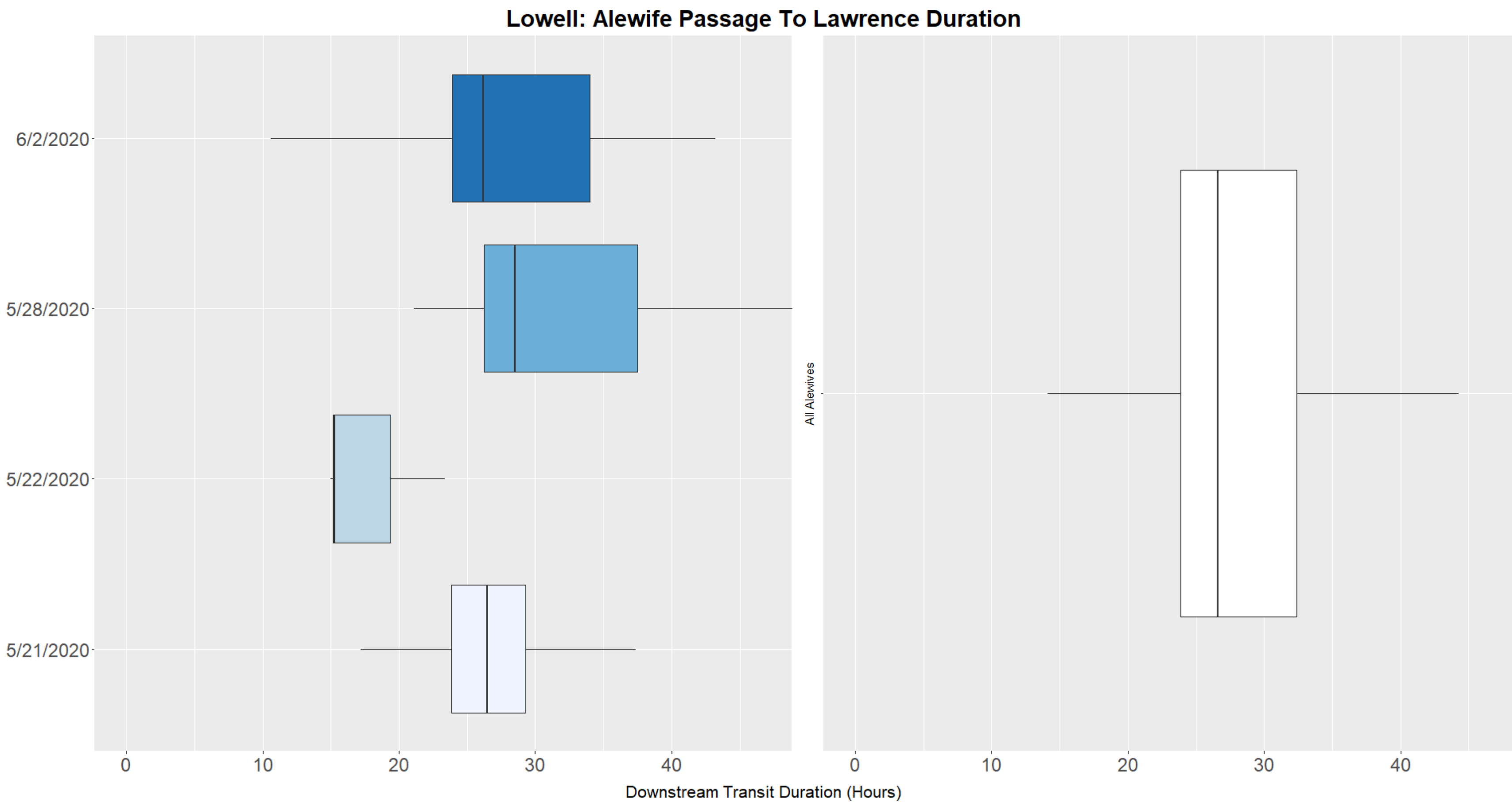

Figure 5–31. Boxplot of the downstream transit duration from Lowell to Lawrence for all radio-tagged alewives at Lowell during the spring 2020 adult alosine passage assessment. [10]

[10] The solid line represents the median while left and right portions of the box represent the first and third quartiles, respectively. Whiskers extend to the range of the data within the interquartile range (quartile*1.05) such that outliers outside of this range are not displayed.

5.7 Downstream Passage Effectiveness – Adult American Shad

A total of 150 adult American shad were radio-tagged and released during early-June 2020 for the purposes of evaluating downstream passage at Lowell (Table 5-46). Tagging was conducted on a total of three dates (June 3, 5, and 8). The New Hampshire Fish and Game Department provided a tank truck to assist with moving radio-tagged shad from the Lawrence lift to the release location upstream of Lowell. Adult shad tagged for evaluation of downstream passage at Lowell were comprised of 37% female, 58% male and 5% undetermined. Total length of individuals tagged ranged from 385-556 mm (mean = 482 mm). A full listing of tagged individuals released upstream of Lowell during the spring of 2020 is provided in Appendix A.

5.7.1 Project Arrival and Upstream Residence Duration

Releases of radio-tagged adult American shad were initiated upstream of Lowell at the Tyngsborough Riverfront Park on June 3, 2020. Figure 5-32 presents the distribution of arrival dates for those individuals at the Pawtucket Dam as indicated by detection at Stations 05 and 06. Initial detections for radio-tagged shad were recorded over a range of dates from June 4 through June 27 with nearly 70% of those fish arriving on or before June 15, 2020. The duration of time from release until arrival at Lowell (i.e., the approach duration) ranged from 13.0 hours to 20.0 days (median = 6.8 days; Table 5-47).

The duration of time radio-tagged individuals were present upstream of the Pawtucket Dam was determined for all individuals which approached and eventually passed downstream and was calculated as the duration of time from their initial detection immediately upstream of the dam until confirmed downstream passage via one of the available routes. When all individuals are considered, the upstream residence duration prior to downstream passage ranged between 0.4 hours to 19.1 days (Table 5-48; Figure 5-33). The median duration of time spent immediately upstream of the dam structure for a radio-tagged adult shad was 3.9 days. Of the radio-tagged adult shad which approached Pawtucket Dam, 30% passed in fewer than 24 hours and 51% passed in fewer than 96 hours after initial detection.

Outmigrating adult alosines encountering the Pawtucket Dam can (1) pass through the Pawtucket Gatehouse and enter the power canal, (2) pass downstream over Pawtucket Dam via spill, or (3) enter the Pawtucket Canal and navigate downstream via the downtown canal system. During the 2020 evaluation there were no radio-tagged adult shad detected at the Guard Locks (Station 28) and determined to have utilized the downtown canal system. The majority of radio-tagged adult shad were determined to have passed through the Pawtucket Gatehouse and entered the Northern Canal to approach the E.L. Field powerhouse. The duration of time to pass through the Pawtucket Gatehouse was determined based on the initial detection for each individual adult at Stations 06 and 07 which independently monitored the upstream and downstream sides of that structure. The median duration of time for radio-tagged adult shad to initially encounter and then pass through the Pawtucket Gatehouse was 2.1 hours (range <0.1 hours to 5.9 days; Table 5-49). The majority (75%) of radio-tagged adult shad passing through the Pawtucket Gatehouse did so in 12 hours or less following their initial detection at the structure.

Radio-tagged adult shad which entered the Northern Canal and passed downstream of E.L. Field powerhouse did so relatively quickly. Of those individuals, 78% were resident in the power canal upstream of E.L. Field for 12 hours or less. The median residence duration in the Northern Canal was 4.4 hours (range = 0.5 hours to 3.0 days; Table 5-50). Five radio-tagged individuals were present in the Northern Canal for greater than 24 hours prior to downstream passage.

5.7.2 Downstream Passage

A total of 150 radio-tagged adult American shad were released upstream of Lowell during the spring of 2020. Of that total, 118 were determined to have approached the Pawtucket Dam and were available for the evaluation of downstream passage route (Table 5-51). Over half of the radio-tagged shad passed through the Pawtucket Gatehouse, approached the E.L. Field powerhouse, and passed downstream via the E.L. Field turbine units (26% of radio-tagged shad) or utilized the downstream bypass (28% of radio-tagged shad). Use of the bypassed reach (i.e., spill or usage of the attraction water gate associated with the upstream fish ladder) was observed for 38% of the radio-tagged adult shad which approached the Project. Of the 45 radio-tagged adult shad which were determined to have passed downstream via the bypassed reach, 89% were initially detected in the area immediately upstream of the Pawtucket Gatehouse prior to downstream passage. Of those same 45 individuals, 9% were determined to have entered and exited the Northern Canal via the Pawtucket Gatehouse prior to their eventual passage downstream via the bypassed reach.

Radio-tagged adult shad were observed passing downstream of Lowell between the dates of June 5 through June 27 (Figure 5-34). Downstream passage of radio-tagged adult shad at Lowell peaked during mid-June with over half of all passage events occurring between June 16 and June 20, 2020. Figure 5-35 presents the timing distribution of downstream passage events for radio-tagged adult shad at Lowell. The majority of individuals passed downstream during the late morning, afternoon and early evening hours (i.e., 1000-2000).

5.7.3 Downstream Transit

Three monitoring stations were installed downstream of Lowell for the purpose of detecting radio-tagged adult alosines following passage at the Project during the spring of 2020. Those receivers were located approximately 2.1 (Monitoring Station 25), 6.0 (Monitoring Station 26), and 10.75 (Monitoring Station 27) miles downstream of the project. The minimum, maximum, and quartile transit times through those three reaches are presented in Table 5-52. The median transit time durations for tagged adult shad moving downstream of Lowell were 6.4, 1.9, and 5.9 hours for the 2.1 mile, 3.9 mile and 4.75 mile downstream reaches, respectively. Table 5-53 provides the minimum, maximum, and quartile transit times through defined sections of the Merrimack River between Lowell and Lawrence as a rate (i.e., miles per hour (mph)).

Table 5-54 and Figure 5-36 present the minimum, maximum and quartile transit times for radio-tagged adult shad to cover the full reach from immediately downstream of Lowell to the upstream face of the Essex Dam in Lawrence (i.e., Station 27). The median travel time for those fish to approach Lawrence following downstream passage at Lowell was 18.5 hours (range = 6.9 hours to 5.6 days).

5.7.4 Passage Survival

The CJS model *Phi(t)p(t)* provided the best fit for the observed mark-recapture data associated with downstream movements of radio-tagged adult American shad approaching and passing at Lowell during 2020 (Table 5-55). The detection efficiency for telemetry receivers recording passage of adult shad for monitoring stations at and downstream of Lowell ranged from 0.987 to 0.859 (Table 5-56). The reach-specific survival estimates for the Merrimack River from the Lowell impoundment receiver to detection immediately upstream of Lawrence are presented in Table 5-57. Passage success for downstream passage of adult shad at Lowell was calculated as the joint probability of the three reach-specific survival estimates which encompasses the full section of the Merrimack River from Lowell downstream to Lawrence (i.e., Lowell to Station 25, Station 25 to Station 26, and Station 26 to Lawrence). This resulted in an estimated downstream passage survival for adult shad at Lowell of 70.0% (75% CI = 64.5%-74.6%). No adjustments were made to encounter histories for shad passing Lowell to reflect the duration of time to detection at Lawrence following downstream passage since there were no documented events for radio-tagged "drift" shad at the downstream receiver stations indicating that the magnitude of downstream travel for that species following dead release into the tailrace was negligible.

Radio-tagged adult shad which approached and passed downstream at Lowell during the 2020 evaluation did so via a variety or passage routes (Table 5-51). When examined by passage route, detection at Station 27 (i.e., Lawrence Dam) occurred for 89% of individuals passing downstream through the bypassed reach, 82% of individuals passing Lowell via the downstream bypass and 35% of individuals passing via the E.L. Field turbine units.

Table 5–46. Summary of tagging and release information for adult American shad released upstream of Lowell during the spring 2020 downstream passage assessment.

Date	Source	Type	Number
3-Jun	Lawrence	Radio	50
5-Jun	Lawrence	Radio	50
8-Jun	Amoskeag	Radio	50
Total		Radio	150

Table 5–47. Minimum, maximum, and quartile values of approach duration (hours) for radio-tagged American shad released upstream of Lowell during the spring 2020 adult alosine passage assessment.

American Shad - Approach Duration (hrs)					
Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
3-Jun	13.0	410.7	53.4	155.1	243.8
5-Jun	16.1	480.5	54.6	155.5	312.6
8-Jun	31.6	455.4	46.9	163.3	262.1
All	**13.0**	**480.5**	**53.4**	**163.3**	**266.6**

Table 5–48. Minimum, maximum, and quartile values of upstream residence duration (hours) for radio-tagged American shad released upstream of Lowell during the spring 2020 adult alosine passage assessment.

American Shad - Upstream Residence (hrs)					
Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
3-Jun	3.1	349.3	39.6	126.5	250.8
5-Jun	0.4	459.3	17.6	133.5	236.7
8-Jun	1.6	239.5	5.6	20.8	140.1
All	**0.4**	**459.3**	**14.6**	**92.8**	**213.2**

Table 5–49. Minimum, maximum, and quartile values of time to pass the Pawtucket Gatehouse and enter Northern Canal (hours) for radio-tagged American shad released upstream of Lowell during the spring 2020 adult alosine passage assessment.

American Shad - Pawtucket Gatehouse Passage (hrs)					
Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
3-Jun	<0.1	141.7	0.5	2.9	14.9
5-Jun	0.1	50.1	0.4	1.5	7.6
8-Jun	0.5	95.3	0.8	2.4	30.5
All	**<0.1**	**141.7**	**0.5**	**2.1**	**11.7**

Table 5–50. Minimum, maximum, and quartile values of Northern Canal residence duration (hours) for radio-tagged American shad released upstream of Lowell during the spring 2020 adult alosine passage assessment.

American Shad - Northern Canal Residence (hrs)					
Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
3-Jun	0.5	73.0	1.5	4.5	9.5
5-Jun	0.7	37.5	1.8	5.8	10.2
8-Jun	0.6	44.9	1.4	3.8	12.7
All	**0.5**	**73.0**	**1.7**	**4.4**	**10.6**

Table 5–51. Downstream passage route selection for radio-tagged American shad released upstream of Lowell during the spring 2020 adult alosine passage assessment.

Release Date	American Shad - Lowell Downstream Passage Route					
	No Detect	No Pass	Downtown	Turbine	Spill	Bypass
3-Jun	9	3	0	15	10	13
5-Jun	7	3	0	10	15	15
8-Jun	16	3	0	6	20	5
All	32	9	0	31	45	33
% of Total Detected		8%	0%	26%	38%	28%

Table 5–52. Minimum, maximum, and quartile values of travel time (hours) through three separate downstream reaches for radio-tagged American shad following downstream passage at Lowell during the spring 2020 adult alosine passage assessment.

American Shad - Downstream Transit Duration (hrs)						
Downstream Reach	Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
Downstream of Lowell to Station 37 (2.1 miles)	21-May	2.0	267.5	3.8	5.6	14.2
	22-May	1.5	71.2	4.6	6.3	20.1
	28-May	2.1	54.8	3.6	6.9	27.0
	All	**1.5**	**267.5**	**3.7**	**6.4**	**19.3**
Station 37 to Station 39 (3.9 miles)	21-May	1.3	9.1	1.5	1.8	2.6
	22-May	1.4	11.2	1.8	2.4	4.1
	28-May	1.3	28.9	1.5	1.7	2.0
	All	**1.3**	**28.9**	**1.6**	**1.9**	**3.0**
Station 39 to Lawrence (Station 40; 4.75 miles)	21-May	1.7	119.3	3.2	5.7	11.5
	22-May	1.7	41.2	2.9	5.7	9.4
	28-May	2.8	24.5	3.4	8.4	14.4
	All	**1.7**	**119.3**	**3.3**	**5.9**	**11.5**

Table 5–53. Minimum, maximum, and quartile values of rate of travel (mph) through three separate downstream reaches for radio-tagged American shad following downstream passage at Lowell during the spring 2020 adult alosine passage assessment.

American Shad - Downstream Transit Rate (mph)						
Downstream Reach	Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
Downstream of Lowell to Station 37 (2.1 miles)	21-May	0.20	1.38	0.69	1.00	1.20
	22-May	0.16	1.29	0.44	0.75	1.00
	28-May	0.06	1.38	0.90	1.06	1.20
	All	**0.06**	**1.38**	**0.60**	**0.95**	**1.13**
Station 37 to Station 39 (3.9 miles)	21-May	0.43	3.00	1.50	2.17	2.60
	22-May	0.35	2.79	0.95	1.63	2.17
	28-May	0.13	3.00	1.95	2.29	2.60
	All	**0.13**	**3.00**	**1.30**	**2.05**	**2.44**
Station 39 to Lawrence (Station 40; 4.75 miles)	21-May	0.04	2.79	0.41	0.83	1.49
	22-May	0.12	2.79	0.51	0.83	1.64
	28-May	0.19	1.70	0.33	0.57	1.40
	All	**0.04**	**2.79**	**0.41**	**0.81**	**1.46**

Table 5–54. Minimum, maximum, and quartile values for downstream travel duration from Lowell to Lawrence (hours) for radio-tagged American shad released upstream of Lowell during the spring 2020 adult alosine passage assessment.

American Shad - Downstream Travel: Lowell to Lawrence (hrs)					
Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
3-Jun	7.5	135.1	11.9	16.8	27.4
5-Jun	9.1	55.6	11.1	18.9	33.7
8-Jun	6.9	53.8	10.5	19.4	37.7
All	**6.9**	**135.1**	**11.1**	**18.5**	**32.6**

Table 5–55. CJS model selection criteria for survival of American shad at Lowell during the spring 2020 adult alosine passage assessment.

Model	AICc	Delta AICc	AICc Weight	Model Likelihood	No. Parameters	Deviance
Phi(t)p(t)	700.94	0.00	0.99	1.00	13	36.10
Phi(t)p(.)	710.68	9.74	0.01	0.01	8	56.15
Phi(.)p(t)	733.58	32.64	0.00	0.00	8	79.06
Phi(.)p(.)	740.85	39.91	0.00	0.00	2	98.51

Where *phi* = survival; *p* = detection probability; t = parameter is allowed to vary with time; and "." = parameter is fixed with time.

Table 5–56. Detection efficiency estimates (p) for monitoring locations installed to detect radio-tagged American shad at Lowell during the spring 2020 adult alosine passage assessment.

Location	S	SE	95% CI	
Station 04	0.966	0.017	0.914	0.987
Lowell	0.965	0.020	0.896	0.989
Station 25	0.987	0.013	0.916	0.998
Station 26	0.859	0.039	0.763	0.920
Station 27	0.897	0.037	0.799	0.950

Table 5–57. Reach-specific survival probability estimates (*phi)*, standard errors, and likelihood 75% and 95% confidence intervals for radio-tagged American shad at Lowell during the spring 2020 adult alosine passage assessment.

Reach	*Phi*	SE	95% CI		75% CI	
Station 04 to Project	0.951	0.020	0.894	0.978	0.923	0.970
Project to Passage	0.948	0.023	0.881	0.979	0.915	0.969
Passage to Station 25	0.753	0.041	0.663	0.825	0.702	0.797
Station 25 to Station 26	0.931	0.028	0.851	0.969	0.890	0.957
Station 26 to Lawrence	1.000	0.016	0.000	1.000	-	-

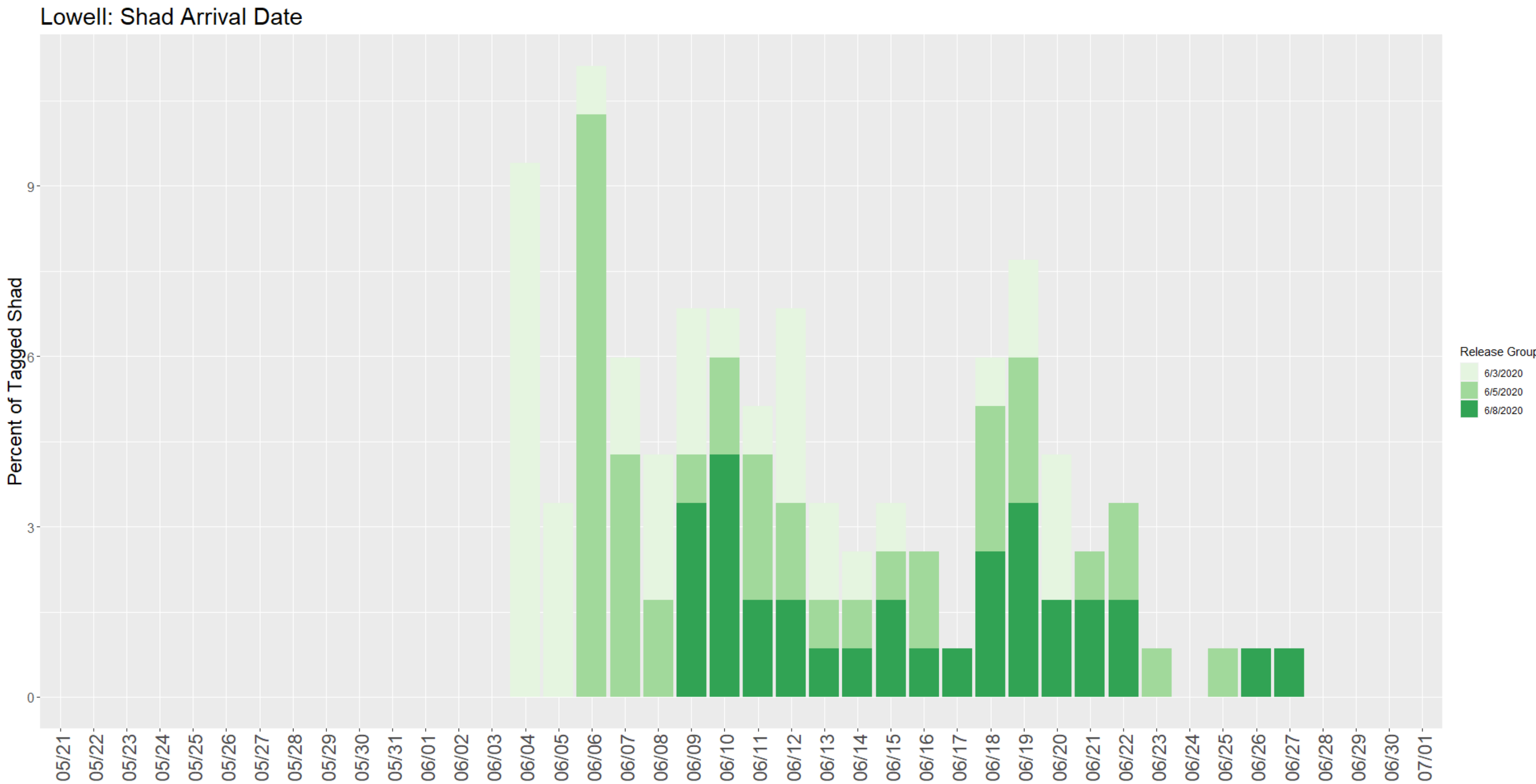

Figure 5–32. Distribution of Pawtucket Dam arrival dates for radio-tagged American shad at Lowell during the spring 2020 adult alosine passage assessment.

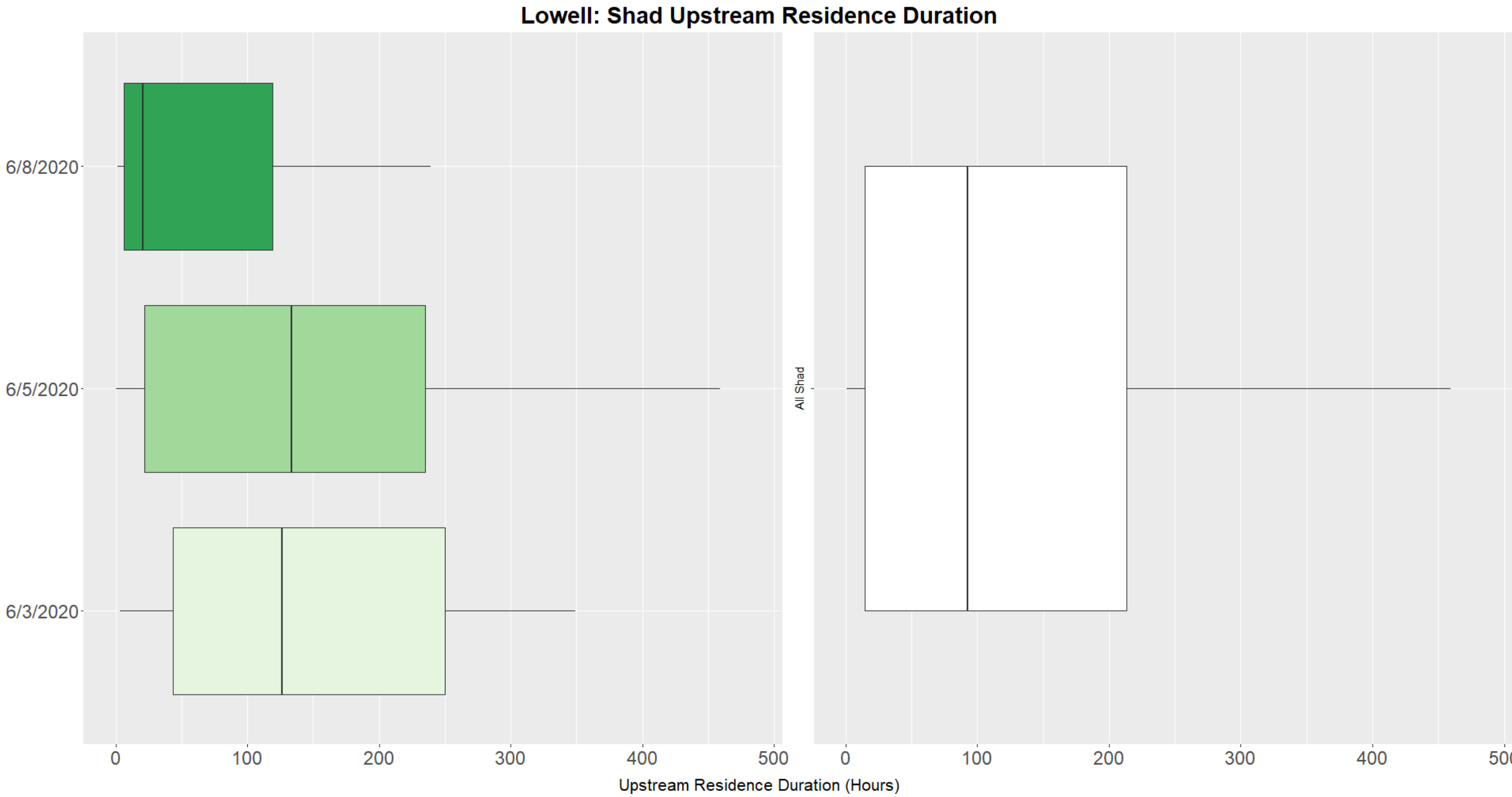

Figure 5–33. Boxplot of the Lowell upstream residence duration for radio-tagged American shad at Lowell during the spring 2020 adult alosine passage assessment. [11]

[11] The solid line represents the median while left and right portions of the box represent the first and third quartiles, respectively. Whiskers extend to the range of the data within the interquartile range (quartile*1.05) such that outliers outside of this range are not displayed.

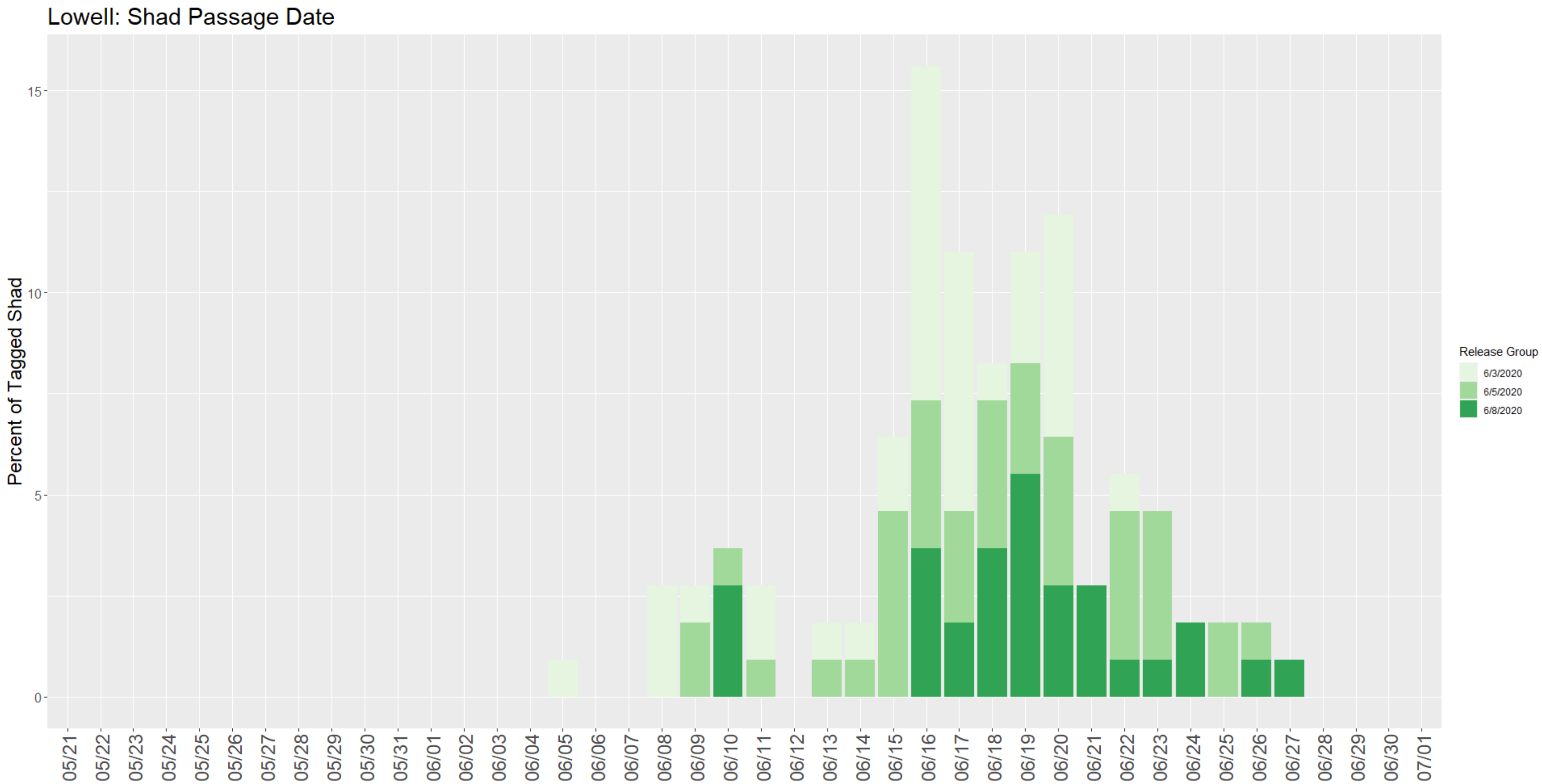

Figure 5–34. Distribution of Pawtucket Dam downstream passage dates for radio-tagged American shad at Lowell during the spring 2020 adult alosine passage assessment.

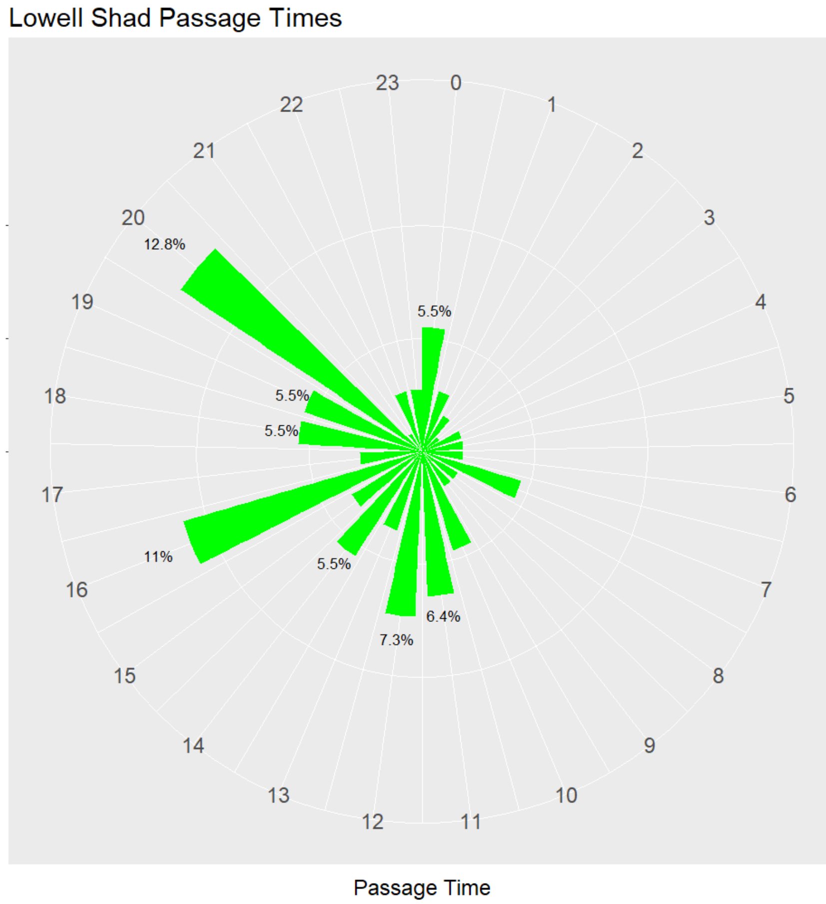

Figure 5–35. Distribution of downstream passage time for all radio-tagged American shad at Lowell during the spring 2020 adult alosine passage assessment.

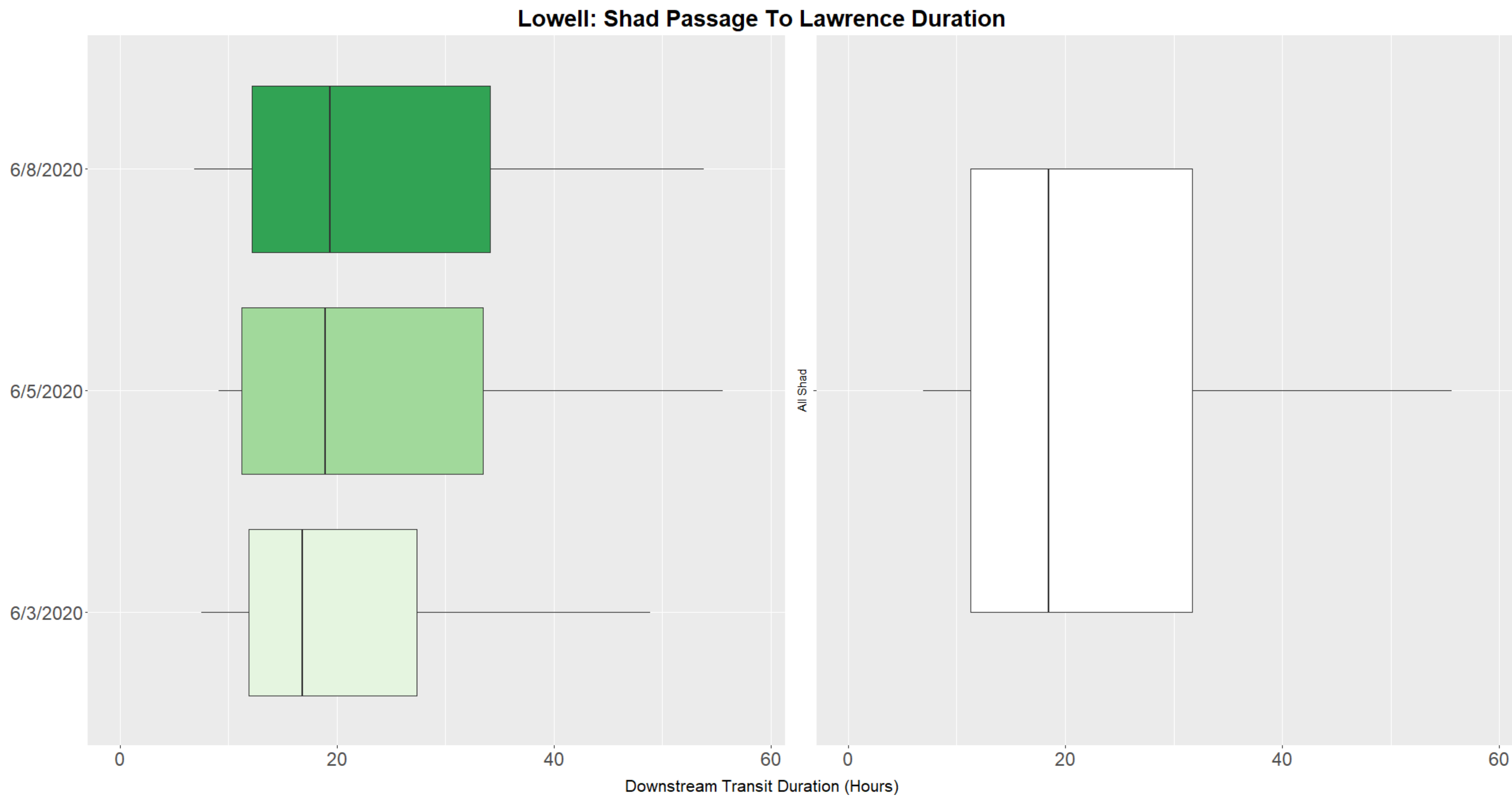

Figure 5–36. Boxplot of the downstream transit duration from Lowell to Lawrence for all radio-tagged American shad at Lowell during the spring 2020 adult alosine passage assessment.[12]

[12] The solid line represents the median while left and right portions of the box represent the first and third quartiles, respectively. Whiskers extend to the range of the data within the interquartile range (quartile*1.05) such that outliers outside of this range are not displayed.

6 Summary

An evaluation of the upstream and downstream passage effectiveness for adult alewives and American shad was conducted in support of the FERC relicensing of the Lowell Hydroelectric Project. Fish passage effectiveness was evaluated using telemetry during the 2020 spring passage season (May through June). Merrimack River conditions during the spring 2020 passage assessment were considered as normal or low for the majority of May and low for most of the month of June. The E.L. Field fish passage facilities (i.e., upstream fish lift and downstream fish bypass) were operated throughout the study period and those turbine units were in operation for the duration of the study period. Two major spill events, associated with increases in river flows, occurred during the early portion of the monitoring period (May 7 and May 18). Flows to the downstream canal system were limited during both months as Boott suspended operation of the generating units in that system prior to the onset of the study due to overriding safety concerns.

6.1 Adult Alewife

A total of 504 adult alewives were radio and/or PIT-tagged over a range of dates from May 7 through June 2, 2020. Of that total, 354 (150 dual-tagged and 204 PIT-tagged) were tagged and released at the Lawrence Project (FERC No. 2800) fish lift facility and were evaluated for upstream passage at Lowell. The remaining 150 radio-tagged adult alewives were sourced from either the fish passage facility at Lawrence or the upstream fish ladder at Amoskeag Dam in Manchester, NH (FERC No. 1893) and were released upstream of Lowell at the Tyngsborough Riverfront Park for the evaluation of downstream passage. Of the dual-tagged adult alewives released downstream of the Project, 85% were determined to have approached Lowell and were available to assess passage effectiveness of either E.L. Field powerhouse fish lift or the Pawtucket Dam fish ladder. Of the 150 radio-tagged adult alewives released upstream of Lowell, 83% approached the Pawtucket Dam and were available to evaluate downstream passage at the Project.

Releases of dual-tagged alewives downstream of the Project occurred over six dates between May 7 and May 19, 2020 and individuals were observed approaching the Lowell Project as early as the initial date of release through May 23. The duration of time for fish to move upstream from the release location at Lawrence to Lowell was around one day for most dual-tagged adult alewives (median = 19.6 hours; 75th percentile = 28.6 hours). Following arrival downstream of the Project, 95% of dual-tagged adult alewives made at least one foray upstream towards either the fish lift or ladder. When examined by structure 64% of dual-tagged alewives made at least one foray in the direction of the fish lift, 67% in the direction of the fish ladder, and 39% in the direction of the fish lift and fish ladder.

The 82 dual-tagged adult alewives determined to have approached the E.L. Field fish lift produced a combined total of 134 unique foray events. Approximately 66% of the set of upstream foray events towards the E.L. Field fish lift resulted in detection of the dual-tagged alewife at the lift entrance and the median duration of time to locate the fish lift entrance was 0.7 hours. Fish lift entrances were recorded over a range of dates from May 8 through May 30 and peaked during mid-May. Upstream effectiveness of the E.L. Field fish lift was assessed using a CJS model and for an individual adult alewife which entered the tailrace channel estimated the probability of locating the entrance (i.e., the nearfield attraction) at 83.3%. The overall effectiveness of the E.L. Field fish lift for adult alewife passage during 2020 was estimated at 43.9% (75% CI = 39.3-51.4%). Following upstream passage at the lift, dual-tagged adult alewives proceed quickly upstream to the downstream face of the Pawtucket Gatehouse (median duration = 0.7 hours). The median duration of time for dual-tagged adult alewives to pass the Pawtucket Gatehouse was 25.7 hours.

A total of 86 adult alewives made at least one foray in the direction of the Pawtucket Dam fish ladder during their time at large in the Project area. Of the 105 total forays towards the fish ladder, 51% resulted in at least one detection at the ladder entrance and the median duration of time to locate the entrance once an individual had arrived at the upper end of the bypassed reach was 4.0 hours. Fish lift entrances were recorded for dual-tagged adult alewives over a range of dates from May 7 through May 23 and peaked during mid-May. Additional observations of PIT-tag only adult alewife entrances into the fish ladder occurred over a comparable range of dates (May 9 to May 27). Upstream effectiveness of the Pawtucket Dam fish ladder was assessed using a CJS model and for an individual adult alewife which ascended to the upper end of the bypassed reach the probability of locating the entrance (i.e., the nearfield attraction) was 93.0%. The overall effectiveness of the Pawtucket Dam fish ladder for adult alewife passage during 2020 was estimated at 75.6% (75% CI = 69.2-82.2%). The median duration of time from initial detection at the fish ladder entrance until exit at the top of the structure for dual-tagged adult alewives was 2.9 hours (lower leg median duration = 2.1 hours; upper leg median duration = 1.1 hours). Supplemental data collected for the PIT-tag only adult alewives which entered the Pawtucket Dam fish ladder corresponded with observations for the dual-tagged fish (median ladder passage duration = 3.8 hours; lower leg passage = 1.6 hours; upper leg passage = 1.2 hours).

Outmigration of radio-tagged adult alewives was observed over a range of dates from May 21 to June 17 with a peak number of events occurring between June 3 and 6. The median upstream residence time prior to downstream passage was 2.0 days with 77% of individuals passing downstream in less than 96 hours after their arrival. The majority of individuals passed downstream of Lowell via the E.L. Field turbine units (52% of radio-tagged alewives) or utilized the downstream bypass (45% of radio-tagged alewives). Downstream passage survival was calculated as the joint probability of the three reach-specific survival estimates which encompasses the full section of the Merrimack River from Lowell downstream to Lawrence and resulted in an estimated downstream passage survival for adult alewives at Lowell of 76.5% (75% CI = 71.5%-80.5%). This estimate of downstream passage survival for adult alewives at Lowell includes background mortality (i.e., natural mortality) for the species in the downstream reach, along with any tagging-related mortalities or tag regurgitations. As a result, this estimate should be viewed as a minimum estimate of total project survival (i.e., due solely to project effects) for adult alewives at the Project.

6.2 Adult American Shad

A total of 534 adult American shad were radio and/or PIT-tagged over a range of dates from May 16 through June 8, 2020. Of that total, 384 (180 dual-tagged and 204 PIT-tagged) were tagged and released at the Lawrence fish lift facility and were evaluated for upstream passage at Lowell. The remaining 150 radio-tagged adult American shad were collected from the fish passage facility at Lawrence and were released upstream of Lowell at the Tyngsborough Riverfront Park for the evaluation of downstream passage. Of the dual-tagged adult American shad released downstream of the Project, 40% were determined to have approached Lowell and were available to assess passage effectiveness of either E.L. Field powerhouse fish lift or the Pawtucket Dam fish ladder. An additional 47% of the dual-tagged shad exhibited upstream movement following tagging and release at Lawrence but did not move the full length of the Merrimack River reach between the two Projects. Of the 150 radio-tagged adult shad released upstream of Lowell, 79% approached the Pawtucket Dam and were available to evaluate downstream passage at the Project.

Releases of dual-tagged American shad downstream of the Project occurred over five dates between May 16 and May 27, 2020 and individuals were observed approaching the Lowell Project between May 17 and June 6. The median duration of time for shad to move upstream from the release location at Lawrence to Lowell was 64.5 hours (2.7 days). Following arrival downstream of the Project, 63% of dual-tagged adult American shad made at least one foray upstream towards either the fish lift or ladder. The vast majority those shad made one or more forays in the direction of the fish lift. Only a single dual-tagged shad was determined to have initiated an upstream ascent into the bypassed reach and in the direction of the fish ladder.

The 43 dual-tagged adult American shad determined to have approached the E.L. Field fish lift produced a combined total of 201 unique foray events. Approximately 37% of the set of upstream foray events towards the E.L. Field fish lift resulted in detection of the dual-tagged shad at the lift entrance and the median duration of time to locate the fish lift entrance was 1.1 hours. Fish lift entrances were recorded over a range of dates from May 18 through June 15 and peaked during late-May. Upstream effectiveness of the E.L. Field fish lift was assessed using a CJS model and for an individual adult shad which entered the tailrace channel estimated the probability of locating the entrance (i.e., the nearfield attraction) at 67.4%. The overall effectiveness of the E.L. Field fish lift for adult American shad passage during 2020 was estimated at 30.4% (75% CI = 22.1-39.5%). Following upstream passage at the lift, dual-tagged adult shad proceed quickly upstream to the downstream face of the Pawtucket Gatehouse (median duration = 0.8 hours). The median duration of time for dual-tagged adult shad to pass the Pawtucket Gatehouse was 5.4 days.

Upstream movement of dual-tagged shad within the Lowell bypassed reach was limited to a single individual which was detected only at the lowermost receiver within that reach. There were no detections of any dual-tagged adult American shad at the Pawtucket Dam fish ladder during the 2020 study. Similarly, detections of PIT-tagged adult shad were also very limited during the 2020 study period. Of the 204 PIT-tagged adult shad released at Lawrence during the onset of the study only two individuals were determined to have entered the fish ladder.

Outmigration of radio-tagged adult American shad was observed over a range of dates from June 4 to June 27 with a peak number of events occurring on or before June 15. The median upstream residence time prior to downstream passage was 3.9 days with 51% of individuals passing downstream in less than 96 hours after their arrival. The majority of individuals passed downstream of Lowell via the E.L. Field turbine units (26%), the downstream bypass (28%) or utilized the bypassed reach (38% of radio-tagged shad). Downstream passage survival was calculated as the joint probability of the three reach-specific survival estimates which encompasses the full section of the Merrimack River from Lowell downstream to Lawrence and resulted in an estimated downstream passage survival for adult shad at Lowell of 70.0% (75% CI = 64.5%-74.6%). This estimate of downstream passage survival for adult shad at Lowell includes background mortality (i.e., natural mortality) for the species in the downstream reach, along with any tagging-related mortalities or tag regurgitations. As a result, this estimate should be viewed as a minimum estimate of total project survival (i.e., due solely to project effects) for adult American shad at the Project.

7 Additional Analysis for the Updated Study Report

FERC issued Scoping Document 2 (SD2) on September 27, 2018. SD2 included the process plan and schedule for the Lowell ILP process. Per the SD2 schedule Boott was to file the Initial Study Report (ISR) on February 25, 2020 and the Updated Study Report (USR) on February 25, 2021. Following the March 11, 2020 ISR meeting, FERC issued a revised process plan and schedule (filed June 12, 2020) to provide Boott with additional time to complete the required studies and analyses for the 2019 and 2020 field season. The revised process plan and schedule incorporated a *Revised* ISR submittal date of September 30, 2020. Field effort associated with this study were completed in early July of 2020. Boott and its consultants accelerated the reporting schedule for this study to provide a robust analysis of upstream and downstream passage of adult alosines at the Project within the revised schedule provided by FERC. Although this Revised ISR will provide FERC and the resource agencies with significant information with which to assess the behavior, approach routes, passage success, survival, and residence duration of adult American shad and alewives as they encounter the Lowell Project during their upstream and downstream migrations Boott acknowledges there are several study components yet to be evaluated and intends to provide this additional information as part of the USR due on February 25, 2021.

Additional information to be included in the updated adult alosine passage assessment will include:

- Incorporation of downstream passage data for adult alewives originally radio-tagged and released in the Nashua River upstream of Lowell as part of the ongoing FERC relicensing process for the Mine Falls Project (FERC No. 3442).
- Summary and synthesis of manual tracking data collected during the spring 2020 monitoring period by Normandeau as well as staff from NHFGD.

- Evaluation of duration of passage attempts using multi-variate Cox proportional hazard models.
- Analysis of the relationship between upstream and downstream passage events and route selection, with river flow, project operations, spill flows, etc.

8 Variances from FERC-Approved Study Plan

The timing of this field study (April – June 2020) coincided with the rapid onset of the COVID-19 pandemic throughout the United States and during the course of this evaluation both the States of New Hampshire and Massachusetts were operating under a “stay-at-home” order. Every effort was made to conduct this evaluation as described in the FERC-approved RSP while still maintaining the health and safety of all Normandeau project staff and Boott operations staff.

Variances from the RSP included:

- Monitoring Station M20 was described in the RSP as a PIT-reader to be installed at the hopper discharge of the E.L. Field fish lift. Range testing conducted following installation of this antenna indicated significant background interference at that location reducing the read range of the antenna to near zero. As a result that unit was moved further upstream to allow for a pair of readers to provide coverage of the fish lift exit flume.
- Monitoring Stations C3 and C7 were described in the RSP as PIT-readers. Following initial site reconnaissance it was determined by Normandeau field staff that the intended detection area was not suitable for a PIT antenna. As a result those two locations were instead monitored using a Sigma-Eight Orion radio telemetry receiver. This change in equipment was noted during the March 2020 ISR meeting held in Lowell, MA.
- As Boott was not operating the downtown canal units due to safety concerns, the 100 radio-tagged adult alewife and shad (50 each) proposed in the RSP for release into the downtown canal system to assess outmigration through those facilities were instead placed in the river upstream of Lowell to increase the sample size for the downstream passage assessment. Boott consulted with both USFWS and NHFGD prior to making this modification.
- Due to uncertainty in returns of adult river herring at Lawrence towards the tail end of the monitoring period, Boott relied on the use of 70 adult alewives collected at the Amoskeag trap and truck facility in Manchester, NH. These individuals were radio-tagged and the released into the river upstream of Lowell to evaluate downstream passage of that species. Boott consulted with both USFWS and NHFGD prior to making this modification.

- In their SPD and based on resource agency comments, FERC recommended placement of an additional stationary receiver along the eastern wall of the E.L. Field tailrace. Boott and Normandeau staff evaluated the eastern tailrace wall during the site installation process and access to that reach was deemed unsafe. The study proceeded with a single tailrace receiver which operated without issue for the duration of the study period.

- In their SPD, FERC recommended fish be released at a point further upstream to reduce the potential for fallback downstream of Lawrence immediately following tagging and release. Adult alosines collected for upstream passage from the Lawrence fish lift were released directly into the exit flume of that facility following tagging. This change was made due to the lack of early season tank truck assistance to move American shad upstream as well as the closure of the public boat access upstream of Lawrence by the City due to the ongoing COVID situation.

- The evaluation of the E.L. Field fish lift as part of the spring 2020 adult alosine passage evaluation was conducted under the same tailrace channel geometry as previous evaluations. As discussed during consultation with the resource agencies prior to the 2020 study, Boott could not guarantee that the planned tailrace ledge modifications could be completed in time to avoid interference with fish lift operations and this study.

9 Appendices

Appendix A. Tagging and release information for adult alosines for the spring 2020 passage assessment at Lowell.

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Alewife	F	295	5/7/2020	Dual	149.440	10	900_230000237305	Lawrence	US
Alewife	M	310	5/7/2020	Dual	149.440	11	900_230000237304	Lawrence	US
Alewife	F	298	5/7/2020	Dual	149.440	12	900_230000237303	Lawrence	US
Alewife	F	319	5/7/2020	Dual	149.440	13	900_230000237302	Lawrence	US
Alewife	F	296	5/7/2020	Dual	149.440	14	900_230000237301	Lawrence	US
Alewife	F	315	5/7/2020	Dual	149.460	40	900_230000237310	Lawrence	US
Alewife	M	292	5/7/2020	Dual	149.460	41	900_230000237309	Lawrence	US
Alewife	M	298	5/7/2020	Dual	149.460	42	900_230000237308	Lawrence	US
Alewife	M	305	5/7/2020	Dual	149.460	43	900_230000237307	Lawrence	US
Alewife	F	314	5/7/2020	Dual	149.460	44	900_230000237306	Lawrence	US
Alewife	M	303	5/7/2020	Dual	149.480	70	900_230000237315	Lawrence	US
Alewife	M	280	5/7/2020	Dual	149.480	71	900_230000237314	Lawrence	US
Alewife	F	311	5/7/2020	Dual	149.480	72	900_230000237313	Lawrence	US
Alewife	M	297	5/7/2020	Dual	149.480	73	900_230000237312	Lawrence	US
Alewife	F	304	5/7/2020	Dual	149.480	74	900_230000237311	Lawrence	US
Alewife	F	319	5/7/2020	Dual	149.760	100	900_230000237320	Lawrence	US
Alewife	F	314	5/7/2020	Dual	149.760	101	900_230000237319	Lawrence	US
Alewife	F	315	5/7/2020	Dual	149.760	102	900_230000237318	Lawrence	US
Alewife	M	305	5/7/2020	Dual	149.760	103	900_230000237317	Lawrence	US
Alewife	F	305	5/7/2020	Dual	149.760	104	900_230000237316	Lawrence	US
Alewife	M	295	5/7/2020	Dual	149.800	130	900_230000237325	Lawrence	US
Alewife	F	330	5/7/2020	Dual	149.800	131	900_230000237324	Lawrence	US
Alewife	M	310	5/7/2020	Dual	149.800	132	900_230000237323	Lawrence	US
Alewife	F	294	5/7/2020	Dual	149.800	133	900_230000237322	Lawrence	US
Alewife	F	295	5/7/2020	Dual	149.800	134	900_230000237321	Lawrence	US
Alewife	F	285	5/7/2020	PIT	-	-	900_230000237328	Lawrence	US
Alewife	M	285	5/7/2020	PIT	-	-	900_230000237356	Lawrence	US
Alewife	M	288	5/7/2020	PIT	-	-	900_230000237348	Lawrence	US
Alewife	M	290	5/7/2020	PIT	-	-	900_230000237329	Lawrence	US
Alewife	F	290	5/7/2020	PIT	-	-	900_230000237330	Lawrence	US
Alewife	M	290	5/7/2020	PIT	-	-	900_230000237331	Lawrence	US
Alewife	M	292	5/7/2020	PIT	-	-	900_230000237341	Lawrence	US
Alewife	M	295	5/7/2020	PIT	-	-	900_230000237353	Lawrence	US
Alewife	M	295	5/7/2020	PIT	-	-	900_230000237359	Lawrence	US
Alewife	M	296	5/7/2020	PIT	-	-	900_230000237354	Lawrence	US
Alewife	F	297	5/7/2020	PIT	-	-	900_230000237334	Lawrence	US
Alewife	M	297	5/7/2020	PIT	-	-	900_230000237347	Lawrence	US
Alewife	M	299	5/7/2020	PIT	-	-	900_230000237333	Lawrence	US

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Alewife	F	299	5/7/2020	PIT	-	-	900_230000237339	Lawrence	US
Alewife	M	300	5/7/2020	PIT	-	-	900_230000237326	Lawrence	US
Alewife	F	300	5/7/2020	PIT	-	-	900_230000237332	Lawrence	US
Alewife	M	300	5/7/2020	PIT	-	-	900_230000237346	Lawrence	US
Alewife	M	300	5/7/2020	PIT	-	-	900_230000237352	Lawrence	US
Alewife	M	303	5/7/2020	PIT	-	-	900_230000237345	Lawrence	US
Alewife	M	303	5/7/2020	PIT	-	-	900_230000237351	Lawrence	US
Alewife	M	304	5/7/2020	PIT	-	-	900_230000237335	Lawrence	US
Alewife	M	304	5/7/2020	PIT	-	-	900_230000237343	Lawrence	US
Alewife	F	305	5/7/2020	PIT	-	-	900_230000237357	Lawrence	US
Alewife	F	308	5/7/2020	PIT	-	-	900_230000237355	Lawrence	US
Alewife	M	310	5/7/2020	PIT	-	-	900_230000237349	Lawrence	US
Alewife	M	312	5/7/2020	PIT	-	-	900_230000237336	Lawrence	US
Alewife	F	312	5/7/2020	PIT	-	-	900_230000237344	Lawrence	US
Alewife	F	313	5/7/2020	PIT	-	-	900_230000237340	Lawrence	US
Alewife	F	314	5/7/2020	PIT	-	-	900_230000237337	Lawrence	US
Alewife	F	314	5/7/2020	PIT	-	-	900_230000237338	Lawrence	US
Alewife	U	315	5/7/2020	PIT	-	-	900_230000237342	Lawrence	US
Alewife	U	316	5/7/2020	PIT	-	-	900_230000237358	Lawrence	US
Alewife	F	319	5/7/2020	PIT	-	-	900_230000237350	Lawrence	US
Alewife	F	330	5/7/2020	PIT	-	-	900_230000237327	Lawrence	US
Alewife	M	294	5/8/2020	Dual	149.440	16	900_230000237419	Lawrence	US
Alewife	M	303	5/8/2020	Dual	149.440	17	900_230000237418	Lawrence	US
Alewife	M	300	5/8/2020	Dual	149.440	18	900_230000237417	Lawrence	US
Alewife	F	335	5/8/2020	Dual	149.440	19	900_230000237416	Lawrence	US
Alewife	F	314	5/8/2020	Dual	149.440	20	900_230000237415	Lawrence	US
Alewife	M	290	5/8/2020	Dual	149.460	46	900_230000237424	Lawrence	US
Alewife	F	311	5/8/2020	Dual	149.460	47	900_230000237423	Lawrence	US
Alewife	M	301	5/8/2020	Dual	149.460	48	900_230000237422	Lawrence	US
Alewife	M	304	5/8/2020	Dual	149.460	49	900_230000237421	Lawrence	US
Alewife	M	289	5/8/2020	Dual	149.460	50	900_230000237420	Lawrence	US
Alewife	M	282	5/8/2020	Dual	149.480	76	900_230000237429	Lawrence	US
Alewife	M	301	5/8/2020	Dual	149.480	77	900_230000237428	Lawrence	US
Alewife	M	314	5/8/2020	Dual	149.480	78	900_230000237427	Lawrence	US
Alewife	M	285	5/8/2020	Dual	149.480	79	900_230000237426	Lawrence	US
Alewife	M	284	5/8/2020	Dual	149.480	80	900_230000237425	Lawrence	US
Alewife	U	320	5/8/2020	Dual	149.760	106	900_230000237434	Lawrence	US
Alewife	M	304	5/8/2020	Dual	149.760	107	900_230000237433	Lawrence	US
Alewife	M	293	5/8/2020	Dual	149.760	108	900_230000237432	Lawrence	US
Alewife	M	290	5/8/2020	Dual	149.760	109	900_230000237431	Lawrence	US
Alewife	F	289	5/8/2020	Dual	149.760	110	900_230000237430	Lawrence	US
Alewife	M	304	5/8/2020	Dual	149.800	136	900_230000237439	Lawrence	US
Alewife	F	315	5/8/2020	Dual	149.800	137	900_230000237438	Lawrence	US
Alewife	M	306	5/8/2020	Dual	149.800	138	900_230000237437	Lawrence	US

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Alewife	F	325	5/8/2020	Dual	149.800	139	900_230000237436	Lawrence	US
Alewife	M	294	5/8/2020	Dual	149.800	140	900_230000237435	Lawrence	US
Alewife	M	280	5/8/2020	PIT	-	-	900_230000237406	Lawrence	US
Alewife	M	285	5/8/2020	PIT	-	-	900_230000237403	Lawrence	US
Alewife	M	287	5/8/2020	PIT	-	-	900_230000237413	Lawrence	US
Alewife	M	290	5/8/2020	PIT	-	-	900_230000237404	Lawrence	US
Alewife	M	290	5/8/2020	PIT	-	-	900_230000237412	Lawrence	US
Alewife	M	291	5/8/2020	PIT	-	-	900_230000237440	Lawrence	US
Alewife	M	292	5/8/2020	PIT	-	-	900_230000237391	Lawrence	US
Alewife	M	292	5/8/2020	PIT	-	-	900_230000237407	Lawrence	US
Alewife	M	294	5/8/2020	PIT	-	-	900_230000237443	Lawrence	US
Alewife	M	295	5/8/2020	PIT	-	-	900_230000237393	Lawrence	US
Alewife	M	295	5/8/2020	PIT	-	-	900_230000237397	Lawrence	US
Alewife	M	295	5/8/2020	PIT	-	-	900_230000237398	Lawrence	US
Alewife	M	297	5/8/2020	PIT	-	-	900_230000237441	Lawrence	US
Alewife	U	298	5/8/2020	PIT	-	-	900_230000237445	Lawrence	US
Alewife	F	300	5/8/2020	PIT	-	-	900_230000237405	Lawrence	US
Alewife	M	300	5/8/2020	PIT	-	-	900_230000237410	Lawrence	US
Alewife	M	302	5/8/2020	PIT	-	-	900_230000237411	Lawrence	US
Alewife	M	302	5/8/2020	PIT	-	-	900_230000237448	Lawrence	US
Alewife	F	304	5/8/2020	PIT	-	-	900_230000237442	Lawrence	US
Alewife	F	305	5/8/2020	PIT	-	-	900_230000237402	Lawrence	US
Alewife	F	305	5/8/2020	PIT	-	-	900_230000237408	Lawrence	US
Alewife	U	305	5/8/2020	PIT	-	-	900_230000237447	Lawrence	US
Alewife	F	307	5/8/2020	PIT	-	-	900_230000237444	Lawrence	US
Alewife	M	308	5/8/2020	PIT	-	-	900_230000237399	Lawrence	US
Alewife	F	308	5/8/2020	PIT	-	-	900_230000237446	Lawrence	US
Alewife	M	310	5/8/2020	PIT	-	-	900_230000237390	Lawrence	US
Alewife	F	310	5/8/2020	PIT	-	-	900_230000237400	Lawrence	US
Alewife	M	310	5/8/2020	PIT	-	-	900_230000237409	Lawrence	US
Alewife	F	314	5/8/2020	PIT	-	-	900_230000237394	Lawrence	US
Alewife	F	314	5/8/2020	PIT	-	-	900_230000237396	Lawrence	US
Alewife	F	314	5/8/2020	PIT	-	-	900_230000237414	Lawrence	US
Alewife	F	315	5/8/2020	PIT	-	-	900_230000237401	Lawrence	US
Alewife	F	317	5/8/2020	PIT	-	-	900_230000237395	Lawrence	US
Alewife	M	318	5/8/2020	PIT	-	-	900_230000237392	Lawrence	US
Alewife	F	321	5/16/2020	Dual	149.440	22	900_230000237461	Lawrence	US
Alewife	M	313	5/16/2020	Dual	149.440	23	900_230000237463	Lawrence	US
Alewife	F	302	5/16/2020	Dual	149.440	24	900_230000237465	Lawrence	US
Alewife	M	304	5/16/2020	Dual	149.440	25	900_230000237467	Lawrence	US
Alewife	F	316	5/16/2020	Dual	149.440	26	900_230000237469	Lawrence	US
Alewife	F	325	5/16/2020	Dual	149.460	52	900_230000237478	Lawrence	US
Alewife	F	321	5/16/2020	Dual	149.460	53	900_230000237477	Lawrence	US
Alewife	F	312	5/16/2020	Dual	149.460	54	900_230000237475	Lawrence	US

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Alewife	M	295	5/16/2020	Dual	149.460	55	900_230000237471	Lawrence	US
Alewife	M	305	5/16/2020	Dual	149.800	142	900_230000237449	Lawrence	US
Alewife	M	315	5/16/2020	Dual	149.800	143	900_230000237456	Lawrence	US
Alewife	M	303	5/16/2020	Dual	149.800	144	900_230000237454	Lawrence	US
Alewife	F	309	5/16/2020	Dual	149.800	145	900_230000237452	Lawrence	US
Alewife	F	325	5/16/2020	Dual	149.800	146	900_230000237450	Lawrence	US
Alewife	F	304	5/17/2020	Dual	149.440	28	900_230000237677	Lawrence	US
Alewife	M	275	5/17/2020	Dual	149.440	29	900_230000237676	Lawrence	US
Alewife	M	290	5/17/2020	Dual	149.440	30	900_230000237675	Lawrence	US
Alewife	F	310	5/17/2020	Dual	149.440	31	900_230000237674	Lawrence	US
Alewife	F	295	5/17/2020	Dual	149.440	32	900_230000237673	Lawrence	US
Alewife	F	305	5/17/2020	Dual	149.460	56	900_230000237613	Lawrence	US
Alewife	F	300	5/17/2020	Dual	149.460	58	900_230000237683	Lawrence	US
Alewife	F	310	5/17/2020	Dual	149.460	59	900_230000237682	Lawrence	US
Alewife	F	292	5/17/2020	Dual	149.460	60	900_230000237681	Lawrence	US
Alewife	F	290	5/17/2020	Dual	149.460	61	900_230000237680	Lawrence	US
Alewife	M	310	5/17/2020	Dual	149.460	62	900_230000237678	Lawrence	US
Alewife	M	300	5/17/2020	Dual	149.480	82	900_230000237618	Lawrence	US
Alewife	F	304	5/17/2020	Dual	149.480	83	900_230000237617	Lawrence	US
Alewife	F	308	5/17/2020	Dual	149.480	84	900_230000237616	Lawrence	US
Alewife	F	310	5/17/2020	Dual	149.480	85	900_230000237615	Lawrence	US
Alewife	F	310	5/17/2020	Dual	149.480	86	900_230000237614	Lawrence	US
Alewife	F	310	5/17/2020	Dual	149.480	88	900_230000237688	Lawrence	US
Alewife	F	310	5/17/2020	Dual	149.480	89	900_230000237687	Lawrence	US
Alewife	F	297	5/17/2020	Dual	149.480	90	900_230000237686	Lawrence	US
Alewife	M	290	5/17/2020	Dual	149.480	91	900_230000237685	Lawrence	US
Alewife	M	300	5/17/2020	Dual	149.480	92	900_230000237684	Lawrence	US
Alewife	F	295	5/17/2020	Dual	149.760	112	900_230000237624	Lawrence	US
Alewife	F	315	5/17/2020	Dual	149.760	113	900_230000237623	Lawrence	US
Alewife	F	310	5/17/2020	Dual	149.760	114	900_230000237622	Lawrence	US
Alewife	F	293	5/17/2020	Dual	149.760	115	900_230000237620	Lawrence	US
Alewife	M	275	5/17/2020	Dual	149.760	116	900_230000237619	Lawrence	US
Alewife	F	310	5/17/2020	Dual	149.760	118	900_230000237693	Lawrence	US
Alewife	F	315	5/17/2020	Dual	149.760	119	900_230000237692	Lawrence	US
Alewife	F	318	5/17/2020	Dual	149.760	120	900_230000237691	Lawrence	US
Alewife	F	295	5/17/2020	Dual	149.760	121	900_230000237690	Lawrence	US
Alewife	F	315	5/17/2020	Dual	149.760	122	900_230000237689	Lawrence	US
Alewife	F	300	5/17/2020	Dual	149.800	148	900_230000237699	Lawrence	US
Alewife	M	295	5/17/2020	Dual	149.800	149	900_230000237698	Lawrence	US
Alewife	F	295	5/17/2020	Dual	149.800	150	900_230000237696	Lawrence	US
Alewife	F	310	5/17/2020	Dual	149.800	151	900_230000237695	Lawrence	US
Alewife	M	290	5/17/2020	Dual	149.800	152	900_230000237694	Lawrence	US
Alewife	M	260	5/17/2020	PIT	-	-	900_230000237743	Lawrence	US
Alewife	F	274	5/17/2020	PIT	-	-	900_230000237745	Lawrence	US

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Alewife	M	275	5/17/2020	PIT	-	-	900_230000237736	Lawrence	US
Alewife	M	280	5/17/2020	PIT	-	-	900_230000237775	Lawrence	US
Alewife	M	281	5/17/2020	PIT	-	-	900_230000237766	Lawrence	US
Alewife	M	281	5/17/2020	PIT	-	-	900_230000237752	Lawrence	US
Alewife	M	285	5/17/2020	PIT	-	-	900_230000237625	Lawrence	US
Alewife	F	285	5/17/2020	PIT	-	-	900_230000237636	Lawrence	US
Alewife	M	286	5/17/2020	PIT	-	-	900_230000237733	Lawrence	US
Alewife	F	288	5/17/2020	PIT	-	-	900_230000237774	Lawrence	US
Alewife	M	288	5/17/2020	PIT	-	-	900_230000237738	Lawrence	US
Alewife	M	290	5/17/2020	PIT	-	-	900_230000237627	Lawrence	US
Alewife	M	290	5/17/2020	PIT	-	-	900_230000237631	Lawrence	US
Alewife	M	290	5/17/2020	PIT	-	-	900_230000237634	Lawrence	US
Alewife	F	290	5/17/2020	PIT	-	-	900_230000237773	Lawrence	US
Alewife	M	291	5/17/2020	PIT	-	-	900_230000237754	Lawrence	US
Alewife	M	292	5/17/2020	PIT	-	-	900_230000237744	Lawrence	US
Alewife	M	292	5/17/2020	PIT	-	-	900_230000237759	Lawrence	US
Alewife	M	293	5/17/2020	PIT	-	-	900_230000237750	Lawrence	US
Alewife	M	293	5/17/2020	PIT	-	-	900_230000237751	Lawrence	US
Alewife	M	294	5/17/2020	PIT	-	-	900_230000237735	Lawrence	US
Alewife	M	295	5/17/2020	PIT	-	-	900_230000237621	Lawrence	US
Alewife	F	295	5/17/2020	PIT	-	-	900_230000237628	Lawrence	US
Alewife	F	295	5/17/2020	PIT	-	-	900_230000237635	Lawrence	US
Alewife	M	295	5/17/2020	PIT	-	-	900_230000237742	Lawrence	US
Alewife	F	295	5/17/2020	PIT	-	-	900_230000237753	Lawrence	US
Alewife	F	296	5/17/2020	PIT	-	-	900_230000237768	Lawrence	US
Alewife	M	296	5/17/2020	PIT	-	-	900_230000237758	Lawrence	US
Alewife	F	299	5/17/2020	PIT	-	-	900_230000237771	Lawrence	US
Alewife	M	300	5/17/2020	PIT	-	-	900_230000237633	Lawrence	US
Alewife	F	300	5/17/2020	PIT	-	-	900_230000237637	Lawrence	US
Alewife	M	300	5/17/2020	PIT	-	-	900_230000237641	Lawrence	US
Alewife	F	300	5/17/2020	PIT	-	-	900_230000237642	Lawrence	US
Alewife	F	300	5/17/2020	PIT	-	-	900_230000237769	Lawrence	US
Alewife	U	300	5/17/2020	PIT	-	-	900_230000237679	Lawrence	US
Alewife	F	301	5/17/2020	PIT	-	-	900_230000237764	Lawrence	US
Alewife	M	302	5/17/2020	PIT	-	-	900_230000237737	Lawrence	US
Alewife	M	302	5/17/2020	PIT	-	-	900_230000237747	Lawrence	US
Alewife	F	303	5/17/2020	PIT	-	-	900_230000237740	Lawrence	US
Alewife	F	304	5/17/2020	PIT	-	-	900_230000237772	Lawrence	US
Alewife	F	304	5/17/2020	PIT	-	-	900_230000237749	Lawrence	US
Alewife	F	305	5/17/2020	PIT	-	-	900_230000237629	Lawrence	US
Alewife	M	305	5/17/2020	PIT	-	-	900_230000237638	Lawrence	US
Alewife	M	305	5/17/2020	PIT	-	-	900_230000237730	Lawrence	US
Alewife	M	305	5/17/2020	PIT	-	-	900_230000237732	Lawrence	US
Alewife	F	305	5/17/2020	PIT	-	-	900_230000237741	Lawrence	US

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Alewife	M	305	5/17/2020	PIT	-	-	900_230000237746	Lawrence	US
Alewife	F	305	5/17/2020	PIT	-	-	900_230000237756	Lawrence	US
Alewife	M	305	5/17/2020	PIT	-	-	900_230000237757	Lawrence	US
Alewife	M	306	5/17/2020	PIT	-	-	900_230000237734	Lawrence	US
Alewife	F	307	5/17/2020	PIT	-	-	900_230000237762	Lawrence	US
Alewife	F	308	5/17/2020	PIT	-	-	900_230000237739	Lawrence	US
Alewife	M	309	5/17/2020	PIT	-	-	900_230000237767	Lawrence	US
Alewife	F	310	5/17/2020	PIT	-	-	900_230000237630	Lawrence	US
Alewife	F	310	5/17/2020	PIT	-	-	900_230000237765	Lawrence	US
Alewife	M	310	5/17/2020	PIT	-	-	900_230000237770	Lawrence	US
Alewife	M	310	5/17/2020	PIT	-	-	900_230000237697	Lawrence	US
Alewife	F	310	5/17/2020	PIT	-	-	900_230000237731	Lawrence	US
Alewife	F	312	5/17/2020	PIT	-	-	900_230000237640	Lawrence	US
Alewife	F	312	5/17/2020	PIT	-	-	900_230000237776	Lawrence	US
Alewife	M	314	5/17/2020	PIT	-	-	900_230000237763	Lawrence	US
Alewife	F	315	5/17/2020	PIT	-	-	900_230000237632	Lawrence	US
Alewife	F	315	5/17/2020	PIT	-	-	900_230000237755	Lawrence	US
Alewife	F	316	5/17/2020	PIT	-	-	900_230000237748	Lawrence	US
Alewife	F	319	5/17/2020	PIT	-	-	900_230000237760	Lawrence	US
Alewife	F	320	5/17/2020	PIT	-	-	900_230000237626	Lawrence	US
Alewife	F	324	5/17/2020	PIT	-	-	900_230000237761	Lawrence	US
Alewife	F	330	5/17/2020	PIT	-	-	900_230000237639	Lawrence	US
Alewife	F	282	5/18/2020	Dual	149.440	34	900_230000237815	Lawrence	US
Alewife	M	306	5/18/2020	Dual	149.440	35	900_230000237812	Lawrence	US
Alewife	M	290	5/18/2020	Dual	149.440	36	900_230000237811	Lawrence	US
Alewife	M	274	5/18/2020	Dual	149.440	37	900_230000237809	Lawrence	US
Alewife	F	306	5/18/2020	Dual	149.440	38	900_230000237807	Lawrence	US
Alewife	M	306	5/18/2020	Dual	149.460	64	900_230000237846	Lawrence	US
Alewife	F	295	5/18/2020	Dual	149.460	65	900_230000237821	Lawrence	US
Alewife	F	315	5/18/2020	Dual	149.460	66	900_230000237819	Lawrence	US
Alewife	M	305	5/18/2020	Dual	149.460	67	900_230000237818	Lawrence	US
Alewife	M	287	5/18/2020	Dual	149.460	68	900_230000237816	Lawrence	US
Alewife	F	307	5/18/2020	Dual	149.480	94	900_230000237858	Lawrence	US
Alewife	F	294	5/18/2020	Dual	149.480	95	900_230000237859	Lawrence	US
Alewife	F	323	5/18/2020	Dual	149.480	96	900_230000237860	Lawrence	US
Alewife	M	291	5/18/2020	Dual	149.480	97	900_230000237861	Lawrence	US
Alewife	F	280	5/18/2020	Dual	149.480	98	900_230000237862	Lawrence	US
Alewife	F	318	5/18/2020	Dual	149.760	124	900_230000237863	Lawrence	US
Alewife	M	281	5/18/2020	Dual	149.760	125	900_230000237864	Lawrence	US
Alewife	M	287	5/18/2020	Dual	149.760	126	900_230000237865	Lawrence	US
Alewife	M	269	5/18/2020	Dual	149.760	127	900_230000237866	Lawrence	US
Alewife	F	318	5/18/2020	Dual	149.760	128	900_230000237504	Lawrence	US
Alewife	M	286	5/18/2020	Dual	149.800	154	900_230000237505	Lawrence	US
Alewife	F	306	5/18/2020	Dual	149.800	155	900_230000237506	Lawrence	US

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Alewife	F	319	5/18/2020	Dual	149.800	156	900_230000237507	Lawrence	US
Alewife	F	286	5/18/2020	Dual	149.800	157	900_230000237508	Lawrence	US
Alewife	F	304	5/18/2020	Dual	149.800	158	900_230000237509	Lawrence	US
Alewife	F	262	5/18/2020	PIT	-	-	900_230000237534	Lawrence	US
Alewife	F	285	5/18/2020	PIT	-	-	900_230000237535	Lawrence	US
Alewife	M	286	5/18/2020	PIT	-	-	900_230000237517	Lawrence	US
Alewife	M	286	5/18/2020	PIT	-	-	900_230000237527	Lawrence	US
Alewife	M	287	5/18/2020	PIT	-	-	900_230000237538	Lawrence	US
Alewife	M	291	5/18/2020	PIT	-	-	900_230000237511	Lawrence	US
Alewife	M	291	5/18/2020	PIT	-	-	900_230000237536	Lawrence	US
Alewife	M	291	5/18/2020	PIT	-	-	900_230000237540	Lawrence	US
Alewife	F	292	5/18/2020	PIT	-	-	900_230000237514	Lawrence	US
Alewife	M	295	5/18/2020	PIT	-	-	900_230000237526	Lawrence	US
Alewife	M	296	5/18/2020	PIT	-	-	900_230000237524	Lawrence	US
Alewife	M	298	5/18/2020	PIT	-	-	900_230000237519	Lawrence	US
Alewife	M	299	5/18/2020	PIT	-	-	900_230000237541	Lawrence	US
Alewife	F	300	5/18/2020	PIT	-	-	900_230000237510	Lawrence	US
Alewife	F	303	5/18/2020	PIT	-	-	900_230000237539	Lawrence	US
Alewife	F	304	5/18/2020	PIT	-	-	900_230000237542	Lawrence	US
Alewife	F	305	5/18/2020	PIT	-	-	900_230000237521	Lawrence	US
Alewife	M	305	5/18/2020	PIT	-	-	900_230000237522	Lawrence	US
Alewife	M	305	5/18/2020	PIT	-	-	900_230000237531	Lawrence	US
Alewife	M	305	5/18/2020	PIT	-	-	900_230000237537	Lawrence	US
Alewife	F	307	5/18/2020	PIT	-	-	900_230000237530	Lawrence	US
Alewife	M	308	5/18/2020	PIT	-	-	900_230000237516	Lawrence	US
Alewife	M	308	5/18/2020	PIT	-	-	900_230000237543	Lawrence	US
Alewife	F	310	5/18/2020	PIT	-	-	900_230000237523	Lawrence	US
Alewife	F	310	5/18/2020	PIT	-	-	900_230000237525	Lawrence	US
Alewife	F	311	5/18/2020	PIT	-	-	900_230000237512	Lawrence	US
Alewife	F	312	5/18/2020	PIT	-	-	900_230000237515	Lawrence	US
Alewife	F	314	5/18/2020	PIT	-	-	900_230000237518	Lawrence	US
Alewife	F	315	5/18/2020	PIT	-	-	900_230000237532	Lawrence	US
Alewife	F	316	5/18/2020	PIT	-	-	900_230000237513	Lawrence	US
Alewife	F	316	5/18/2020	PIT	-	-	900_230000237529	Lawrence	US
Alewife	F	317	5/18/2020	PIT	-	-	900_230000237528	Lawrence	US
Alewife	F	319	5/18/2020	PIT	-	-	900_230000237520	Lawrence	US
Alewife	F	326	5/18/2020	PIT	-	-	900_230000237533	Lawrence	US
Alewife	M	295	5/19/2020	Dual	149.440	40	900_230000237955	Lawrence	US
Alewife	F	297	5/19/2020	Dual	149.440	41	900_230000237956	Lawrence	US
Alewife	F	312	5/19/2020	Dual	149.440	42	900_230000237957	Lawrence	US
Alewife	F	301	5/19/2020	Dual	149.440	43	900_230000237958	Lawrence	US
Alewife	F	314	5/19/2020	Dual	149.440	44	900_230000237959	Lawrence	US
Alewife	M	304	5/19/2020	Dual	149.460	70	900_230000237960	Lawrence	US
Alewife	F	310	5/19/2020	Dual	149.460	71	900_230000237961	Lawrence	US

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Alewife	F	316	5/19/2020	Dual	149.460	72	900_230000237962	Lawrence	US
Alewife	F	314	5/19/2020	Dual	149.460	73	900_230000237963	Lawrence	US
Alewife	M	312	5/19/2020	Dual	149.460	74	900_230000237964	Lawrence	US
Alewife	F	305	5/19/2020	Dual	149.480	100	900_230000237965	Lawrence	US
Alewife	M	299	5/19/2020	Dual	149.480	101	900_230000237966	Lawrence	US
Alewife	M	295	5/19/2020	Dual	149.480	102	900_230000237967	Lawrence	US
Alewife	M	308	5/19/2020	Dual	149.480	103	900_230000237968	Lawrence	US
Alewife	F	305	5/19/2020	Dual	149.480	104	900_230000237969	Lawrence	US
Alewife	M	307	5/19/2020	Dual	149.760	130	900_230000237970	Lawrence	US
Alewife	F	309	5/19/2020	Dual	149.760	131	900_230000237971	Lawrence	US
Alewife	F	320	5/19/2020	Dual	149.760	132	900_230000237972	Lawrence	US
Alewife	F	310	5/19/2020	Dual	149.760	133	900_230000237973	Lawrence	US
Alewife	F	324	5/19/2020	Dual	149.760	134	900_230000237974	Lawrence	US
Alewife	M	287	5/19/2020	Dual	149.800	160	900_230000237975	Lawrence	US
Alewife	M	305	5/19/2020	Dual	149.800	161	900_230000237976	Lawrence	US
Alewife	F	313	5/19/2020	Dual	149.800	162	900_230000237977	Lawrence	US
Alewife	F	302	5/19/2020	Dual	149.800	163	900_230000237978	Lawrence	US
Alewife	M	307	5/19/2020	Dual	149.800	164	900_230000237979	Lawrence	US
Alewife	M	285	5/19/2020	PIT	-	-	900_230000237921	Lawrence	US
Alewife	F	287	5/19/2020	PIT	-	-	900_23000023865	Lawrence	US
Alewife	M	288	5/19/2020	PIT	-	-	900_23000023855	Lawrence	US
Alewife	M	289	5/19/2020	PIT	-	-	900_23000023843	Lawrence	US
Alewife	M	289	5/19/2020	PIT	-	-	900_23000023849	Lawrence	US
Alewife	M	290	5/19/2020	PIT	-	-	900_23000023862	Lawrence	US
Alewife	F	291	5/19/2020	PIT	-	-	900_23000023848	Lawrence	US
Alewife	M	291	5/19/2020	PIT	-	-	900_23000023859	Lawrence	US
Alewife	M	292	5/19/2020	PIT	-	-	900_23000023844	Lawrence	US
Alewife	M	294	5/19/2020	PIT	-	-	900_23000023860	Lawrence	US
Alewife	F	295	5/19/2020	PIT	-	-	900_23000023866	Lawrence	US
Alewife	M	295	5/19/2020	PIT	-	-	900_23000023870	Lawrence	US
Alewife	F	296	5/19/2020	PIT	-	-	900_23000023840	Lawrence	US
Alewife	M	296	5/19/2020	PIT	-	-	900_23000023851	Lawrence	US
Alewife	F	296	5/19/2020	PIT	-	-	900_23000023854	Lawrence	US
Alewife	M	296	5/19/2020	PIT	-	-	900_23000023857	Lawrence	US
Alewife	F	298	5/19/2020	PIT	-	-	900_23000023856	Lawrence	US
Alewife	F	300	5/19/2020	PIT	-	-	900_23000023867	Lawrence	US
Alewife	M	302	5/19/2020	PIT	-	-	900_23000023864	Lawrence	US
Alewife	M	303	5/19/2020	PIT	-	-	900_23000023861	Lawrence	US
Alewife	F	304	5/19/2020	PIT	-	-	900_23000023852	Lawrence	US
Alewife	M	305	5/19/2020	PIT	-	-	900_23000023846	Lawrence	US
Alewife	M	306	5/19/2020	PIT	-	-	900_23000023847	Lawrence	US
Alewife	F	307	5/19/2020	PIT	-	-	900_23000023863	Lawrence	US
Alewife	M	311	5/19/2020	PIT	-	-	900_23000023842	Lawrence	US
Alewife	M	312	5/19/2020	PIT	-	-	900_23000023872	Lawrence	US

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Alewife	F	315	5/19/2020	PIT	-	-	900_23000023853	Lawrence	US
Alewife	F	316	5/19/2020	PIT	-	-	900_23000023850	Lawrence	US
Alewife	F	316	5/19/2020	PIT	-	-	900_23000023868	Lawrence	US
Alewife	F	320	5/19/2020	PIT	-	-	900_23000023869	Lawrence	US
Alewife	F	321	5/19/2020	PIT	-	-	900_23000023845	Lawrence	US
Alewife	F	321	5/19/2020	PIT	-	-	900_23000023858	Lawrence	US
Alewife	F	325	5/19/2020	PIT	-	-	900_23000023841	Lawrence	US
Alewife	F	330	5/19/2020	PIT	-	-	900_23000023871	Lawrence	US
Alewife	M	289	5/21/2020	Radio	149.440	158	-	Lawrence	DS
Alewife	M	287	5/21/2020	Radio	149.440	159	-	Lawrence	DS
Alewife	M	271	5/21/2020	Radio	149.440	160	-	Lawrence	DS
Alewife	M	299	5/21/2020	Radio	149.440	161	-	Lawrence	DS
Alewife	M	304	5/21/2020	Radio	149.440	162	-	Lawrence	DS
Alewife	M	295	5/21/2020	Radio	149.440	163	-	Lawrence	DS
Alewife	F	307	5/21/2020	Radio	149.440	164	-	Lawrence	DS
Alewife	M	273	5/21/2020	Radio	149.440	165	-	Lawrence	DS
Alewife	F	313	5/21/2020	Radio	149.440	166	-	Lawrence	DS
Alewife	F	220	5/21/2020	Radio	149.440	167	-	Lawrence	DS
Alewife	M	298	5/21/2020	Radio	149.440	168	-	Lawrence	DS
Alewife	M	298	5/21/2020	Radio	149.440	169	-	Lawrence	DS
Alewife	M	301	5/21/2020	Radio	149.460	76	-	Lawrence	DS
Alewife	M	295	5/21/2020	Radio	149.460	77	-	Lawrence	DS
Alewife	M	293	5/21/2020	Radio	149.460	78	-	Lawrence	DS
Alewife	M	267	5/21/2020	Radio	149.460	79	-	Lawrence	DS
Alewife	F	290	5/21/2020	Radio	149.460	80	-	Lawrence	DS
Alewife	F	294	5/21/2020	Radio	149.460	81	-	Lawrence	DS
Alewife	M	306	5/21/2020	Radio	149.460	82	-	Lawrence	DS
Alewife	M	285	5/21/2020	Radio	149.460	83	-	Lawrence	DS
Alewife	M	295	5/21/2020	Radio	149.460	84	-	Lawrence	DS
Alewife	F	261	5/21/2020	Radio	149.460	85	-	Lawrence	DS
Alewife	F	292	5/21/2020	Radio	149.460	86	-	Lawrence	DS
Alewife	M	270	5/21/2020	Radio	149.460	87	-	Lawrence	DS
Alewife	M	288	5/21/2020	Radio	149.480	106	-	Lawrence	DS
Alewife	M	298	5/21/2020	Radio	149.480	107	-	Lawrence	DS
Alewife	M	302	5/21/2020	Radio	149.480	108	-	Lawrence	DS
Alewife	F	314	5/21/2020	Radio	149.480	109	-	Lawrence	DS
Alewife	M	287	5/21/2020	Radio	149.480	110	-	Lawrence	DS
Alewife	M	293	5/21/2020	Radio	149.480	111	-	Lawrence	DS
Alewife	F	310	5/21/2020	Radio	149.480	112	-	Lawrence	DS
Alewife	M	294	5/21/2020	Radio	149.480	113	-	Lawrence	DS
Alewife	M	304	5/21/2020	Radio	149.480	114	-	Lawrence	DS
Alewife	M	315	5/21/2020	Radio	149.480	115	-	Lawrence	DS
Alewife	M	282	5/21/2020	Radio	149.480	116	-	Lawrence	DS
Alewife	F	321	5/21/2020	Radio	149.480	117	-	Lawrence	DS

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Alewife	M	309	5/21/2020	Radio	149.760	180	-	Lawrence	DS
Alewife	F	289	5/21/2020	Radio	149.760	181	-	Lawrence	DS
Alewife	M	308	5/21/2020	Radio	149.760	182	-	Lawrence	DS
Alewife	F	282	5/21/2020	Radio	149.760	183	-	Lawrence	DS
Alewife	F	298	5/21/2020	Radio	149.760	184	-	Lawrence	DS
Alewife	M	297	5/21/2020	Radio	149.760	185	-	Lawrence	DS
Alewife	M	295	5/21/2020	Radio	149.760	186	-	Lawrence	DS
Alewife	F	304	5/21/2020	Radio	149.760	187	-	Lawrence	DS
Alewife	M	260	5/21/2020	Radio	149.760	188	-	Lawrence	DS
Alewife	M	305	5/21/2020	Radio	149.760	189	-	Lawrence	DS
Alewife	F	330	5/21/2020	Radio	149.760	190	-	Lawrence	DS
Alewife	F	308	5/21/2020	Radio	149.760	191	-	Lawrence	DS
Alewife	F	305	5/21/2020	Radio	149.800	41	-	Lawrence	DS
Alewife	F	304	5/21/2020	Radio	149.800	42	-	Lawrence	DS
Alewife	M	297	5/21/2020	Radio	149.800	43	-	Lawrence	DS
Alewife	M	304	5/21/2020	Radio	149.800	44	-	Lawrence	DS
Alewife	F	296	5/21/2020	Radio	149.800	45	-	Lawrence	DS
Alewife	F	308	5/21/2020	Radio	149.800	46	-	Lawrence	DS
Alewife	M	286	5/21/2020	Radio	149.800	47	-	Lawrence	DS
Alewife	M	314	5/21/2020	Radio	149.800	48	-	Lawrence	DS
Alewife	F	320	5/21/2020	Radio	149.800	49	-	Lawrence	DS
Alewife	F	310	5/21/2020	Radio	149.800	50	-	Lawrence	DS
Alewife	F	309	5/21/2020	Radio	149.800	51	-	Lawrence	DS
Alewife	F	323	5/21/2020	Radio	149.800	52	-	Lawrence	DS
Alewife	M	277	5/22/2020	Radio	149.440	170	-	Lawrence	DS
Alewife	M	265	5/22/2020	Radio	149.440	171	-	Lawrence	DS
Alewife	M	290	5/22/2020	Radio	149.440	172	-	Lawrence	DS
Alewife	M	299	5/22/2020	Radio	149.440	173	-	Lawrence	DS
Alewife	M	278	5/22/2020	Radio	149.460	88	-	Lawrence	DS
Alewife	M	283	5/22/2020	Radio	149.460	89	-	Lawrence	DS
Alewife	M	284	5/22/2020	Radio	149.460	90	-	Lawrence	DS
Alewife	F	314	5/22/2020	Radio	149.460	91	-	Lawrence	DS
Alewife	F	295	5/22/2020	Radio	149.480	118	-	Lawrence	DS
Alewife	M	275	5/22/2020	Radio	149.480	119	-	Lawrence	DS
Alewife	M	291	5/22/2020	Radio	149.480	120	-	Lawrence	DS
Alewife	M	288	5/22/2020	Radio	149.480	121	-	Lawrence	DS
Alewife	M	282	5/22/2020	Radio	149.760	192	-	Lawrence	DS
Alewife	F	316	5/22/2020	Radio	149.760	194	-	Lawrence	DS
Alewife	F	294	5/22/2020	Radio	149.760	195	-	Lawrence	DS
Alewife	M	295	5/22/2020	Radio	149.760	193	-	Lawrence	DS
Alewife	F	318	5/22/2020	Radio	149.800	53	-	Lawrence	DS
Alewife	M	282	5/22/2020	Radio	149.800	54	-	Lawrence	DS
Alewife	M	296	5/22/2020	Radio	149.800	55	-	Lawrence	DS
Alewife	F	304	5/22/2020	Radio	149.800	56	-	Lawrence	DS

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Alewife	F	310	5/28/2020	Radio	149.440	174	-	Amoskeag	DS
Alewife	M	268	5/28/2020	Radio	149.440	175	-	Amoskeag	DS
Alewife	M	291	5/28/2020	Radio	149.440	176	-	Amoskeag	DS
Alewife	M	302	5/28/2020	Radio	149.440	177	-	Amoskeag	DS
Alewife	F	293	5/28/2020	Radio	149.460	92	-	Amoskeag	DS
Alewife	F	298	5/28/2020	Radio	149.460	93	-	Amoskeag	DS
Alewife	M	282	5/28/2020	Radio	149.460	94	-	Amoskeag	DS
Alewife	M	286	5/28/2020	Radio	149.460	95	-	Amoskeag	DS
Alewife	F	314	5/28/2020	Radio	149.480	122	-	Amoskeag	DS
Alewife	M	277	5/28/2020	Radio	149.480	123	-	Amoskeag	DS
Alewife	M	302	5/28/2020	Radio	149.480	124	-	Amoskeag	DS
Alewife	M	273	5/28/2020	Radio	149.480	125	-	Amoskeag	DS
Alewife	M	285	5/28/2020	Radio	149.760	196	-	Amoskeag	DS
Alewife	M	297	5/28/2020	Radio	149.760	197	-	Amoskeag	DS
Alewife	F	290	5/28/2020	Radio	149.760	198	-	Amoskeag	DS
Alewife	M	271	5/28/2020	Radio	149.760	199	-	Amoskeag	DS
Alewife	M	295	5/28/2020	Radio	149.800	57	-	Amoskeag	DS
Alewife	M	292	5/28/2020	Radio	149.800	58	-	Amoskeag	DS
Alewife	M	294	5/28/2020	Radio	149.800	59	-	Amoskeag	DS
Alewife	M	299	5/28/2020	Radio	149.800	60	-	Amoskeag	DS
Alewife	U	283	6/2/2020	Radio	149.440	55	-	Amoskeag	DS
Alewife	F	291	6/2/2020	Radio	149.440	56	-	Amoskeag	DS
Alewife	M	306	6/2/2020	Radio	149.440	57	-	Amoskeag	DS
Alewife	F	283	6/2/2020	Radio	149.440	58	-	Amoskeag	DS
Alewife	M	283	6/2/2020	Radio	149.440	59	-	Amoskeag	DS
Alewife	U	295	6/2/2020	Radio	149.440	60	-	Amoskeag	DS
Alewife	M	280	6/2/2020	Radio	149.440	61	-	Amoskeag	DS
Alewife	F	293	6/2/2020	Radio	149.440	62	-	Amoskeag	DS
Alewife	F	291	6/2/2020	Radio	149.440	63	-	Amoskeag	DS
Alewife	F	310	6/2/2020	Radio	149.440	64	-	Amoskeag	DS
Alewife	F	271	6/2/2020	Radio	149.460	141	-	Amoskeag	DS
Alewife	M	292	6/2/2020	Radio	149.460	142	-	Amoskeag	DS
Alewife	F	315	6/2/2020	Radio	149.460	143	-	Amoskeag	DS
Alewife	F	301	6/2/2020	Radio	149.460	144	-	Amoskeag	DS
Alewife	F	305	6/2/2020	Radio	149.460	145	-	Amoskeag	DS
Alewife	F	286	6/2/2020	Radio	149.460	146	-	Amoskeag	DS
Alewife	F	306	6/2/2020	Radio	149.460	147	-	Amoskeag	DS
Alewife	F	293	6/2/2020	Radio	149.460	148	-	Amoskeag	DS
Alewife	M	274	6/2/2020	Radio	149.460	149	-	Amoskeag	DS
Alewife	M	284	6/2/2020	Radio	149.460	150	-	Amoskeag	DS
Alewife	M	264	6/2/2020	Radio	149.480	127	-	Amoskeag	DS
Alewife	F	295	6/2/2020	Radio	149.480	128	-	Amoskeag	DS
Alewife	F	303	6/2/2020	Radio	149.480	129	-	Amoskeag	DS
Alewife	F	298	6/2/2020	Radio	149.480	130	-	Amoskeag	DS

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Alewife	F	310	6/2/2020	Radio	149.480	131	-	Amoskeag	DS
Alewife	M	282	6/2/2020	Radio	149.480	132	-	Amoskeag	DS
Alewife	F	296	6/2/2020	Radio	149.480	133	-	Amoskeag	DS
Alewife	M	275	6/2/2020	Radio	149.480	134	-	Amoskeag	DS
Alewife	F	293	6/2/2020	Radio	149.480	135	-	Amoskeag	DS
Alewife	F	317	6/2/2020	Radio	149.480	136	-	Amoskeag	DS
Alewife	F	302	6/2/2020	Radio	149.760	83	-	Amoskeag	DS
Alewife	F	316	6/2/2020	Radio	149.760	84	-	Amoskeag	DS
Alewife	F	293	6/2/2020	Radio	149.760	85	-	Amoskeag	DS
Alewife	M	294	6/2/2020	Radio	149.760	86	-	Amoskeag	DS
Alewife	F	320	6/2/2020	Radio	149.760	87	-	Amoskeag	DS
Alewife	F	293	6/2/2020	Radio	149.760	88	-	Amoskeag	DS
Alewife	M	274	6/2/2020	Radio	149.760	89	-	Amoskeag	DS
Alewife	M	286	6/2/2020	Radio	149.760	90	-	Amoskeag	DS
Alewife	F	323	6/2/2020	Radio	149.760	91	-	Amoskeag	DS
Alewife	M	279	6/2/2020	Radio	149.760	92	-	Amoskeag	DS
Alewife	M	264	6/2/2020	Radio	149.800	166	-	Amoskeag	DS
Alewife	F	289	6/2/2020	Radio	149.800	167	-	Amoskeag	DS
Alewife	M	286	6/2/2020	Radio	149.800	168	-	Amoskeag	DS
Alewife	M	287	6/2/2020	Radio	149.800	169	-	Amoskeag	DS
Alewife	M	255	6/2/2020	Radio	149.800	170	-	Amoskeag	DS
Alewife	F	298	6/2/2020	Radio	149.800	173	-	Amoskeag	DS
Alewife	M	276	6/2/2020	Radio	149.800	174	-	Amoskeag	DS
Alewife	M	292	6/2/2020	Radio	149.800	175	-	Amoskeag	DS
Alewife	F	310	6/2/2020	Radio	149.800	176	-	Amoskeag	DS
Alewife	F	306	6/2/2020	Radio	149.800	177	-	Amoskeag	DS
Shad	M	492	5/16/2020	Dual	149.440	121	900_230000237479	Lawrence	US
Shad	M	429	5/16/2020	Dual	149.440	122	900_230000237460	Lawrence	US
Shad	F	533	5/16/2020	Dual	149.440	123	900_230000237462	Lawrence	US
Shad	M	500	5/16/2020	Dual	149.440	124	900_230000237464	Lawrence	US
Shad	F	527	5/16/2020	Dual	149.440	125	900_230000237466	Lawrence	US
Shad	M	482	5/16/2020	Dual	149.440	126	900_230000237468	Lawrence	US
Shad	M	471	5/16/2020	Dual	149.460	156	900_230000237476	Lawrence	US
Shad	M	475	5/16/2020	Dual	149.460	157	900_230000237474	Lawrence	US
Shad	M	466	5/16/2020	Dual	149.460	158	900_230000237473	Lawrence	US
Shad	M	510	5/16/2020	Dual	149.460	159	900_230000237472	Lawrence	US
Shad	M	487	5/16/2020	Dual	149.460	160	900_230000237470	Lawrence	US
Shad	M	467	5/16/2020	Dual	149.460	161	900_230000237488	Lawrence	US
Shad	M	475	5/16/2020	Dual	149.480	10	900_230000237487	Lawrence	US
Shad	M	490	5/16/2020	Dual	149.480	11	900_230000237486	Lawrence	US
Shad	M	445	5/16/2020	Dual	149.480	12	900_230000237485	Lawrence	US
Shad	M	500	5/16/2020	Dual	149.480	13	900_230000237484	Lawrence	US
Shad	M	474	5/16/2020	Dual	149.480	14	900_230000237483	Lawrence	US
Shad	M	495	5/16/2020	Dual	149.480	15	900_230000237482	Lawrence	US

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Shad	M	456	5/16/2020	Dual	149.760	46	900_230000237481	Lawrence	US
Shad	F	480	5/16/2020	Dual	149.760	47	900_230000237480	Lawrence	US
Shad	M	467	5/16/2020	Dual	149.760	48	900_230000237499	Lawrence	US
Shad	F	493	5/16/2020	Dual	149.760	49	900_230000237498	Lawrence	US
Shad	M	482	5/16/2020	Dual	149.760	50	900_230000237497	Lawrence	US
Shad	M	525	5/16/2020	Dual	149.760	51	900_230000237496	Lawrence	US
Shad	M	457	5/16/2020	Dual	149.800	83	900_230000237459	Lawrence	US
Shad	M	494	5/16/2020	Dual	149.800	84	900_230000237458	Lawrence	US
Shad	M	492	5/16/2020	Dual	149.800	85	900_230000237457	Lawrence	US
Shad	M	501	5/16/2020	Dual	149.800	86	900_230000237455	Lawrence	US
Shad	M	497	5/16/2020	Dual	149.800	87	900_230000237453	Lawrence	US
Shad	M	484	5/16/2020	Dual	149.800	88	900_230000237451	Lawrence	US
Shad	M	400	5/16/2020	PIT	-	-	900_230000237606	Lawrence	US
Shad	M	426	5/16/2020	PIT	-	-	900_230000237607	Lawrence	US
Shad	M	441	5/16/2020	PIT	-	-	900_230000237491	Lawrence	US
Shad	M	441	5/16/2020	PIT	-	-	900_230000237605	Lawrence	US
Shad	M	452	5/16/2020	PIT	-	-	900_230000237495	Lawrence	US
Shad	M	452	5/16/2020	PIT	-	-	900_230000237611	Lawrence	US
Shad	M	455	5/16/2020	PIT	-	-	900_230000237494	Lawrence	US
Shad	M	465	5/16/2020	PIT	-	-	900_230000237600	Lawrence	US
Shad	M	468	5/16/2020	PIT	-	-	900_230000237610	Lawrence	US
Shad	M	469	5/16/2020	PIT	-	-	900_230000237612	Lawrence	US
Shad	M	472	5/16/2020	PIT	-	-	900_230000237490	Lawrence	US
Shad	M	474	5/16/2020	PIT	-	-	900_230000237601	Lawrence	US
Shad	M	485	5/16/2020	PIT	-	-	900_230000237604	Lawrence	US
Shad	M	490	5/16/2020	PIT	-	-	900_230000237603	Lawrence	US
Shad	M	491	5/16/2020	PIT	-	-	900_230000237608	Lawrence	US
Shad	F	502	5/16/2020	PIT	-	-	900_230000237493	Lawrence	US
Shad	F	510	5/16/2020	PIT	-	-	900_230000237489	Lawrence	US
Shad	F	511	5/16/2020	PIT	-	-	900_230000237492	Lawrence	US
Shad	F	532	5/16/2020	PIT	-	-	900_230000237309	Lawrence	US
Shad	F	545	5/16/2020	PIT	-	-	900_230000237602	Lawrence	US
Shad	M	472	5/18/2020	Dual	149.440	127	900_230000237820	Lawrence	US
Shad	M	432	5/18/2020	Dual	149.440	128	900_230000237817	Lawrence	US
Shad	U	535	5/18/2020	Dual	149.440	129	900_230000237814	Lawrence	US
Shad	M	462	5/18/2020	Dual	149.440	130	900_230000237813	Lawrence	US
Shad	U	497	5/18/2020	Dual	149.440	131	900_230000237810	Lawrence	US
Shad	F	545	5/18/2020	Dual	149.440	132	900_230000237808	Lawrence	US
Shad	F	470	5/18/2020	Dual	149.460	162	900_230000237827	Lawrence	US
Shad	M	440	5/18/2020	Dual	149.460	163	900_230000237826	Lawrence	US
Shad	M	505	5/18/2020	Dual	149.460	164	900_230000237825	Lawrence	US
Shad	F	533	5/18/2020	Dual	149.460	165	900_230000237824	Lawrence	US
Shad	M	480	5/18/2020	Dual	149.460	166	900_230000237823	Lawrence	US
Shad	M	470	5/18/2020	Dual	149.460	167	900_230000237822	Lawrence	US

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Shad	U	445	5/18/2020	Dual	149.480	16	900_230000237833	Lawrence	US
Shad	F	520	5/18/2020	Dual	149.480	17	900_230000237832	Lawrence	US
Shad	M	473	5/18/2020	Dual	149.480	18	900_230000237831	Lawrence	US
Shad	M	467	5/18/2020	Dual	149.480	19	900_230000237830	Lawrence	US
Shad	M	520	5/18/2020	Dual	149.480	20	900_230000237829	Lawrence	US
Shad	F	515	5/18/2020	Dual	149.480	21	900_230000237828	Lawrence	US
Shad	M	468	5/18/2020	Dual	149.760	52	900_230000237838	Lawrence	US
Shad	M	455	5/18/2020	Dual	149.760	53	900_230000237837	Lawrence	US
Shad	M	460	5/18/2020	Dual	149.760	54	900_230000237836	Lawrence	US
Shad	M	483	5/18/2020	Dual	149.760	55	900_230000237835	Lawrence	US
Shad	M	445	5/18/2020	Dual	149.760	56	900_230000237834	Lawrence	US
Shad	F	515	5/18/2020	Dual	149.760	57	900_230000237839	Lawrence	US
Shad	M	453	5/18/2020	Dual	149.800	89	900_230000237845	Lawrence	US
Shad	M	461	5/18/2020	Dual	149.800	90	900_230000237844	Lawrence	US
Shad	M	466	5/18/2020	Dual	149.800	91	900_230000237843	Lawrence	US
Shad	M	483	5/18/2020	Dual	149.800	92	900_230000237842	Lawrence	US
Shad	F	558	5/18/2020	Dual	149.800	93	900_230000237841	Lawrence	US
Shad	M	486	5/18/2020	Dual	149.800	94	900_230000237840	Lawrence	US
Shad	M	404	5/18/2020	PIT	-	-	900_230000237887	Lawrence	US
Shad	M	413	5/18/2020	PIT	-	-	900_230000237849	Lawrence	US
Shad	M	418	5/18/2020	PIT	-	-	900_230000237503	Lawrence	US
Shad	M	429	5/18/2020	PIT	-	-	900_230000237882	Lawrence	US
Shad	M	433	5/18/2020	PIT	-	-	900_230000237502	Lawrence	US
Shad	M	445	5/18/2020	PIT	-	-	900_230000237878	Lawrence	US
Shad	M	445	5/18/2020	PIT	-	-	900_230000237886	Lawrence	US
Shad	M	447	5/18/2020	PIT	-	-	900_230000237501	Lawrence	US
Shad	M	449	5/18/2020	PIT	-	-	900_230000237897	Lawrence	US
Shad	U	450	5/18/2020	PIT	-	-	900_230000237884	Lawrence	US
Shad	M	451	5/18/2020	PIT	-	-	900_230000237891	Lawrence	US
Shad	M	452	5/18/2020	PIT	-	-	900_230000237890	Lawrence	US
Shad	M	453	5/18/2020	PIT	-	-	900_230000237894	Lawrence	US
Shad	M	455	5/18/2020	PIT	-	-	900_230000237888	Lawrence	US
Shad	M	456	5/18/2020	PIT	-	-	900_230000237867	Lawrence	US
Shad	M	456	5/18/2020	PIT	-	-	900_230000237880	Lawrence	US
Shad	M	457	5/18/2020	PIT	-	-	900_230000237500	Lawrence	US
Shad	M	458	5/18/2020	PIT	-	-	900_230000237881	Lawrence	US
Shad	M	462	5/18/2020	PIT	-	-	900_230000237879	Lawrence	US
Shad	M	465	5/18/2020	PIT	-	-	900_230000237868	Lawrence	US
Shad	M	467	5/18/2020	PIT	-	-	900_230000237893	Lawrence	US
Shad	F	468	5/18/2020	PIT	-	-	900_230000237870	Lawrence	US
Shad	M	469	5/18/2020	PIT	-	-	900_230000237885	Lawrence	US
Shad	M	470	5/18/2020	PIT	-	-	900_230000237852	Lawrence	US
Shad	M	472	5/18/2020	PIT	-	-	900_230000237895	Lawrence	US
Shad	M	474	5/18/2020	PIT	-	-	900_230000237856	Lawrence	US

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Shad	M	480	5/18/2020	PIT	-	-	900_230000237877	Lawrence	US
Shad	M	481	5/18/2020	PIT	-	-	900_230000237899	Lawrence	US
Shad	M	485	5/18/2020	PIT	-	-	900_230000237874	Lawrence	US
Shad	F	490	5/18/2020	PIT	-	-	900_230000237853	Lawrence	US
Shad	M	493	5/18/2020	PIT	-	-	900_230000237847	Lawrence	US
Shad	M	493	5/18/2020	PIT	-	-	900_230000237855	Lawrence	US
Shad	M	493	5/18/2020	PIT	-	-	900_230000237876	Lawrence	US
Shad	F	494	5/18/2020	PIT	-	-	900_230000237898	Lawrence	US
Shad	F	495	5/18/2020	PIT	-	-	900_230000237851	Lawrence	US
Shad	F	498	5/18/2020	PIT	-	-	900_230000237883	Lawrence	US
Shad	M	499	5/18/2020	PIT	-	-	900_230000237892	Lawrence	US
Shad	F	500	5/18/2020	PIT	-	-	900_230000237875	Lawrence	US
Shad	M	505	5/18/2020	PIT	-	-	900_230000237896	Lawrence	US
Shad	F	510	5/18/2020	PIT	-	-	900_230000237872	Lawrence	US
Shad	M	511	5/18/2020	PIT	-	-	900_230000237871	Lawrence	US
Shad	M	518	5/18/2020	PIT	-	-	900_230000237889	Lawrence	US
Shad	F	521	5/18/2020	PIT	-	-	900_230000237850	Lawrence	US
Shad	M	527	5/18/2020	PIT	-	-	900_230000237869	Lawrence	US
Shad	F	530	5/18/2020	PIT	-	-	900_230000237854	Lawrence	US
Shad	M	535	5/18/2020	PIT	-	-	900_230000237848	Lawrence	US
Shad	M	540	5/18/2020	PIT	-	-	900_230000237873	Lawrence	US
Shad	M	466	5/18/2020	PIT			900_230000237857	Lawrence	US
Shad	F	573	5/22/2020	Dual	149.440	133	900_23000023879	Lawrence	US
Shad	F	543	5/22/2020	Dual	149.440	134	900_23000023878	Lawrence	US
Shad	M	453	5/22/2020	Dual	149.440	135	900_23000023877	Lawrence	US
Shad	M	445	5/22/2020	Dual	149.440	136	900_23000023876	Lawrence	US
Shad	M	509	5/22/2020	Dual	149.440	137	900_23000023875	Lawrence	US
Shad	M	510	5/22/2020	Dual	149.440	138	900_23000023874	Lawrence	US
Shad	F	504	5/22/2020	Dual	149.460	168	900_23000023885	Lawrence	US
Shad	U	482	5/22/2020	Dual	149.460	169	900_23000023884	Lawrence	US
Shad	F	457	5/22/2020	Dual	149.460	170	900_23000023883	Lawrence	US
Shad	M	470	5/22/2020	Dual	149.460	171	900_23000023882	Lawrence	US
Shad	M	469	5/22/2020	Dual	149.460	172	900_23000023881	Lawrence	US
Shad	F	540	5/22/2020	Dual	149.460	173	900_23000023880	Lawrence	US
Shad	M	538	5/22/2020	Dual	149.480	22	900_23000023892	Lawrence	US
Shad	M	467	5/22/2020	Dual	149.480	23	900_23000023891	Lawrence	US
Shad	F	531	5/22/2020	Dual	149.480	24	900_23000023890	Lawrence	US
Shad	M	485	5/22/2020	Dual	149.480	25	900_23000023888	Lawrence	US
Shad	M	468	5/22/2020	Dual	149.480	26	900_23000023887	Lawrence	US
Shad	F	511	5/22/2020	Dual	149.480	27	900_23000023886	Lawrence	US
Shad	M	448	5/22/2020	Dual	149.760	58	900_23000023899	Lawrence	US
Shad	M	493	5/22/2020	Dual	149.760	59	900_23000023898	Lawrence	US
Shad	M	480	5/22/2020	Dual	149.760	60	900_23000023897	Lawrence	US
Shad	M	460	5/22/2020	Dual	149.760	61	900_23000023896	Lawrence	US

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Shad	M	428	5/22/2020	Dual	149.760	62	900_23000023895	Lawrence	US
Shad	M	480	5/22/2020	Dual	149.760	63	900_23000023893	Lawrence	US
Shad	M	467	5/22/2020	Dual	149.800	95	900_230000238100	Lawrence	US
Shad	M	478	5/22/2020	Dual	149.800	96	900_230000238101	Lawrence	US
Shad	M	448	5/22/2020	Dual	149.800	97	900_230000238103	Lawrence	US
Shad	M	486	5/22/2020	Dual	149.800	98	900_230000238104	Lawrence	US
Shad	F	475	5/22/2020	Dual	149.800	99	900_230000238105	Lawrence	US
Shad	M	495	5/22/2020	Dual	149.800	100	900_230000238106	Lawrence	US
Shad	M	423	5/22/2020	PIT	-	-	900_230000238113	Lawrence	US
Shad	M	433	5/22/2020	PIT	-	-	900_230000238122	Lawrence	US
Shad	M	434	5/22/2020	PIT	-	-	900_230000238129	Lawrence	US
Shad	M	440	5/22/2020	PIT	-	-	900_230000238110	Lawrence	US
Shad	M	447	5/22/2020	PIT	-	-	900_230000238109	Lawrence	US
Shad	M	448	5/22/2020	PIT	-	-	900_23000023873	Lawrence	US
Shad	M	453	5/22/2020	PIT	-	-	900_230000238128	Lawrence	US
Shad	M	453	5/22/2020	PIT	-	-	900_230000238131	Lawrence	US
Shad	M	454	5/22/2020	PIT	-	-	900_230000238134	Lawrence	US
Shad	M	455	5/22/2020	PIT	-	-	900_23000023889	Lawrence	US
Shad	M	456	5/22/2020	PIT	-	-	900_230000238119	Lawrence	US
Shad	M	457	5/22/2020	PIT	-	-	900_230000238125	Lawrence	US
Shad	M	457	5/22/2020	PIT	-	-	900_230000238133	Lawrence	US
Shad	M	465	5/22/2020	PIT	-	-	900_230000238117	Lawrence	US
Shad	M	468	5/22/2020	PIT	-	-	900_230000238116	Lawrence	US
Shad	M	468	5/22/2020	PIT	-	-	900_230000238121	Lawrence	US
Shad	M	468	5/22/2020	PIT	-	-	900_230000238132	Lawrence	US
Shad	M	470	5/22/2020	PIT	-	-	900_230000238124	Lawrence	US
Shad	M	470	5/22/2020	PIT	-	-	900_230000238127	Lawrence	US
Shad	M	475	5/22/2020	PIT	-	-	900_230000238107	Lawrence	US
Shad	M	478	5/22/2020	PIT	-	-	900_230000238123	Lawrence	US
Shad	M	482	5/22/2020	PIT	-	-	900_230000238112	Lawrence	US
Shad	M	482	5/22/2020	PIT	-	-	900_230000238130	Lawrence	US
Shad	M	483	5/22/2020	PIT	-	-	900_230000238120	Lawrence	US
Shad	M	487	5/22/2020	PIT	-	-	900_230000238136	Lawrence	US
Shad	M	506	5/22/2020	PIT	-	-	900_230000238118	Lawrence	US
Shad	M	513	5/22/2020	PIT	-	-	900_230000238108	Lawrence	US
Shad	M	520	5/22/2020	PIT	-	-	900_230000238102	Lawrence	US
Shad	F	520	5/22/2020	PIT	-	-	900_230000238126	Lawrence	US
Shad	M	525	5/22/2020	PIT	-	-	900_230000238111	Lawrence	US
Shad	F	531	5/22/2020	PIT	-	-	900_23000023894	Lawrence	US
Shad	M	532	5/22/2020	PIT	-	-	900_230000238114	Lawrence	US
Shad	M	554	5/22/2020	PIT	-	-	900_230000238115	Lawrence	US
Shad	M	560	5/22/2020	PIT	-	-	900_230000238135	Lawrence	US
Shad	M	482	5/26/2020	Dual	149.440	145	900_230000238137	Lawrence	US
Shad	M	484	5/26/2020	Dual	149.440	146	900_230000238138	Lawrence	US

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Shad	M	450	5/26/2020	Dual	149.440	147	900_230000238139	Lawrence	US
Shad	M	465	5/26/2020	Dual	149.440	148	900_230000238140	Lawrence	US
Shad	F	510	5/26/2020	Dual	149.440	149	900_230000238141	Lawrence	US
Shad	M	484	5/26/2020	Dual	149.440	150	900_230000238142	Lawrence	US
Shad	M	498	5/26/2020	Dual	149.440	151	900_230000238205	Lawrence	US
Shad	M	478	5/26/2020	Dual	149.440	152	900_230000238204	Lawrence	US
Shad	M	462	5/26/2020	Dual	149.440	153	900_230000238203	Lawrence	US
Shad	F	525	5/26/2020	Dual	149.440	154	900_230000238202	Lawrence	US
Shad	M	462	5/26/2020	Dual	149.440	155	900_230000238201	Lawrence	US
Shad	M	478	5/26/2020	Dual	149.440	156	900_230000238200	Lawrence	US
Shad	M	492	5/26/2020	Dual	149.460	180	900_230000238143	Lawrence	US
Shad	F	536	5/26/2020	Dual	149.460	181	900_230000238144	Lawrence	US
Shad	F	535	5/26/2020	Dual	149.460	182	900_230000238145	Lawrence	US
Shad	F	495	5/26/2020	Dual	149.460	183	900_230000238146	Lawrence	US
Shad	M	440	5/26/2020	Dual	149.460	184	900_230000238147	Lawrence	US
Shad	M	461	5/26/2020	Dual	149.460	185	900_230000238148	Lawrence	US
Shad	M	468	5/26/2020	Dual	149.460	186	900_230000238211	Lawrence	US
Shad	M	444	5/26/2020	Dual	149.460	187	900_230000238210	Lawrence	US
Shad	F	496	5/26/2020	Dual	149.460	188	900_230000238209	Lawrence	US
Shad	M	456	5/26/2020	Dual	149.460	189	900_230000238208	Lawrence	US
Shad	M	452	5/26/2020	Dual	149.460	190	900_230000238207	Lawrence	US
Shad	M	458	5/26/2020	Dual	149.460	191	900_230000238206	Lawrence	US
Shad	M	478	5/26/2020	Dual	149.480	34	900_230000238149	Lawrence	US
Shad	M	444	5/26/2020	Dual	149.480	35	900_230000238150	Lawrence	US
Shad	M	445	5/26/2020	Dual	149.480	36	900_230000238152	Lawrence	US
Shad	M	460	5/26/2020	Dual	149.480	37	900_230000238153	Lawrence	US
Shad	F	549	5/26/2020	Dual	149.480	38	900_230000238154	Lawrence	US
Shad	F	532	5/26/2020	Dual	149.480	39	900_230000238155	Lawrence	US
Shad	M	438	5/26/2020	Dual	149.480	40	900_230000238217	Lawrence	US
Shad	M	485	5/26/2020	Dual	149.480	41	900_230000238216	Lawrence	US
Shad	M	433	5/26/2020	Dual	149.480	42	900_230000238215	Lawrence	US
Shad	F	520	5/26/2020	Dual	149.480	43	900_230000238214	Lawrence	US
Shad	M	485	5/26/2020	Dual	149.480	44	900_230000238213	Lawrence	US
Shad	M	533	5/26/2020	Dual	149.480	45	900_230000238212	Lawrence	US
Shad	M	467	5/26/2020	Dual	149.760	70	900_230000238156	Lawrence	US
Shad	F	540	5/26/2020	Dual	149.760	71	900_230000238157	Lawrence	US
Shad	M	480	5/26/2020	Dual	149.760	72	900_230000238158	Lawrence	US
Shad	M	536	5/26/2020	Dual	149.760	74	900_230000238159	Lawrence	US
Shad	M	478	5/26/2020	Dual	149.760	75	900_230000238160	Lawrence	US
Shad	M	463	5/26/2020	Dual	149.760	76	900_230000238223	Lawrence	US
Shad	M	476	5/26/2020	Dual	149.760	77	900_230000238222	Lawrence	US
Shad	F	559	5/26/2020	Dual	149.760	78	900_230000238221	Lawrence	US
Shad	M	450	5/26/2020	Dual	149.760	79	900_230000238220	Lawrence	US
Shad	M	475	5/26/2020	Dual	149.760	80	900_230000238219	Lawrence	US

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Shad	F	505	5/26/2020	Dual	149.760	81	900_230000238218	Lawrence	US
Shad	M	451	5/26/2020	Dual	149.800	107	900_230000238161	Lawrence	US
Shad	M	477	5/26/2020	Dual	149.800	110	900_230000238164	Lawrence	US
Shad	M	469	5/26/2020	Dual	149.800	111	900_230000238165	Lawrence	US
Shad	M	450	5/26/2020	Dual	149.800	112	900_230000238166	Lawrence	US
Shad	F	501	5/26/2020	Dual	149.800	113	900_230000238229	Lawrence	US
Shad	M	492	5/26/2020	Dual	149.800	114	900_230000238228	Lawrence	US
Shad	M	480	5/26/2020	Dual	149.800	115	900_230000238227	Lawrence	US
Shad	M	492	5/26/2020	Dual	149.800	116	900_230000238226	Lawrence	US
Shad	M	441	5/26/2020	Dual	149.800	117	900_230000238225	Lawrence	US
Shad	M	462	5/26/2020	Dual	149.800	118	900_230000238224	Lawrence	US
Shad	M	475	5/26/2020	Dual	149.800	708	900_230000238162	Lawrence	US
Shad	U	475	5/26/2020	Dual	149.800	709	900_230000238163	Lawrence	US
Shad	M	430	5/26/2020	PIT	-	-	900_230000238246	Lawrence	US
Shad	M	435	5/26/2020	PIT	-	-	900_230000238176	Lawrence	US
Shad	M	438	5/26/2020	PIT	-	-	900_230000238232	Lawrence	US
Shad	M	440	5/26/2020	PIT	-	-	900_230000238234	Lawrence	US
Shad	M	441	5/26/2020	PIT	-	-	900_230000238187	Lawrence	US
Shad	M	450	5/26/2020	PIT	-	-	900_230000238241	Lawrence	US
Shad	U	455	5/26/2020	PIT	-	-	900_230000238235	Lawrence	US
Shad	M	455	5/26/2020	PIT	-	-	900_230000238253	Lawrence	US
Shad	M	456	5/26/2020	PIT	-	-	900_230000238189	Lawrence	US
Shad	M	457	5/26/2020	PIT	-	-	900_230000238182	Lawrence	US
Shad	M	457	5/26/2020	PIT	-	-	900_230000238259	Lawrence	US
Shad	M	460	5/26/2020	PIT	-	-	900_230000238172	Lawrence	US
Shad	U	460	5/26/2020	PIT	-	-	900_230000238180	Lawrence	US
Shad	U	460	5/26/2020	PIT	-	-	900_230000238240	Lawrence	US
Shad	M	460	5/26/2020	PIT	-	-	900_230000238257	Lawrence	US
Shad	M	461	5/26/2020	PIT	-	-	900_230000238258	Lawrence	US
Shad	M	462	5/26/2020	PIT	-	-	900_230000238186	Lawrence	US
Shad	M	463	5/26/2020	PIT	-	-	900_230000238195	Lawrence	US
Shad	M	463	5/26/2020	PIT	-	-	900_230000238254	Lawrence	US
Shad	F	464	5/26/2020	PIT	-	-	900_230000238247	Lawrence	US
Shad	M	465	5/26/2020	PIT	-	-	900_230000238173	Lawrence	US
Shad	F	465	5/26/2020	PIT	-	-	900_230000238190	Lawrence	US
Shad	M	465	5/26/2020	PIT	-	-	900_230000238196	Lawrence	US
Shad	M	465	5/26/2020	PIT	-	-	900_230000238249	Lawrence	US
Shad	M	465	5/26/2020	PIT	-	-	900_230000238255	Lawrence	US
Shad	M	466	5/26/2020	PIT	-	-	900_230000238250	Lawrence	US
Shad	U	467	5/26/2020	PIT	-	-	900_230000238239	Lawrence	US
Shad	M	470	5/26/2020	PIT	-	-	900_230000238233	Lawrence	US
Shad	M	472	5/26/2020	PIT	-	-	900_230000238260	Lawrence	US
Shad	M	473	5/26/2020	PIT	-	-	900_230000238245	Lawrence	US
Shad	M	474	5/26/2020	PIT	-	-	900_230000238178	Lawrence	US

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Shad	M	474	5/26/2020	PIT	-	-	900_230000238236	Lawrence	US
Shad	M	475	5/26/2020	PIT	-	-	900_230000238177	Lawrence	US
Shad	M	477	5/26/2020	PIT	-	-	900_230000238151	Lawrence	US
Shad	M	477	5/26/2020	PIT	-	-	900_230000238168	Lawrence	US
Shad	U	477	5/26/2020	PIT	-	-	900_230000238185	Lawrence	US
Shad	M	477	5/26/2020	PIT	-	-	900_230000238248	Lawrence	US
Shad	M	478	5/26/2020	PIT	-	-	900_230000238192	Lawrence	US
Shad	M	479	5/26/2020	PIT	-	-	900_230000238181	Lawrence	US
Shad	M	480	5/26/2020	PIT	-	-	900_230000238238	Lawrence	US
Shad	M	481	5/26/2020	PIT	-	-	900_230000238263	Lawrence	US
Shad	M	482	5/26/2020	PIT	-	-	900_230000238243	Lawrence	US
Shad	M	484	5/26/2020	PIT	-	-	900_230000238194	Lawrence	US
Shad	M	485	5/26/2020	PIT	-	-	900_230000238174	Lawrence	US
Shad	M	485	5/26/2020	PIT	-	-	900_230000238184	Lawrence	US
Shad	M	485	5/26/2020	PIT	-	-	900_230000238256	Lawrence	US
Shad	U	487	5/26/2020	PIT	-	-	900_230000238198	Lawrence	US
Shad	F	489	5/26/2020	PIT	-	-	900_230000238197	Lawrence	US
Shad	F	490	5/26/2020	PIT	-	-	900_230000238231	Lawrence	US
Shad	F	490	5/26/2020	PIT	-	-	900_230000238242	Lawrence	US
Shad	M	490	5/26/2020	PIT	-	-	900_230000238262	Lawrence	US
Shad	F	492	5/26/2020	PIT	-	-	900_230000238244	Lawrence	US
Shad	F	498	5/26/2020	PIT	-	-	900_230000238167	Lawrence	US
Shad	U	498	5/26/2020	PIT	-	-	900_230000238170	Lawrence	US
Shad	F	500	5/26/2020	PIT	-	-	900_230000238199	Lawrence	US
Shad	F	504	5/26/2020	PIT	-	-	900_230000238191	Lawrence	US
Shad	M	504	5/26/2020	PIT	-	-	900_230000238230	Lawrence	US
Shad	U	507	5/26/2020	PIT	-	-	900_230000238183	Lawrence	US
Shad	F	510	5/26/2020	PIT	-	-	900_230000238175	Lawrence	US
Shad	U	512	5/26/2020	PIT	-	-	900_230000238193	Lawrence	US
Shad	F	513	5/26/2020	PIT	-	-	900_230000238237	Lawrence	US
Shad	U	515	5/26/2020	PIT	-	-	900_230000238169	Lawrence	US
Shad	F	515	5/26/2020	PIT	-	-	900_230000238261	Lawrence	US
Shad	F	518	5/26/2020	PIT	-	-	900_230000238188	Lawrence	US
Shad	F	518	5/26/2020	PIT	-	-	900_230000238251	Lawrence	US
Shad	F	518	5/26/2020	PIT	-	-	900_230000238252	Lawrence	US
Shad	F	520	5/26/2020	PIT	-	-	900_230000238179	Lawrence	US
Shad	F	536	5/26/2020	PIT	-	-	900_230000238171	Lawrence	US
Shad	F	503	5/27/2020	Dual	149.440	139	900_230000238269	Lawrence	US
Shad	M	469	5/27/2020	Dual	149.440	140	900_230000238268	Lawrence	US
Shad	M	483	5/27/2020	Dual	149.440	141	900_230000238267	Lawrence	US
Shad	M	470	5/27/2020	Dual	149.440	142	900_230000238266	Lawrence	US
Shad	M	519	5/27/2020	Dual	149.440	143	900_230000238265	Lawrence	US
Shad	U	482	5/27/2020	Dual	149.440	144	900_230000238264	Lawrence	US
Shad	U	516	5/27/2020	Dual	149.460	174	900_230000238275	Lawrence	US

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Shad	M	464	5/27/2020	Dual	149.460	175	900_230000238274	Lawrence	US
Shad	F	522	5/27/2020	Dual	149.460	176	900_230000238273	Lawrence	US
Shad	M	443	5/27/2020	Dual	149.460	177	900_230000238272	Lawrence	US
Shad	M	483	5/27/2020	Dual	149.460	178	900_230000238271	Lawrence	US
Shad	M	480	5/27/2020	Dual	149.460	179	900_230000238270	Lawrence	US
Shad	M	460	5/27/2020	Dual	149.480	28	900_230000238281	Lawrence	US
Shad	M	466	5/27/2020	Dual	149.480	29	900_230000238280	Lawrence	US
Shad	M	469	5/27/2020	Dual	149.480	30	900_230000238279	Lawrence	US
Shad	M	444	5/27/2020	Dual	149.480	31	900_230000238278	Lawrence	US
Shad	F	500	5/27/2020	Dual	149.480	32	900_230000238277	Lawrence	US
Shad	M	492	5/27/2020	Dual	149.480	33	900_230000238276	Lawrence	US
Shad	M	472	5/27/2020	Dual	149.760	64	900_230000238287	Lawrence	US
Shad	U	504	5/27/2020	Dual	149.760	65	900_230000238286	Lawrence	US
Shad	M	471	5/27/2020	Dual	149.760	66	900_230000238285	Lawrence	US
Shad	F	509	5/27/2020	Dual	149.760	67	900_230000238284	Lawrence	US
Shad	M	440	5/27/2020	Dual	149.760	68	900_230000238283	Lawrence	US
Shad	M	485	5/27/2020	Dual	149.760	69	900_230000238282	Lawrence	US
Shad	M	467	5/27/2020	Dual	149.760	73	900_230000238294	Lawrence	US
Shad	F	533	5/27/2020	Dual	149.800	101	900_230000238293	Lawrence	US
Shad	F	542	5/27/2020	Dual	149.800	102	900_230000238292	Lawrence	US
Shad	M	463	5/27/2020	Dual	149.800	103	900_230000238291	Lawrence	US
Shad	M	488	5/27/2020	Dual	149.800	104	900_230000238290	Lawrence	US
Shad	M	413	5/27/2020	Dual	149.800	105	900_230000238289	Lawrence	US
Shad	M	480	5/27/2020	Dual	149.800	106	900_230000238288	Lawrence	US
Shad	M	460	5/27/2020	PIT	-	-	900_230000238312	Lawrence	US
Shad	M	410	5/27/2020	PIT	-	-	900_230000238311	Lawrence	US
Shad	M	419	5/27/2020	PIT	-	-	900_230000238307	Lawrence	US
Shad	M	420	5/27/2020	PIT	-	-	900_230000238303	Lawrence	US
Shad	M	420	5/27/2020	PIT	-	-	900_230000238323	Lawrence	US
Shad	M	434	5/27/2020	PIT	-	-	900_230000238316	Lawrence	US
Shad	M	438	5/27/2020	PIT	-	-	900_230000238327	Lawrence	US
Shad	M	440	5/27/2020	PIT	-	-	900_230000238325	Lawrence	US
Shad	M	456	5/27/2020	PIT	-	-	900_230000238317	Lawrence	US
Shad	M	458	5/27/2020	PIT	-	-	900_230000238309	Lawrence	US
Shad	M	460	5/27/2020	PIT	-	-	900_230000238295	Lawrence	US
Shad	M	462	5/27/2020	PIT	-	-	900_230000238308	Lawrence	US
Shad	F	471	5/27/2020	PIT	-	-	900_230000238320	Lawrence	US
Shad	M	472	5/27/2020	PIT	-	-	900_230000238296	Lawrence	US
Shad	M	474	5/27/2020	PIT	-	-	900_230000238299	Lawrence	US
Shad	M	476	5/27/2020	PIT	-	-	900_230000238313	Lawrence	US
Shad	M	477	5/27/2020	PIT	-	-	900_230000238298	Lawrence	US
Shad	M	480	5/27/2020	PIT	-	-	900_230000238301	Lawrence	US
Shad	M	480	5/27/2020	PIT	-	-	900_230000238310	Lawrence	US
Shad	M	480	5/27/2020	PIT	-	-	900_230000238322	Lawrence	US

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Shad	F	482	5/27/2020	PIT	-	-	900_230000238314	Lawrence	US
Shad	U	489	5/27/2020	PIT	-	-	900_230000238321	Lawrence	US
Shad	F	490	5/27/2020	PIT	-	-	900_230000238328	Lawrence	US
Shad	F	491	5/27/2020	PIT	-	-	900_230000238305	Lawrence	US
Shad	M	495	5/27/2020	PIT	-	-	900_230000238300	Lawrence	US
Shad	F	500	5/27/2020	PIT	-	-	900_230000238319	Lawrence	US
Shad	U	500	5/27/2020	PIT	-	-	900_230000238326	Lawrence	US
Shad	F	504	5/27/2020	PIT	-	-	900_230000238318	Lawrence	US
Shad	U	506	5/27/2020	PIT	-	-	900_230000238315	Lawrence	US
Shad	F	506	5/27/2020	PIT	-	-	900_230000238324	Lawrence	US
Shad	M	510	5/27/2020	PIT	-	-	900_230000238302	Lawrence	US
Shad	F	510	5/27/2020	PIT	-	-	900_230000238306	Lawrence	US
Shad	M	519	5/27/2020	PIT	-	-	900_230000238297	Lawrence	US
Shad	F	540	5/27/2020	PIT	-	-	900_230000238304	Lawrence	US
Shad	M	494	6/3/2020	Radio	149.440	77	-	Lawrence	DS
Shad	F	504	6/3/2020	Radio	149.440	78	-	Lawrence	DS
Shad	M	460	6/3/2020	Radio	149.440	79	-	Lawrence	DS
Shad	F	497	6/3/2020	Radio	149.440	80	-	Lawrence	DS
Shad	F	508	6/3/2020	Radio	149.440	81	-	Lawrence	DS
Shad	M	472	6/3/2020	Radio	149.440	82	-	Lawrence	DS
Shad	M	436	6/3/2020	Radio	149.440	83	-	Lawrence	DS
Shad	F	512	6/3/2020	Radio	149.440	84	-	Lawrence	DS
Shad	M	442	6/3/2020	Radio	149.440	87	-	Lawrence	DS
Shad	F	500	6/3/2020	Radio	149.440	88	-	Lawrence	DS
Shad	M	422	6/3/2020	Radio	149.460	97	-	Lawrence	DS
Shad	M	411	6/3/2020	Radio	149.460	98	-	Lawrence	DS
Shad	F	490	6/3/2020	Radio	149.460	99	-	Lawrence	DS
Shad	M	448	6/3/2020	Radio	149.460	100	-	Lawrence	DS
Shad	F	551	6/3/2020	Radio	149.460	101	-	Lawrence	DS
Shad	F	497	6/3/2020	Radio	149.460	102	-	Lawrence	DS
Shad	F	505	6/3/2020	Radio	149.460	103	-	Lawrence	DS
Shad	M	446	6/3/2020	Radio	149.460	104	-	Lawrence	DS
Shad	M	493	6/3/2020	Radio	149.460	107	-	Lawrence	DS
Shad	F	490	6/3/2020	Radio	149.460	108	-	Lawrence	DS
Shad	M	463	6/3/2020	Radio	149.480	161	-	Lawrence	DS
Shad	M	466	6/3/2020	Radio	149.480	162	-	Lawrence	DS
Shad	U	463	6/3/2020	Radio	149.480	163	-	Lawrence	DS
Shad	F	542	6/3/2020	Radio	149.480	164	-	Lawrence	DS
Shad	F	503	6/3/2020	Radio	149.480	165	-	Lawrence	DS
Shad	F	445	6/3/2020	Radio	149.480	166	-	Lawrence	DS
Shad	M	476	6/3/2020	Radio	149.480	167	-	Lawrence	DS
Shad	F	505	6/3/2020	Radio	149.480	168	-	Lawrence	DS
Shad	M	500	6/3/2020	Radio	149.480	171	-	Lawrence	DS
Shad	M	413	6/3/2020	Radio	149.480	172	-	Lawrence	DS

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Shad	M	436	6/3/2020	Radio	149.760	25	-	Lawrence	DS
Shad	F	521	6/3/2020	Radio	149.760	26	-	Lawrence	DS
Shad	M	485	6/3/2020	Radio	149.760	27	-	Lawrence	DS
Shad	M	453	6/3/2020	Radio	149.760	28	-	Lawrence	DS
Shad	M	440	6/3/2020	Radio	149.760	29	-	Lawrence	DS
Shad	U	498	6/3/2020	Radio	149.760	30	-	Lawrence	DS
Shad	M	435	6/3/2020	Radio	149.760	31	-	Lawrence	DS
Shad	M	459	6/3/2020	Radio	149.760	35	-	Lawrence	DS
Shad	M	455	6/3/2020	Radio	149.760	36	-	Lawrence	DS
Shad	F	550	6/3/2020	Radio	149.760	132	-	Lawrence	DS
Shad	M	455	6/3/2020	Radio	149.800	20	-	Lawrence	DS
Shad	M	422	6/3/2020	Radio	149.800	21	-	Lawrence	DS
Shad	U	510	6/3/2020	Radio	149.800	22	-	Lawrence	DS
Shad	F	470	6/3/2020	Radio	149.800	23	-	Lawrence	DS
Shad	F	506	6/3/2020	Radio	149.800	24	-	Lawrence	DS
Shad	M	444	6/3/2020	Radio	149.800	25	-	Lawrence	DS
Shad	M	445	6/3/2020	Radio	149.800	26	-	Lawrence	DS
Shad	F	495	6/3/2020	Radio	149.800	27	-	Lawrence	DS
Shad	M	482	6/3/2020	Radio	149.800	30	-	Lawrence	DS
Shad	M	521	6/3/2020	Radio	149.800	31	-	Lawrence	DS
Shad	M	500	6/5/2020	Radio	149.440	85	-	Lawrence	DS
Shad	M	422	6/5/2020	Radio	149.440	86	-	Lawrence	DS
Shad	M	493	6/5/2020	Radio	149.440	89	-	Lawrence	DS
Shad	M	425	6/5/2020	Radio	149.440	90	-	Lawrence	DS
Shad	M	488	6/5/2020	Radio	149.440	91	-	Lawrence	DS
Shad	M	481	6/5/2020	Radio	149.440	92	-	Lawrence	DS
Shad	M	500	6/5/2020	Radio	149.440	93	-	Lawrence	DS
Shad	M	425	6/5/2020	Radio	149.440	94	-	Lawrence	DS
Shad	M	445	6/5/2020	Radio	149.440	95	-	Lawrence	DS
Shad	F	527	6/5/2020	Radio	149.440	96	-	Lawrence	DS
Shad	F	494	6/5/2020	Radio	149.460	105	-	Lawrence	DS
Shad	M	490	6/5/2020	Radio	149.460	106	-	Lawrence	DS
Shad	M	444	6/5/2020	Radio	149.460	109	-	Lawrence	DS
Shad	M	502	6/5/2020	Radio	149.460	110	-	Lawrence	DS
Shad	M	443	6/5/2020	Radio	149.460	111	-	Lawrence	DS
Shad	F	530	6/5/2020	Radio	149.460	112	-	Lawrence	DS
Shad	M	471	6/5/2020	Radio	149.460	113	-	Lawrence	DS
Shad	M	393	6/5/2020	Radio	149.460	114	-	Lawrence	DS
Shad	M	465	6/5/2020	Radio	149.460	115	-	Lawrence	DS
Shad	F	501	6/5/2020	Radio	149.460	116	-	Lawrence	DS
Shad	U	481	6/5/2020	Radio	149.480	169	-	Lawrence	DS
Shad	M	413	6/5/2020	Radio	149.480	170	-	Lawrence	DS
Shad	F	528	6/5/2020	Radio	149.480	173	-	Lawrence	DS
Shad	M	520	6/5/2020	Radio	149.480	174	-	Lawrence	DS

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Shad	F	459	6/5/2020	Radio	149.480	175	-	Lawrence	DS
Shad	U	502	6/5/2020	Radio	149.480	176	-	Lawrence	DS
Shad	M	437	6/5/2020	Radio	149.480	177	-	Lawrence	DS
Shad	M	481	6/5/2020	Radio	149.480	178	-	Lawrence	DS
Shad	M	472	6/5/2020	Radio	149.480	179	-	Lawrence	DS
Shad	F	530	6/5/2020	Radio	149.480	180	-	Lawrence	DS
Shad	M	490	6/5/2020	Radio	149.760	33	-	Lawrence	DS
Shad	M	465	6/5/2020	Radio	149.760	34	-	Lawrence	DS
Shad	M	457	6/5/2020	Radio	149.760	37	-	Lawrence	DS
Shad	M	385	6/5/2020	Radio	149.760	38	-	Lawrence	DS
Shad	M	500	6/5/2020	Radio	149.760	40	-	Lawrence	DS
Shad	M	475	6/5/2020	Radio	149.760	41	-	Lawrence	DS
Shad	M	508	6/5/2020	Radio	149.760	42	-	Lawrence	DS
Shad	M	482	6/5/2020	Radio	149.760	43	-	Lawrence	DS
Shad	M	475	6/5/2020	Radio	149.760	44	-	Lawrence	DS
Shad	F	505	6/5/2020	Radio	149.760	59	-	Lawrence	DS
Shad	M	475	6/5/2020	Radio	149.800	28	-	Lawrence	DS
Shad	M	468	6/5/2020	Radio	149.800	29	-	Lawrence	DS
Shad	M	492	6/5/2020	Radio	149.800	32	-	Lawrence	DS
Shad	U	526	6/5/2020	Radio	149.800	33	-	Lawrence	DS
Shad	F	470	6/5/2020	Radio	149.800	34	-	Lawrence	DS
Shad	F	486	6/5/2020	Radio	149.800	35	-	Lawrence	DS
Shad	F	508	6/5/2020	Radio	149.800	36	-	Lawrence	DS
Shad	F	545	6/5/2020	Radio	149.800	37	-	Lawrence	DS
Shad	M	460	6/5/2020	Radio	149.800	38	-	Lawrence	DS
Shad	M	432	6/5/2020	Radio	149.800	39	-	Lawrence	DS
Shad	F	530	6/8/2020	Radio	149.440	65	-	Lawrence	DS
Shad	F	481	6/8/2020	Radio	149.440	66	-	Lawrence	DS
Shad	F	532	6/8/2020	Radio	149.440	67	-	Lawrence	DS
Shad	F	518	6/8/2020	Radio	149.440	68	-	Lawrence	DS
Shad	F	490	6/8/2020	Radio	149.440	69	-	Lawrence	DS
Shad	M	496	6/8/2020	Radio	149.440	70	-	Lawrence	DS
Shad	M	452	6/8/2020	Radio	149.440	71	-	Lawrence	DS
Shad	M	476	6/8/2020	Radio	149.440	72	-	Lawrence	DS
Shad	F	538	6/8/2020	Radio	149.440	73	-	Lawrence	DS
Shad	F	530	6/8/2020	Radio	149.440	74	-	Lawrence	DS
Shad	F	505	6/8/2020	Radio	149.440	75	-	Lawrence	DS
Shad	M	393	6/8/2020	Radio	149.440	76	-	Lawrence	DS
Shad	F	525	6/8/2020	Radio	149.460	30	-	Lawrence	DS
Shad	M	450	6/8/2020	Radio	149.460	31	-	Lawrence	DS
Shad	F	552	6/8/2020	Radio	149.460	32	-	Lawrence	DS
Shad	M	452	6/8/2020	Radio	149.460	33	-	Lawrence	DS
Shad	F	556	6/8/2020	Radio	149.460	34	-	Lawrence	DS
Shad	F	553	6/8/2020	Radio	149.460	35	-	Lawrence	DS

Species	Gender	Total Length (mm)	Release Date	Type	Frequency	ID	PIT ID	Collection Location	US_DS
Shad	F	519	6/8/2020	Radio	149.460	36	-	Lawrence	DS
Shad	M	505	6/8/2020	Radio	149.460	37	-	Lawrence	DS
Shad	M	460	6/8/2020	Radio	149.460	38	-	Lawrence	DS
Shad	M	450	6/8/2020	Radio	149.460	39	-	Lawrence	DS
Shad	F	497	6/8/2020	Radio	149.460	117	-	Lawrence	DS
Shad	F	506	6/8/2020	Radio	149.460	118	-	Lawrence	DS
Shad	M	440	6/8/2020	Radio	149.480	181	-	Lawrence	DS
Shad	F	522	6/8/2020	Radio	149.480	182	-	Lawrence	DS
Shad	F	495	6/8/2020	Radio	149.480	183	-	Lawrence	DS
Shad	F	545	6/8/2020	Radio	149.480	184	-	Lawrence	DS
Shad	F	550	6/8/2020	Radio	149.480	185	-	Lawrence	DS
Shad	U	525	6/8/2020	Radio	149.480	186	-	Lawrence	DS
Shad	M	470	6/8/2020	Radio	149.480	187	-	Lawrence	DS
Shad	F	535	6/8/2020	Radio	149.480	188	-	Lawrence	DS
Shad	M	442	6/8/2020	Radio	149.480	189	-	Lawrence	DS
Shad	F	505	6/8/2020	Radio	149.480	190	-	Lawrence	DS
Shad	M	450	6/8/2020	Radio	149.480	191	-	Lawrence	DS
Shad	F	545	6/8/2020	Radio	149.480	192	-	Lawrence	DS
Shad	F	516	6/8/2020	Radio	149.760	14	-	Lawrence	DS
Shad	M	475	6/8/2020	Radio	149.760	15	-	Lawrence	DS
Shad	M	473	6/8/2020	Radio	149.760	16	-	Lawrence	DS
Shad	M	463	6/8/2020	Radio	149.760	17	-	Lawrence	DS
Shad	M	432	6/8/2020	Radio	149.760	18	-	Lawrence	DS
Shad	F	502	6/8/2020	Radio	149.760	19	-	Lawrence	DS
Shad	M	462	6/8/2020	Radio	149.760	20	-	Lawrence	DS
Shad	M	482	6/8/2020	Radio	149.760	21	-	Lawrence	DS
Shad	F	540	6/8/2020	Radio	149.760	22	-	Lawrence	DS
Shad	M	440	6/8/2020	Radio	149.760	23	-	Lawrence	DS
Shad	M	470	6/8/2020	Radio	149.760	24	-	Lawrence	DS
Shad	M	438	6/8/2020	Radio	149.800	119	-	Lawrence	DS
Shad	M	468	6/8/2020	Radio	149.800	120	-	Lawrence	DS
Shad	M	470	6/8/2020	Radio	149.800	121	-	Lawrence	DS

Technical Report for the Fish Assemblage Study

Lowell Hydroelectric Project (FERC No. 2790)

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Table of Contents

List of Tables

1 Introduction

A survey of the resident fish community was conducted in support of the relicensing for the Lowell Hydroelectric Project (Lowell or Project), Federal Energy Regulatory Commission (FERC) No. 2790, as identified in the Revised Study Plan (RSP) submitted by Boott Hydropower, LLC (Boott) on January 28, 2019. The approach and methodology described in the RSP for the fish community study was approved by FERC in its Study Plan Determination letter dated March 13, 2019. This technical report was prepared on behalf of Boott to provide a description of the objectives, methodologies and results of the 2019 field sampling intended to describe the fish community within the Lowell Project area.

2 Objectives

The goal of this study was to characterize the fish assemblage in areas affected by the Lowell Project, specifically the impoundment and bypassed reach.

Specific objectives included:

- Field sampling to describe the fish assemblage structure, distribution, and abundance within the Project affected area along spatial and temporal gradients; and
- A comparison of historical records of fish species occurrence in the Project area to results of this study.

3 Project Description and Study Area

The Lowell Project is located at River Mile (RM) 41 on the Merrimack River in the City of Lowell in Middlesex County, Massachusetts, with an impoundment extending approximately 23 miles upstream into Hillsborough County, New Hampshire. The existing Lowell Project consists of: (1) a 1,093-foot-long, 15-foot-high masonry gravity dam (Pawtucket dam) that includes a 982.5-foot-long spillway with a crest elevation of 87.2 feet National Geodetic Vertical Datum 1929 (NGVD 29) topped by 5-foot-high pneumatically-operated crest gates deployed in five independently-operable zones; (2) a 720-acre impoundment with a normal maximum water surface elevation of 92.2 feet NGVD 29; (3) a 5.5-mile-long canal system which includes several small dams and gatehouses; (4) a powerhouse (E.L. Field) which uses water from the Northern Canal and contains two turbine-generator units with a total installed capacity of 15.0 megawatts (MW); (5) a 440-foot-long tailrace channel; (6) four powerhouses (Assets, Bridge Street, Hamilton, and John Street) housed in nineteenth century mill buildings along the Northern and Pawtucket Canal System containing 15 turbine-generator units with a total installed capacity of approximately 5.1 MW; (7) a 4.5-mile long, 13.8-kilovolt transmission line connecting the powerhouses to the regional distribution grid; (8) upstream and downstream fish passage facilities including a fish elevator and downstream fish bypass at the E.L. Field powerhouse, and a vertical-slot fish ladder at the Pawtucket dam; and (9) appurtenant facilities. At the normal pond elevation of 92.2 feet NGVD 1929 (crest of the pneumatic flashboards), the surface area of the impoundment encompasses an area of approximately 720 acres. The gross storage capacity between the normal surface elevation of 92.2 feet and the minimum pond level of 87.2 feet is approximately 3,600 acre-feet. The Project operates essentially in a run-of-river (ROR) mode using automatic pond level control, and has no usable storage capacity.

The study area for this fish community survey included the mainstem Merrimack River from the Pawtucket Dam to the upper extent of the Project's impoundment located approximately 23 river miles upstream, and the Project's 0.7-mile-long bypassed reach.

4 Methods

4.1 Lowell Impoundment

The 23-mile-long (37 kilometer) impoundment was stratified based on mesohabitat characteristics. Each stratum was delineated in 547-yard (500-meter) segments using Aeronautical Reconnaissance Coverage Geographic Information System (ArcGIS). Sampling locations were randomly selected and weighted proportional to mesohabitat type frequency (e.g., if 50 percent of a particular geographic reach was shallow, riffle habitat, then 50 percent of the total number of sampling locations for that geographic reach were randomly placed within that habitat type). As long as habitat was accessible, efforts were made to ensure that a minimum of three sampling locations were placed within each strata (i.e., habitat type). A total of twelve, 547-yard (500-meter) segments were randomly selected within the reach so that approximately 16% of the impoundment was sampled. The stratified-random site selection process was repeated for each of three seasonal surveys (spring, summer, and fall).

Following selection of the twelve, 500-meter sample units, boat electrofish sampling took place during the nighttime hours (as defined by daily sunset/sunrise times). A single bank (east or west) was randomly selected for each sample unit. Prior to the start of sampling, settings on the electrofishing unit were adjusted by a trained crew member to ensure that approximately 4.0 amps of pulsed DC current was being generated. After recording the start time, boat electrofish sampling consisted of a single shoreline pass starting at the upstream end of each 500m transect and proceeded downstream. Effort was made by the boat driver to follow the shoreline contour and probe the sampling anodes into habitat areas (i.e., overhanging vegetation, submerged aquatic vegetation, woody debris, etc.). The boat driver maintained the boat in near-shore littoral habitat (< 10-feet deep) where the sampling field would be most effective. A pair of netters stood on the bow of the sampling vessel and placed all stunned fish into an onboard live well for processing. Once the sample transect was finished, the driver recorded the completion time and duration of the sampling effort.

An experimental gill net was set concurrent with boat electrofishing in each 500-m sample unit. Gill nets were fished within all sample units containing adequate water depths and flow conditions to allow for proper performance of the nets, specifically deep and mid-channel microhabitats. Experimental gillnets were eight feet deep and were constructed of four 25-ft panels of increasing mesh size (1.0, 2.0, 3.0, and 4.0-inch stretch mesh). Gillnets were set during nighttime hours (as defined by daily sunset/sunrise times) when fish species are most susceptible to the gear due to the reduced visual avoidance. Gillnets were deployed perpendicular to the shoreline in areas where water depths were greater than the net height and capture area was maximized. Nets were set and fished for an approximate four-hour period prior to retrieval to minimize netting mortality. Net set coordinates and the date and time of each set and pull were recorded.

To supplement experimental gill net sampling in deeper habitats (> 10 ft) where electrofishing is not effective and small fish and eels are not susceptible to gillnets, a pair of standard minnow traps were deployed. The traps were 2.5 feet long galvanized wire mesh (0.25 square inch) cylinders with two entry fykes. Traps were baited and anchored to remain on station for the duration of their soak time. For each sample unit, two traps were fished simultaneously with gillnets for an approximate four-hour period. Trap set coordinates and the date and time of each set and pull were recorded.

All fish collected from the impoundment were identified to the lowest possible taxonomic classification (preferably to species), enumerated, measured to total length (to the nearest mm), and weighed (to the nearest g). If large numbers of small fish (i.e., YOY or small cyprinid species) were captured, length and weight information was collected from the first 25 individuals within the sample and the remaining individuals were grouped, enumerated, and batch weighed.

For each 500-m sample unit, the sampling crews visually evaluated habitat within the reach. The dominant substrate (organics, sand/silt/clay, cobble/gravel, boulder, or ledge), proportion of transect with submerged aquatic vegetation (i.e., 0-25%, 5-50%, 50-75%, or 75-100%), and the proportion of transect with overhanging vegetative cover (i.e., 0-25%, 5-50%, 50-75%, or 75-100%) was recorded. To get a sense of relative water depth for the Merrimack River at each sampling transect, a series of nine measurements were collected. River depths were recorded at the quarter points (i.e., 25, 50, and 75%) of three cross sections placed at the upstream extent, downstream extent, and midpoint of each sample unit. A representative water velocity (ft/s) was recorded at the midpoint of the middle cross-section of each habitat unit. Following documentation of sample unit habitat and characteristics, a representative water quality measurement was collected at approximately one meter of depth. Water temperature (^{o}C), dissolved oxygen (mg/L) conductivity (µs/cm), pH, and turbidity (ntu) were recorded.

4.2 Lowell Bypassed Reach

Delineation of sample units was scaled for the shorter, less accessible bypassed reach. Each stratum was delineated in 55-yard (50-meter) segments using ArcGIS. Sampling locations were randomly selected and weighted proportional to mesohabitat type frequency. As long as habitat was available, effort was made to ensure that at least one sampling location was placed within each strata (i.e., habitat type) within the bypassed reach. A total of three segments were randomly selected within the bypassed reach during each of three seasonal surveys (spring, summer, fall). Due to safety and gear limitations, sampling was not conducted in (1) the reach from the Pawtucket Dam downstream to the School Street Bridge, and (2) the lowermost section of the bypass channel downstream of the Northern Canal surge gate. Sampling was limited to periods of minimum flow in the bypassed reach.

Backpack electrofish sampling was conducted within the Lowell bypassed reach. Halltech Aquatic Research Model HT2000B/MK5, battery-powered backpack electrofishers with ring probes and rattail cathodes were used to sample within the bypassed reach. Sampling was conducted by anchoring a fine mesh seine at the downstream end of a 50-m sample unit. A pair of backpack electrofishing units and four technicians moved in a downstream direction towards the seine while actively netting stunned individuals and kicking the substrate to drive additional stunned individuals towards the collection net. Backpack electrofish sampling was conducted during daylight hours. The backpack units were set at 550 volts at 100 Hertz (Hz). The start time, end time and duration of sampling were recorded for each sample unit. Specifics related to habitat and effort were the same as described above for impoundment sampling.

5 Results

5.1 Lowell Impoundment

5.1.1 Habitat Evaluation and Sample Unit Selection

A pair of biologists boated the stretch of the Merrimack River from the Pawtucket Dam upstream 23.0 miles to the uppermost extent of the Project area on May 18, 2019. Changes in mesohabitat type were visually identified and their locations recorded. Following importation of those habitat break points into ArcGIS, the 23.0 miles of the Merrimack River upstream of Lowell impoundment was subdivided into a total of 74 547-yard (500-meter) segments. The majority of those (78%) were classified as impoundment habitat. Lesser amounts of the overall reach were classified as run (7%) and pool (15%). The spatial distribution of mesohabitat types and 500-m segments for the 23.0 miles upstream of Lowell is provided in Appendix A.

Table 5-1 provides a listing of the habitat units upstream of the Pawtucket Dam that were randomly selected for sampling during the spring, summer, and fall periods of 2019. A total of twelve, 500-m segments were selected per season. During the spring season, a total of six impoundment, three run and three pool habitat units were sampled. River conditions (i.e., water depth) prevented effective sampling within some of the run habitat at the uppermost end of the Project area during the summer and fall sampling periods. As a result, seven impoundment, two run, and three pool habitat units were sampled during those seasons.

5.1.2 Sampling Effort

Fish community data were collected from a total of 36, 500-m sample units during the spring, summer, and fall of 2019 (12 sites per season). Effort expended at a sample unit during each of the three seasons consisted of (1) a 500-m shoreline boat electrofish sample, (2) a four hour experimental gill net set, and (3) a four hour baited minnow trap set. Fish community sampling in the Lowell impoundment occurred on June 24-26 (spring), August 19-21 (summer) and October 28-30 (fall). Tables 5-2 through 5-4 provide a summary of boat electrofish, gill net and minnow trap sampling in the Lowell impoundment. Impoundment sample units selected by season are presented visually in Appendix A.

5.1.3 Species Richness and Composition

A total of 1,847 individuals representing twenty-two fish species were collected from the Lowell impoundment during 2019 when all sampling seasons and sample units are considered (Table 5-5). The total impoundment catch represents all individuals collected and identified during boat electrofish and gill net sampling. There were no fish collected via minnow trap during the 2019 survey. Table 5-6 provides a summary of the impoundment community composition by season (electrofish and gill net). Spottail shiner (23.0%), redbreast sunfish (20.5%) and smallmouth bass (12.3%) were the three most numerically abundant species within the Lowell impoundment during the 2019 sampling. When examined by species, spottail shiner were most abundant during the spring (27.6% of seasonal catch) and fall (33.9% of seasonal catch) whereas redbreast sunfish were most abundant during the summer period (27.1% of seasonal catch).

Total catch and community composition from sampling units upstream of Pawtucket Dam and classified as impoundment, pool and run mesohabitat types are presented in Table 5-7. Centrarchid species were the most abundant within impoundment habitat with redbreast sunfish (24.2%), pumpkinseed (14.2%), and smallmouth bass (12.5%) representing the three most abundantly sampled species. Spottail shiner were the most abundantly sampled fish species in the pool (28.4%) and run (46.3%) habitat areas.

The majority of catch in the impoundment was observed during boat electrofishing efforts (Table 5-8). A total of 1,792 individuals representing 20 fish species were collected. Spottail shiner, redbreast sunfish, and smallmouth bass were the most frequently observed species within the impoundment electrofish catch. Total boat electrofish catch within the impoundment was fairly even across seasons (high of 677 individuals during the summer to a low of 543 individuals during the fall). A total of 55 individuals representing 15 species were recorded during gill net sampling in the Lowell impoundment. Yellow bullhead was the most frequently encountered species during gill net sampling and the majority of catch was recorded during the summer season.

5.1.4 Relative Abundance

Relative abundance, the number of fish captured with known sampling effort and indexed as catch per unit of effort (CPUE), was calculated on a species-specific basis. CPUE values were standardized to a fixed unit of time or distance using the following equations:

For time (i.e., fish per hour): CPUE for taxon j in sample i = (catch ji / duration i) * 60 min

Where: duration is expressed in minutes

For distance (i.e., fish per 100 m): CPUE for taxon j in sample i = (catch ji / length i) * 100m

Where: length is expressed in meters

Prior to the calculation of any CPUE values the data set was "zero filled" for each fish species, such that each species collected in the study was represented in every sample. CPUE values were calculated for each fish species by season and gear.

Catch rates were highest for spottail shiner, redbreast sunfish and smallmouth bass captured by boat electrofish sampling in the 23.0 mile reach upstream of Pawtucket Dam during the 2019 sampling (Table 5-9). Values for fish per unit of effort were highest for spottail shiner and smallmouth bass during the spring sampling event, redbreast sunfish and spottail shiner during the summer sampling event and fallfish and alewife during the fall sampling event. Table 5-10 provides CPUE rates for fish collected during gill net sampling in the upstream reach during 2019. The CPUE rate for yellow bullhead was the highest for fish collected in the experimental gill nets. A listing of CPUE rates for all species by season and mesohabitat type is provided in Appendix B.

5.1.5 Biocharacteristics

Length frequency distributions for fish species where 25 or more individuals were collected and measured during the impoundment sampling are presented in Appendix E. The observed range for fish sizes recorded for species observed in both the boat electrofish and gill net catch from the Lowell impoundment fall within the expected bounds for those species in the northeastern U.S. (Table 5-11). A full listing of catch data is provided in Appendix F.

5.1.6 Habitat and Water Quality Characteristics

Tables 5-12 and 5-13 provide summaries of habitat and water quality information recorded for each of the 36, 500-m sample units surveyed during the spring, summer and fall seasons. Dominant substrate, presence of submerged aquatic vegetation (SAV), and presence of general cover were consistent among all sample units regardless of mesohabitat classification (i.e., pool, run or impoundment). Sampled areas upstream of Pawtucket Dam were characterized by sand-silt-clay sediments, presence of SAV over 0-25% of the sample area and the presence of general cover over 0-25% of the sample area. Mean water depth (as sampled at quarter points of the river channel at the upper, middle, and lower points of each transect) trended towards shallower at the upper end of the reach upstream of Pawtucket Dam in areas classified as pool and run and deeper at the lower end in areas classified as impoundment.

Water temperature was relatively consistent among sample units with a ± 1-2^{o}C range in values within each season. The average Merrimack River water temperature was 21.5^{o}C during the spring sampling, 25.6^{o}C during the summer sampling, and 10.8^{o}C during the fall sampling. Dissolved oxygen was measured at 8.1 mg/L or greater at all stations upstream of Pawtucket Dam regardless of season. Conductivity averaged 114 µs/cm during the spring sampling, 181 µs/cm during the summer sampling, and 117 µs/cm during the fall sampling. In general, conductivity increased with proximity to the Pawtucket Dam. River pH was consistent across seasons ranging from 6.5-7.5. The average turbidity reading was higher during the spring sampling (2.6 NTU) than was observed during the summer or fall periods (1.8 and 1.6 NTUs, respectively).

Table 5–1. Sample unit habitat type and location for the spring, summer and fall Lowell impoundment fish community survey

Season	Sample Unit	Mesohabitat Type	Upstream		Downstream		Efish Bank
			Latitude	Longitude	Latitude	Longitude	
Spring	LIMP_002	Run	42.88173	-71.47036	42.87818	-71.47409	W
	LIMP_004	Run	42.87414	-71.47563	42.87073	-71.47963	E
	LIMP_005	Pool	42.87073	-71.47963	42.86747	-71.48384	W
	LIMP_012	Pool	42.84162	-71.48371	42.83729	-71.48473	E
	LIMP_015	Pool	42.82889	-71.48038	42.82455	-71.47880	E
	LIMP_016	Run	42.82455	-71.47880	42.82055	-71.47999	W
	LIMP_017	Impoundment	42.82055	-71.47999	42.81789	-71.47512	W
	LIMP_021	Impoundment	42.80479	-71.47225	42.80101	-71.46898	W
	LIMP_027	Impoundment	42.78203	-71.45706	42.77753	-71.45706	W
	LIMP_049	Impoundment	42.69368	-71.42215	42.69125	-71.41704	W
	LIMP_050	Impoundment	42.69125	-71.41704	42.68765	-71.41352	W
	LIMP_069	Impoundment	42.63767	-71.36403	42.63851	-71.35805	W
Summer	LIMP_001	Run	42.88500	-71.46616	42.88173	-71.47036	W
	LIMP_002	Run	42.88173	-71.47036	42.87818	-71.47409	W
	LIMP_006	Pool	42.86747	-71.48384	42.86341	-71.48632	E
	LIMP_011	Pool	42.84596	-71.48228	42.84162	-71.48371	E
	LIMP_014	Pool	42.83315	-71.48236	42.82889	-71.48038	W
	LIMP_020	Impoundment	42.80909	-71.47339	42.80479	-71.47225	E
	LIMP_021	Impoundment	42.80479	-71.47225	42.80101	-71.46898	E
	LIMP_042	Impoundment	42.72045	-71.43789	42.71597	-71.43723	W
	LIMP_045	Impoundment	42.70703	-71.43625	42.70288	-71.43394	W
	LIMP_056	Impoundment	42.67057	-71.41675	42.66851	-71.41135	E
	LIMP_065	Impoundment	42.64835	-71.37998	42.64423	-71.37771	E
	LIMP_068	Impoundment	42.63777	-71.37011	42.63767	-71.36403	E
Fall	LIMP_002	Run	42.88173	-71.47036	42.87818	-71.47409	E
	LIMP_003	Run	42.87818	-71.47409	42.87414	-71.47563	W
	LIMP_005	Pool	42.87073	-71.47963	42.86747	-71.48384	W
	LIMP_011	Pool	42.84596	-71.48228	42.84162	-71.48371	E
	LIMP_015	Pool	42.82889	-71.48038	42.82455	-71.47880	W
	LIMP_023	Impoundment	42.79761	-71.46500	42.79481	-71.46027	W
	LIMP_037	Impoundment	42.74124	-71.43966	42.73705	-71.43771	E
	LIMP_044	Impoundment	42.71149	-71.43696	42.70703	-71.43625	W
	LIMP_058	Impoundment	42.66630	-71.40605	42.66252	-71.40286	W
	LIMP_060	Impoundment	42.65840	-71.40047	42.65406	-71.39903	W
	LIMP_061	Impoundment	42.65406	-71.39903	42.64990	-71.39711	E
	LIMP_067	Impoundment	42.64024	-71.37510	42.63777	-71.37011	E

Table 5–2. Impoundment boat electrofish effort for the spring, summer and fall Lowell impoundment fish community survey

Season	Sample Unit	Sample			No. Amps	No. Netters	No. Runs
		Date	Time	Duration (Sec)			
Spring	LIMP_002	6/24/2019	21:01	753	4	2	1
	LIMP_004	6/24/2019	22:04	956	4	2	1
	LIMP_005	6/24/2019	23:29	741	4	2	1
	LIMP_012	6/25/2019	0:37	782	4	2	1
	LIMP_015	6/26/2019	22:31	907	4	2	1
	LIMP_016	6/26/2019	21:49	968	4	2	1
	LIMP_017	6/26/2019	21:01	1001	4	2	1
	LIMP_021	6/26/2019	23:30	833	4	2	1
	LIMP_027	6/26/2019	1:25	888	4	2	1
	LIMP_049	6/25/2019	23:56	909	4	2	1
	LIMP_050	6/25/2019	22:42	842	4	2	1
	LIMP_069	6/25/2019	21:26	837	4	2	1
Summer	LIMP_001	8/19/2019	20:38	851	4	2	1
	LIMP_002	8/19/2019	21:44	722	4	2	1
	LIMP_006	8/19/2019	22:54	775	4	2	1
	LIMP_011	8/20/2019	0:02	959	4	2	1
	LIMP_014	8/21/2019	22:02	837	4	2	1
	LIMP_020	8/21/2019	20:56	841	4	2	1
	LIMP_021	8/21/2019	20:20	729	4	2	1
	LIMP_042	8/21/2019	0:17	903	4	2	1
	LIMP_045	8/20/2019	23:32	852	4	2	1
	LIMP_056	8/20/2019	22:22	815	4	2	1
	LIMP_065	8/20/2019	21:35	881	4	2	1
	LIMP_068	8/20/2019	20:21	812	4	2	1
Fall	LIMP_002	10/29/2019	16:54	839	4	2	1
	LIMP_003	10/29/2019	18:02	834	4	2	1
	LIMP_005	10/29/2019	20:02	814	4	2	1
	LIMP_011	10/29/2019	21:11	939	4	2	1
	LIMP_015	10/29/2019	21:48	842	4	2	1
	LIMP_023	10/29/2019	22:45	946	4	2	1
	LIMP_037	10/30/2019	18:39	835	4	2	1
	LIMP_044	10/30/2019	17:45	942	4	2	1
	LIMP_058	10/28/2019	17:54	900	4	2	1
	LIMP_060	10/28/2019	18:24	1140	4	2	1
	LIMP_061	10/28/2019	19:00	1080	4	2	1
	LIMP_067	10/28/2019	20:00	1140	4	2	1

Table 5–3. Impoundment experimental gill net effort for the spring, summer and fall Lowell impoundment fish community survey

Season	Sample Unit	Sample			Set Location	
		Date	Time	Duration (hr)	Latitude	Longitude
Spring	LIMP_002	6/24/2019	20:49	4.3	42.87818	71.47409
	LIMP_004	6/24/2019	21:02	4.3	42.87054	71.47924
	LIMP_005	6/24/2019	21:09	4.6	42.86747	71.48384
	LIMP_012	6/24/2019	21:30	4.7	42.83729	71.48472
	LIMP_015	6/26/2019	21:02	4.1	42.82588	71.47865
	LIMP_016	6/26/2019	21:14	4.2	42.82069	71.47828
	LIMP_017	6/26/2019	21:24	4.3	42.81857	71.47600
	LIMP_021	6/26/2019	21:35	4.4	42.80157	71.46944
	LIMP_027	6/25/2019	22:22	4.2	42.77752	71.45763
	LIMP_049	6/25/2019	21:55	4.1	42.69118	71.41750
	LIMP_050	6/25/2019	21:47	4.0	42.68747	71.41373
	LIMP_069	6/25/2019	21:18	4.1	42.63792	71.35815
Summer	LIMP_001	8/19/2019	20:33	4.7	42.88173	71.47036
	LIMP_002	8/19/2019	21:04	4.5	42.87818	71.47409
	LIMP_006	8/19/2019	21:30	4.4	42.86341	71.48632
	LIMP_011	8/19/2019	21:54	4.5	42.84162	71.48371
	LIMP_014	8/21/2019	20:20	4.1	42.82890	71.48038
	LIMP_020	8/21/2019	19:52	5.2	42.80479	71.47225
	LIMP_021	8/21/2019	19:44	5.6	42.80101	71.46984
	LIMP_042	8/20/2019	21:58	5.7	42.71597	71.43723
	LIMP_045	8/20/2019	21:42	5.6	42.70288	71.43394
	LIMP_056	8/20/2019	21:10	5.6	42.66851	71.41135
	LIMP_065	8/20/2019	20:39	5.7	42.64423	71.37771
	LIMP_068	8/20/2019	20:18	5.4	42.63767	71.36403
Fall	LIMP_002	10/29/2019	17:50	4.2	42.87818	71.47409
	LIMP_003	10/29/2019	18:06	4.3	42.87414	71.47563
	LIMP_005	10/29/2019	18:15	4.7	42.86747	71.48384
	LIMP_011	10/29/2019	18:35	5.0	42.84162	71.48371
	LIMP_015	10/29/2019	18:50	5.3	42.82455	71.47880
	LIMP_023	10/30/2019	17:41	4.0	42.79481	71.46027
	LIMP_037	10/30/2019	18:01	4.2	42.73705	71.43771
	LIMP_044	10/30/2019	18:16	4.5	42.70703	71.43625
	LIMP_058	10/28/2019	17:48	4.0	42.66252	71.40286
	LIMP_060	10/28/2019	18:06	4.1	42.65406	71.39903
	LIMP_061	10/28/2019	18:13	4.2	42.64990	71.39711
	LIMP_067	10/28/2019	18:29	4.3	42.63777	71.37011

Table 5–4. Impoundment minnow trap effort for the spring, summer and fall Lowell impoundment fish community survey

Season	Sample Unit	Sample			Set Location	
		Date	Time	Duration (hr)	Latitude	Longitude
Spring	LIMP_002	6/24/2019	23:05	1.9	42.87818	71.47409
	LIMP_004	6/24/2019	22:29	3.1	42.87073	71.47963
	LIMP_005	6/24/2019	22:11	3.6	42.86747	71.48384
	LIMP_012	6/24/2019	21:30	4.8	42.83729	71.48472
	LIMP_015	6/25/2019	22:23	4.0	42.77731	71.45747
	LIMP_016	6/25/2019	21:56	4.1	42.69115	71.41727
	LIMP_017	6/25/2019	21:48	4.0	42.68721	71.41364
	LIMP_021	6/25/2019	21:22	4.0	42.63770	71.35809
	LIMP_027	6/26/2019	21:02	4.1	42.82511	71.47849
	LIMP_049	6/26/2019	21:15	4.2	42.82085	71.47791
	LIMP_050	6/26/2019	21:26	4.1	42.81836	71.47588
	LIMP_069	6/26/2019	21:36	4.2	42.80159	71.46933
Summer	LIMP_001	8/19/2019	22:42	2.8	42.88173	71.47036
	LIMP_002	8/19/2019	22:36	3.0	42.87818	71.47409
	LIMP_006	8/19/2019	22:20	3.7	42.86341	71.48632
	LIMP_011	8/19/2019	21:59	4.4	42.84162	71.48371
	LIMP_014	8/21/2019	20:22	4.0	42.82890	71.48038
	LIMP_020	8/21/2019	19:53	5.1	42.80479	71.47225
	LIMP_021	8/21/2019	19:46	5.5	42.80101	71.46984
	LIMP_042	8/20/2019	22:04	5.5	42.71597	71.43723
	LIMP_045	8/20/2019	21:45	5.5	42.70288	71.43394
	LIMP_056	8/20/2019	21:13	5.6	42.66851	71.41135
	LIMP_065	8/20/2019	22:48	3.5	42.64423	71.37771
	LIMP_068	8/20/2019	20:22	2.3	42.63767	71.36403
Fall	LIMP_002	10/29/2019	17:52	4.1	42.87818	71.47409
	LIMP_003	10/29/2019	18:07	4.2	42.87414	71.47563
	LIMP_005	10/29/2019	18:17	4.7	42.86747	71.48384
	LIMP_011	10/29/2019	18:37	5.0	42.84162	71.48371
	LIMP_015	10/29/2019	18:52	5.2	42.82455	71.47880
	LIMP_023	10/30/2019	17:42	4.0	42.79481	71.46027
	LIMP_037	10/30/2019	18:02	4.2	42.73705	71.43771
	LIMP_044	10/30/2019	18:18	4.4	42.70703	71.43625
	LIMP_058	10/28/2019	17:50	4.2	42.66252	71.40286
	LIMP_060	10/28/2019	18:04	4.2	42.65406	71.39903
	LIMP_061	10/28/2019	18:15	4.1	42.64990	71.39711
	LIMP_067	10/28/2019	18:31	4.2	42.63777	71.37011

Table 5–5. Number of fish captured upstream of Pawtucket Dam by boat electrofishing and experimental gill net during the spring, summer and fall sampling, 2019

Common Name	Spring	Summer	Fall	2019
	N	N	N	N
Alewife	0	21	92	113
American Eel	6	10	1	17
Black Crappie	2	2	1	5
Bluegill	24	77	21	122
Channel Catfish	0	1	0	1
Common Carp	1	3	1	5
Fallfish	34	34	75	143
Golden Shiner	1	5	7	13
Largemouth Bass	2	32	7	41
Lepomis spp.	1	3	0	4
Margined Madtom	3	5	1	9
Pumpkinseed	10	126	19	155
Redbreast Sunfish	137	196	45	378
Rock Bass	3	2	2	7
Sea Lamprey	7	6	8	21
Smallmouth Bass	127	50	50	227
Spottail Shiner	160	79	185	424
Tessellated Darter	14	14	3	31
Walleye	0	1	0	1
White Perch	0	1	0	1
White Sucker	24	9	22	55
Yellow Bullhead	7	42	5	54
Yellow Perch	16	3	1	20
Total	**579**	**722**	**546**	**1847**

Table 5–6. Percent composition of fish captured upstream of Pawtucket Dam by boat electrofishing and experimental gill net during the spring, summer and fall sampling, 2019

Common Name	Spring	Summer	Fall	2019
	Pct.	Pct.	Pct.	Pct.
Alewife	<0.1	2.9	16.8	6.1
American Eel	1.0	1.4	0.2	0.9
Black Crappie	0.3	0.3	0.2	0.3
Bluegill	4.1	10.7	3.8	6.6
Channel Catfish	<0.1	0.1	<0.1	0.1
Common Carp	0.2	0.4	0.2	0.3
Fallfish	5.9	4.7	13.7	7.7
Golden Shiner	0.2	0.7	1.3	0.7
Largemouth Bass	0.3	4.4	1.3	2.2
Lepomis spp.	0.2	0.4	<0.1	0.2
Margined Madtom	0.5	0.7	0.2	0.5
Pumpkinseed	1.7	17.5	3.5	8.4
Redbreast Sunfish	23.7	27.1	8.2	20.5
Rock Bass	0.5	0.3	0.4	0.4
Sea Lamprey	1.2	0.8	1.5	1.1
Smallmouth Bass	21.9	6.9	9.2	12.3
Spottail Shiner	27.6	10.9	33.9	23.0
Tessellated Darter	2.4	1.9	0.5	1.7
Walleye	<0.1	0.1	<0.1	0.1
White Perch	<0.1	0.1	<0.1	0.1
White Sucker	4.1	1.2	4.0	3.0
Yellow Bullhead	1.2	5.8	0.9	2.9
Yellow Perch	2.8	0.4	0.2	1.1

Table 5–7. Number and percent composition of fish captured upstream of Pawtucket Dam by boat electrofishing and experimental gill net within impoundment, pool and run mesohabitat areas, 2019

Common Name	Impoundment		Pool		Run	
	N	Pct.	N	Pct.	N	Pct.
Alewife	104	9.9	4	1.3	5	1.0
American Eel	11	1.0	1	0.3	5	1.0
Black Crappie	1	0.1	3	1.0	1	0.2
Bluegill	87	8.2	28	9.0	7	1.5
Channel Catfish	1	0.1	0	0.0	0	0.0
Common Carp	4	0.4	0	0.0	1	0.2
Fallfish	66	6.3	37	11.9	40	8.3
Golden Shiner	3	0.3	6	1.9	4	0.8
Largemouth Bass	22	2.1	15	4.8	4	0.8
Lepomis spp.	2	0.2	1	0.3	1	0.2
Margined Madtom	6	0.6	2	0.6	1	0.2
Pumpkinseed	150	14.2	3	1.0	2	0.4
Redbreast Sunfish	255	24.2	39	12.6	84	17.4
Rock Bass	3	0.3	2	0.6	2	0.4
Sea Lamprey	11	1.0	5	1.6	5	1.0
Smallmouth Bass	132	12.5	35	11.3	60	12.4
Spottail Shiner	113	10.7	88	28.4	223	46.3
Tessellated Darter	14	1.3	11	3.5	6	1.2
Walleye	1	0.1	0	0.0	0	0.0
White Perch	1	0.1	0	0.0	0	0.0
White Sucker	21	2.0	12	3.9	22	4.6
Yellow Bullhead	42	4.0	6	1.9	6	1.2
Yellow Perch	5	0.5	12	3.9	3	0.6
Total	**1055**	**100.0**	**310**	**100.0**	**482**	**100.0**

Table 5–8. Number of fish captured upstream of Pawtucket Dam by boat electrofishing or experimental gill net during spring, summer, and fall, 2019

Common Name	Boat Efish				Gill Net			
	Spring	Summer	Fall	Total	Spring	Summer	Fall	Total
Alewife	0	19	92	111	0	2	0	2
American Eel	6	10	1	17	0	0	0	0
Black Crappie	2	2	1	5	0	0	0	0
Bluegill	23	77	21	121	1	0	0	1
Channel Catfish	0	0	0	0	0	1	0	1
Common Carp	1	2	1	4	0	1	0	1
Fallfish	33	32	75	140	1	2	0	3
Golden Shiner	1	4	7	12	0	1	0	1
Largemouth Bass	2	32	7	41	0	0	0	0
Lepomis spp.	1	3	0	4	0	0	0	0
Margined Madtom	2	5	1	8	1	0	0	1
Pumpkinseed	10	125	19	154	0	1	0	1
Redbreast Sunfish	137	191	45	373	0	5	0	5
Rock Bass	3	2	2	7	0	0	0	0
Sea Lamprey	7	6	8	21	0	0	0	0
Smallmouth Bass	126	46	50	222	1	4	0	5
Spottail Shiner	159	79	184	422	1	0	1	2
Tessellated Darter	14	14	3	31	0	0	0	0
Walleye	0	0	0	0	0	1	0	1
White Perch	0	1	0	1	0	0	0	0
White Sucker	22	7	22	51	2	2	0	4
Yellow Bullhead	7	19	3	29	0	23	2	25
Yellow Perch	16	1	1	18	0	2	0	2
Total	**572**	**677**	**543**	**1792**	**7**	**45**	**3**	**55**

Table 5–9. Catch per unit of effort for fish captured upstream of Pawtucket Dam by boat electrofishing during spring, summer, and fall, 2019

Common Name	Spring		Summer		Fall		Total	
	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m
Alewife	0.00	0.00	1.39	0.06	10.15	0.61	3.85	0.23
American Eel	0.53	0.03	2.17	0.09	<0.01	<0.01	0.90	0.04
Black Crappie	0.53	0.02	0.23	0.01	0.31	0.01	0.36	0.02
Bluegill	3.04	0.14	9.13	0.43	3.15	0.15	5.11	0.24
Common Carp	0.07	<0.01	0.76	0.03	0.13	0.01	0.32	0.01
Fallfish	7.27	0.34	6.43	0.28	14.09	0.65	9.26	0.43
Golden Shiner	0.06	<0.01	0.75	0.03	1.66	0.07	0.82	0.04
Largemouth Bass	0.34	0.02	4.28	0.20	1.43	0.06	2.02	0.09
Lepomis spp.	0.07	<0.01	0.92	0.04	0.00	0.00	0.33	0.01
Margined Madtom	0.37	0.02	1.06	0.05	0.12	0.01	0.52	0.02
Pumpkinseed	0.80	0.04	9.60	0.44	2.13	0.13	4.18	0.20
Redbreast Sunfish	22.79	1.05	35.24	1.55	5.52	0.29	21.18	0.96
Rock Bass	1.19	0.05	0.24	0.01	0.10	0.01	0.51	0.02
Sea Lamprey	1.63	0.08	0.42	0.02	1.20	0.06	1.08	0.06
Smallmouth Bass	25.51	1.16	9.26	0.42	5.58	0.29	13.45	0.62
Spottail Shiner	35.29	1.55	25.94	1.12	8.30	0.37	23.17	1.01
Tessellated Darter	3.02	0.14	1.56	0.07	0.12	0.01	1.57	0.07
White Perch	0.00	0.00	0.08	0.00	0.00	0.00	0.03	0.00
White Sucker	4.19	0.21	1.27	0.06	2.46	0.12	2.64	0.13
Yellow Bullhead	0.90	0.05	2.00	0.09	0.52	0.03	1.14	0.05
Yellow Perch	4.66	0.20	0.21	0.01	<0.01	<0.01	1.62	0.07

Table 5–10. Catch per unit of effort for fish captured upstream of Pawtucket Dam by experimental gill net during spring, summer, and fall, 2019

Common Name	Spring	Summer	Fall	Total
	Fish/hr	Fish/hr	Fish/hr	Fish/hr
Alewife	<0.01	0.01	0.00	0.00
Bluegill	0.02	<0.01	<0.01	0.01
Channel Catfish	<0.01	0.00	<0.01	<0.01
Common Carp	<0.01	0.00	<0.01	<0.01
Fallfish	0.00	0.01	<0.01	0.01
Golden Shiner	<0.01	0.03	<0.01	0.01
Margined Madtom	0.00	<0.01	<0.01	<0.01
Pumpkinseed	<0.01	0.00	<0.01	<0.01
Redbreast Sunfish	<0.01	0.02	<0.01	0.01
Smallmouth Bass	0.00	0.01	<0.01	0.01
Spottail Shiner	0.03	<0.01	0.02	0.02
Walleye	<0.01	0.00	<0.01	<0.01
White Sucker	0.02	0.01	<0.01	0.01
Yellow Bullhead	<0.01	0.08	0.04	0.04
Yellow Perch	<0.01	0.01	<0.01	<0.01

Table 5–11. Minimum, mean, and maximum total length (mm) and weight (g) for fish captured upstream of Pawtucket Dam by boat electrofish and experimental gill net sampling during spring, summer, and fall, 2019

Sampling Gear	Common Name	No. Individuals	Total Length (mm)			Total Weight (g)		
			Min.	Mean	Max.	Min.	Mean	Max.
Boat Electrofish	Alewife	111	59	69	104	1	4	102
	American Eel	17	225	459	670	20	236	535
	Black Crappie	5	84	133	155	8	36	49
	Bluegill	121	47	110	220	1	38	255
	Common Carp	4	429	662	793	1350	4813	6500
	Fallfish	140	55	127	310	2	28	335
	Golden Shiner	12	80	120	208	6	23	73
	Largemouth Bass	41	57	141	382	2	108	900
	Margined Madtom	8	82	102	138	4	9	23
	Pumpkinseed	154	57	97	150	3	27	685
	Redbreast Sunfish	373	38	113	190	1	35	160
	Rock Bass	7	121	157	189	41	86	140
	Sea Lamprey	21	90	127	174	1	4	8
	Smallmouth Bass	222	64	158	494	3	93	1450
	Spottail Shiner	422	49	93	126	1	11	840
	Tessellated Darter	31	39	65	80	1	3	5
	White Perch	1	69	69	69	5	5	5
	White Sucker	51	84	310	520	7	600	1800
	Yellow Bullhead	29	104	183	297	15	95	310
	Yellow Perch	18	80	156	287	5	75	325
Gill Net	Alewife	2	101	101	101	11	12	12
	Bluegill	1	136	136	136	52	52	52
	Channel Catfish	1	296	296	296	290	290	290
	Common Carp	1	552	552	552	2400	2400	2400
	Fallfish	3	219	299	354	120	353	540
	Golden Shiner	1	95	95	95	9	9	9
	Margined Madtom	1	114	114	114	14	14	14
	Pumpkinseed	1	173	173	173	115	115	115
	Redbreast Sunfish	5	131	150	180	45	63	99
	Smallmouth Bass	5	178	217	270	80	132	240
	Spottail Shiner	2	110	118	125	15	18	20
	Walleye	1	630	630	630	2800	2800	2800
	White Sucker	4	358	398	430	550	788	950
	Yellow Bullhead	25	160	202	254	49	122	240
	Yellow Perch	2	178	223	268	70	175	280

Table 5–12. Physical habitat measurements recorded for sample units upstream of Pawtucket Dam during spring, summer, and fall, 2019

Season	Mesohabitat Type	Sample Unit	Habitat Parameter			
			Dominant Substrate	Pct. SAV	Pct. Cover	Mean Depth (ft)
Spring	Run	LIMP-002	Sand-Silt-Clay	0-25%	0-25%	16.3
	Run	LIMP-004	Sand-Silt-Clay	0-25%	0-25%	9.7
	Pool	LIMP-005	Sand-Silt-Clay	0-25%	0-25%	9.4
	Pool	LIMP-012	Sand-Silt-Clay	0-25%	0-25%	9.6
	Pool	LIMP-015	Sand-Silt-Clay	0-25%	0-25%	8.8
	Run	LIMP-016	Sand-Silt-Clay	0-25%	0-25%	6.4
	Impoundment	LIMP-017	Sand-Silt-Clay	0-25%	0-25%	8.4
	Impoundment	LIMP-021	Sand-Silt-Clay	0-25%	0-25%	11.6
	Impoundment	LIMP-027	Sand-Silt-Clay	0-25%	0-25%	6.8
	Impoundment	LIMP-049	Sand-Silt-Clay	0-25%	0-25%	14.6
	Impoundment	LIMP-050	Sand-Silt-Clay	0-25%	0-25%	12.6
	Impoundment	LIMP-069	Sand-Silt-Clay	0-25%	0-25%	16.1
Summer	Run	LIMP-001	Sand-Silt-Clay	0-25%	0-25%	11.0
	Run	LIMP-002	Sand-Silt-Clay	0-25%	0-25%	16.3
	Pool	LIMP-006	Sand-Silt-Clay	25-50%	0-25%	6.9
	Pool	LIMP-011	Sand-Silt-Clay	0-25%	0-25%	8.5
	Pool	LIMP-014	Sand-Silt-Clay	0-25%	0-25%	5.9
	Impoundment	LIMP-020	Sand-Silt-Clay	0-25%	0-25%	8.7
	Impoundment	LIMP-021	Sand-Silt-Clay	0-25%	0-25%	11.6
	Impoundment	LIMP-042	Sand-Silt-Clay	0-25%	0-25%	13.7
	Impoundment	LIMP-045	Sand-Silt-Clay	0-25%	0-25%	17.3
	Impoundment	LIMP-056	Sand-Silt-Clay	0-25%	0-25%	19.2
	Impoundment	LIMP-065	Sand-Silt-Clay	0-25%	0-25%	17.4
	Impoundment	LIMP-068	-	-	-	17.0
Fall	Run	LIMP-002	Sand-Silt-Clay	0-25%	0-25%	16.3
	Run	LIMP-003	Sand-Silt-Clay	0-25%	0-25%	6.4
	Pool	LIMP-005	Sand-Silt-Clay	0-25%	0-25%	9.4
	Pool	LIMP-011	Sand-Silt-Clay	0-25%	0-25%	8.5
	Pool	LIMP-015	Sand-Silt-Clay	0-25%	0-25%	8.8
	Impoundment	LIMP-023	Sand-Silt-Clay	0-25%	0-25%	9.7
	Impoundment	LIMP-037	Sand-Silt-Clay	0-25%	0-25%	14.8
	Impoundment	LIMP-044	Sand-Silt-Clay	0-25%	0-25%	19.8
	Impoundment	LIMP-058	Sand-Silt-Clay	0-25%	0-25%	13.4
	Impoundment	LIMP-060	Sand-Silt-Clay	0-25%	0-25%	14.7
	Impoundment	LIMP-061	Sand-Silt-Clay	0-25%	0-25%	17.4
	Impoundment	LIMP-067	Sand-Silt-Clay	0-25%	0-25%	14.3

Table 5–13. Water quality parameters recorded upstream of Pawtucket Dam during spring, summer, and fall, 2019

Season	Mesohabitat Type	Sample Unit	Water Quality Parameter				
			Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µs/cm)	pH	Turbidity (NTU)
Spring	Run	LIMP-002	21.6	8.8	98.0	7.4	1.6
	Run	LIMP-004	21.4	8.7	100.0	6.6	2.5
	Pool	LIMP-005	21.5	8.8	97.0	6.6	2.2
	Pool	LIMP-012	21.6	8.9	99.0	6.7	2.4
	Pool	LIMP-015	22.1	8.7	114.0	6.5	3.1
	Run	LIMP-016	22.0	9.0	112.0	6.5	3.7
	Impoundment	LIMP-017	22.0	8.8	114.0	6.6	2.2
	Impoundment	LIMP-021	21.9	8.7	120.0	6.6	3.2
	Impoundment	LIMP-027	20.8	8.6	115.0	6.7	2.5
	Impoundment	LIMP-049	20.6	8.5	133.0	6.6	2.7
	Impoundment	LIMP-050	20.7	8.5	131.0	6.6	3.5
	Impoundment	LIMP-069	21.2	8.4	139.0	6.6	2.0
Summer	Run	LIMP-001	26.0	8.3	169.0	7.5	1.9
	Run	LIMP-002	26.0	8.3	169.0	7.5	1.9
	Pool	LIMP-006	25.9	8.3	166.0	7.5	1.9
	Pool	LIMP-011	25.5	8.1	171.0	7.3	1.9
	Pool	LIMP-014	25.2	8.1	169.0	7.0	1.8
	Impoundment	LIMP-020	25.4	8.2	176.0	6.8	1.8
	Impoundment	LIMP-021	25.4	8.3	180.0	6.8	1.8
	Impoundment	LIMP-042	25.8	8.4	191.0	6.9	1.7
	Impoundment	LIMP-045	25.7	8.4	187.0	6.7	1.6
	Impoundment	LIMP-056	25.7	8.8	199.0	6.9	1.6
	Impoundment	LIMP-065	25.7	8.6	195.0	6.9	1.6
	Impoundment	LIMP-068	25.4	8.4	195.0	6.9	1.5
Fall	Run	LIMP-002	10.3	11.1	91.0	6.5	2.2
	Run	LIMP-003	10.4	11.1	91.0	6.6	2.1
	Pool	LIMP-005	10.4	11.1	92.0	6.7	2.0
	Pool	LIMP-011	10.5	11.1	95.0	6.9	2.0
	Pool	LIMP-015	10.5	11.0	96.0	7.4	1.9
	Impoundment	LIMP-023	10.8	10.9	96.0	6.9	2.2
	Impoundment	LIMP-037	11.0	10.8	125.0	7.0	1.8
	Impoundment	LIMP-044	10.9	10.6	123.0	7.1	1.9
	Impoundment	LIMP-058	11.2	10.1	145.0	7.2	0.9
	Impoundment	LIMP-060	11.2	10.1	146.0	7.2	1.0
	Impoundment	LIMP-061	11.3	10.0	152.0	7.2	0.9
	Impoundment	LIMP-067	11.5	9.8	151.0	7.3	0.8

5.2 Lowell Bypassed Reach

5.2.1 Habitat Evaluation and Sample Unit Selection

Changes in general habitat types within the Lowell bypassed reach were visually identified and marked in ArcGIS. The approximately 0.75 mile reach downstream of Pawtucket Dam was subdivided into a total of 23, 55-yard (50-meter) segments. The bypassed reach was subdivided into habitat classifications associated with the upper chute (i.e., the area between Pawtucket Dam and School Street Bridge), pooled section immediately downstream of the School Street Bridge, ledge channel area in the vicinity of the University Avenue Bridge, and the lower bypassed reach downstream of the power canal surge gate. Site conditions were considered inappropriate or unsafe for sampling in the upper chute reach and downstream of the spill gate. As a result back pack electrofish sampling in the bypassed reach occurred within the two middle reaches. Sampling locations were randomly selected on a seasonal basis. The spatial distribution of habitat classifications and 50-m segments within the 0.75 mile bypassed reach is provided in Appendix C.

Table 5-14 provides a listing of the habitat units downstream of the Pawtucket Dam and within the Lowell bypassed reach that were randomly selected for sampling during the spring, summer, and fall periods of 2019. A total of three, 50-m segments were selected per season.

5.2.2 Sampling Effort

Fish community data were collected from a total of 12, 50-m sample units during the spring, summer, and fall of 2019 (12 sites per season). Effort expended at a sample unit during each of the three seasons consisted of an approximately 50-m back pack electrofish sample. Fish community sampling in the Lowell bypassed reach occurred on June 28 (spring), August 27 (summer) and October 21 (fall). Table 5-15 provides a summary of the back pack electrofish sampling in the Lowell bypassed reach. Bypassed reach sample units selected by season are presented visually in Appendix C.

5.2.3 Species Richness and Composition

A total of 526 individuals representing fourteen fish species were collected during back pack electrofishing efforts within the Lowell bypassed reach during 2019 when all sampling seasons and sample units are considered (Table 5-16). Table 5-17 provides a summary of the bypassed reach community composition by season. Fallfish (39.9%), smallmouth bass (20.3%) and spottail shiner (16.7%) were the three most numerically abundant species within the Lowell bypassed reach during the 2019 sampling. When examined by species, spottail shiner were most abundant during the spring (48.8%), fallfish during the summer (55.0%) and fallfish during the fall (39.9%).

Total catch and community composition from sampling units within the pooled and ledge channel sections of the bypassed reach downstream of Pawtucket Dam are presented in Table 5-18. Fallfish were the most abundant fish species collected within the pooled habitat within the Lowell bypassed reach and downstream of Pawtucket Dam, representing 47% of the total catch. Fish catch from the ledge channel habitat located in the lower portion of the bypassed reach was dominated by smallmouth bass which represented 60.6% of the total catch from that area. American eel represented 13.8% of the total electrofish catch from the ledge channel habitat within the Lowell bypassed reach.

5.2.4 Relative Abundance

CPUE values for back pack electrofish sampling within the Lowell bypassed reach downstream of Pawtucket Dam were standardized to a fixed unit of time or distance using the equations and methods provided in Section 5.1.4. Catch rates were highest for smallmouth bass, fallfish, and spottail shiner captured by back pack electrofish sampling in the 0.75 mile bypassed reach downstream of Pawtucket Dam during the 2019 sampling (Table 5-19). Values for fish per unit of effort were highest for spottail shiner and fallfish during the spring sampling event, fallfish and smallmouth bass during the summer sampling event and smallmouth bass and redbreast sunfish during the fall sampling event. A listing of CPUE rates for all species by season and habitat type is provided in Appendix D.

5.2.5 Biocharacteristics

Length frequency distributions for fish species where 25 or more individuals were collected and measured during the bypassed reach sampling are presented in Appendix E. The observed range for fish sizes recorded for species observed in the back pack electrofish catch from the reach downstream of the Pawtucket Dam fall within the expected bounds for those species in the northeastern U.S. (Table 5-11). A full listing of catch data is provided in Appendix F.

5.2.6 Habitat and Water Quality Characteristics

Tables 5-21 and 5-22 provide summaries of habitat and water quality information recorded for each of the 9, 50-m sample units surveyed within the Lowell bypassed reach during the spring, summer and fall seasons. A range of substrate types was sampled during each of the three seasons, ranging from areas of boulders to sand-silt-clay habitat. Sampled areas within the Lowell bypassed reach downstream of Pawtucket Dam were characterized by the presence of SAV over 0-25% of the sample area and the presence of general cover over 0-25% of the sample area. Mean water depth (as measured at quarter points of the electrofished area at the upper, middle, and lower points of each transect) was consistent among sample areas and season, ranging from 1.5-2.4 feet.

Water temperature was relatively consistent among sample units within each season[1] and averaged 22.9°C during the spring sampling, 23.8°C during the summer sampling, and 13.1°C during the fall sampling. Dissolved oxygen was measured at 8.9 mg/L or greater at all bypassed reach stations downstream of Pawtucket Dam regardless of season. Conductivity averaged 148 µs/cm during the spring sampling, 194 µs/cm during the summer sampling, and 100 µs/cm during the fall sampling. The average river pH in the bypassed reach was higher during the summer sampling event (7.8) than was observed during the spring (6.5) or fall (6.6).

[1] Water quality readings were available at only sample unit LBYP-011 during the spring event due to a malfunction with the meter handset during sampling.

Table 5–14. Sample unit habitat type and location for the spring, summer and fall Lowell bypassed reach fish community survey

Season	Sample Unit	Mesohabitat Type	Upstream		Downstream		Efish Bank
			Latitude	Longitude	Latitude	Longitude	
Spring	LBYP-011	Ledge Channels	42.65102	-71.32619	42.65094	-71.32679	West
	LBYP-013	Pooled Section	42.65087	-71.32739	42.65080	-71.32800	West
	LBYP-017	Pooled Section	42.65038	-71.32970	42.65007	-71.33015	West
Summer	LBYP-011	Ledge Channels	42.65102	-71.32619	42.65094	-71.32679	West
	LBYP-014	Pooled Section	42.65080	-71.32800	42.65070	-71.32859	West
	LBYP-018	Pooled Section	42.65007	-71.33015	42.64977	-71.33059	West
Fall	LBYP-011	Ledge Channels	42.65102	-71.32619	42.65094	-71.32679	West
	LBYP-013	Pooled Section	42.65087	-71.32739	42.65080	-71.32800	West
	LBYP-016	Pooled Section	42.65058	-71.32918	42.65038	-71.32970	West

Table 5–15. Back pack electrofish effort for the spring, summer and fall Lowell bypassed reach fish community survey

Season	Sample Unit	Sample			Settings (V/Hz)	No. Netters	No. Runs
		Date	Time	Duration (Sec)			
Spring	LBYP-011	6/28/2019	11:11	1270	550/100	4	1
	LBYP-013	6/28/2019	9:50	978	550/100	4	1
	LBYP-017	6/28/2019	12:47	1068	550/100	4	1
Summer	LBYP-011	8/27/2019	9:55	1048	550/100	4	1
	LBYP-014	8/27/2019	11:23	887	550/100	4	1
	LBYP-018	8/27/2019	13:25	917	550/100	4	1
Fall	LBYP-011	10/21/2019	12:02	1089	550/100	4	1
	LBYP-013	10/21/2019	11:06	922	550/100	4	1
	LBYP-016	10/21/2019	9:54	1033	550/100	4	1

Table 5–16. Number of fish captured within the bypassed reach downstream of Pawtucket Dam by back pack electrofishing during the spring, summer and fall sampling, 2019

Common Name	Spring	Summer	Fall	2019
	N	N	N	N
American Eel	10	18	5	33
Bluegill	2	1	0	3
Brown Trout	1	0	0	1
Fallfish	22	187	1	210
Largemouth Bass	0	2	0	2
Lepomis spp.	0	0	1	1
Longnose Dace	1	0	1	2
Margined Madtom	1	2	14	17
Redbreast Sunfish	1	5	7	13
Sea Lamprey	0	0	1	1
Smallmouth Bass	2	37	68	107
Spottail Shiner	39	49	0	88
Tessellated Darter	1	5	4	10
White Sucker	0	30	3	33
Yellow Bullhead	0	4	1	5
Total	**80**	**340**	**106**	**526**

Table 5–17. Percent composition of fish captured within the bypassed reach downstream of Pawtucket Dam by back pack electrofishing during the spring, summer and fall sampling, 2019

Common Name	Spring	Summer	Fall	2019
	Pct.	Pct.	Pct.	Pct.
American Eel	12.5	5.3	4.7	6.3
Bluegill	2.5	0.3	0.0	0.6
Brown Trout	1.3	0.0	0.0	0.2
Fallfish	27.5	55.0	0.9	39.9
Largemouth Bass	0.0	0.6	0.0	0.4
Lepomis spp.	0.0	0.0	0.9	0.2
Longnose Dace	1.3	0.0	0.9	0.4
Margined Madtom	1.3	0.6	13.2	3.2
Redbreast Sunfish	1.3	1.5	6.6	2.5
Sea Lamprey	0.0	0.0	0.9	0.2
Smallmouth Bass	2.5	10.9	64.2	20.3
Spottail Shiner	48.8	14.4	0.0	16.7
Tessellated Darter	1.3	1.5	3.8	1.9
White Sucker	0.0	8.8	2.8	6.3
Yellow Bullhead	0.0	1.2	0.9	1.0

Table 5–18. Number and percent composition of fish captured within the bypassed reach downstream of Pawtucket Dam by back pack electrofishing within pooled and ledge channel habitat areas, 2019

Common Name	Pooled Section		Ledge Channels	
	N	Pct.	N	Pct.
American Eel	20	4.6	13	13.8
Bluegill	3	0.7	0	0.0
Brown Trout	0	0.0	1	1.1
Fallfish	203	47.0	7	7.4
Largemouth Bass	2	0.5	0	0.0
Lepomis spp.	1	0.2	0	0.0
Longnose Dace	0	0.0	2	2.1
Margined Madtom	16	3.7	1	1.1
Redbreast Sunfish	4	0.9	9	9.6
Sea Lamprey	1	0.2	0	0.0
Smallmouth Bass	50	11.6	57	60.6
Spottail Shiner	88	20.4	0	0.0
Tessellated Darter	9	2.1	1	1.1
White Sucker	30	6.9	3	3.2
Yellow Bullhead	5	1.2	0	0.0

Table 5–19. Catch per unit of effort for fish captured within the bypassed reach downstream of Pawtucket Dam by back pack electrofishing during spring, summer, and fall, 2019

Common Name	Backpack E-Fish							
	Spring		Summer		Fall		Total	
	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m
American Eel	12.40	7.83	12.00	8.00	1.81	0.83	8.74	5.56
Bluegill	0.76	0.33	0.28	0.17	0.00	0.00	0.35	0.17
Brown Trout	1.48	1.00	0.00	0.00	0.00	0.00	0.49	0.33
Fallfish	20.65	11.17	48.72	31.17	0.36	0.17	23.24	14.17
Largemouth Bass	0.00	0.00	0.56	0.33	0.00	0.00	0.19	0.11
Lepomis spp.	0.00	0.00	0.00	0.00	0.84	0.33	0.28	0.11
Longnose Dace	1.48	1.00	0.00	0.00	1.48	1.00	0.98	0.67
Margined Madtom	1.48	1.00	0.52	0.33	6.03	2.67	2.68	1.33
Redbreast Sunfish	1.48	1.00	2.55	1.67	10.33	7.00	4.79	3.22
Sea Lamprey	0.00	0.00	0.00	0.00	0.84	0.33	0.28	0.11
Smallmouth Bass	2.95	2.00	40.15	27.00	63.33	38.17	35.48	22.39
Spottail Shiner	32.83	13.00	12.78	8.17	0.00	0.00	15.20	7.06
Tessellated Darter	0.38	0.17	2.52	1.67	1.93	0.83	1.61	0.89
White Sucker	0.00	0.00	7.83	5.00	4.43	3.00	4.09	2.67
Yellow Bullhead	0.00	0.00	1.11	0.67	0.36	0.17	0.49	0.28

Table 5–20. Minimum, mean, and maximum total length (mm) and weight (g) for fish captured within the bypassed reach downstream of Pawtucket Dam by back pack electrofish sampling during spring, summer, and fall, 2019

Common Name	No. Individuals	Total Length (mm)			Total Weight (g)		
		Min.	Mean	Max.	Min.	Mean	Max.
American Eel	33	100	285	550	2	78	325
Bluegill	3	35	107	175	1	50	120
Brown Trout	1	225	225	225	110	110	110
Fallfish	210	22	46	86	1	10	415
Largemouth Bass	2	69	72	75	5	6	7
Lepomis spp.	1	31	31	31	1	1	1
Longnose Dace	2	80	90	99	6	8	10
Margined Madtom	17	50	85	133	1	7	21
Redbreast Sunfish	13	37	165	395	1	53	180
Sea Lamprey	1	160	160	160	7	7	7
Smallmouth Bass	107	79	118	215	6	24	110
Spottail Shiner	88	40	75	97	1	8	180
Tessellated Darter	10	56	66	86	1	3	6
White Sucker	33	55	87	279	2	14	240
Yellow Bullhead	5	59	70	87	4	6	9

Table 5–21. Physical habitat measurements recorded for sample units within the bypassed reach downstream of Pawtucket Dam during spring, summer, and fall, 2019

Season	Habitat Type	Sample Unit	Habitat Parameter			
			Dominant Substrate	Pct. SAV	Pct. Cover	Mean Depth (ft)
Spring	Ledge Channels	LBYP-011	Boulder/Rip-Rap	0-25%	0-25%	1.5
	Pooled Section	LBYP-013	Cobble-Gravel	0-25%	0-25%	1.8
	Pooled Section	LBYP-017	Sand-Silt-Clay	0-25%	0-25%	1.7
Summer	Ledge Channels	LBYP-011	Boulder/Rip-Rap	0-25%	0-25%	1.5
	Pooled Section	LBYP-014	Cobble-Gravel	0-25%	0-25%	1.8
	Pooled Section	LBYP-018	Sand-Silt-Clay	0-25%	0-25%	2.4
Fall	Ledge Channels	LBYP-011	Boulder/Rip-Rap	0-25%	0-25%	1.5
	Pooled Section	LBYP-013	Cobble-Gravel	0-25%	0-25%	1.8
	Pooled Section	LBYP-016	Sand-Silt-Clay	0-25%	0-25%	1.6

Table 5–22. Water quality parameters recorded within the bypassed reach downstream of Pawtucket Dam during spring, summer, and fall, 2019

Season	Habitat Type	Sample Unit	Water Quality Parameter			
			Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µs/cm)	pH
Spring	Ledge Channels	LBYP-011	22.9	9.5	148	6.5
	Pooled Section	LBYP-013	*	*	*	*
	Pooled Section	LBYP-017	*	*	*	*
Summer	Ledge Channels	LBYP-011	23.4	9.6	191	7.4
	Pooled Section	LBYP-014	23.9	9.1	195	7.8
	Pooled Section	LBYP-018	24.1	9.4	197	8.1
Fall	Ledge Channels	LBYP-011	13.2	9.8	104	6.3
	Pooled Section	LBYP-013	13.1	8.9	102	6.6
	Pooled Section	LBYP-016	13.0	10.6	95	6.8

* Water quality readings were available at only sample unit LBYP-011 during the spring event due to a malfunction with the meter handset during sampling

5.3 Historic Data

As described in the Lowell relicensing Pre-Application Document (PAD), the Merrimack River is home to a diverse assemblage of fishes, including cold water and warm water species. Stolte (1982; as cited in the Technical Committee for Anadromous Fishery Management of the Merrimack River Basin [Technical Committee] 1997) noted that during the last 150 years, over 15 non-indigenous species such as largemouth bass, smallmouth bass, walleye, common carp, rainbow trout, brown trout, various catfish species and goldfish have established through human introductions within the Merrimack River. At that time, the Merrimack River was identified as home to approximately 50 species of fish, nine of which were anadromous. The slower moving, ponded reaches of the Merrimack contain a higher predominance of warm water species whereas those areas with higher gradient contain the majority of cold water species. Hartel et al. (2002) identified a total of 57 reproducing fish species within the drainage; 21 primary species (i.e., those living full life cycle in freshwater), 8 secondary species (i.e., those with physiological capacity to move between fresh and salt water), 18 introduced species, and 10 diadromous species.

Fish assemblage sampling within the Lowell impoundment and bypassed reach during the spring, summer and fall of 2019 resulted in the identification of 24 fish species (Table 5-23). Of those species, 21 are considered freshwater and 3 are considered as diadromous. Based on information presented in Hartel et al. (2002) species observed during the 2019 fish sampling considered to be native to the Merrimack River watershed in Massachusetts represented 53% of the total catch across all seasons (12 species, 1,249 individuals). Conversely, species classified by Hartel et al. (2002) as introduced to the Merrimack River watershed represented 47% of the total catch across all seasons (12 species, 1,119 individuals).

Table 5–23. Classifications for fish species recorded within the Lowell impoundment and bypassed reach downstream of Pawtucket Dam during spring, summer, and fall, 2019

Common Name	Freshwater Resident	Diadromous	Native	Introduced
Alewife		X	X	
American Eel		X	X	
Black Crappie	X			X
Bluegill	X			X
Brown Trout	X			X
Channel Catfish	X			X
Common Carp	X			X
Fallfish	X		X	
Golden Shiner	X		X	
Largemouth Bass	X			X
Longnose Dace	X		X	
Margined Madtom	X			X
Pumpkinseed	X		X	
Redbreast Sunfish	X		X	
Rock Bass	X			X
Sea Lamprey		X	X	
Smallmouth Bass	X			X
Spottail Shiner	X			X
Tessellated Darter	X		X	
Walleye	X			X
White Perch	X		X	
White Sucker	X		X	
Yellow Bullhead	X			X
Yellow Perch	X		X	

6 Summary

The Lowell RSP identified two specific objectives for the fish assemblage study including (1) sampling to describe the fish assemblage structure, distribution, and abundance within the Project affected area along spatial and temporal gradients, and (2) a comparison of historical records of species occurrence with observations from this study.

Fish community sampling was conducted over spatial (impoundment versus bypassed reach) and temporal (spring, summer, and fall) gradients during 2019. Within the Lowell impoundment, fish were collected from standardized 500-m transects using a stratified random sampling design where mesohabitat type (i.e., impoundment, run, pool) was used to stratify. Once sites were identified, impoundment sampling was conducted via nighttime boat electrofishing, experimental gill netting, and minnow traps. Fish community data were collected from a total of 36, 500-m sample units during the spring, summer, and fall of 2019 (12 sites per season). A total of 1,847 individuals representing twenty-two fish species were collected from the Lowell impoundment during 2019 when all sampling seasons and sample units are considered. Spottail shiner (23.0%), redbreast sunfish (20.5%) and smallmouth bass (12.3%) were the three most numerically abundant species within the Lowell impoundment during the 2019 sampling. Centrarchid species were the most abundant within impoundment habitat with redbreast sunfish (24.2%), pumpkinseed (14.2%), and smallmouth bass (12.5%) representing the three most abundantly sampled species. Spottail shiner were the most abundantly sampled fish species in the pool (28.4%) and run (46.3%) habitat areas. The majority of catch in the impoundment was observed during boat electrofishing efforts.

Within the Lowell bypassed reach, fish were collected from standardized 50-m transects using a stratified random sampling design where habitat type was used to stratify. Site conditions were considered inappropriate or unsafe for sampling in two portions of the bypassed reach (i.e., the upper chute reach and downstream of the spill gate) and as a result back pack electrofish sampling in the bypassed reach occurred within the two middle reaches (i.e., the pooled section immediately downstream of the School Street Bridge and ledge channel area in the vicinity of the University Ave Bridge). A total of 526 individuals representing fourteen fish species were collected during back pack electrofishing efforts within the Lowell bypassed reach during 2019 when all sampling seasons and sample units are considered. Fallfish (39.9%), smallmouth bass (20.3%) and spottail shiner (16.7%) were the three most numerically abundant species within the Lowell bypassed reach during the 2019 sampling. Fallfish were the most abundant fish species collected within the pooled habitat within the Lowell bypassed reach and downstream of Pawtucket Dam, representing 47% of the total catch. Fish catch from the ledge channel habitat located in the lower portion of the bypassed reach was dominated by smallmouth bass which represented 60.6% of the total catch from that area.

Fish assemblage sampling within the Lowell impoundment and bypassed reach during the spring, summer and fall of 2019 resulted in the identification of 24 fish species. Approximately 53% of individuals collected during the 2019 sampling were classified as fish species native to the Merrimack River watershed in Massachusetts (12 species, 1,249 individuals). Conversely, 47% of the total catch across all seasons were classified as introduced to the Merrimack River watershed (12 species, 1,119 individuals).

7 Variances from FERC-Approved Study Plan

There was no variance from the methodologies and schedule as described in the FERC-approved study plan.

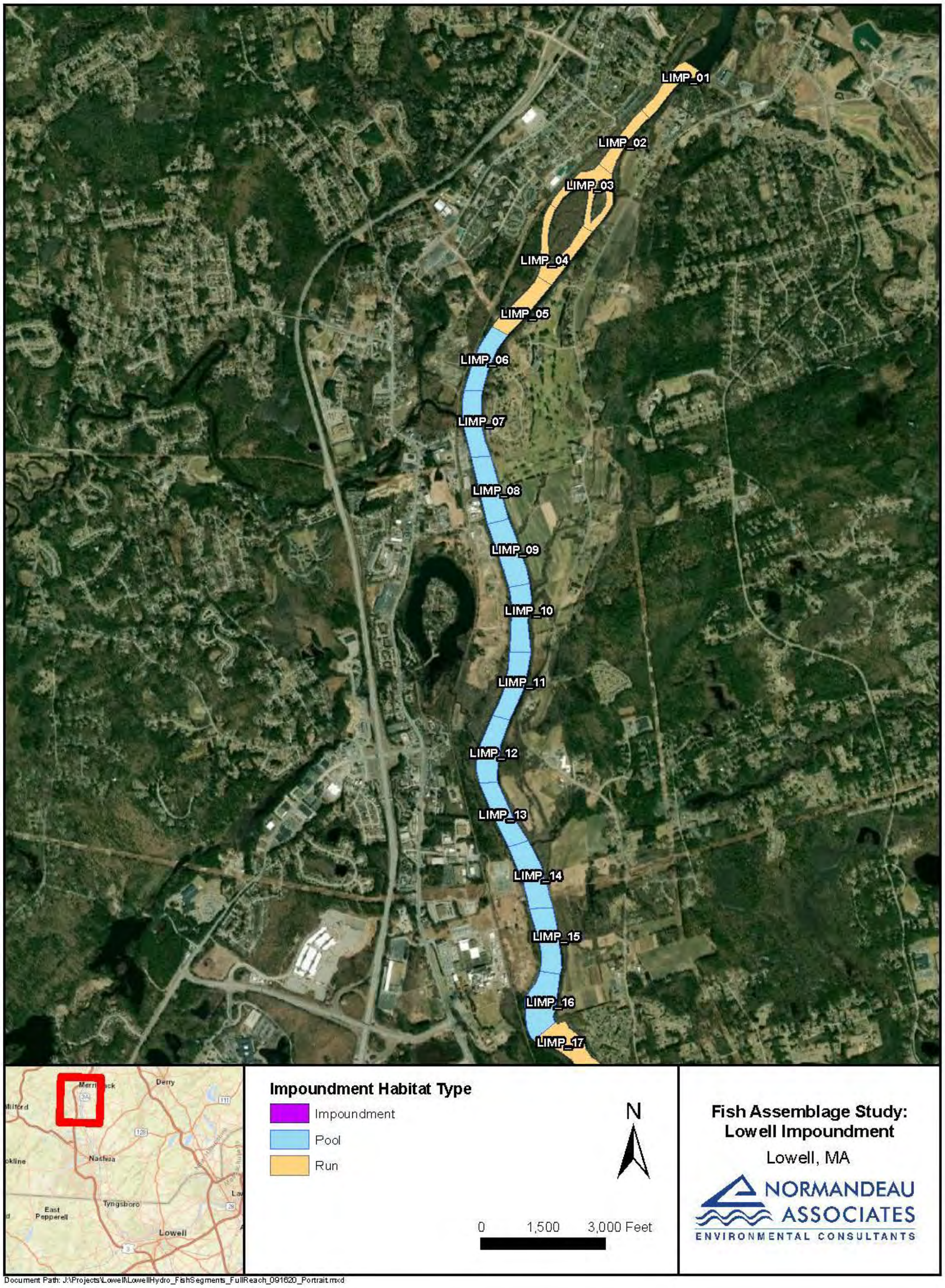
8 References

Hartel, K.E., D.B. Halliwell, and A.E. Launer. 2002. Inland Fishes of Massachusetts. Massachusetts Audubon Society.

Technical Committee for Anadromous Fishery Management of the Merrimack River Basin (Technical Committee). 1997. Strategic Plan and Status Review Anadromous Fish Restoration Program Merrimack River. Technical Committee for Anadromous Fishery Management of the Merrimack River Basin and Advisors to the Technical Committee.

9 Appendices

Appendix A. Spatial distribution of 500-m mesohabitat units for the 23.0 mile reach upstream of Pawtucket Dam.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LIMP_07
LIMP_08
LIMP_09
LIMP_10
LIMP_11
LIMP_12
LIMP_13
LIMP_14
LIMP_15
LIMP_16
LIMP_17
Impoundment Habitat Type
Impoundment
Pool
Run
N
0 1,500 3,000 Feet
Fish Assemblage Study: Lowell Impoundment
Lowell, MA
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
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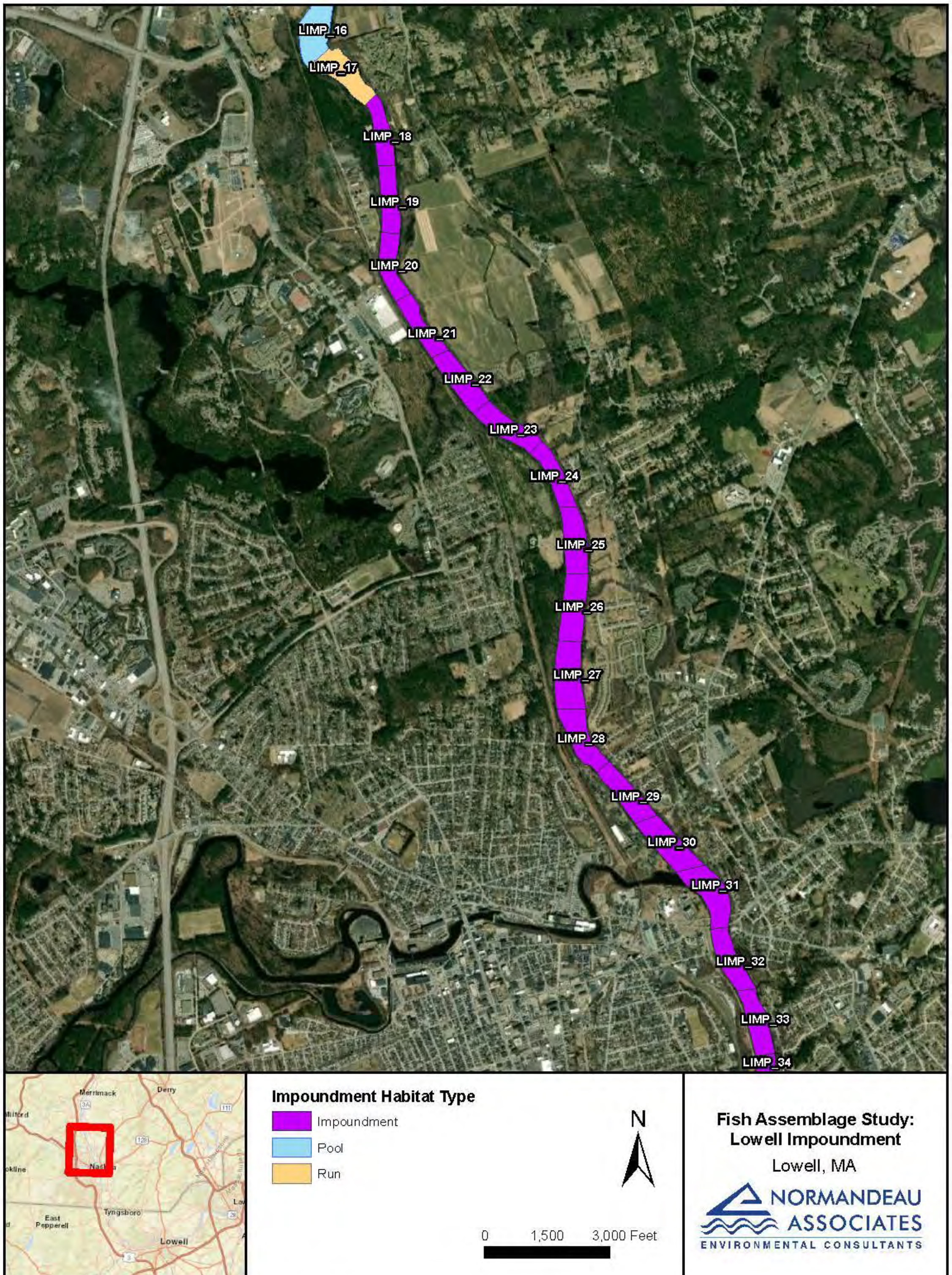

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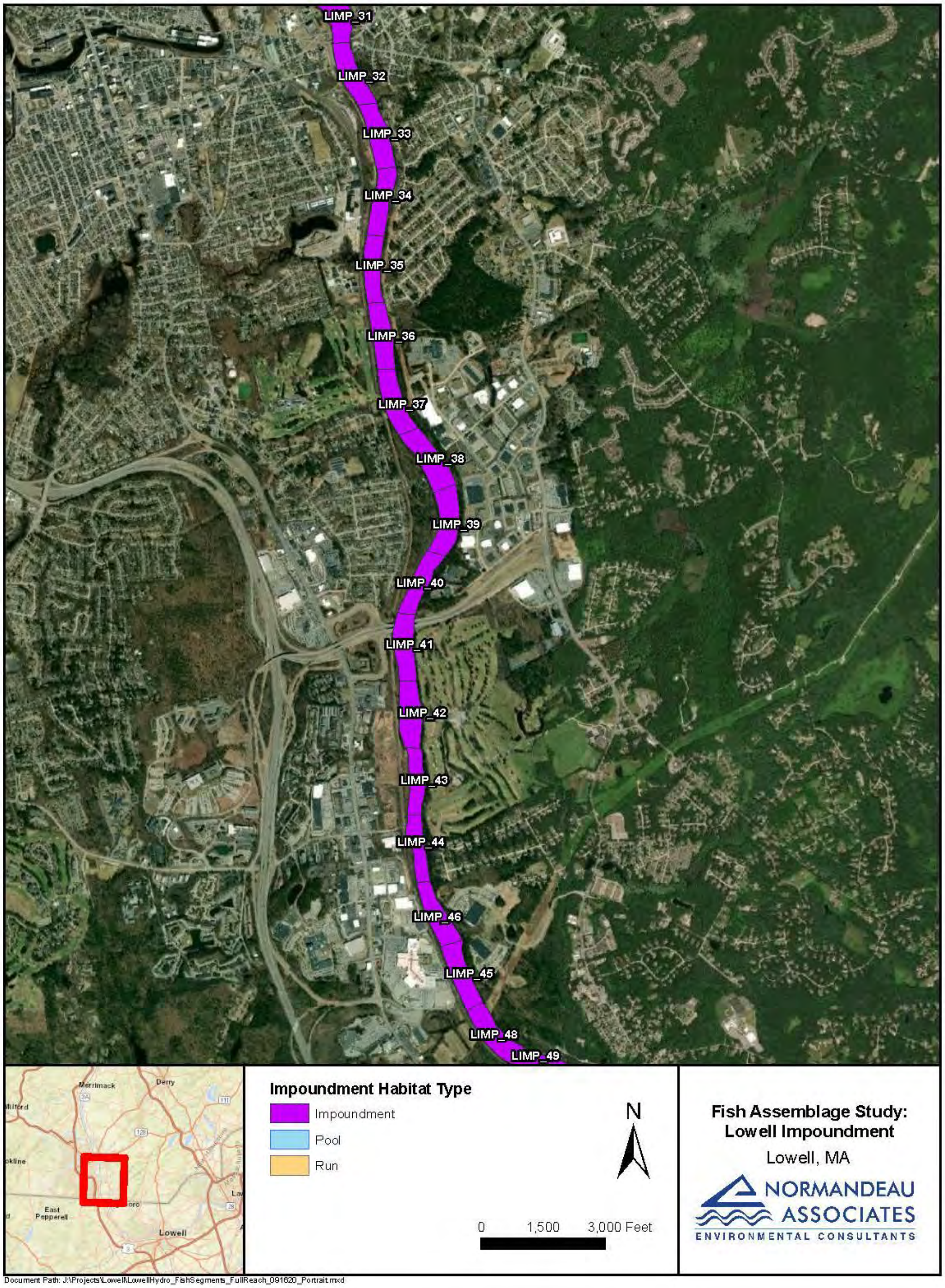
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LIMP_38
LIMP_39
LIMP_40
LIMP_41
LIMP_42
LIMP_43
LIMP_44
LIMP_46
LIMP_45
LIMP_48
LIMP_49
Impoundment Habitat Type
Impoundment
Pool
Run
N
0 1,500 3,000 Feet
Fish Assemblage Study: Lowell Impoundment
Lowell, MA
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
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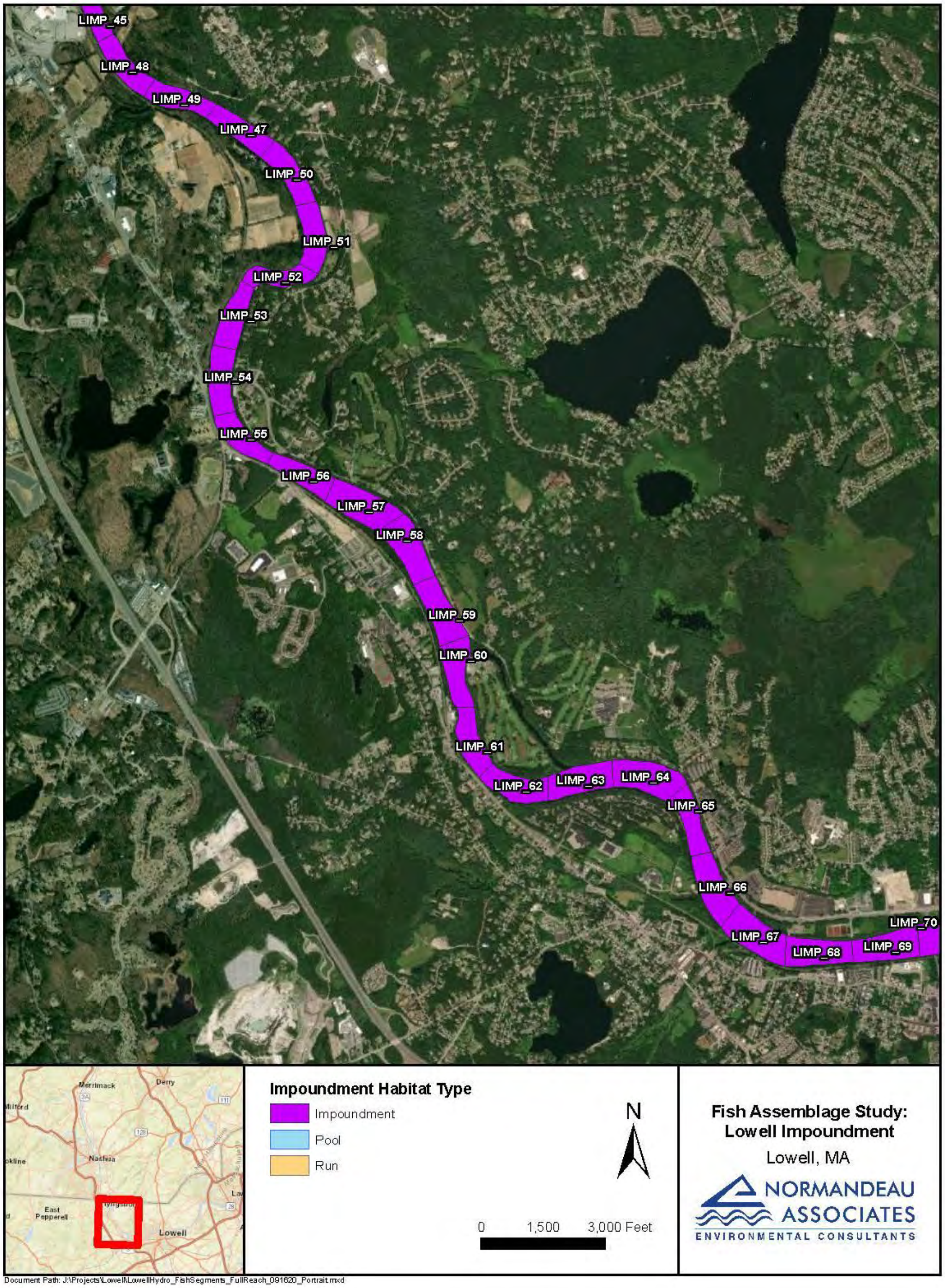
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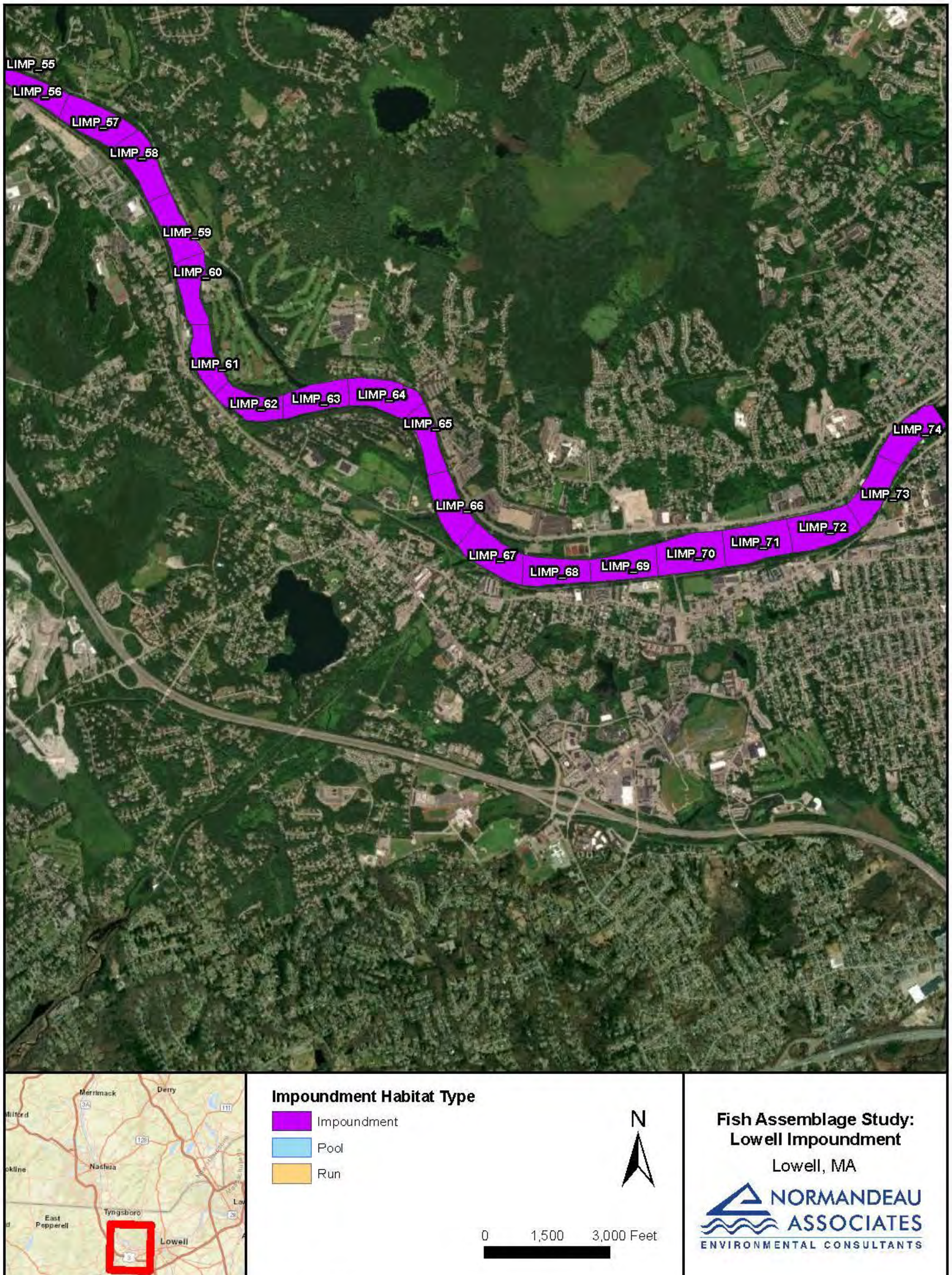
LIMP_56
LIMP_57
LIMP_58
LIMP_59
LIMP_60
LIMP_61
LIMP_62
LIMP_63
LIMP_64
LIMP_65
LIMP_66
LIMP_67
LIMP_68
LIMP_69
LIMP_70
Merrimack
Derry
Nashua
East Pepperell
Lowell
Impoundment Habitat Type
Impoundment
Pool
Run
N
0 1,500 3,000 Feet
Fish Assemblage Study: Lowell Impoundment
Lowell, MA
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Document Path: J:\Projects\Lowell\LowellHydro_FishSegments_FullReach_091620_Portrait.mxd



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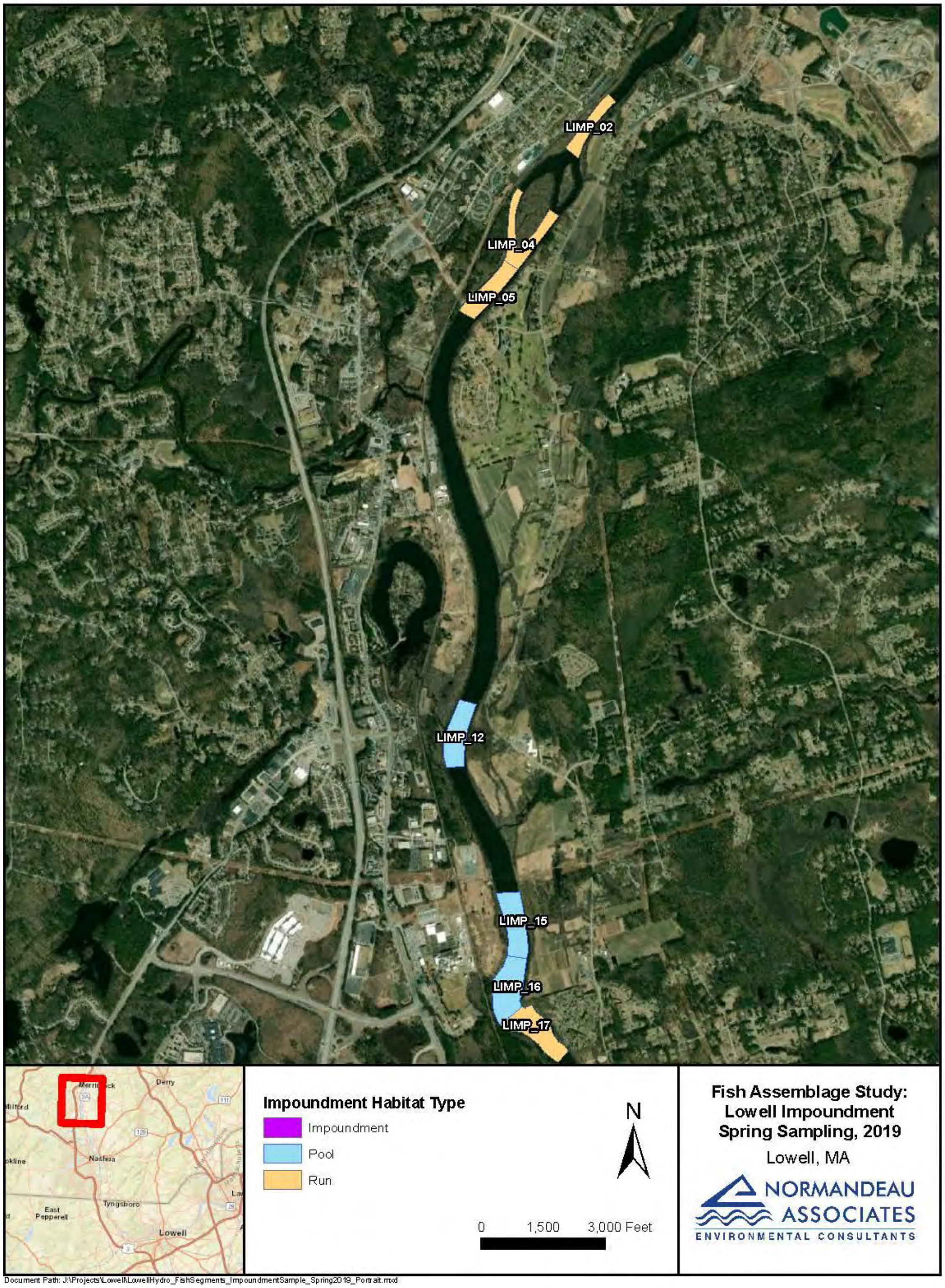
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LIMP_04
LIMP_05
LIMP_12
LIMP_15
LIMP_16
LIMP_17
Derry
Nashua
Tyngsboro
East Pepperell
Lowell
Impoundment Habitat Type
Impoundment
Pool
Run
N
0 1,500 3,000 Feet
Fish Assemblage Study:
Lowell Impoundment
Spring Sampling, 2019
Lowell, MA
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
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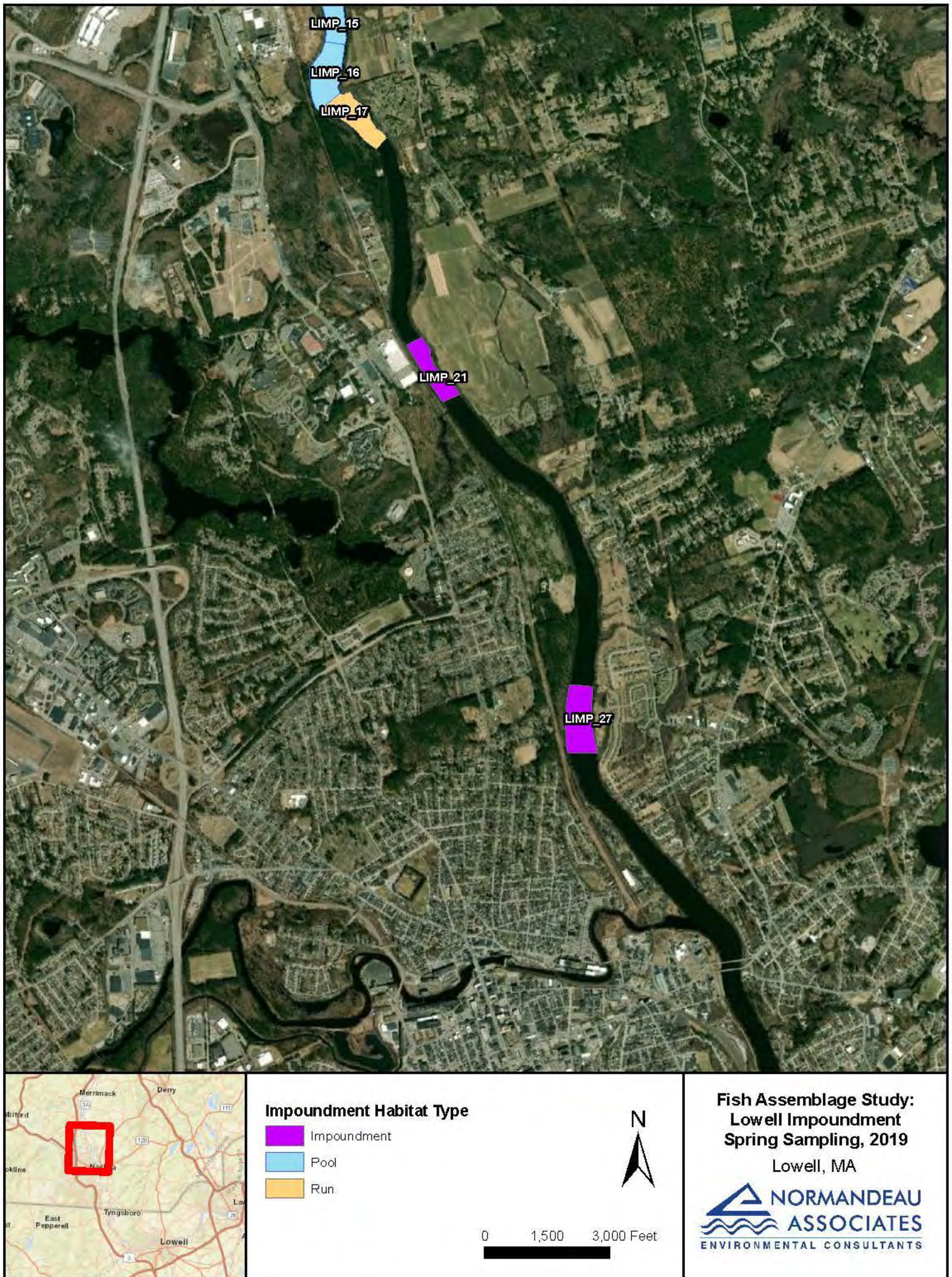

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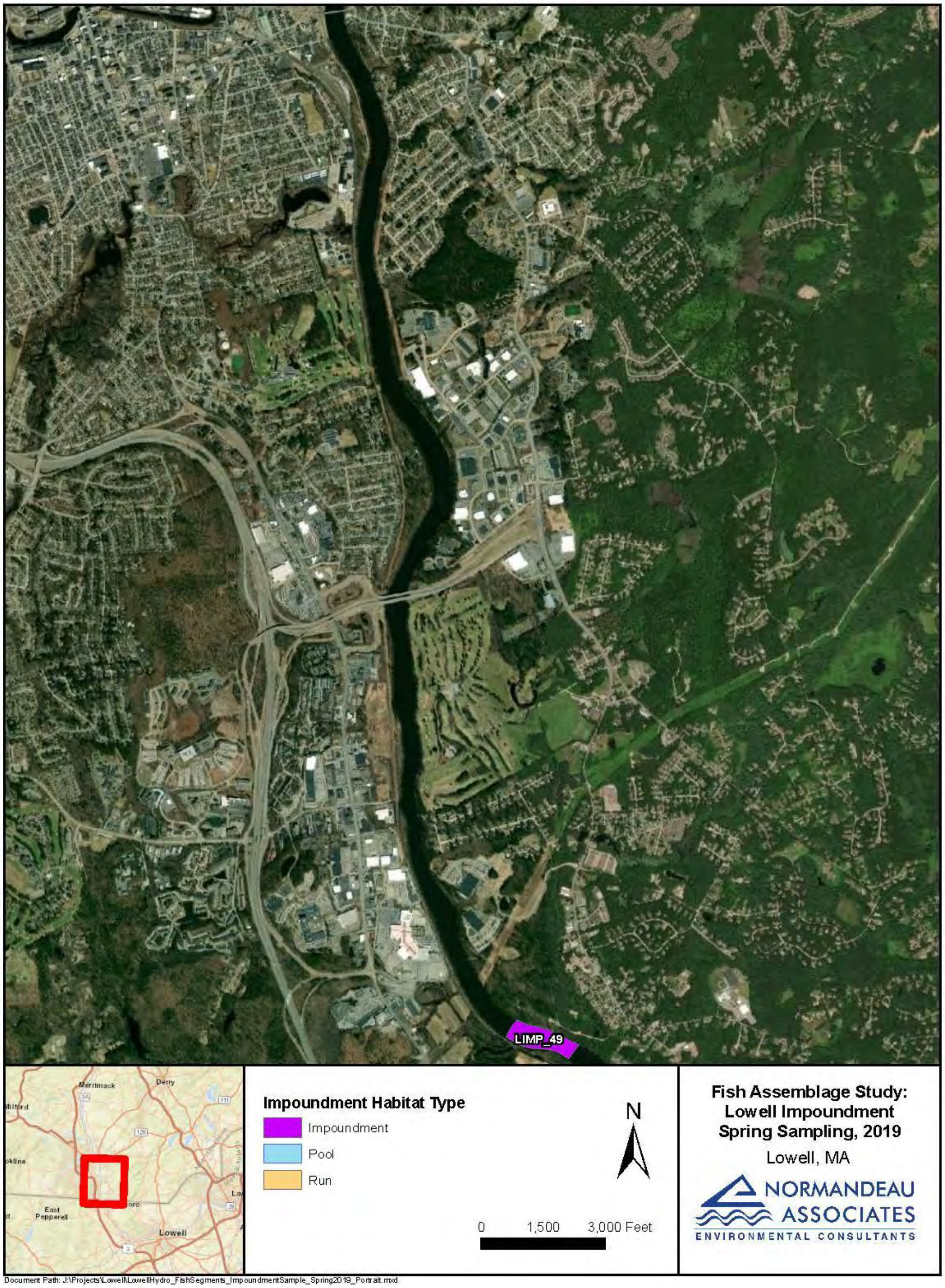
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Merrimack
Derry
East Pepperell
Lowell
Impoundment Habitat Type
Impoundment
Pool
Run
N
0 1,500 3,000 Feet
Fish Assemblage Study:
Lowell Impoundment
Spring Sampling, 2019
Lowell, MA
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
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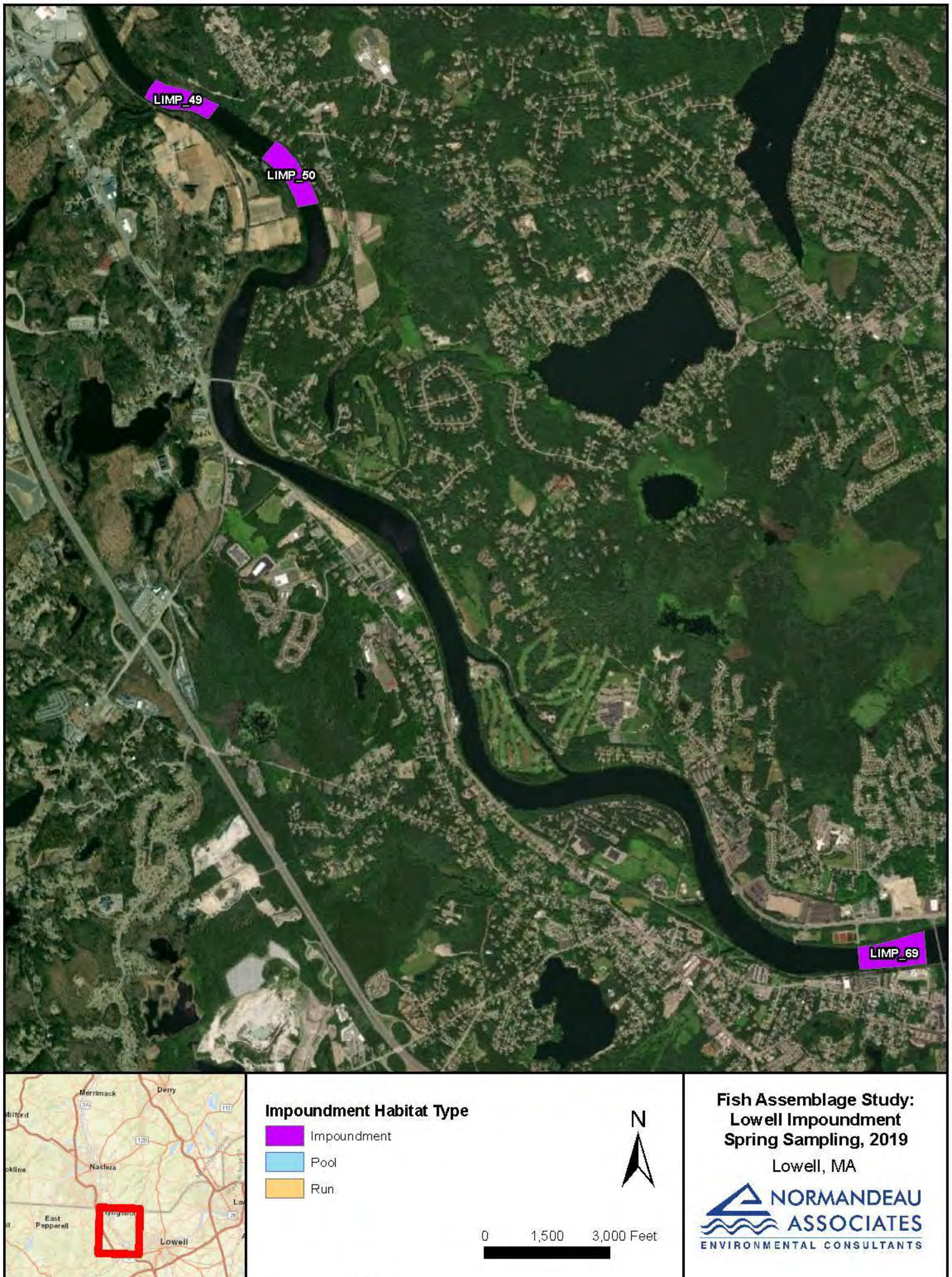

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LIMP_69
Merrimack
Derry
Nashua
Tyngsboro
East Pepperell
Lowell
Impoundment Habitat Type
Impoundment
Pool
Run
N
0 1,500 3,000 Feet
Fish Assemblage Study: Lowell Impoundment Spring Sampling, 2019
Lowell, MA
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
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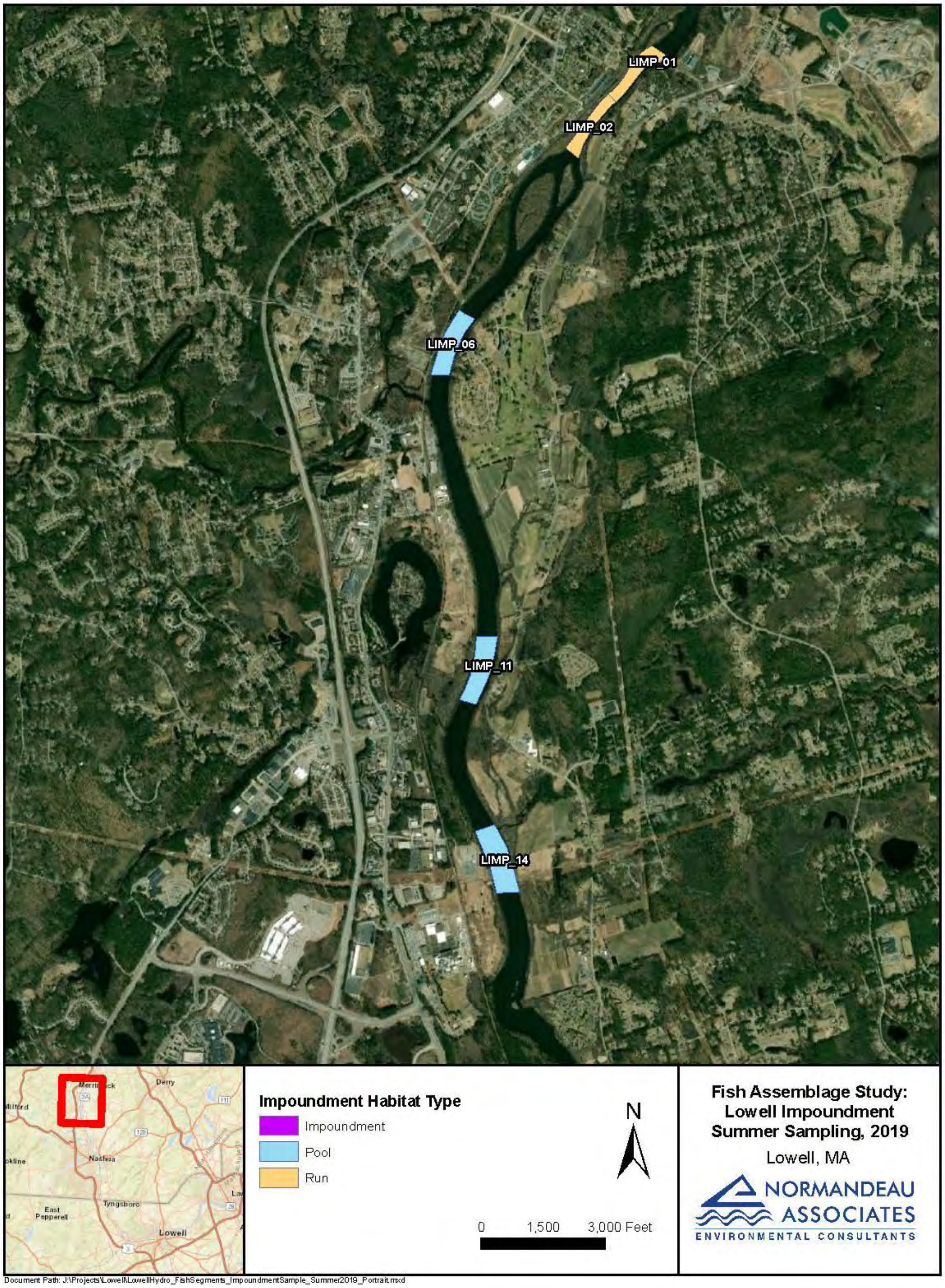
LIMP_01
LIMP_02
LIMP_06
LIMP_11
LIMP_14
Impoundment Habitat Type
Impoundment
Pool
Run
N
0 1,500 3,000 Feet
Fish Assemblage Study: Lowell Impoundment Summer Sampling, 2019
Lowell, MA
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Derry
Nashua
Tyngsboro
East Pepperell
Lowell
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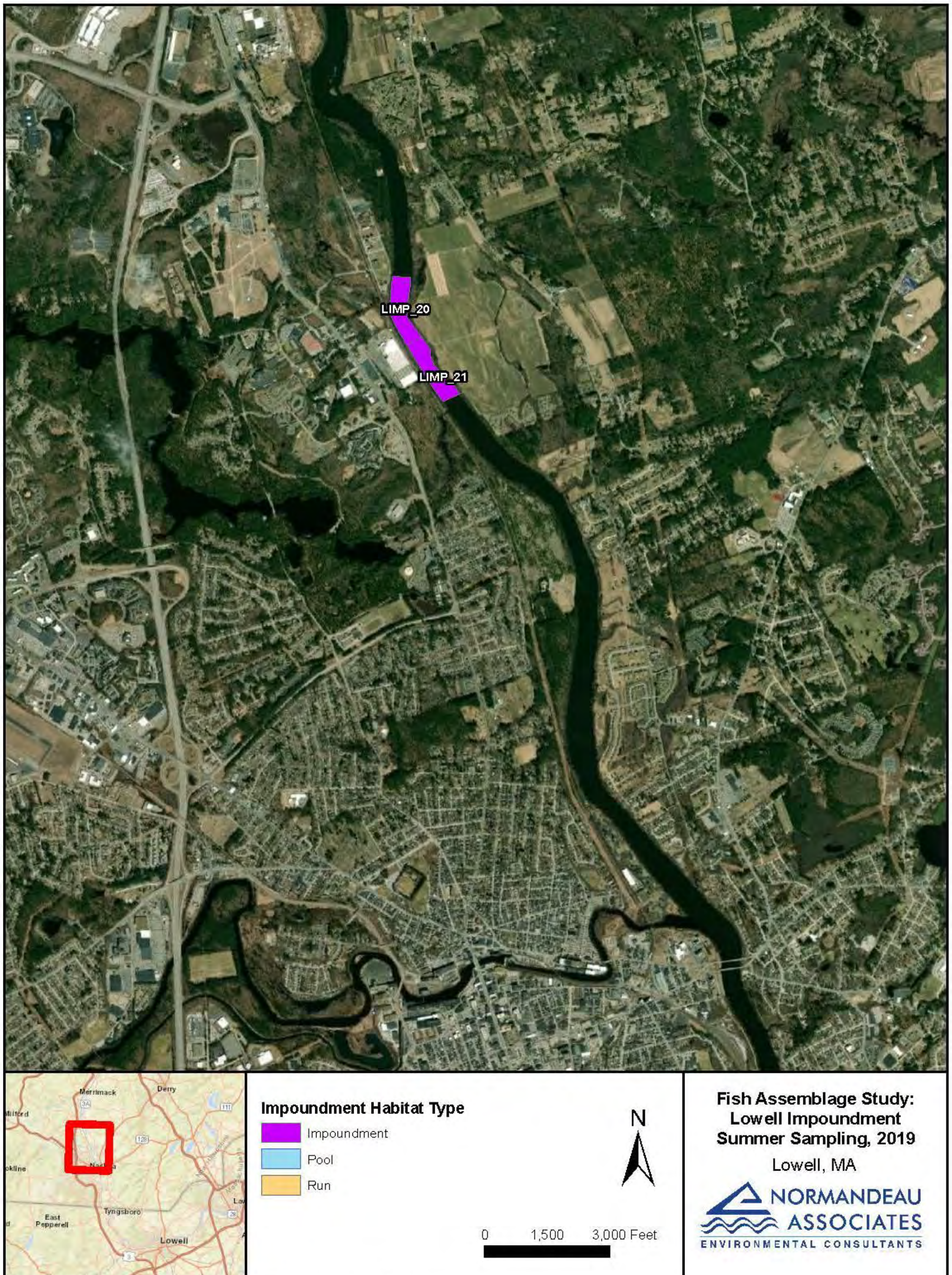

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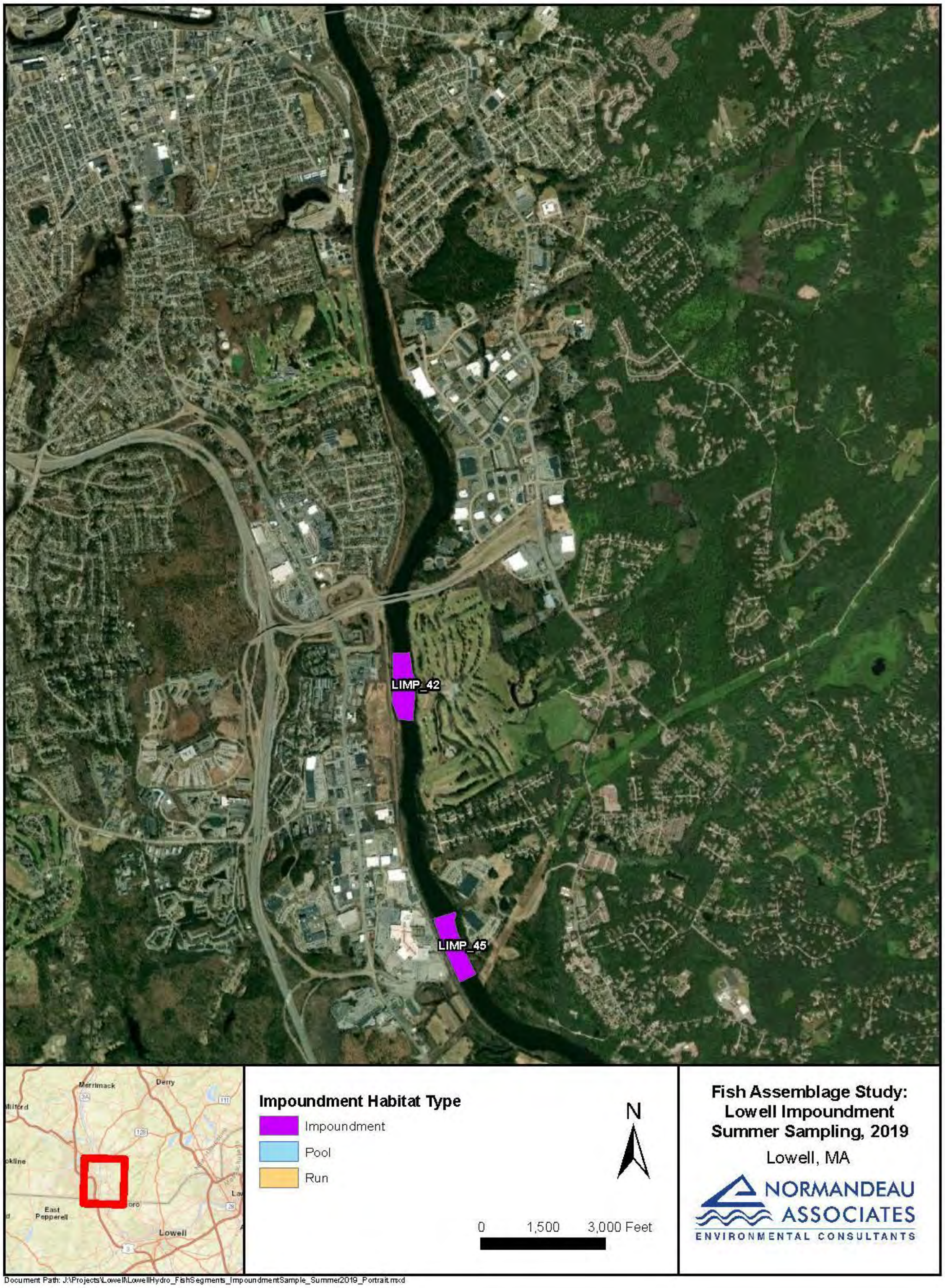
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Merrimack
Derry
Milford
Brookline
East Pepperell
Lowell
Impoundment Habitat Type
Impoundment
Pool
Run
N
0 1,500 3,000 Feet
Fish Assemblage Study: Lowell Impoundment Summer Sampling, 2019
Lowell, MA
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
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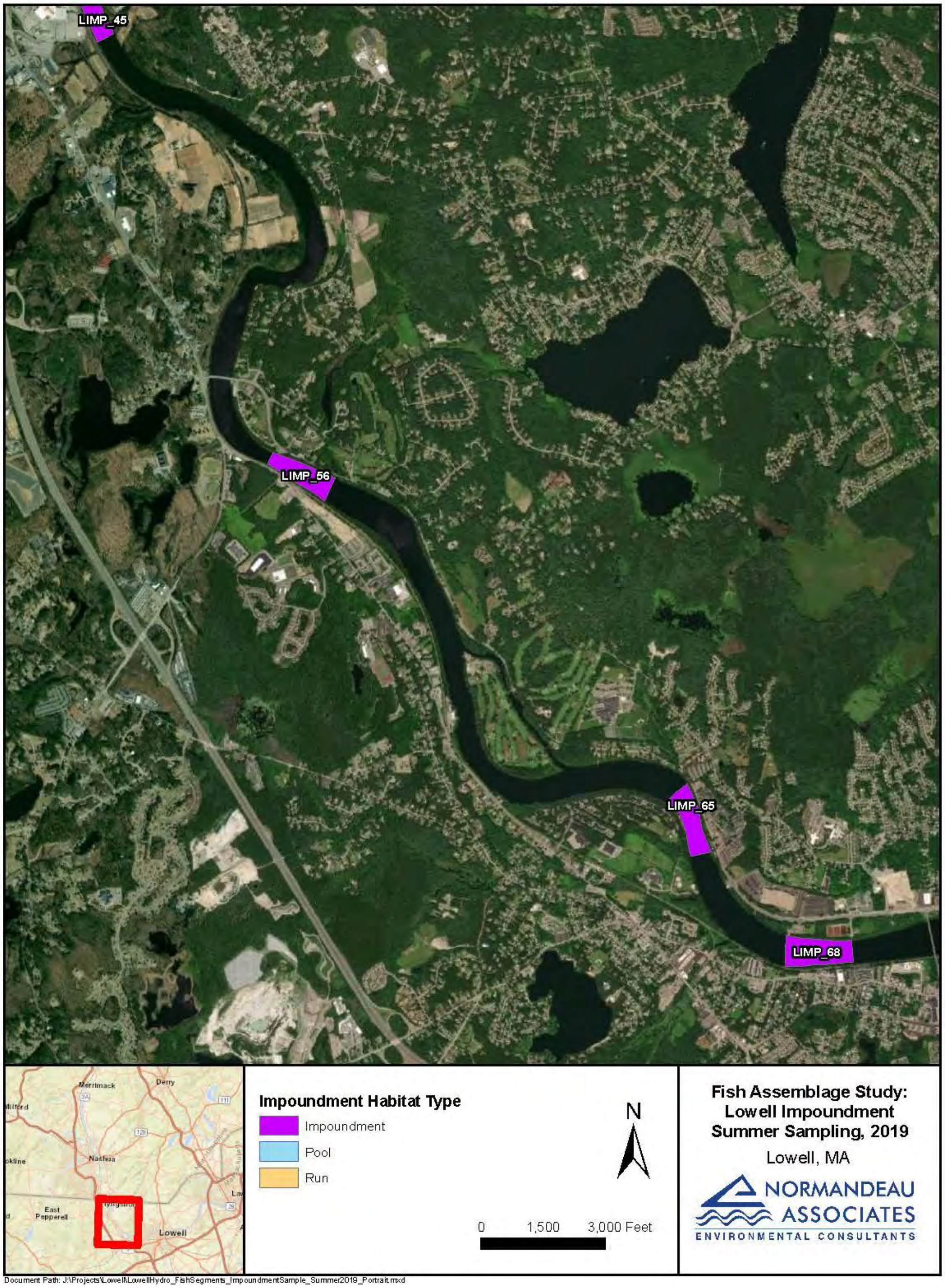
LIMP_45
LIMP_56
LIMP_65
LIMP_68
Merrimack
Derry
Nashua
East Pepperell
Lowell
Impoundment Habitat Type
Impoundment
Pool
Run
N
0 1,500 3,000 Feet
Fish Assemblage Study: Lowell Impoundment Summer Sampling, 2019
Lowell, MA
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
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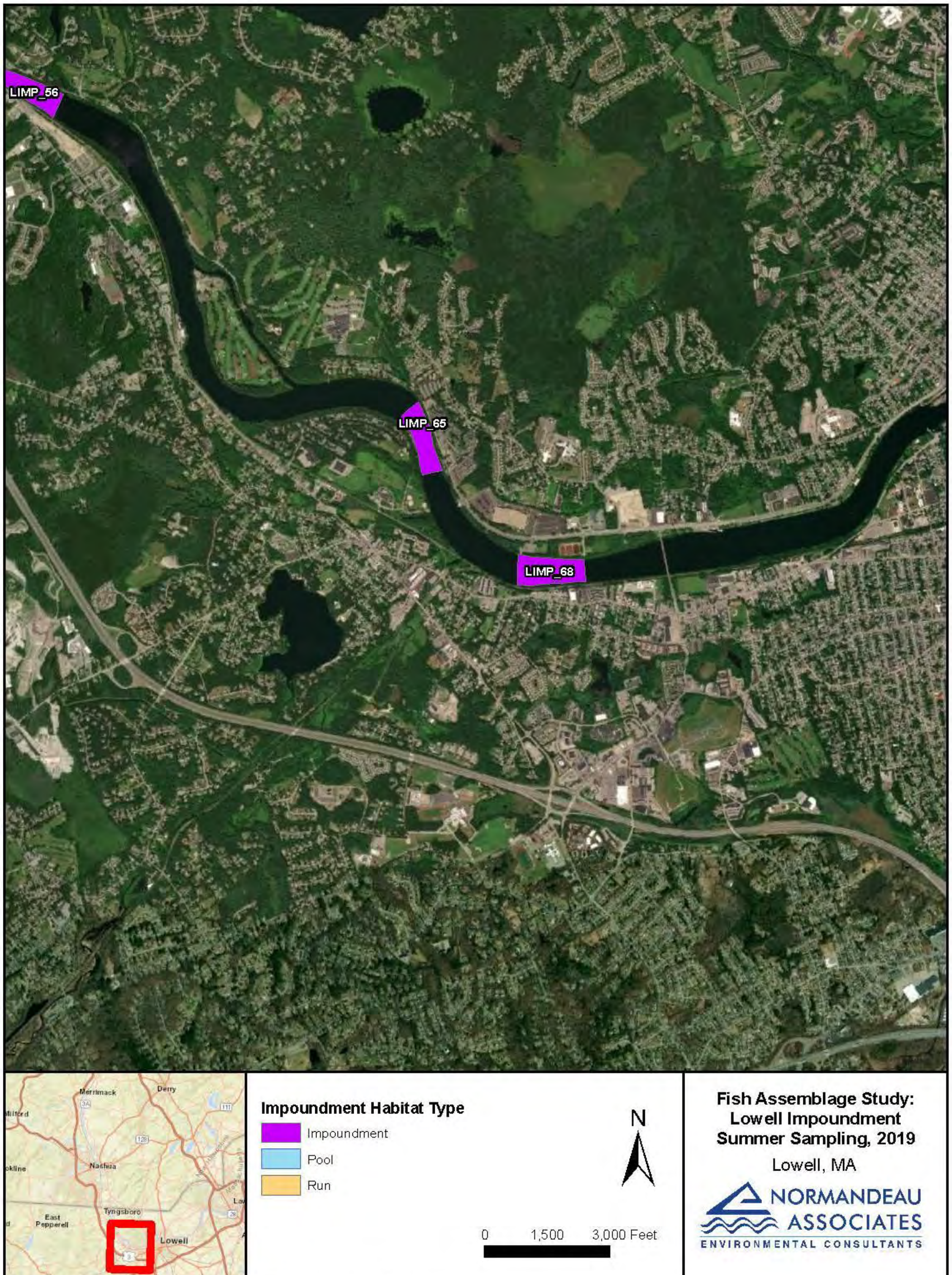

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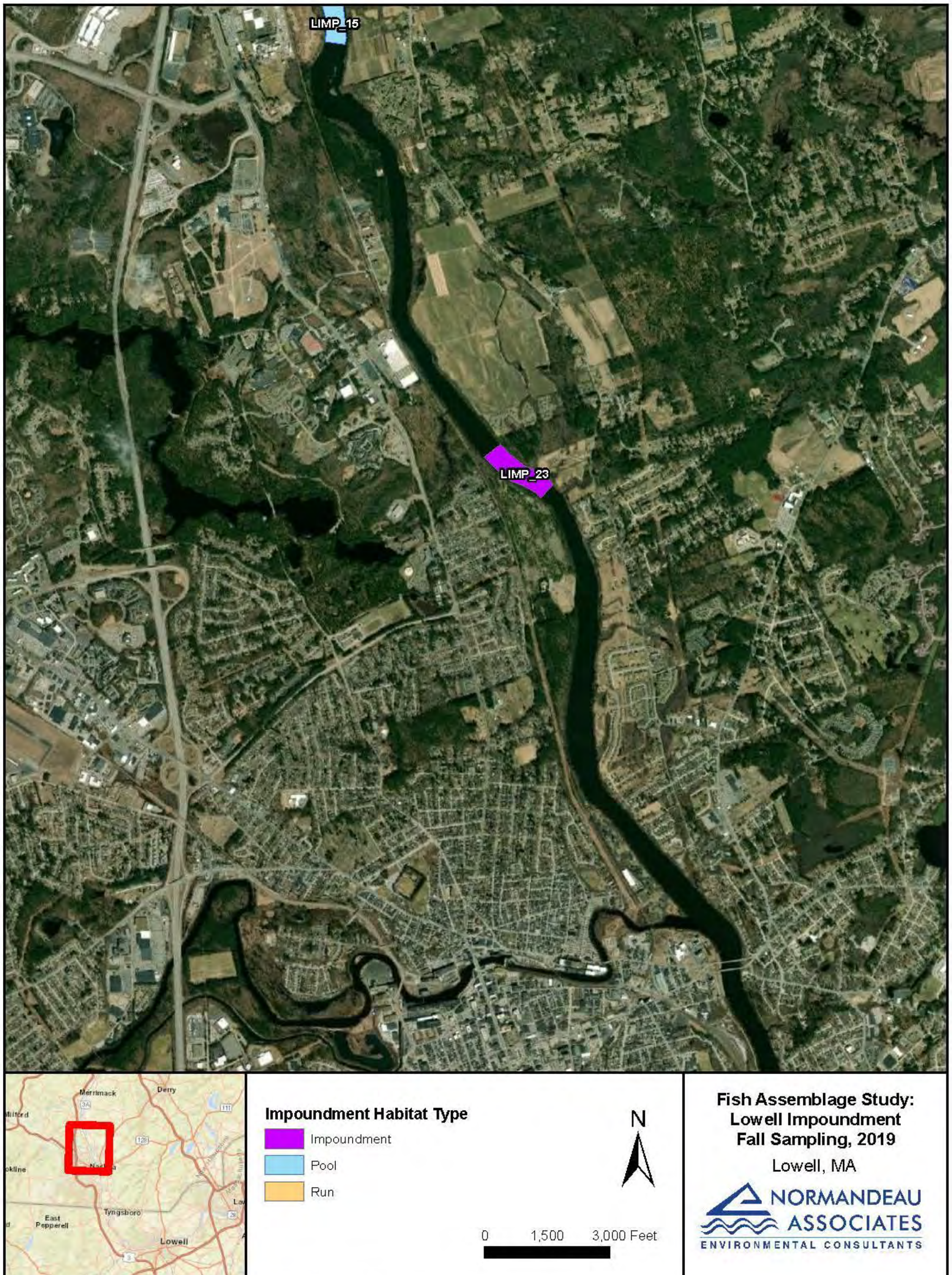

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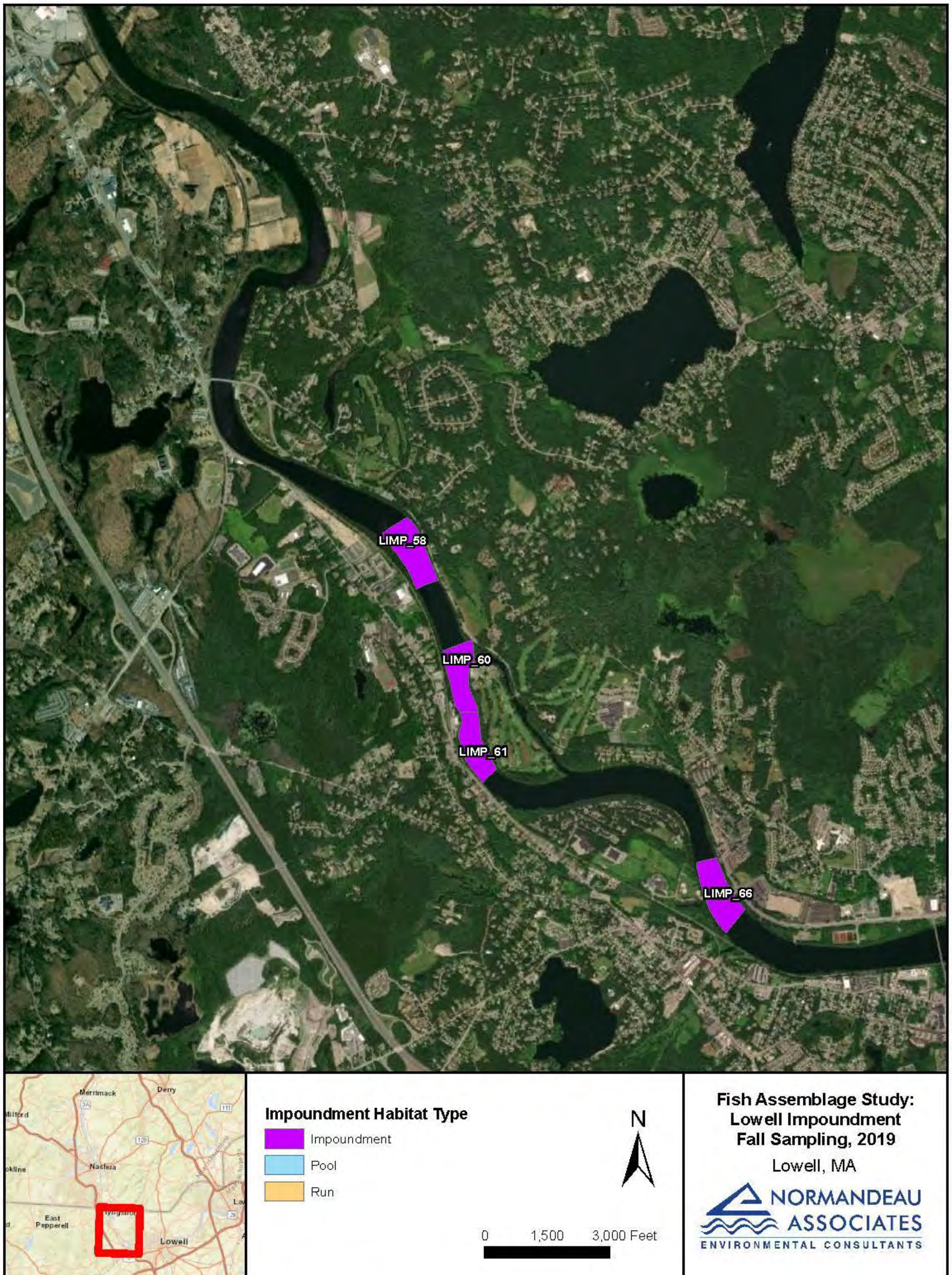

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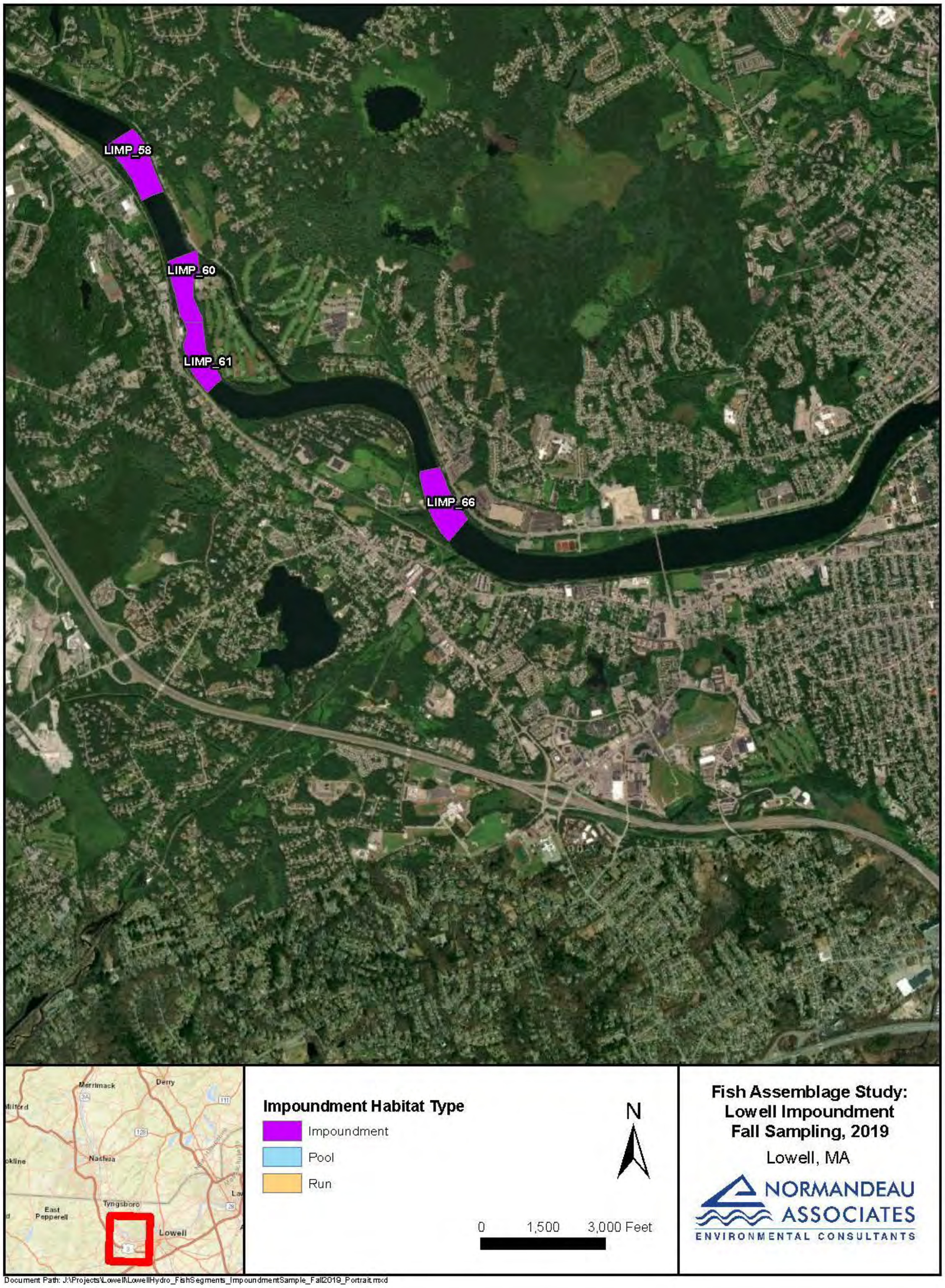

LIMP_58
LIMP_60
LIMP_61
LIMP_66
Impoundment Habitat Type
Impoundment
Pool
Run
N
0 1,500 3,000 Feet
Fish Assemblage Study:
Lowell Impoundment
Fall Sampling, 2019
Lowell, MA
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Lowell

Appendix B. Catch Per Unit of Effort (CPUE) information for boat electrofish and gill net sampling upstream of Pawtucket dam by season (spring, summer, and fall) and mesohabitat type (impoundment, pool, run).

Boat electrofish: Spring 2019

	Impoundment		Pool		Run		Total	
Common Name	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m
American Eel	1.07	0.05	0.00	0.00	0.53	0.03	0.53	0.03
Black Crappie	0.00	0.00	1.06	0.04	0.53	0.03	0.53	0.02
Bluegill	5.29	0.24	2.78	0.13	1.06	0.06	3.04	0.14
Common Carp	0.20	0.01	0.00	0.00	0.00	0.00	0.07	0.00
Fallfish	3.15	0.14	4.56	0.20	14.09	0.69	7.27	0.34
Golden Shiner	0.18	0.01	0.00	0.00	0.00	0.00	0.06	0.00
Largemouth Bass	0.00	0.00	0.51	0.02	0.53	0.03	0.34	0.02
Lepomis spp.	0.20	0.01	0.00	0.00	0.00	0.00	0.07	0.00
Margined Madtom	0.18	0.01	0.93	0.04	0.00	0.00	0.37	0.02
Pumpkinseed	1.87	0.09	0.00	0.00	0.53	0.03	0.80	0.04
Redbreast Sunfish	24.57	1.13	15.24	0.67	28.57	1.34	22.79	1.05
Rock Bass	0.47	0.02	1.06	0.04	2.05	0.09	1.19	0.05
Sea Lamprey	0.00	0.00	2.78	0.13	2.12	0.11	1.63	0.08
Smallmouth Bass	21.89	1.02	16.41	0.73	38.22	1.71	25.51	1.16
Spottail Shiner	38.11	1.64	23.84	1.04	43.91	1.97	35.29	1.55
Tessellated Darter	0.63	0.03	6.31	0.27	2.12	0.11	3.02	0.14
White Sucker	1.25	0.07	3.98	0.18	7.34	0.37	4.19	0.21
Yellow Bullhead	1.12	0.05	0.00	0.00	1.59	0.09	0.90	0.05
Yellow Perch	0.85	0.04	12.59	0.53	0.53	0.03	4.66	0.20

Boat electrofish: Summer 2019

Common Name	Impoundment		Pool		Run		Total	
	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m
Alewife	4.17	0.19	0.00	0.00	0.00	0.00	1.39	0.06
American Eel	1.30	0.06	0.48	0.02	4.72	0.20	2.17	0.09
Black Crappie	0.22	0.01	0.48	0.02	0.00	0.00	0.23	0.01
Bluegill	14.99	0.68	11.79	0.58	0.62	0.03	9.13	0.43
Common Carp	0.22	0.01	0.00	0.00	2.05	0.09	0.76	0.03
Fallfish	4.61	0.21	1.52	0.07	13.17	0.57	6.43	0.28
Golden Shiner	0.00	0.00	1.01	0.04	1.24	0.06	0.75	0.03
Largemouth Bass	4.04	0.19	6.13	0.29	2.67	0.11	4.28	0.20
Lepomis spp.	0.22	0.01	0.48	0.02	2.05	0.09	0.92	0.04
Margined Madtom	0.63	0.03	0.51	0.02	2.05	0.09	1.06	0.05
Pumpkinseed	26.72	1.21	1.45	0.07	0.62	0.03	9.60	0.44
Redbreast Sunfish	29.42	1.34	12.18	0.58	64.10	2.74	35.24	1.55
Rock Bass	0.22	0.01	0.51	0.02	0.00	0.00	0.24	0.01
Sea Lamprey	1.27	0.06	0.00	0.00	0.00	0.00	0.42	0.02
Smallmouth Bass	5.32	0.24	8.06	0.40	14.41	0.63	9.26	0.42
Spottail Shiner	0.45	0.02	18.23	0.82	59.13	2.51	25.94	1.12
Tessellated Darter	2.39	0.11	2.31	0.11	0.00	0.00	1.56	0.07
White Perch	0.23	0.01	0.00	0.00	0.00	0.00	0.08	0.00
White Sucker	0.00	0.00	1.95	0.09	1.86	0.09	1.27	0.06
Yellow Bullhead	2.92	0.13	2.46	0.11	0.62	0.03	2.00	0.09
Yellow Perch	0.00	0.00	0.00	0.00	0.62	0.03	0.21	0.01

Boat electrofish: Fall 2019

Common Name	Impoundment		Pool		Run		Total	
	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m
Alewife	13.23	0.83	3.98	0.18	13.23	0.83	10.15	0.61
American Eel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black Crappie	0.00	0.00	0.93	0.04	0.00	0.00	0.31	0.01
Bluegill	2.21	0.12	5.04	0.22	2.21	0.12	3.15	0.15
Common Carp	0.20	0.01	0.00	0.00	0.20	0.01	0.13	0.01
Fallfish	7.81	0.38	26.66	1.20	7.81	0.38	14.09	0.65
Golden Shiner	0.37	0.02	4.24	0.18	0.37	0.02	1.66	0.07
Largemouth Bass	0.62	0.03	3.05	0.13	0.62	0.03	1.43	0.06
Margined Madtom	0.19	0.01	0.00	0.00	0.19	0.01	0.12	0.01
Pumpkinseed	3.20	0.19	0.00	0.00	3.20	0.19	2.13	0.13
Redbreast Sunfish	6.89	0.37	2.78	0.13	6.89	0.37	5.52	0.29
Rock Bass	0.16	0.01	0.00	0.00	0.16	0.01	0.10	0.01
Sea Lamprey	0.84	0.05	1.92	0.09	0.84	0.05	1.20	0.06
Smallmouth Bass	5.42	0.30	5.89	0.27	5.42	0.30	5.58	0.29
Spottail Shiner	5.62	0.26	13.65	0.58	5.62	0.26	8.30	0.37
Tessellated Darter	0.19	0.01	0.00	0.00	0.19	0.01	0.12	0.01
White Sucker	2.10	0.12	3.18	0.13	2.10	0.12	2.46	0.12
Yellow Bullhead	0.32	0.02	0.93	0.04	0.32	0.02	0.52	0.03
Yellow Perch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Experimental gill net: Spring 2019

Common Name	Impoundment	Pool	Run	Total
	Fish/hr	Fish/hr	Fish/hr	Fish/hr
Bluegill	0.00	0.05	0.00	0.02
Fallfish	0.01	0.00	0.00	0.00
Margined Madtom	0.01	0.00	0.00	0.00
Smallmouth Bass	0.01	0.00	0.00	0.00
Spottail Shiner	0.00	0.00	0.10	0.03
White Sucker	0.01	0.00	0.03	0.02

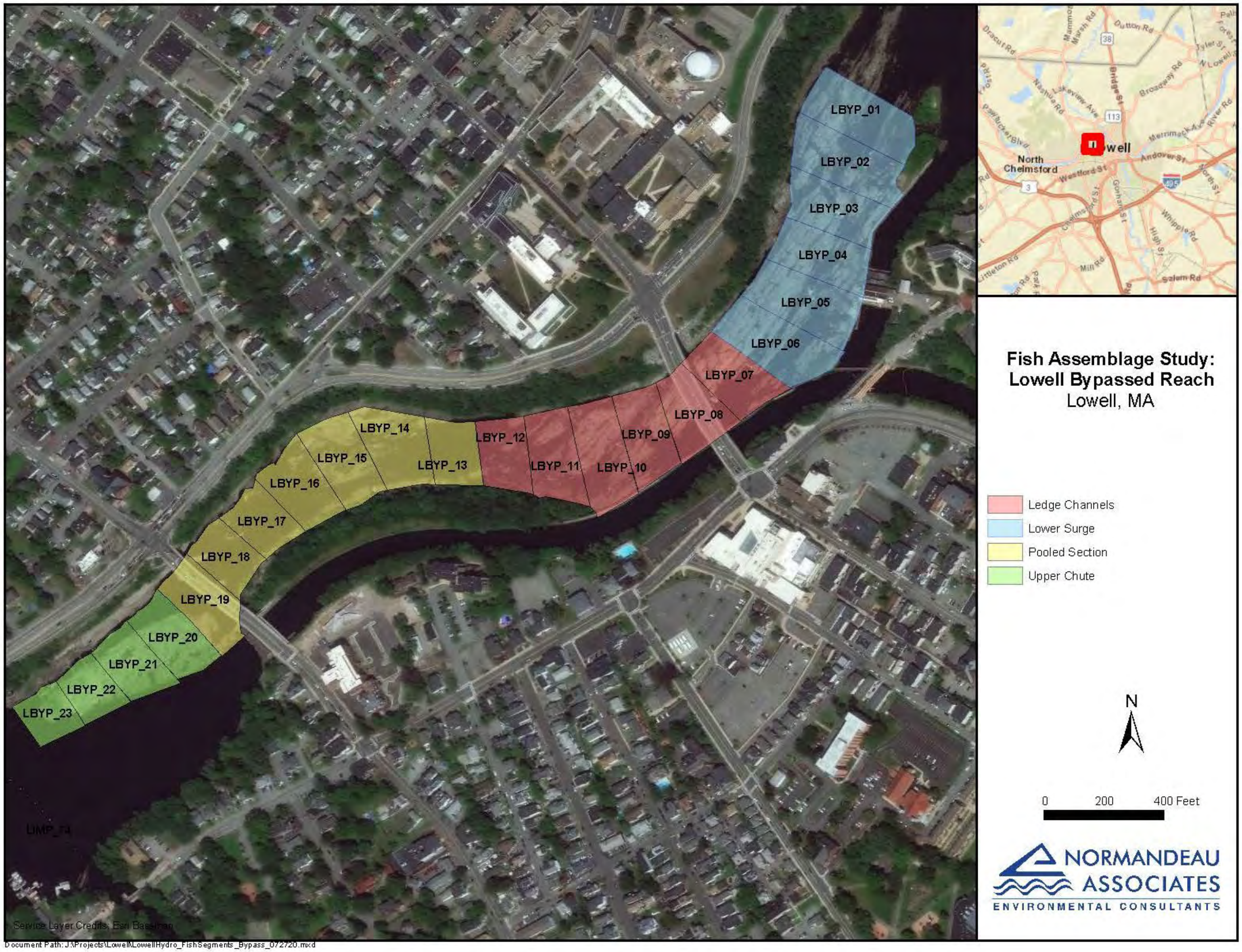
Experimental gill net: Summer 2019

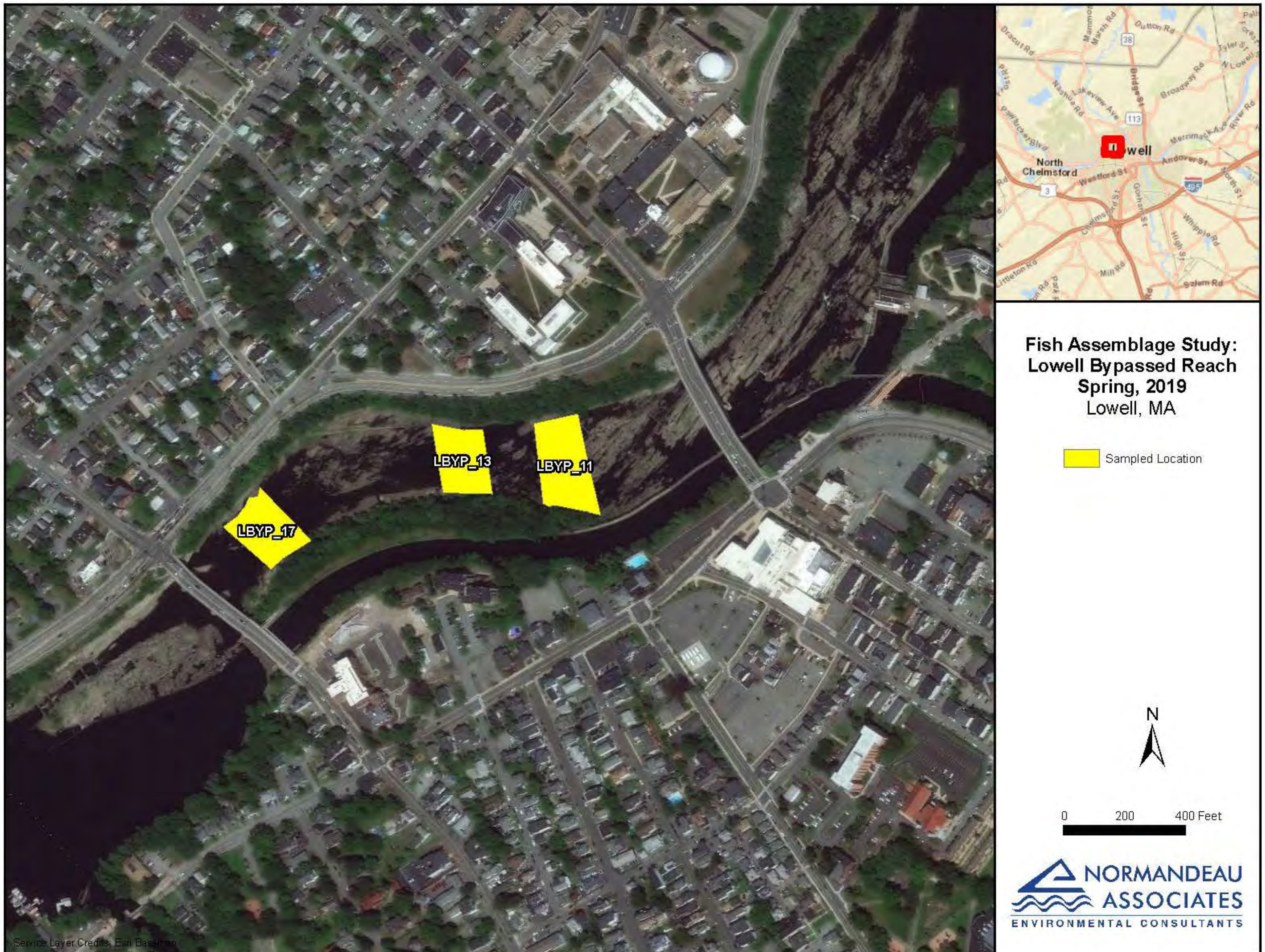
Common Name	Impoundment	Pool	Run	Total
	Fish/hr	Fish/hr	Fish/hr	Fish/hr
Alewife	0.02	0.00	0.00	0.01
Channel Catfish	0.01	0.00	0.00	0.00
Common Carp	0.01	0.00	0.00	0.00
Fallfish	0.01	0.03	0.00	0.01
Golden Shiner	0.00	0.00	0.10	0.03
Pumpkinseed	0.01	0.00	0.00	0.00
Redbreast Sunfish	0.05	0.00	0.00	0.02
Smallmouth Bass	0.04	0.00	0.00	0.01
Walleye	0.01	0.00	0.00	0.00
White Sucker	0.01	0.03	0.00	0.01
Yellow Bullhead	0.20	0.00	0.03	0.08
Yellow Perch	0.02	0.00	0.00	0.01

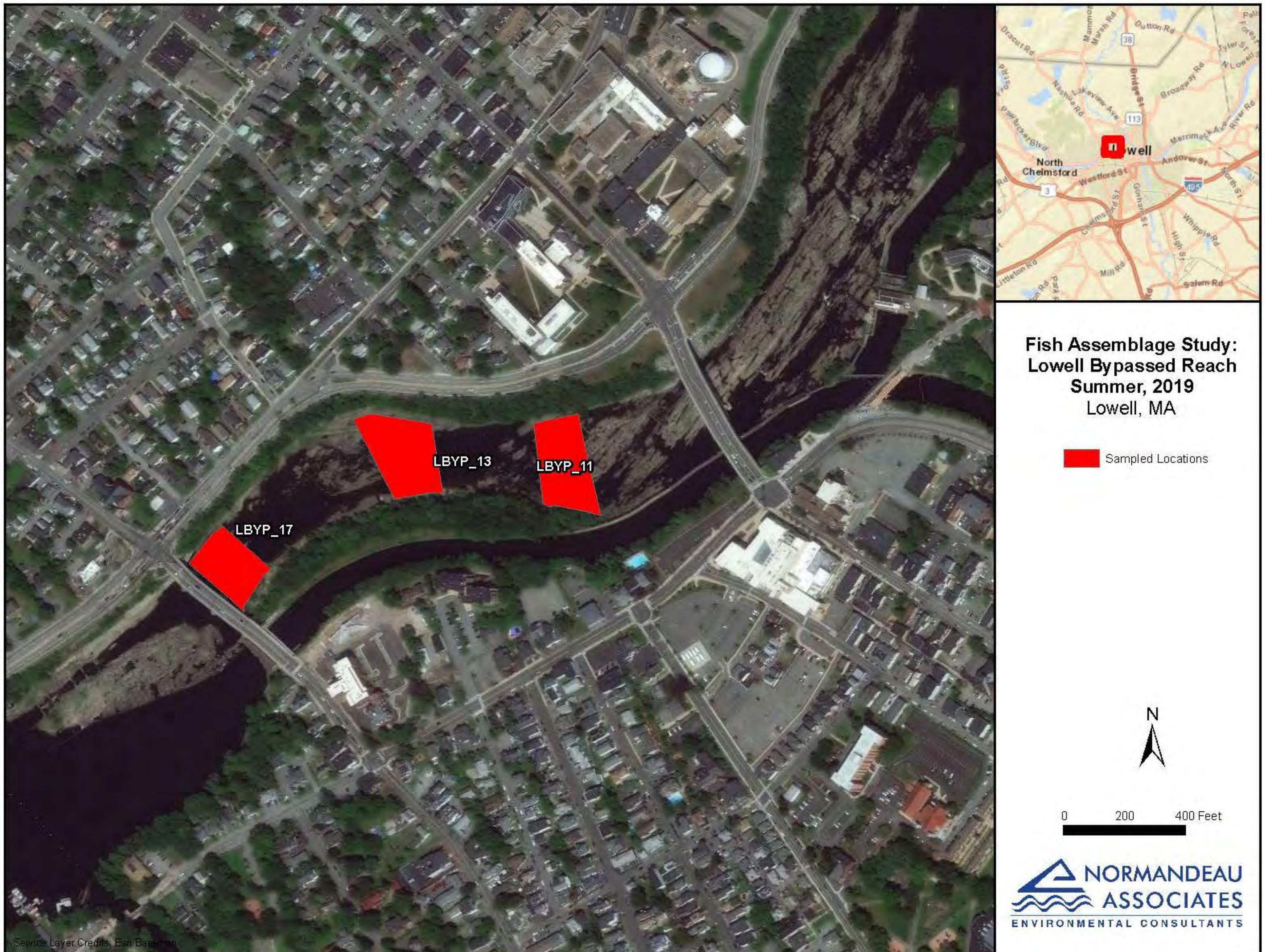
Experimental gill net: Fall 2019

Common Name	Impoundment	Pool	Run	Total
	Fish/hr	Fish/hr	Fish/hr	Fish/hr
Spottail Shiner	0.00	0.05	0.00	0.02
Yellow Bullhead	0.01	0.00	0.10	0.04

Appendix C. Spatial distribution of 50-m habitat units for the 0.75 mile bypassed reach downstream of Pawtucket Dam.


LBYP_01
LBYP_02
LBYP_03
LBYP_04
LBYP_05
LBYP_06
LBYP_07
LBYP_08
LBYP_09
LBYP_10
LBYP_11
LBYP_12
LBYP_13
LBYP_14
LBYP_15
LBYP_16
LBYP_17
LBYP_18
LBYP_19
LBYP_20
LBYP_21
LBYP_22
LBYP_23
Fish Assemblage Study:
Lowell Bypassed Reach
Lowell, MA
Ledge Channels
Lower Surge
Pooled Section
Upper Chute
N
0 200 400 Feet
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Document Path: J:\Projects\Lowell\LowellHydro_FishSegments_Bypass_072720.mxd


LBYP_13
LBYP_11
LBYP_17
North Chelmsford
Fish Assemblage Study: Lowell Bypassed Reach Spring, 2019
Lowell, MA
Sampled Location
N
0 200 400 Feet
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Service Layer Credits: Esri Basemap
Document Path: J:\Projects\Lowell\LowellHydro_FishSegments_BypassSample_Spring2019.mxd



Document Path: J:\Projects\Lowell\LowellHydro_FishSegments_BypassSample_Summer2019.mxd


LBYP_16
LBYP_13
LBYP_11
Fish Assemblage Study:
Lowell Bypassed Reach
Fall, 2019
Lowell, MA
Sampled Locations
N
0 200 400 Feet
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Service Layer Credits: Esri Basemap
Document Path: J:\Projects\Lowell\LowellHydro_FishSegments_BypassSample_Fall2019.mxd

Appendix D. Catch Per Unit of Effort (CPUE) information for back pack electrofish sampling within the bypassed reach downstream of Pawtucket dam by season (spring, summer, and fall) and habitat type (pool and ledge channels).

Back pack electrofish: Spring 2019

Common Name	Ledge Channels		Pooled Section		Total	
	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m
American Eel	20.67	14.00	4.12	1.67	12.40	7.83
Bluegill	0.00	0.00	1.52	0.67	0.76	0.33
Brown Trout	2.95	2.00	0.00	0.00	1.48	1.00
Fallfish	20.67	14.00	20.62	8.33	20.65	11.17
Longnose Dace	2.95	2.00	0.00	0.00	1.48	1.00
Margined Madtom	2.95	2.00	0.00	0.00	1.48	1.00
Redbreast Sunfish	2.95	2.00	0.00	0.00	1.48	1.00
Smallmouth Bass	5.91	4.00	0.00	0.00	2.95	2.00
Spottail Shiner	0.00	0.00	65.66	26.00	32.83	13.00
Tessellated Darter	0.00	0.00	0.76	0.33	0.38	0.17

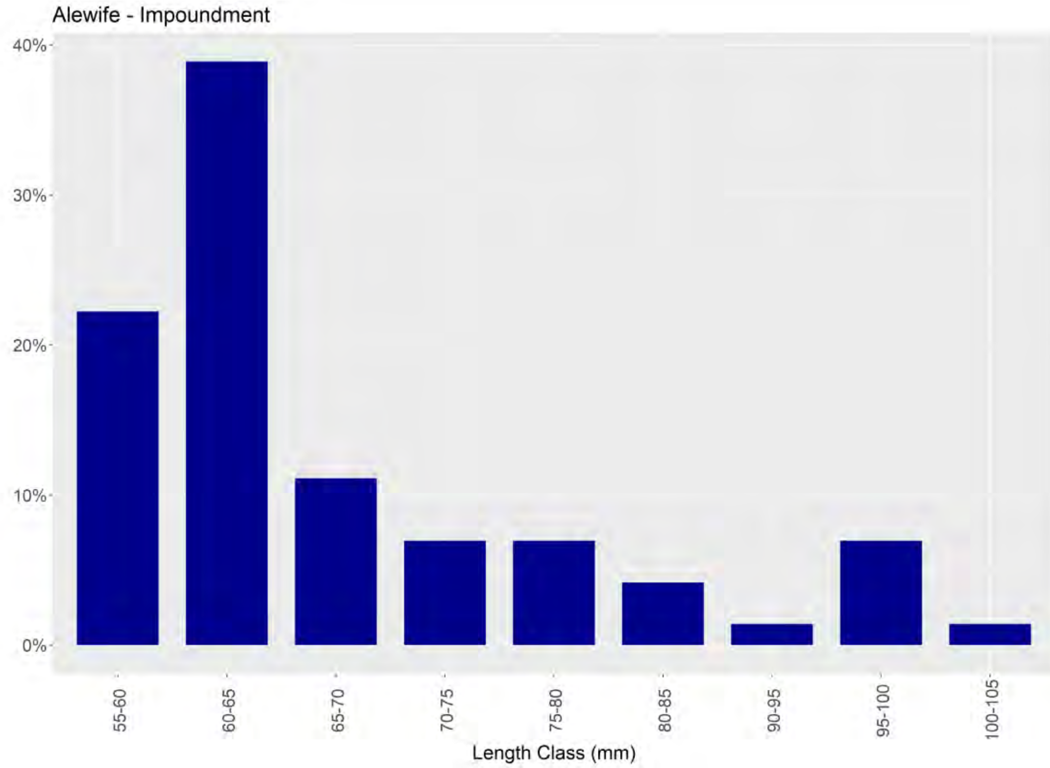
Back pack electrofish: Summer 2019

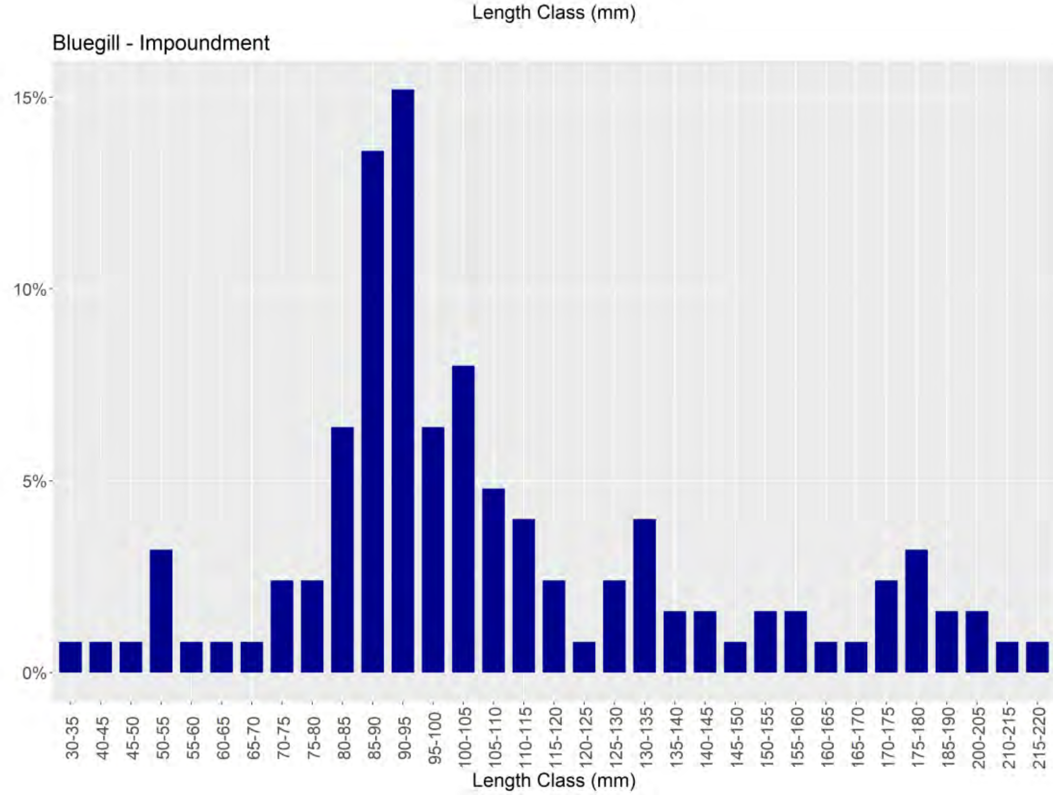
Common Name	Ledge Channels		Pooled Section		Total	
	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m
American Eel	17.72	12.00	6.28	4.00	12.00	8.00
Bluegill	0.00	0.00	0.56	0.33	0.28	0.17
Fallfish	0.00	0.00	97.43	62.33	48.72	31.17
Largemouth Bass	0.00	0.00	1.11	0.67	0.56	0.33
Margined Madtom	0.00	0.00	1.04	0.67	0.52	0.33
Redbreast Sunfish	2.95	2.00	2.15	1.33	2.55	1.67
Smallmouth Bass	73.82	50.00	6.49	4.00	40.15	27.00
Spottail Shiner	0.00	0.00	25.56	16.33	12.78	8.17
Tessellated Darter	2.95	2.00	2.08	1.33	2.52	1.67
White Sucker	0.00	0.00	15.66	10.00	7.83	5.00
Yellow Bullhead	0.00	0.00	2.22	1.33	1.11	0.67

Back pack electrofish: Fall 2019

Common Name	Ledge Channels		Pooled Section		Total	
	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m
American Eel	0.00	0.00	3.62	1.67	1.81	0.83
Fallfish	0.00	0.00	0.72	0.33	0.36	0.17
Lepomis spp.	0.00	0.00	1.68	0.67	0.84	0.33
Longnose Dace	2.95	2.00	0.00	0.00	1.48	1.00
Margined Madtom	0.00	0.00	12.06	5.33	6.03	2.67
Redbreast Sunfish	20.67	14.00	0.00	0.00	10.33	7.00
Sea Lamprey	0.00	0.00	1.68	0.67	0.84	0.33
Smallmouth Bass	88.58	60.00	38.08	16.33	63.33	38.17
Tessellated Darter	0.00	0.00	3.86	1.67	1.93	0.83
White Sucker	8.86	6.00	0.00	0.00	4.43	3.00
Yellow Bullhead	0.00	0.00	0.72	0.33	0.36	0.17

Appendix E. Length frequency distributions for common fish species collected by boat electrofish and experimental gill net sampling in the Lowell impoundment and back pack electrofish sampling within the bypassed reach downstream of Pawtucket dam.


Alewife - Impoundment
40%
30%
20%
10%
0%
55-60
60-65
65-70
70-75
75-80
80-85
90-95
95-100
100-105
Length Class (mm)


Bluegill - Impoundment
15%
10%
5%
0%
30-35
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
100-105
105-110
110-115
115-120
120-125
125-130
130-135
135-140
140-145
145-150
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170-175
175-180
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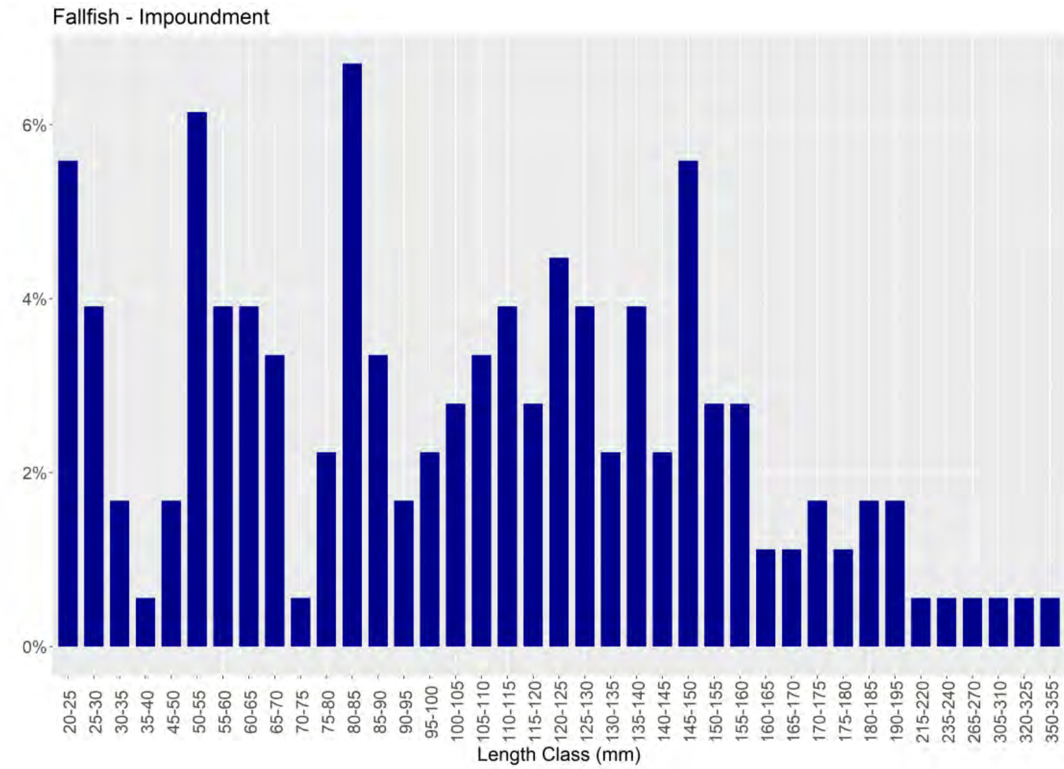
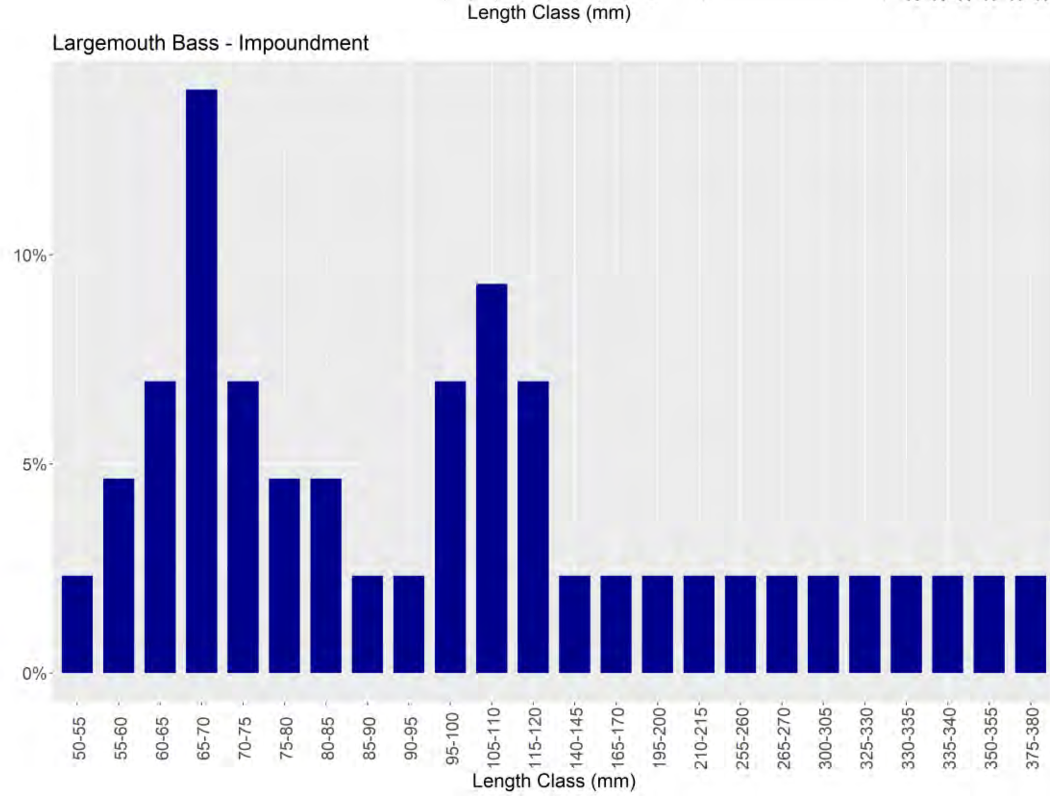
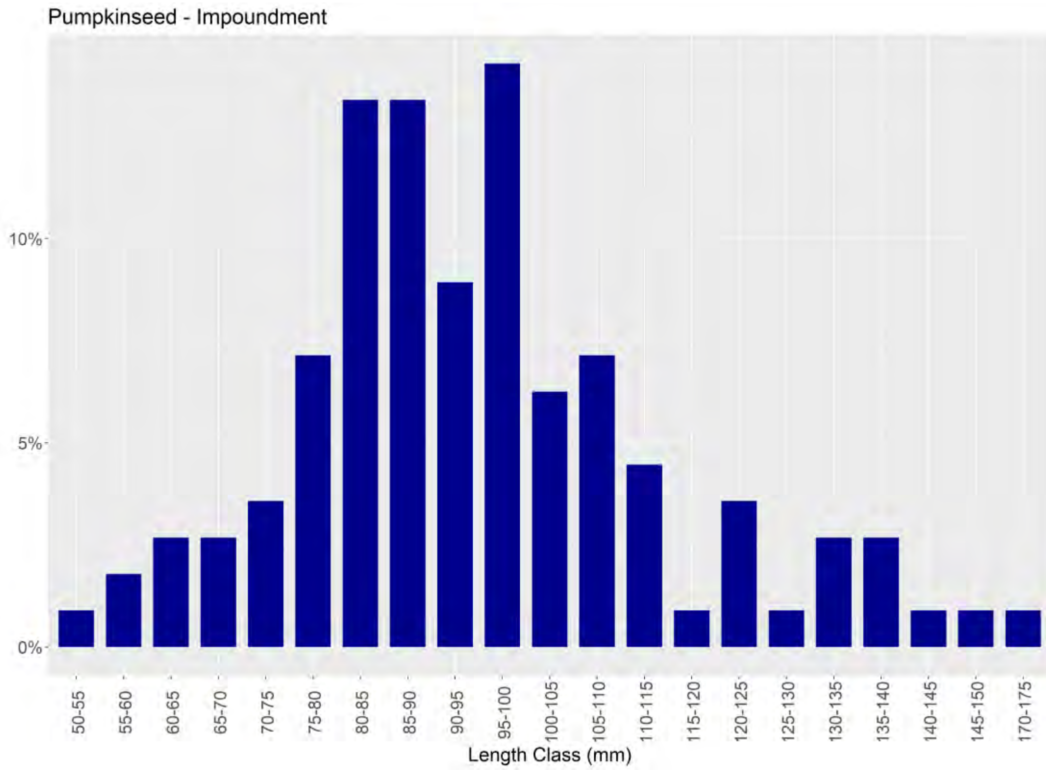
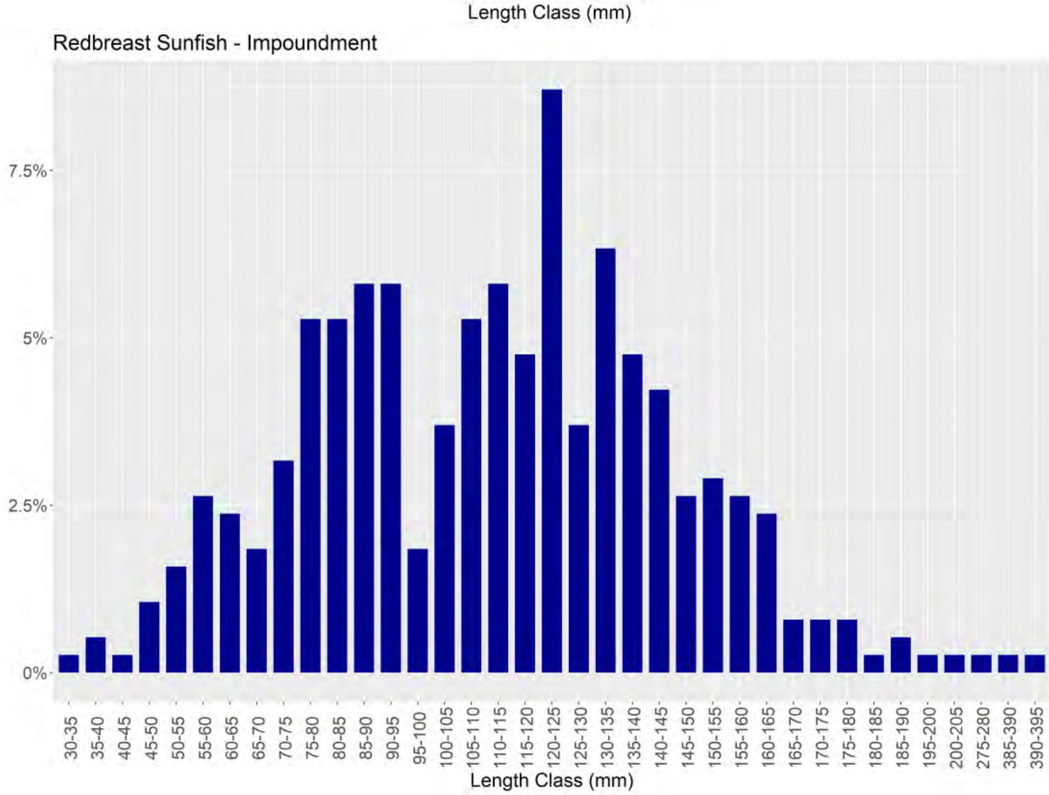
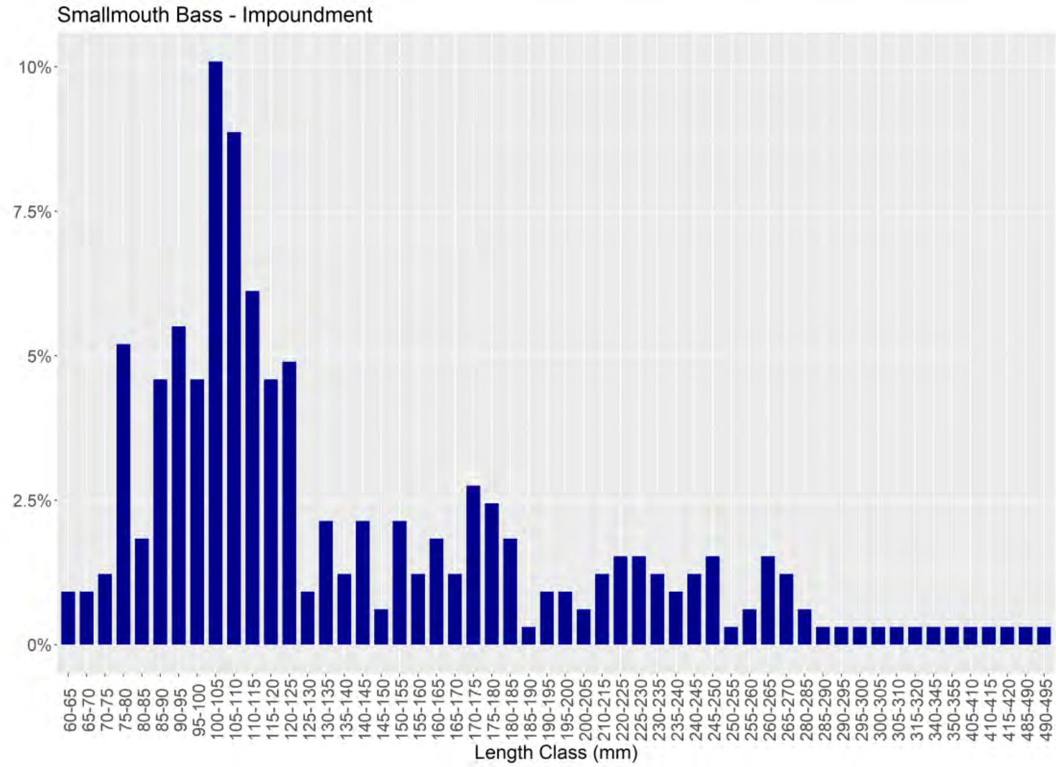
200-205
210-215
215-220
Length Class (mm)

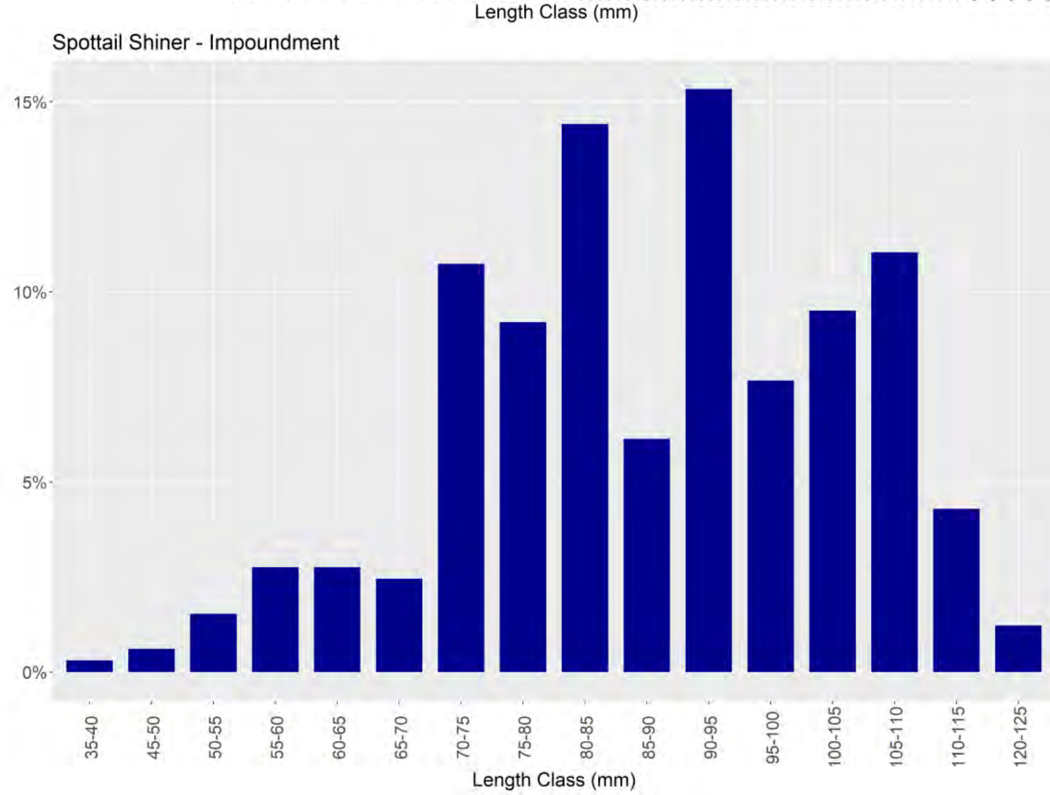

Fallfish - Impoundment
6%
4%
2%
0%
20-25
25-30
30-35
35-40
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
100-105
105-110
110-115
115-120
120-125
125-130
130-135
135-140
140-145
145-150
150-155
155-160
160-165
165-170
170-175
175-180
180-185
190-195
215-220
235-240
265-270
305-310
320-325
350-355
Length Class (mm)

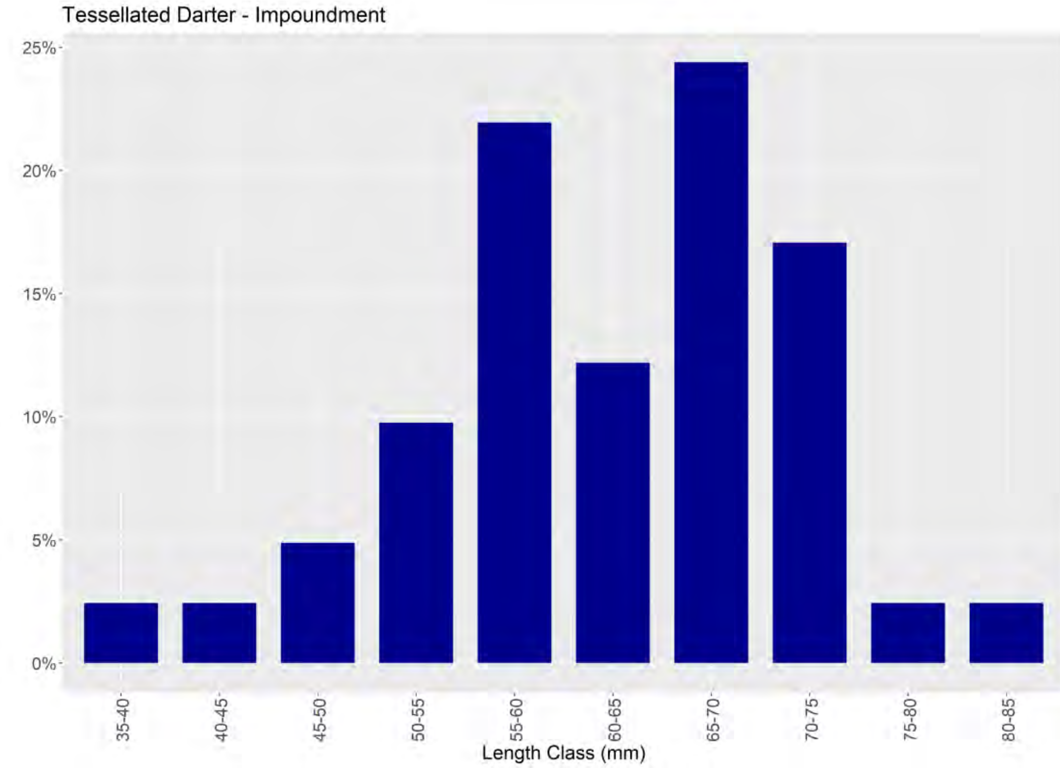

Largemouth Bass - Impoundment
10%
5%
0%
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
105-110
115-120
140-145
165-170
195-200
210-215
255-260
265-270
300-305
325-330
330-335
335-340
350-355
375-380
Length Class (mm)

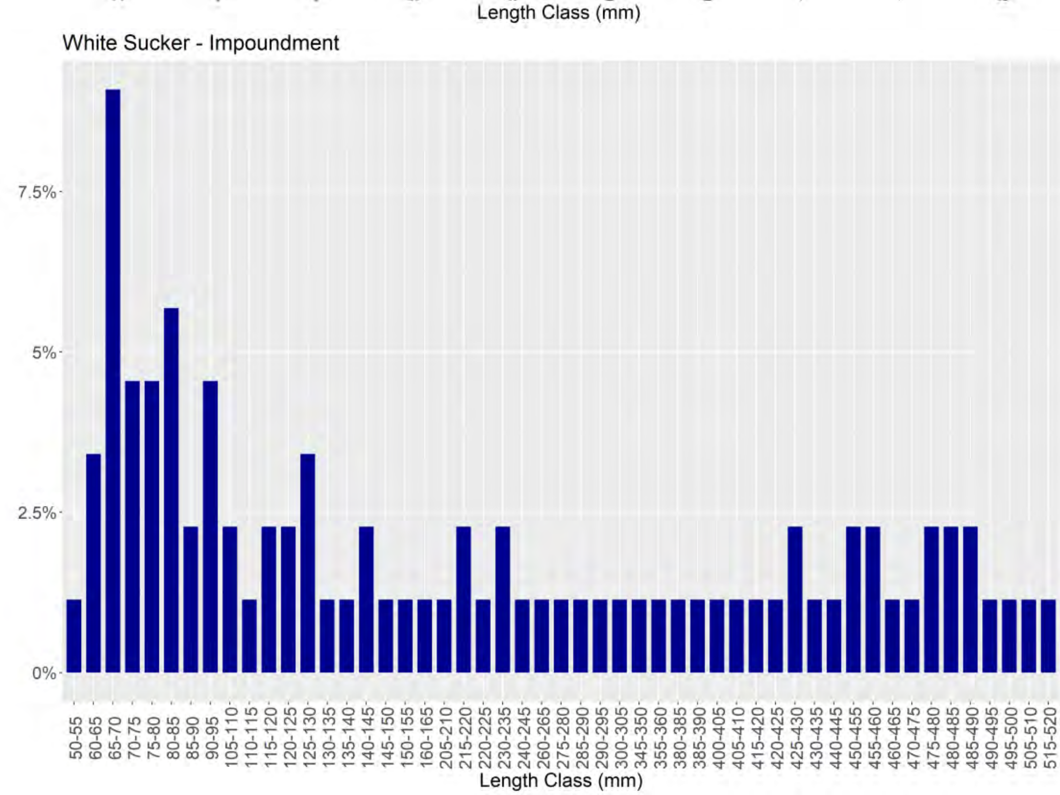

Pumpkinseed - Impoundment
10%
5%
0%
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
100-105
105-110
110-115
115-120
120-125
125-130
130-135
135-140
140-145
145-150
170-175
Length Class (mm)


Redbreast Sunfish - Impoundment
7.5%
5%
2.5%
0%
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
100-105
105-110
110-115
115-120
120-125
125-130
130-135
135-140
140-145
145-150
150-155
155-160
160-165
165-170
170-175
175-180
180-185
185-190
195-200
200-205
275-280
385-390
390-395
Length Class (mm)


Smallmouth Bass - Impoundment
10%
7.5%
5%
2.5%
0%
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
100-105
105-110
110-115
115-120
120-125
125-130
130-135
135-140
140-145
145-150
150-155
155-160
160-165
165-170
170-175
175-180
180-185
185-190
190-195
195-200
200-205
210-215
220-225
225-230
230-235
235-240
240-245
245-250
250-255
255-260
260-265
265-270
280-285
285-290
290-295
295-300
300-305
305-310
315-320
340-345
350-355
405-410
410-415
415-420
485-490
490-495
Length Class (mm)


Spottail Shiner - Impoundment
15%
10%
5%
0%
35-40
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
100-105
105-110
110-115
120-125
Length Class (mm)


Tessellated Darter - Impoundment
25%
20%
15%
10%
5%
0%
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
Length Class (mm)


White Sucker - Impoundment
7.5%
5%
2.5%
0%
50-55
60-65
65-70
70-75
75-80
80-85
85-90
90-95
105-110
110-115
115-120
120-125
125-130
130-135
135-140
140-145
145-150
150-155
160-165
205-210
215-220
220-225
230-235
240-245
260-265
275-280
285-290
290-295
300-305
345-350
355-360
380-385
385-390
400-405
405-410
415-420
420-425
425-430
430-435
440-445
450-455
455-460
460-465
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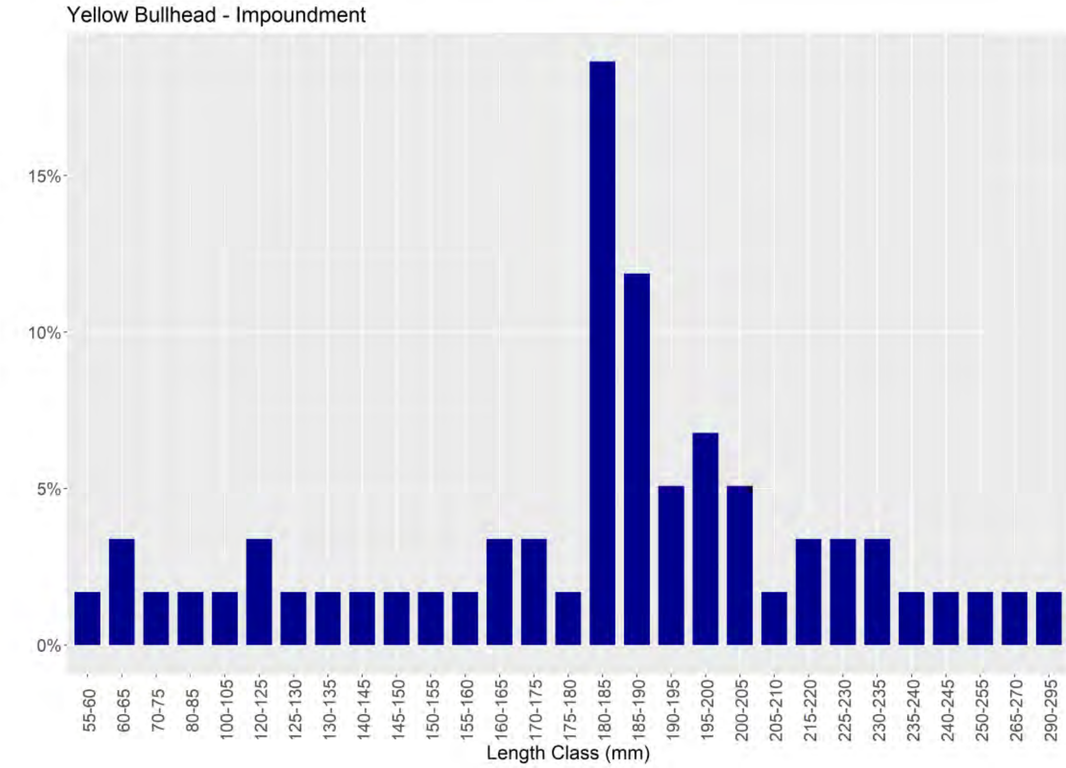
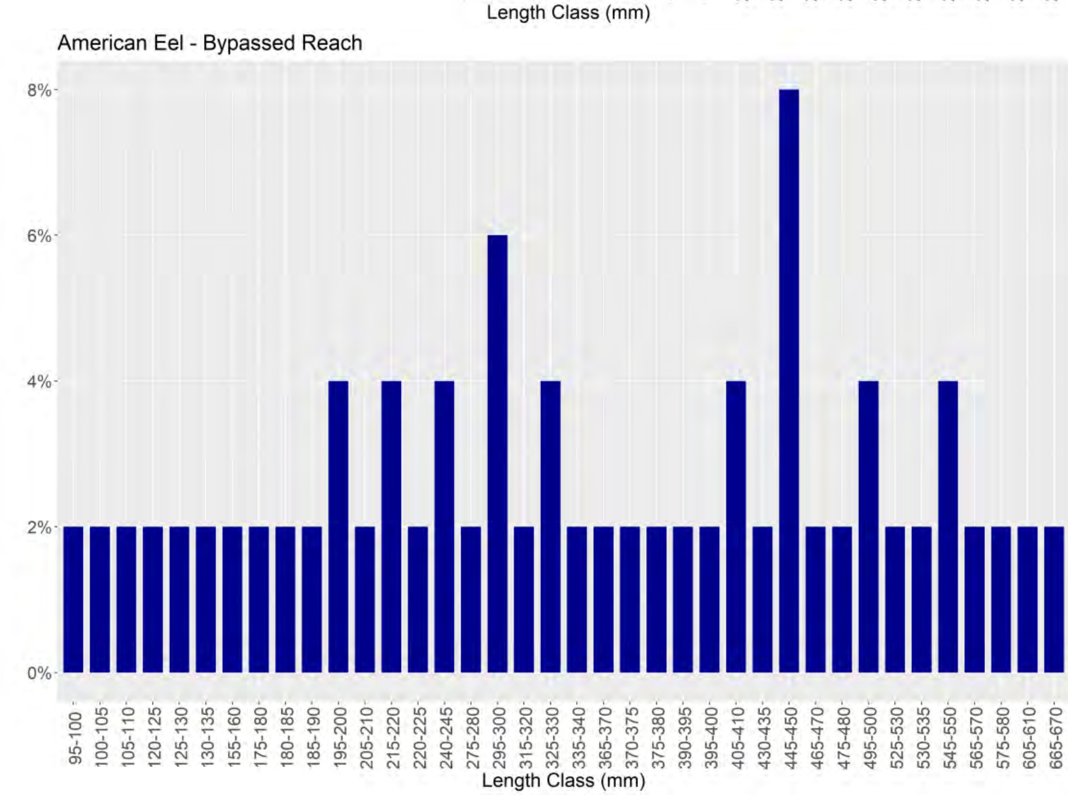
475-480
480-485
485-490
490-495
495-500
505-510
515-520
Length Class (mm)


Yellow Bullhead - Impoundment
15%
10%
5%
0%
55-60
60-65
70-75
80-85
100-105
120-125
125-130
130-135
140-145
145-150
150-155
155-160
160-165
170-175
175-180
180-185
185-190
190-195
195-200
200-205
205-210
215-220
225-230
230-235
235-240
240-245
250-255
265-270
290-295
Length Class (mm)


American Eel - Bypassed Reach
8%
6%
4%
2%
0%
95-100
100-105
105-110
120-125
125-130
130-135
155-160
175-180
180-185
185-190
195-200
205-210
215-220
220-225
240-245
275-280
295-300
315-320
325-330
335-340
365-370
370-375
375-380
390-395
395-400
405-410
430-435
445-450
465-470
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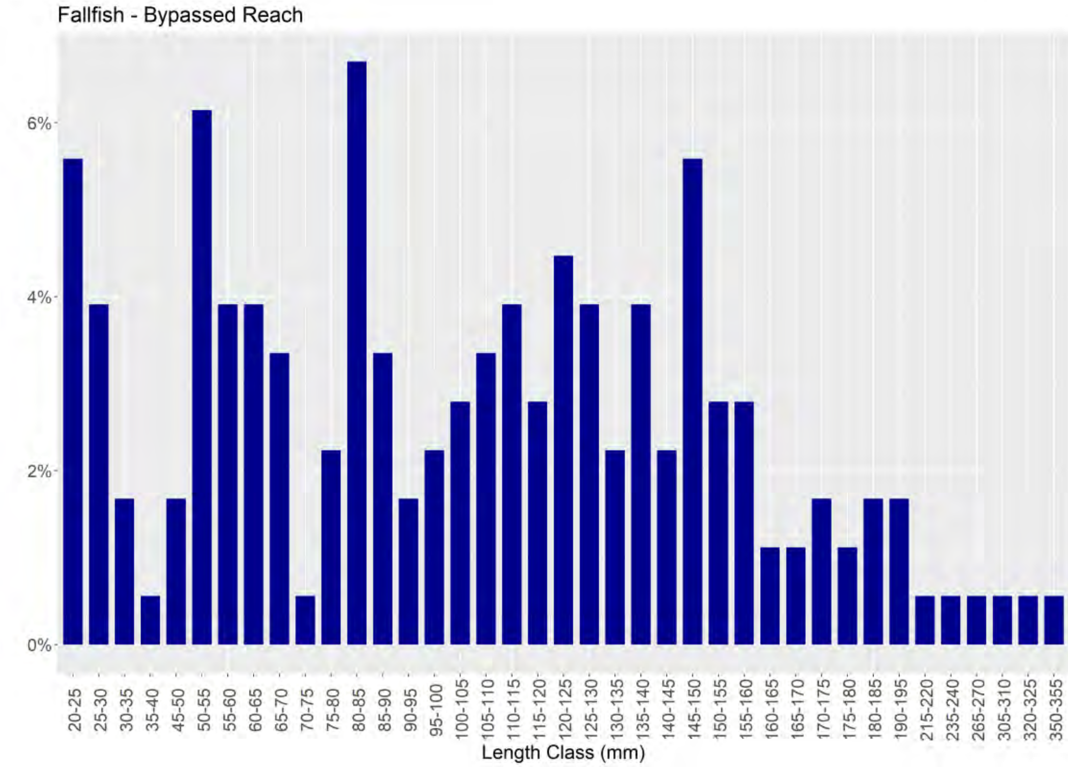
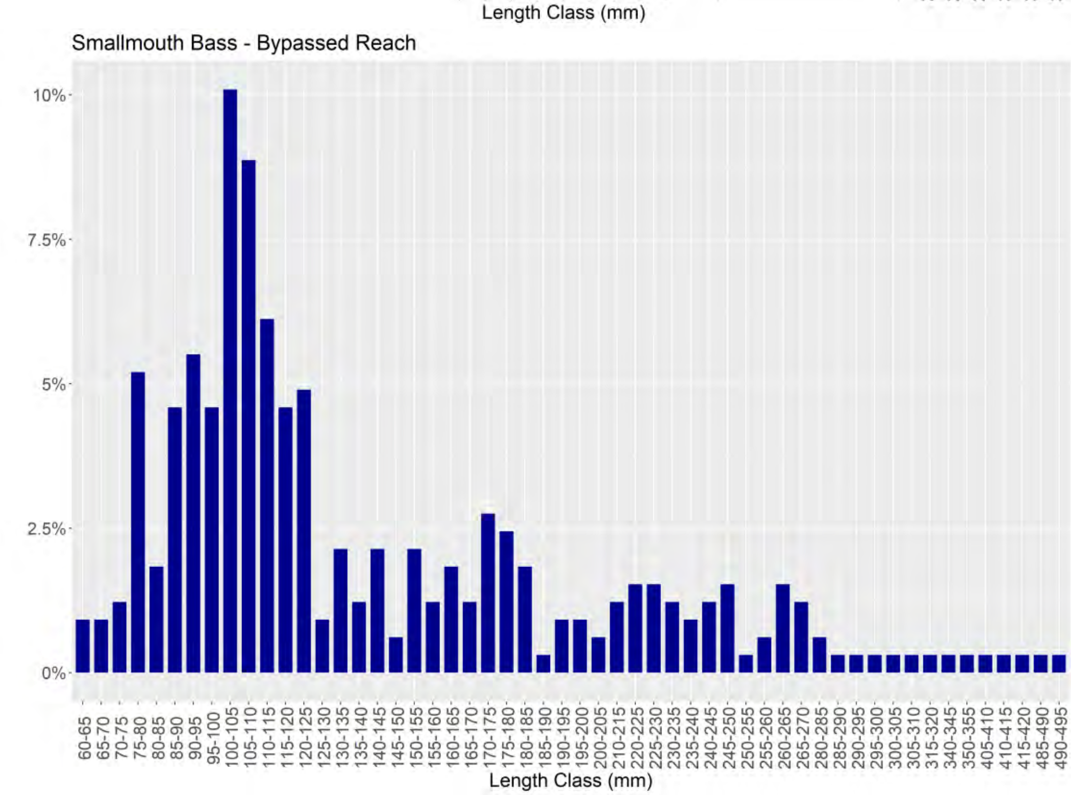
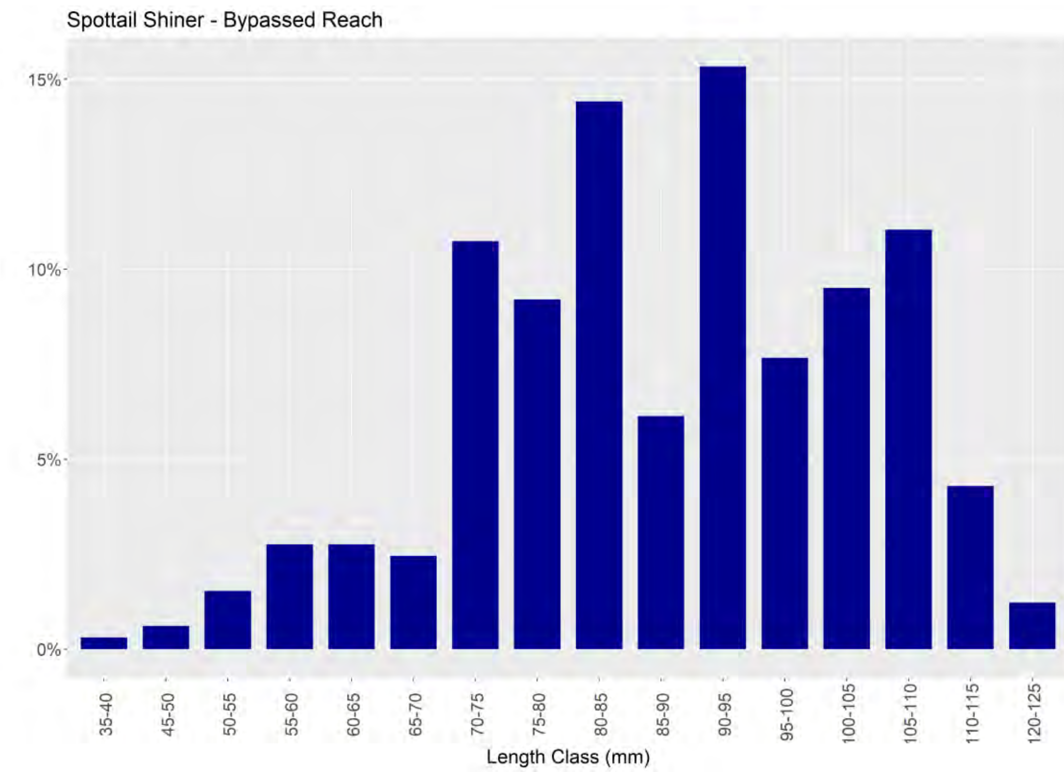
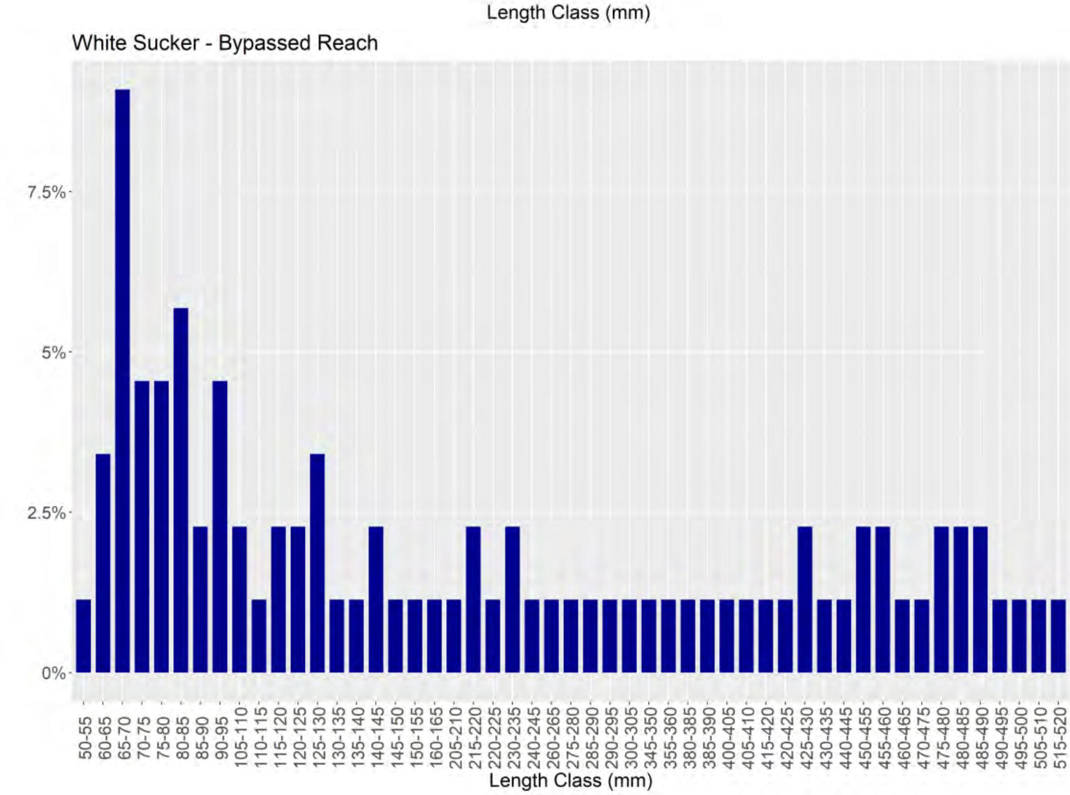
495-500
525-530
530-535
545-550
565-570
575-580
605-610
665-670
Length Class (mm)


Fallfish - Bypassed Reach
0%
2%
4%
6%
Length Class (mm)


Smallmouth Bass - Bypassed Reach
0%
2.5%
5%
7.5%
10%
Length Class (mm)


Spottail Shiner - Bypassed Reach
15%
10%
5%
0%
35-40
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
100-105
105-110
110-115
120-125
Length Class (mm)


White Sucker - Bypassed Reach
7.5%
5%
2.5%
0%
50-55
60-65
65-70
70-75
75-80
80-85
85-90
90-95
105-110
110-115
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260-265
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345-350
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380-385
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400-405
405-410
415-420
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425-430
430-435
440-445
450-455
455-460
460-465
470-475
475-480
480-485
485-490
490-495
495-500
505-510
515-520
Length Class (mm)

Appendix F. Catch information for fish species collected by boat electrofish and experimental gill net sampling in the Lowell impoundment and back pack electrofish sampling within the bypassed reach downstream of Pawtucket dam (2019).

Report Appendix F available as Microsoft Excel data listing.

Technical Report for the Juvenile Alosine Downstream Passage Assessment

Lowell Hydroelectric Project (FERC No. 2790)

Prepared For
Boott Hydropower, LLC
Subsidiary of Central Rivers Power US, LLC
670 N. Commercial Street, Suite 204
Manchester, NH 03102

Central Rivers Power

Prepared By
Normandeau Associates, Inc.
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Portsmouth, NH 03801
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NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS

September 30, 2020

Table of Contents

List of Tables

List of Figures

1 Introduction

A radio-telemetry assessment of the effects of project operation on downstream migrating juvenile alosines was conducted in support of the relicensing for the Lowell Hydroelectric Project (Lowell or Project), Federal Energy Regulatory Commission (FERC) No. 2790, as identified in the Revised Study Plan (RSP) submitted by Boott Hydropower, LLC (Boott) on January 28, 2019. The approach and methodology described in the RSP for the juvenile alosine study was approved without modifications by FERC in its Study Plan Determination (SPD) letter dated March 13, 2019. This technical report was prepared on behalf of Boott to provide a description of the objectives, methodologies and results of the 2019 radio-telemetry assessment to evaluate the effect of operations on downstream migrating juvenile alosines at the Lowell Project.

2 Objectives

The goal of this study was to determine the Lowell Project's impact on the outmigration of juvenile alosines.

Specific objectives included:

- Assess the effects of the Project on the timing, orientation, passage routes, and migration rates of juvenile alosines.
- Determine the proportion of juvenile alosines that select the Pawtucket Canal versus the E.L. Field Powerhouse, downstream bypass facility, or dam spill as a downstream passage route, under varied operational conditions.
- Determine if there are any delays associated with downstream movement related to either dam spill or the E.L. Field Powerhouse due to operations.

3 Project Description and Study Area

The Lowell Project is located at River Mile (RM) 41 on the Merrimack River in the City of Lowell in Middlesex County, Massachusetts, with an impoundment extending approximately 23 miles upstream into Hillsborough County, New Hampshire. The existing Lowell Project consists of: (1) a 1,093-foot-long, 15-foot-high masonry gravity dam (Pawtucket dam) that includes a 982.5-foot-long spillway with a crest elevation of 87.2 feet National Geodetic Vertical Datum 1929 (NGVD 29) topped by 5-foot-high pneumatically-operated crest gates deployed in five independently-operable zones; (2) a 720-acre impoundment with a normal maximum water surface elevation of 92.2 feet NGVD 29; (3) a 5.5-mile-long canal system which includes several small dams and gatehouses; (4) a powerhouse (E.L. Field) which uses water from the Northern Canal and contains two turbine-generator units with a total installed capacity of 15.0 megawatts (MW); (5) a 440-foot-long tailrace channel; (6) four powerhouses (Assets, Bridge Street, Hamilton, and John Street) housed in nineteenth century mill buildings along the Northern and Pawtucket Canal System containing 15 turbine-generator units with a total installed capacity of approximately 5.1 MW; (7) a 4.5-mile long, 13.8-kilovolt transmission line connecting the powerhouses to the regional distribution grid; (8) upstream and downstream fish passage facilities including a fish elevator and downstream fish bypass at the E.L. Field powerhouse, and a vertical-slot fish ladder at the Pawtucket dam; and (9) appurtenant facilities. At the normal pond elevation of 92.2 feet NGVD 1929 (crest of the pneumatic flashboards), the surface area of the impoundment encompasses an area of approximately 720 acres. The gross storage capacity between the normal surface elevation of 92.2 feet and the minimum pond level of 87.2 feet is approximately 3,600 acre-feet. The Project operates essentially in a run-of-river (ROR) mode using automatic pond level control, and has no usable storage capacity.

The study area for the juvenile alosine passage assessment included the section of the Merrimack River from the point approximately 1.0 mile upstream of the Pawtucket Gatehouse to a point approximately 2.1 miles downstream from the E.L. Field Powerhouse tailrace (Figure 3-1). The Upper Pawtucket Canal and Guard Locks facility were also considered as part of the study area.

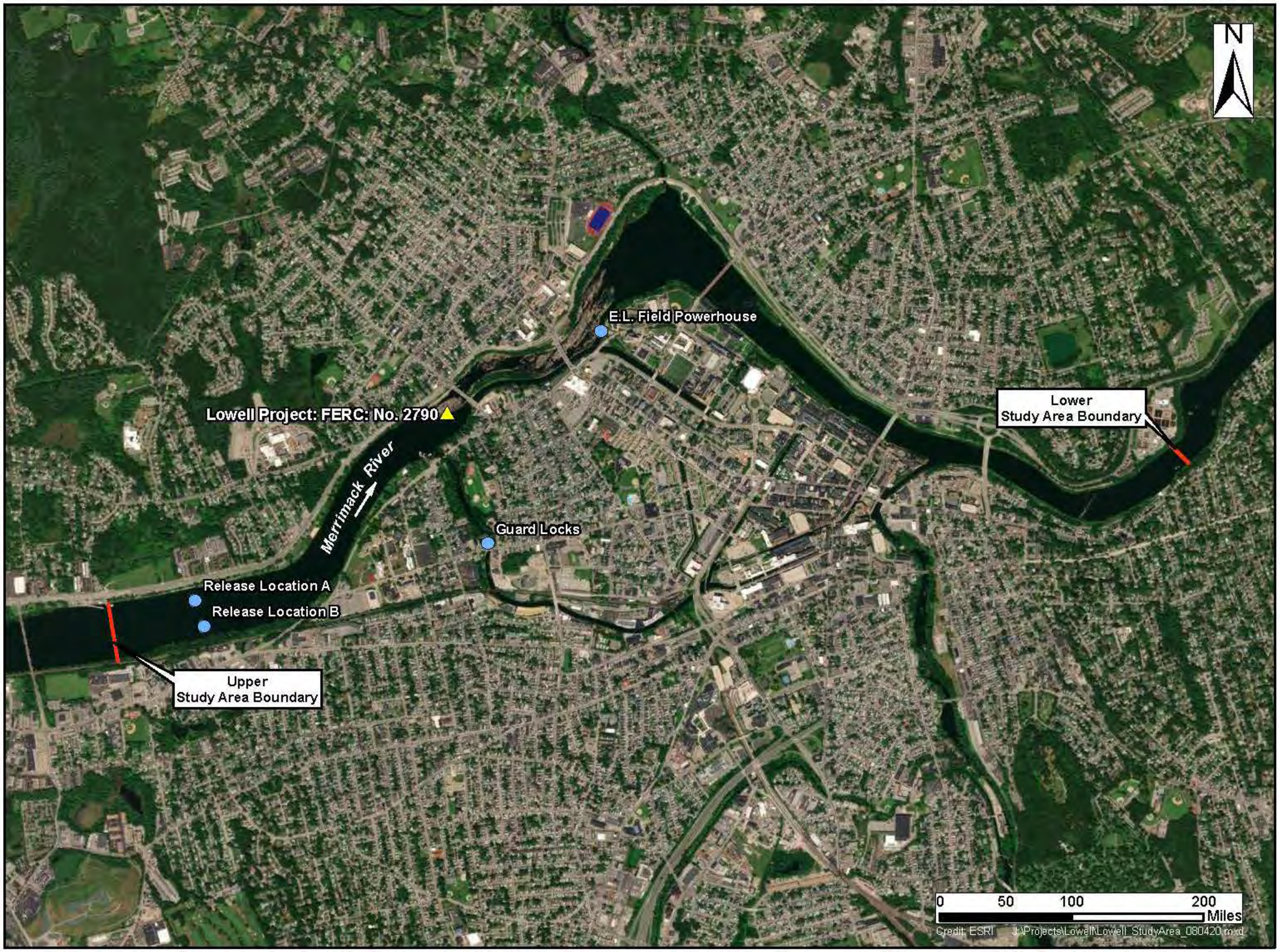

Figure 3–1. Merrimack River study reach considered during the fall 2019 juvenile alosine downstream passage assessment.

4 Methods

Downstream passage of juvenile alosines through the Lowell Project reach was evaluated using radio-telemetry during the fall of 2019. Following the release of radio-tagged individuals into the Lowell impoundment at a point approximately 1.0 miles upstream of the Pawtucket Gatehouse, downstream movements were monitored using a series of stationary radio-telemetry receivers in place at the Project as well as stationary monitoring stations installed at bank-side locations upstream and downstream of the Project to inform on general movements, distribution among available passage routes and continued downstream travel.

4.1 Radio Telemetry Equipment

Movements of radio-tagged individuals during the 2019 study were recorded via a series of stationary radio-telemetry receivers. Radio-telemetry equipment used during the evaluation of downstream passage at Lowell included Orion receivers, manufactured by Sigma Eight, as well as SRX receivers manufactured by Lotek Wireless. Each receiver was paired with either an aerial or underwater antenna (dropper antenna). Aerial antennas (four or six element Yagi) were utilized to detect radio-tagged individuals within the larger, more open sections of river, such as within the tailrace or at locations downriver of Lowell. Dropper antennas were fixed at downstream passage locations (e.g., downstream bypass).

Juvenile alosines radio-tagged during 2019 were equipped with a Lotek NTF-1-1 transmitter. The NTF-1-1 transmitters measured approximately 5 x 3 x 9.6 mm, weighed 0.24 grams and had an estimated battery life of 13 days when set at a 2.0 second burst rate. Each transmitter was coded to emit a unique identifying signal so that individual juvenile alosines could be identified by any given receiver.

4.2 Monitoring Stations

The RSP identified a total of ten monitoring stations to be set up at Lowell for the downstream juvenile alosine passage assessment. Each of the ten monitoring locations identified in the RSP were installed as described and each location consisted of a data-logging receiver, antenna, power source, and were configured to receive transmitter signals from a designated area continuously throughout the study period. During installation of each station, range testing was conducted to configure the antennas and receivers in a manner which maximized detection efficiencies at each location. The operation of the radio telemetry receivers was initially established during installation, then confirmed throughout the study period by using beacon tags. A number of beacon tags were stationed at strategic locations within the detection range of either multiple or single antennas, and they emitted signals at programmed time intervals. These signals were detected and logged by the receivers and used to record the functionality of the system throughout the study period.

The locations of monitoring stations installed for the 2019 juvenile alosine passage evaluation at Lowell are outlined here and presented in Figures 4-1 through 4-3.

Monitoring Station 20: This station was installed at a location downstream of the release location and upstream of Pawtucket Dam and was intended to detect radio-tagged juvenile alosines following their initial downstream movement away from the release location. Station 20 consisted of a single Lotek SRX receiver and an aerial antenna oriented perpendicular to the river channel and was located at a point approximately 0.6 miles upstream of the Pawtucket Gatehouse.

Monitoring Station 21: This station consisted of a single Lotek SRX radio-receiver and an aerial antenna located at the Project compressor building. Station 21 was installed and calibrated to provide information on radio-tagged juvenile alosines as they approached the upstream face of Pawtucket Dam. Detections at this location were used to inform on the arrival of radio-tagged juveniles at the Project.

Monitoring Station 24: Monitoring Station 24 consisted of a Lotek SRX radio-receiver and an aerial antenna installed to detect radio-tagged juvenile alosines which had entered the Pawtucket Canal system. The entrance to the Pawtucket Canal sits at a point upstream of the Pawtucket Dam and the Northern Canal. Station 24 was located at the Guard Locks, approximately 1,700 feet downstream from the entrance to the canal. The monitoring zone for Station 24 was focused downstream of the Guard Locks facility to ensure any detections recorded at that location were of fish which had definitively entered the downtown canal system.

Monitoring Station 26: Station 26 consisted of a single Orion radio-receiver and aerial antenna installed and calibrated to provide coverage of the upstream side of the Pawtucket Gatehouse. This station informed on radio-tagged juvenile alosines which had approached the upstream side of the Pawtucket Gatehouse.

Monitoring Station 28: Station 28 consisted of a single Lotek radio-receiver and aerial antenna installed and calibrated to provide coverage of the downstream side of the Pawtucket Gatehouse. This station informed on radio-tagged juvenile alosines which had successfully passed through the Pawtucket Gatehouse and entered the Northern Canal.

Monitoring Station 30: Station 30 consisted of a single Lotek SRX radio-receiver and aerial antenna installed and calibrated to provide detection information for radio-tagged juvenile alosines that passed through the Pawtucket Gatehouse, entered the E.L. Field Powerhouse forebay (i.e., the downstream potion of the Northern Canal) and were in the vicinity of the entrance to the downstream bypass and intake racks.

Monitoring Station 32: This station consisted of a single Orion radio-receiver and underwater drop antenna installed and calibrated to provide detection information for radio-tagged juvenile alosines exiting the forebay via the downstream bypass.

Monitoring Station 34: Station 34 consisted of a single Lotek SRX radio-receiver and aerial antenna installed and calibrated to scan across the bypassed reach at a point downstream of where the surge gate enters from the power canal and upstream from the downstream bypass.

Detections at this location confirmed downstream passage of juvenile alosines using the spillway or surge gate.

Monitoring Station 36: This station consisted of a single Lotek radio-receiver and aerial antenna installed at a location overlooking the project tailrace. Detections at this location were used to confirm the downstream passage of radio-tagged juvenile alosines via the E.L. Field powerhouse turbine units.

Monitoring Station 38: This station was installed at a point along the mainstem of the Merrimack River downstream of both the E.L. Field Powerhouse tailrace and the confluence with the Concord River. Station 38 consisted of a single Lotek SRX receiver and aerial antenna oriented perpendicular to the river channel and was installed at the Lowell Waste Water Treatment Plant, approximately 2.1 miles downstream of the tailrace.

4.3 Tagging and Release Procedures

Juvenile alosines were collected by boat electrofishing from Turtletown Pond located in Concord, NH. Following collection, juvenile alosines were transported by tank truck to a temporary holding facility at the Garvins Falls Dam on the Merrimack River. Once transferred to the holding tanks, collected juvenile alosines were allowed to acclimate for a minimum of 24 hours prior to tagging in order to observe for any latent post capture mortality.

NTF-1-1 transmitters were attached to a dry fly hook using bonding cement. The hook was inserted posterior to the dorsal fin with the majority of the tag and antenna trailing behind the insertion point (Figure 4-4). After tagging, fish were held in holding containers and maintained in ambient Merrimack River water until they were transported to the release site. As part of the 2019 passage route evaluation, a total of 10 separate release groups, each comprising up to 15 tagged and 15 untagged juvenile alosines, were released. Each release group was separated into two holding containers, each consisting of 7-8 tagged and 7-8 untagged juvenile alosines resulting in a total of 15 fish per container. Tagged juvenile alosines driven to the Rourke Brothers Boat Ramp and were then transported by boat to a location approximately 1.0 miles upstream of the Pawtucket Gatehouse. During each release event, the two holding containers were lowered over the side of the boat and the tagged and untagged juvenile alosines were allowed to volitionally exit the container. On each release date the total number of individuals placed in the river were split over two separate release points, one in the eastern third of the river and the other in the western third of the river. The date, time, and release location of each group of tagged alosines was recorded.

4.4 Data Collection

4.4.1 Stationary Telemetry Data

Receiver downloads occurred three to four times weekly during the period from the initial tag and release event until November 12, 2019 (i.e., six days beyond the anticipated battery life for radio-transmitters used for the final test fish release group (October 24, 2019)). Backup copies of all telemetry data were made prior to receiver initialization. Field tests at the time of download to ensure data integrity and receiver performance included confirmation of file integrity, confirmation that the last record was consistent with the downloaded data (beacon tags were critical to this step), and lastly, confirmation that the receiver was operational upon restart and actively collecting data post download. Within a data file, transmitter detections were stored as a single event (i.e., single data line). Each event included the date and time of detection, frequency, ID code, and signal strength.

4.4.2 Manual Telemetry Data

To provide supplemental detection information to the stationary receiver data set, manual tracking was conducted on a number of occasions from the time of initial release through mid-November, 2019. Manual effort was exerted in the vicinity of the Lowell Project (i.e., tailrace and headpond immediately upstream of Pawtucket Dam) on most dates when stationary telemetry equipment was checked. In addition, a number of boat or truck-based efforts were conducted to look for radio-tagged individuals within the lower Lowell impoundment and the reach of the Merrimack downstream to Lawrence.

4.4.3 Operational and Environmental Data

Merrimack River water temperature was recorded via a continuously operating logger installed within the Lowell intake canal. Hourly records for operations data were provided by Boott for the 2019 evaluation period and included:

- Headpond elevation (ft);
- Power canal elevation (ft);
- Headpond-power canal differential (ft);
- Tailrace elevation (ft);
- Head differential for E.L. Field turbines (ft);
- Total inflow (cfs);
- Unit 1 discharge (cfs) and output (KW);
- Unit 2 discharge (cfs) and output (KW);
- Downstream bypass discharge (cfs);
- Upstream fishway discharge (cfs);
- Downtown canal flow (cfs); and
- Spill flow through the bypassed reach.

4.5 Data Analysis

The tagging, telemetry and Project operations data sets collected as part of this effort were examined and used to evaluate a number of metrics related to downstream passage success and movement through the Project area.

4.5.1 Downstream Movement and Passage Route Selection

A complete record of all valid stationary receiver detections for each radio-tagged juvenile alosines was generated. The pattern and timing of detections in these individual records were reviewed, and a route of passage as well as project arrival and passage times were assigned to each radio-tagged individual. In the instance that a downstream route could not be clearly determined from the collected data, the passage event for that particular fish was classified as ‘unknown’.

Where data were available, project residence times were calculated. Upstream residence duration was defined as the duration of time from the initial detection at Station 21 until the determined time of downstream passage. Time spent immediately upstream of the dam was further evaluated using initial detection times for radio-tagged juvenile alosines at Monitoring Stations 26 and 28 to provide an understanding of passage times associated with moving through the Pawtucket Gatehouse and entering into the Northern Canal approach to the E.L. Field powerhouse (i.e. “Pawtucket Gatehouse Passage”). Power canal residency was evaluated using the initial detection at Station 28 and the time of downstream passage to provide an understanding of the time spent within the Northern Canal prior to passage route selection (i.e. “Northern Canal Residence”).

4.5.2 Time to Event Analysis

4.5.2.1 Cox Proportional Hazard Model

Utilizing available methodology for quantifying fish passage performance (Castro-Santos and Perry 2012), multi-variate Cox proportional hazard models were developed to assess the impact of various operational and environmental variables on the rate of passage success. Operational and environmental variables considered as part of this analysis included:

- Merrimack River water temperature (°C);
- Head differential (ft) at the Pawtucket Gatehouse (i.e., headpond vs. Northern Canal);
- Bypassed reach spill flow (cfs);
- E.L. Field turbine discharge (cfs);
- Merrimack River inflow (cfs); and
- E.L. Field head differential (ft) (i.e., Northern Canal vs. tailwater).

Although additional variables such as turbine operation at E.L. Field (i.e., Unit 1, Unit 2, both, or neither) and head pond elevation (ft) were available, there was not enough resolution in the data during the fall 2019 passage period to provide meaningful results. This assessment on the rate of passage success focused on approach events at (1) the Pawtucket Gatehouse (i.e., Station 25), and (2) at the E.L. Field Powerhouse (i.e., Station 29).

Regression models for the time to event analyses were constructed using the *coxph*() function from the package “*survival*” in R (R Core Team 2020) and were used to evaluate the rate of passage success and identify operational hazards at sites which contained a physical barrier or a structure through which tagged individuals would have to navigate (i.e., the Pawtucket Gatehouse and E.L. Field Powerhouse).

The Cox proportional hazard regression can be described as a hazard function to evaluate the proportionate risk at time (t) such that

$$h(t) = h_0(t) \times exp(b_1x_1 + b_2x_2 + \ldots + b_ix_i)$$

where $h(t)$ represents that hazard at a given time point which is equal to the initial or baseline hazard at time 0:00 ($h_0(t)$) multiplied by e (the base of the natural logarithm) to the power of the additive relationship between each covariate (x_i) multiplied by its associated coefficient (b_i).

From the above equation, the relative impact of an operational parameter on the rate of passage success is represented by its associated coefficient. The hazard ratio of a given operational parameter is calculated by exponentiating the coefficient of a given parameter, which represents that multiplicative impact of that parameter. It is important to note that exponentiating these coefficients makes the value relative to a value of 1 (e^0), which represents a baseline of no hazard. For example, if the hazard ratio is greater than 1, e.g., 1.5, that will be interpreted as that covariate increasing the risk of passage failure by a factor of 1.5. Alternatively stated, a hazard ratio of 1.5 indicates that the associated covariate increases the risk by 50% as it is 0.5 greater than 1. In contrast, a hazard ratio below 1, e.g., 0.75, indicates that the associated covariate reduces the risk of passage failure by a factor of 0.75, or 25%. In short, a hazard ratio >1 indicates an increase in the risk of passage failure, a hazard ratio of 1 indicates no significant directional effect on passage, and a hazard ratio <1 indicates a reduction in the risk of passage failure.

4.5.2.2 Model Evaluation and Selection

As is the case with any statistical model, the type of model selected makes inherent assumptions about the nature of the data being modelled. The primary assumption of a Cox proportional hazard model is that the hazards are proportional. However, this assumption is not always appropriate for the data. As a result, the *cox.zph()* function was used during this assessment to assess the validity of the proportional hazard assumption. This function assessed scaled Schoenfield residuals to evaluate whether Cox regression residuals of each covariate in addition to the model as a whole are independent of time. In the event that the Schoenfield residuals are not independent of time, it can be said that the assumption of proportional hazards is violated and a Cox proportional hazards model may be misrepresentative of the true relationships between the selected covariates and passage success.

4.5.2.3 Event Definition

To evaluate the impact of operational parameters on passage success, instances of passage success and failure required definition and represent the 'events' (or passage attempts) in this analysis. Ostensibly, the transmitters deployed during this study should transmit a signal that when within range of a particular receiver will be detected every 2.0 seconds. However, various sources of outside noise or areas of poor coverage due to structures, etc. introduce variation into the frequency of detection for a unique transmitter's signal. Given that different site locations and receiver types are subject to varying degrees of ambient noise, the duration between successive detections was calculated for each tagged individual at each receiver location. A threshold interval for determining continued presence of a transmitter within the detection zone of a specific receiver was identified as the 95th percentile of the observed set of interval durations. This value was calculated at 14.5 minutes for Station 26 and 25.2 seconds for Station 30. These two threshold values were then used to delineate when each event was started and completed for a tagged individual. The lengthier threshold value at Station 26 was likely a function of multiple entrances and exits of radio-tagged juveniles from the relatively limited detection zone (receiver was adjusted to only provide coverage in area immediately upstream of the Pawtucket Gatehouse). The departure of a radio-tagged individual from the detection zone of a particular receiver was determined when the time interval between successive detections exceeded the specific threshold interval for that zone.

From this, a passage failure event (assigned a value of 0) was defined as any duration where all detections lay within the 95th percentile of durations for all individuals at that site. Passage failure represents events in which a tagged individual enters the field of detection at a given site without passing to the next site (i.e., moving downstream) in the system. A passage success event (assigned a status of 1) was defined using the final instance of detection for a tagged individual at a singular site where that tagged individual was next detected at a downstream receiver (i.e., successfully passed). Passage success/failure (1/0) was used as the status coinciding with time in the Cox proportional hazard models. After defining passage events for every individual, the time duration for the regression was defined as the duration from one event to the next.

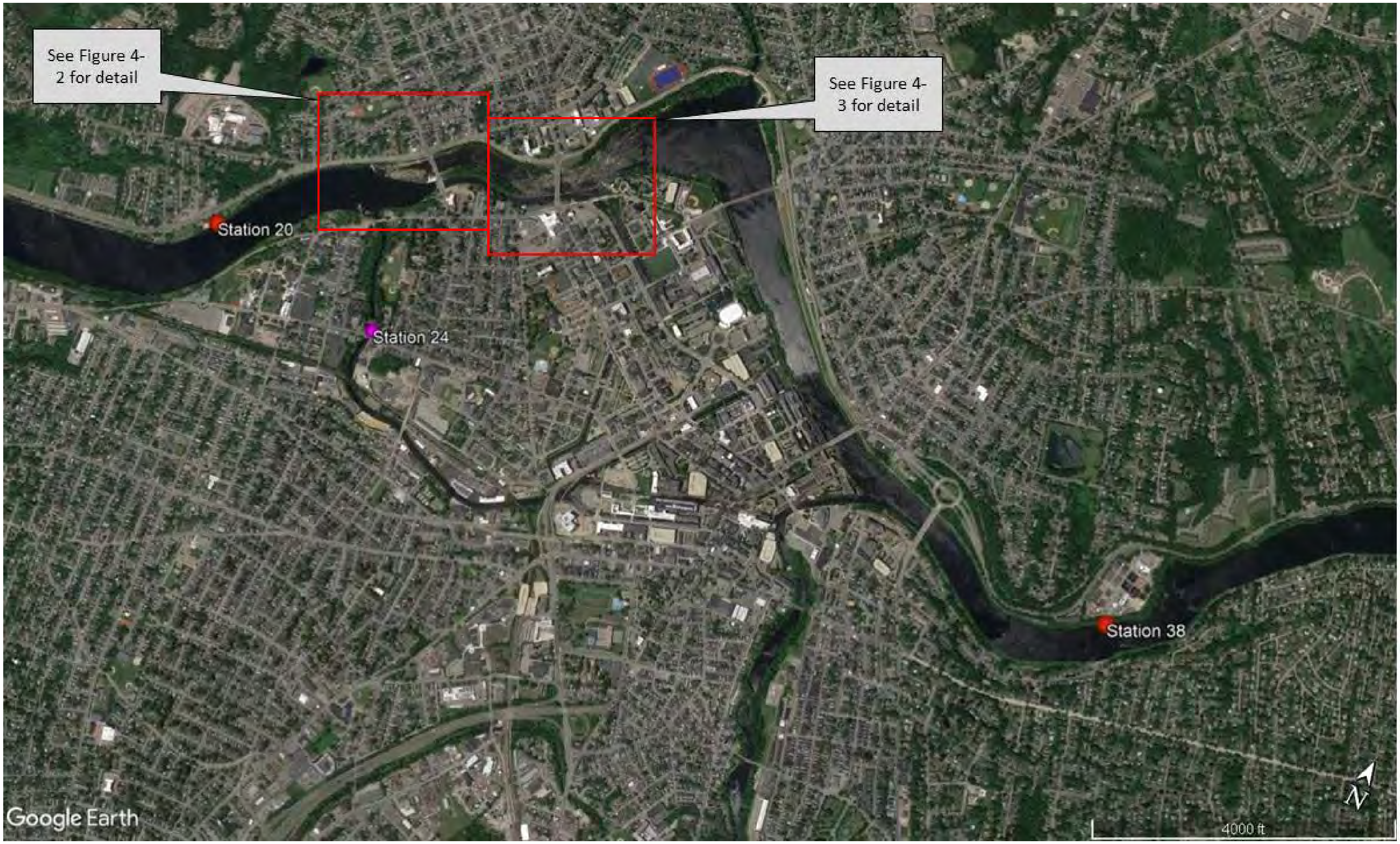

Figure 4–1. Locations and approximate detection areas for stationary radio-telemetry receivers installed during the 2019 juvenile alosine downstream passage assessment.

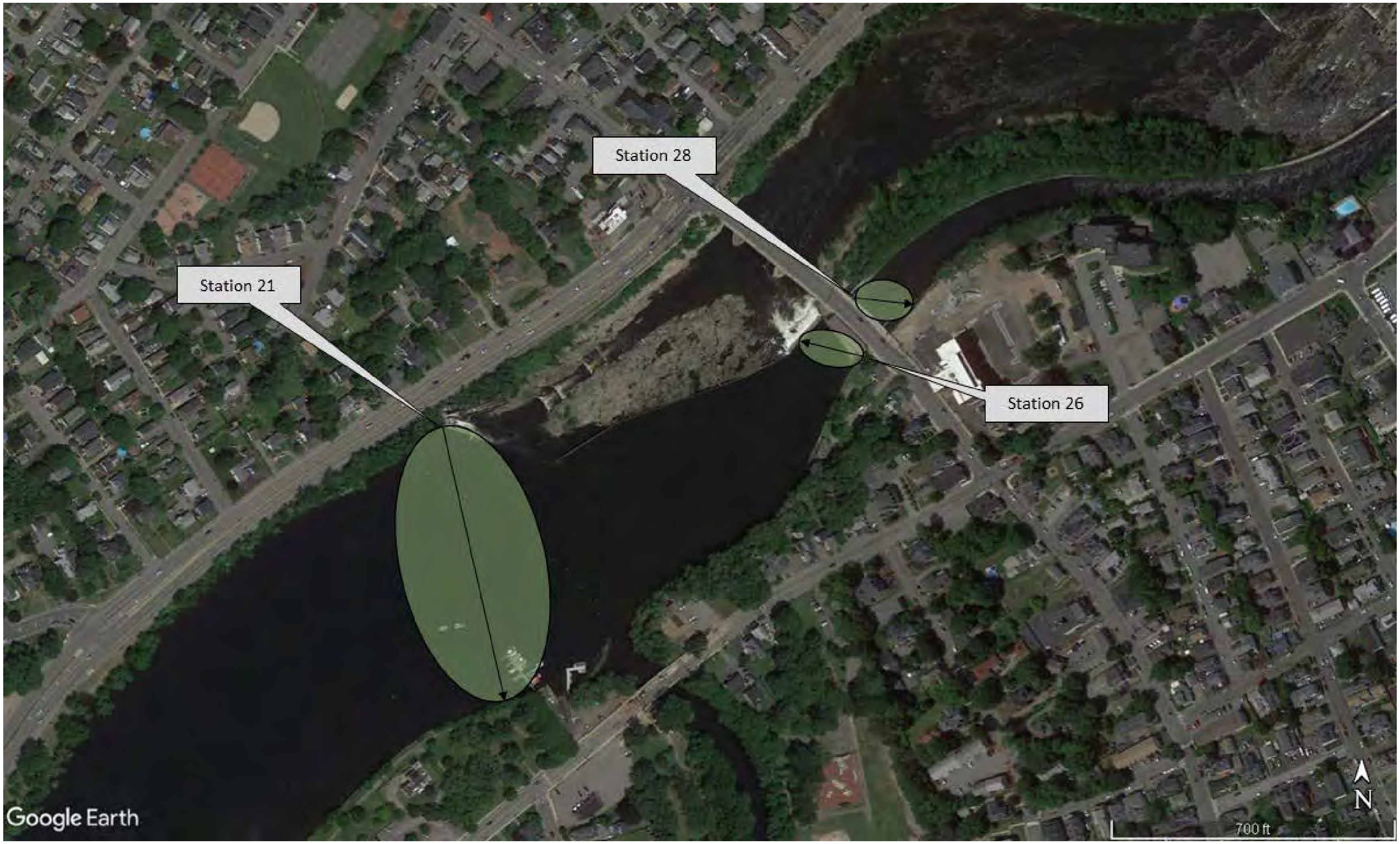

Figure 4–2. Locations and approximate detection areas for stationary radio-telemetry receivers installed upstream of Pawtucket Dam and at the Northern Gatehouse during the 2019 juvenile alosine downstream passage assessment at Lowell.

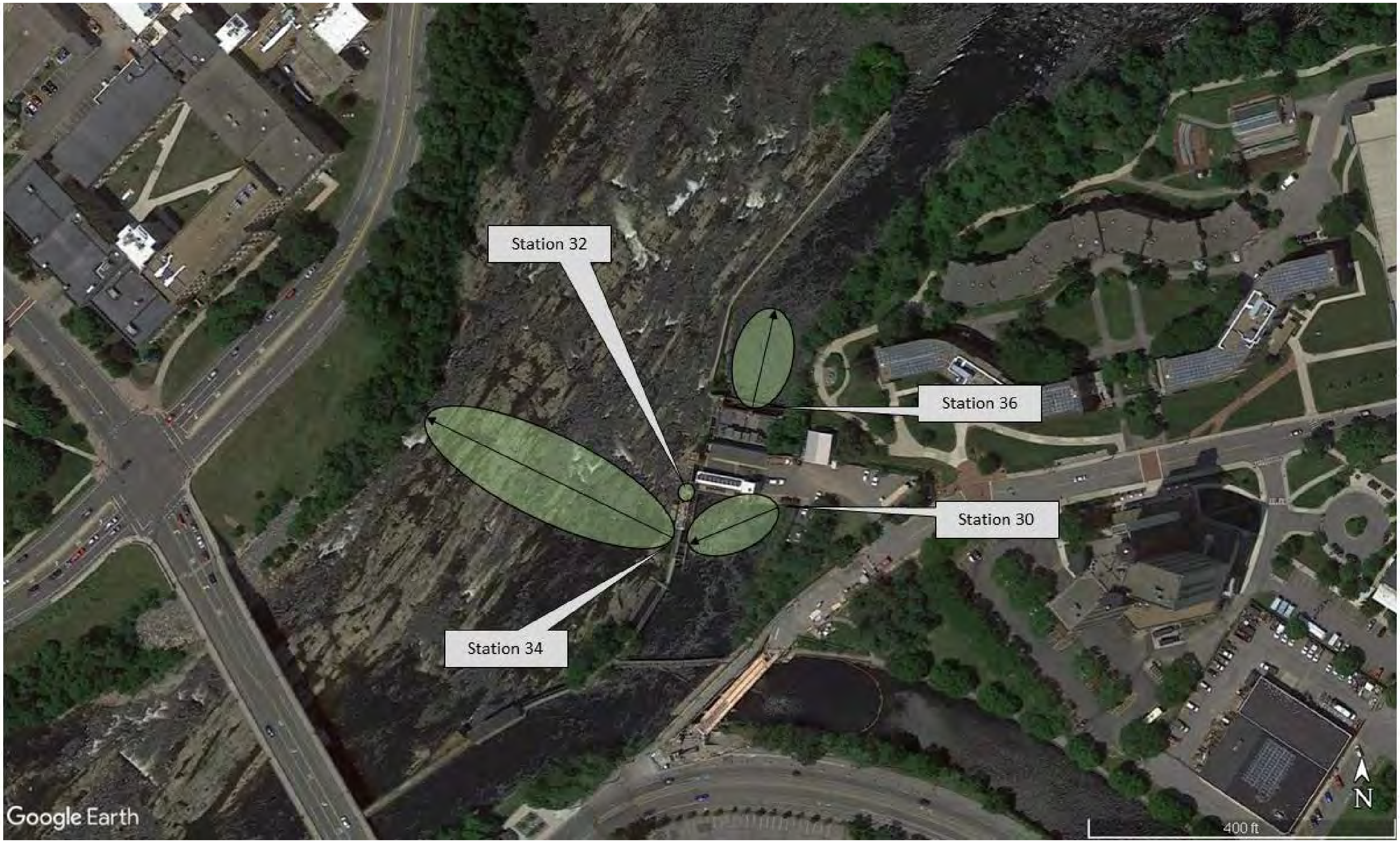

Figure 4–3. Locations and approximate detection areas for stationary radio-telemetry receivers installed in the vicinity of the E.L. Field Powerhouse during the 2019 juvenile alosine downstream passage assessment at Lowell.

Figure 4–4. Externally radio-tagged juvenile alosine showing relative position of transmitter attachment.

5 Results

5.1 Merrimack River Conditions and Lowell Project Operations

Figure 5-1 presents the Merrimack River flow and water temperature for the period of time from the first alosine release on October 9 until the end of the monitoring period on November 12, 2019. Merrimack River water temperature at the Project ranged from 16°C to 6°C during the monitoring period. Total river flow values represent the reported inflow at the Lowell Project and ranged between 1,089 and 11,435 cfs during the fall monitoring period. Figure 5-2 presents the monthly flow duration curves prepared for Lowell during the development of the Preliminary Application Document. The median flow condition at the Project is approximately 3,600 cfs during October and 6,500 cfs during November. Merrimack River conditions have a ~20% probability during October and a ~38% probability during November to exceed the ~8,000 cfs capacity of the E.L. Field powerhouse.

Table 5-1 summarizes the percentage of inflow records from the 2019 study period categorized by volume (to the nearest 1,000 cfs) as well as the percentage of time that each volume category is historically exceeded[1]. To help characterize the 2019 passage season, monthly exceedance probabilities less than 0.35 were classified as "high" flow conditions, 0.35 to 0.65 were classified as "normal" flow conditions, and greater than 0.65 were classified as "low" flow conditions. Inflows at the Project for the period October 9 through 31 were representative of high flow conditions (i.e., those with a probability of exceedance of less than 0.35) for 35% of the period, normal flow conditions (i.e., those with a probability of exceedance of 0.35-0.65) for 29% of the time and low flow conditions (i.e., those with a probability of exceedance of greater than 0.65) for 36% of the time. For the month of November, inflows were representative of high flow conditions 19% of the time, normal flow conditions 30% of the time and low flow conditions 51% of the time.

Figure 5-3 summarizes the allocation of water among the E.L. Field powerhouse, bypassed reach, downstream fishway, and downtown canal system at Lowell. Turbine units were in operation at the E.L. Field powerhouse for the duration of the study period with Unit 1 in operation throughout the study and Unit 2 coming online at 0900 on October 16. The downstream bypass was operated throughout the study period, passing approximately 130 cfs. A major spill event, associated with increases in river flows, occurred during the monitoring period. The event occurred from approximately October 29 to November 5, towards the end of the monitoring period. Flows to the downstream canal system represented between 15-20% of the 2,000 cfs canal capacity during October and 20% of the 2,000 cfs canal capacity for the majority of monitoring during early November. Due to overriding safety concerns, Boott limited operation of the turbine units within the downtown canal system during the study period. To the extent possible, Boott's operations staff attempted to operate the canal system as if there were canal units available, by opening gates when river flows exceeded the hydraulic

[1] Estimates of monthly exceedance estimated from monthly flow duration curves provided in Appendix H of the PAD.

capacity of the E.L. Field turbines (7,000 to 8,000 cfs). As a result, flows through the downtown canal system were largely restricted to passage via open gates. The Licensee manually recorded gate and unit settings once weekly during the study period within the downtown canal system. A breakdown of those values and related discharge estimates are provided in Appendix A.

Table 5–1. Frequency of occurrence of river inflow at Lowell (to nearest 1,000 cfs) during 2019 juvenile alosine downstream passage assessment and corresponding percentage of time flows are historically exceeded.

	October 9-31, 2019		November 1-12, 2019	
River Flow (Nearest 1k)	Percentage of Month	Percentage of Time Historically Exceeded	Percentage of Month	Percentage of Time Historically Exceeded
1000	16.1%	90	-	> 95
2000	19.4%	85	-	> 95
3000	6.0%	60	-	88
4000	22.6%	45	14.5%	78
5000	12.7%	34	36.6%	66
6000	9.4%	27	11.1%	55
7000	6.2%	23	12.8%	45
8000	4.2%	19	6.6%	38
9000	3.1%	16	4.8%	30
10000	0.4%	14	3.5%	25
11000	-	<5	10.4%	5
12000	-	<5	-	<5
13000	-	<5	-	<5

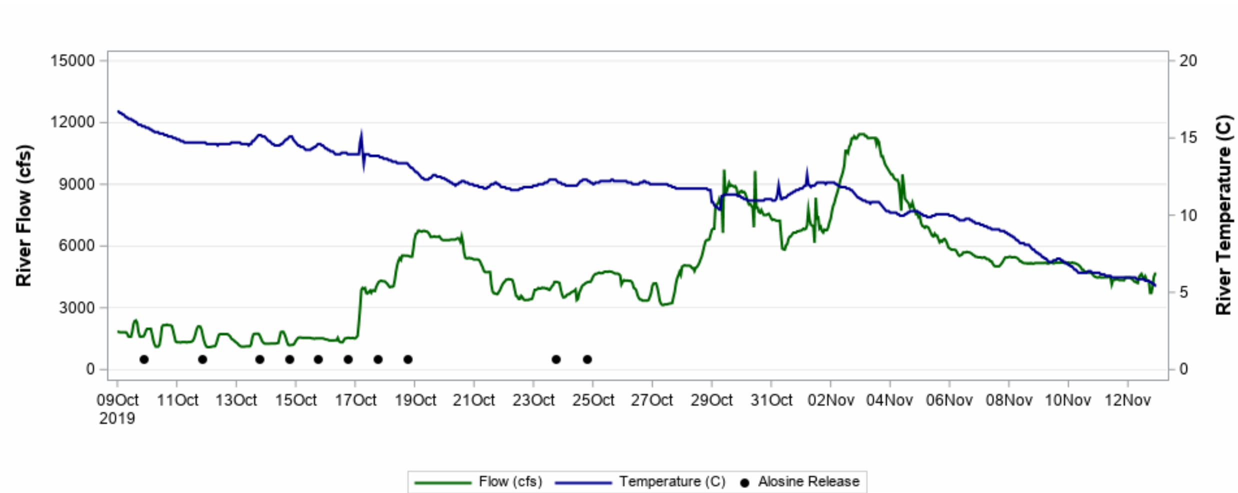

Figure 5–1. Merrimack River flow and water temperature at Lowell for the period October 9 to November 12, 2019.

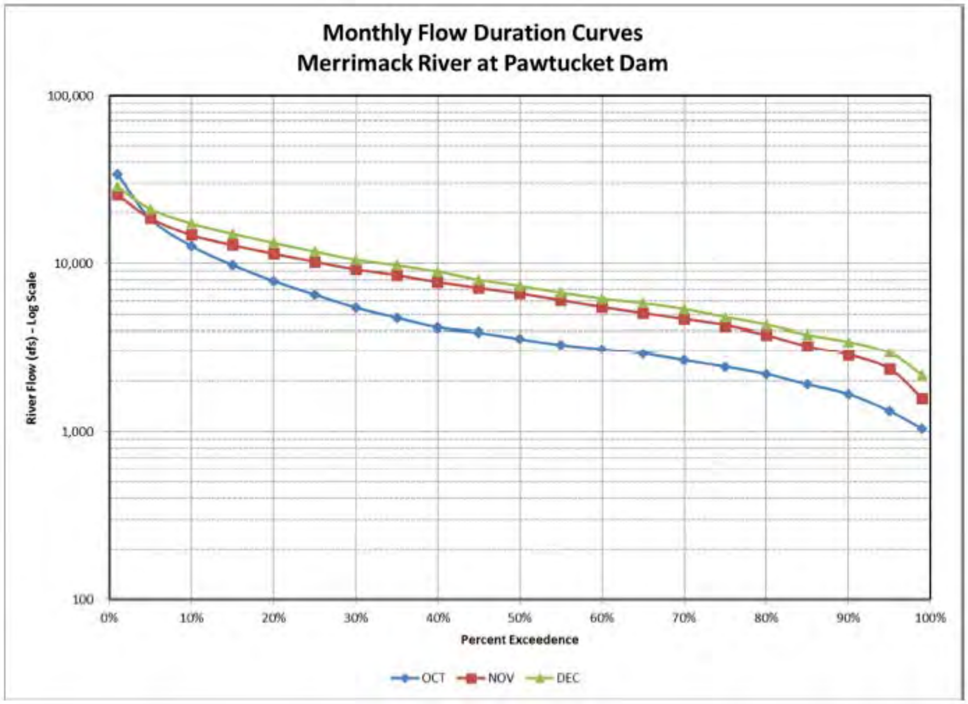

Figure 5–2. Flow duration curves for the months of October, November and December at the Lowell hydroelectric project.

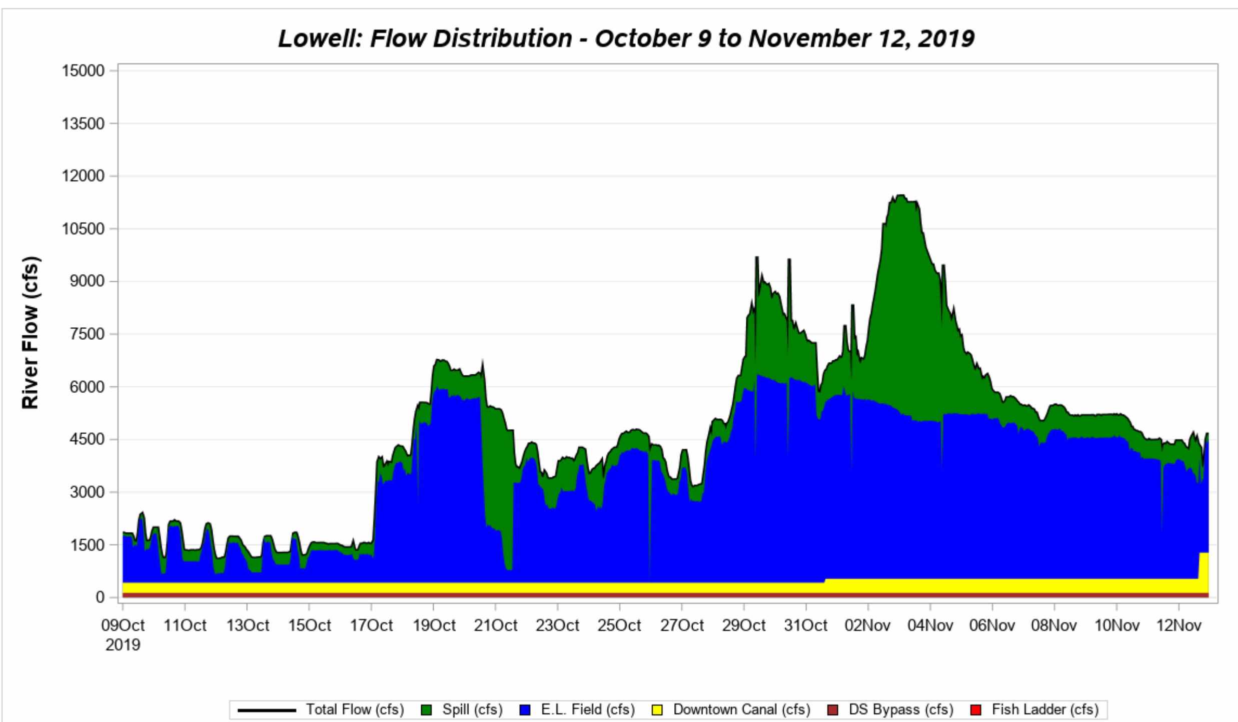

Figure 5–3. Total, spill, E.L. Field, downstream bypass and downstream canal system flow (cfs) for the period October 9 to November 12, 2019.

5.2 Monitoring Station Functionality

Radio-tagged juvenile alosines were released into the Merrimack River beginning in early October, 2019 and the RSP called for continuous monitoring at each stationary receiver location for 14 days after the final release of tagged fish. Figure 5-4 provides an overview of the continuity of monitoring at each of the ten stationary receiver locations during the fall period from the date of first release until November 12, 2019. The majority of the radio-telemetry monitoring stations installed to evaluate passage at Lowell during the fall study operated without issue for the full period.

Interruptions in continuous coverage were observed at two locations during the latter part of the 2019 monitoring period. These locations included Station 28 (downstream side of the Pawtucket Gatehouse) from 1900 on November 9 through the end of the monitoring period at Station 38 (receiver downstream of Lowell) from 0000 on November 5 to 1300 on November 7. There were no radio-tagged juvenile alosines which approached the Pawtucket Gatehouse after October 25 nor any downstream passage events for radio-tagged individuals after October 31. The late-season timing of these relatively short interruptions in coverage likely eliminated any potential impacts to the study results for monitoring juvenile alosine passage.

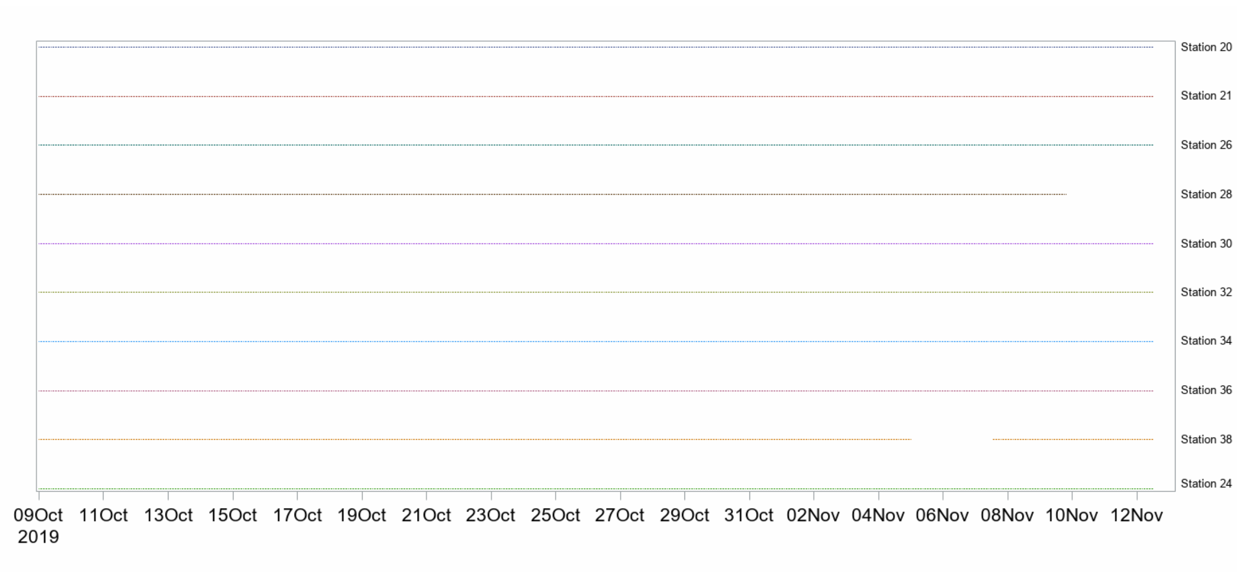

Figure 5–4. Operational coverage for telemetry receivers at Lowell during the juvenile alosine downstream passage assessment, October 9 to November 12, 2019.

5.3 Juvenile Alosine Tagging and Releases

Juvenile alosines were radio-tagged and released approximately 1.0 mile upstream of the Pawtucket Gatehouse starting on October 9 and ending on October 24. Table 5-2 provides a summary of the release dates and number of individuals released during the 2019 passage assessment. A total of 145 radio-tagged juvenile alosines were released over a span of 16 days and were potentially available for evaluation of downstream passage at Lowell. All test fish originated from Turtletown Pond in Concord, NH and were released with an equal number of untagged fish to promote schooling behavior. Fish tagged and released upstream of Lowell as part of the fall downstream passage evaluation ranged in length from 116 to 155 mm TL with a mean length of 134 mm. The majority of test fish (90%) measured between 125-144 mm. Mean length among release groups were similar across all ten release dates. A full listing of individuals radio-tagged and released as a part of this evaluation is included in Appendix B.

5.4 Project Arrival and Upstream Residence Duration

Releases of radio-tagged juvenile alosines were initiated on October 9, 2019. The distribution of arrival dates for radio-tagged alosines at the Pawtucket Dam as indicated by detection at Station 21 is provided in Figure 5-5. Initial detections for tagged alosines were recorded over a range of dates from October 9 through October 25 with all radio-tagged fish which successfully transited the approach reach doing so within a day or two of release.

Upstream residence (i.e., the duration of time radio-tagged individuals were present upstream of the Pawtucket Dam as determined for all individuals which approached and eventually passed downstream) was calculated as the duration of time from initial detection at Station 21 until confirmed downstream passage. When all individuals are considered, the upstream residence duration for radio-tagged juvenile alosines ranged between 0.4 hours to 4.8 days (Table 5-3; Figure 5-6). The median duration of time spent immediately upstream of the dam structure was 1.3 days, ranging from 0.8 hours to 3.6 days when examined among the ten separate release dates. Of the radio-tagged juvenile alosines which approached Pawtucket Dam, 42% passed in less than 24 hours and 68% in less than 48 hours after initial detection.

Outmigrating juvenile alosines encountering the Pawtucket Dam can (1) pass through the Pawtucket Gatehouse and enter the power canal, (2) pass downstream over Pawtucket Dam via spill, or (3) enter the Pawtucket Canal and navigate downstream via the downtown canal system. The majority of radio-tagged juvenile alosines were determined to have passed through the Pawtucket Gatehouse and entered the Northern Canal to approach the E.L. Field powerhouse. The duration of time required to pass through the Pawtucket Gatehouse was evaluated as the difference in time of the initial detection for each individual radio-tagged juvenile at Stations 26 and 28 which independently monitored the upstream and downstream sides of that structure. The median duration of time for radio-tagged juvenile alosines to pass downstream of the Pawtucket Gatehouse following their approach at that structure was 0.1 hours (range <0.1 hours to 0.4 hours; Table 5-4), indicating rapid passage at that structure.

Whereas passage of radio-tagged juvenile alosines through the Pawtucket Gatehouse structure occurred relatively rapidly, the transit time for those tagged individuals to pass downstream of the Project after entering into the Northern Canal ranged from 0.2 hours up to 4.7 days (median = 22.0 hours; Table 5-5). Of those individuals, 56% were resident in the power canal upstream of E.L. Field for 24 hours or less. The overall percentage of radio-tagged juvenile alosines departing the power canal within 48 hours of entry increased to 68%.

5.5 Downstream Passage

A total of 145 radio-tagged juvenile alosines were released upstream of the Pawtucket Dam during the fall of 2019. Three radio-tagged individuals (2% of total) did not approach the Pawtucket Dam following their initial release (as indicated by no detection at Station 21 or points further downstream). The final disposition of all tagged juveniles is presented in Table 5-6. Three radio-tagged juvenile alosines (2.1% of the total approaching the dam) were determined to have entered the downtown canal system as evidenced by detection at the Guard Locks (Station 24). The majority of individual passed downstream of the Project via spill over the Pawtucket Dam (9.2%) or entered the power canal and approached the E.L. Field Powerhouse to pass downstream via the downstream bypass (12.0%) or turbine units (57.7%). A portion of individuals (12.7% of the total approaching the dam) failed to pass downstream. Reasons for this may include transmitter loss, predation, other mortality, or failure to locate a viable passage route. A definitive passage route could not be determined for nine individuals and as a result those fish were classified as unknown.

Radio-tagged alosines were detected passing downstream between the dates of October 12 and October 31 (Figure 5-7) with a primary peak representing individuals associated with a number of release groups occurring on October 17-18. Passage events on the dates of October 17 and 18 represented 37.3% of the passage observed for radio-tagged juveniles during the study. Figure 5-8 presents the distribution of downstream passage events on an hourly basis. Passage occurred at almost all hours of the day with the highest passage rate occurring during the 1600 hour (10.7%). Overall passage was fairly uniform with 52% of detected events occurring between the hours of 1700 and 0500 and 48% between the hours of 0600 to 1600.

5.6 Downstream Transit

A single monitoring station was installed downstream of Lowell for the purpose of detecting radio-tagged juvenile alosines following passage at the Project. That receiver (Station 38) was located approximately 2.1 miles downstream of the project. The minimum, maximum, and quartile transit times through that reach are presented in Table 5-7 and Figure 5-9. The median transit time durations for tagged juvenile alosines moving downstream of Lowell was 6.2 hours (range = 1.0 hours to 1.8 days) for the 2.1 mile downstream reach.

5.7 Proportional Hazard

A total of 145 Pawtucket Gatehouse and 126 E.L. Field Powerhouse forebay events were defined based on recorded detections of juvenile alosines during the 2019 study to evaluate the impact of operational parameters on passage success. The median event duration recorded for radio-tagged juvenile alosines was 4.6 minutes for individuals in the detection field of Station 26 immediately upstream of the Pawtucket Gatehouse and 47 seconds for individuals in the detection field of Station 30 covering the area immediately upstream of the intakes to the downstream bypass and turbine units at the E.L. Field Powerhouse.

5.7.1 Pawtucket Gatehouse

The Pawtucket Gatehouse model failed to meet the criteria necessary to accept the assumption that hazards are proportional (Table 5-9). The water temperature and inflow parameters are not independent of time in this scenario ($p < 0.05$), which means these values may misrepresent the true nature of the relationships with passage success/failure. In addition, the full model also has a p-value less than 0.05, which suggests it may be misrepresenting or masking the relationships between operational variables and rate of passage for juvenile alosines at the Pawtucket Gatehouse. Although results of the Cox proportional hazard model for the Pawtucket Gatehouse are provided in Table 5-8 and illustrated in Figure 5-10, they were not evaluated due to the lack of significance for the full model.

5.7.2 E.L. Field Powerhouse

Results of the Cox proportional hazards model for E.L. Field forebay events suggest a positive relationship between water temperature and the forebay-tailrace head differential versus passage success, decreasing the probability of passage failure by 8% and 7%, respectively (Table 5-10). Despite these marginal impacts, neither water temperature nor the forebay-tailrace head differential were found to be statistically significant in this model. In order to make sure the data met the assumption of proportional hazards and ensure the use of an appropriate modelling framework, inflow and spill were maintained as continuous variables (Table 5-10). Both spill and inflow were found to be insignificant variables with no measurable impact on passage success in the forebay. The only operational variable with a statistically significant impact on the probability of passage failure to depart the E.L Field forebay was combined turbine discharge, which was split into three bins: 592-1980 cfs (i.e., low), 1980-3950 cfs (i.e., mid), and 3950-5930 cfs (i.e., high). As illustrated in Figure 5-11, the low generation condition was used as a reference for the mid and high generation conditions. Results suggest a strong, statistically significant interaction between the mid and high generation conditions in relation to passage failure from the E.L. Field forebay. Mid-levels of turbine discharge (1980 and 3950 cfs) increased the probability of passage failure from the E.L. Field forebay by 605%, while high levels of turbine discharge (3950-5930 cfs) increased the probability of passage failure from the E.L. Field forebay by 2223%. The E.L. Field forebay model achieved the criteria necessary to accept the assumption that hazards are proportional (Table 5-11).

5.8 Manual Tracking

In addition to the continuous monitoring provided by the 10 stationary receivers installed throughout the Project area for duration from early October through mid-November 2019, a total of 21 manual detections representing 13 individuals were recorded between October 21 and November 7. Manual tracking for radio-tagged juvenile alosines was most effective via foot and in the vicinity of Project structures (i.e., bypassed reach, tailrace, Northern Canal/forebay).

Appendix C contains a listing of manual detections identified to those relative locations and classified as “Transit” for individuals which were subsequently detected at stationary receivers downstream of their manually determined position or “Stationary” for individuals which were not detected again at stationary receivers downstream of their manually determined position(s). The majority of detections were classified as stationary as indicated by a lack of future downstream detections. Two individuals were detected within the Northern Canal downstream of the Pawtucket Gatehouse prior to their eventual downstream passage at the Project (as determined by the stationary receiver data).

Table 5–2. Release date and number of radio-tagged juvenile alosines released upstream of the Pawtucket Dam during the downstream passage assessment, October 9 through November 12, 2019.

	Release Date									
	Oct. 9	Oct. 11	Oct. 13	Oct. 14	Oct. 15	Oct. 16	Oct. 17	Oct. 18	Oct. 23	Oct. 24
Number Released	15	15	14	15	15	15	15	15	15	11
Release Time	20:27	20:04	19:33	18:52	18:15	18:12	17:53	17:58	18:18	18:45
Minimum Length (mm)	123	123	125	125	124	123	122	123	116	126
Maximum Length (mm)	138	144	145	142	147	144	143	146	143	155
Mean Length (mm)	133	131	134	135	134	134	132	137	134	137

Table 5–3. Minimum, maximum, and quartile values of upstream residence duration (hours) for radio-tagged juvenile alosines released upstream of the Pawtucket Dam during the fall 2019 downstream passage assessment.

Release Date	Upstream Residence Duration (Hours)				
	Minimum	Maximum	Q25	Q50 (Median)	Q75
9-Oct	50.6	113.4	74.5	86.7	111.0
11-Oct	37.5	67.9	39.9	45.4	62.3
13-Oct	18.5	114.7	19.1	19.6	71.8
14-Oct	52.2	63.5	52.8	54.2	60.0
15-Oct	29.7	68.2	30.4	33.0	60.6
16-Oct	7.5	45.8	26.1	38.9	40.9
17-Oct	0.9	23.0	7.5	12.7	21.5
18-Oct	0.4	8.2	0.4	0.8	4.4
23-Oct	0.7	23.2	0.8	0.9	12.4
24-Oct	0.9	25.3	0.9	5.1	17.2
All	0.4	114.7	7.9	30.5	54.1

Table 5–4. Minimum, maximum, and quartile values of time to pass the Pawtucket Gatehouse and enter Northern Canal (hours) for radio-tagged juvenile alosines released upstream of the Pawtucket Dam during the fall 2019 downstream passage assessment.

Release Date	Pawtucket Gatehouse Passage (Hours)				
	Minimum	Maximum	Q25	Q50 (Median)	Q75
9-Oct	< 0.1	0.3	0.1	0.1	0.2
11-Oct	< 0.1	0.2	0.1	0.1	0.2
13-Oct	< 0.1	0.2	0.1	0.1	0.1
14-Oct	< 0.1	0.1	< 0.1	< 0.1	0.1
15-Oct	< 0.1	0.2	0.1	0.1	0.2
16-Oct	0.1	0.2	0.1	0.1	0.1
17-Oct	0.1	0.2	0.1	0.1	0.2
18-Oct	< 0.1	0.6	0.1	0.1	0.3
23-Oct	0.1	0.3	0.1	0.1	0.2
24-Oct	0.1	0.4	0.2	0.2	0.3
All	< 0.1	0.4	0.1	0.1	0.2

Table 5–5. Minimum, maximum, and quartile values of residence time within Northern Canal (hours) for radio-tagged juvenile alosines released upstream of the Pawtucket Dam during the fall 2019 downstream passage assessment.

Release Date	Northern Canal Residence (Hours)				
	Minimum	Maximum	Q25	Q50 (Median)	Q75
9-Oct	31.8	151.0	50.0	77.0	100.7
11-Oct	19.3	66.9	25.2	36.4	51.9
13-Oct	12.7	105.4	17.3	18.8	71.3
14-Oct	39.5	62.5	51.5	53.5	62.5
15-Oct	23.9	24.0	23.9	24.0	24.0
16-Oct	17.9	22.4	20.0	22.0	22.2
17-Oct	0.2	21.9	0.9	10.6	12.3
18-Oct	0.2	8.0	0.2	0.8	5.0
23-Oct	0.3	0.5	0.4	0.4	0.5
24-Oct	0.3	25.1	0.4	6.0	25.1
All	0.2	112.1	4.6	22.0	52.8

Table 5–6. Downstream passage route selection and percent utilization of route options after detection at Station 21 for radio-tagged juvenile alosines released upstream of Pawtucket Dam during the fall 2019 downstream passage assessment.

Release Date	Lowell Downstream Passage Route						
	Did not Detect	Did Not Pass	Downtown Canal System	Spill	Bypass	Turbine	Unknown
9-Oct	0	2	1	1	5	6	0
11-Oct	0	2	1	0	4	8	0
13-Oct	1	3	0	1	4	4	1
14-Oct	1	1	1	0	1	10	1
15-Oct	0	2	0	2	2	8	1
16-Oct	0	0	0	6	0	7	2
17-Oct	0	2	0	2	0	9	3
18-Oct	0	2	0	0	0	13	0
23-Oct	1	3	0	0	1	11	1
24-Oct	0	4	0	1	0	6	0
All	3	18	3	13	17	82	9
Percent Utilization		12.7%	2.1%	9.2%	12.0%	57.7%	6.3%

Table 5–7. Minimum, maximum, and quartile values of downstream transit time (hours) for radio-tagged juvenile alosines following passage at the Lowell project during the fall 2019 downstream passage assessment.

Release Date	Downstream Transit (Hours)				
	Minimum	Maximum	Q25	Q50 (Median)	Q75
9-Oct	3.0	18.0	4.9	7.2	8.3
11-Oct	3.7	42.2	4.8	6.1	9.7
13-Oct	2.6	24.6	5.5	7.4	17.7
14-Oct	1.5	14.8	5.5	9.5	13.9
15-Oct	1.6	15.0	7.5	12.2	13.9
16-Oct	2.6	14.6	3.6	4.4	12.0
17-Oct	1.6	10.6	1.9	3.0	10.0
18-Oct	1.0	17.3	1.3	2.0	3.6
23-Oct	1.7	9.9	2.7	3.0	7.4
24-Oct	3.0	13.5	3.0	12.3	13.5
All	1.0	42.2	2.9	6.2	11.4

Table 5–8. Results of the Cox proportional hazards model for juvenile alosine passage through Pawtucket Gatehouse. Significance is determined by p < 0.05.

Pawtucket Gatehouse										
Model: Time to Event ~ Temperature + Inflow + Spill										
Model Parameter	*b*	se	z	P-value	Significance	e^b	e^{-b}	Lower .95	Upper .95	Percent Change Failure
Temp	-0.93	0.08	-11.04	<0.001	Significant	0.4	2.53	0.34	0.47	↓ 60%
Inflow	0	0	-2.36	0.02	No Hazard	1	1	1	1	0
Spill 2080-4150 cfs	0.84	0.52	1.62	0.11	Insignificant	2.31	0.43	0.84	6.37	↑ 131%
Spill 4150-6240 cfs	2.57	1.14	2.26	0.02	Significant	13.05	0.08	1.4	121.28	↑ 1205%

Significance is determined by p < 0.05.

Table 5–9. Output of the Schoenfield residual test for time independence of covariates in Cox proportional hazard model of Pawtucket Gatehouse passage events.

Variable	Chi-squared	df	P-Value
Temperature (°C)	8.22	1	0
Inflow (cfs)	9.03	1	0
Spill (cfs)	4.23	2	0.12
Full Model	14.54	4	0.01

Note: p < 0.05 indicates a violation of the proportional hazard assumption.

Table 5–10. Results of the Cox proportional hazards model for juvenile alosine passage through E.L. Field Powerhouse forebay.

Forebay										
Model: Time to Event ~ Temperature + Combined Turbine cfs + Spill + Inflow + ELF Head										
Model Parameter	*b*	se	z	P-value	Significance	e^b	e^{-b}	Lower .95	Upper .95	Percent Change Failure
Temp	-0.08	0.16	-0.52	0.60	Insignificant	0.92	1.09	0.68	1.25	↓ 8%
Inflow	0	0	-1.62	0.11	No Hazard	1	1	1	1	0
Spill	0	0	1.16	0.25	No Hazard	1	1	1	1	0
Turbine CFS 1980-3950 cfs	1.8	0.53	3.40	<0.001	Significant	6.05	0.17	2.14	17.07	↑ 605%
Turbine CFS 3950-5930 cfs	3.15	0.88	3.58	<0.001	Significant	23.23	0.04	4.15	130.02	↑ 2223%
ELF Head	-0.08	0.07	-1.05	0.30	Insignificant	0.93	1.08	0.8	1.07	↓ 7%

Significance is determined by p < 0.05.

Table 5–11. Output of the Schoenfield Residual test for time independence of covariates in Cox proportional hazard model of E.L. Field Powerhouse forebay events.

Variable	Chi-squared	df	P-Value
Temperature (°C)	1.06	1	0.3
Inflow (cfs)	0	1	0.97
Spill (cfs)	0.21	1	0.64
Turbine Discharge (cfs)	0.41	2	0.81
ELF Head Differential (ft)	0.02	1	0.88
Full Model	5.85	6	0.44

Note: $p < 0.05$ indicates a violation of the proportional hazard assumption.

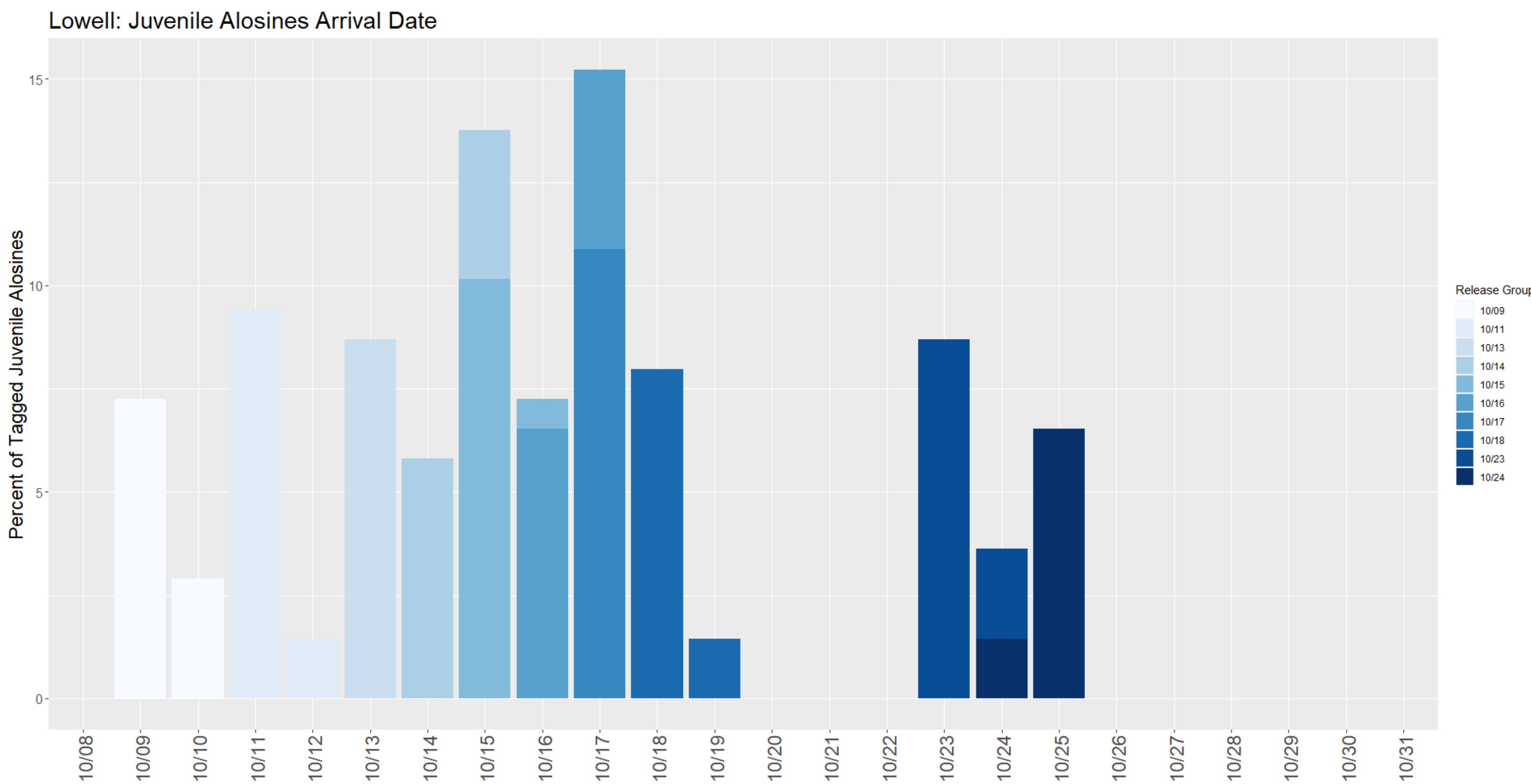

Figure 5–5. Distribution of Pawtucket Dam arrival dates for radio-tagged juvenile alosines released upstream of the Pawtucket Dam during the 2019 downstream passage assessment.

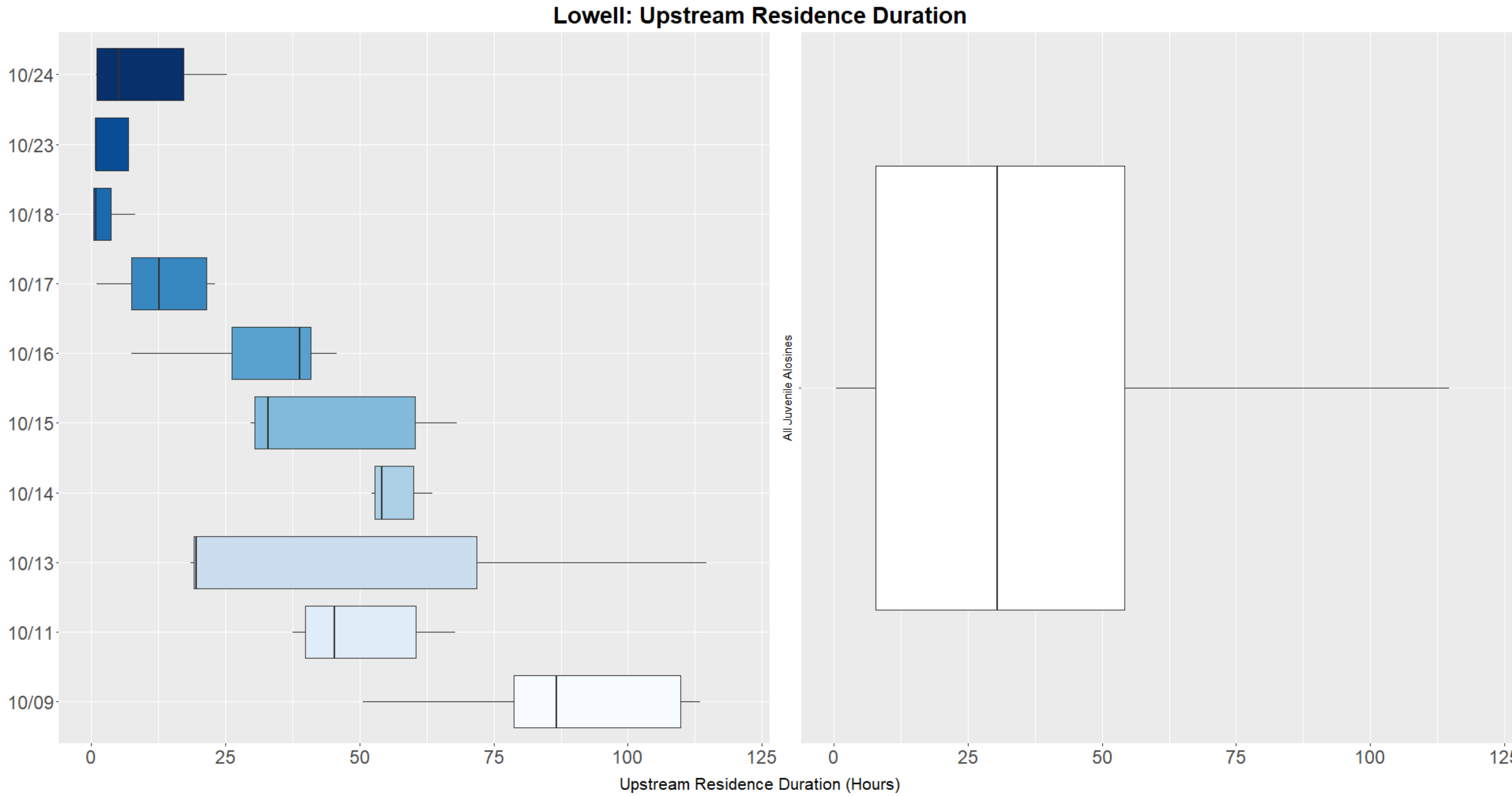

Figure 5–6. Box plot of upstream residence time for radio-tagged juvenile alosines passing downstream of Lowell during the 2019 downstream passage assessment. [2]

[2] The solid line represents the median while left and right portions of the box represent the first and third quartiles, respectively. Whiskers extend to the range of the data within the interquartile range (quartile*1.05) such that outliers outside of this range are not displayed.

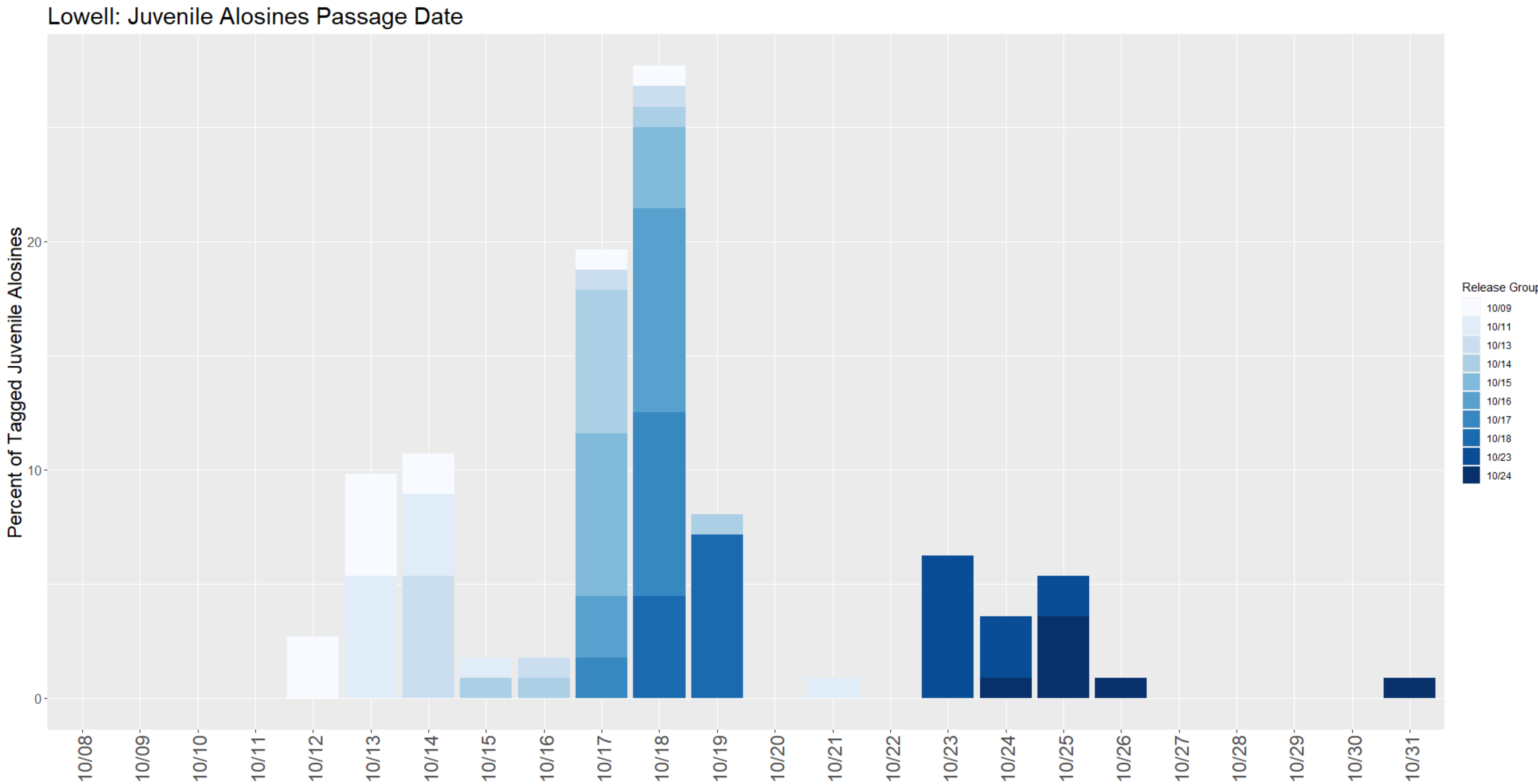

Figure 5–7. Distribution of Pawtucket Dam downstream passage dates for radio-tagged juvenile alosines during the 2019 downstream passage assessment.

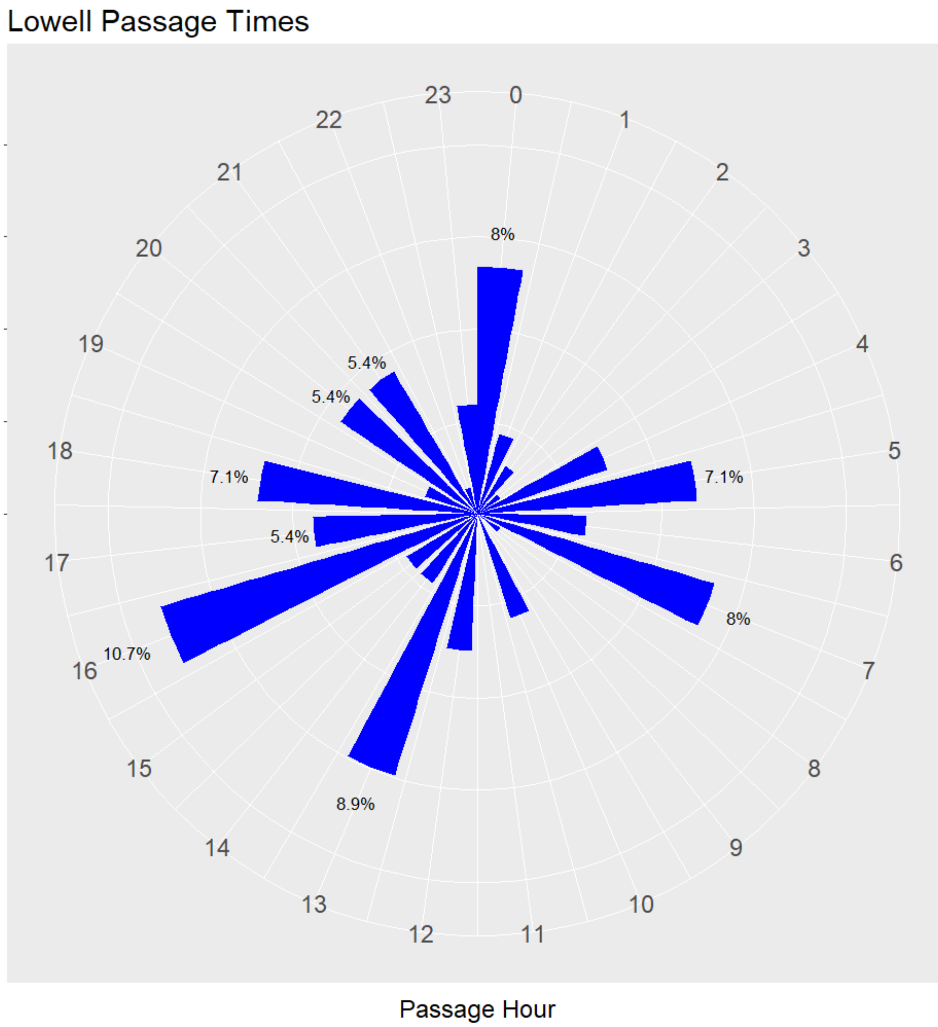

Figure 5–8. Distribution of downstream passage time for all radio-tagged juvenile alosine released upstream of Lowell during the 2019 downstream passage assessment.

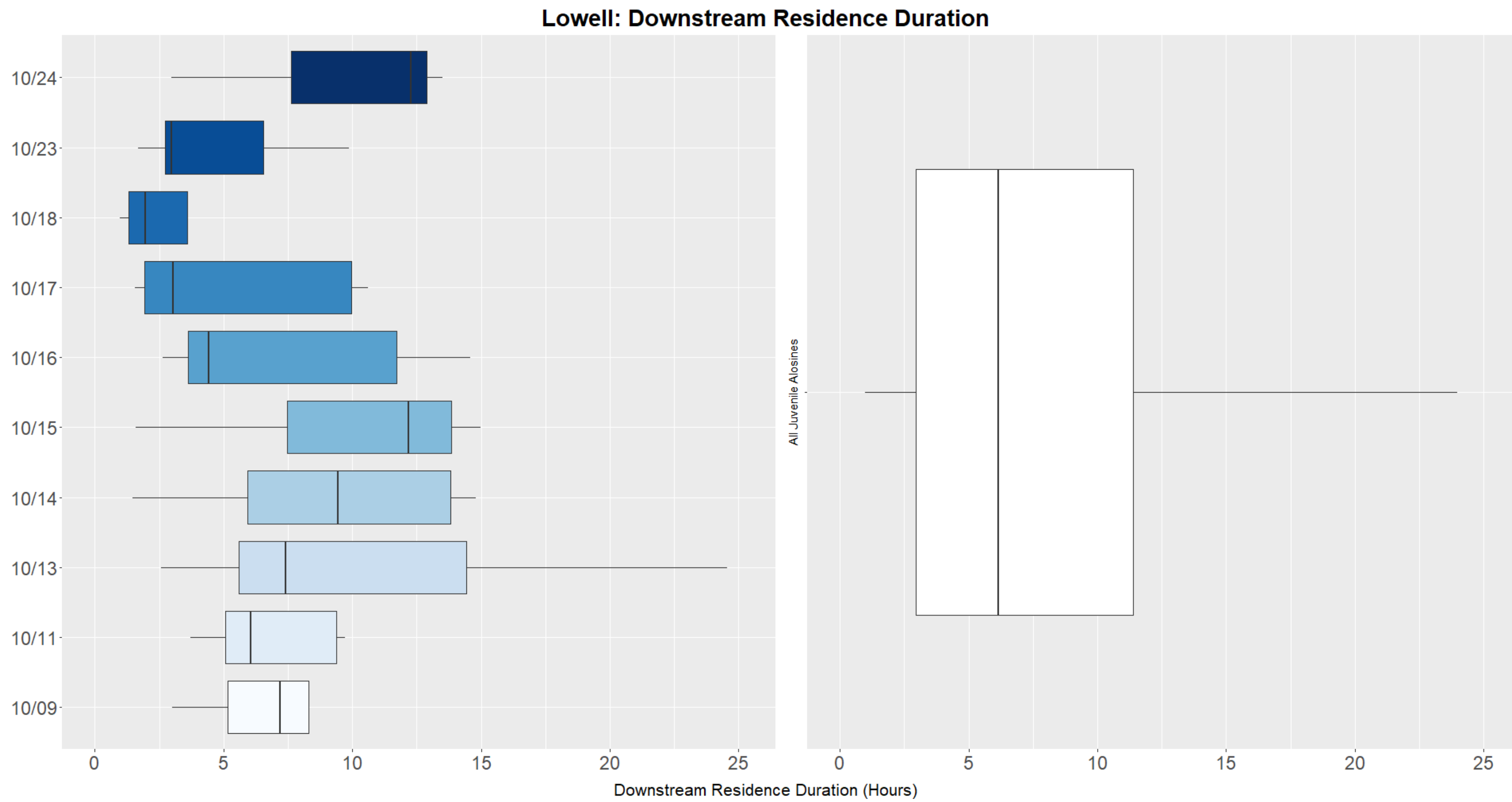

Figure 5–9. Box plot of downstream transit time for radio-tagged juvenile alosines following passage at Lowell during the 2019 downstream passage assessment. [3]

[3] The solid line represents the median while left and right portions of the box represent the first and third quartiles, respectively. Whiskers extend to the range of the data within the interquartile range (quartile*1.05) such that outliers outside of this range are not displayed.

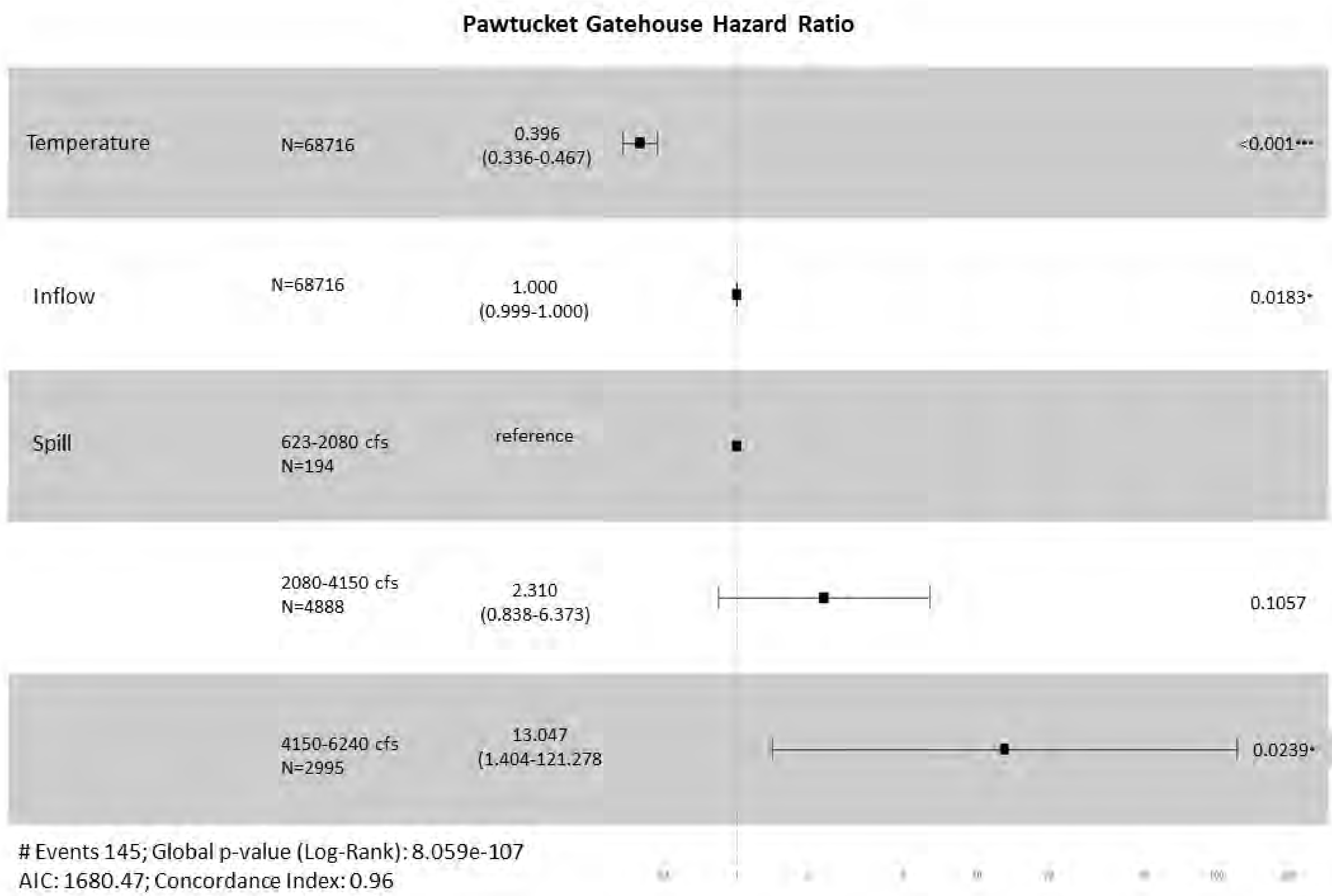

Figure 5–10. Cox proportional hazards model results for passage success of radio-tagged juvenile alosines at the Pawtucket Gatehouse.

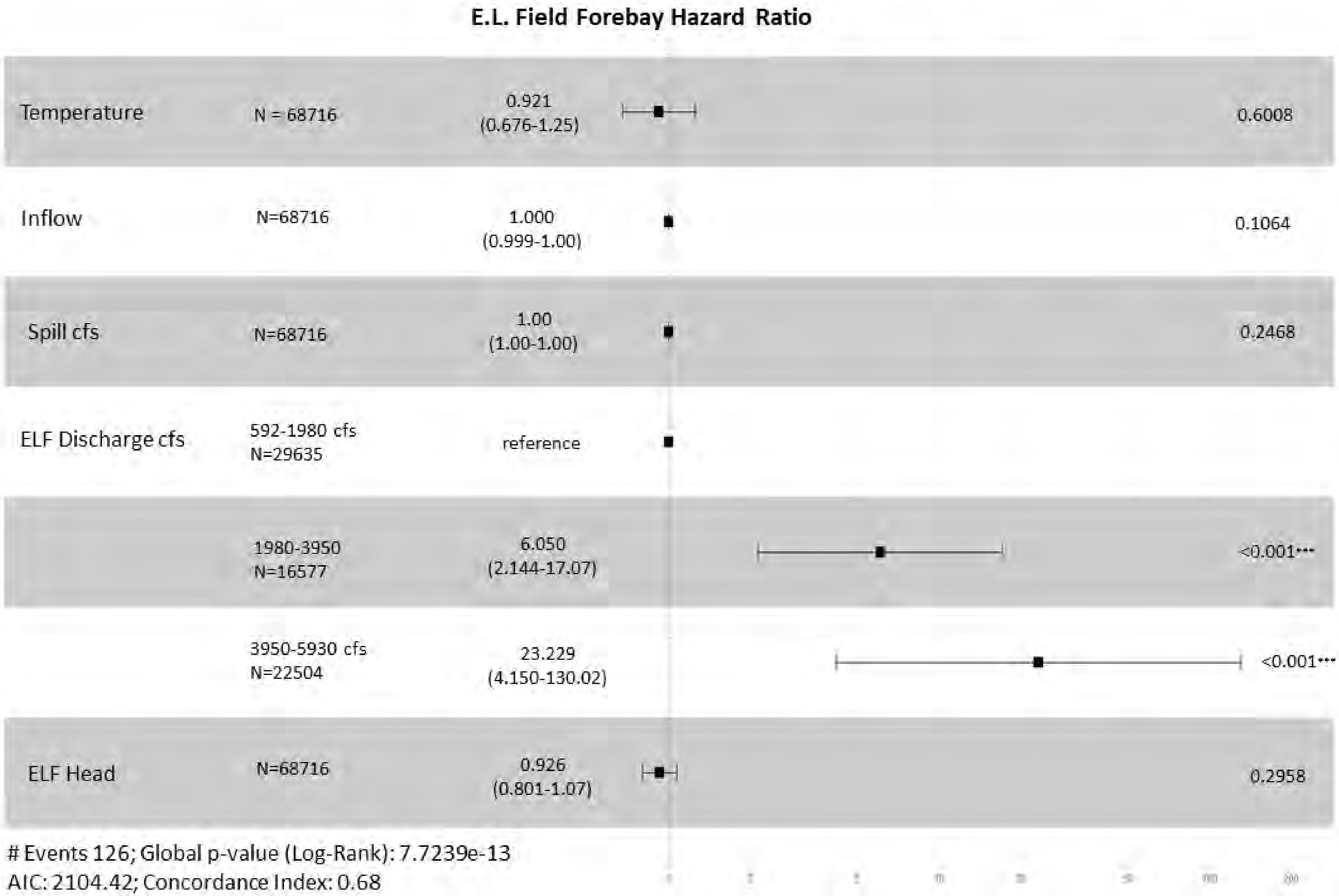

Figure 5–11. Cox proportional hazards model results for passage success of radio-tagged juvenile alosines at the E.L. Field Powerhouse forebay.

6 Summary

An evaluation of the potential impacts on the outmigration of juvenile alosines was conducted in support of the FERC relicensing of the Lowell Project on the Merrimack River. Downstream passage route utilization was evaluated using radio-telemetry during the 2019 fall migration season (October 9 to November 12, 2019). Monitoring of outmigrating juvenile alosines focused on the evaluation of the residence time immediately upstream of the Pawtucket Dam and prior to passage as well as passage route utilization at the Project.

A total of 145 juvenile alosines were tagged and released at mid-river locations approximately one mile upstream of the Pawtucket Gatehouse. Their subsequent downstream arrival and passage at the Project was monitored via a series of fixed-location telemetry receivers within the Lowell Project area. All of the juvenile alosines utilized for this study were collected from Turtletown Pond in Concord, New Hampshire and ranged in total length from 125-144 mm. Radio transmitters were bonded to small fish hooks and then externally affixed to each individual prior to their release. Releases of radio-tagged juveniles were spread over a 16 day period between October 9 and 24.

Upon initial detection at the Pawtucket Dam, the median duration of time spent immediately upstream of the dam structure was 1.3 days with 42% passing downstream within the first 24 hours of their initial detection. Closer examination of the total residence time for radio-tagged juvenile alosines indicated that all individuals determined to have entered the Northern Canal passed through the Pawtucket Gatehouse in less than 30 minutes. Upon entry into the Northern Canal, the median residence duration prior to downstream passage was longer (22.0 hours; range = 0.2 hours to 4.7 days). Nearly 70% of all downstream passage events for radio-tagged juvenile alosines occurred within 48 hours of initial detection in the E.L. Field forebay. The Cox proportional hazards model suggested a statistically significant interaction between the mid and high generation conditions in relation to passage failure from the E.L. Field forebay. The presence of higher generation flows increased the probability that a radio-tagged individual would approach downstream passage options in the power canal (i.e., turbines or downstream bypass) and reject the passage attempt relative to lower generation flows.

Outmigrating juvenile alosines encountering the Pawtucket Dam can (1) pass through the Pawtucket Gatehouse and enter the power canal, (2) pass downstream over Pawtucket Dam via spill, or (3) enter the Pawtucket Canal and navigate downstream via the downtown canal system. Individuals which enter the Northern Canal can subsequently pass downstream via one of the two turbine units at the E.L. Field Powerhouse, utilize the downstream bypass, or pass via the surge gate (operated only in the event of a station trip). During the 2019 evaluation the majority of radio-tagged individuals passed through the Pawtucket Gatehouse and approached the E.L. Field powerhouse. Of the individuals which approached the E.L. Field powerhouse and had a known downstream passage route, 83% eventually passed downstream via the turbine units[4]. Use of the existing downstream bypass system is estimated at 17%. The existing

[4] Note that downstream passage survival for juvenile alosines will be assessed as part of the desktop based *Fish Passage Survival Study*. Downstream passage survival was not estimated for radio-tagged juvenile alosines as part

downstream bypass at Lowell was last assessed for the effectiveness of passing juvenile alosines during 1994 and effectiveness was estimated at 37% during that study (Normandeau 1995). Only two percent of all radio-tagged juvenile alosines were determined to have entered the Pawtucket Canal and attempted downstream passage via the downtown canal system. Of the three individuals which entered the downtown canal system, one was determined to have exited the canal system and was detected downstream at Station 38.

7 Variances from FERC-Approved Study Plan

The FERC-approved RSP indicated that a total of 150 radio-tagged juvenile alosines. Five of the transmitters purchased for this study could not be activated. As a result, a total of 145 radio-tagged juvenile alosines were released and assessed for downstream passage at the Project. There were no additional variances from the FERC-approved study plan.

8 References

Castro-Santos, T. and R. Perry. 2012. Time-to-event analysis as a framework for quantifying fish passage performance. Pages 427-452 *in* N.S. Adams, J.W. Beeman, and J.H. Eiler, editors. Telemetry techniques: a user guide for fisheries research. American Fisheries Society, Bethesda, Maryland.

Normandeau Associates, Inc. (Normandeau). 1995. Use of the fish bypass by juvenile clupeids at the Lowell Hydroelectric Project during fall, 1994. Report Prepared for Consolidated Hydro, Inc.

R Core Team. (2020). R: A Language and Environment for Statistical Computing. Vienna, Austria.

of this assessment due to the uncertainty related to retention of externally mounted transmitters and the potential for negatively biasing a survival estimate due to loss of tags during the act of passage.

9 Appendices

Appendix A. Estimated weekly discharge values (cfs) for the Guard Locks, Swamp Locks, Hamilton Station, Section 8 Station, John Street Station, Boott Gate and Lower Locks.

BOOTT HYDROPOWER DOWNTOWN OPERATIONS: ESTIMATED FLOWS

Date	10/10/2019	10/17/2019	10/23/2019	10/31/2019	11/7/2019	11/12/2019
Time	900	1100	900	1445	1000	1530

Guard Locks						
Gate 1	197	197	197	246	246	529
Gate 2	128	128	128	0	0	0
Gate 3	0	0	0	0	0	0
Gate 4	0	0	0	0	0	176
Gate 5	0	0	0	197	197	441
Total	325	325	325	443	443	1145

Swamp Locks						
Gate 1	0	0	0	0	0	0
Gate 2	252	252	252	252	252	492
Bayboards opened	0	0	0	0	0	0
Total	252	252	252	252	252	492

Hamilton						
Unit 1	26	13	13	13	13	100
Unit 2	13	13	13	13	13	158
Unit 3	20	20	20	20	20	0
Unit 4	10	10	10	10	10	127
Unit 5	17	17	17	17	17	14
Hamilton Wasteway	0	0	0	0	0	0
Total	86	73	73	73	73	399

Section 8						
Unit 1	0	0	0	0	0	0
Unit 2	0	0	0	0	0	133
Unit 3	75	75	75	75	75	0
Total	75	75	75	75	75	133

John St.						
Unit 3	0	0	0	0	0	0
Unit 4	0	0	0	0	0	0
Unit 5	0	0	0	0	0	0
Unit 6	0	0	0	0	0	236
Total	0	0	0	0	0	236

Boott Gate						
Gate	0	0	0	0	0	0
Bayboards opened	0	0	0	0	0	0
Total	0	0	0	0	0	0

Lower Locks						
Gate	120	120	120	120	120	120
Bayboards opened	0	0	0	0	0	0
Total	120	120	120	120	120	120

Appendix B. Juvenile alosine tagging, release, and biocharacteristics information for the 2019 downstream passage assessment at Lowell.

Frequency	Tag ID	Total Length (mm)	Release Date	Release Bank
150.360	27	134	10/9/2019	East
150.360	28	132	10/9/2019	East
150.360	30	136	10/9/2019	East
150.380	80	135	10/9/2019	East
150.380	87	134	10/9/2019	East
150.600	113	138	10/9/2019	East
150.600	140	126	10/9/2019	East
150.600	159	136	10/9/2019	East
150.360	26	134	10/9/2019	West
150.360	29	134	10/9/2019	West
150.380	68	129	10/9/2019	West
150.380	81	131	10/9/2019	West
150.380	83	137	10/9/2019	West
150.600	137	123	10/9/2019	West
150.600	143	128	10/9/2019	West
150.360	11	132	10/11/2019	East
150.360	12	137	10/11/2019	East
150.360	13	126	10/11/2019	East
150.380	67	133	10/11/2019	East
150.380	89	132	10/11/2019	East
150.380	91	138	10/11/2019	East
150.600	117	130	10/11/2019	East
150.600	136	123	10/11/2019	East
150.360	14	144	10/11/2019	West
150.360	15	126	10/11/2019	West
150.380	62	124	10/11/2019	West
150.380	75	129	10/11/2019	West
150.600	126	138	10/11/2019	West
150.600	144	128	10/11/2019	West
150.600	147	128	10/11/2019	West
150.360	32	138	10/13/2019	East
150.360	37	133	10/13/2019	East
150.360	40	127	10/13/2019	East
150.360	78	138	10/13/2019	East
150.380	79	140	10/13/2019	East
150.380	85	142	10/13/2019	East
150.380	107	132	10/13/2019	East
150.360	21	137	10/13/2019	West
150.360	34	128	10/13/2019	West
150.360	35	131	10/13/2019	West
150.360	45	134	10/13/2019	West
150.380	84	127	10/13/2019	West

Frequency	Tag ID	Total Length (mm)	Release	
			Date	Bank
150.380	96	129	10/13/2019	West
150.380	102	125	10/13/2019	West
150.360	17	141	10/14/2019	East
150.360	22	142	10/14/2019	East
150.360	25	139	10/14/2019	East
150.380	77	134	10/14/2019	East
150.380	95	137	10/14/2019	East
150.600	111	131	10/14/2019	East
150.600	133	137	10/14/2019	East
150.360	16	138	10/14/2019	West
150.360	20	134	10/14/2019	West
150.380	65	127	10/14/2019	West
150.380	70	135	10/14/2019	West
150.380	94	137	10/14/2019	West
150.600	112	133	10/14/2019	West
150.600	148	138	10/14/2019	West
150.600	149	125	10/14/2019	West
150.360	18	134	10/15/2019	East
150.360	19	124	10/15/2019	East
150.360	36	133	10/15/2019	East
150.380	82	129	10/15/2019	East
150.380	108	135	10/15/2019	East
150.600	122	133	10/15/2019	East
150.600	152	135	10/15/2019	East
150.360	23	127	10/15/2019	West
150.360	31	147	10/15/2019	West
150.380	69	141	10/15/2019	West
150.380	106	134	10/15/2019	West
150.380	110	127	10/15/2019	West
150.600	115	140	10/15/2019	West
150.600	119	132	10/15/2019	West
150.600	129	134	10/15/2019	West
150.360	42	136	10/16/2019	East
150.360	47	144	10/16/2019	East
150.360	60	133	10/16/2019	East
150.380	98	136	10/16/2019	East
150.380	100	128	10/16/2019	East
150.600	123	135	10/16/2019	East
150.600	153	133	10/16/2019	East
150.360	48	141	10/16/2019	West
150.360	56	132	10/16/2019	West
150.380	61	140	10/16/2019	West
150.380	97	128	10/16/2019	West
150.380	103	132	10/16/2019	West
150.600	127	138	10/16/2019	West
150.600	139	123	10/16/2019	West

Frequency	Tag ID	Total Length (mm)	Release	
			Date	Bank
150.600	154	137	10/16/2019	West
150.360	41	132	10/17/2019	East
150.360	43	133	10/17/2019	East
150.360	57	128	10/17/2019	East
150.380	88	143	10/17/2019	East
150.380	99	134	10/17/2019	East
150.600	120	139	10/17/2019	East
150.600	151	127	10/17/2019	East
150.360	44	140	10/17/2019	West
150.360	59	122	10/17/2019	West
150.380	64	124	10/17/2019	West
150.380	71	129	10/17/2019	West
150.380	92	127	10/17/2019	West
150.600	125	138	10/17/2019	West
150.600	134	122	10/17/2019	West
150.600	158	141	10/17/2019	West
150.360	49	142	10/18/2019	East
150.360	58	146	10/18/2019	East
150.360	82	123	10/18/2019	East
150.380	63	128	10/18/2019	East
150.380	93	138	10/18/2019	East
150.380	109	138	10/18/2019	East
150.600	130	135	10/18/2019	East
150.600	160	132	10/18/2019	East
150.360	46	129	10/18/2019	West
150.360	50	132	10/18/2019	West
150.380	90	131	10/18/2019	West
150.380	105	136	10/18/2019	West
150.600	114	133	10/18/2019	West
150.600	116	139	10/18/2019	West
150.600	155	123	10/18/2019	West
150.360	51	140	10/23/2019	East
150.360	55	139	10/23/2019	East
150.380	74	136	10/23/2019	East
150.380	76	124	10/23/2019	East
150.600	132	135	10/23/2019	East
150.600	142	116	10/23/2019	East
150.600	145	131	10/23/2019	East
150.600	156	138	10/23/2019	East
150.360	53	141	10/23/2019	West
150.360	54	132	10/23/2019	West
150.380	73	139	10/23/2019	West
150.380	101	143	10/23/2019	West
150.380	104	121	10/23/2019	West
150.600	118	141	10/23/2019	West
150.600	121	136	10/23/2019	West

Frequency	Tag ID	Total Length (mm)	Release	
			Date	Bank
150.380	72	131	10/24/2019	East
150.600	124	146	10/24/2019	East
150.600	141	155	10/24/2019	East
150.600	146	127	10/24/2019	East
150.600	150	141	10/24/2019	East
150.600	157	136	10/24/2019	East
150.380	86	132	10/24/2019	West
150.600	128	130	10/24/2019	West
150.600	131	139	10/24/2019	West
150.600	135	126	10/24/2019	West
150.600	138	140	10/24/2019	West

Appendix C. Listing of manual tracking detections within the Lowell Project area.

Date	Frequency	ID	Location	Type
10/21/2019	150.600	143	Bypassed Reach	Stationary
10/21/2019	150.600	136	Bypassed Reach	Stationary
10/21/2019	150.380	89	Northern Canal	Transit
10/21/2019	150.380	87	Tailrace	Stationary
10/21/2019	150.380	69	Northern Canal	Stationary
10/21/2019	150.380	62	Northern Canal	Stationary
10/21/2019	150.360	41	Northern Canal	Stationary
10/24/2019	150.600	136	Bypassed Reach	Stationary
10/24/2019	150.600	132	Northern Canal	Transit
10/24/2019	150.380	87	Tailrace	Stationary
10/24/2019	150.380	69	Northern Canal	Stationary
10/28/2019	150.600	157	Northern Canal	Stationary
10/28/2019	150.600	138	Northern Canal	Stationary
10/28/2019	150.600	124	Northern Canal	Stationary
10/28/2019	150.380	69	Northern Canal	Stationary
11/5/2019	150.600	146	Northern Canal	Stationary
11/5/2019	150.600	138	Northern Canal	Stationary
11/7/2019	150.600	157	Northern Canal	Stationary
11/7/2019	150.600	146	Northern Canal	Stationary
11/7/2019	150.600	138	Northern Canal	Stationary
11/7/2019	150.600	135	Tailrace	Stationary

Technical Report for the Downstream American Eel Passage Assessment

Lowell Hydroelectric Project (FERC No. 2790)

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Table of Contents

List of Tables

List of Figures

1 Introduction

A radio-telemetry assessment of the downstream passage success for adult silver-phase American eels (*Anguilla rostrata*) was conducted in support of the relicensing for the Lowell Hydroelectric Project (Lowell or Project), Federal Energy Regulatory Commission (FERC) No. 2790, as identified in the Revised Study Plan (RSP) submitted by Boott Hydropower, LLC (Boott) on January 28, 2019. The approach and methodology described in the RSP for the downstream eel passage study was approved with modifications by the FERC in its Study Plan Determination (SPD) letter dated March 13, 2019. In their SPD, FERC staff commented on several points related to the original resource agency study requests and the eel passage study proposed by Boott as part of the PSP.

- Resource agency request for a HI-Z balloon tag turbine survival assessment.
    - *FERC recommended no HI-Z balloon tag assessment be conducted during 2019. Information from the radio-telemetry and desktop analyses should provide adequate estimates of passage route survival. In the event these findings are inconclusive FERC would consider additional study requests.*
- Resource agency request for eel releases to start in mid-September.
    - *FERC recommended that Boott should initiate eel releases as early in the fall season as the commercial collection and associated bacterial and viral screening process prior to import allows.*
- Resource agency request for release of 10 dead tagged eels in conjunction with each upstream release of live tagged eels.
    - *FERC recommended Boott release two dead tagged eels in conjunction with each upstream release of live tagged eels.*
- Resource agency request for two years of radio-telemetry data collection.
    - *FERC noted there was no indication at the time of issuance for the SPD that a second study year was warranted. If the first study year failed to meet study objectives and provide the necessary information for assessing project effects then stakeholders will have an opportunity to file a request to modify the study to collect additional information.*

This technical report was prepared on behalf of Boott to provide a description of the objectives, methodologies and results of the 2019 radio-telemetry assessment to evaluate the downstream passage of adult silver eels at the Lowell Project. In addition to the radio-tagged silver-phase eels marked as part of this evaluation, an additional eel passage study was conducted outside of the Licensing efforts for Lowell to assess downstream movement at the Merrimack River Project (FERC No. 1893). Adult eels tagged as part of the upstream project were also monitored as they moved through the Lowell Project area. Findings for those individuals have been included in this report.

2 Objectives

The goal of this study was to determine the Lowell Project's impact on the outmigration of adult silver-phase American eels.

Specific objectives included:

- Quantification of the movement rates and relative proportion of eels passing via various routes at the project (i.e., turbines, downstream bypass, and spill); and
- Evaluation of mortality of eels passed via each potential route.

3 Project Description and Study Area

The Lowell Project is located at River Mile (RM) 41 on the Merrimack River in the City of Lowell in Middlesex County, Massachusetts, with an impoundment extending approximately 23 miles upstream into Hillsborough County, New Hampshire. The existing Lowell Project consists of: (1) a 1,093-foot-long, 15-foot-high masonry gravity dam (Pawtucket dam) that includes a 982.5-foot-long spillway with a crest elevation of 87.2 feet National Geodetic Vertical Datum 1929 (NGVD 29) topped by 5-foot-high pneumatically-operated crest gates deployed in five independently-operable zones; (2) a 720-acre impoundment with a normal maximum water surface elevation of 92.2 feet NGVD 29; (3) a 5.5-mile-long canal system which includes several small dams and gatehouses; (4) a powerhouse (E.L. Field) which uses water from the Northern Canal and contains two turbine-generator units with a total installed capacity of 15.0 megawatts (MW); (5) a 440-foot-long tailrace channel; (6) four powerhouses (Assets, Bridge Street, Hamilton, and John Street) housed in nineteenth century mill buildings along the Northern and Pawtucket Canal System containing 15 turbine-generator units with a total installed capacity of approximately 5.1 MW; (7) a 4.5-mile long, 13.8-kilovolt transmission line connecting the powerhouses to the regional distribution grid; (8) upstream and downstream fish passage facilities including a fish elevator and downstream fish bypass at the E.L. Field powerhouse, and a vertical-slot fish ladder at the Pawtucket dam; and (9) appurtenant facilities. At the normal pond elevation of 92.2 feet NGVD 1929 (crest of the pneumatic flashboards), the surface area of the impoundment encompasses an area of approximately 720 acres. The gross storage capacity between the normal surface elevation of 92.2 feet and the minimum pond level of 87.2 feet is approximately 3,600 acre-feet. The Project operates essentially in a run-of-river (ROR) mode using automatic pond level control, and has no usable storage capacity.

The study area for the downstream eel passage assessment included the mainstem Merrimack River from the upper extent of the Project's impoundment located approximately 23 river miles upstream from the Pawtucket Dam in Litchfield, New Hampshire, to the Lawrence Hydroelectric Project (FERC No. 2800), located approximately 11 river miles downstream of the Pawtucket Dam (Figure 3-1). The Upper Pawtucket Canal and Guard Locks facility were also considered as part of the study area.

Figure 3–1. Merrimack River study reach considered during the fall 2019 adult silver-phase American eel downstream passage assessment.

4 Methods

Downstream passage of adult American eels through the Lowell Project reach was evaluated via radio-telemetry during the fall of 2019. Following the release of radio-tagged individuals into the Merrimack River upstream of the Lowell impoundment, their movements were monitored using a series of stationary radio-telemetry receivers in place at the Project as well as at several additional stationary monitoring stations installed at bank-side locations upstream and downstream of the Project to inform on general movements, distribution among available passage routes and Project passage success.

4.1 Radio Telemetry Equipment

Movements of radio-tagged individuals during the 2019 study were recorded via a series of stationary radio-telemetry receivers. Radio-telemetry equipment used during the evaluation of downstream passage at Lowell included Orion receivers, manufactured by Sigma Eight, as well as SRX receivers manufactured by Lotek Wireless. Each receiver was paired with either an aerial or underwater antenna (dropper antenna). Aerial antennas (four or six element Yagi) were utilized to detect radio-tagged individuals within the larger, more open sections of river, such as within the tailrace or at locations downriver of Lowell. Dropper antennas were fixed at downstream passage locations (e.g., downstream bypass). Dropper antennas were custom built by stripping the shielded ends of RG-58 coaxial cables.

All eels radio-tagged during 2019 were equipped with a Sigma Eight TX-PSC-I-450 radio transmitter (149.320, 149.340 or 149.360 MHz, pulse rate = 2.0 seconds). The TX-PSC-I-450 transmitters measured approximately 12 x 12 x 46 mm, weighed 8.5 g and had an estimated battery life of 357 days when set at a 2.0 second burst rate. Each transmitter was coded to emit a unique identifying signal so that individual eels could be identified by a receiver.

4.2 Monitoring Stations

The RSP identified a total of twelve monitoring stations to be set up at Lowell for the downstream eel passage assessment. Each of the twelve monitoring locations identified in the RSP were installed as described and each location consisted of a data-logging receiver, antenna, power source, and were configured to receive transmitter signals from a designated area continuously throughout the study period. During installation of each station, range testing was conducted to configure the antennas and receivers in a manner which maximized detection efficiencies at each location. The operation of the radio telemetry receivers was initially established during installation, then confirmed throughout the study period by using beacon tags. A number of beacon tags were stationed at strategic locations within the detection range of either multiple or single antennas, and they emitted signals at programmed time intervals. These signals were detected and logged by the receivers and used to record the functionality of the system throughout the study period.

The locations of monitoring stations installed for the 2019 Lowell eel passage study are outlined here and presented in Figures 4-1 through 4-3.

Monitoring Station 19: This station was installed at the upper end of the Project impoundment and detected eels following their initial movement downstream from the release location and upon entry into the project area. Station 19 consisted of a single Lotek SRX receiver and aerial antenna oriented perpendicular to the river channel.

Monitoring Station 21: This station consisted of a single Lotek SRX radio-receiver and an aerial antenna and was installed and calibrated in a manner to provide detection information for radio-tagged eels as they approached the upstream face of Pawtucket Dam. Detections at this location were used to inform on arrival of eels immediately upstream of the project.

Monitoring Station 25: Station 25 consisted of a single Orion radio-receiver and aerial antenna installed and calibrated to provide coverage of the upstream side of the Pawtucket Gatehouse. This station informed on radio-tagged eels which had approached the upstream side of the Pawtucket Gatehouse.

Monitoring Station 27: Station 27 consisted of a single Lotek radio-receiver and aerial antenna installed and calibrated to provide coverage of the downstream side of the Pawtucket Gatehouse. This station informed on radio-tagged eels which had successfully passed through the Pawtucket Gatehouse and entered the Northern Canal.

Monitoring Station 29: Station 29 consisted of a single Lotek SRX radio-receiver and aerial antenna installed and calibrated to provide detection information for radio-tagged eels that passed through the Pawtucket Gatehouse, entered the E.L. Field Powerhouse forebay (i.e., the Northern Canal) and were in the vicinity of the entrance to the downstream bypass and intake racks.

Monitoring Station 31: This station consisted of a single Orion radio-receiver and underwater drop antenna installed and calibrated to provide detection information for radio-tagged eels exiting the forebay via the downstream bypass.

Monitoring Station 33: Station 33 consisted of a single Lotek SRX radio-receiver and aerial antenna installed to monitor across the bypassed reach at a point downstream of where the surge gate enters from the power canal and upstream of the downstream bypass discharge. Detections at this location were used to confirm the downstream passage of individuals using the spillway or surge gate.

Monitoring Station 35: This station consisted of a single Lotek SRX radio-receiver and aerial antenna installed at a location overlooking the E.L. Field Powerhouse tailrace. Detections at this location were used to confirm downstream passage of individuals via the Project turbine units.

Monitoring Station 37: This station was installed at a point along the mainstem of the Merrimack River downstream of both the E.L. Field Powerhouse tailrace and the confluence with the Concord River. Station 37 consisted of a single Lotek SRX receiver and aerial antenna oriented perpendicular to the river channel. Station 37 was installed at the Lowell Waste Water Treatment Plant, approximately 2.1 miles downstream of the tailrace.

Monitoring Station 39: Station 39 was installed at a commercial business near the midpoint between the Lowell and Lawrence projects and consisted of a single Lotek SRX receiver and aerial antenna oriented perpendicular to the river channel. Station 39 was located approximately 6.0 miles downstream of the tailrace.

Monitoring Station 40: This station consisted of a single Lotek SRX radio-receiver and an aerial antenna and was installed and calibrated in a manner to provide detection information for radio-tagged eels as they approached the upstream face of Essex Dam (approximately 10.75 miles downstream of the Lowell tailrace).

Monitoring Station 23: This station was installed to detect eels which entered the downtown canal system via the Pawtucket Canal rather than pass the Project via one of the mainstem passage routes. The entrance to the Pawtucket Canal sits at a point upstream of the Pawtucket Dam and the Northern Canal. Station 23 was installed at the Guard Locks, approximately 1,700 feet downstream from the entrance to the canal. The monitoring zone for Station 23 was directed downstream to ensure detections recorded at that location were of individuals which had definitively entered the downtown canal system.

4.3 Tagging and Release Procedures

Silver-phase American eels were purchased from a commercial eel trapper operating on the St. Croix River in Maine. Eels were transported by truck from the St. Croix area to holding tanks installed at Garvins Falls Dam (Merrimack River Project, Bow, NH) on October 3, 2019. The total number of eels available for purchase from the St. Croix River was slightly less than the number required to achieve the study sample size described in the FERC-approved RSP. An additional twelve silver eels were provided by the New Hampshire Fish and Game Department (NHFGD) following their collection in a sampling weir being operated on the Soucook River. NHFGD staff maintained Soucook River eels at the Nashua Fish Hatchery until Normandeau staff transported them to the holding tanks at Garvins Falls on October 21.

All eels were held for a minimum of 24 hours prior to tagging. Individuals were visually examined and if they appeared healthy were anesthetized in a clove oil and ethanol solution (Figure 4-4). Eels were held and visually monitored in the anesthesia bath for approximately 10–15 min prior to tagging. Once sedated, eels were removed from the bath and placed on a clean, wet towel. The total length (TL) and eye diameter (horizontal and vertical; nearest 0.1 mm) were measured. Although the capture method virtually guarantees sample specimens are migratory, a previously described correlation between eye size, body length and gonad development was used to confirm whether individuals were mature and likely to be active outmigrants (Pankhurst 1982). This eye index relationship (I) was described using the formula:

$$I = [(A+B/4)2\pi/L]*100$$

where A = horizontal eye diameter, B = vertical eye diameter, and L = total body length. Silver-phase American eels typically have an eye index between 6.0 and 13.5, with a bronze coloration along the lateral line that separates the dark, silver back from the white belly. Eels meeting these characteristics were selected for surgical tagging. In short, an incision was made off center on the ventral surface of the individual and of an adequate length to insert the transmitter into the body cavity. A hollow needle was inserted into the incision and was pushed through the body wall just off of the ventral mid-line and at a point posterior to the incision. The antenna was fed through the needle and gently pulled so that the transmitter entered the body cavity. The needle was then fully pulled through the body wall and removed from the antenna. The transmitter was positioned by pulling the antenna so that it lay directly under the incision. The incision was closed with two or three interrupted sutures (chromic gut with a 4-0 cutting needle) evenly spaced across the incision. A small amount of an antibacterial ointment was applied to the incision site to prevent infection.

Following tagging, each individual was transferred to an acclimation tank supplied with ambient river water for an additional 24-h observation period to allow eels to recover from surgery. Following the recovery period, eels were assessed for normal behavior prior to release and were then trucked to the car-top boat launch located adjacent to the Fisher Cat Stadium in Manchester, NH and upstream of the Lowell Project impoundment[1]. Radio-tagged individuals were carefully netted from the truck tank and were released from the shoreline. A total of five separate release groups, each comprising 20 radio-tagged eels were released during the 2019 study. The date and time of each release was recorded.

4.4 Data Collection

4.4.1 Stationary Telemetry Data

Receiver downloads occurred three to four times weekly during the period from the initial tag and release event until the end of November, 2019. Backup copies of all telemetry data were made prior to receiver initialization. Field tests at the time of download to ensure data integrity and receiver performance included confirmation of file integrity, confirmation that the last record was consistent with the downloaded data (beacon tags were critical to this step), and lastly, confirmation that the receiver was operational upon restart and actively collecting data post download. Within a data file, transmitter detections were stored as a single event (i.e., single data line). Each event included the date and time of detection, frequency, ID code, and signal strength.

4.4.2 Manual Telemetry Data

To provide supplemental detection information to the stationary receiver data set, manual tracking was conducted on a number of occasions from the time of initial release through the end of November, 2019. Manual effort was exerted in the vicinity of the Lowell Project (i.e., tailrace and headpond immediately upstream of Pawtucket Dam) on most dates when stationary telemetry equipment was checked. In addition, a number of boat or truck-based

[1] Normandeau Associates simultaneously conducted an additional downstream adult eel passage study at the Merrimack River Project (FERC No. 1893) during fall 2019. A total of 60 eels were radio-tagged during that assessment and were also monitored for passage at Lowell. Results from that group of eels at Lowell and points downriver have been incorporated into this report.

efforts were conducted to look for radio-tagged eels within the Lowell impoundment and the reach of the Merrimack downstream to Lawrence.

4.4.3 Operational and Environmental Data

Merrimack River water temperature was recorded via a continuously operating logger installed within the Lowell intake canal. Hourly records for operations data were provided by Boott for the 2019 evaluation period and included:

- Headpond elevation (ft);
- Power canal elevation (ft);
- Headpond-power canal differential (ft);
- Tailrace elevation (ft);
- Head differential for E.L. Field turbines (ft);
- Total inflow (cfs);
- Unit 1 discharge (cfs) and output (KW);
- Unit 2 discharge (cfs) and output (KW);
- Downstream bypass discharge (cfs);
- Upstream fishway discharge (cfs);
- Downtown canal flow (cfs); and
- Spill flow through the bypassed reach.

4.4.4 Downstream Drift Assessment

A total of ten freshly dead adult silver-phase eels were radio-tagged and released downstream of Lowell during the 2019 study period. Two individuals were released on each date that a group of live test eels was released upstream of the Lowell impoundment. Dead, radio-tagged eels were released directly into the discharge of an active turbine unit at the E.L. Field powerhouse. The downstream progression of these known mortalities was recorded via both the stationary receivers as well as during manual tracking events.

4.5 Data Analysis

The tagging, telemetry and Project operations data sets collected as part of this effort were examined and used to evaluate a number of metrics related to downstream passage success and movement through the Project area.

4.5.1 Downstream Movement and Passage Route Selection

A complete record of all valid stationary receiver detections for each radio-tagged adult American eel was generated. The pattern and timing of detections in these individual records were reviewed, and a route of passage as well as project arrival and passage times were assigned to each radio-tagged individual. In the instance that a downstream route could not be clearly determined from the collected data, the passage event for that particular fish was classified as ‘unknown’.

Where data were available, impoundment duration and project residence times were calculated. Values for impoundment duration were calculated as the duration of time from detection at Station 19 until detection at Station 21. Upstream project residence time was defined as the duration of time from the initial detection at Station 21 until the determined time of downstream passage. Time spent immediately upstream of the dam was further evaluated using initial detection times for eels at Monitoring Stations 25 and 27 to provide an understanding of passage times associated with moving through the Pawtucket Gatehouse and entering into the Northern Canal approach to the E.L. Field powerhouse.

4.5.2 Parameter Estimates for Evaluation of Downstream Passage

Downstream passage success at the Project was estimated for adult American eels using a standard Cormack-Jolly-Seber (CJS) model run for the set of individual encounter histories (i.e., the series of detection/no detection through the linear sequence of receivers from upstream to downstream; Lebreton et al. 1992). This approach provided a series of reach-specific “survival” or passage success estimates for:

- Monitoring Station 19 to Monitoring Station 21 (i.e., impoundment duration);
- Monitoring Station 21 (i.e., upstream approach) to downstream passage;
- Downstream passage to Monitoring Station 37 (i.e., first downstream receiver); and
- Monitoring Station 37 (i.e., first downstream receiver) to Monitoring Station 39 (i.e., second downstream receiver)

Standard error and confidence bounds for each estimate were generated. The joint probability of three reach survival estimates (i.e., (Lowell to Station 37)*(Station 37 to Station 39)*(Station 39 to Lawrence)) was used as the estimate of total passage survival for the Project. This approach resulted in a mortality estimate that included both background mortality (i.e., natural mortality such as predation) and mortality due to Project effects in the reach extending from Lowell downstream to Lawrence. Thus, the results presented in this report reflect a minimum estimate of survival attributable to Project effects for adult silver eels.

To evaluate passage success using the CJS models, a suite of candidate models were developed in Program MARK (White and Burnham 1999) based on whether survival (i.e., passage success), recapture (i.e., detection), or both vary or are constant among stations. Models developed during this study included:

- *Phi(t)p(t)*: survival and recapture may vary between receiver stations;
- *Phi(t)p(.)*: survival may vary between stations; recapture is constant between stations;
- *Phi(.)p(t)*: survival is constant between stations; recapture may vary between stations;
- *Phi(.)p(.)*: survival and recapture are constant between stations;

Where;

- *Phi* = probability of survival
- *p* = probability of detection
- *(t)* = parameter varies
- *(.)* = parameter is constant

To evaluate the fit of the CJS model, goodness of fit testing was conducted for the “starting model” (i.e., the fully parameterized model) using the function RELEASE within Program MARK. Akaike’s Information Criterion (AIC) was used to rank the models as to how well they fit the observed mark-recapture data (Lebreton et al. 1992). Lower AIC values denote a more explanatory yet parsimonious fit than higher AIC values. Assuming the assumptions of the model with the lowest AIC value were reasonable with regards to this study, that model was selected for the purposes of generating passage effectiveness estimates.

Models were prepared which evaluated downstream passage success of adult eels at Lowell as follows:

- All eels – based on detection at Station 37, Station 39 and Lawrence;
- Garvins Falls release group – based on detection at Station 37, Station 39, and Lawrence;
- Lowell Project release group – based on detection at Station 37, Station 39, and Lawrence;
- All eels – adjusted for median “travel time” for freshly dead eels released in Lowell tailrace to reach Lawrence (i.e., test eels with downstream travel times in excess of median drift duration manually adjusted to reflect a mortality at the Project); and
- All eels – by downstream passage route.

4.5.3 Time to Event Analysis

4.5.3.1 Cox Proportional Hazard Model

Utilizing available methodology for quantifying fish passage performance (Castro-Santos and Perry 2012), multi-variate Cox proportional hazard models were developed to assess the impact of various operational and environmental variables on the rate of passage success. Operational and environmental variables considered as part of this analysis included:

- Merrimack River water temperature (^{o}C);
- Head differential (ft) at the Pawtucket Gatehouse (i.e., headpond vs. Northern Canal);
- Bypassed reach spill flow (cfs);
- E.L. Field turbine discharge (cfs);
- Merrimack River inflow (cfs); and
- E.L. Field head differential (ft) (i.e., Northern Canal vs. tailwater).

This assessment on the rate of passage success focused on approach events at (1) the Pawtucket Gatehouse (i.e., Station 25), and (2) at the E.L. Field Powerhouse (i.e., Station 29).

Regression models for the time to event analyses were constructed using the *coxph*() function from the package "*survival*" in R (R Core Team 2020) and were used to evaluate the rate of passage success and identify operational hazards at sites which contained a physical barrier or a structure through which tagged individuals would have to navigate (i.e., the Pawtucket Gatehouse and E.L. Field Powerhouse).

The Cox proportional hazard regression can be described as a hazard function to evaluate the proportionate risk at time (t) such that

$$h(t) = h_0(t) \times exp(b_1x_1 + b_2x_2 + \ldots + b_ix_i)$$

where $h(t)$ represents that hazard at a given time point which is equal to the initial or baseline hazard at time 0:00 ($h_0(t)$) multiplied by e (the base of the natural logarithm) to the power of the additive relationship between each covariate (x_i) multiplied by its associated coefficient (b_i).

From the above equation, the relative impact of an operational parameter on the rate of passage success is represented by its associated coefficient. The hazard ratio of a given operational parameter is calculated by exponentiating the coefficient of a given parameter, which represents that multiplicative impact of that parameter. It is important to note that exponentiating these coefficients makes the value relative to a value of 1 (e^0), which represents a baseline of no hazard. For example, if the hazard ratio is greater than 1, e.g., 1.5, that will be interpreted as that covariate increasing the risk of passage failure by a factor of 1.5. Alternatively stated, a hazard ratio of 1.5 indicates that the associated covariate increases the risk by 50% as it is 0.5 greater than 1. In contrast, a hazard ratio below 1, e.g., 0.75, indicates that the associated covariate reduces the risk of passage failure by a factor of 0.75, or 25%. In short, a hazard ratio >1 indicates an increase in the risk of passage failure, a hazard ratio of 1 indicates no significant directional effect on passage, and a hazard ratio <1 indicates a reduction in the risk of passage failure.

4.5.3.2 Model Evaluation and Selection

As is the case with any statistical model, the type of model selected makes inherent assumptions about the nature of the data being modelled. The primary assumption of a Cox proportional hazard model is that the hazards are proportional. However, this assumption is not always appropriate for the data. As a result, the *cox.zph()* function was used during this assessment to assess the validity of the proportional hazard assumption. This function assessed scaled Schoenfield residuals to evaluate whether Cox regression residuals of each covariate in addition to the model as a whole are independent of time. In the event that the Schoenfield residuals are not independent of time, it can be said that the assumption of proportional hazards is violated and a Cox proportional hazards model may be misrepresentative of the true relationships between the selected covariates and passage success.

4.5.3.3 Event Definition

To evaluate the impact of operational parameters on passage success, instances of passage success and failure required definition and represent the 'events' (or passage attempts) in this analysis. Ostensibly, the transmitters deployed during this study should transmit a signal that when within range of a particular receiver will be detected every 2.0 seconds. However, various sources of outside noise or areas of poor coverage due to structures, etc. introduce variation into the frequency of detection for a unique transmitters signals. Given that different site locations and receiver types are subject to varying degrees of ambient noise, the duration between successive detections was calculated for each tagged individual at each receiver location. A threshold interval for determining continued presence of a transmitter within the detection zone of a specific receiver was identified as the 95th percentile of the observed set of interval durations. This value was calculated at 14.4 seconds for Station 25 and 32.4 seconds for Station 29. These two threshold values were then used to delineate when each event was started and completed for a tagged individual. The departure of a radio-tagged individual from the detection zone of a particular receiver was determined when the time interval between successive detections exceeded the specific threshold interval for that zone.

From this, a passage failure event (assigned a value of 0) was defined as any duration where all detections lay within the 95th percentile of durations for all individuals at that site. Passage failure represents events in which a tagged individual enters the field of detection at a given site without passing to the next site (i.e., moving downstream) in the system. A passage success event (assigned a status of 1) was defined using the final instance of detection for a tagged individual at a singular site where that tagged individual was next detected at a downstream receiver (i.e., successfully passed). Passage success/failure (1/0) was used as the status coinciding with time in the Cox proportional hazard models. After defining passage events for every individual, the time duration for the regression was defined as the duration from one event to the next.

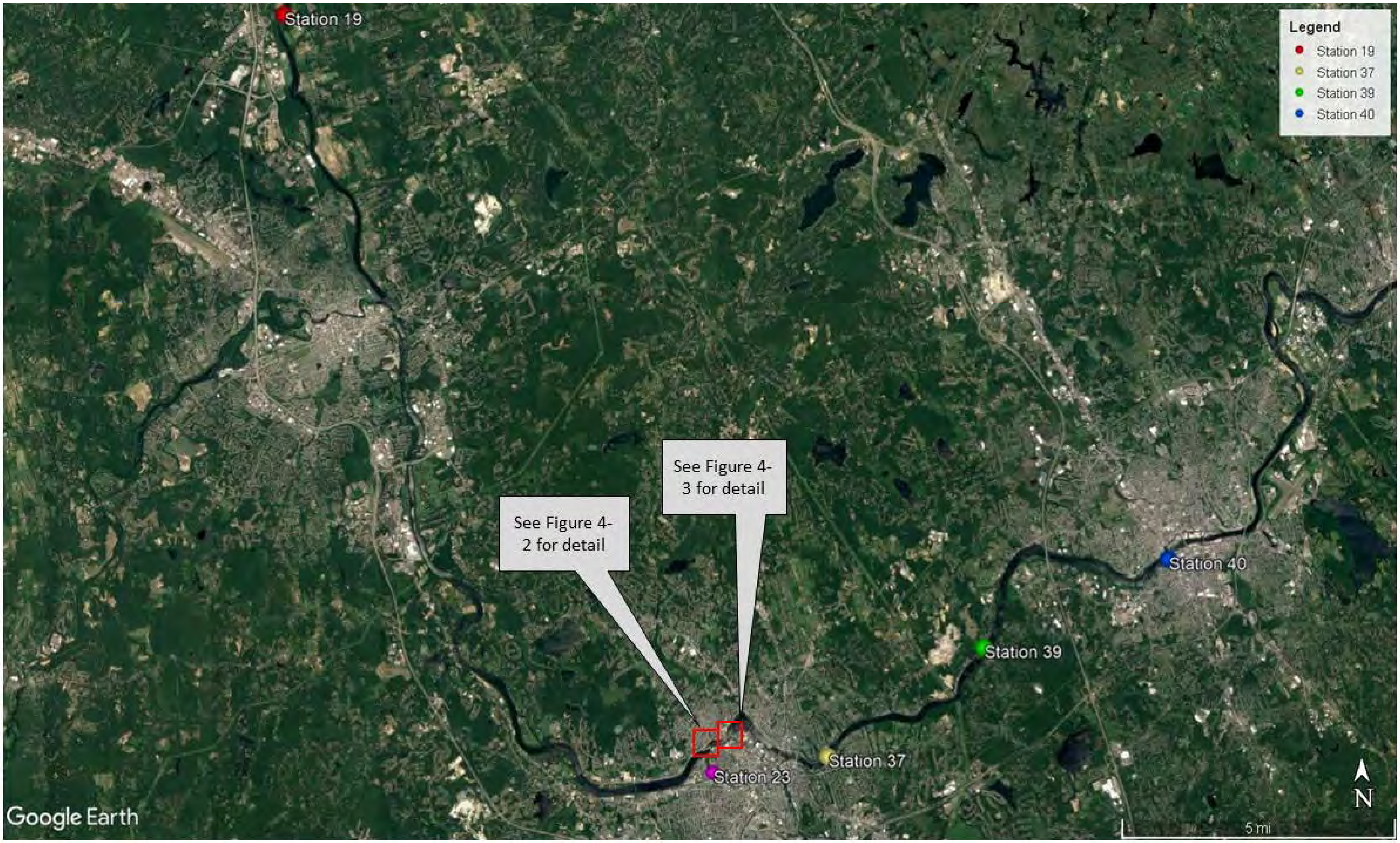

Figure 4–1. Locations of remote stationary radio-telemetry receivers installed during the 2019 adult American eel downstream passage assessment at Lowell.

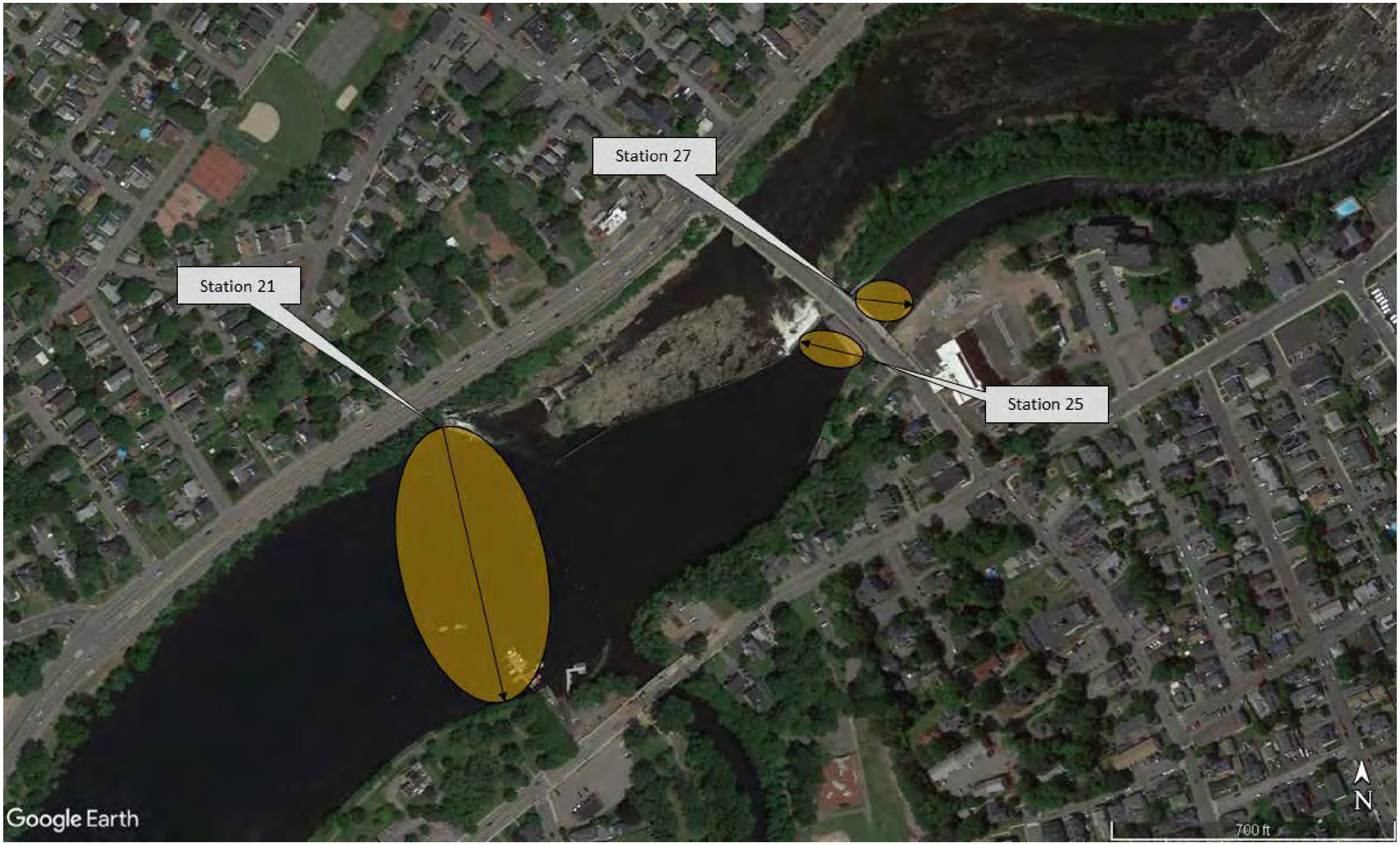

Figure 4–2. Locations and approximate detection areas for stationary radio-telemetry receivers installed upstream of Pawtucket Dam and at the Northern Gatehouse during the 2019 adult American eel downstream passage assessment at Lowell.

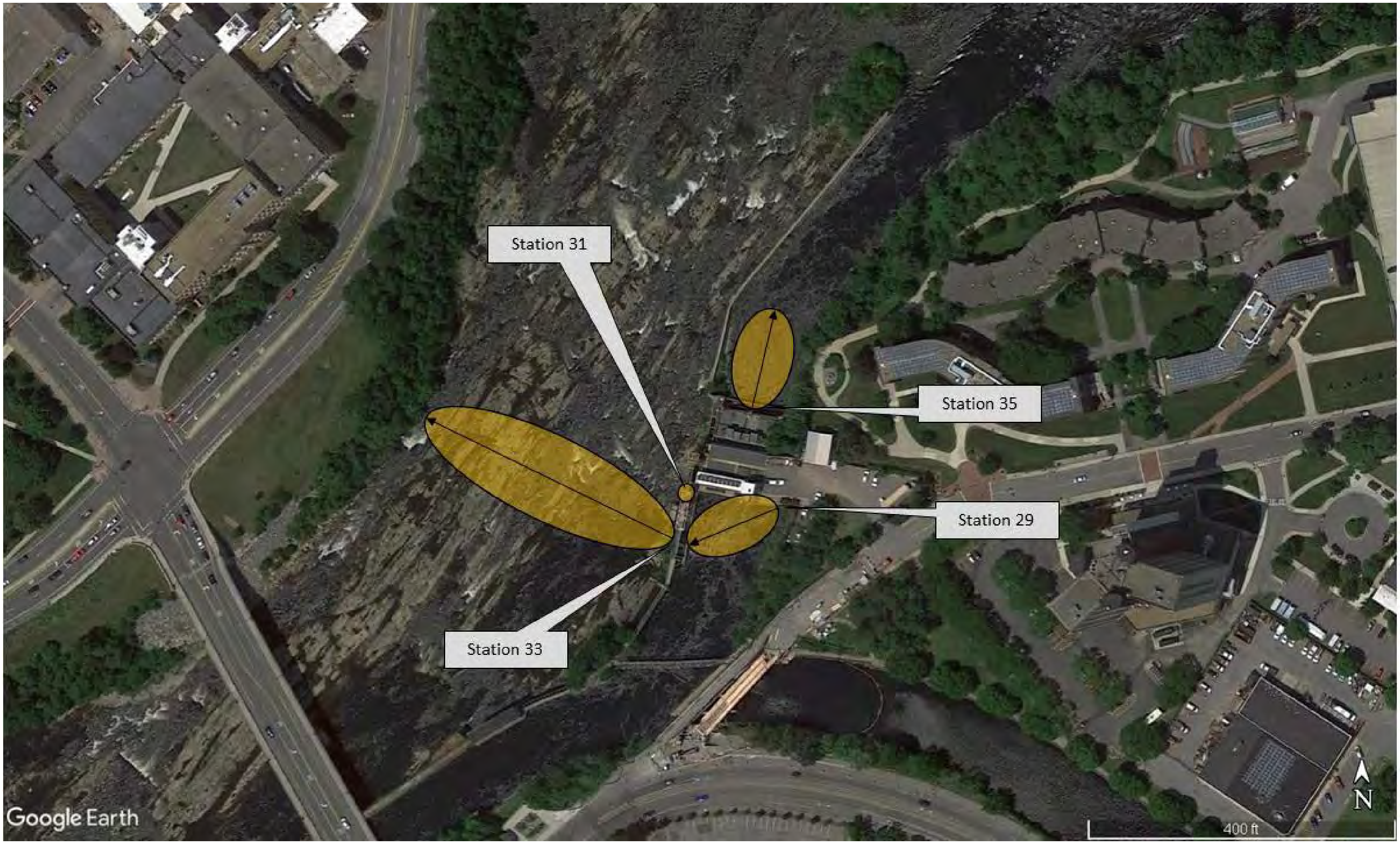

Figure 4–3. Locations and approximate detection areas for stationary radio-telemetry receivers installed in the vicinity of the E.L. Field Powerhouse during the 2019 adult American eel downstream passage assessment at Lowell.

Figure 4–4. Tagging process for silver-phase American eels.

5 Results

5.1 Merrimack River Conditions and Lowell Project Operations

Figure 5-1 presents the Merrimack River flow and water temperature for the period of time from the first eel release on October 9 until the end of the monitoring period on November 31, 2019. Water temperatures at Lowell ranged from 16°C at the onset of the study to 2°C on November 30. Total river flow values represent the reported inflow at the Lowell Project. Merrimack River flow at Lowell ranged between 1,089 and 12,995 cfs during the nearly two month fall study period. Figure 5-2 presents the monthly flow duration curves prepared for Lowell during the development of the Preliminary Application Document. The median flow condition at the Project is approximately 3,600 cfs during October and 6,500 cfs during November. Merrimack River conditions have a ~20% probability during October and a ~38% probability during November to exceed the ~8,000 cfs capacity of the E.L. Field powerhouse.

Table 5-1 summarizes the percentage of inflow records from the 2019 study period categorized by volume (to the nearest 1,000 cfs) as well as the percentage of time that each volume category is historically exceeded[2]. To help characterize the 2019 passage season, monthly exceedance probabilities less than 0.35 were classified as “high” flow conditions, 0.35 to 0.65 were classified as “normal” flow conditions, and greater than 0.65 were classified as “low” flow conditions. Inflows at the Project for the period October 9 through 31 were representative of high flow conditions (i.e., those with a probability of exceedance of less than 0.35) for 35% of the period, normal flow conditions (i.e., those with a probability of exceedance of 0.35-0.65) for 29% of the time and low flow conditions (i.e., those with a probability of exceedance of greater than 0.65) for 36% of the time. For the month of November, inflows were representative of high flow conditions 26% of the time, normal flow conditions 15% of the time and low flow conditions 59% of the time.

Figure 5-3 summarizes the allocation of water among the E.L. Field powerhouse, bypassed reach, downstream fishway, and downtown canal system at Lowell. Turbine units were in operation at the E.L. Field powerhouse for the duration of the study period with Unit 1 in operation throughout the study and Unit 2 coming online at 0900 on October 16. The downstream bypass was operated throughout the study period, passing approximately 130 cfs. Two major spill events, associated with increases in river flows, occurred during the monitoring period. The first major spill event occurred from approximately October 29 to November 5 and the second occurred towards the end of the passage season (~November 25). Flows to the downstream canal system represented between 15-20% of the 2,000 cfs capacity during October and between 20-57% of the 2,000 cfs capacity during November. Due to overriding safety concerns, Boott limited operation of the turbine units within the downtown canal system during the study period. To the extent possible, Boott’s operations staff attempted to operate the canal system as if there were canal units available, by opening gates when river flows

[2] Estimates of monthly exceedance estimated from monthly flow duration curves provided in Appendix H of the PAD.

exceeded the hydraulic capacity of the E.L. Field turbines (7,000 to 8,000 cfs). As a result, flows through the downtown canal system were largely restricted to passage via open gates. The Licensee manually recorded gate and unit settings during the study period within the downtown canal system. A breakdown of those values and related discharge estimates are provided in Appendix A.

Table 5–1. Frequency of occurrence of river inflow at Lowell (to nearest 1,000 cfs) during 2019 adult American eel passage assessment and corresponding percentage of time flows are historically exceeded.

	October 9-31, 2019		November 1-30, 2019	
River Flow (nearest 1k)	Percentage of Month	Percentage of Time Historically Exceeded	Percentage of Month	Percentage of Time Historically Exceeded
1000	16.1%	90	-	> 95
2000	19.4%	85	-	> 95
3000	6.0%	60	10.7%	88
4000	22.6%	45	25.1%	78
5000	12.7%	34	23.6%	66
6000	9.4%	27	5.5%	55
7000	6.2%	23	6.5%	45
8000	4.2%	19	2.8%	38
9000	3.1%	16	2.8%	30
10000	0.4%	14	5.4%	25
11000	-	<5	9.8%	5
12000	-	<5	5.4%	<5
13000	-	<5	2.4%	<5

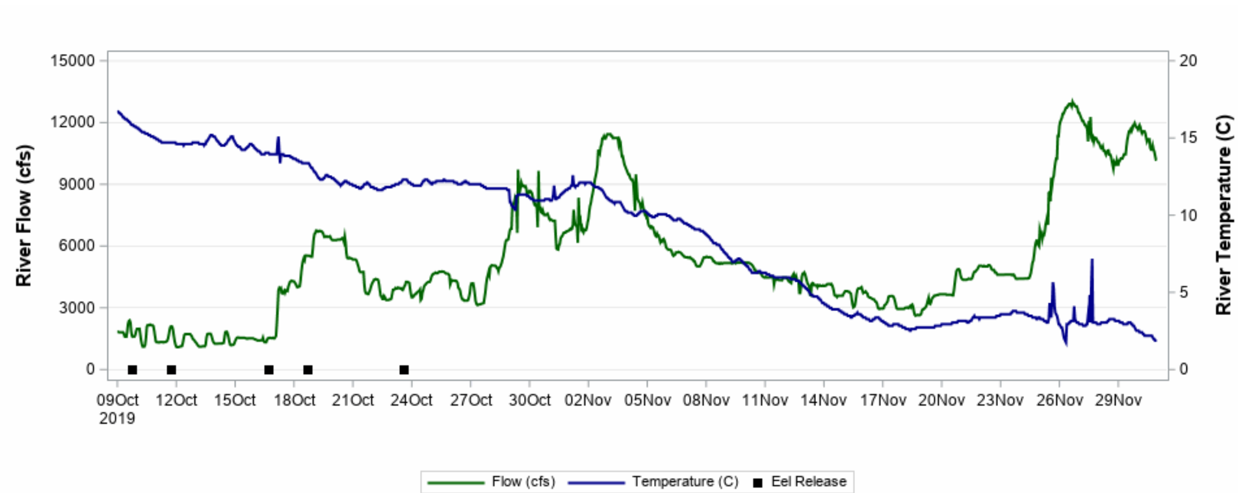

Figure 5–1. Merrimack River flow and water temperature at Lowell for the period October 9 to November 30, 2019.

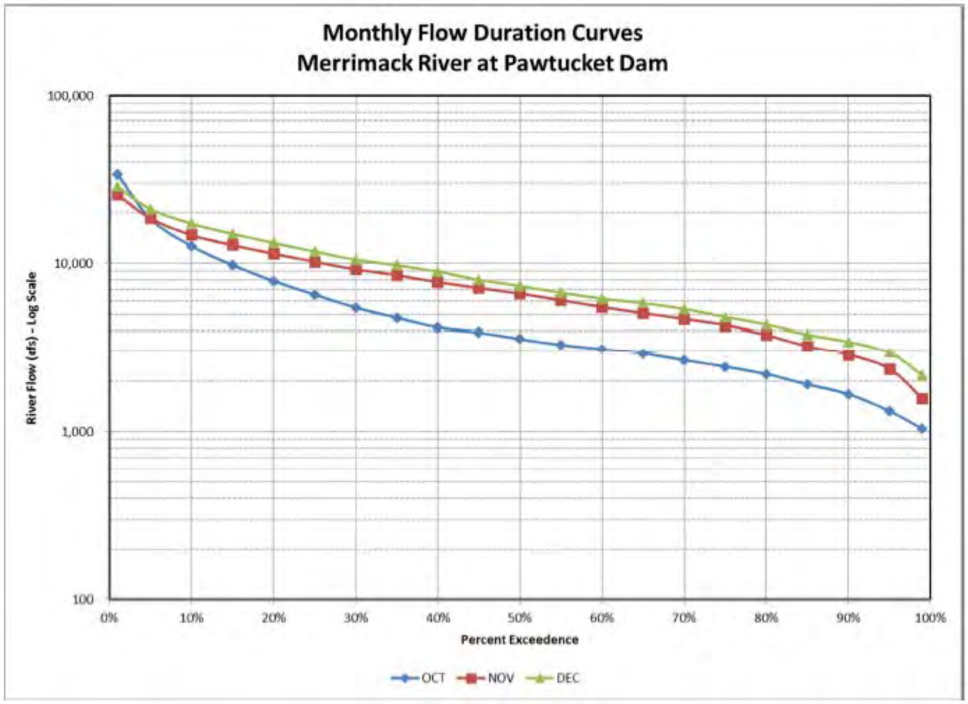

Figure 5–2. Flow duration curves for the months of October, November and December at the Lowell hydroelectric project.

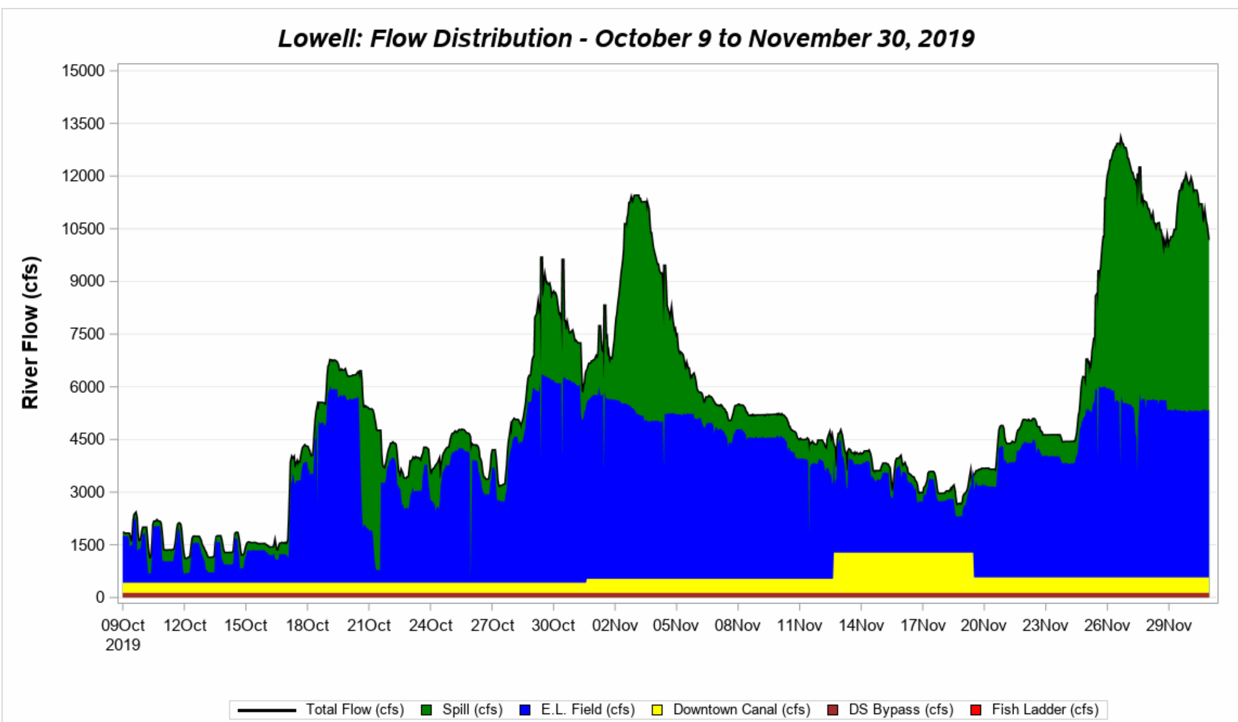

Figure 5–3. Total, spill, E.L. Field, downstream bypass and downstream canal system flow (cfs) for the period October 9 to November 30, 2019.

5.2 Monitoring Station Functionality

Radio-tagged adult American eels were released into the Merrimack River beginning in early October, 2019. The RSP called for continuous monitoring at each stationary receiver location through the end of November. Figure 5-4 provides an overview of the continuity of monitoring at each of the twelve stationary receiver locations during the fall period. The majority of the radio-telemetry monitoring stations installed to evaluate passage at Lowell during the fall study operated without issue for the full period.

Interruptions in continuous coverage were observed at three locations during the latter part of the study when lessened levels of daylight led to reduced efficiency of solar panel charge. These locations included Station 19 (upstream end of the Lowell impoundment) from 2000 on November 10 to 1400 on November 12, Station 27 (downstream side of the Pawtucket Gatehouse) from 0830 to 1030 on November 12, and Station 37 (first receiver downstream of Lowell) from 0200 to 1300 on November 5. Potential impacts to the study results from these three outages were likely limited. A single radio-tagged eel which approached the Pawtucket Dam after 2000 on November 10 lacked a detection at Station 19 and may have passed during the outage at that location preventing calculation of an impoundment residence duration for that individual. The outage at Station 27 was extremely short in duration and there were no radio-tagged eels detected upstream of the gatehouse that went undetected at that location prior to initial detection in the E.L. Field forebay. No radio-tagged eels passing downstream of Lowell on November 5 (or preceding two dates) went undetected at Station 37.

The aerial antenna at Station 25 (upstream side of the Pawtucket Gatehouse was removed by Boott operations staff to facilitate the installation of a crane to remove the in-river debris load from the upstream side of the gatehouse structure on November 21. A single radio-tagged eel did approach on November 22 and the outage at that station prevented a determination of the time to pass through the Pawtucket Gatehouse for that individual.

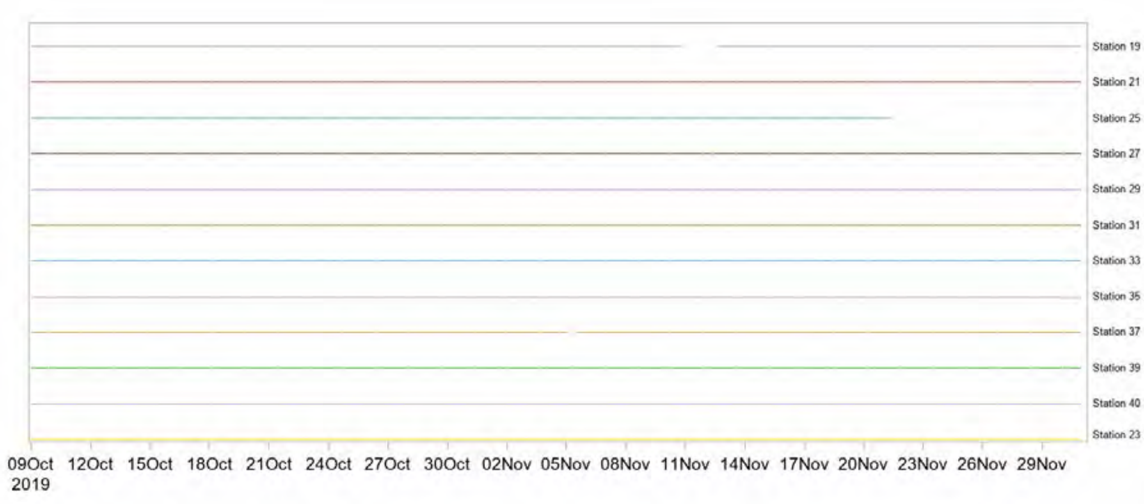

Figure 5–4. Operational coverage for telemetry receivers at Lowell during the adult silver eel downstream passage assessment, October 9 to November 30, 2019.

5.3 Downstream Drift Assessment

A total of ten freshly dead, radio-tagged American eels were released from the back deck of the E.L. Field powerhouse and directly into the upper portion of the discharge from an active turbine unit during the 2019 evaluation period. Freshly-dead eels were released intact and would be representative of an individual which did not suffer a physical strike which may result in partial or full severing of the body. Two individuals were released in the tailrace on each date where a group of radio-tagged eels were released upstream of the Project impoundment in Manchester, NH. Table 5-2 provides a summary of the release schedule and date-time of first detection for the drift eels to arrive at monitoring stations downstream of Lowell (Stations 37, 39, and 40).

Of the ten freshly dead, radio-tagged eels released at Lowell, seven were eventually detected at Station 40 (located at Lawrence, 10.75 miles downstream of the Lowell tailrace). The median duration to drift from the Lowell tailrace downstream to Lawrence was 216.4 hours (range = 59.4-538.9 hours). Three freshly dead eels did not drift the full distance from the tailrace to Station 40 at Lawrence. Of those individuals, two moved away from the Lowell tailrace but were not detected at Station 37 (2.1 miles downstream of Lowell). The third individual drifted from the Lowell tailrace to Station 37 over a period of 247.8 hours.

5.4 Eel Tagging and Releases

Eels were tagged and released upstream of the Project starting on October 9 and ending on October 23. Monitoring coverage at Lowell provided detection information on radio-tagged individuals released upstream of Lowell as part of this relicensing study (n = 102) as well as individuals released as part of a separate study conducted upstream at Garvins Falls Dam (Merrimack River Project, FERC No. 1893; n = 60) in Bow, NH. Table 5-3 provides a summary of the release dates and number of individuals for the 2019 passage assessment. A total of 162 live, radio-tagged adult eels were released over a span of two weeks and were potentially available for evaluation of downstream passage at Lowell. The majority of those individuals originated from the St. Croix River whereas the rest were captured locally (Soucook River; n = 10).[3] Eels tagged and released at locations upstream of Lowell as part of the 2019 passage evaluation ranged in length from 646 to 1,032 mm with the highest contribution of individuals to the 800-849 mm length class (Figure 5-5). The mean length of radio-tagged individuals released upstream of Garvins Falls (mean = 828 mm; range = 646-999 mm) was similar to that for eels released upstream of the Lowell impoundment (mean = 823 mm; range = 679-1,032 mm). The majority of eye index values recorded (98%) were within the literature reported range (6.0-13.5) for outmigrating eels. A full listing of tagging and biocharacteristics information for eels released during 2019 is provided in Appendix B.

[3] See Appendix D for a comparison of passage metrics for the October 23 release group comprised of eels originating from the Soucook River (n = 10) and St. Croix River (n = 12).

5.5 Impoundment Passage

Radio-tagged eels released upstream of the Lowell impoundment and upstream of Garvins Falls Dam were initially detected at Monitoring Station 19, located at the upstream extent of the Lowell impoundment (~ 23 miles from the Pawtucket Dam). The duration of time for radio-tagged individuals to move through the Lowell impoundment and arrive at the Pawtucket Dam (as indicated by detection at Station 21) ranged from 12.5 hours to 16.4 days (Table 5-4; Figure 5-6. The median duration of time spent in the Lowell impoundment was 2.1 days and did not appear to differ for eels originally released upstream of the Lowell impoundment or upstream of Garvins Falls.

5.6 Project Arrival and Upstream Residence Duration

Releases of radio-tagged eels were initiated on October 9 at locations upstream of the Project boundary and upstream of Garvins Falls Dam. Figure 5-7 presents the distribution of arrival dates for radio-tagged eels at the Pawtucket Dam as indicated by detection at Station 21. Initial detections for eels were recorded over a range of dates from October 13 through November 22 with just over fifty percent of individuals initially detected between the dates of October 24 and 30.

The duration of time radio-tagged individuals were present upstream of the Pawtucket Dam was determined for all individuals which approached and eventually passed downstream and was calculated as the duration of time from initial detection at Station 21 until confirmed downstream passage via one of the available routes. When all individuals are considered, upstream residence duration prior to downstream passage ranged between 0.2 hours to 16.5 days (Table 5-5; Figure 5-8). The median duration of time spent immediately upstream of the dam structure was 0.4 hours and did not appear to differ for eels originally released upstream of the Lowell impoundment or upstream of Garvins Falls. Of the radio-tagged eels which approached Pawtucket Dam, 94% passed in fewer than 24 hours after initial detection. Eight radio-tagged adult eels took greater than 24 hours to pass downstream following their initial detection at Station 21.

Outmigrating adult eels encountering the Pawtucket Dam can (1) pass through the Pawtucket Gatehouse and enter the power canal, (2) pass downstream over Pawtucket Dam via spill, or (3) enter the Pawtucket Canal and navigate downstream via the downtown canal system. During the 2019 evaluation there were no detections of radio-tagged eels at Monitoring Station 23 indicating individuals passed downstream of Lowell in the mainstem Merrimack rather than entering the downtown canal system. The majority of radio-tagged eels were determined to have passed through the Pawtucket Gatehouse and entered the Northern Canal to approach the E.L. Field powerhouse. The duration of time to pass through the Pawtucket Gatehouse was determined based on the initial detection for each individual eel at Stations 25 and 27 which independently monitored the upstream and downstream sides of that structure. The median duration of time for radio-tagged eels to approach and pass through the Pawtucket Gatehouse was 0.1 hours (range <0.1 hours to 3.9 days; Table 5-6). The vast majority (95%) of radio-tagged eels passing through the Pawtucket Gatehouse did so in 30 minutes or less.

Similar to observations at the Pawtucket Gatehouse, radio-tagged eels which entered the Northern Canal and passed downstream of E.L. Field powerhouse did so relatively quickly. Of those individuals, 94% were resident in the power canal upstream of E.L. Field for 3 hours or less. The median residence duration in the Northern Canal was 0.2 hours (range = 0.1 hours to 22.1 days; Table 5-7). Seven radio-tagged individuals were present in the Northern Canal for 36 hours or greater prior to downstream passage.

5.7 Downstream Passage

A total of 162 radio-tagged eels were released at points upstream of the Lowell Project during the fall of 2019. Of that total, 147 were determined to have approached the Pawtucket Dam and were available for the evaluation of downstream passage route (Table 5-8). The majority of radio-tagged individuals passed through the Pawtucket Gatehouse and approached the E.L. Field powerhouse. Most individuals (92.5%) passed downstream of Lowell via the E.L. Field turbine units. Use of the downstream bypass was limited to two individuals (1.4% of those approaching the Pawtucket Dam). Use of the bypassed reach was limited to four individuals, representing 2.8% of radio-tagged eels which approached the Pawtucket Dam.

Radio-tagged silver eels were observed passing downstream of Lowell between the dates of October 13 and November 22 (Figure 5-9). Downstream passage of radio-tagged eels at Lowell peaked during the last part of October with 81% of all downstream passage events at the Project occurring on or before October 31. Figure 5-10 presents the timing distribution of downstream passage events for silver eels at Lowell. The majority of individuals passed downstream at dusk (hours 1800 – 2200) with a peak in the number of downstream passage events during the hour of 2000 (20%).

5.8 Downstream Transit

Three monitoring stations were installed downstream of Lowell for the purpose of detecting radio-tagged adult eels following passage at the Project. Those receivers were located approximately 2.1 (Monitoring Station 37), 6.0 (Monitoring Station 39), and 10.75 (Monitoring Station 40) miles downstream of the project. The minimum, maximum, and quartile transit times through those three reaches are presented in Table 5-9. The median transit time durations for tagged adult eels moving downstream of Lowell were 2.1, 15.0, and 21.8 hours for the 2.1 mile, 3.9 mile and 4.75 mile-long downstream reaches, respectively.

Table 5-10 and Figure 5-11 present the minimum, maximum and quartile transit times for radio-tagged silver eels to cover the reach from immediately downstream of Lowell to the upstream face of the Essex Dam in Lawrence (i.e., Station 40). The median travel time for radio-tagged eels to approach Lawrence following downstream passage at Lowell was 2.3 days (range = 6.7 hours to 38.2 days). Figure 5-12 presents the distribution of observed downstream transit rates for radio-tagged eels moving from Lowell to Lawrence. Reference lines for the 25, 50, and 75% quartiles observed for the freshly-dead drift eels are included (5.7, 9.0, and 19.0 days, respectively; Table 5-2). Of the live-radio-tagged eels which passed downstream of Lowell and were subsequently detected at Lawrence, 85% did so in less time than the 25th percentile of occurrence for the dead drift eels, 91% did so in less time than the 50th percentile (median) of occurrence for the dead drift eels, and 99% did so in less time than the 75th percentile of occurrence for the dead drift eels.

5.9 Passage Survival

The CJS model *Phi(t)p(t)* provided the best fit for the observed mark-recapture data associated with downstream movements of radio-tagged silver-phase American eels approaching and passing at Lowell during 2019 (Table 5-11). The detection efficiency for telemetry receivers recording passage of adult eels at monitoring stations at Lowell and Lawrence as well as the remote riverside locations ranged from 1.000 to 0.839 (Table 5-12). The relatively poor detection efficiency rate (0.839) was estimated for Station 37 (first receiver downstream of Lowell). It is suspected that background interference in the vicinity of the Waste Water Treatment Plant property may have led to the lower than desired detection rate. However, detection was 100% for eels at Station 39 and Lawrence.

The reach-specific survival estimates for the Merrimack River from the upstream extent of the Lowell impoundment to detection immediately upstream of Lawrence are presented in Table 5-13. There was no mortality associated with passage for adult radio-tagged eels moving downstream through the Lowell impoundment. Passage success for downstream adult American eels at Lowell was calculated as the joint probability of the three reach-specific survival estimates which encompasses the full section of the Merrimack River from Lowell downstream to Lawrence (i.e., Lowell to Station 37, Station 37 to Station 39, and Station 39 to Lawrence). This resulted in an estimated downstream passage survival for silver-phase American eels at Lowell of 75.5% (75% CI = 71.4%-79.6%). Estimates of downstream passage for eels released upstream of Garvins Falls (75.6%; 75% CI = 68.8%-82.2%) and immediately upstream of the Lowell impoundment (75.5%; 75% CI = 70.5%-80.4%) did not differ.

Encounter histories for all radio-tagged eels which approached and passed downstream of Lowell were evaluated relative to the calculated downstream transit durations for freshly dead eels released into the Lowell tailrace. Individual test eels with a transit duration from Lowell to Lawrence in excess of the median duration required to drift the 10.75 mile reach were manually adjusted to reflect mortality at the Lowell Project. When those individuals are adjusted, the estimate of overall project passage survival at Lowell is 68.7% (75% CI = 64.5%-72.9%).

Radio-tagged eels which approached and passed downstream at Lowell during the 2019 evaluation did so primarily via the E.L. Field turbine units (Table 5-8) and the number of individuals (n = 136) permitted the generation of a route-specific passage survival rate (75.0%; 75% CI = 70.6%-79.4%). The limited number of radio-tagged eels passing the Project via spill (n = 4) or via the downstream bypass system (n = 2) were all determined to have successfully approached the Lawrence Project following downstream passage at Lowell.

5.10 Time to Event Analysis

A total of 144 Pawtucket Gatehouse and 61 E.L. Field Powerhouse forebay events were defined based on recorded detections of adult American eels during the 2019 study to evaluate the impact of operational parameters on passage success. The median event duration recorded for a radio-tagged adult eel was 1.6 minutes for individuals in the detection field of Station 25 immediately upstream of the Pawtucket Gatehouse and 29 seconds for individuals in the detection field of Station 29 covering the area immediately upstream of the intakes to the downstream bypass and turbine units at the E.L. Field Powerhouse.

5.10.1 Pawtucket Gatehouse

Results of the Cox proportional hazard model for the Pawtucket Gatehouse can be found in Table 5-14 and illustrated in Figure 5-13. Model results suggest a statistically significant and negative relationship between water temperature and passage success at the Pawtucket Gatehouse wherein a decrease in temperature leads to a 22% increase in the probability of passage failure (i.e., the probability of successfully passing downstream through the Pawtucket Gatehouse decreases as the water temperature decreases (presumably later in the season)). For this model, inflow data was split into three bins based on volume: 1080-5060 cfs (i.e., low), 5060-9030 cfs (i.e., mid), and 9030-13,000 cfs (i.e., high). The low inflow condition was used as a reference for comparison with mid and high inflow conditions, as illustrated in Figure 5-13. Although the model suggests an insignificant, negative relationship between inflow values from 1080-5060 cfs and passage success, a statistically significant, positive relationship was found between passage success and high inflow values ranging from 9030-13,000 cfs. This indicates inflow values classified as “high” reduced the probability of passage failure by 33% (i.e., likelihood of successful passage at the Pawtucket Gatehouse increases with rising inflow). Similarly, spill data was split into three bins: 0-3040 cfs (i.e., low), 3040-6070 cfs (i.e., mid), and 6070-9120 cfs (i.e., high) and the low spill flow category was used as reference for comparison with mid and high spill conditions (Figure 5-13). Mid-levels of spill flow were found to be significantly correlated with passage success. The probability of passage failure for adult eels at the Pawtucket Gatehouse decreases by 79% when spill is between 2080 and 6070 cfs. Additionally, it should be noted that Table 5-15 demonstrates the Pawtucket Gatehouse model meets the criteria necessary to accept the assumption that hazards are proportional, as all covariates were found to be independent of time.

5.10.2 E.L. Field Powerhouse Forebay

Results of the Cox proportional hazards model for E.L. Field forebay events suggest a statistically significant, negative relationship between both water temperature and the forebay-tailrace head differential versus passage success, increasing the probability of passage failure by 26% and 58%, respectively (Table 5-16). In order to make sure the data met the assumption of proportional hazards and ensure the use of an appropriate modelling framework, spill was maintained as a continuous variable and inflow was split into three bins (1080-5060 cfs (i.e., low), 5060-9030 cfs (i.e., mid), and 9030-13,000 cfs (i.e., high; Table 5-16). However, neither spill nor inflow were found to be significant variables with neither exhibiting a measurable impact on passage success out of the E.L. Field Powerhouse forebay. Model results indicate the combined turbine discharge (cfs) exhibited a negative, statistically significant impact on passage success, which was also classified into three bins: 592-1980 cfs (i.e., low generation), 1980-3950 cfs (i.e., mid generation), and 3950-5930 cfs (i.e., high generation). As illustrated in Figure 5-14, the low generation category was used as a reference for comparison to the mid and high generation conditions. Results suggest a strong, statistically significant interaction for the rate of passage failure under the mid and high generation conditions with an increase in the observed rate of passage failure for those two conditions relative to the low generation condition. Table 5-17 demonstrates that the E.L. Field Powerhouse forebay model meets the criteria necessary to accept the assumption that hazards are proportional, as all covariates were found to be independent of time.

5.11 Manual Tracking

In addition to the continuous monitoring provided by the 12 stationary receivers installed throughout the Project area for the duration from early October through November 2019, a total of 116 manual detections representing 66 individuals were recorded between October 21 and November 25. Appendix C contains a listing of manual detections identified to the nearest 0.25 mile and classified as “Transit” for eels which were detected at stationary receivers downstream of their manually determined position or “Stationary” for eels which were not detected again at stationary receivers downstream of their manually determined position(s). A total of 39 individuals were located a single time within the Lowell impoundment with the majority (38 or 39) representing an individual which exhibited continued downstream movement following manual detection. A total of 10 individuals were manually detected within the Merrimack River downstream of Lowell and upstream of Station 37. The majority of those individuals (8 of 10) represented stationary individuals which were not detected at any of the downstream stationary receivers (i.e., Stations 37, 39, or 40). Similarly, a total of 18 individuals were manually detected within the Merrimack River between Stations 37 and 39. The majority of those individuals (11 of 18) represented stationary individuals which were not detected at additional downstream stationary receivers (i.e., Stations 39, or 40). Five radio-tagged eels were each detected on a single occasion in the reach between Station 39 and immediately upstream of Lawrence (Station 40).

Table 5–2. Summary of the downstream drift distance and duration for freshly dead, radio-tagged silver eels released in the Lowell tailrace during the downstream passage assessment, October 9 to November 30, 2019.

Release Date	River Condition (cfs)		Frequency (ID)	Total Length (mm)	Station 37 Arrival		Station 39 Arrival		Station 40 Arrival		Drift Duration	
	Inflow	ELF Discharge			Date	Time	Date	Time	Date	Time	Hours	Days
9-Oct	1830	1265	149.320 (80)	806	-	-	17-Oct	22:01	18-Oct	2:29	198.8	8.3
			149.320 (81)	761	-	-	-	-	-	-	-	-
11-Oct	1515	824	149.320 (82)	726	14-Oct	4:12	15-Oct	3:47	1-Nov	18:44	503.4	21.0
			149.320 (83)	775	22-Oct	3:08	-	-	-	-	-	-
16-Oct	1454	780	149.320 (84)	807	27-Oct	20:06	8-Nov	1:19	8-Nov	5:35	538.9	22.5
			149.320 (85)	802	-	-	23-Oct	23:20	25-Oct	19:06	216.4	9.0
18-Oct	4938	3932	149.320 (86)	806	-	-	-	-	-	-	-	-
			149.320 (87)	932	20-Oct	5:56	2-Nov	19:29	4-Nov	18:28	407.0	17.0
23-Oct	3981	2795	149.320 (88)	958	24-Oct	3:58	25-Oct	2:29	26-Oct	18:44	72.6	3.0
			149.320 (89)	751	25-Oct	3:46	25-Oct	23:18	26-Oct	5:33	59.4	2.5

Table 5–3. Release date and location for radio-tagged silver eels upstream of Lowell during the downstream passage assessment, October 9 to November 30, 2019.

Release Date	Release Location	No. of Individuals
9-Oct	Upstream of Garvins Falls	20
9-Oct	Upstream of Lowell Impoundment	20
11-Oct	Upstream of Garvins Falls	20
11-Oct	Upstream of Lowell Impoundment	20
15-Oct	Upstream of Garvins Falls	20
16-Oct	Upstream of Lowell Impoundment	20
18-Oct	Upstream of Lowell Impoundment	20
23-Oct	Upstream of Lowell Impoundment	22

Table 5–4. Minimum, maximum, and quartile values of impoundment duration (hours) for radio-tagged eels released upstream of the Lowell project boundary and upstream of Garvins Falls Dam during the fall 2019 downstream passage assessment.

Release Location	Release Date	Impoundment Duration (hours)				
		Minimum	Maximum	Q25	Q50 (Median)	Q75
Garvins Falls	9-Oct	21.2	393.9	28.2	49.2	82.4
Garvins Falls	11-Oct	24.6	242.6	28.9	51.2	72.5
Garvins Falls	15-Oct	19.7	266.9	24.6	50.4	126.3
Garvins Falls	All	19.7	393.9	28.6	50.7	74.9
Lowell	9-Oct	12.5	239.3	47.8	68.9	131.8
Lowell	11-Oct	13.7	335.6	27.4	63.7	101.1
Lowell	16-Oct	21.8	287.7	46.0	68.1	137.0
Lowell	18-Oct	23.3	240.9	29.4	51.8	94.0
Lowell	23-Oct	23.2	71.8	26.7	29.0	51.5
Lowell	All	12.5	335.6	29.0	51.7	107.5
All		12.5	393.9	28.8	51.3	95.3

Table 5–5. Minimum, maximum, and quartile values of upstream residence duration (hours) for radio-tagged eels released upstream of the Lowell project boundary and upstream of Garvins Falls Dam during the fall 2019 downstream passage assessment.

Release Location	Release Date	Upstream Residence Duration (hours)*				
		Minimum	Maximum	Q25	Q50 (Median)	Q75
Garvins Falls	9-Oct	0.3	24.1	0.3	0.4	1.7
Garvins Falls	11-Oct	0.2	17.1	0.3	0.3	0.5
Garvins Falls	15-Oct	0.2	17.5	0.3	0.5	1.4
Garvins Falls	All	0.2	24.1	0.3	0.4	1.3
Lowell	9-Oct	0.2	395.4	0.3	0.4	1.3
Lowell	11-Oct	0.2	47.7	0.3	0.4	1.3
Lowell	16-Oct	0.2	0.5	0.2	0.3	0.4
Lowell	18-Oct	0.3	113.9	0.3	0.4	0.5
Lowell	23-Oct	0.2	165.3	0.3	0.4	1.5
Lowell	All	0.2	395.4	0.3	0.4	0.6
All		0.2	395.4	0.3	0.4	0.7

*Upstream residence duration = duration from arrival at Pawtucket Dam until confirmed downstream passage

Table 5–6. Minimum, maximum, and quartile values of time to pass the Pawtucket Gatehouse and enter Northern Canal (hours) for radio-tagged eels released upstream of the Lowell project boundary and upstream of Garvins Falls Dam during the fall 2019 downstream passage assessment.

Release Location	Release Date	Pawtucket Gatehouse Passage (hours)				
		Minimum	Maximum	Q25	Q50 (Median)	Q75
Garvins Falls	9-Oct	<0.1	23.0	0.1	0.1	0.3
Garvins Falls	11-Oct	<0.1	36.8	0.1	0.1	0.1
Garvins Falls	15-Oct	<0.1	0.5	0.1	0.1	0.1
Garvins Falls	All	<0.1	36.8	0.1	0.1	0.1
Lowell	9-Oct	<0.1	10.2	0.1	0.1	0.1
Lowell	11-Oct	<0.1	0.2	0.1	0.1	0.1
Lowell	16-Oct	<0.1	0.2	<0.1	0.1	0.1
Lowell	18-Oct	<0.1	0.2	0.1	0.1	0.1
Lowell	23-Oct	<0.1	93.5	0.1	0.1	0.1
Lowell	All	<0.1	93.5	0.1	0.1	0.1
All		<0.1	93.5	0.1	0.1	0.1

Table 5–7. Minimum, maximum, and quartile values of Northern Canal residence duration (hours) for radio-tagged eels released upstream of the Lowell project boundary and upstream of Garvins Falls Dam during the fall 2019 downstream passage assessment.

Release Location	Release Date	Northern Canal Residence (hours)				
		Minimum	Maximum	Q25	Q50 (Median)	Q75
Garvins Falls	9-Oct	0.2	1.0	0.2	0.2	0.7
Garvins Falls	11-Oct	0.1	3.1	0.2	0.2	0.3
Garvins Falls	15-Oct	0.1	0.5	0.1	0.2	0.3
Garvins Falls	All	0.1	3.1	0.2	0.2	0.3
Lowell	9-Oct	0.1	530.5	0.1	0.2	0.3
Lowell	11-Oct	0.1	47.6	0.2	0.2	0.5
Lowell	16-Oct	0.1	0.3	0.1	0.2	0.3
Lowell	18-Oct	0.1	113.7	0.2	0.2	0.3
Lowell	23-Oct	0.1	165.1	0.2	0.2	0.3
Lowell	All	0.1	530.5	0.2	0.2	0.3
All		0.1	530.5	0.2	0.2	0.3

Table 5–8. Downstream passage route selection for radio-tagged eels released upstream of the Lowell project boundary and upstream of Garvins Falls Dam during the fall 2019 downstream passage assessment.

Release Location	Release Date	Lowell Downstream Passage Route					
		No Detect	No Pass	Unknown	Turbine	Spill	Bypass
Garvins Falls	9-Oct	7	0	1	11	1	0
Garvins Falls	11-Oct	2	1	0	15	1	1
Garvins Falls	15-Oct	6	0	0	13	1	0
Garvins Falls	All	15	1	1	39	3	1
Lowell	9-Oct	0	0	1	19	0	0
Lowell	11-Oct	0	0	0	19	0	1
Lowell	16-Oct	0	0	1	18	1	0
Lowell	18-Oct	0	0	0	20	0	0
Lowell	23-Oct	0	0	1	21	0	0
Lowell	All	0	0	3	97	1	1
All		15	1	4	136	4	2
Percent Utilization			0.7%	2.7%	92.5%	2.7%	1.4%

Table 5–9. Minimum, maximum, and quartile values of travel time (hours) through three separate downstream reaches for radio-tagged eels released upstream of the Lowell project boundary and upstream of Garvins Falls Dam during the fall 2019 downstream passage assessment.

Downstream Reach	Release Location	Release Date	Minimum	Maximum	Q25	Q50 (Median)	Q75
Downstream of Lowell to Station 37 (2.1 miles)	Garvins Falls	9-Oct	0.8	425.8	2.0	13.5	164.8
	Garvins Falls	11-Oct	0.8	667.7	1.1	1.4	6.8
	Garvins Falls	15-Oct	0.7	517.8	1.3	3.5	88.2
	Garvins Falls	All	0.7	667.7	1.1	2.6	29.0
	Lowell	9-Oct	0.7	23.9	0.9	2.2	10.3
	Lowell	11-Oct	0.7	453.6	1.0	1.2	3.2
	Lowell	16-Oct	0.7	237.6	1.7	2.7	3.9
	Lowell	18-Oct	0.7	44.1	1.0	1.9	7.5
	Lowell	23-Oct	0.7	600.5	1.1	1.6	14.3
	Lowell	All	0.7	600.5	1.1	2.0	10.3
	All		0.7	667.7	1.1	2.1	14.3
Station 37 to Station 39 (3.9 miles)	Garvins Falls	9-Oct	2.2	12.6	2.5	2.8	5.1
	Garvins Falls	11-Oct	1.4	86.7	2.0	3.4	67.2
	Garvins Falls	15-Oct	2.4	499.5	14.8	16.4	51.9
	Garvins Falls	All	1.4	499.5	2.5	9.1	41.5
	Lowell	9-Oct	1.8	324.9	17.7	37.3	66.7
	Lowell	11-Oct	1.4	187.3	2.2	19.9	108.4
	Lowell	16-Oct	2.1	69.4	15.5	18.6	20.6
	Lowell	18-Oct	1.9	381.0	2.3	3.0	15.1
	Lowell	23-Oct	1.7	190.8	2.3	2.8	32.5
	Lowell	All	1.4	381.0	2.5	16.6	38.5
	All		1.4	499.5	2.5	15.0	39.8
Station 39 to Lawrence (Station 40; 4.75 miles)	Garvins Falls	9-Oct	3.7	91.3	5.2	21.8	39.3
	Garvins Falls	11-Oct	3.7	89.2	7.9	16.3	23.4
	Garvins Falls	15-Oct	2.8	270.3	21.4	52.8	70.9
	Garvins Falls	All	2.8	270.3	7.9	21.6	56.2
	Lowell	9-Oct	3.0	182.3	3.8	23.5	70.0
	Lowell	11-Oct	3.1	119.4	3.4	4.5	21.9
	Lowell	16-Oct	3.5	114.4	4.7	27.3	47.6
	Lowell	18-Oct	3.7	113.1	19.1	23.5	57.8
	Lowell	23-Oct	3.3	356.2	4.5	20.4	46.0
	Lowell	All	3.0	356.2	4.5	22.1	47.1
	All		2.8	356.2	4.7	21.8	48.1

Table 5–10. Minimum, maximum, and quartile values for downstream travel duration from Lowell to Lawrence (hours) for radio-tagged eels released upstream of the Lowell project boundary and upstream of Garvins Falls Dam during the fall 2019 downstream passage assessment.

Release Location	Release Date	Downstream Travel: Lowell to Lawrence (hours)				
		Minimum	Maximum	Q25	Q50 (Median)	Q75
Garvins Falls	9-Oct	19.4	431.7	38.5	55.6	97.6
Garvins Falls	11-Oct	7.7	169.8	20.7	27.7	80.7
Garvins Falls	15-Oct	19.9	917.2	52.4	78.9	176.9
Garvins Falls	All	7.7	917.2	27.7	63.0	97.6
Lowell	9-Oct	10.9	427.5	38.9	70.6	165.3
Lowell	11-Oct	7.1	415.5	32.3	45.9	125.2
Lowell	16-Oct	8.2	146.8	33.6	57.7	87.0
Lowell	18-Oct	6.7	399.2	25.2	42.2	80.0
Lowell	23-Oct	21.1	359.8	41.9	60.9	97.6
Lowell	All	6.7	427.5	33.6	50.2	96.7
All		6.7	917.2	28.0	56.3	97.1

Table 5–11. CJS model selection criteria for survival of adult American eels at Lowell during the fall 2019 downstream passage assessment.

Model	AICc	Delta AICc	AICc Weight	Model Likelihood	No. Parameters	Deviance
Phi(t)p(t)	657.65	0.00	1.00	1.00	8	11.92
Phi(.)p(t)	714.22	56.57	0.00	0.00	5	74.59
Phi(t)p(.)	719.99	62.34	0.00	0.00	6	78.33
Phi(.)p(.)	800.54	142.89	0.00	0.00	2	166.96

Where *phi* = survival; *p* = detection probability; t = parameter is allowed to vary with time; and "." = parameter is fixed with time.
AIC = Akaike's Information Criterion – comparison value among set of evaluated survival models

Table 5–12. Detection efficiency estimates (p) for monitoring locations installed to detect radio-tagged adult American eels approaching and passing Lowell during the fall 2019 downstream passage assessment.

Location	S	SE	95% CI	
Station 19	0.952	0.018	0.903	0.977
Lowell	1.000	0.000	-	-
Station 37	0.839	0.035	0.759	0.896
Station 39	1.000	0.000	-	-
Lawrence	1.000	0.000	-	-

Table 5–13. Reach-specific survival probability estimates (*phi)*, standard errors, and likelihood 75% and 95% confidence intervals for radio-tagged adult American eels approaching and passing Lowell during the fall 2019 downstream passage assessment.

Reach	Reach Length (mile)	*Phi*	SE	95% CI		75% CI	
Lowell Impoundment	23.0	1.000	0.000	-	-	-	-
Lowell to Station 37	2.1	0.900	0.029	0.828	0.944	0.861	0.928
Station 37 to Station 39	3.9	0.847	0.034	0.767	0.903	0.803	0.882
Station 39 to Lawrence	4.8	0.991	0.009	0.939	0.999	0.972	0.997
Lawrence to Station 45	2.1	0.903	0.039	0.795	0.957	0.848	0.939

Table 5–14. Results of the Cox proportional hazards model for adult American eel passage through Pawtucket Gatehouse. Significance is determined by p < 0.05.

Pawtucket Gatehouse										
Model: Time to Event ~ Temperature + Inflow + Spill										
Model Parameter	*b*	se	z	P-value	Significance	e^{b}	e^{-b}	Lower .95	Upper .95	Percent Change
Temp	0.2	0.07	2.86	0	Significant	1.22	0.82	1.06	1.4	↑ 22%
Inflow 5060-9030 cfs	0.04	0.31	0.14	0.89	Insignificant	1.05	0.96	0.56	1.94	↑ 5%
Inflow 9030-13,000 cfs	-0.27	0.79	-0.34	0.74	Insignificant	0.77	1.31	0.16	3.62	↓ 33%
Spill 3040-6070 cfs	-1.56	0.41	-3.86	0	Significant	0.21	4.78	0.09	0.46	↓ 79%
Spill 6070-9120 cfs	1.22	0.91	1.33	0.18	Insignificant	3.37	0.3	0.56	20.16	↑ 237%
Canal Height Diff.	-0.09	0.12	-0.75	0.45	Insignificant	0.91	1.09	0.72	1.16	↓ 9%

Significance is determined by p < 0.05.

Table 5–15. Output of the Schoenfield residual test for time independence of covariates in Cox proportional hazard model of Pawtucket Gatehouse passage events.

Variable	Chi-squared	df	P-Value
Temperature (°C)	3.35	1	0.067
Inflow (cfs)	1.34	2	0.512
Spill (cfs)	1.3	2	0.521
Gatehouse Differential (ft)	2.35	1	0.125
Full Model	11.88	6	0.065

Note: p < 0.05 indicates a violation of the proportional hazard assumption.

Table 5–16. Results of the Cox proportional hazards model for adult American eel passage through E.L. Field Powerhouse forebay.

Forebay										
Model: Time to Event ~ Temperature + Combined Turbine cfs + Spill + Inflow + ELF Head										
Model Parameter	*b*	se	z	P-value	Significance	e^b	e^{-b}	Lower .95	Upper .95	Percent Change
Temp	0.23	0.08	2.96	0	Significant	1.26	0.79	1.08	1.47	↑ 26%
Inflow 5060-9030 cfs	0.76	0.89	0.85	0.39	Insignificant	2.14	0.47	0.37	12.25	↑ 114%
Inflow 9030-13,000 cfs	-1.3	1.56	-0.84	0.4	Insignificant	0.27	3.68	0.01	5.78	↓ 73%
Spill cfs	0	0	2.19	0.03	No Hazard	1	1	1	1	0
Turbine CFS 1980-3950 cfs	2.26	0.73	3.09	0	Significant	9.56	0.1	2.28	39.98	↑ 856%
Turbine CFS 3950-5930 cfs	4.69	0.97	4.82	0	Significant	109	0.01	16.15	735.5	↑ 10798%
E.L. Field Powerhouse Head	0.46	0.18	2.47	0.01	Significant	1.58	0.63	1.1	2.27	↑ 58%

Significance is determined by $p < 0.05$.

Table 5–17. Output of the Schoenfield Residual test for time independence of covariates in Cox proportional hazard model of E.L. Field Powerhouse forebay events.

Variable	Chi-squared	df	P-Value
Temperature (°C)	0.0689	1	0.79
Inflow (cfs)	2.7546	2	0.25
Spill (cfs)	1.6921	1	0.19
Turbine Discharge (cfs)	1.3068	2	0.52
ELF Head Differential (ft)	0.099	1	0.75
Full Model	9.2518	7	0.24

Note: $p < 0.05$ indicates a violation of the proportional hazard assumption.

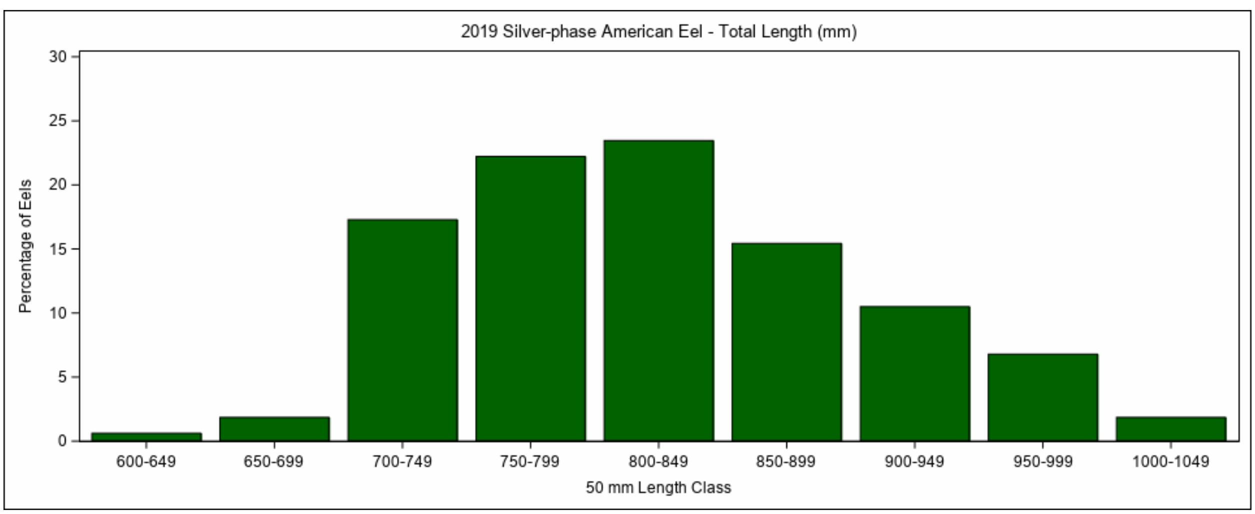

Figure 5–5. Length frequency distribution of adult American eels radio-tagged and released upstream of Lowell during 2019.

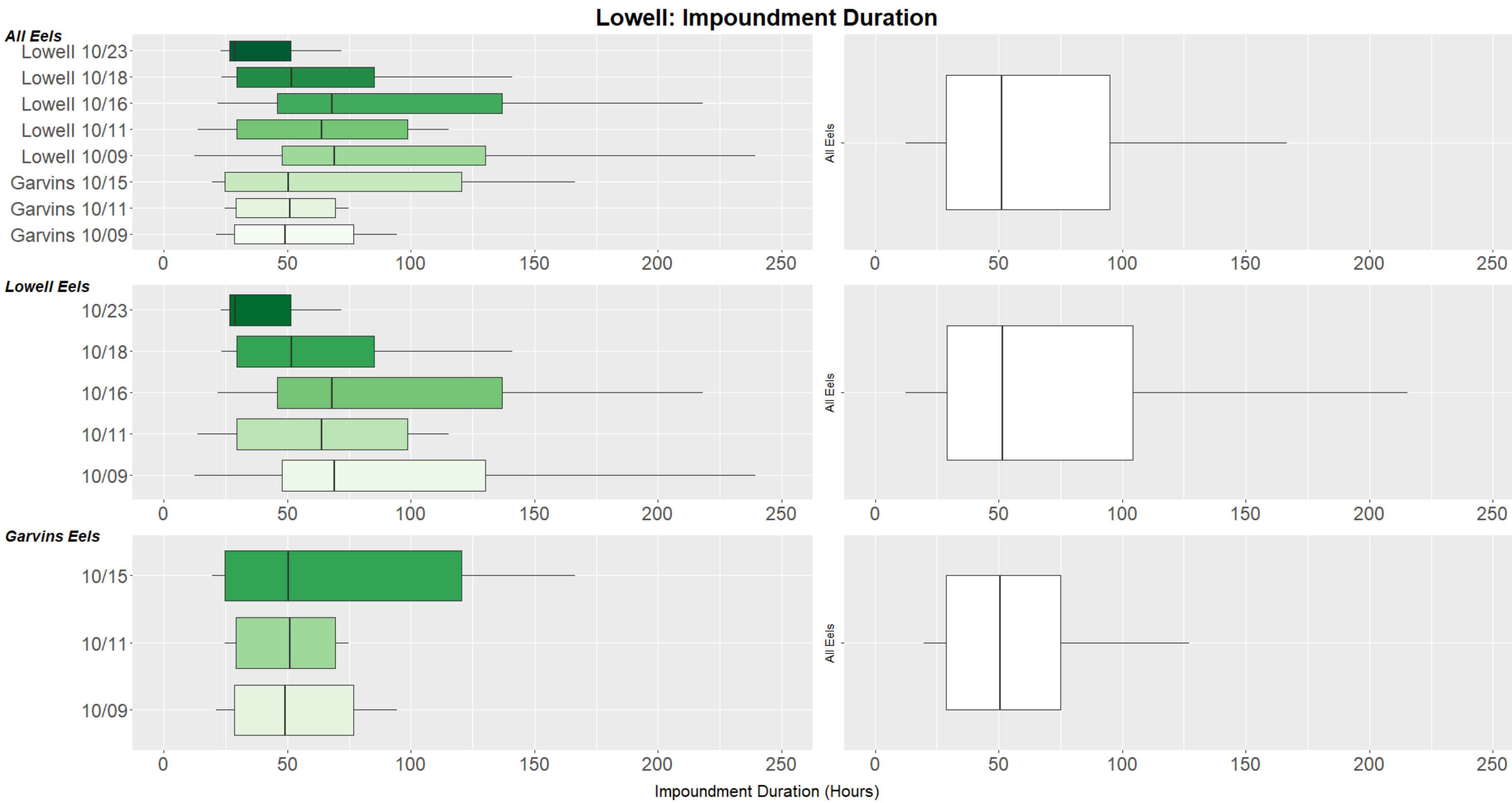

Figure 5–6. Boxplot of the Lowell impoundment duration for all radio-tagged eels (top panel), radio-tagged eels released upstream of Project boundary (middle panel) and upstream of Garvins Falls Dam (bottom panel).[4]

[4] The solid line represents the median while left and right portions of the box represent the first and third quartiles, respectively. Whiskers extend to the range of the data within the interquartile range (quartile*1.05) such that outliers outside of this range are not displayed.

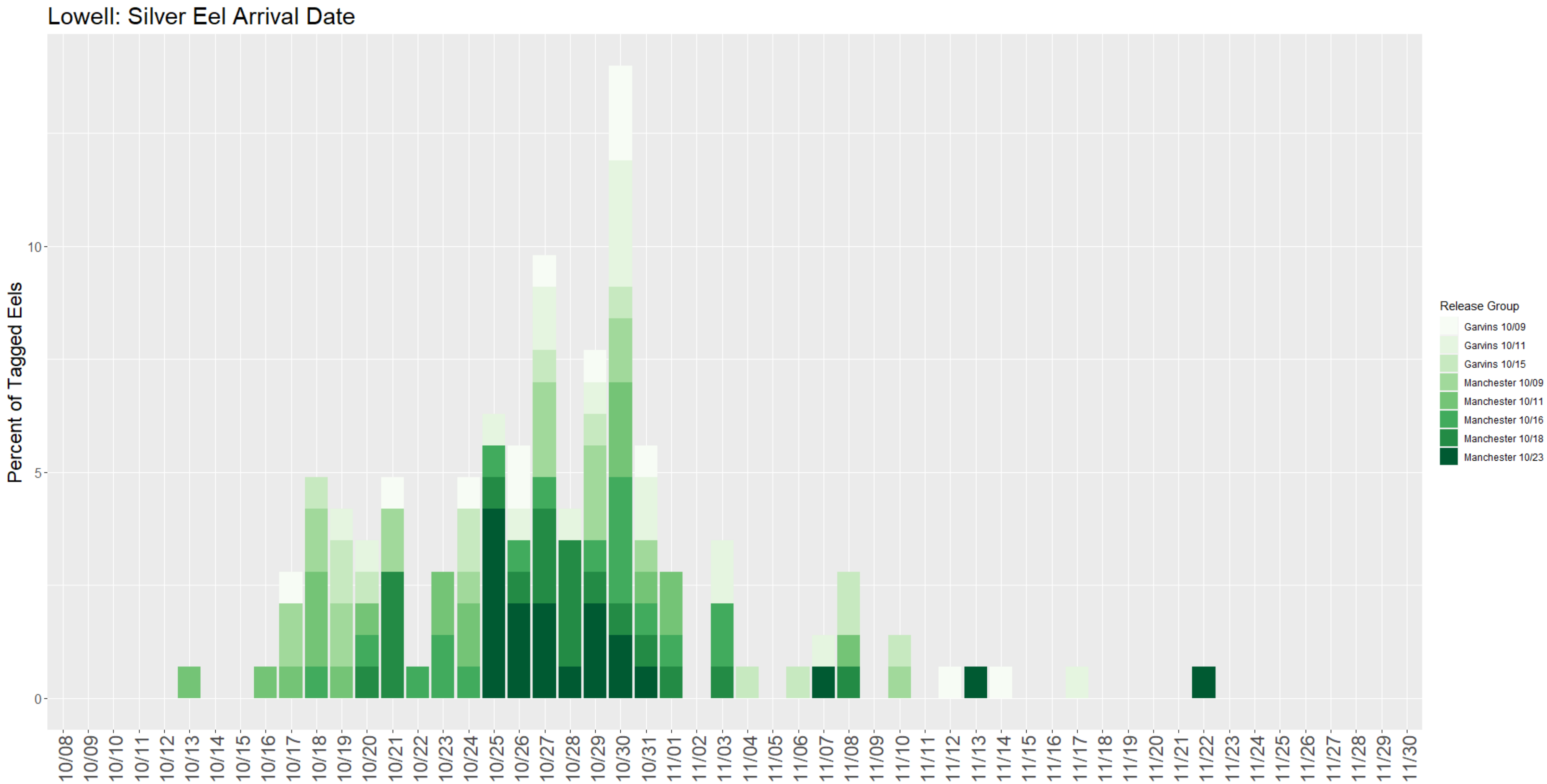

Figure 5–7. Distribution of Pawtucket Dam arrival dates for radio-tagged eels originally released upstream of the Project boundary (Manchester) and upstream of Garvins Falls Dam (Garvins Falls).

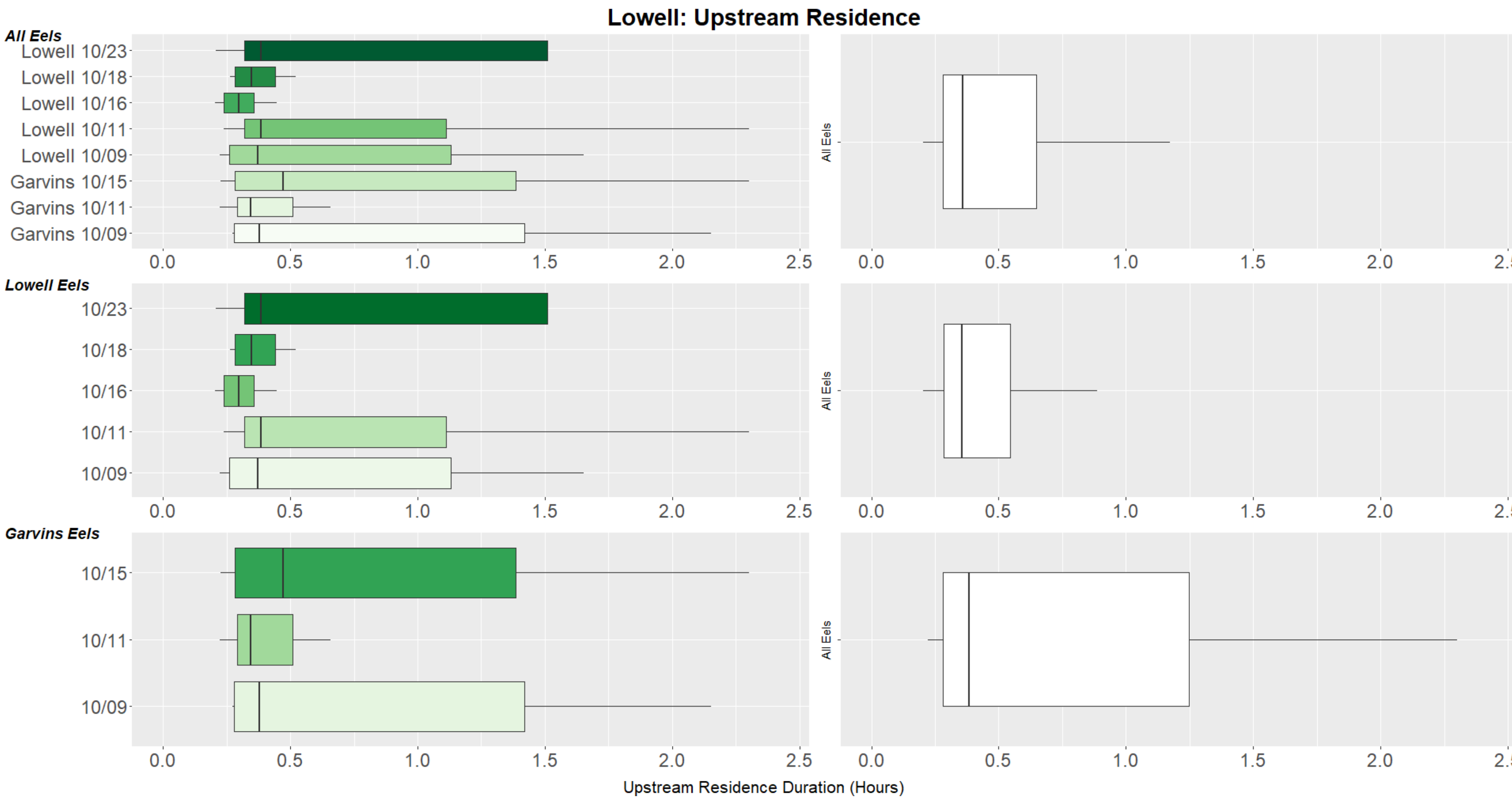

Figure 5–8. Boxplot of the residence duration upstream of Lowell for all radio-tagged eels (top panel), radio-tagged eels released upstream of Project boundary (middle panel) and upstream of Garvins Falls Dam (bottom panel).[5]

[5] The solid line represents the median while left and right portions of the box represent the first and third quartiles, respectively. Whiskers extend to the range of the data within the interquartile range (quartile*1.05) such that outliers outside of this range are not displayed.

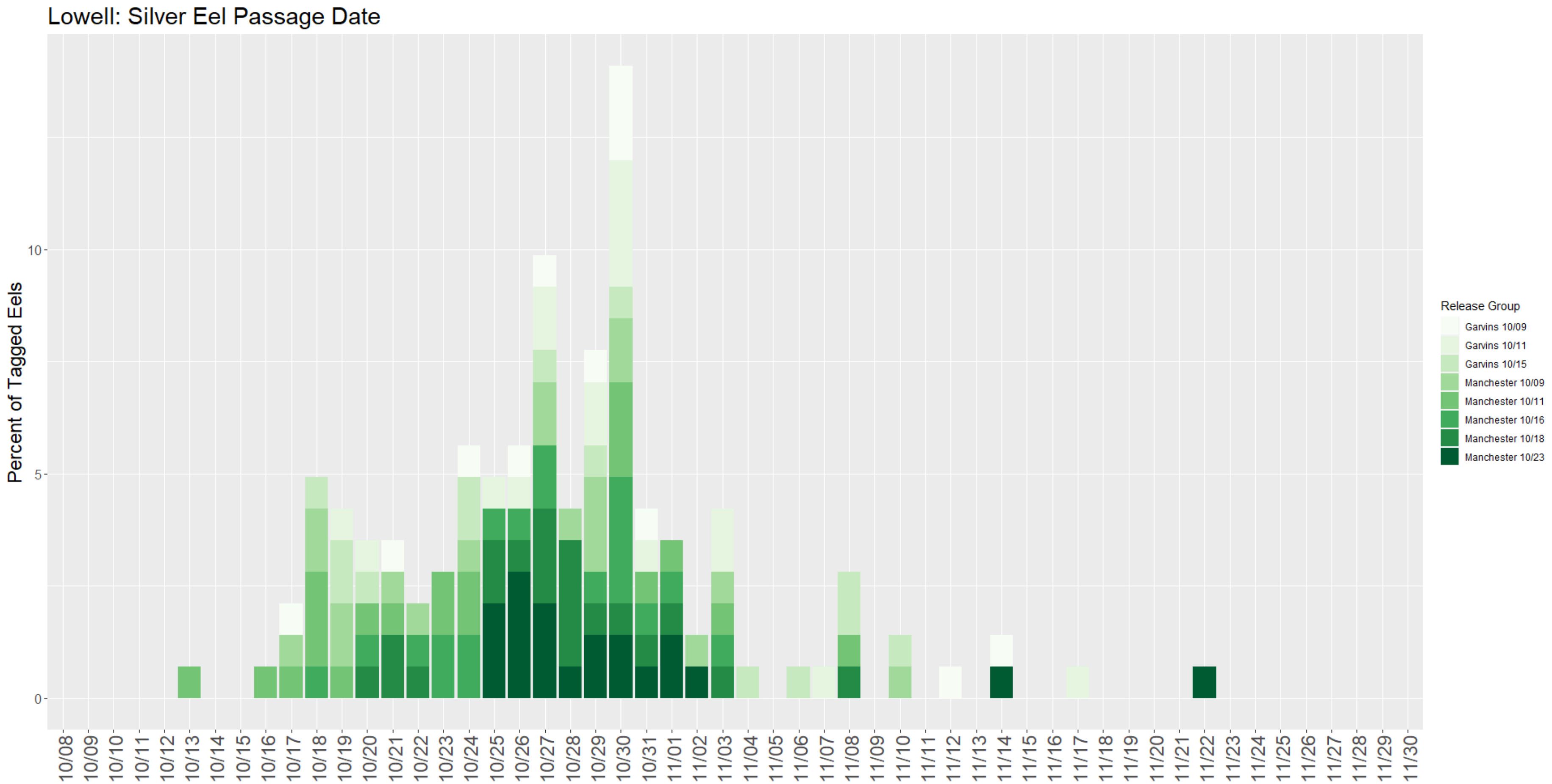

Figure 5–9. Distribution of Pawtucket Dam downstream passage dates for radio-tagged eels originally released upstream of the Project boundary (Manchester) and upstream of Garvins Falls Dam (Garvins Falls).

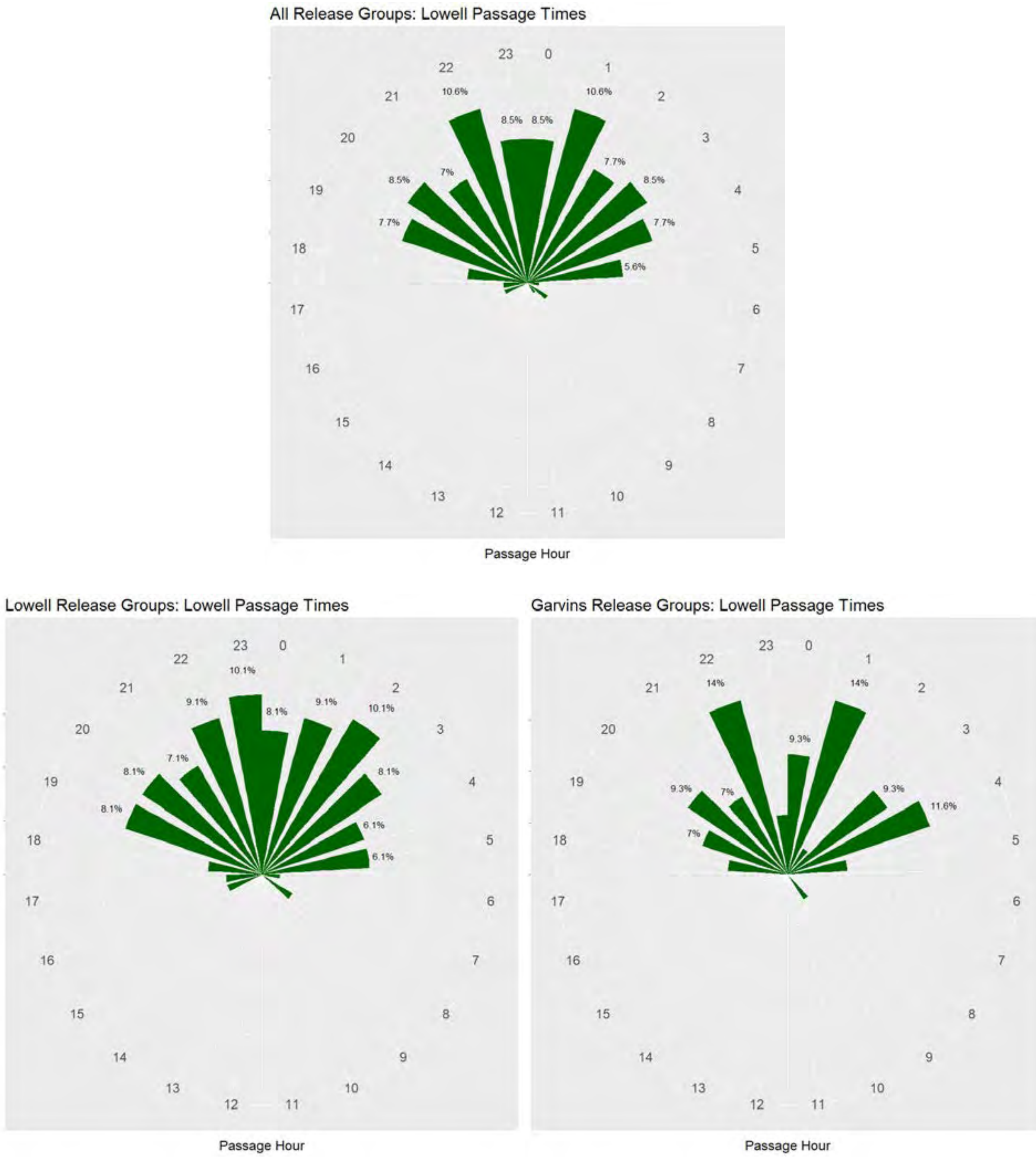

Figure 5–10. Distribution of downstream passage time for all radio-tagged silver eels (top), individuals released upstream of the Lowell Project boundary (bottom left) and upstream of Garvins Falls (bottom right).

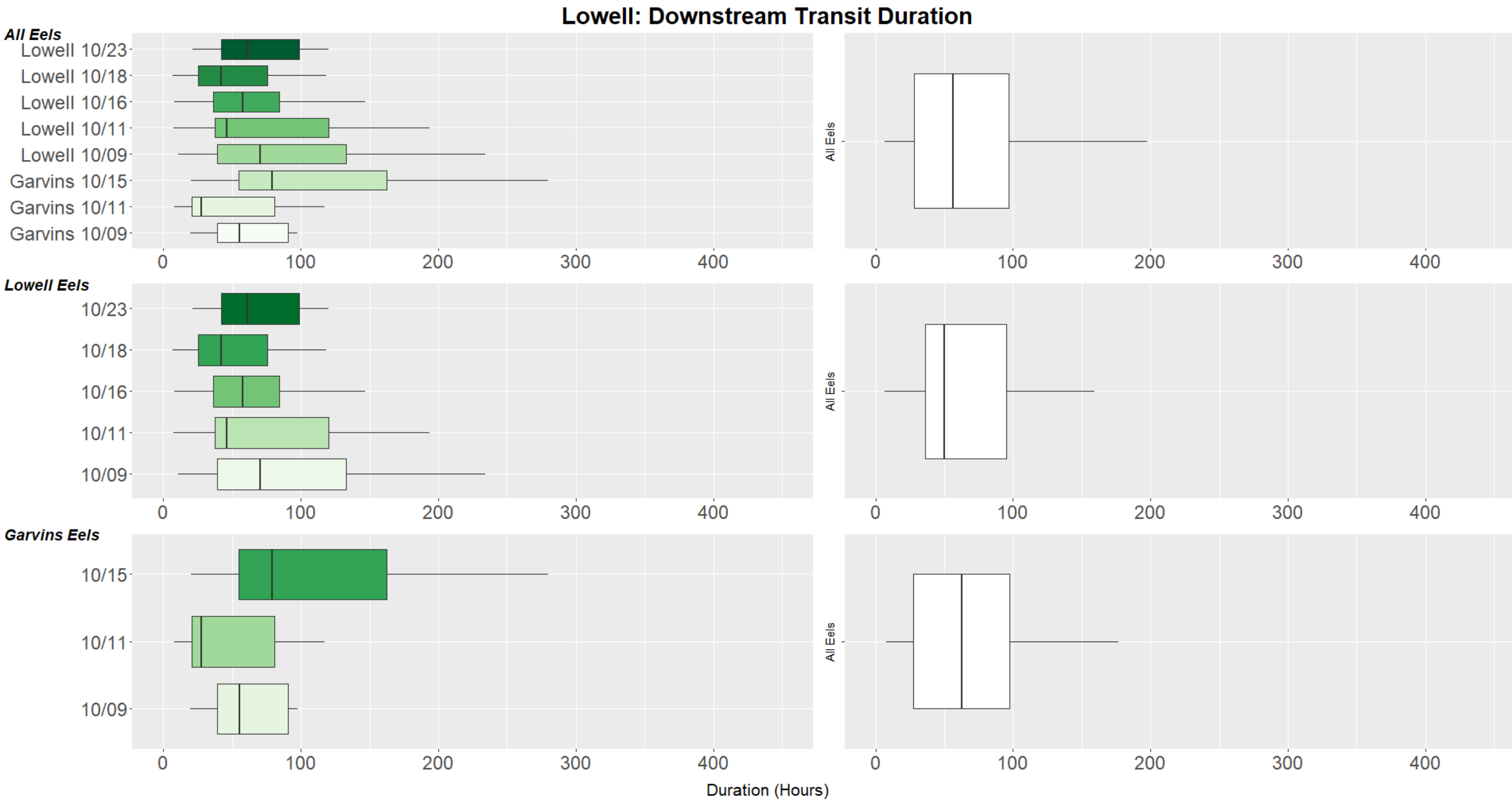

Figure 5–11. Boxplot of the downstream transit duration from Lowell to Lawrence for all radio-tagged eels (top panel), radio-tagged eels released upstream of Project boundary (middle panel) and upstream of Garvins Falls Dam (bottom panel).[6]

[6] The solid line represents the median while left and right portions of the box represent the first and third quartiles, respectively. Whiskers extend to the range of the data within the interquartile range (quartile*1.05) such that outliers outside of this range are not displayed.

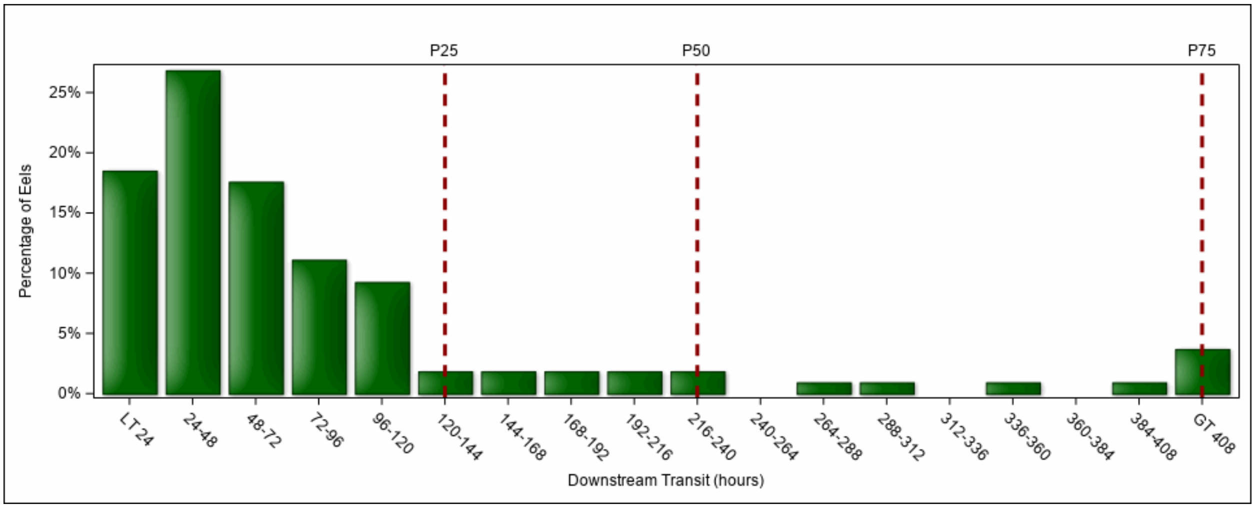

Figure 5–12. Distribution of downstream transit duration from Lowell to Lawrence for radio-tagged silver eels released upstream of the Lowell Project boundary and Garvins Falls. Vertical lines represent the 25th, 50th, and 75th percentiles for downstream transit durations from Lowell to Lawrence for freshly-dead drift eels.

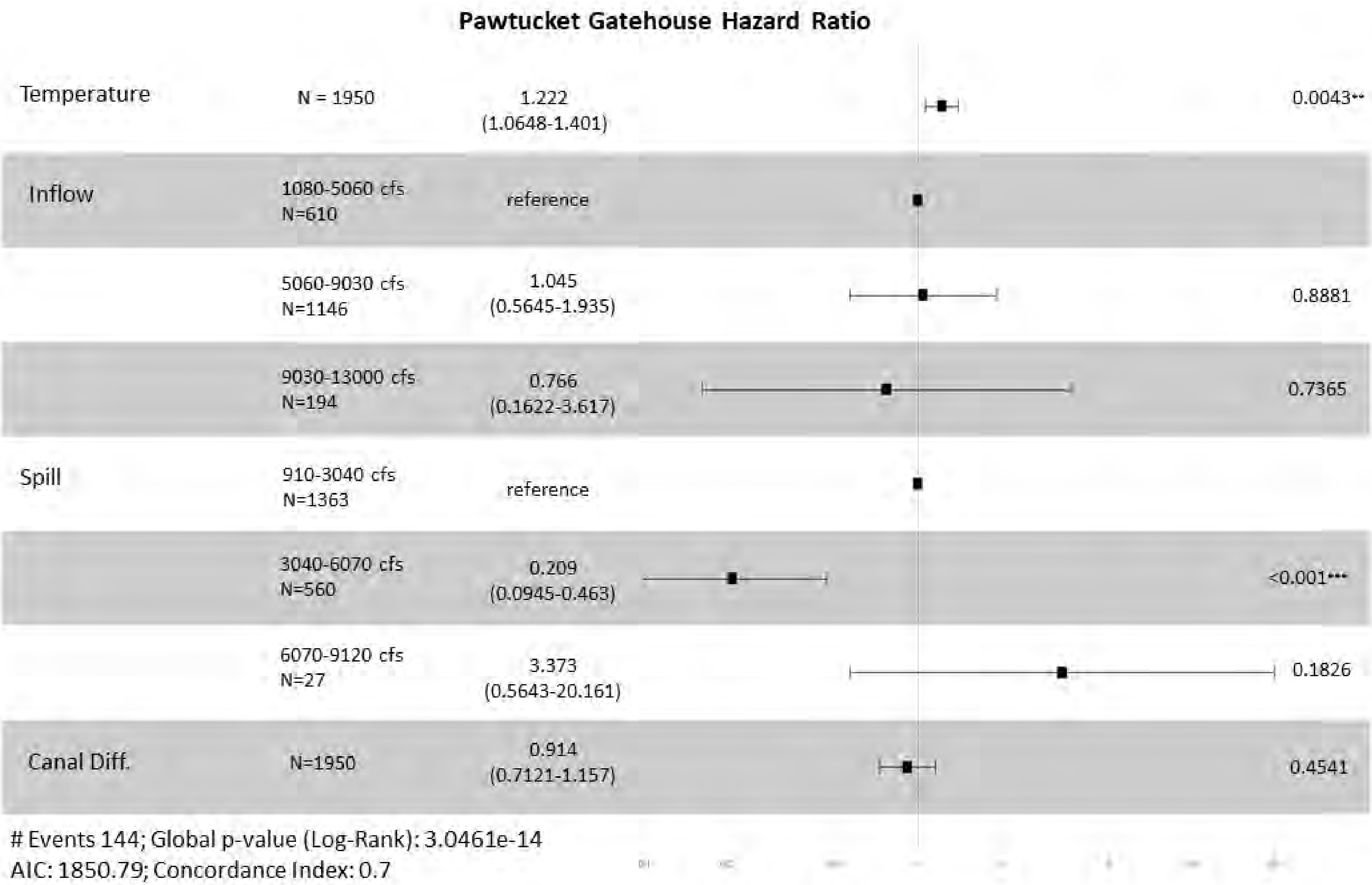

Figure 5–13. Cox proportional hazards model results for passage success of radio-tagged adult American eels at the Pawtucket Gatehouse.

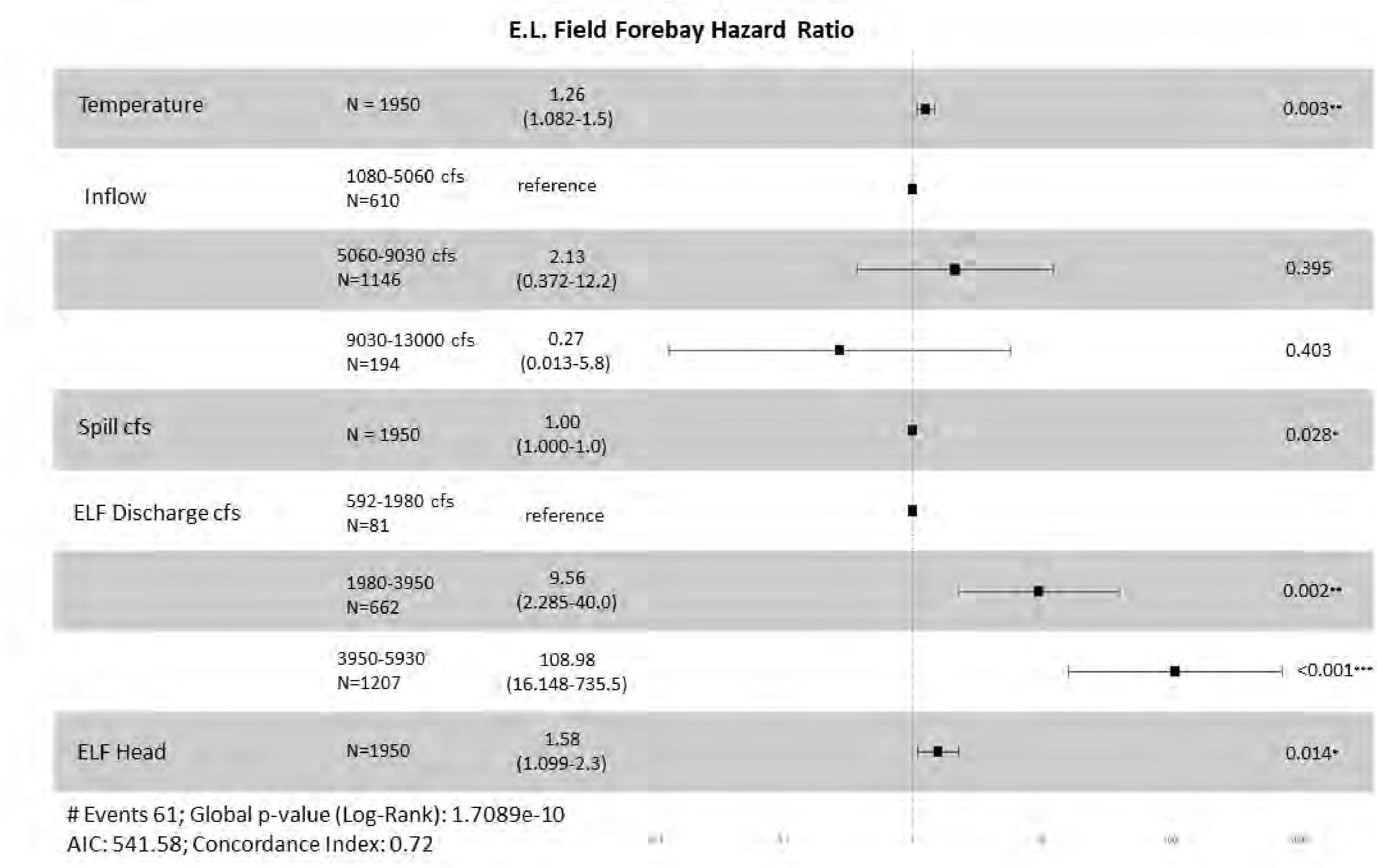

Figure 5–14. Cox proportional hazards model results for passage success of radio-tagged adult American eels at the E.L. Field Powerhouse forebay.

6 Summary

An evaluation of the potential impacts on the outmigration of adult silver-phase American eels was conducted in support of the FERC relicensing of the Lowell Project on the Merrimack River. Downstream passage effectiveness was evaluated using radio-telemetry during the 2019 fall migration season (October 9 to November 30, 2019). Monitoring of outmigrating adult American eels focused on the evaluation of movement through the Project impoundment, residence time immediately upstream of the Pawtucket Dam and prior to passage, passage route utilization and estimation of downstream passage survival at the Project.

A total of 102 adult silver eels were tagged and released at a shoreline location approximately 11 miles upstream of the upper end of the Lowell Project impoundment. Their subsequent downstream arrival and passage at the Project was monitored via a series of fixed-location telemetry receivers within the Lowell Project area. Arrival and downstream passage information was also monitored for 60 radio-tagged individuals released upstream of the Garvins Falls Dam as part of a separate study. The majority of individuals (152 of the 162) were obtained from a commercial vendor operating on the St. Croix River, Maine. The New Hampshire Fish and Game Department provided an additional 12 adult eels collected by a weir in the Soucook River, ten of which were also radio-tagged and released upstream of the Lowell impoundment. All 162 individuals were surgically radio-tagged and were released into the Merrimack over a range of release dates between October 9 and 23.

Radio-tagged eels moved through the 23 mile long Project impoundment in a median duration of 2.1 days. Upon initial detection at the Pawtucket Dam, the median duration of time spent immediately upstream of the dam structure was 0.4 hours with 94% passing downstream within the first 24 hours of their initial detection. Closer examination of the total residence time for radio-tagged eels indicated that the 95% of individuals passing through the Pawtucket Gatehouse did so in 30 minutes or less and upon entry into the Northern Canal the median residence duration prior to downstream passage was 0.2 hours.

Outmigrating adult eels encountering the Pawtucket Dam can (1) pass through the Pawtucket Gatehouse and enter the power canal, (2) pass downstream over Pawtucket Dam via spill, or (3) enter the Pawtucket Canal and navigate downstream via the downtown canal system. Individuals which enter the Northern Canal can pass downstream via one of the two turbine units at the E.L. Field Powerhouse, utilize the downstream bypass, or pass via the surge gate (operated only in the event of a station trip). During the 2019 evaluation there was no use of the downtown canal system. The majority of radio-tagged individuals passed through the Pawtucket Gatehouse and approached the E.L. Field powerhouse with 92.5% eventually passing downstream via the turbine units. Use of the existing downstream bypass system was limited to only two individuals. Downstream passage at the Project peaked during late October with all passage events completed by October 31. The majority of downstream passage events occurred during the evening and overnight hours.

Downstream passage survival was estimated for all radio-tagged eels from the point of initial detection upstream of the Pawtucket Dam downstream to Lawrence. This resulted in an estimated downstream passage survival for silver-phase American eel at Lowell of 75.5% (75% CI = 71.4%-79.6%). This estimate of downstream passage survival for adult eels at the Project includes any background (i.e., natural) or tagging-related mortality for the species in the reach from approach to the Pawtucket Dam to Lawrence. As a result, this estimate should be viewed as a minimum estimate of total project survival (i.e., due solely to project effects) for adult eels at the Project. Due to the limited distribution of downstream passage route selection, route-specific estimates of passage were developed for only individuals using turbine units at the E.L. Field powerhouse (n = 136; 75.0% survival; 75% CI = 70.6%-79.4%). The limited number of radio-tagged eels passing the Project via spill or the downstream bypass system were all determined to have successfully approached the Lawrence Project following downstream passage at Lowell.

7 Variances from FERC-Approved Study Plan

The FERC-approved RSP indicated that a total of 100 radio-tagged silver-phase American eels would be released just upstream of upper boundary of the Project impoundment. The availability of two additional transmitters and test eels resulted in a total of 102 radio-tagged individuals released upstream of Lowell. To further enhance the sample size for evaluation of downstream passage, Boott also monitored the passage of radio-tagged silver-phase adult eels released further upstream in the Merrimack River. This resulted in an additional 45 individuals which approached Lowell and were available for analysis. There were no additional variances from the FERC-approved study plan.

8 References

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9 Appendices

Appendix A. Estimated weekly discharge values (cfs) for the Guard Locks, Swamp Locks, Hamilton Station, Section 8 Station, John Street Station, Boott Gate and Lower Locks.

BOOTT HYDROPOWER DOWNTOWN OPERATIONS: ESTIMATED FLOWS

Date	10/10/2019	10/17/2019	10/23/2019	10/31/2019	11/7/2019	11/12/2019	11/13/2019	11/19/2019
Time	900	1100	900	1445	1000	1530	1600	1200

Guard Locks								
Gate 1	197	197	197	246	246	529	529	246
Gate 2	128	128	128	0	0	0	0	0
Gate 3	0	0	0	0	0	0	0	0
Gate 4	0	0	0	0	0	176	176	0
Gate 5	0	0	0	197	197	441	441	246
Total	325	325	325	443	443	1145	1145	493

Swamp Locks								
Gate 1	0	0	0	0	0	0	0	0
Gate 2	252	252	252	252	252	492	492	252
Bayboards opened	0	0	0	0	0	0	0	0
Total	252	252	252	252	252	492	492	252

Hamilton								
Unit 1	26	13	13	13	13	100	109	0
Unit 2	13	13	13	13	13	158	127	0
Unit 3	20	20	20	20	20	0	0	0
Unit 4	10	10	10	10	10	127	127	0
Unit 5	17	17	17	17	17	14	14	0
Hamilton Wasteway	0	0	0	0	0	0	0	0
Total	86	73	73	73	73	399	377	0

Section 8								
Unit 1	0	0	0	0	0	0	0	0
Unit 2	0	0	0	0	0	133	133	0
Unit 3	75	75	75	75	75	0	0	0
Total	75	75	75	75	75	133	133	0

John St.								
Unit 3	0	0	0	0	0	0	0	0
Unit 4	0	0	0	0	0	0	0	0
Unit 5	0	0	0	0	0	0	0	0
Unit 6	0	0	0	0	0	236	0	0
Total	0	0	0	0	0	236	0	0

Boott Gate								
Gate	0	0	0	0	0	0	399	0
Bayboards opened	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	399	0

Lower Locks								
Gate	120	120	120	120	120	120	120	120
Bayboards opened	0	0	0	0	0	0	0	0
Total	120	120	120	120	120	120	120	120

Appendix B. Silver eel source, release, and biocharacteristics information for the 2019 downstream passage assessment at Lowell.

Frequency	ID	Source Location	Release		Total Length (mm)	Eye Measurements		
			Location	Date		Horizontal (mm)	Vertical (mm)	Index
149.340	10	St. Croix	Garvins	10/9/2019	815	10.2	10.2	10.0
149.340	11	St. Croix	Garvins	10/9/2019	842	10.2	10.1	9.5
149.340	12	St. Croix	Garvins	10/9/2019	764	9.5	9.2	9.0
149.340	13	St. Croix	Garvins	10/9/2019	744	9.9	10.0	10.5
149.340	14	St. Croix	Garvins	10/9/2019	723	8.8	9.0	8.6
149.340	15	St. Croix	Garvins	10/9/2019	720	9.5	9.3	9.6
149.340	16	St. Croix	Garvins	10/9/2019	821	9.9	9.7	9.1
149.340	17	St. Croix	Garvins	10/9/2019	874	11.2	10.9	11.0
149.340	18	St. Croix	Garvins	10/9/2019	892	10.0	10.0	8.8
149.340	19	St. Croix	Garvins	10/9/2019	824	9.7	9.8	9.1
149.360	20	St. Croix	Garvins	10/9/2019	807	9.5	9.1	8.4
149.360	21	St. Croix	Garvins	10/9/2019	838	10.4	10.2	9.9
149.360	22	St. Croix	Garvins	10/9/2019	817	9.2	9.0	7.9
149.360	23	St. Croix	Garvins	10/9/2019	912	10.0	9.9	8.5
149.360	24	St. Croix	Garvins	10/9/2019	919	10.1	10.1	8.7
149.360	25	St. Croix	Garvins	10/9/2019	975	10.2	10.2	8.4
149.360	26	St. Croix	Garvins	10/9/2019	917	10.0	10.0	8.6
149.360	27	St. Croix	Garvins	10/9/2019	806	9.2	9.3	8.4
149.360	28	St. Croix	Garvins	10/9/2019	883	9.9	9.9	8.7
149.360	29	St. Croix	Garvins	10/9/2019	946	10.5	10.1	8.8
149.340	90	St. Croix	Lowell	10/9/2019	727	.	.	.
149.340	91	St. Croix	Lowell	10/9/2019	734	11.0	8.0	9.7
149.340	92	St. Croix	Lowell	10/9/2019	883	10.5	9.0	8.5
149.340	93	St. Croix	Lowell	10/9/2019	896	12.0	10.0	10.6
149.340	94	St. Croix	Lowell	10/9/2019	709	9.0	7.0	7.1
149.340	95	St. Croix	Lowell	10/9/2019	901	12.2	9.8	10.5
149.340	96	St. Croix	Lowell	10/9/2019	811	9.5	8.1	7.5
149.340	97	St. Croix	Lowell	10/9/2019	814	9.8	8.7	8.3
149.340	98	St. Croix	Lowell	10/9/2019	742	7.5	6.8	5.4
149.340	99	St. Croix	Lowell	10/9/2019	901	11.6	10.9	11.0
149.360	100	St. Croix	Lowell	10/9/2019	853	11.2	9.5	9.9
149.360	101	St. Croix	Lowell	10/9/2019	956	10.2	9.8	8.2
149.360	102	St. Croix	Lowell	10/9/2019	995	10.0	9.5	7.5
149.360	103	St. Croix	Lowell	10/9/2019	988	10.0	9.2	7.3
149.360	104	St. Croix	Lowell	10/9/2019	803	10.0	9.1	8.9
149.360	105	St. Croix	Lowell	10/9/2019	1019	11.1	10.0	8.6
149.360	106	St. Croix	Lowell	10/9/2019	865	10.8	9.9	9.7
149.360	107	St. Croix	Lowell	10/9/2019	1032	11.6	10.0	8.9
149.360	108	St. Croix	Lowell	10/9/2019	796	7.9	7.5	5.9
149.360	109	St. Croix	Lowell	10/9/2019	815	9.8	8.9	8.4

Frequency	ID	Source Location	Release		Total Length (mm)	Eye Measurements		
			Location	Date		Horizontal (mm)	Vertical (mm)	Index
149.340	30	St. Croix	Garvins	10/11/2019	742	8.3	8.1	7.1
149.340	31	St. Croix	Garvins	10/11/2019	711	9.8	9.0	9.8
149.340	32	St. Croix	Garvins	10/11/2019	808	10.8	10.2	10.7
149.340	33	St. Croix	Garvins	10/11/2019	765	9.3	9.3	8.8
149.340	34	St. Croix	Garvins	10/11/2019	793	10.0	9.9	9.8
149.340	35	St. Croix	Garvins	10/11/2019	740	9.7	9.3	9.5
149.340	36	St. Croix	Garvins	10/11/2019	842	11.3	10.8	11.3
149.340	37	St. Croix	Garvins	10/11/2019	758	8.7	8.8	7.9
149.340	38	St. Croix	Garvins	10/11/2019	791	9.9	10.0	9.8
149.340	39	St. Croix	Garvins	10/11/2019	797	9.0	8.4	7.5
149.360	40	St. Croix	Garvins	10/11/2019	884	10.6	9.9	9.3
149.360	41	St. Croix	Garvins	10/11/2019	873	10.1	10.0	9.0
149.360	42	St. Croix	Garvins	10/11/2019	734	8.9	8.6	8.2
149.360	43	St. Croix	Garvins	10/11/2019	782	8.9	9.0	8.0
149.360	44	St. Croix	Garvins	10/11/2019	646	7.9	7.8	7.5
149.360	45	St. Croix	Garvins	10/11/2019	757	9.9	9.5	9.7
149.360	46	St. Croix	Garvins	10/11/2019	843	10.4	10.0	9.7
149.360	47	St. Croix	Garvins	10/11/2019	798	10.1	10.0	10.0
149.360	48	St. Croix	Garvins	10/11/2019	806	9.2	9.0	8.1
149.360	49	St. Croix	Garvins	10/11/2019	816	10.2	9.8	9.6
149.340	110	St. Croix	Lowell	10/11/2019	875	11.0	9.8	9.7
149.340	111	St. Croix	Lowell	10/11/2019	724	9.5	8.5	8.8
149.340	112	St. Croix	Lowell	10/11/2019	845	11.1	10.0	10.3
149.340	113	St. Croix	Lowell	10/11/2019	876	10.1	9.2	8.3
149.340	114	St. Croix	Lowell	10/11/2019	804	11.0	9.8	10.6
149.340	115	St. Croix	Lowell	10/11/2019	816	10.3	9.8	9.7
149.340	116	St. Croix	Lowell	10/11/2019	793	9.1	8.8	7.9
149.340	117	St. Croix	Lowell	10/11/2019	969	10.6	9.5	8.2
149.340	118	St. Croix	Lowell	10/11/2019	751	9.0	7.9	7.5
149.340	119	St. Croix	Lowell	10/11/2019	706	7.1	6.0	4.8
149.360	120	St. Croix	Lowell	10/11/2019	902	10.2	9.8	8.7
149.360	121	St. Croix	Lowell	10/11/2019	749	10.2	8.1	8.8
149.360	122	St. Croix	Lowell	10/11/2019	787	8.0	7.2	5.8
149.360	123	St. Croix	Lowell	10/11/2019	808	9.9	9.0	8.7
149.360	124	St. Croix	Lowell	10/11/2019	894	10.7	9.6	9.1
149.360	125	St. Croix	Lowell	10/11/2019	854	10.3	9.6	9.1
149.360	126	St. Croix	Lowell	10/11/2019	911	13.0	10.2	11.6
149.360	127	St. Croix	Lowell	10/11/2019	890	10.3	9.5	8.6
149.360	128	St. Croix	Lowell	10/11/2019	932	12.0	10.1	10.3
149.360	129	St. Croix	Lowell	10/11/2019	934	10.4	9.3	8.2
149.340	50	St. Croix	Garvins	10/15/2019	795	10.7	9.5	10.1
149.340	51	St. Croix	Garvins	10/15/2019	928	10.1	10.1	8.6
149.340	52	St. Croix	Garvins	10/15/2019	894	9.8	8.6	7.4
149.340	53	St. Croix	Garvins	10/15/2019	810	10.9	9.8	10.4

Frequency	ID	Source Location	Release		Total Length (mm)	Eye Measurements		
			Location	Date		Horizontal (mm)	Vertical (mm)	Index
149.340	54	St. Croix	Garvins	10/15/2019	884	10.2	9.6	8.7
149.340	55	St. Croix	Garvins	10/15/2019	775	10.0	8.8	9.0
149.340	56	St. Croix	Garvins	10/15/2019	941	10.2	9.7	8.3
149.340	57	St. Croix	Garvins	10/15/2019	995	13.4	12.2	12.9
149.340	58	St. Croix	Garvins	10/15/2019	741	9.2	8.7	8.5
149.340	59	St. Croix	Garvins	10/15/2019	829	10.3	8.9	8.7
149.360	60	St. Croix	Garvins	10/15/2019	834	10.5	9.1	9.0
149.360	61	St. Croix	Garvins	10/15/2019	802	9.4	8.8	8.1
149.360	62	St. Croix	Garvins	10/15/2019	728	8.6	7.9	7.3
149.360	63	St. Croix	Garvins	10/15/2019	999	12.8	11.0	11.1
149.360	64	St. Croix	Garvins	10/15/2019	972	11.0	10.1	9.0
149.360	65	St. Croix	Garvins	10/15/2019	766	8.0	7.4	6.1
149.360	66	St. Croix	Garvins	10/15/2019	798	9.2	8.3	7.5
149.360	67	St. Croix	Garvins	10/15/2019	996	12.3	11.3	11.0
149.360	68	St. Croix	Garvins	10/15/2019	845	11.0	9.9	10.1
149.360	69	St. Croix	Garvins	10/15/2019	824	9.3	8.0	7.1
149.340	130	St. Croix	Lowell	10/16/2019	1025	11.5	9.2	8.2
149.340	131	St. Croix	Lowell	10/16/2019	842	10.0	9.1	8.5
149.340	132	St. Croix	Lowell	10/16/2019	889	11.0	9.9	9.6
149.340	133	St. Croix	Lowell	10/16/2019	751	8.8	7.6	7.0
149.340	134	St. Croix	Lowell	10/16/2019	812	9.1	7.6	6.7
149.340	135	St. Croix	Lowell	10/16/2019	716	8.3	7.3	6.7
149.340	136	St. Croix	Lowell	10/16/2019	830	9.7	8.8	8.1
149.340	137	St. Croix	Lowell	10/16/2019	857	10.0	9.1	8.4
149.340	138	St. Croix	Lowell	10/16/2019	777	10.3	8.9	9.3
149.340	139	St. Croix	Lowell	10/16/2019	762	9.0	7.8	7.3
149.360	140	St. Croix	Lowell	10/16/2019	691	7.8	6.9	6.1
149.360	141	St. Croix	Lowell	10/16/2019	702	9.2	7.3	7.6
149.360	142	St. Croix	Lowell	10/16/2019	969	11.1	9.9	8.9
149.360	143	St. Croix	Lowell	10/16/2019	819	11.5	9.4	10.5
149.360	144	St. Croix	Lowell	10/16/2019	721	9.1	8.2	8.2
149.360	145	St. Croix	Lowell	10/16/2019	820	10.0	9.0	8.6
149.360	146	St. Croix	Lowell	10/16/2019	956	10.1	9.0	7.5
149.360	147	St. Croix	Lowell	10/16/2019	823	9.9	8.3	7.9
149.360	148	St. Croix	Lowell	10/16/2019	886	10.4	9.1	8.4
149.360	149	St. Croix	Lowell	10/16/2019	794	9.0	7.8	7.0
149.340	70	St. Croix	Lowell	10/18/2019	791	8.9	7.2	6.4
149.340	71	St. Croix	Lowell	10/18/2019	836	9.4	8.1	7.2
149.340	72	St. Croix	Lowell	10/18/2019	767	9.8	8.7	8.8
149.340	73	St. Croix	Lowell	10/18/2019	890	11.0	9.9	9.6
149.340	74	St. Croix	Lowell	10/18/2019	729	10.3	8.6	9.6
149.340	75	St. Croix	Lowell	10/18/2019	909	11.8	10.6	10.8
149.340	76	St. Croix	Lowell	10/18/2019	782	9.5	8.1	7.8
149.340	77	St. Croix	Lowell	10/18/2019	811	10.5	9.2	9.4

Frequency	ID	Source Location	Release		Total Length (mm)	Eye Measurements		
			Location	Date		Horizontal (mm)	Vertical (mm)	Index
149.340	78	St. Croix	Lowell	10/18/2019	879	10.6	9.2	8.8
149.340	79	St. Croix	Lowell	10/18/2019	705	9.1	7.3	7.5
149.360	80	St. Croix	Lowell	10/18/2019	891	10.6	9.2	8.6
149.360	81	St. Croix	Lowell	10/18/2019	730	8.9	7.8	7.5
149.360	82	St. Croix	Lowell	10/18/2019	815	9.2	8.3	7.4
149.360	83	St. Croix	Lowell	10/18/2019	732	9.0	8.1	7.8
149.360	84	St. Croix	Lowell	10/18/2019	796	9.1	8.0	7.2
149.360	85	St. Croix	Lowell	10/18/2019	938	11.1	9.1	8.5
149.360	86	St. Croix	Lowell	10/18/2019	679	8.7	7.6	7.7
149.360	87	St. Croix	Lowell	10/18/2019	939	10.6	9.0	8.0
149.360	88	St. Croix	Lowell	10/18/2019	790	10.7	8.9	9.5
149.360	89	St. Croix	Lowell	10/18/2019	853	9.9	8.2	7.5
149.340	150	St. Croix	Lowell	10/23/2019	933	11.5	10.3	10.0
149.340	151	St. Croix	Lowell	10/23/2019	756	9.8	8.5	8.7
149.340	152	St. Croix	Lowell	10/23/2019	757	10.0	8.5	8.9
149.340	153	St. Croix	Lowell	10/23/2019	708	10.8	10.0	12.0
149.340	154	St. Croix	Lowell	10/23/2019	898	10.2	9.8	8.7
149.340	155	St. Croix	Lowell	10/23/2019	709	10.0	9.5	10.5
149.340	156	St. Croix	Lowell	10/23/2019	813	11.0	10.6	11.3
149.340	157	St. Croix	Lowell	10/23/2019	752	9.8	8.5	8.7
149.340	158	St. Croix	Lowell	10/23/2019	942	10.5	10.5	9.2
149.340	159	St. Croix	Lowell	10/23/2019	719	9.3	8.0	8.2
149.360	160	Soucook	Lowell	10/23/2019	750	8.0	8.5	7.1
149.360	161	Soucook	Lowell	10/23/2019	693	9.1	9.0	9.3
149.360	162	Soucook	Lowell	10/23/2019	758	10.0	9.7	10.1
149.360	163	Soucook	Lowell	10/23/2019	862	8.9	9.1	7.4
149.360	164	Soucook	Lowell	10/23/2019	734	9.0	9.6	9.3
149.360	165	Soucook	Lowell	10/23/2019	760	9.1	9.6	9.0
149.360	166	Soucook	Lowell	10/23/2019	836	8.8	9.2	7.6
149.360	167	Soucook	Lowell	10/23/2019	792	8.8	9.0	7.9
149.360	168	Soucook	Lowell	10/23/2019	773	9.8	9.2	9.2
149.360	169	Soucook	Lowell	10/23/2019	774	9.1	9.0	8.3
149.360	170	St. Croix	Lowell	10/23/2019	750	8.3	9.0	7.8
149.340	171	St. Croix	Lowell	10/23/2019	747	9.0	9.0	8.5

Appendix C. Listing of manual tracking detections within the Lowell Project area.

River mile demarcations for reaches defined by stationary receivers:

Reach	River Mile	
	Upper End	Lower End
Station 19-Station 21	61.5	41.75
Station 35-Station 37	41.75	39.25
Station 37-Station 39	39.25	35.25
Station 39-Station 40	35.25	30.25

Date	Frequency	ID	RM	Location	Type
10/21/2019	149.340	74	42	Station 19-Station 21	Transit
10/28/2019	149.340	156	42	Station 19-Station 21	Transit
10/24/2019	149.360	21	42.5	Station 19-Station 21	Transit
10/24/2019	149.360	80	43.75	Station 19-Station 21	Transit
10/24/2019	149.340	139	44	Station 19-Station 21	Transit
11/6/2019	149.360	64	44.25	Station 19-Station 21	Transit
10/24/2019	149.340	58	44.5	Station 19-Station 21	Transit
10/24/2019	149.340	116	45.25	Station 19-Station 21	Transit
10/24/2019	149.360	101	47.75	Station 19-Station 21	Transit
11/6/2019	149.360	46	48	Station 19-Station 21	Transit
10/24/2019	149.340	53	49	Station 19-Station 21	Transit
10/24/2019	149.360	23	49.25	Station 19-Station 21	Transit
10/24/2019	149.360	142	49.25	Station 19-Station 21	Transit
10/24/2019	149.340	138	49.75	Station 19-Station 21	Transit
11/21/2019	149.340	159	49.75	Station 19-Station 21	Transit
10/24/2019	149.340	35	50.5	Station 19-Station 21	Transit
11/6/2019	149.360	89	50.5	Station 19-Station 21	Transit
10/24/2019	149.340	77	51.25	Station 19-Station 21	Transit
10/24/2019	149.340	95	51.25	Station 19-Station 21	Transit
11/6/2019	149.360	120	51.25	Station 19-Station 21	Transit
11/6/2019	149.340	17	51.5	Station 19-Station 21	Transit
11/6/2019	149.340	59	51.5	Station 19-Station 21	Transit
10/24/2019	149.360	41	52	Station 19-Station 21	Transit
11/6/2019	149.340	158	52.5	Station 19-Station 21	Transit
10/24/2019	149.360	83	52.75	Station 19-Station 21	Transit
11/6/2019	149.360	47	53	Station 19-Station 21	Transit
10/24/2019	149.360	147	53.25	Station 19-Station 21	Transit
10/24/2019	149.340	78	53.5	Station 19-Station 21	Transit
10/24/2019	149.360	166	53.5	Station 19-Station 21	Transit
10/24/2019	149.340	79	53.75	Station 19-Station 21	Transit
10/24/2019	149.360	105	54.25	Station 19-Station 21	Transit
10/24/2019	149.360	162	55.25	Station 19-Station 21	Transit
10/24/2019	149.360	20	55.5	Station 19-Station 21	Transit
10/24/2019	149.340	24	56.25	Station 19-Station 21	Stationary
10/24/2019	149.340	156	56.25	Station 19-Station 21	Transit

Date	Frequency	ID	RM	Location	Type
10/24/2019	149.340	171	56.25	Station 19-Station 21	Transit
10/24/2019	149.360	69	57.5	Station 19-Station 21	Transit
10/24/2019	149.360	165	59	Station 19-Station 21	Transit
10/24/2019	149.340	118	60.5	Station 19-Station 21	Transit
10/24/2019	149.340	10	61.25	Station 19-Station 21	Transit
11/11/2019	149.360	81	39.25	Station 35-Station 37	Stationary
11/18/2019	149.360	81	39.25	Station 35-Station 37	Stationary
11/25/2019	149.360	81	39.25	Station 35-Station 37	Stationary
11/25/2019	149.360	120	40.25	Station 35-Station 37	Transit
11/25/2019	149.340	171	40.25	Station 35-Station 37	Transit
11/11/2019	149.340	171	40.5	Station 35-Station 37	Transit
11/18/2019	149.360	120	40.75	Station 35-Station 37	Transit
11/18/2019	149.340	171	40.75	Station 35-Station 37	Transit
11/11/2019	149.340	55	41	Station 35-Station 37	Stationary
11/11/2019	149.360	102	41	Station 35-Station 37	Stationary
11/11/2019	149.340	131	41	Station 35-Station 37	Stationary
11/18/2019	149.340	55	41.25	Station 35-Station 37	Stationary
11/25/2019	149.340	55	41.25	Station 35-Station 37	Stationary
11/18/2019	149.360	80	41.25	Station 35-Station 37	Stationary
11/18/2019	149.360	102	41.25	Station 35-Station 37	Stationary
11/25/2019	149.360	102	41.25	Station 35-Station 37	Stationary
11/18/2019	149.360	108	41.25	Station 35-Station 37	Stationary
11/25/2019	149.360	108	41.25	Station 35-Station 37	Stationary
11/25/2019	149.340	131	41.25	Station 35-Station 37	Stationary
10/28/2019	149.340	35	41.5	Station 35-Station 37	Stationary
11/11/2019	149.340	35	41.5	Station 35-Station 37	Stationary
11/14/2019	149.360	132	41.5	Station 35-Station 37	Stationary
11/5/2019	149.360	103	35.25	Station 37-Station 39	Transit
11/5/2019	149.360	66	36.25	Station 37-Station 39	Transit
11/11/2019	149.340	154	36.25	Station 37-Station 39	Stationary
11/25/2019	149.360	164	36.25	Station 37-Station 39	Stationary
11/5/2019	149.340	154	36.5	Station 37-Station 39	Stationary
11/11/2019	149.360	164	36.5	Station 37-Station 39	Stationary
11/18/2019	149.360	164	36.5	Station 37-Station 39	Stationary
11/5/2019	149.360	65	36.75	Station 37-Station 39	Transit
11/5/2019	149.340	117	36.75	Station 37-Station 39	Stationary
11/11/2019	149.340	117	36.75	Station 37-Station 39	Stationary
11/18/2019	149.340	117	36.75	Station 37-Station 39	Stationary
11/25/2019	149.340	117	36.75	Station 37-Station 39	Stationary
11/5/2019	149.340	130	36.75	Station 37-Station 39	Stationary
11/5/2019	149.360	148	36.75	Station 37-Station 39	Stationary
11/11/2019	149.360	148	36.75	Station 37-Station 39	Stationary
11/25/2019	149.360	148	36.75	Station 37-Station 39	Stationary
11/5/2019	149.360	128	37	Station 37-Station 39	Transit
11/5/2019	149.360	164	37.5	Station 37-Station 39	Stationary
11/5/2019	149.340	155	37.75	Station 37-Station 39	Transit
11/5/2019	149.340	99	38	Station 37-Station 39	Stationary

Date	Frequency	ID	RM	Location	Type
11/5/2019	149.340	114	38	Station 37-Station 39	Transit
11/5/2019	149.360	22	38.25	Station 37-Station 39	Stationary
11/11/2019	149.360	22	38.25	Station 37-Station 39	Stationary
11/11/2019	149.340	93	38.25	Station 37-Station 39	Stationary
11/18/2019	149.340	93	38.25	Station 37-Station 39	Stationary
11/25/2019	149.340	93	38.25	Station 37-Station 39	Stationary
11/11/2019	149.340	99	38.25	Station 37-Station 39	Stationary
11/14/2019	149.340	99	38.25	Station 37-Station 39	Stationary
11/18/2019	149.340	99	38.25	Station 37-Station 39	Stationary
11/25/2019	149.340	99	38.25	Station 37-Station 39	Stationary
11/5/2019	149.340	33	38.5	Station 37-Station 39	Stationary
11/11/2019	149.340	33	38.5	Station 37-Station 39	Stationary
11/14/2019	149.360	33	38.5	Station 37-Station 39	Stationary
11/18/2019	149.340	33	38.5	Station 37-Station 39	Stationary
11/5/2019	149.360	145	38.5	Station 37-Station 39	Stationary
11/11/2019	149.360	145	38.5	Station 37-Station 39	Stationary
11/18/2019	149.360	145	38.5	Station 37-Station 39	Stationary
11/25/2019	149.360	145	38.5	Station 37-Station 39	Stationary
11/25/2019	149.340	33	39	Station 37-Station 39	Stationary
11/5/2019	149.360	41	39	Station 37-Station 39	Stationary
11/11/2019	149.360	41	39	Station 37-Station 39	Stationary
11/14/2019	149.360	41	39	Station 37-Station 39	Stationary
11/18/2019	149.360	41	39	Station 37-Station 39	Stationary
11/25/2019	149.360	41	39	Station 37-Station 39	Stationary
11/5/2019	149.360	144	39	Station 37-Station 39	Transit
11/11/2019	149.360	144	39	Station 37-Station 39	Stationary
11/14/2019	149.360	144	39	Station 37-Station 39	Stationary
11/18/2019	149.360	144	39	Station 37-Station 39	Stationary
11/25/2019	149.360	144	39	Station 37-Station 39	Stationary
11/5/2019	149.340	52	33.25	Station 39-Station 40	Stationary
11/5/2019	149.340	92	33.25	Station 39-Station 40	Transit
11/5/2019	149.360	85	34	Station 39-Station 40	Stationary
11/5/2019	149.340	90	34.5	Station 39-Station 40	Transit
11/18/2019	149.360	66	35	Station 39-Station 40	Transit

Appendix D. October 23, 2019 eel release: Soucook and St. Croix River eels.

The October 23, 2019 release of radio-tagged eels upstream of the Lowell impoundment was comprised of 10 individuals originating from the Soucook River in New Hampshire and 12 individuals originating from the St. Croix River, Maine. Table D-1 provides a comparison of the range of values for movement indices evaluated during this study and between the two groups. For most metrics the median duration did not appear to differ between the two groups. The median duration to pass downstream through the Lowell impoundment was nearly twice as long for eels originating in the St. Croix River. However, the minimum duration to do so was nearly the same for eels from both locations.

With regard to passage at Lowell there was no differentiation in passage route usage. All ten eels originating in the Soucook River and eleven of the twelve[7] eels originating in the St. Croix River passed downstream via the turbine units. Based on downriver detections, 83% of the eels originating in the St. Croix River and 80% of the eels originating in the Soucook River reached the Essex Dam in Lawrence.

Table D-1. Minimum, maximum, and quartile values for the suite of movement metrics assessed for radio-tagged eels originating from the Soucook and St. Croix Rivers and released upstream of the Lowell project boundary on October 23, 2019.

Movement Metric	Origin	Value				
		Min	Max	P25	Median	P75
Impoundment Duration (hrs)	Soucook	23.2	51.5	23.4	26.7	26.8
	St. Croix	25.4	71.8	29.0	49.9	66.0
Upstream Residence Duration (hrs)	Soucook	0.3	94.4	0.3	0.5	22.6
	St. Croix	0.2	165.3	0.3	0.4	1.5
Pawtucket Gatehouse Passage (hrs)	Soucook	<0.1	93.5	0.1	0.1	0.2
	St. Croix	<0.1	0.2	0.1	0.1	0.1
Northern Canal Residence (hrs)	Soucook	0.1	38.6	0.2	0.3	0.4
	St. Croix	0.1	165.1	0.2	0.2	0.3
Downstream Travel: Lowell to Lawrence (hrs)	Soucook	41.9	359.8	47.0	57.6	102.8
	St. Croix	21.1	196.7	26.1	60.9	97.6

[7] Passage route for one individual was left as unknown.

Recreation and Aesthetics Study Report

Lowell Hydroelectric Project (FERC No. 2790)

September 30, 2020

Prepared by:

HDR

Prepared for:

Boott Hydropower, LLC
Manchester, New Hampshire

Central Rivers Power

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Contents

Tables

Figures

Appendices

List of Acronyms

ADA	Americans with Disabilities Act
AW	American Whitewater
Boott	Boott Hydropower, LLC (or Licensee)
C.F.R.	Code of Federal Regulations
cfs	cubic feet per second
Commonwealth	Commonwealth of Massachusetts
DBH	diameter at breast height
EPA	Environmental Protection Agency
FERC	Federal Energy Regulatory Commission (or Commission)
FGMP	Final General Management Plan
GIS	Geographic Information System
GPS	Global Positioning System
ILP	Integrated Licensing Process
ISR	Initial Study Report
LNHP	Lowell National Historical Park
MADCR	Massachusetts Department of Conservation and Recreation
MADEM	Massachusetts Department of Emergency Management
MEOEEA	Massachusetts Executive Office of Energy and Environmental Affairs
MOU	memorandum of understanding
MW	megawatt
NGVD 29	National Geodetic Vertical Datum 1929
NHDES	New Hampshire Department of Environmental Services
NHDNCR	New Hampshire Department of Natural and Cultural Resources
NHFGD	New Hampshire Fish and Game Department
NHL	National Historic Landmark
NOI	Notice of Intent

NPS	National Park Service
NRPC	Nashua Regional Planning Commission
OSRP	Open Space and Recreation Plan
PAD	Pre-Application Document
Project	Lowell Hydroelectric Project (or Lowell Project)
Proprietors	Proprietors of the Locks and Canals
PSP	Proposed Study Plan
RM	river mile
RMP	Resources Management Plan
ROR	run-of-river
RSP	Revised Study Plan
SCORP	Statewide Comprehensive Outdoor Recreation Plan
SD1	Scoping Document 1
SD2	Scoping Document 2
SPD	Study Plan Determination
Study Workshop	Lowell Hydroelectric Project Study Workshop
USFS	U.S. Forest Service
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
Visitor Center	E.L. Field Powerhouse Visitor Center
VP	vegetation point

1 Introduction and Background

Boott Hydropower, LLC (Boott or Licensee) is the Licensee, owner, and operator of the 20.2-megawatt Lowell Hydroelectric Project (Project or Lowell Project) (FERC No. 2790). Boott operates and maintains the Project under a license from the Federal Energy Regulatory Commission (FERC or Commission). The Project's existing license expires on April 30, 2023. Boott is pursuing a new license for the Project using the Commission's Integrated Licensing Process (ILP) as defined in 18 Code of Federal Regulations (C.F.R.) Part 5.

In accordance with 18 C.F.R. § 5.15, Boott has conducted studies as provided in the study plan and schedule approved in the Commission's March 13, 2019 Study Plan Determination (SPD) for the Project.[1] This report describes the methods and results of the approved Recreation and Aesthetics Study conducted in support of a new license for the Project.

1.1 Project Description and Background

The Lowell Project is located at river mile (RM) 41 on the Merrimack River in the City of Lowell in Middlesex County, Massachusetts, with an impoundment extending approximately 23 miles upstream into Hillsborough County, New Hampshire. The existing Lowell Project consists of:

1) A 1,093-foot-long, 15-foot-high masonry gravity dam (Pawtucket Dam) that includes a 982.5-foot-long spillway with a crest elevation of 87.2 feet National Geodetic Vertical Datum 1929 (NGVD 29) topped by 5-foot-high pneumatically-operated crest gates deployed in five independently-operable zones;
2) A 720-acre impoundment with a normal maximum water surface elevation of 92.2 feet NGVD 29;
3) A 5.5-mile-long canal system which includes several small dams and gatehouses;
4) A powerhouse (E.L. Field) which uses water from the Northern Canal and contains two turbine-generator units with a total installed capacity of 15.0 megawatts (MW);
5) A 440-foot-long tailrace channel;
6) Four powerhouses (Assets, Bridge Street, Hamilton, and John Street) housed in nineteenth century mill buildings along the Northern and Pawtucket Canal systems containing 15 turbine-generator units with a total installed capacity of approximately 5.1 MW;

[1] The Commission issued a Revised Process Plan and Schedule on June 12, 2020.

7) A 4.5-mile-long, 13.8-kilovolt transmission line connecting the powerhouses to the regional distribution grid;

8) Upstream and downstream fish passage facilities including a fish elevator and downstream fish bypass at the E.L. Field powerhouse, and a vertical-slot fish ladder at the Pawtucket Dam; and

9) Appurtenant facilities.

At the normal pond elevation of 92.2 feet NGVD 29 (crest of the pneumatic flashboards), the surface area of the impoundment encompasses an area of approximately 720 acres. The gross storage capacity between the normal surface elevation of 92.2 feet and the minimum pond level of 87.2 feet is approximately 3,600 acre-feet. The Project operates essentially in a run-of-river (ROR) mode using automatic pond level control and has no usable storage capacity.

The Project's primary features are located along the Merrimack River in the City of Lowell, Massachusetts. The City of Lowell was founded in the early 1820s by Boston merchant capitalists and became one of the most significant planned industrial cities in America (Hay 1991). Lowell's factory system, which used the waterpower of the Merrimack River, incorporated new technologies to provide for the mass production of cotton cloth in mills throughout the city (National Park Service [NPS] 1981). Lowell established the pattern for large-scale waterpower development for the next 50 years (Hay 1991).

Several Project facilities are located within overlapping locally, state, and nationally designated parks and historic properties/preservation districts. The Project's Pawtucket Dam and E.L. Field Powerhouse are located along the mainstem of the Merrimack River. The Project's two-tiered network of man-made canals extends throughout downtown Lowell. The 5.5-mile-long canal system provides flow to the Project's Hamilton, Assets, Bridge Street, and John Street developments. The Hamilton, Assets, Bridge Street, and John Street power stations and turbines are housed in large former mill buildings. The mill buildings are not included in the Project; the Project Boundary includes only the turbines and associated waterways and equipment at these downtown mill sites. In addition to the Pawtucket Dam and hydroelectric developments, the Project also includes miscellaneous civil works in the City of Lowell, including the Guard Lock and Gates, Moody Street Feeder Gatehouse, Lawrence Dam, Hall Street Dam, Tremont Wasteway, Lower Locks and Dam, Swamp Locks and Dam, Merrimack Dam and Merrimack Gate, Rolling Dam, and the Boott Dam.

The canal system, the downtown mill sites, and many of the Project's civil works, are contributing resources to Lowell Locks and Canals National Historic Landmark (NHL) District. The canal system and many Project facilities are also located within the Lowell National Historical Park (LNHP) managed by the NPS and the larger Lowell Historic Preservation District. The LNHP was established by Congress in 1978 to "preserve and interpret the nationally significant historical and cultural sites, structures, and districts in Lowell, Massachusetts, for the benefit and inspiration of present and future generations." The park is by design a partnership park in which federal, state, and local governments as well as the private sector and local community carry out the legislative intent of the park unit. The Lowell National Historical Park is also listed on the National Register of Historic Places (NRHP), and certain properties within the park overlap with properties in the NHL District.

The Lowell Heritage State Park, established in 1974 as a precursor to the LNHP, is also located within the City of Lowell and is comprised of linear greenways along the Merrimack River and canal system and a collection of historic buildings and structures related to the industrial development of the city. These buildings and structures include Project features and properties located within the NHL District. The Lowell Heritage State Park is operated by the Massachusetts Department of Conservation and Recreation (MADCR) and features exhibits created in partnership with the NPS (MADCR 2018). With the exception of the Rynne Bathhouse, all of the built resources within the Lowell Heritage State Park fall within the Lowell Historic District, designated by the City of Lowell to "…ensure that development activities within the district are consistent with the preservation of its 19th century setting" (MADCR 2014). Portions of the Lowell Heritage State Park also overlap with the Lowell Locks and Canals NHL District and the LNHP.

On April 30, 2018, Boott initiated the ILP by filing a Pre-Application Document (PAD) and Notice of Intent (NOI) with the Commission. Major ILP milestones to-date are presented in Table 1-1.

Table 1-1. Major ILP Milestones Completed

Date	Milestone
April 30, 2018	PAD and NOI Filed
June 15, 2018	Scoping Document 1 (SD1) Issued by FERC
July 17, 2018	FERC Agency and Public Scoping Meetings Conducted
July 18, 2018	Project Site Visit Held
September 27, 2018	Scoping Document 2 (SD2) Issued by FERC
September 28, 2018	Proposed Study Plan (PSP) Filed
October 18 & 19, 2018	PSP Meeting Conducted
January 28, 2019	Revised Study Plan (RSP) Filed
March 13, 2019	FERC Issued SPD
February 25, 2020	Initial Study Report (ISR) Filed
March 11, 2020	ISR Meeting
June 12, 2020	FERC Issued Revised Process Plan and Schedule

Boott has continued consultation with stakeholders regarding the approved studies as required by the Commission's SPD. In accordance with the schedule presented in the RSP, Boott has also provided stakeholders with Quarterly ILP Study Progress Reports that include a description of study activities conducted during the previous quarter, activities expected to occur in the next quarter, and identified variances from the approved study plan.

1.2 Project Recreation Facilities

Pursuant to existing License Article 38 and the FERC-approved Recreation Plan, Boott maintains the E. L Field Powerhouse Visitor Center (Visitor Center). The Visitor Center is the Project's only FERC-approved recreation facility. The Visitor Center offers a secured view of the interior of the turbine gallery and an interpretive display which provides information regarding the development, history, and operation of the Project and nearby historic, natural, cultural, and recreational resources.

Non-Project related recreational facilities and opportunities in the Project's vicinity include the Depot Street Boat Ramp, Greely Boat Ramp, LNHP, Lowell Heritage State Park, Merrill Park, Moore's Falls Conservation Area, and the Rourke Brothers Boat Ramp. The Merrimack River provides extensive recreational opportunities, including boating, canoeing, kayaking, rowing, fishing, and swimming. The surrounding vicinity is used for hiking, picnicking, bird watching, nature study, and overall enjoyment of scenic views.

2 Study Goals and Objectives

The goals of this study are to (a) document recreation resources and recreational activities that occur in the Project area; (b) determine the adequacy and capacity of existing recreational facilities to accommodate proposed enhancements and/or additional recreational activities; (c) assess potential effects of water levels and flow rates on existing recreational facilities; (d) assess the potential for expanded access to the canal system for recreation; and (e) identify areas within the canal system where vegetation growth on historic canal walls and waterborne trash are a concern.

The specific objectives of the study are to:

- Identify existing recreation facilities in the Project area;
- Quantify current recreational use based on recent and new surveys and interviews, and consultation with stakeholders, regional and statewide plans, and other available data (including NPS and MADCR planning documents);
- Identify proposed recreational uses based on surveys and interviews in consultation with stakeholders;
- Evaluate the potential effects of continued operation of the Project (including water levels and flow rates) on recreation resources and activities in the Project area;
- Assess the potential for expanded recreational access to the canal system in consultation with the NPS, MADCR, the City of Lowell, Lowell Parks and Conservation Trust, the Lowell Heritage Partnership, and other partners in recreation;

- Identify areas of concern related to waterborne trash and vegetation growth on historic canal walls and other structures or historic properties owned or under the control of Boott; and,
- Gather information on the condition of Boott's recreation facilities and identify any need for improvement.

3 Study Area

In accordance with the Commission's SPD, the study area for the Recreation and Aesthetics Study is a general area that includes the FERC Project Boundary and adjacent recreation facilities (Figure 3-1, Figure 3-2).

Figure 3-1. Project Location and Boundary

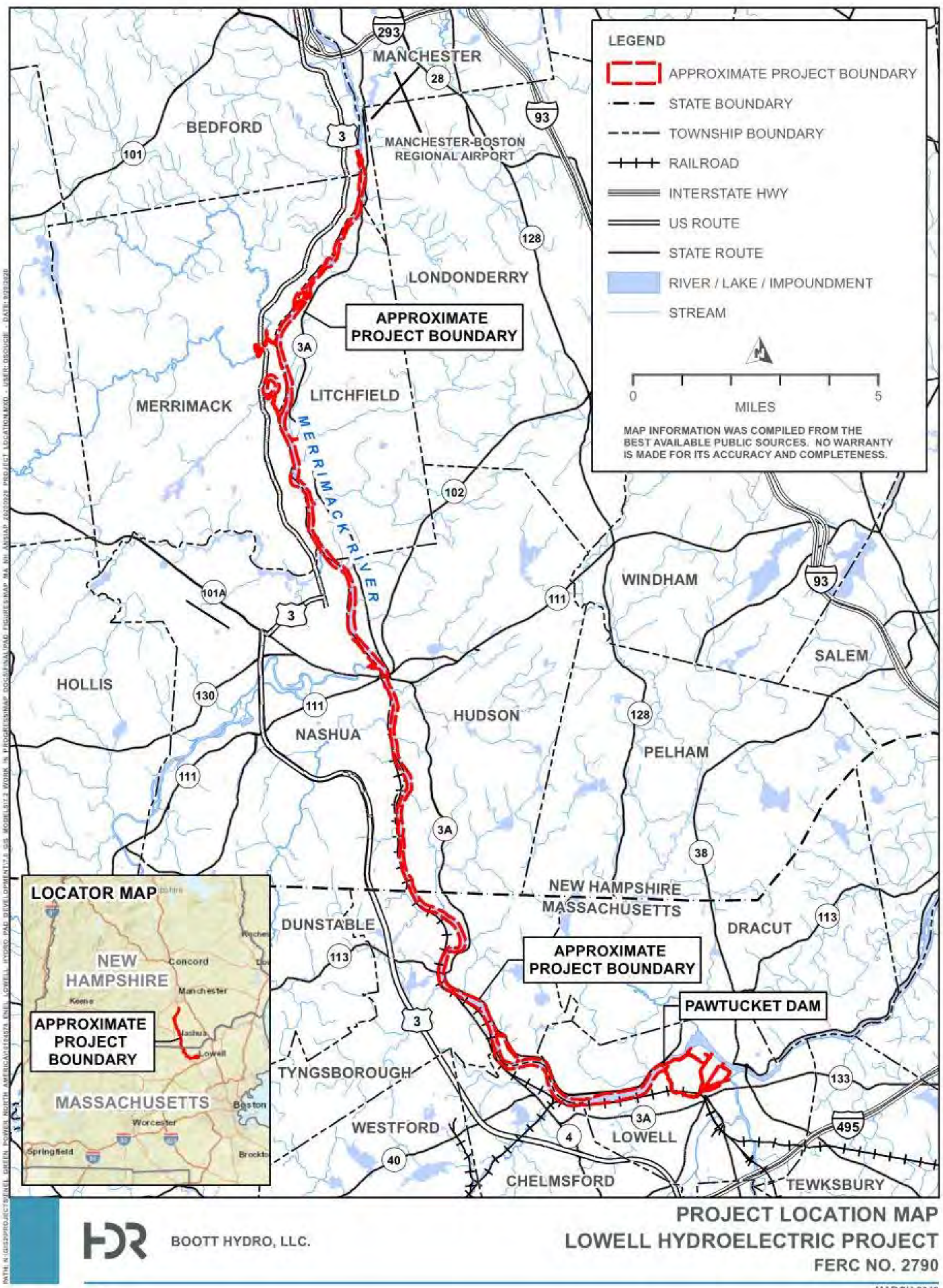
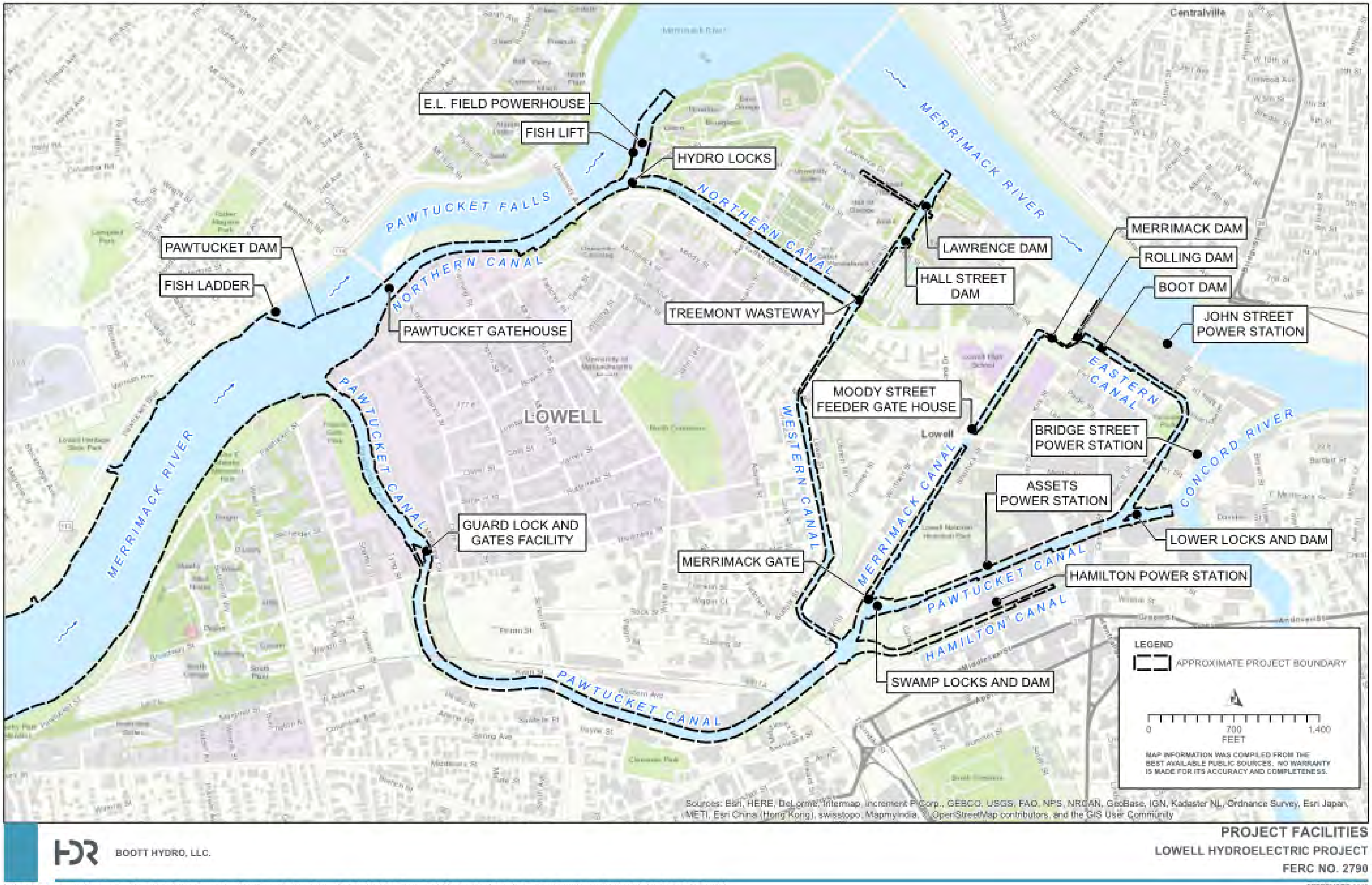


Figure 3-2. Project Boundary and Facilities in Downtown Lowell



4 Methodology

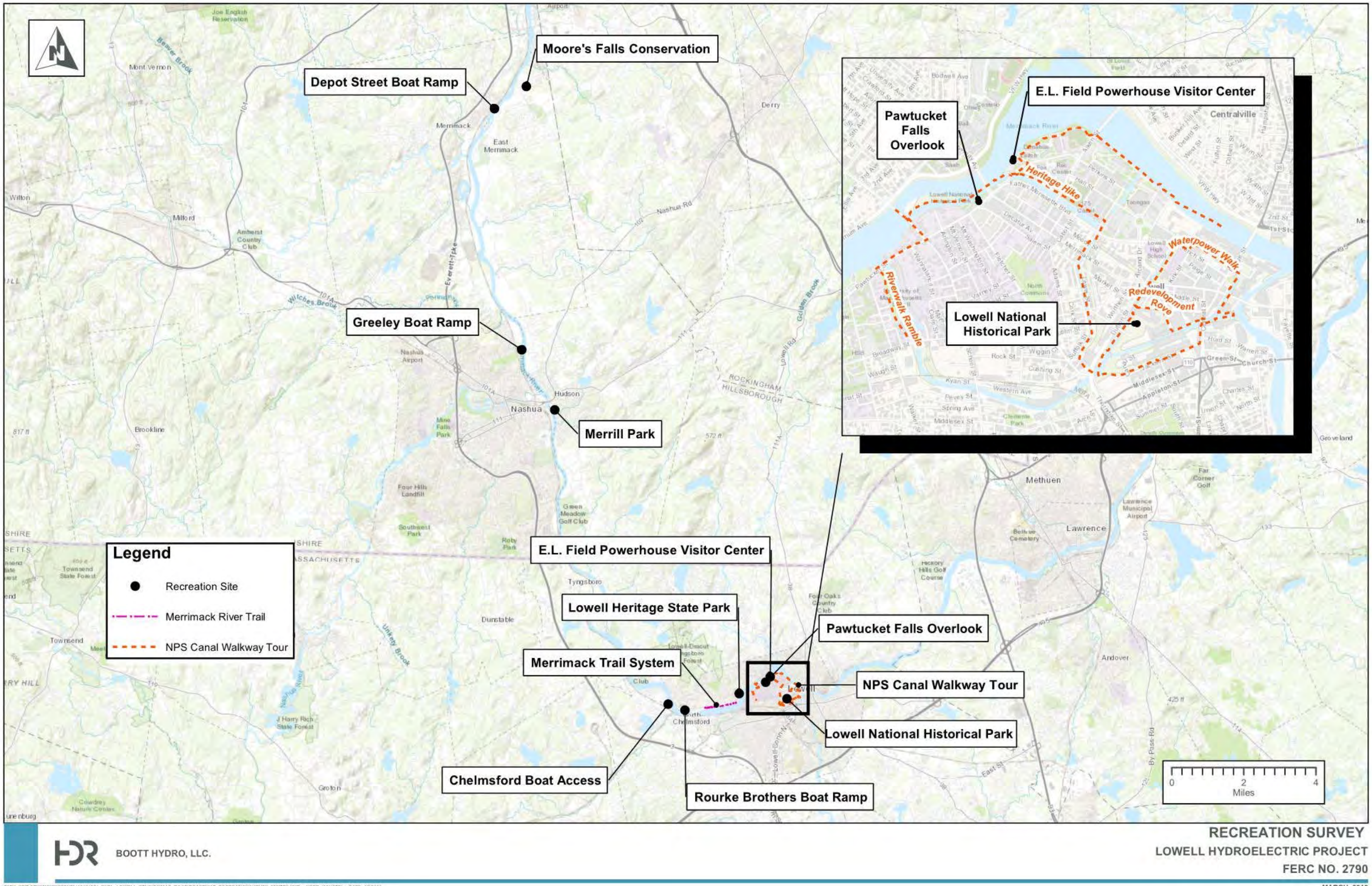
4.1 Literature Review

Boott conducted desktop research and a literature review to identify and describe recreational uses in the Project area, including (but not limited to) whitewater boating, canoeing, kayaking, fishing, swimming, walking, and architectural/historical tours. As a component of this research, Boott reviewed existing recreational uses, facilities management plans (as applicable), and limitations and regulations applicable to the Project area. Additionally, Boott conducted a records search and literature review on the historical and current practices regarding vegetation and waterborne trash management and control on historic canal walls and other structures or historic properties owned or under the control of Boott.

4.2 Field Inventory

Boott conducted a field inventory to document existing non-Project recreation facilities within the Project's vicinity in the fall of 2019. Recreation sites inventoried included the Moore's Falls Conservation Area, Depot Street Boat Ramp, Chelmsford Boat Access, Greeley Boat Ramp, the Rourke Brothers Boat Ramp, Lowell Heritage State Park, Merrimack Trail System, LNHP, Merrill Park, NPS Canal Walkways, and Pawtucket Falls Overlook (Figure 4-1). The Visitor Center, the only Project-related recreation facility, was also inventoried. Pursuant to the RSP, Boott collected information regarding each facility including the type and location of existing recreation facilities, the type of recreation provided (e.g., boat access, angler access, picnicking, etc.), existing amenities and sanitation, the type of vehicular access and parking (if any), the suitability of facilities to provide recreational opportunities and access for persons with disabilities (i.e., compliance with current Americans with Disabilities Act [ADA] standards for accessible design), Global Positioning System (GPS) location data, and representative photographic documentation of recreation facilities.

Figure 4-1. Recreation Field Inventory Locations



4.3 Collection of Visitor Use Data and Field Reconnaissance

4.3.1 Personal Interviews and Field Reconnaissance

As provided in the approved study plan, Boott conducted personal interviews (visitor-intercept surveys) and field reconnaissance activities at recreation facilities in the Project's vicinity between May and October 2019. Boott conducted field reconnaissance and personal interview surveys on random weekdays and weekend days throughout the months of May, June, July, August, September, and October of 2019. Personal interviews and field reconnaissance were conducted on four days of each month on both weekdays, weekend days, and holidays. The actual dates that personal interviews and field reconnaissance took place in 2019 are presented in Table 4-1.

Table 4-1. Personal Interviews and Field Reconnaissance Schedule

Month	Specific Dates
May	• Saturday May 25, 2019 • Sunday May 26, 2019 • Monday May 27, 2019 • Tuesday May 28, 2019
June	• Friday June 7, 2019 • Monday June 10, 2019 • Saturday June 15, 2019 • Sunday June 16, 2019
July	• Wednesday July 10, 2019 • Friday July 19, 2019 • Saturday July 27, 2019 • Sunday July 28, 2019
August	• Tuesday August 6, 2019 • Sunday August 18, 2019 • Wednesday August 21, 2019 • Saturday August 24, 2019
September	• Saturday September 14, 2019 • Thursday September 19, 2019 • Sunday September 22, 2019 • Wednesday September 25, 2019
October	• Wednesday October 9, 2019 • Tuesday October 15, 2019 • Saturday October 19, 2019 • Sunday October 27, 2019

Boott developed survey questions based on general concepts and guidance from the U.S. Forest Service's (USFS) National Visitor Use Monitoring Handbook (USFS 2007) and questions that were asked during recreation studies for other relevant hydropower relicensings. The survey questions that were asked during the personal interviews are included in Appendix A of this study report. Boott consulted with the NPS, MADCR, and

American Whitewater (AW) to identify specific recreation survey locations. The selected locations for the personal interviews and field reconnaissance (Figure 4-1) were:

- Lowell Heritage State Park
- Merrimack Trail System
- Pawtucket Falls Overlook
- NPS Canal Walkways
- LNHP Visitor Center
- Chelmsford Boat Access
- Rourke Brothers Boat Ramp
- Merrill Park, and
- Whitewater takeout location[2]

A team of two technicians traveled between each of the selected recreation sites and spent approximately one hour at each site conducting the personal interviews and collecting field reconnaissance data including (a) the various types of recreation activities, (b) an estimation of the number of vehicles, and (c) the approximate numbers of recreationists observed at each site. Before rotating to the next site, technicians also recorded the date, time, and weather conditions observed. For the personal interviews, individual recreationists and groups were interviewed, including visitors using boat launches and LNHP-managed facilities. Respondents answered questions verbally while a technician recorded their responses using the Qualtrics® offline survey platform to record and submit answers.[3] The personal interview questions included topics such as: general user information; age group, resident/visitor; purpose and duration of visit; distance traveled; history of visiting the site or area; types of recreational activities respondents participated in or planned to participate in during their visit; other recreational sites that respondents visited or intended to visit during their trip; general satisfaction with recreational opportunities, flow conditions, facilities, and the respondents overall visit and/or areas that need improvement; accessibility of facilities or areas; economic aspects, including dollars spent during their trip; and day use/overnight lodging during their visit.

4.3.2 Online Visitor Use Surveys

In addition to the personal interviews, Boott developed a version of the interview questions to allow respondents to provide survey responses online. In accordance with the approved study plan, the survey was made available for one year, from June 2019 to June 2020, on the Project's relicensing website (www.lowellprojectrelicensing.com). The

[2] The Whitewater takeout location is not identified on Figure 4-1. This informal non-Project recreation area is located along the riverfront behind Edward A. Lelacheur Park.

[3] While the survey questions in the approved study plan were utilized for these interviews, the numbering and specific wording was adapted during the interview to better facilitate the interview and to accommodate the Qualtrics® survey platform.

online survey was developed using the Qualtrics® survey platform. Boott posted a brief description of the purpose and intent of the survey and the website address at popular recreation access areas at the Project (Photo 4-1). During personal interviews and field reconnaissance, Boott provided handouts to recreationists with the relevant information on how to access the online survey. Boott notified the Commission and stakeholders of the availability of the online survey in the Second Quarterly Study Progress Report filed with the Commission on October 1, 2019. The survey questions developed for the online survey are also included in Appendix A of this study report.

Photo 4-1. Example of Signage for Participating in Online Visitor Use Surveys

4.4 Evaluation of Expanded Recreational Access in Project Canals

NPS and NPS partners have expressed interest in new, different, and expanded recreational access to and within the Project canals. Boott consulted with the NPS to discuss various recreational opportunities based on the NPS's plans for developing recreational access within the LNHP and the visitor use data collected pursuant to Section 4.3 of this report.

Boott conducted an evaluation of prospective recreation access. This evaluation considered:

- Public safety concerns associated with canal access;

- Infrastructure enhancement that may be required to provide safe public access to the canal system and how such improvements may affect aesthetic and historic resources; and,
- Potential options for improving canal system access, such as operational changes or other measures.

4.5 Documentation of Current Water Levels and Flows

In accordance with the SPD, Boott initiated the data collection associated with the Water Level and Flow Effects on Historic Resources Study and the Operations Analysis of the Lowell Canal System Study, both to be filed with FERC by February 25, 2021. Boott continues to document current water levels and flows by collecting photos, videos, and from direct observations of flows under varying flow conditions. Pressure transducers (level loggers) were installed in the Project's canal system in 2019. On December 18, 2019, Boott held a Lowell Hydroelectric Project Study Workshop (Study Workshop)[4] with stakeholders and refined the data needs for this study based on consultation with the NPS and NPS partners. This included moving the level loggers to locations in the Upper Pawtucket Canal and Northern Canal in March 2020 to better understand and collect data regarding the effects of the crest gate and the NPS boat tours. Boott is currently collecting water level and flow data; as such the initial analysis of water levels and flow effects on recreational resources is expected be filed with the Revised ISR[5] to be filed with FERC by February 25, 2021.

4.6 Visual Survey for Vegetation Growth

The visual survey for vegetation growth was conducted between September 25 and 27, 2019. The visual survey was conducted to identify vegetation growth along the canal walls within the study area. Technicians identified the relative quantity and spatial distribution of each vegetation type using aerial photography and observations of habitat and specific plant species occurrences. The methods for this study followed those that were described in the study plan approved by the Commission.

4.6.1 Review of Existing Information

Terrestrial vegetation types occurring in the study area were described based on a review of existing information, an inspection of aerial photography, a review of the U.S. Geological Survey (USGS) 7.5-minute quadrangles, and observations of habitat and

[4] The meeting minutes of the December 18, 2019 Study Workshop were appended to the ISR filed with FERC on February 25, 2020.

[5] According to FERC's June 12, 2020 Revised Process Plan and Schedule, the deadline for Boott to file the second Revised ISR is February 25, 2021, and the deadline to file all final study reports is to be determined.

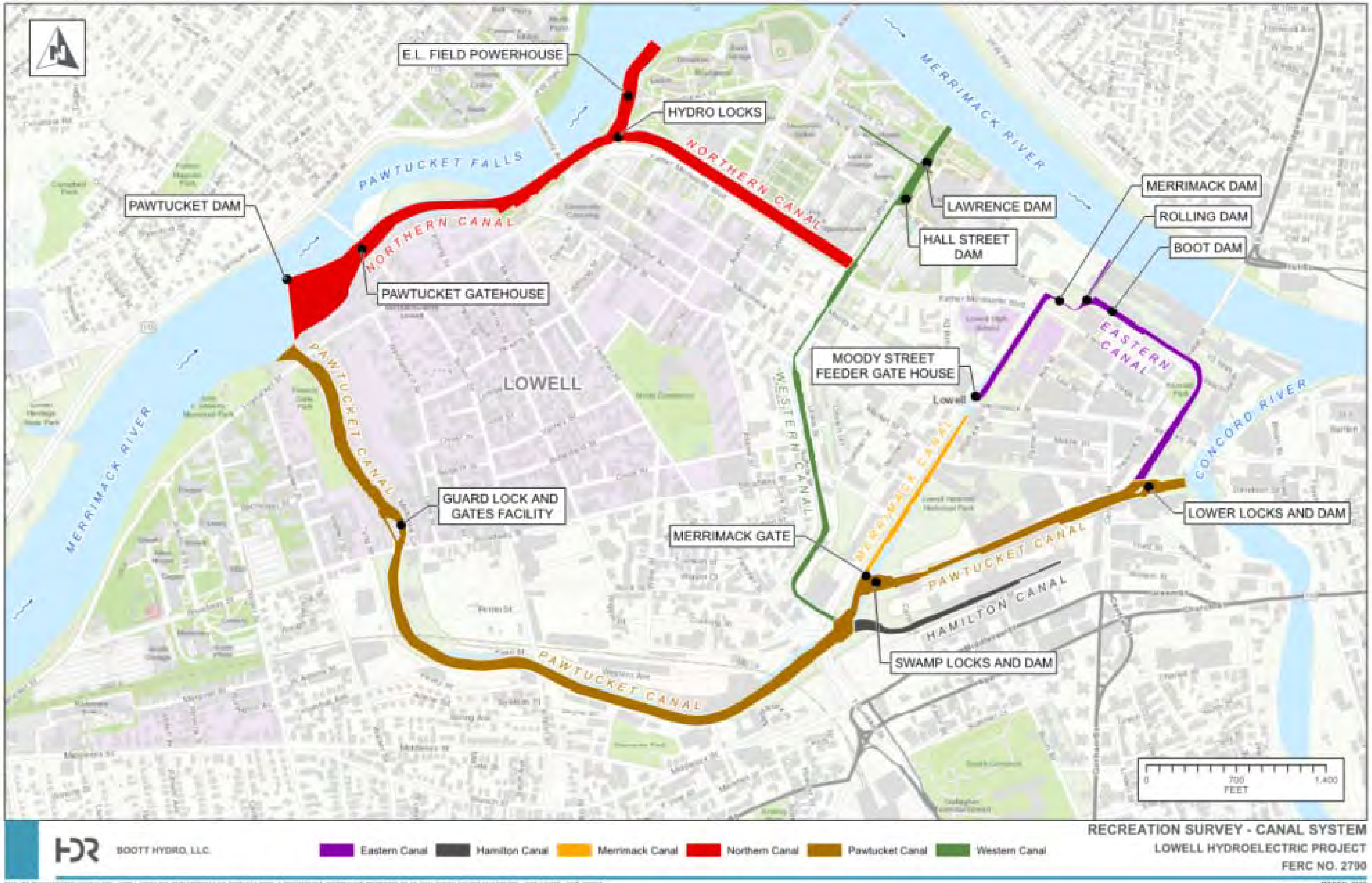
specific vegetation type occurrences during the field surveys. Sources of existing information included but were not limited to the following:

- Massachusetts Natural Heritage and Endangered Species Program Classification of the Natural Communities of Massachusetts (Swain 2020): provides a basis for the discussion and conserving the diversity of the types of natural communities and the species they support within the Commonwealth of Massachusetts (Commonwealth). The primary aim of the classification is to describe the natural communities that are of conservation interest, while also including all types of natural communities in the state.
- Flora of the Northeast – A Manual of the Vascular Flora of New England and Adjacent New York (Magee and Ahles 1999): a reference work and year-round field manual that contains more than 2,400 range maps and over 900 line drawings for identifying the vascular flora of New England and New York.
- Invasive Plants (Kaufman and Kaufman 2007): a guide to the identification and the impacts and control of common North American invasive plant species.

4.6.2 Mapping of Vegetation Growth on Canal Walls

For the purposes of examining vegetation type distribution, the study area was divided into the six canals associated with the Lowell Project canal system including: 1) Pawtucket Canal; 2) Northern Canal; 3) Western Canal; 4) Merrimack Canal; 5) Eastern Canal; and 6) Hamilton Canal (Figure 4-2).

Figure 4-2. Visual Survey for Vegetation Growth Study Area



Visual qualitative surveys were conducted in the study area by foot along the shorelines of the canals, or via an NPS boat for the surveys conducted in the Pawtucket Canal from the Swamp Locks and Dam to the Merrimack River. Vegetation was characterized by dominant type (i.e., Herbaceous, Scrub-Shrub, Trees, Forested, or Mixed) (Table 4-2). The vegetation type assessments were based on overall dominant vegetation characteristics at the time of the survey that may have variations within small areas. In addition, the shoreline/canal was characterized by dominant features (i.e., Block Wall, Concrete, Earthen/Terrestrial Cultural, Stone Wall, Block Wall/Concrete/Stone Wall Mix) (Table 4-3). The shoreline/canal type assessments were based on overall dominant features at the time of the survey that may have variations within small areas.

Table 4-2. Dominant vegetation types used during field surveys

Vegetation Type	Description
Herbaceous	Characterized by primarily herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and woody plants less than 3 feet tall.
Scrub-Shrub	Consists of woody plants less than 3 inches diameter at breast height (DBH) and greater than or equal to 3 feet tall.
Trees	Consists of woody plants 3 inches or more in DBH, regardless of height. This vegetation type description was generally used to describe areas along canal walls where only a few trees were growing in a clump.
Forested	Characterized as a relatively large area that consists of primarily trees and underbrush.
Mixed	Characterized by a mosaic of herbaceous, scrub-shrub, and/or trees.

Table 4-3. Dominant shoreline/canal types used during field surveys

Shoreline/Canal Type	Description
Block Wall	Canal walls primarily dominated by placed, generally uniform sized blocks with concrete caps or block alone.
Concrete	Canal walls primarily dominated by concrete, with various types of cement and aggregate.
Earthen/Terrestrial Cultural	Canal walls generally dominated by earthen embankments (forested and unforested) and areas of exposed bedrock. Some of these areas (e.g., riprapped areas) have been created and/or maintained by human activities.
Stone Wall	Canal walls primarily dominated by placed, generally non-uniformly sized blocks with concrete caps or block alone.
Block Wall/ Concrete/Stone Wall Mix	Areas of canal walls predominantly composed of a conglomeration of block wall, concrete, or stone wall at varying quantities.

Mapped Vegetation Polygons and Vegetation Points (VPs)[6] were located using an EOS Positioning Systems Arrow 100™ GNSS receiver linked to an iPad™ Air 2 or Android device operating Collector for ArcGIS™ hand-held GPS unit (equipped with a data dictionary aiding in feature attribution). The presence and extent of cover of the vegetation on/along the canal walls observed at the time of the field survey was evaluated based on photographs and field observations. Geospatial vegetation data were transferred to a Geographic Information System (GIS) format and used to develop both visual maps depicting vegetation presence boundaries and VPs along the canal walls as well as tabular information quantifying the abundance and distribution of dominant vegetation types in the study area. Vegetation polygons were then analyzed to calculate the percentage represented by each vegetation category within each canal; VPs were not included in vegetation category percentage calculations because they represent a single point on the canal wall.

Each representative vegetation type was photographed. Each vegetation polygon and VPs, including any canal descriptive features (e.g., riprap, concrete walls, earthen embankments, etc.) within a polygon or near a VP, was photo documented when possible.

4.6.3 Data Analysis and Processing

During the field effort, mapped vegetation type polygons were collected to represent current conditions. Vegetation type boundaries were mapped to reflect field observations of vegetation composition.

Upon completion of the field data collection effort, all data were checked for errors and omissions. The percentages of each vegetation type were calculated. Minor adjustments were made to a small number of vegetation polygon boundaries and subsequent percentages based on examination of the location of the GPS polygon data relative to banks and bends along the canals, or from recorded field data during mapping.

4.7 Visual Survey for Waterborne Trash

The visual survey for waterborne trash was formally conducted on April 9, 2020. The survey was conducted to identify locations within the study area where waterborne trash accumulates within the Project Boundary. Waterborne trash occurring along the canals was described based on observations of accumulated waterborne trash during the field reconnaissance survey. The methods for this study followed those that were described in the study plan approved by the Commission.

[6] Vegetation points were used to identify areas along canal walls where a single vegetation type point was recorded. Vegetation points generally identify where a single species (e.g., shrub, tree) was located.

4.7.1 Review of Existing Information

Areas of waterborne trash occurring in the study area were described based on a review of existing information, an inspection of aerial photography, the observation of accumulated waterborne trash during other Project relicensing studies, a review of information provided to Boott by the NPS that identifies areas of trash accumulation (both on the canal bottom and waterborne) within the study area, as well as the specific waterborne trash occurrences during the field survey.

4.7.2 Waterborne Trash Mapping

For the purposes of examining waterborne trash accumulation areas, the study area was divided into the six canals associated with the Lowell Project canal system including: 1) Pawtucket Canal; 2) Northern Canal; 3) Western Canal; 4) Merrimack Canal; 5) Eastern Canal; and 6) Hamilton Canal, and associated NPS gatehouses and locks (Figure 4-2).

Visual qualitative surveys were conducted in the study area by vehicle as well as on foot along the shorelines of the canals. Waterborne trash was characterized by dominant type (i.e., Plastics/Household, Woody Debris, or Assorted) (Table 4-4). The canal level (low, medium, high) at the time of the site investigation was also recorded. The waterborne trash assessments were based on the overall dominant trash type observed at the time of the survey.

Table 4-4. Dominant Waterborne Trash Types Used During Field Surveys

Waterborne Trash Type	Description
Plastics/Household	Characterized by plastic cups, plastic bags, wrapping materials, plastic water bottles, plastic containers, rubber balls, fast-food wrappers, shoes, construction barrels, etc.
Woody Debris	Characterized by trees, logs, branches, stumps, boards, sections of plywood, etc.
Assorted	Characterized by a conglomeration at varying densities of plastics/household and woody debris.

Mapped areas of waterborne trash were located using an EOS Positioning Systems Arrow 100™ GNSS receiver linked to an iPad™ Air 2 or Android device operating Collector for ArcGIS™ hand-held GPS unit (equipped with a data dictionary aiding in feature attribution). The presence and extent of waterborne trash within the canals observed at the time of the field survey was evaluated based on field observations and photographs. Geospatial waterborne trash data were transferred to a GIS format and used to develop both visual maps depicting mapped areas of accumulated waterborne trash within the canals as well as tabular information describing the abundance and distribution of waterborne trash in the study area. The mapped polygons were then analyzed to calculate the area represented by each dominant trash type within each canal.

Each representative trash type was photographed. Each waterborne trash polygon, including any canal descriptive features (e.g., active construction adjacent to canal, primarily residential, commercial, etc.) in the vicinity of a polygon, was photo documented when possible.

4.7.3 Data Analysis and Processing

During the field effort, mapped waterborne trash polygons were collected to represent current conditions. Waterborne trash polygon boundaries were mapped to reflect field observations at the time of the investigations.

Upon completion of the field data collection effort, all data were checked for errors and omissions. The areas of each mapped waterborne trash polygon were calculated. Minor adjustments were made to a small number of mapped waterborne trash polygon boundaries and subsequent areas based on examination of the location of the GPS polygon data relative to banks and bends along the canals, or from recorded field data during mapping.

5 Study Results

5.1 Literature Review

Pursuant to the approved study plan, Boott reviewed several sources to summarize recreation in the Project area, including the Massachusetts Statewide Comprehensive Outdoor Recreation Plan (SCORP) (Massachusetts Executive Office of Energy and Environmental Affairs [MEOEEA] 2017); the New Hampshire Department of Natural and Cultural Resources (NHDNCR) SCORP 2018; the Massachusetts Recreational Trails Program Guide (MassTrails) 2020; the LNHP Foundation Document (LNHP 2017); The City of Lowell Open Space and Recreation Plan (City of Lowell 2018); and the City of Lowell's Comprehensive Master Plan, known as Sustainable Lowell 2025 (City of Lowell 2013). Additionally, Boott conducted a records and literature review on the historical and current practices regarding management of vegetation growth and waterborne trash. This section summarizes the results of the literature review to characterize these aspects in the Project area.

5.1.1 Recreation in the Project Area

The Merrimack River provides widespread recreational opportunities. The 116-mile-long Merrimack River begins at the confluence of the Winnipesaukee and Pemigewasset Rivers in the City of Franklin, New Hampshire, flows southward into Massachusetts, and then travels northeast until it discharges into the Atlantic Ocean (New Hampshire Department of Environmental Services [NHDES 2019]). Although the Merrimack River watershed is heavily forested (75% of the land area is covered with forest), it also supports all or parts of approximately 200 communities with a total population of 2.6

million people (Environmental Protection Agency [EPA] 2020; U.S. Army Corps of Engineers [USACE] 2006). The Merrimack River provides numerous recreational opportunities to the residents of the communities along its banks but is also utilized by residents of major cities in the region, particularly residents from Boston (Nashua Regional Planning Commission [NRPC] 2008; NHDES 2019; USACE 2006).

The Project dam is located at river mile 41 on the Merrimack River, and the impoundment extends upstream approximately 23 miles almost to the City of Manchester in New Hampshire. The Project impoundment is characterized by the urban/industrialized cities of Nashua, New Hampshire and Lowell, Massachusetts. Recreational opportunities differ closer to these larger, more populated cities along the river. The State of New Hampshire reports many recreational uses of the Project impoundment, including fishing, canoeing, kayaking, rowing, and motor boating. Lands adjacent to the Project impoundment are used for hiking, picnicking, birdwatching, nature study, and overall enjoyment of the scenic views (NHDES 2019; NHDNCR 2018; New Hampshire Fish and Game Department [NHFGD] 2020; NHFGD 2016).

The state of Massachusetts reports that recreation along the Project impoundment changes as open space generally decreases further downstream and riverfront communities are more industrialized (MEOEEA 2001). Water-based recreation (boating, fishing, canoeing, and swimming), is provided on the downstream portion of the Project impoundment by multiple boat ramps and waterfront parks. The City of Lowell, NPS, and MADCR report many additional recreational opportunities in and surrounding Lowell, including networks of trails, thousands of acres of nearby state forest, and urban passive parks for walking, jogging, dog-walking, and picnicking (City of Lowell 2018; MADCR 2014; LNHP 2017). As part of the LNHP or Lowell Heritage State Park, different sites in and around the city of Lowell are related to the historical era of textile manufacturing and offer museum exhibits, walking tours, and interpretive/interactive displays (LNHP 2017; MADCR 2014).

Although portions of the LNHP are within the Project boundary, it is not a FERC-approved recreation facility. As noted above in Section 1.2, the Visitor Center is the Project’s only FERC-approved recreation facility. The Visitor Center offers a secured view of the interior of the turbine gallery and an interpretive display which provides information regarding the development, history, and operation of the Project and nearby historic, natural, cultural, and recreational resources.

Recreational opportunities available along the 23-mile impoundment are summarized in Table 5-1 and described in more detail below.

Table 5-1. Recreational Opportunities Available on the Project Impoundment

Recreational Facility	Canoe/Kayak Access	Boat Ramp	Picnic Area	Fishing Access	Trail System	Light Trails	Designated Swimming Area	Visitor Center	Historical/Heritage Exhibits
Moore's Falls Conservation Area	✓		✓	✓	✓	✓			
Depot Street Boat Ramp	✓		✓	✓					
John Bryant River Access	✓		✓	✓					
Thornton's Ferry Boat Launch	✓			✓					
Greeley Park & Boat Ramp	✓	✓	✓	✓	✓	✓			
Merrill Park	✓		✓	✓		✓			
Chelmsford Boat Access	✓	✓	✓	✓	✓				
Rourke Brothers Boat Ramp	✓	✓		✓					
Lowell Heritage State Park			✓	✓	✓	✓	✓		✓
Pawtucket Falls Overlook									✓
Lowell National Historical Park					✓	✓		✓	✓
E.L. Field Powerhouse Visitor Center								✓	✓

Much of the Project impoundment is in Hillsborough County in New Hampshire. The New Hampshire SCORP estimated that the county has approximately 54,480 acres of recreation lands and 116 public access sites to the water. Public lands maintained by state, federal, or local municipalities comprise the majority of identified recreational acreage in the county, followed by private non-profit organizations/land trusts. With an estimated 197 natural/passive recreation areas and 111 parks, picnics, and playground areas, Hillsborough County has the most of all counties in New Hampshire. Given the national trend of individuals choosing to recreate closer to home, the New Hampshire

SCORP states it is important that larger population bases, such as that of Hillsborough County, have higher proportions of recreation sites (NHDNCR 2018).

Most of the shore lands along the Merrimack River in New Hampshire are privately owned. Activities such as boating, canoeing, kayaking, rowing, and fishing take place immediately on the Merrimack River (NRPC 2008). There are six known boat access facilities in New Hampshire with direct access to the Project impoundment. These facilities range in design from concrete ramps to shoreline access and are described below:

Moore's Falls Conservation Area: Moore's Falls Conservation Area offers shoreline fishing and car-top boating access to Moore's Falls in the Project impoundment. Moore's Falls are a length of rapids on the Merrimack River which drop 6 feet in elevation over 650 feet in distance. There are also walking trails through the woods, an old trolly track trail, multiple access points to the Merrimack River for fishing, educational information regarding environmental conservation, and birdhouses. NHDES recommends this conservation area for angler fishing, as small and large mouth bass are often caught, as well as rainbow and brook trout, both of which are stocked by the NHFGD in the Lower Merrimack River (Middlesex Canal Association 2009; NHDES 2019).

Depot Street Boat Ramp: The Depot Street Boat Ramp offers a carry-in boat ramp and fishing access to the Merrimack River and is managed by the Town of Merrimack. The trail to the river runs under railroad tracks. This access is suitable for motorboats, as the river slows from the rocky rapids upstream (NHDES 2019; Merrimack Parks and Recreation 2020). There is also a scenic picnic area.

John Bryant River Access: The John Bryant River Access is a canoe/kayak car top facility managed by the Litchfield Recreation Commission. It provides fishing access, scenic views of the river, and birdwatching. It is available only to Town of Litchfield, New Hampshire residents (Litchfield Recreation Commission 2020).

Thornton's Ferry Boat Launch: Thornton's Ferry Boat Launch is owned by the Town of Merrimack and offers cartop carry-in boating and fishing access to the Merrimack River (NHFGD undated).

Greeley Park & Boat Ramp: Greeley Park is a 125-acre city park located in Nashua, New Hampshire. Greely Park offers many recreation amenities/facilities including baseball/softball fields, historical sites, picnic areas, playgrounds, restrooms, tennis courts, trails, and wading pools (NHFGD undated; City of Nashua 2020). In 2019, the City of Nashua issued an invitation to bid for reconstruction of the Greeley Park Boat Ramp, as well as construction of a gravel parking lot, placement of new signs, and three biological retention ponds. The work was scheduled for completion in July 2020 (NHFGD undated; City of Nashua 2019). A paved ramp at the north end of Greeley Park in Nashua also allows access to the river for boaters. NHDES recommends this conservation area for angler fishing (NHDES 2019).

Merrill Park: Merrill Park is a 9.3-acre city park located in Hudson, New Hampshire. It is adjacent to the east riverbank and Project boundary. The park is mostly forested with a few walking paths and picnic benches. It has a path which leads down to the Merrimack River, allowing hand-carry access for canoes or kayaks, or fishing (Town of Hudson undated).

The Merrimack River provides quickwater and flatwater experiences for canoeists and kayakers and is one of the largest surface water bodies in the region for motor boating. Local watershed organizations sponsor a variety of paddling trips on the Merrimack River and its tributaries throughout the spring, summer, and fall for beginner and intermediate paddlers (NHDES 2017). Upstream of the northern extent of the Project impoundment is a whitewater kayak course located in Manchester, New Hampshire. There are also class I-II+ rapids located between Amoskeag Falls to Goffs Falls (City of Manchester 2018).

The most popular outdoor activities for New Hampshire residents include wildlife observation, driving for pleasure, sightseeing, and jogging/running/walking. Day hiking tends to be more popular in New Hampshire than the national average (NHDNCR 2018). Natural areas in the vicinity of the Project in New Hampshire are also used for cross country skiing, picnicking, bird watching, nature study, and overall enjoyment of scenic views (NRPC 2008). In addition to the facilities mentioned above, the following facilities are within a 30-minute drive from the Project impoundment and are provided for these types of activities:

Litchfield State Forest: The Litchfield State Forest is a 450-acre forest in Litchfield managed by the State of New Hampshire. It is located about 1.5 miles east of the Project boundary. The 1.3-mile Litchfield State Forest Trail provides comfortable walking and biking trails. Off trails provide an additional four miles of hiking, wildlife observation, and scenic opportunities. The trails are often used for cross country skiing in the winter (Litchfield Recreation Commission 2020; ExploreYourSpaces 2020).

Flints Pond Access: Flints pond is a 50-acre, warm water pond located in the Town of Hollis in New Hampshire. The pond is open to the public for fishing, kayaking, and canoeing in the summer. In the winter, ice fishing, snowshoeing, and snowmobiling are also popular. A boat ramp is available at the north end of the pond (Flints Pond Improvement Association 2015). Flints Pond Access is approximately 0.2 miles west of the Project boundary.

Horse Hill Nature Preserve: Horse Hill Nature Preserve is a 560-acre property owned by the town of Merrimack, located about three miles west of the Project Boundary. It is primarily a mixed hardwood forest, with a series of streams, ponds, swamps, and numerous wetlands. Old logging roads form the basis of what is today a trail network used by hikers, bikers, cross country skiing, snowshoeing, hunters, snowmobilers, and horseback riders. This trail network covers most of the property, however, there are still large areas without defined access.

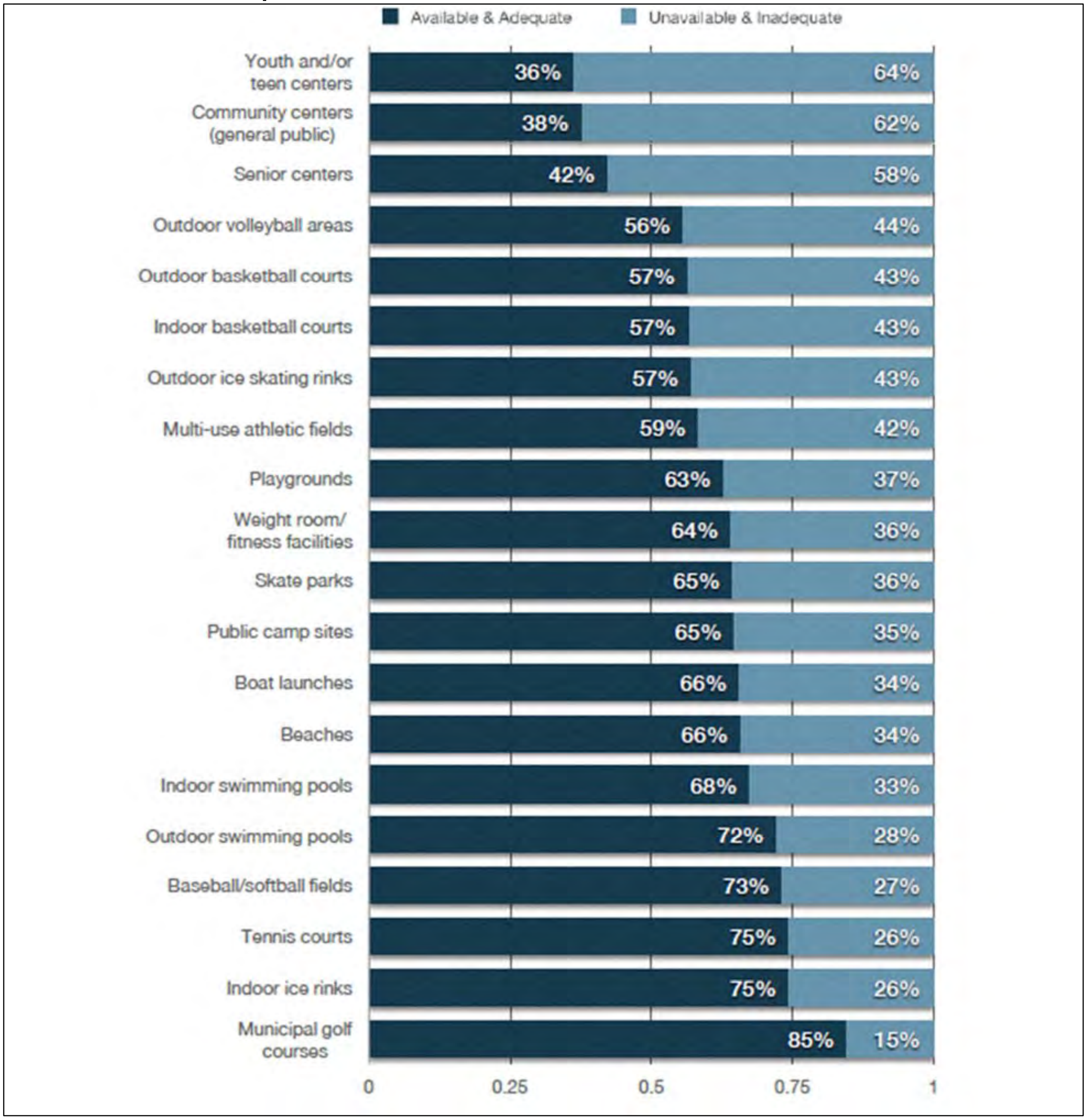
Leslie Bockes Memorial Forest: Forest Society owns and manages this approximately 226-acre forest located in Londonderry, New Hampshire (five miles east of the Project boundary). Nearly four miles of old logging roads provide hiking, skiing, and snowshoeing with numerous access points. The trails are on well-maintained woods roads that enable easy walking and generally good footing. The tract is a known spot for bird and nature-watching (Forest Society 2020).

Twin Bridge Park: Twin Bridge Park is in Merrimack, New Hampshire, and features a baseball field, playground, picnic area, and extensive hiking trails through 27 acres of woods along Baboosic Brook (Town of Merrimack undated). Twin Bridge Park is approximately 0.2 miles west of the Project boundary.

New Hampshire Heritage Trail: The completed trail system will connect trail segments along the Lower Merrimack River and ultimately extend south into Massachusetts, and north along the Merrimack, Pemigewasset, and Connecticut Rivers to the Canadian border. Several trail sections have been completed along this part of the river and northward, with existing segments in Nashua, Hooksett and Manchester, New Hampshire (NHDES 2019).

The most recent New Hampshire SCORP was developed in 2018 for the 2019-2023 program years (NHDNCR 2018). The primary goals of the New Hampshire SCORP are to identify outdoor recreation trends, needs, and issues for New Hampshire, as well as to provide a strategic plan to address changing recreation needs, conservation of natural resources, and the economic vitality of communities. Municipal officials in New Hampshire reported the availability and adequacy of developed recreation facilities and amenities to meet needs within their communities. Figure 5-1 below shows the facilities in order of greatest need in New Hampshire. Municipal officials reported youth and/or teen centers as least available and adequate to meet growing needs, while reporting indoor ice rinks and municipal golf courses as most available and adequate to meet needs. The most relevant to the Project of these rated recreation facilities and amenities in New Hampshire are state/municipal parks, beaches, boat launches, and public camping sites, all of which were identified as being at least moderately available and adequate to meet recreation needs (>50%).

Figure 5-1. Availability and Adequacy of Developed Recreation Facilities/Amenities in New Hampshire



Source: NHDNCR 2018

The Massachusetts SCORP (MEOEEA 2017) is a planning document that discusses the available recreational resources in a state, as well as its changing recreation needs. In drafting of the SCORP, the Massachusetts Executive Office of Energy and Environmental Affairs hosted a series of public meetings across the state in the fall of 2017. Online surveys were also utilized to gather input from both residents and recreation providers. Around 780 citizens responded to the resident survey and 58 municipalities and 38 land trusts responded to the recreation provider survey. The Massachusetts SCORP categorized the most common recreational activities as either water-based recreation (e.g. boating, fishing, swimming at beach/lake/river) or trail-based recreation (e.g., hiking, biking, cross-country). The nearness of an outdoor recreation facility to home was the top reason that it was visited most frequently. Accordingly, when asked to identify the most-needed improvements, recreationists identified trail and water-based recreation enhancements. Massachusetts municipalities reported the highest funding priorities for the next five years are playgrounds, ballfields (soccer, lacrosse, baseball, etc.), community or regional trail systems, and improved pedestrian access to parks (sidewalks, safe road crossings, etc.).

The downstream portion of the Project impoundment is accessible for water-based recreation by the following recreational facilities in Massachusetts:

Lowell Heritage State Park: The 83-acre Lowell Heritage State Park occupies a 2-mile long stretch along the north bank of the Project impoundment, upstream of the Pawtucket Dam. The park features historical exhibits that were created in partnership with the NPS to educate the public regarding the network of canals and mills constructed in the 19th century to power Lowell's then bustling textile industry. Activities available include biking, boating (non-motorized and motorized), canoeing and kayaking, swimming, fishing, hiking, and educational programs. Facilities include a paved bike path and walking esplanade, picnic area, a beach, restrooms, scenic viewing area, an outdoor concert stage, and visitors center (Commonwealth of Massachusetts 2018a). Also located within the park boundary is the University of Massachusetts Lowell Bellegarde Boathouse, which also houses the Merrimack River Rowing Association, a non-profit rowing club.

Rourke Brothers Boat Ramp (part of the Lowell Heritage State Park): The park provides a trailered boat launch, located on the north bank of the impoundment about 2 miles upstream of the Pawtucket Dam. Adjacent to the boat launch is an access dock for boating and fishing.

Chelmsford Boat Access: The park provides a trailered boat launch, shoreline fishing access, picnic areas, athletic fields, and trails.

The Resource Management Plan (RMP) for the MADCR Lowell/Great Brook Planning Unit (MADCR 2014) reports the following recreational facilities within the planning unit, located within a 30-minute drive from the Project boundary:

Lowell-Dracut Tyngsborough State Forest: The Lowell-Dracut Tyngsborough State Forest is approximately one mile north of the Project boundary. The Lowell-Dracut Tyngsborough State Forest spreads across three towns and features over 1,140 acres of protected land, including 180 acres of open water or wetlands and 457 acres of land in the city of Lowell. Popular activities include hiking, fishing, hunting, cycling, birding, picnicking, nature walking, mountain biking, and playing various field sports. In the winter, people sled, ice skate, and cross-country ski (Commonwealth of Massachusetts 2018b).

Great Brook Farm State Park: Located seven miles south of the Project, this park is a working dairy farm connected to miles of trails that can be used for a variety of recreational activities. The park also includes historic buildings and resources, interpretive programming, and a cross-country ski concession.

Warren H. Manning State Forest: Located five miles south of the Project, this state forest is a largely wooded property with a small recreation area, complete with a spray deck, picnic area, water playground, and fitness trail.

Billerica State Forest: Located six miles south of the Project, this state forest offers rustic, multi-use trails and wooded areas for walking and wildlife viewing.

Carlisle State Forest: Located ten miles south of the Project, this state forest provides over a mile of trails through wooded property protected from forestry activities at the turn of the 20th century. The forest includes an older stand of exceptionally large eastern white pines.

Governor Thomas Dudley State Park: Located ten miles south of the Project, this 11-acre park is a small wooded parcel that provides access to the Concord River and links to other protected open spaces.

At the state level, the focus of outdoor recreation tends to be on recreation lands and facilities outside of urban areas. This is evidenced in the Massachusetts SCORP and MADCR's RMP for the area, which primarily discuss and address recreation in open undeveloped areas like state lands and forests.

Sustainable Lowell 2025 and the 2018 Lowell Open Space and Recreation Plan (OSRP) prepared by City of Lowell, estimates there are 463 acres of open space/recreational land owned or maintained by the city. The City of Lowell reports a variety of recreational amenities including sports facilities (basketball, tennis, softball, swimming, and skateboarding), passive parks for walking, jogging, dog-walking, and picnicking, community gardens, playgrounds, multiuse trails, and greenspaces. City-funded cemeteries provide an additional 222 acres of open space to Lowell residents and visitors (City of Lowell 2018). The City of Lowell has also collaborated with the LNHP to secure funding for and manage the development and redevelopment of 6,662 linear feet of canal walkways throughout Lowell, with work on an additional 11,360 linear feet underway (City of Lowell 2018).

The Concord River Greenway is still in development, but to date has 2,700 linear feet of trail and 1.3 acres of open space cutting through the City of Lowell. Public art and interpretive signs line the multi-modal path. Once complete, the Concord River Greenway will link to a network of trails in the area, including the Bay Circuit Trail, a 200-mile trail from coastal Boston to Kingston, as well as the Bruce Freeman Rail Trail from

Lowell to Framingham. It will also connect Rogers Fort Hill Park and Shedd Park with Lowell Cemetery and the city's cemeteries (City of Lowell 2018).

The attractions in Lowell that are open to the public as part of the LNHP are largely managed by NPS. The LNHP was established in 1978 and is operated by the NPS. It is a primary recreation attraction for the city of Lowell. According to the NPS Visitor Use Statistics website, the LNHP received around 481,536 visitors for the 2019 calendar year (NPS 2020). Opportunities available include museum exhibits, walking tours of the waterways, historic trolly rides, guided tours, music concerts, and boat tours on the Project canals.

The museum exhibits and activities are hands-on, interpretive, and educational opportunities. Key park experiences include the following:

Boott Cotton Mill Museum: Located in the Boott Cotton Mills Museum are interactive exhibits, a weave room, and video programs about the Industrial Revolution, labor, and the rise, fall, and rebirth of Lowell. This complex contains an adapted mill yard and is the most intact surviving example of the first phase of Lowell's mill construction. All four of the original 1835 mills in the Boott mill yard remain as part of an interconnected series of mill buildings.

Mill Girls and Immigrants Exhibit: The Mill Girls and Immigrants Exhibit is a self-guided tour through renovated boardinghouses displaying the kitchen, dining room, and bedrooms furnished in the style of the 1850s. Traditional museum exhibits are located on the second floor, including old photographs, newspaper articles, excerpts from letters, and highlights the lives of specific mill girls and immigrant workers.

Suffolk Mill Turbine Exhibit: This exhibit shows how water from the Western Canal flowed through an opening in the wall of a mill and fell on a large waterwheel in the basement to create kinetic energy. A guided tour also shows one restored turbine using a 13-foot drop of water to rotate shafts, gears, belts, and pulleys to a power loom.

Lowell National Historic Park Canal Walkways Tours: Self or professionally guided recreationists can follow walkways along the network of canals originating at the Pawtucket Dam and ending at the confluence of the Concord and Merrimack Rivers (NPS undated). Most of the walkways that follow the canals are also integrated into the common thoroughfares of the City of Lowell.

The Northern Canal Walkway: The Northern Canal Walkway provides interactive recreation with the historic structures of the Lowell Project, as well as a greenway along a scenic reach of the Merrimack River (NPS undated).

Boat tours led by NPS-guides also provide access to the Project impoundment. The canal boat tours highlight some of the Lowell Project facilities by travelling through the historic navigation locks (NPS undated). Additional recreational opportunities provided by NPS at the LNHP include trolley rides available for touring the city.

5.1.2 Vegetation and Waterborne Trash Management

Pursuant to the approved study plan, Boott reviewed several sources to summarize historical and current practices for vegetation and waterborne trash management in the Project Area.

Following establishment of the LNHP in 1978, MADCR[7], NPS, and Proprietors of the Locks and Canals (Proprietors), entered into an agreement in 1979 regarding management of the Lowell canal system. This agreement establishes MADCR as the lead party responsible for the maintenance of canal structural components, including canal banks and walls. As the lead party, MADCR was responsible for “landscaping and damage repair” to canal banks and walls, with assistance provided by NPS if needed. NPS was charged with the operation of the canal-related exhibits and services, and Proprietors were responsible for the operation and maintenance of the hydroelectric and hydromechanical parts of the Lowell canal system (NPS 1981). NPS developed and issued a Final General Management Plan (FGMP) in August 1981 to provide a basis for visitor use, resource management, and general development within the LNHP. The FGMP states management of the Lowell canal system will be accomplished through cooperative agreements between private and public entities, but MADCR is the lead agency responsible for maintaining, developing, and renovating the major elements of the canal system (NPS 1981).

In 1991, MADCR, the NPS, and Boott executed a Memorandum of Understanding (MOU) for the purpose of maintaining and operating the Lowell Canal System.[8] The MOU assigned specific responsibilities to each party and was filed with the Commission[9] on April 25, 1991 (MOU 1991). Article IV of the MOU directed NPS to assist MADCR in the removal and control of vegetation along the canal system, (“particularly that growing on and in the canal walls”) and to assist MADCR in performing ground maintenance. Article IV also directed NPS to assist MADCR in the removal of litter and other waterborne trash from the Lowell Canal System, and states NPS is solely responsible for maintaining and cleaning, (“including removal of trash”) all existing trash booms and safety lines/booms on the Lowell Canal System (MOU 1991).

Responsibilities assigned to MADCR under Article V of the MOU include serving as the lead agency for all grounds maintenance, keeping all grass, trees, and shrubs neatly trimmed and in a healthy condition, removing dead or diseased plants, fertilizing, pruning, and thinning of plants (as required), and approving ground maintenance or improvement plans as proposed by NPS. Article V also directs MADCR to assist NPS in

[7] The signatory of the 1979 agreement was the Massachusetts Department of Environmental Management, the predecessor agency to MADCR.

[8] Proprietors of the Locks and Canals on the Merrimack River was included as a party in the MOU but did not execute the agreement.

[9] The 1991 Memorandum of Understanding is available on FERC’s eLibrary (https://elibrary.ferc.gov/eLibrary/search) under docket number p-2790.

the removal and control of destructive vegetation along the canal system, and to cooperate with the NPS on developing a litter removal program for waterborne litter and trash on the canals. (MOU 1991). This article also directed MADCR to reimburse NPS for time and materials for work done on the canal system.

Article VI of the MOU directed NPS and MADCR to hold a joint annual meeting to develop an annual destructive vegetation clearing program and canal surface water cleanup program. The annual programs were to be developed in accordance with each agency's budget and seasonal staffing level. Under Article VI, MADCR was also directed to consult with NPS to develop a long-term capital improvement program for the canal system. The minutes of this annual meeting between MADCR and NPS were to be provided to Boott and the Proprietors each year (MOU 1991).

Article IX stated that the MOU would expire five years from the date of signing, with an option for renewal. Efforts to renew the MOU stalled in 1996, as MADCR issued a Grant of Easement[10] to the NPS in late 1995. This Grant of Easement provided NPS rights to implement construction and maintenance improvements at forty-two MADCR-owned parcels around the canal system. Such rights include landscaping, decking, and lighting. The Grant of Easement did not exclusively limit NPS's rights, only stating that construction and maintenance improvements must be consistent with the use of the area as a park. The Grant of Easement did not relinquish MADCR's waterborne trash and vegetation management responsibilities provided by the FGMP or MOU, as described above.

In the RMP for the Lowell/Great Brook Planning Unit, MADCR elaborates the agency was directed by the Commonwealth in 1993 to "concentrate on maximizing the riverfront component and minimizing, but not eliminating, [its] position in the downtown." Under a lower annual budget, MADCR states it has since focused its resources on the riverfront portion of the Lowell Heritage State Park system and less on the downtown canal system (MADCR 2014).

Through the current license term, FERC and Boott have corresponded on vegetation growth and waterborne trash accumulation at facilities within the Project boundary. The FERC Regional Office has regularly inspected the Project pursuant to its dam safety authority under Part 12 of the Commission's regulations. The most recent inspection of the Lowell Project performed on May 14, 2019 found that the facilities were in satisfactory condition, and there were no safety issues observed which required immediate attention. Following the inspection, FERC directed Boott to remove the vegetation and small tree growth observed at the crest of the Great River Wall and on the Hall Street Dam (FERC 2020; FERC 2019). A review of previous inspection reports indicate FERC found the Project facilities to be in overall good condition, and if necessary, directed Boott to remove vegetation growth or waterborne trash observed at Project structures. Boott typically identifies canal structures in need of vegetation removal and control in its Dam Safety Surveillance and Monitoring Reports annually

[10] The 1995 Grant of Easement is also generally referred to as LNHP Deed No. 40.

submitted to the FERC's New York Regional Office, and documents progress made during the preceding year.

Boott annually removes accumulated river-borne debris from the upstream side of the Northern Canal Gatehouse under an MADCR permit. This effort is performed as necessary, typically two to three times annually. Boott also removes debris that accumulates from the upstream side of the Guard Locks and Gatehouse in the Pawtucket Canal on an as necessary basis, both for aesthetics and to ensure that debris does not interfere with the proper functioning of the Guard Gates. Recently, Boott has agreed with the City of Lowell to conduct canal debris removal at recognized accumulation points, many of which are noted in this study.

According to documents and reports filed with the Commission, additional efforts to remove vegetation and waterborne trash from the Lowell canal system of have largely been independent or coordinated efforts between NPS, the City of Lowell, and Boott. In accordance with the MOU, NPS implemented frequent maintenance measures to limit trash accumulation and vegetation growth. On June 18, 2003, NPS filed their 2003 Lock Chamber Operations Manual with FERC. The manual states NPS employees should remove upstream trash in the vicinity of the lock chambers daily, and the lock chambers were to be flushed daily and cleaned of debris (NPS 2003). Operators were instructed to remove trash from in front of the following lock structures: Northern Lock at Pawtucket Gatehouse, Hydro Lock, Swamp Locks, and Francis Gate Lock (NPS 2003).

On October 26-27, 2006, Boott, the NPS, and the City of Lowell collaborated in a major effort to clean-up the canals and walkways The canals were drained for three days before workers from Boott, the City of Lowell, and LNHP could use heavy equipment to remove debris from within the canals. Volunteers also trimmed vegetation and picked up trash along the canal walkways (FERC 2007; Lowell Sun 2006).

After the Study Workshop, NPS provided a copy of their Exotic Species Treatment Calendar (dated September 11, 2018) prepared for the 2019 calendar year. The document presents the reported locations of target exotic vegetation species, methods for management, and an implementation calendar. The target exotic species were primarily reported at upland LNHP-structures outside of the Project boundary (Blacksmith Shop, Kerouac Park, Visitor Center Courtyard, Tremont Street Tracks, Kirk Street Headquarters, and Western Canal Walkway). At Project structures, NPS reported incidents of common invasive species including Garlic mustard (*Alliaria petiolata),* Asiatic bittersweet (*Celastrus orbiculatus*), Tree of Heaven (*Ailanthus altissima),* and Japanese knotweed (*Fallopia japonica*). Treatment methods employed by NPS include mechanical methods of hand-pulling, digging, cutting, seed-heading, mowing, and stump grinding, and chemical methods of foliar spray, herbicidal application to a cut stem/stump, basal bark, stem injection, and hand wicking (LNHP 2018).

There are also community efforts to manage the waterborne trash and vegetation growth. Local nonprofit groups including youth groups, Lowell Canalwaters Cleaners, Coalition for a Better Acre, and Do-It-Yourself Lowell regularly host cleanup efforts during the warmer seasons.

Boott conducted visual surveys for vegetation growth and waterborne trash locations, and the results are provided below in Sections 5.5 and 5.6.

5.2 Field Inventory

As previously described, Boott conducted a field inventory to document existing non-Project recreation facilities within the Project's vicinity in the fall of 2019. Recreation sites inventoried included the Chelmsford Boat Access, Depot Street Boat Ramp, Greeley Boat Ramp, Lowell Heritage State Park, LNHP, Merrill Park, Merrimack Trail System, Moore's Falls Conservation Area, NPS Canal Walkway, Pawtucket Falls Overlook, and Rourke Brothers Boat Ramp. The Visitor Center (the only-FERC approved recreation facility), was closed on the days of inventory, but the external features (e.g. parking lot) were also inventoried.

Field inventory documentation, including a map of non-Project recreation facilities, representative photographs, and a description of amenities available at each facility is presented as Appendix B to this study report. The field inventory indicates there are considerable opportunities for recreation in the Project area. Most sites inventoried were reported in good condition, with parking lots, ample signage, and educational exhibits.

5.3 Visitor Use Data and Field Reconnaissance

In total, Boott conducted 53 personal interviews/visitor-intercept surveys between May 2019 and October 2019. In accordance with the approved study plan, Boott also collected field reconnaissance data during the personal interviews including estimating the number of vehicles, recreationists, and observed recreational activities. Results from the personal interviews are compiled in Appendix C and field reconnaissance data is summarized in Appendix D to this study report.

The online visitor use survey was made available to the public from June 2019 until June 2020. A total of 96 respondents completed the online survey. Results from the online surveys are compiled in Appendix E to this study report, and respondent zip codes with a representative map are compiled in Appendix F (for both the personal interviews and online surveys).

Of the personal interviews and online recreation surveys completed, the respondents thus far are typically regular visitors who visit three or more times per year (72 percent of personal interviewees and 76 percent of online respondents) and the remaining respondents identified themselves as first-time visitors or infrequent visitors. Personal interviewees travelled an average of 7.3 miles to the recreation area, with a range of 0.1 miles to 3,000 miles. Online respondents stated they travelled on average around 11 miles to the Project area. Most respondents stated they do not stay overnight in the

Project area in accommodations other than their primary residence (96 percent of personal interviewees and 90 percent of online respondents).

The most common recreational activities survey respondents participated in were trail-related activities (walking, dog-walking, hiking, running, or jogging), bank and/or boat fishing, and kayaking. Walking was the most common primary recreation activity. The majority (77 percent) of personal interview respondents rated their overall experience of recreational activities at the Project as “totally acceptable” or “acceptable.” The majority (92 percent) of personal interview respondents rated their overall experience of recreational activities at the Project as “totally acceptable” or “acceptable.”

According to respondents, the most frequently visited recreational facilities in the Project area were the Lowell Heritage State Park, the Rourke Brothers Boat Ramp, Chelmsford Boat Access, Merrimack Trail System, and LNHP-facilities. Participants were asked several questions regarding their general opinions of recreation in the vicinity of the Project, potential issues with the recreation facilities (i.e., crowding, safety), and recommendations for improvements to existing facilities. In general, the participants did not experience much crowding at the recreational facilities, parking issues, or lack of accessibility to the specific recreational facilities. Respondents both in-person and online tended to rate their overall experience at specific recreation facilities as “totally acceptable.” The most common recommendations for recreational enhancements were: (1) bathrooms/porta potty (2) improving/maintaining the existing structures such as the boat ramps, and (3) the addition of trash cans/trash control measures.

Field reconnaissance data obtained during personal interviews indicates the recreation facilities are well-utilized for many different activities. Walking (and dog-walking) and jogging/running were by far the most common activities observed by technicians. Additional common activities included bicycling, boating, picnicking, and fishing. The Merrimack Trail System and the Lowell Heritage State Park were highly utilized for many different recreational opportunities; these are connecting facilities, so it was common for recreationists to visit both. The Rourke Brothers Boat Ramp and the Chelmsford Boat Access were predictably mostly used for boating, but also commonly utilized for walking, dog-walking, fishing, and picnicking. The Chelmsford Boat Access adjoins a series of softball fields, and technicians reported softball tournaments with hundreds of attendees during the summer weekends. At all facilities, technicians generally reported less activity during the early daylight hours, and during rainy, cool times of the day.

5.4 Evaluation of Expanded Recreational Access in Project Canals

NPS and other stakeholders have expressed interest in new, different, and expanded recreational access to and within the Project canals. In accordance with the SPD, Boott consulted with the NPS, the City of Lowell, and other interested stakeholders to discuss various recreational opportunities associated with the Project canals. During the Study Workshop, stakeholders clarified they were looking for specific practical opportunities for community on-water recreation. Boott and stakeholders' primary concerns were the recreational rights to the canal system and understanding public safety issues associated with providing recreational access in the Project's canal system.

5.4.1 Rights to Recreational Access to Project Canals

Boott reviewed many sources to understand the recreational rights to the Lowell canal system, including the MOU, the 1984 Great Deed between Proprietors and Boott (Proprietors 1984), the 1986 Order of Taking (Commonwealth of Massachusetts 1986), and the 1995 Grant of Easement from the Commonwealth of Massachusetts to the LNHP (Commonwealth 1995). These documents form the basis of the Resources, Ownership, Boundaries, and Land Rights Study to be filed with the Commission by February 25, 2021. The 1984 Great Deed details the sale of portions of the Project from the Proprietors to the current owner (Boott), and provides the metes, bounds, and elevations of all the structures conveyed, as well as associated easements, access and repair rights (Proprietors 1984). The 1986 Order of Taking details the take of properties, rights, and responsibilities from Boott to the Commonwealth, operating through MADCR (Commonwealth 1986). The 1995 Grant of Easement describes the properties and parcels that were leased from the Commonwealth to the NPS and the rights and responsibilities of both parties with respect to those properties and parcels (Commonwealth 1995).

The review of these documents indicates that the 1984 Great Deed conveyed all canals throughout the canal system to Boott, except for the Pawtucket Canal and the Lower Pawtucket Canal. Proprietors instead retained ownership of the Pawtucket Canal and Lower Pawtucket Canal, and granted Boott an easement for the right to operate the structures of these canals, to "install conduits, pipes, and wiring" and the right to maintain, repair, or replace the existing structures (Proprietors 1984).

By letter dated May 14, 1980, MADCR stated that they were currently in the process of negotiating purchase rights to the Lowell canal system which would allow for recreational boating in the canals, stating further that use of the canals and implementation of the boating program were key elements of the Lowell Heritage State Park (Massachusetts Department of Emergency Management [MADEM] 1980). Through the 1986 Order of Taking, MADCR purchased all air rights over the canals, including over the canal walls and dams, and the exclusive right to use water in the entire canal system for recreational, educational, and navigational purposes, unless said purposes interfere with Boott's hydroelectric generation (Commonwealth 1986). Included in the 1986 Order of Taking is a permanent and exclusive easement to MADCR for all canal walls, beds, or bottoms throughout the canal system for purposes consistent with the use of the canal system as a recreational park. These purposes specifically include placement and attachment of docks, wharves, walls, and boat ramps of a temporary or permanent nature (Commonwealth 1986). The 1995 Grant of Easement from MADCR to LNHP did not convey these exclusive recreation rights to LNHP (Commonwealth 1995).

Based on the review of the MOU, the 1984 Great Deed between Proprietors and Boott, the 1986 Order of Taking, and the 1995 Grant of Easement from the Commonwealth of Massachusetts to the LNHP, Boott currently does not have any right to expand recreational opportunities throughout the Lowell canal system. MADCR purchased all recreational rights over all the canals and canal walls (even canals owned by Boott), including exclusive navigational rights such as boating or canoeing. MADCR maintains an exclusive and permanent easement throughout the entire canal system to install access points such as boat ramps, wharves, and docks. Boott and other stakeholders are not permitted to use the canals as recreational resources, as those rights are exclusively held by MADCR. Boott anticipates providing more information on the recreational rights and responsibilities in the Resources, Ownership, Boundaries, and Land Rights Study Report to be filed with FERC by February 25, 2021.

In the RMP for the Lowell/Great Brook Planning Unit, MADCR does reference its recreational rights over the Lowell canal system, but further elaborates the agency was directed in 1993 to minimize its position in the downtown area (MADCR 2014). On August 14, 2018, MADCR filed comments with FERC on the PAD and Scoping Document 1 for the Project. The comments discuss the various MADCR-owned properties, but do not reference their recreational rights to the Lowell canal system (MADCR 2018).

5.4.2 Public Safety of Recreational Access to Project Canals

Boott reviewed relevant safety and security requirements, guidance documents, and study reports, including the Project’s approved Public Safety Plan (Boott 2020), FERC’s Guidelines for Public Safety at Hydropower Projects (FERC 2011), Recreation Development at Licensed Hydropower Projects (FERC 1996a), and the Security Program for Hydropower Projects (FERC 2016). Boott also reviewed pertinent guidance, design, and planning documents relating to recreational access throughout the canal system.

In accordance with the Commission’s approved Public Safety Plan for the Project, Boott maintains fences and gates, lights, sirens, and warning signs to protect the public from the hazards of Project operations (Boott 2020). Boott has historically worked with FERC to strengthen the Public Safety Plan and allow access only where appropriate and safe. As described above, Boott does not have recreational or navigational rights to the canal system. Further, because of the steep canal walls, dams, historic locks and gate structures, and intake/outlet structures associated with the Project, Boott maintains that such access presents an unacceptable risk to public safety and Project security. In the 1990s, incidents of accidental drownings/body recoveries throughout the canal system triggered Boott and FERC to update the Public Safety Plan, install additional warning signs, and fencing to enhance public safety (Boott 1991; FERC 1996b; Boott 1998; Boott 2000).

While Boott does not have recreational or navigational rights to the canal system, Boott believes that providing access would present a number of significant safety concerns. As an example, FERC's Guidelines for Public Safety at Hydropower Projects states that canals create hazardous conditions due to the steep sides and hard surfaces. The safety guidelines indicate water, algae, and mud make conditions too slick and dangerous for recreationists to escape or be rescued. The multiple dams located throughout the canal system (Swamp Locks Dam, Lower Locks and Dam, Lawrence Dam, Hall Street Dam, Merrimack Dam, Rolling Dam, and Boott Dam) as well as the many gates and lock structures, are all also considered potentially hazardous (Figure 3-2). Such structures can create unexpected dangers as surface waters appear calm, but undercurrents are unpredictable. Powerhouse intake areas throughout the canal system also pose hazards to recreationists as currents can change unexpectedly. Boaters will often want to go over lower dams or explore restricted areas, but this must be discouraged by warning signs and barrier systems. As stated in FERC's guidelines, allowing recreationists access to or near to Project facilities poses significant safety and security risks.

5.4.3 Expansion of Recreational Access to Project Canals

Given the information presented in Section 5.4.1 and 5.4.2, the opportunities for expansion of recreational opportunities in the Project canals are limited. MADCR exclusively owns all rights to allow recreation on or in the Project canals and holds easement rights to install recreational access points. As such, Boott does not have the rights to provide expanded recreational opportunities within the canal system.

In accordance with the SPD, Boott researched infrastructure enhancement that may be required to provide safe public access to the canal system and how such improvements may affect aesthetic and historic resources. FERC recommends that access points, such as canoe/kayak or boat ramps, should be at least 300 feet away from any structure that may pose a hazard (such as dams, intakes, and gate structures). A system of warning devices such as signs, boat restraining barriers, sirens, and buoys also may need installation at least 300 feet from any hazardous structure. At a minimum, escape devices such as life preservers and safety ropes are recommended to be installed near dams, canals, and any other hazardous structures, although FERC acknowledges theft and vandalism can be an issue with such installations. Permanent escape ladders may be considered (especially for canals) and should be installed every 250 feet on either side, but these devices are "attractive nuisances" and can often exacerbate unsafe conditions. Boaters will need escape ladders or other similar emergency escape points as situations can turn dangerous, such as unexpected lightning storms. Any provision of public access to the canals would necessarily create additional responsibilities for city, state and NPS public safety and law enforcement authorities. Additionally, information on dangerous areas, restrictions on speed, direction, or access (especially in canals), alcohol use restrictions, enforcement and penalties, and other information relevant to safe recreational practice should be provided to recreationists at access points (FERC 2011).

5.5 Visual Survey for Vegetation Growth

In total, 96 Vegetation Polygons (representing 80% of the total survey data collected in the study area) and 24 VPs (representing 20% of the total survey data collected in the study area) were mapped between September 25 and September 27, 2019 (Appendix G; Appendix H). As shown in Table 5-2, the total study area encompassed approximately 44 acres and mapped vegetation on/along canal walls accounted for approximately 5 acres (11%) of the study area[11]. The Pawtucket Canal (19.63 acres; 44% of the total study area), Northern Canal (11.67 acres; 26% of the total study area), and Western Canal (5.51 acres; 13% of the total study area) represent more than 80 percent of the total study area (Table 5-2, Appendix G).

Maps showing the results of the vegetation assessment and mapping within the study area are illustrated in a 21-sheet, 11 by 17-inch vegetation type map set with numbered polygons (e.g., 1, 2) and VPs (e.g., VP1, VP2) for each vegetation polygon and/or VP, respectively in Appendix G. Results from the canal wall vegetation mapping are compiled in Appendix H and field reconnaissance data is summarized in Appendix I to this study report.

Table 5-2. Percent total acreage and mapped vegetation acreage of the six major canals associated with the Lowell Project canal system

Canal	Area (acres)	Percentage (%) of Total Study Area	Mapped Vegetation Area (acres)	Percentage (%) of Total Study Area with Mapped Vegetation
Eastern Canal	4.03	9%	0.93	2%
Hamilton Canal	2.01	5%	0.35	1%
Merrimack Canal	1.40	3%	0.38	1%
Northern Canal	11.67	26%	0.89	2%
Pawtucket Canal	19.63	44%	1.33	3%
Western Canal	5.51	13%	0.90	2%
Total	**44.25**	**100%**	**4.78**	**11%**

Pursuant to the approved study plan, vegetation type assessments were completed in the Pawtucket Canal, Northern Canal, Western Canal, Merrimack Canal, Eastern Canal, and Hamilton Canal. In addition, the shoreline/canal type was characterized by dominant features found in each of the mapped polygons and VPs. Field inventory documentation, including a map identifying each polygon or VP, representative photographs, and a

[11] VPs are not included in mapped vegetation acreage calculations because they represent a single point(s) on a canal wall.

description of the vegetation type observed at each polygon or VP is presented in Appendices G-J to this study report.

5.5.1 Eastern Canal

The vegetation mapping and characterization effort was conducted in the Eastern Canal on September 25, 2019. Sheets 8, 11, 12, and 16 present mapped vegetation types within the Eastern Canal (Appendix G). Additional canal-specific information describing vegetation and shoreline/canal features is provided in Appendix H.

The Eastern Canal study area represents 4.03 acres (approximately 9%) of the total study area (Table 5-2, Appendix G). Three (3) VPs were mapped in the Eastern Canal, representing approximately 13 percent of total mapped VPs in the total study area. At the time of the study, mapped VPs in the Eastern Canal had a dominant vegetation type of Scrub-Shrub (100% of the total). The dominant shoreline type of mapped VPs within the Eastern Canal is either Block Wall (approximately 33.3% of the total) or Block Wall/Concrete/Stone Wall Mix (approximately 66.7% of the total) (Appendix G, Appendix H, and Appendix I).

Fifteen (15) Vegetation Polygons were mapped in the Eastern Canal, representing approximately 16 percent of total mapped Vegetation Polygons in the total study area (Appendix G, Appendix H, and Appendix I). Vegetation was mapped on 0.93 acres of the Eastern Canal walls, representing approximately 19 percent of the total mapped vegetation area within the total study area and approximately 23 percent of the Eastern Canal study area. At the time of the study, the majority of mapped Vegetation Polygons in the Eastern Canal had a dominant vegetation type of Mixed (approximately 62% of the total). The dominant shoreline type of mapped Vegetation Polygons within the Eastern Canal is either Block Wall (approximately 80% of the total) or Block Wall/Concrete/Stone Wall Mix (approximately 20%) (Appendix G, Appendix H, and Appendix I).

Mapped Vegetation Polygons within the Eastern Canal with a dominant shoreline type of Block Wall had a dominant vegetation type of Mixed (0.43 acres; approximately 58% of the total) at the time of the study. Scrub-Shrub (0.17 acres; approximately 23% of the total) and Herbaceous (0.12 acres; approximately 16% of the total) were present in lesser amounts, with Trees (0.02 acres; approximately 3% of the total) being minimal at the time of the study. Mapped Vegetation Polygons within the Eastern Canal with a dominant shoreline type of Block Wall/Concrete/Stone Wall Mix had a dominant vegetation type of Mixed (0.15 acres; approximately 79% of the total) or Trees (0.04 acres; approximately 21% of the total) at the time of the study (Appendix G, Appendix H, and Appendix I).

At the time of the study, no mapped VPs or Vegetation Polygons within the Eastern Canal had a dominant vegetation type of Forested. No mapped VPs or Vegetation Polygons within the Eastern Canal have dominant shoreline types of Concrete, Earthen/Terrestrial Cultural, or Stone Wall. (Appendix G, Appendix H, and Appendix I).

5.5.2 Hamilton Canal

The vegetation mapping and characterization effort was conducted in the Hamilton Canal on September 25, 2019. Sheets 19 and 20 present mapped vegetation types within the Hamilton Canal (Appendix G). Additional canal specific information describing vegetation and shoreline/canal features is provided in Appendices H and I.

The Hamilton Canal study area represents 2.01 acres (approximately 5%) of the total study area (Table 5-2). One (1) VP was mapped in the Hamilton Canal, representing approximately 4 percent of total mapped VPs in the total study area. At the time of the study, the mapped VP in the Hamilton Canal had a dominant vegetation type of Herbaceous (100% of the total). The dominant shoreline type of the mapped VP within the Hamilton Canal is Block Wall/Concrete/Stone Wall Mix (100% of the total) (Appendix G, Appendix H, and Appendix I).

Seven (7) Vegetation Polygons were mapped in the Hamilton Canal, representing approximately 7 percent of total mapped Vegetation Polygons in the total study area. Vegetation was mapped on 0.35 acres of the Hamilton Canal walls, representing approximately 7 percent of the total mapped vegetation area within the total study area and approximately 17 percent of the Hamilton Canal study area. At the time of the study, the majority of mapped Vegetation Polygons in the Hamilton Canal had a dominant vegetation type of Mixed (approximately 74% of the total). The majority of mapped Vegetation Polygons in the Hamilton Canal have a dominant shoreline type of Block Wall/Concrete/Stone Wall Mix (approximately 83% of the total) (Appendix G, Appendix H, and Appendix I).

Mapped Vegetation Polygons within the Hamilton Canal with a dominant shoreline type of Block Wall/Concrete/Stone Wall Mix had a dominant vegetation type of Mixed (0.26 acres; approximately 90% of the total), Herbaceous (0.02 acres; approximately 7% of the total), or Trees (0.01 acres; approximately 3% of the total) at the time of the study. Mapped Vegetation Polygons within the Hamilton Canal that had a dominant shoreline type of Block Wall had a dominant vegetation type of Trees (0.03 acres; 50% of the total) or Scrub-Shrub (0.03 acres; 50% of the total) at the time of the study. (Appendix G, Appendix H, and Appendix I)

At the time of the study, no mapped VPs or Vegetation Polygons within the Hamilton Canal had a dominant vegetation type of Forested. No mapped VPs or Vegetation Polygons within the Hamilton Canal have a dominant shoreline type of Concrete, Earthen/Terrestrial Cultural, or Stone Wall (Appendix G, Appendix H, and Appendix I).

5.5.3 Merrimack Canal

The vegetation mapping and characterization effort was conducted in the Merrimack Canal on September 25, 2019. Sheets 11 and 15 present mapped vegetation types within the Merrimack Canal (Appendix G).

The Merrimack Canal study area represents 1.4 acres (approximately 3%) of the total study area (Table 5-2). No VPs were mapped in the Merrimack Canal at the time of the study (Appendix G, Appendix H, and Appendix I).

Nine (9) Vegetation Polygons were mapped in the Merrimack Canal, representing approximately 9 percent of total mapped Vegetation Polygons in the total study area. Vegetation was mapped on 0.38 acres of the Merrimack Canal walls, representing approximately 8 percent of the total mapped vegetation area within the total study area and approximately 27 percent of the Hamilton Canal study area. At the time of the study, the majority of mapped Vegetation Polygons in the Merrimack Canal had a dominant vegetation type of Herbaceous (approximately 53% of the total). The majority of mapped Vegetation Polygons in the Merrimack Canal have a dominant shoreline type of Block Wall/Concrete/Stone Wall Mix (approximately 54% of the total), followed closely by Block Wall (approximately 46% of the total) (Appendix G, Appendix H, and Appendix I).

Mapped Vegetation Polygons within the Merrimack Canal with a dominant shoreline type of Block Wall/Concrete/Stone Wall Mix had a dominant vegetation type of Herbaceous (0.15 acres; approximately 75% of the total) or Scrub-Shrub (0.05 acres, approximately 25% of the total) at the time of the study. Mapped Vegetation Polygons within the Merrimack Canal with a dominant shoreline type of Block Wall had a dominant vegetation type of Mixed (0.12 acres; 71% of the total) or Herbaceous (0.05 acres; 29% of the total), at the time of the study. Trees represented less than 1 percent (0.003 acres) of the total mapped vegetation area within the Merrimack Canal study area and were the dominant vegetation type of mapped Vegetation Polygons that have a dominant shoreline type of Concrete. (Appendix G, Appendix H, and Appendix I)

At the time of the study, no mapped Vegetation Polygons within the Merrimack Canal had a dominant vegetation type of Forested. No mapped Vegetation Polygons within the Merrimack Canal have a dominant shoreline type of Earthen/Terrestrial Cultural or Stone Wall (Appendix G, Appendix H, and Appendix I).

5.5.4 Northern Canal

The vegetation mapping and characterization effort was conducted in the Northern Canal on September 26 and 27, 2019. Sheets 2, 3, 5, and 6 present mapped vegetation types within the Northern Canal (Appendix G).

As previously described, the Northern Canal study area represents 11.67 acres (approximately 26%) of the total study (Table 5-2). Eight (8) VPs were mapped in the Northern Canal, representing approximately 33 percent of total mapped VPs in the total study area. At the time of the study, the dominant vegetation type of mapped VPs in the Northern Canal was either Trees (50% of the total) or Scrub-Shrub (50% of the total). The dominant shoreline type of all mapped VPs within the Northern Canal is Block Wall (100% of the total) (Appendix G, Appendix H, and Appendix I)

Thirteen (13) Vegetation Polygons were mapped in the Northern Canal, representing approximately 14 percent of total mapped Vegetation Polygons in the total study area. Vegetation was mapped on 0.89 acres of the Northern Canal walls, representing approximately 19 percent of the total mapped vegetation area within the total study area and approximately 8 percent of the Northern Canal study area. At the time of the study, the majority of mapped Vegetation Polygons in the Northern Canal had a dominant vegetation type of Mixed (approximately 32% of the total), followed closely by Forested and Herbaceous (each representing 28% of the total). The majority of mapped Vegetation Polygons in the Northern Canal have a dominant shoreline type of Block Wall (approximately 53% of the total) (Appendix G, Appendix H, and Appendix I).

Mapped Vegetation Polygons within the Northern Canal with a dominant shoreline type of Block Wall had a dominant vegetation type of Forested (0.19 acres; approximately 40% of the total), Mixed (0.16 acres; approximately 34% of the total); Scrub-Shrub (0.08 acres; approximately 17% of the total), Trees (0.03 acres; approximately 6% of the total); or Herbaceous (0.01 acres; approximately 2% of the total) at the time of the study. Mapped Vegetation Polygons within the Northern Canal with a dominant shoreline type of Bock Wall/Concrete/Stone Wall Mix had a dominant vegetation type of Forested (0.05 acres; 17% of the total) or Herbaceous (0.24 acres; 83% of the total) at the time of the study. Mapped Vegetation Polygons within the Northern Canal with a dominant shoreline type of Earthen/Terrestrial Cultural had a dominant vegetation type of Mixed (0.13 acres; 100% of the total) at the time of the study. (Appendix G, Appendix H, and Appendix I)

At the time of the study, the Northern Canal is the only canal with Forested vegetation observed on the dominant shoreline type of Block Wall. No mapped VPs or Vegetation Polygons within the Northern Canal had a dominant shoreline type of Concrete or Stone Wall (Appendix G).

5.5.5 Pawtucket Canal

The vegetation mapping and characterization effort was conducted on the Pawtucket Canal on September 25 and 26, 2019. An NPS boat was used to collect data in the Pawtucket Canal from the Swamp Locks and Dam to the Merrimack River on September 26, 2019. Additional data was collected for the remainder of the Pawtucket Canal on foot from the shoreline on September 25 and 26, 2019. Sheets 13 and 15 through 21 present mapped vegetation types within the Pawtucket Canal (Appendix G). Additional canal specific information describing vegetation and shoreline/canal features is provided in Appendix H and Appendix I.

As previously described, the Pawtucket Canal study area represents 19.63 acres (approximately 44%) of the total study area (Table 5-2, Appendix G). Eight (8) VPs were mapped in the Pawtucket Canal, representing approximately 33 percent of total mapped VPs in the total study area (Appendix G). At the time of the study, the majority of mapped VPs within the Pawtucket Canal had a dominant vegetation type of Trees (approximately 63% of the total). The majority of mapped VPs within the Pawtucket Canal have a dominant shoreline type of Block Wall (38% of the total), followed closely by Block

Wall/Concrete/Stone Wall Mix and Stone Wall (each representing 25% of the total) (Appendix G, Appendix H, and Appendix I).

Thirty-two (32) Vegetation Polygons were mapped in the Pawtucket Canal, representing approximately 33 percent of total mapped Vegetation Polygons in the total study area. Vegetation was mapped on 1.33 acres of the Pawtucket Canal walls, representing approximately 28 percent of the total mapped vegetation area within the total study area and approximately 7 percent of the Pawtucket Canal study area. At the time of the study, the majority of mapped Vegetation Polygons in the Pawtucket Canal had a dominant vegetation type of Trees (53% of the total). The majority of mapped Vegetation Polygons in the Pawtucket Canal have a dominant shoreline type of Block Wall (approximately 85% of the total) (Appendix G, Appendix H, and Appendix I).

Mapped Vegetation Polygons within the Pawtucket Canal with a dominant shoreline type of Block Wall had a dominant vegetation type of Trees (0.61 acres; approximately 54% of the total), Mixed (0.42 acres; 37% of the total), Scrub-Shrub (0.08 acres; 8% of the total), or Herbaceous (0.01 acres; 1% of the total) at the time of the study. The majority of mapped Vegetation Polygons within the Pawtucket Canal with a dominant shoreline type of Block Wall/Concrete/Stone Wall Mix had a dominant vegetation type of Scrub-Shrub (0.03 acres; 34% of the total) at the time of the study. Mapped Vegetation Polygons within the Pawtucket Canal with a dominant shoreline type of Concrete had a dominant vegetation type of either Mixed (0.04 acres; 50% of the total) or Trees (0.04 acres; 50% of the total) at the time of the study and mapped Vegetation Polygons within the Pawtucket Canal with a dominant shoreline type of Stone Wall had a dominant vegetation type of Trees (0.03 acres; 100% of the total) at the time of the study. (Appendix G, Appendix H, and Appendix I).

At the time of the study, no mapped VPs or Vegetation Polygons within the Pawtucket Canal had a dominant vegetation type of Forested. No mapped VPs or Vegetation Polygons within the Pawtucket Canal have a dominant shoreline type of Earthen/Terrestrial Cultural. The Pawtucket Canal is the only canal in the total study area that had vegetation mapped on the dominant shoreline type of Stone Wall (Appendix G, Appendix H, and Appendix I).

It should be noted, based on the elevation of the water within the Pawtucket Canal at the time of the investigation, that the majority of the upstream extent of the Pawtucket Canal, upstream of the NPS Guard Lock and Gates Facility, is dominated by typical forested/riparian vegetation on earthen stream embankments and the canal in this area is assumed to not be bordered by one of the shoreline/canal types described in Table 4-2, therefore, no mapping of dominant vegetation types occurred in this area.

5.5.6 Western Canal

The vegetation mapping and characterization effort was conducted in the Western Canal on September 25 and 26, 2019. Mapbook sheets 6, 7, 10, 14, and 19 present mapped vegetation types within the Western Canal (Appendix G). Additional canal specific information describing vegetation and shoreline/canal features is provided in Appendix H and Appendix I.

As previously described, the Western Canal study area represents 5.51 acres (13%) of the total study area (Table 5-2, Appendix G). Four (4) VPs were mapped in the Western Canal, representing approximately 17 percent of total mapped VPs in the total study area. At the time of the study, the majority of mapped VPs in the Western Canal had a dominant vegetation type of Scrub-Shrub (approximately 50% of the total). Mapped VPs in the Western Canal have a dominant shoreline type of either Block Wall (75% of the total) or Block Wall/Concrete/Stone Wall Mix (Appendix G, Appendix H, and Appendix I).

Twenty (20) Vegetation Polygons were mapped in the Western Canal, representing approximately 21 percent of total mapped Vegetation Polygons in the total study area. Vegetation was mapped on 0.9 acres of the Western Canal walls, representing approximately 19 percent of the total mapped vegetation area within the total study area and approximately 16 percent of the Western Canal study area. At the time of the study, the majority of mapped Vegetation Polygons in the Western Canal had a dominant vegetation type of Forested (approximately 53% of the total). The majority of mapped Vegetation Polygons in the Western Canal have a dominant shoreline type of Block Wall/Concrete/Stone Wall Mix (approximately 77% of the total) (Appendix G, Appendix H, and Appendix I).

Mapped Vegetation Polygons within the Western Canal with a dominant shoreline type of Block Wall/Concrete/Stone Wall Mix had a dominant vegetation type of Forested (0.48 acres; 62% of the total), Mixed (0.16 acres; approximately 21% of the total), or Herbaceous (0.05 acres; 6% of the total) at the time of the study. Mapped Vegetation Polygons within the Western Canal with a dominant shoreline type of Block Wall had a dominant vegetation type of Mixed (0.01 acres; 8% of the total); Herbaceous (0.09 acres; 75% of the total); or Scrub-Shrub (0.02 acres; 17% of the total) at the time of the study. No mapped Vegetation Polygons within the Western Canal had dominant shoreline type of Concrete, Earthen/Terrestrial Cultural, or Stone Wall (Appendix G, Appendix H, and Appendix I).

5.6 Visual Survey for Waterborne Trash

Pursuant to the RSP, on April 9, 2020, Boott mapped areas within the canal system owned or under the control of Boott where waterborne trash may be a potential concern. The amount and type of waterborne trash that accumulates within the Project Boundary can vary according to several factors including the season, Project operations, the magnitude and duration of the flow events. During the visual survey for waterborne trash, the USGS Gage 01100000 Merrimack River BL Concord River at Lowell, MA, reported a discharge of over approximately 16,000 cubic feet per second (cfs) (USGS 2020), and Boott's operations data reported an inflow of 14,500 cfs.[12]

Accumulated waterborne trash includes material floating on the impoundment surface and/or found on the surface of the canal system. Most of the waterborne trash accumulation within the Lowell Canal system appears to be derived from upstream inputs (the Merrimack River) as well as direct canal inputs (accidental and intentional littering) and from runoff events (also likely from accidental and intentional littering).

In total, eight (8) areas of waterborne trash totaling 0.21 acres (representing 0.48% of the total study area) were mapped on April 9, 2020 (Appendix K) as well as three additional areas of accumulated trash on the canal bed and a single area with a waterborne sheen. The total study area encompassed approximately 44 acres and as shown in Table 5-3 all mapped areas within the canal were 3.531 acres or approximately 154,000 square feet.

Maps showing the results of the waterborne trash assessment and mapping within the study area are illustrated by a map set with numbered polygons (e.g., WBT-1, WBT-2) for each mapped waterborne trash polygon (Appendix K). Results from the waterborne trash mapping are compiled in Appendix K and field reconnaissance data is summarized in Table 5-3 and Photo 5-2 through Photo 5-11.

Table 5-3. Percent total acreage of waterborne trash mapped within the Lowell canal system.

Mapped Polygon Identifier	Location	Mapped Area (acres)	Mapped Area (sq. ft.)	Canal Water Level	Potential Local Cause
WBT-1	Merrimack River at Fishway Exit	0.007	286.0	High	Eddy Area at head of fishway
WBT-2	Merrimack River Upstream of Pawtucket Gatehouse	0.063	2,765.0	High	Gatehouse
WBT-3	Western Canal at Merrimack Street	0.011	488.0	Normal	Iron support beams for bridge
WBT-4	Western Canal at Moody Street	0.038	1,674.0	Normal	Gate
WBT-5	Northern Canal and Western Canal Junction	0.013	545.0	Normal	Fremont Gatehouse, structure creating eddy
WBT-6	Merrimack Canal at Market Street	0.024	1,045.0	Normal	Gates

[12] Inflow to the project is typically estimated as flow reported at USGS Gage 01100000 Merrimack River BL Concord River at Lowell, MA minus the flow reported at USGS 01099500 Concord River Below Meadow Brook, at Lowell, MA.

Mapped Polygon Identifier	Location	Mapped Area (acres)	Mapped Area (sq. ft.)	Canal Water Level	Potential Local Cause
WBT-7	Pawtucket Canal at Guard Locks	0.049	2,120.0	Normal	Gatehouse
WBT-8	Hamilton Canal adjacent to Hamilton Mills	0.004	182.0	Normal	End of Canal (Intake)
CBT-1	Pawtucket Canal from Industrial Canyon to Kerouac Park	1.833	79,832.0	Low	Canal dewatered
CBT-2	Pawtucket Canal adjacent to Appleton Mills	0.537	23,411.0	Low	Canal dewatered
CBT-3	Eastern Canal adjacent to Tsongas and Boarding House Park	0.468	20,395.0	Low	Canal dewatered
WBS-1	Merrimack Canal adjacent to Visitor Center	0.484	21,066.0	Normal	Unknown sheen
	Total	**3.531**	**153,809.0**	**-**	**-**

Pursuant to the approved study plan, waterborne trash assessments were completed in the Pawtucket Canal, Northern Canal, Western Canal, Merrimack Canal, Eastern Canal, Hamilton Canal, and in the Merrimack River upstream of the dam and Northern Canal intake. Field inventory documentation, including a map identifying each polygon and a description of the type of waterborne trash observed at each polygon is presented in Appendix K to this study report.

Boott surveyed the Lowell canal system on foot and by vehicle to visually inspect and document waterborne trash within the study area. Observations were recorded regarding evidence and location of waterborne trash. Data collected during this portion of the survey included field notes, digitized locations of waterborne trash, and photographic documentation.

In addition to mapping waterborne trash, during incidental observations for other field efforts, Boott observed aged substrate trash accumulation in the bottom of the Eastern Canal and portions of the Pawtucket Canal during dewatered for various construction and maintenance activities not associated with hydroelectric operations. This aged substrate trash is further described in Section 5.6.9 below and is also depicted on the map of the study area in Appendix K.

Boott also observed a surface sheen on the Merrimack Canal on April 9, 2020. This sheen is further described in Section 5.6.10 below and is also depicted on the map of the study area in Appendix K.

5.6.1 Merrimack River at the Fishway Exit

Waterborne trash observed on the Merrimack River fishway exit (WBT-1) encompassed a water surface area of approximately 0.007 acres (Table 5-3). This trash appears to accumulate in an eddy type feature and above the intake water for the fishway. Waterborne trash consisted of buoys, plastics, shoes, rubber mats, foam, and bait containers (No photo available).

5.6.2 Merrimack River Upstream of the Pawtucket Gatehouse

Waterborne trash observed on the Merrimack River upstream of the Pawtucket Gatehouse (WBT-2) encompassed a water surface area of approximately 0.063 acres (Table 5-3). This trash appears to accumulate in an eddy type feature and above the gatehouse intakes. Waterborne trash consisted of logs, boards, organic debris, plastic cups, plates, shoes, water bottles, buoys, plastics, foam, and bait containers (Photo 5-1).

Photo 5-1. Waterborne trash on the Merrimack River upstream of the Northern Canal Gate entrance.

5.6.3 Western Canal at Merrimack Street

Waterborne trash observed on the Western Canal at Merrimack Street (WBT-3) encompassed a water surface area of approximately 0.011 acres (Table 5-3). This trash appears to be behind steel beams across the canal, potentially for structural support of the road bridge for Merrimack Street. Waterborne trash consisted of foam plates, plastic cups, rubber balls plastic jugs, plastic wrappers and bags (Photo 5-2).

Photo 5-2. Waterborne trash on the Western Canal at Merrimack Street.

5.6.4 Western Canal at Moody Street

Waterborne trash observed on the Western Canal at Moody Street (WBT-4) encompassed a water surface area of approximately 0.038 acres (Table 5-3). This trash appears to accumulate behind an operable gate structure. Waterborne trash consisted of tires, umbrellas, foam plates, plastic cups, plastic bottles, rubber balls, plastic jugs, plastic wrappers, foam boards and bags (Photo 5-3).

Photo 5-3. Waterborne trash on the Western Canal at Moody Street.

5.6.5 Northern Canal and Western Canal Junction at the Tremont Gatehouse and Powerhouse

Waterborne trash observed on the Northern Canal and Western Canal junction at the Tremont Gatehouse and Powerhouse (WBT-5) encompassed a water surface area of approximately 0.013 acres (Table 5-3). This trash appears to accumulate in an eddy within a large indent within the canal wall structure located just upstream of the Fremont Gatehouse. Waterborne trash consisted of foam board pieces, plastic cups, foam plates, foam bait containers, shoes, plastic bottles, and organic debris (Photo 5-4).

Photo 5-4. Waterborne trash on the Western Canal at the Northern Canal Junction.

5.6.6 Merrimack Canal at Market Street

Waterborne trash observed on the Merrimack Canal at Market Street (WBT-6) encompassed a water surface area of approximately 0.024 acres (Table 5-3). This trash appears to accumulate behind the operational gates at this location. Waterborne trash consisted of plastic bottles, foam containers, foam cups, plastic bags, rubber balls, diapers, glass bottles, wood, plastic wrappers, soft drink cans, and organic debris (Photo 5-5).

Photo 5-5. Waterborne trash on the Merrimack Canal at Market Street.

5.6.7 Pawtucket Canal at the Guard Lock and Gate Facility

Waterborne trash observed on the Pawtucket Canal at the Guard Lock and Gate Facility (WBT-7) encompassed a water surface area of approximately 0.049 acres (Table 5-3). This trash appears to accumulate upstream of the Guard Lock water release structure on river left. Waterborne trash consisted of paper, foam boards, all types of balls (rubber, plastic, baseball, soccer, etc.), organic matter, logs, tires, construction barrels, plastic bottles, cans, foam containers (Photo 5-6).

5.6.8 Hamilton Canal Adjacent to Hamilton Mills

Waterborne trash observed at the end of Hamilton Canal at the intake (WBT-8) encompassed a water surface area of approximately 0.004 acres (Table 5-3). This trash appears to accumulate at the intake (No photo available).

Photo 5-6. Waterborne trash on the Pawtucket Canal at Guard Lock and Gate Facility.

5.6.9 Observations of Aged Substrate Trash Accumulation on the bottom of the Eastern Canal and Portions of the Bottom of the Pawtucket Canal

Observations of substrate trash accumulation on the bottom of the Eastern Canal and portions of the Pawtucket Canal occurred during a dewatering event associated with non-Project construction and maintenance activities. This substrate accumulation encompassed an area of approximately 0.468 acres (Table 5-3) in the Eastern Canal, approximately 1.833 acres in the Pawtucket Canal near “Industrial Canyon”, and 0.537 acres in the Pawtucket Canal immediately downstream of the Swamp Locks. The substrate trash in the Eastern Canal consist largely of iron, traffic cones, cans, and woody debris. In the Pawtucket Canal near Industrial Canyon, the substrate trash consists mostly of wood, iron, and plastic trash. The Pawtucket Canal downstream of Swamp Locks consists mostly of metal and some minimal floating plastic bottles (Photo 5-7 through Photo 5-10).

Photo 5-7. Substrate trash on bottom of Eastern Canal across from Boarding House Park.

Photo 5-8. Substrate trash on bottom of Eastern Canal across from Boott Cotton Mills Museum and Tsongas Industrial History Center.

Photo 5-9. Substrate debris at the bottom of Pawtucket Canal adjacent to Appleton Mills and downstream of Swamp Locks.

Photo 5-10. Waterborne trash immediately downstream of Swamp Locks.

5.6.10 Observations of Surface Sheen

Boott also observed a surface sheen on the Merrimack Canal on April 9, 2020. The location of the source of this sheen was undetermined but appear to begin at or upstream of the Swamp Locks (Photo 5-11).

Photo 5-11. Surface sheen observed on April 9, 2020 on Merrimack Canal adjacent to the Visitor Center and downstream of the Swamp Locks.

6 Summary and Discussion

6.1 Field Inventory and Visitor Use Data

The results from the field inventory and the visitor use data (personal interviews, field reconnaissance, and online surveys) are consistent with the literature review. The field inventory identified extensive recreational facilities in the Project area, with the available amenities reported in good condition. Of the fifty-three (53) personal interviews and ninety-six (96) online recreation surveys completed, the respondents are typically regular visitors who visit three or more times per year. Respondents travelled an average of 7.3 miles (personal interviews) and 11 miles (online survey respondents) to the Project area. The most reported recreational activities are light activities such as walking, dog walking, and jogging, with most respondents rating their overall experience of recreational activities at the Project as “acceptable” or “totally acceptable.” The most frequently visited recreational facilities in the Project area were the Lowell Heritage State Park, the Rourke Brothers Boat Ramp, Chelmsford Boat Access, Merrimack Trail System, and LNHP-related facilities. Respondents both in-person and online tended to rate their overall experience at these specific recreation facilities as “acceptable” or “totally acceptable.”

6.2 Visual Survey for Vegetation Growth

A wide variety of vegetation types, occurrences, and distribution, ranging from herbaceous, non-woody plants to forested areas of trees and underbrush, and shoreline/canal types, ranging from earthen embankments to placed, uniformly sized blocks, were observed during the canal wall vegetation surveys. The following summary statements are based on an analysis of survey results (Appendix G-Appendix I):

- Mapped vegetation[13] was greatest in the Pawtucket Canal (1.33 acres; approximately 28% of the total study area), followed by the Eastern Canal (0.93 acres), Western Canal (0.90 acres), and Northern Canal (0.89 acres) (each representing approximately 19% of the total study area).
- At the time of the study, most mapped VPs within the total study area had a dominant vegetation type of Scrub-Shrub (46% of the total VP count), followed closely by Trees (38% of the total VP count). The majority of mapped Vegetation Polygons within the total study area had a dominant vegetation type of Mixed (41% of the total mapped vegetation area) at the time of the study.
- Within the total study area, most mapped VPs had a dominant shoreline type of Block Wall (63% of the total VP count). The majority of mapped Vegetation Polygons within the total study area also had a dominant shoreline type of Block Wall (58% of the total mapped vegetation area).
- Mapped Vegetation Polygons with a dominant vegetation type of Forested were only recorded within the Western Canal (53% of the Western Canal study area), and the Northern Canal (28% of the Northern Canal study area) at the time of the study. Forested vegetation was recorded on Block Wall (0.19 acres; approximately 4% of total mapped vegetation area) and Block/Wall/Concrete Stone Wall Mix (0.53 acres; approximately 11% of the total mapped vegetation area) at the time of the study.

6.3 Visual Survey for Waterborne Trash

The surveys for waterborne trash have shown that waterborne trash accumulates within the Project's canal system, and these accumulations are somewhat dependent on the level of the water within the canals as well as the required operation of some of the NPS gates within the study area. For example, NPS gates that are operated on a routine basis had minimal signs of waterborne trash associated with them, while others that are largely in the closed position tended to have accumulations of waterborne trash behind them at varying densities.

The combination of past and present land use activities in and around the Project area have contributed and will likely continue to contribute to the accumulation of waterborne trash within the Project's canal system that occur in the study area today (e.g.,

[13] VPs are not included in mapped vegetation acreage calculations because they represent a single point(s) on a canal wall.

industrialization, commercial development, residential areas in close proximity to canals, etc.). However, the complexity and diversity of historical and current land use activities in the study area create a problem for tracing and identifying the sources of waterborne trash and its movement and distribution within the study area. Waterborne trash consisted of common materials such as foam board pieces, plastic cups, foam plates, foam bait containers, shoes, plastic bottles, and organic debris.

It is well known that many types of land uses contribute to the accumulations of waterborne trash including stormwater drainage systems, upstream sources, inappropriately discarded trash, natural events (woody debris), densely populated areas, etc. Roads, construction, recreation, residential developments, and commercial and industrial developments all can contribute to the problem. Ongoing Project operation and maintenance has very little potential to cause and/or significantly contribute to the waterborne trash accumulation areas observed during the study.

7 Variances from FERC-Approved Study Plan

The Recreation and Aesthetics Study was conducted in full accordance with the methods described in the FERC-approved study plan except for the following variances:

- When conducting personal interviews at the recreation facilities identified in consultation with stakeholders, field technicians generally attempted to visit each of the selected recreation facilities during every survey event. In some instances, field technicians encountered conditions at recreation facilities that presented safety risks. In such instances, field technicians avoided those facilities during the survey event and documented the unsafe conditions encountered that prevented personal interviews from occurring.
- When conducting canal wall vegetation surveys within/along the six canals identified, field technicians generally attempted to survey the entirety of the canal study area. In some instances, field technicians encountered conditions within/along the canals that restricted access for surveying. In such instances, field technicians advanced within/along the canal wall to the extent practicable and assessed vegetation from a distance collecting photo documentation.
- During the evaluation of expanded recreational access to the canal system, Boott did not generate cost estimates to develop recreational access to the Lowell canal system, as proposed in the RSP. Boott did not develop these cost estimates because Boott does not have any rights to develop recreational access to the Lowell canal system.

8 Germane Consultation and Correspondence

A summary of germane correspondence and consultation related to the Recreation and Aesthetics Study is presented in Table 8-1. Appendix L provides copies of relevant correspondence.

Table 8-1. Germane Consultation and Correspondence

Date	Type	From	To	Subject
May 7, 2019	Email/Letter	HDR and Boott	NPS, American Whitewater, and MADCR	Consultation on locations for visitor-intercept/personal interview locations
May 17, 2019	Letter	American Whitewater	HDR and Boott	Consultation on locations for visitor-intercept/personal interview locations
June 3, 2019	Email	HDR	NPS	Schedule regarding trash mapping activities for the Lowell Recreation and Aesthetics Study
June 4, 2019	Email	NPS	HDR	Schedule regarding trash mapping activities for the Lowell Recreation and Aesthetics Study
June 12, 2019	Email	NPS	HDR	Schedule regarding trash mapping activities for the Lowell Recreation and Aesthetics Study
June 12, 2019	Email	HDR	NPS	Schedule regarding trash mapping activities for the Lowell Recreation and Aesthetics Study
June 14, 2019	Email	HDR	NPS	Schedule regarding trash mapping activities for the Lowell Recreation and Aesthetics Study
July 2, 2020	Email	HDR	NPS	Lowell Recreation and Aesthetics Study
July 3, 2020	Email	NPS	HDR	Lowell Recreation and Aesthetics Study
October 1, 2019 (Accession Number 20191001-5038)	Letter	NPS	FERC, Boott, HDR	Comments on Study Process and the Recreation and Aesthetics Study
November 1, 2019	Email	HDR and Boott	NPS, MADCR, City of Lowell, Lowell Parks and Conservation Trust	Study Workshop Planning
November 1, 2019	Email	NPS	HDR	Study Workshop Planning
November 4, 2019	Email	City of Lowell	HDR	Study Workshop Planning
November 8, 2019	Email	HDR and Boott	NPS, MADCR, City of Lowell, Lowell Parks and Conservation Trust	Study Workshop Planning

Date	Type	From	To	Subject
December 9, 2019	Email	HDR and Boott	NPS, MADCR, City of Lowell, Lowell Parks and Conservation Trust	Study Workshop Planning
December 19, 2019	Email	NPS	HDR	Vegetation Mapping Consultation
December 20, 2019	Email	MADCR	HDR	Lowell Recreation and Aesthetics Study
December 20, 2019	Email	HDR	MADCR	Lowell Recreation and Aesthetics Study
March 13, 2020	Email	HDR	NPS	Schedule regarding trash mapping activities for the Lowell Recreation and Aesthetics Study
March 13, 2020	Email	NPS	HDR	Schedule regarding trash mapping activities for the Lowell Recreation and Aesthetics Study
April 10, 2020 (Accession Number 20200410-5033)	Email	NPS	HDR	Comments on the Recreation and Aesthetics Study
April 22, 2020 (Accession Number 20200422-5027)	Letter	American Whitewater	FERC, Boott, HDR	Comments on the Recreation and Aesthetics Study

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Appendix A - Recreation Interview and Survey Forms

Personal Interview Survey Form

ON-SITE/IN-PERSON RECREATION INTERVIEW
Lowell Project (FERC No. 2790)
Recreation Survey

Boott Hydropower, LLC (Boott), a subsidiary of Enel Green Power North America, Inc., owns and operates the Lowell Project, which is licensed by the Federal Energy Regulatory Commission (FERC). The current operating license for the Project was issued on May 1, 1973 and expires on April 30, 2023. Boott will file its application with FERC for a new license for continued project operation no later than April 30, 2021. As part of this relicensing process, Boott is conducting a series of resource studies to enable FERC to prepare its environmental review document and develop a new operating license. The purpose of this survey is to gather information regarding participation in outdoor recreation activities at the Lowell Project.

Interview Location:			
Home Zip Code:	______________________	**Date:**	______________________
Age:	______________________	**Time:**	______________________
River Conditions:			______________________
Are you:	**Male** ☐	**Female** ☐	**Prefer not to answer** ☐
Interviewer:			

Q-1. Regarding the Lowell Project area, do you consider yourself: (**Please circle one)**

1. A regular visitor to this area (*3 or more times per year*)
2. An occasional visitor (*1-2 times per year*)
3. An infrequent visitor (*Less than 1 time per year*)
4. This is my first visit

Q-2. On this trip to the Lowell Project area, when did you arrive?

Arrival Date	**Arrival Time**
_____/_____/_____	____________AM/PM

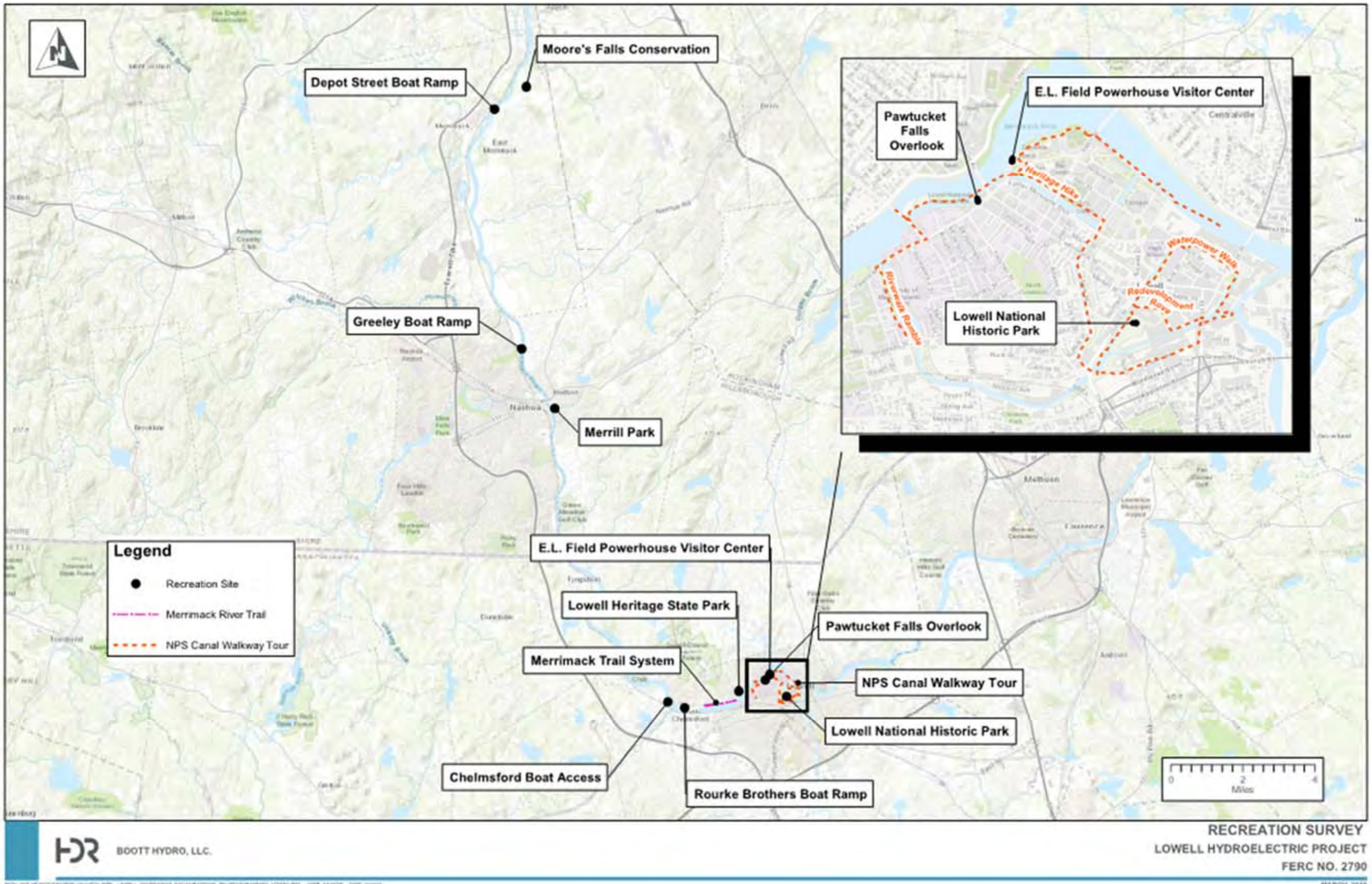
When did you or do you expect to leave the Lowell Project area?

Departure Date	**Departure Time**
_____/_____/_____	____________AM/PM

Q-3. During the last 12 months (including this trip), which month(s) did you visit the Lowell Project area?

A. _________________

Project Area Recreation Map



Q-4. Which of the following recreation areas at or near the Lowell Project did you utilize for recreation during the past 12 months? **(Please circle all that apply)**

1. Lowell Heritage State Park
2. Merrimack River Trail
3. E.L. Field Powerhouse Visitor Center
4. NPS Walkway Tours
5. Riverwalk Ramble
6. Waterpower Walk
7. Heritage Hike
8. Northern Canal Walkway
9. Redevelopment Rove
10. Boat access facilities on the Project impoundment
11. Lowell Heritage State Park – Rourke Brothers Boat Ramp
12. Pawtucket Falls Overlook (Lowell, MA)
13. Chelmsford Boat Access (Chelmsford, MA)
14. Merrill Park (Hudson, NH)
15. Greeley Boat Ramp (Nashua, NH)
16. Depot St. Boat Ramp (Merrimack, NH)
17. Moore's Falls Conservation Area (Litchfield, NH)
18. Informal Shoreline Parking/Access Areas
19. None of the above
20. Other (Please list)

____

____

____

Q-5. On your last trip, about how many miles did you travel to get to the Lowell Project?

A. _________miles

Q-6. Are you staying overnight in the Lowell Project area (not including at your own home) on this trip?

1. Yes 2. No

Q-7. If you answered yes to **Q-6**, at what type of accommodations will you be staying? (**Please circle one)**

1. RV/Auto/Tent Campground
2. Motel/hotel
3. Bed and Breakfast
4. Vacation or rental home
5. Other (Please specify: ____)

Q-8. How many people (including you) are in your group?

A. _____________people

Q-9. Which of the following best describes your group during this trip?

1. Individual
2. Adult group (over 21)
3. Youth group (under 21)
4. Family (with children)
5. Mixed group (groups with children, adults, and/or teens)

Q-10. On this trip to the Lowell Project area, in which of the following activities have you or do you expect to participate? (**Please circle all that apply**)

1. Bank fishing	12. Canoeing	24. RV camping
2. Boat fishing	13. Kayaking	25. Tent camping
3. Guided fishing experience	14. Commercial whitewater boating	26. Photography
4. Walking tour	15. Museum-going	27. Sightseeing
5. Hiking	16. Shopping and/or dining	28. Relaxing
6. Backpacking	17. Swimming	29. Sunbathing
7. Guided canal tours	18. Off-highway vehicle (dirt bike/ATV)	30. Dog walking
8. Historical/heritage site visiting	19. Horseback riding	31. Painting/drawing
9. Running, jogging, and fitness	20. Off-road mountain biking	32. Other (please describe):
10. Rock climbing/bouldering	21. Road cycling	
11. Picnicking	22. Adventure sports	
	23. Geo-caching	

Q-11. Of the activities you circled in **Q-10** above, what is the primary activity that you participated in, or expect to participate in, on this visit? (**Please write in the corresponding number from above**)

A. Primary activity # __________

Q-12. **Please rate the following for the primary activity you chose above:**

	Totally Unacceptable	Unacceptable	Neutral	Acceptable	Totally Acceptable
Challenge	1	2	3	4	5

Safety	1	2	3	4	5
Enjoyment	1	2	3	4	5
River/Canal Flow	1	2	3	4	5
Crowding	1	2	3	4	5
Overall Experience	1	2	3	4	5

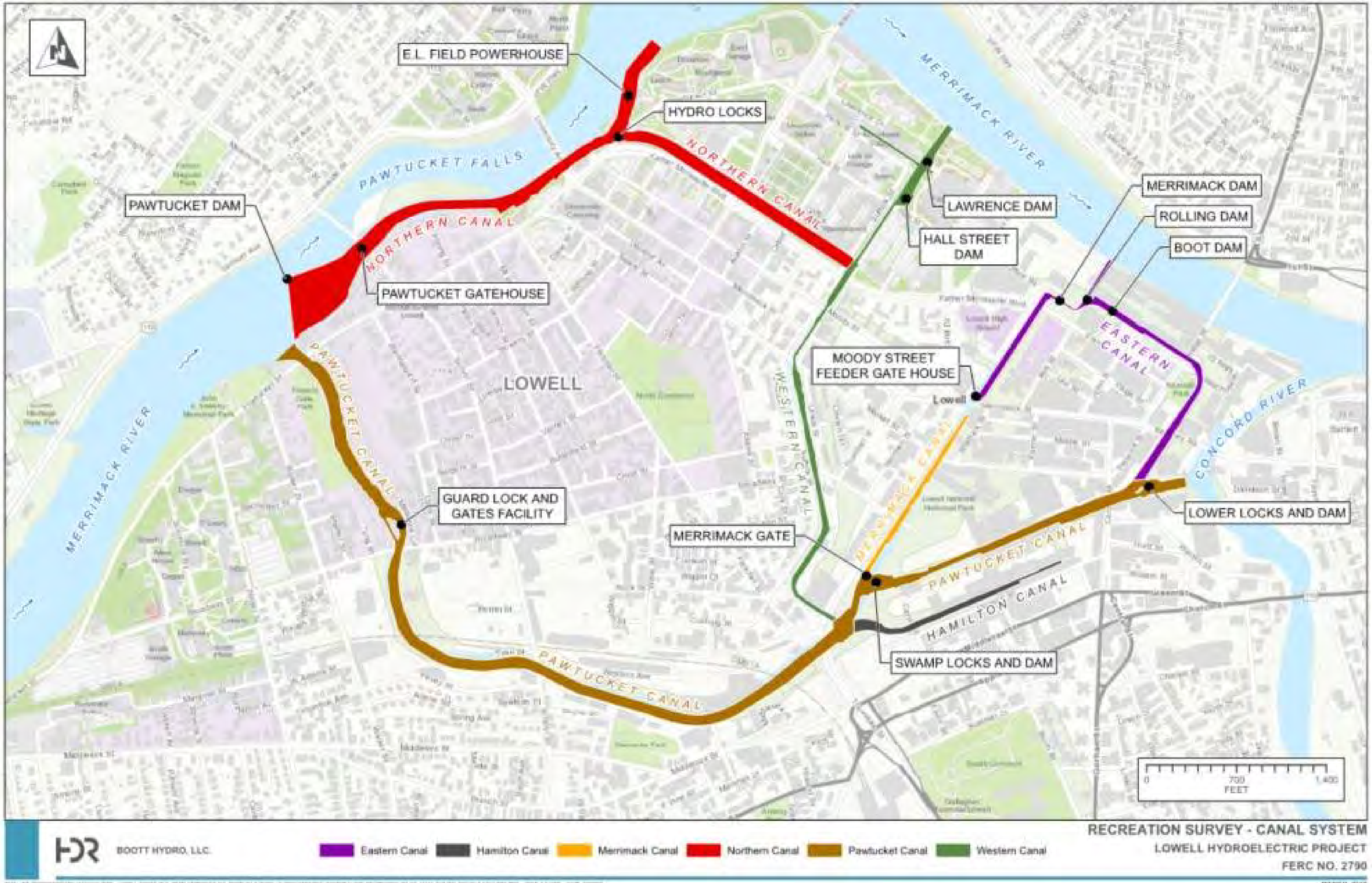
Q-13. Approximately how much money did you or do you intend to spend in preparation for or in association with your recreational trip to the Lowell Project (meals, gas, lodging, equipment, etc.)

A. $____________

Q-14. On previous visits to the Lowell Project, how would you rate the accumulation of waterborne trash in any of the canals shown in the figure below?

	Totally Unacceptable	**Unacceptable**	**Neutral**	**Acceptable**	**Totally Acceptable**
Eastern Canal	1	2	3	4	5
Hamilton Canal	1	2	3	4	5
Merrimack Canal	1	2	3	4	5
Northern Canal	1	2	3	4	5
Pawtucket Canal	1	2	3	4	5
Western Canal	1	2	3	4	5

Lowell Canal System



Q-15. On previous trips to the Project, please rate the following:

	Accessibility	Parking	Crowding	Condition of Recreation Facilities	Available Amenities	River/Canal Flow	Overall Experience
Lowell Heritage State Park							
Merrimack River Trail							
E.L. Field Powerhouse Visitor Center							
NPS Walkway Tours							
Riverwalk Ramble							
Waterpower Walk							
Heritage Hike							
Northern Canal Walkway							
Redevelopment Rove							
Boat access facilities							
Rourke Brothers Boat Ramp							
Pawtucket Falls Overlook							
Chelmsford Boat Access							
Merrill Park							
Greeley Boat Ramp							
Moore's Falls Conservation Area							
Informal Shoreline Parking/Access Areas							

Please use the following numerical scale to rate the formal recreation areas at the Lowell Project:
1) Totally Unacceptable; 2) Unacceptable; 3) Neutral; 4) Acceptable; 5) Totally Acceptable

Q-16. Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project.

1. Type of recreation enhancement:____

   Location(s):____
   ____

2. Type of recreation enhancement:____

   Location(s):____
   ____

3. Type of recreation enhancement:____

   Location(s):____
   ____

Q-17. Please share any other comments that you have regarding recreation at the Lowell Project:____
____
____
____
____
____
____
____
____

Thank you for completing the Recreation Survey!

Online Recreation Survey Form

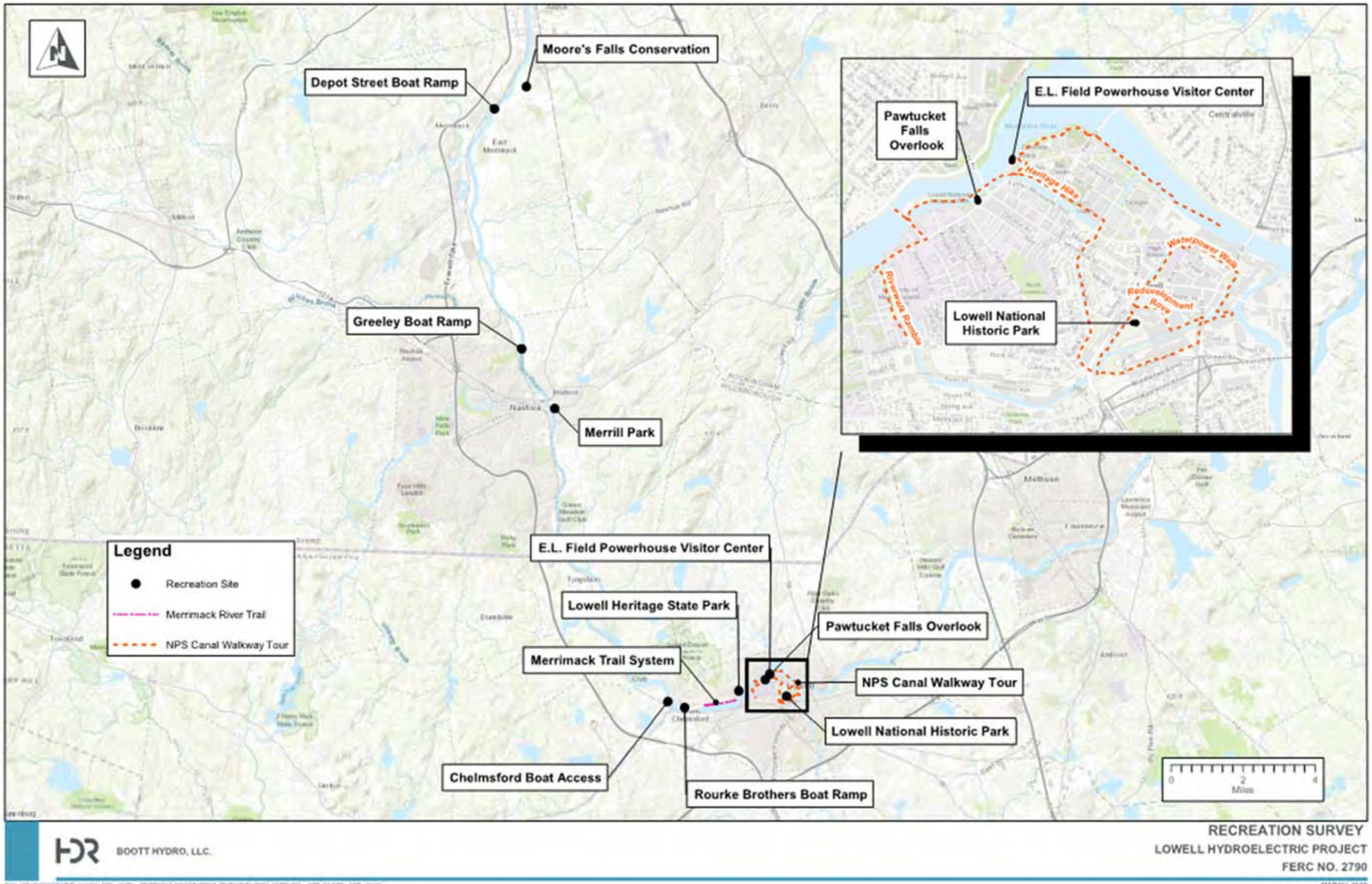
Boott Hydropower, LLC (Boott), a subsidiary of Enel Green Power North America, Inc., owns and operates the Lowell Project, which is licensed by the Federal Energy Regulatory Commission (FERC). The current operating license for the Lowell Project was issued on May 1, 1973 and expires on April 30, 2023. Boott will file its application with FERC for a new license for continued project operation no later than April 30, 2021. As part of this relicensing process, Boott is conducting a series of resource studies to enable FERC to prepare its environmental review document and develop a new operating license.

The purpose of this survey is to gather information regarding participation in outdoor recreation activities at the Lowell Project.

The E.L. Field Powerhouse Visitor Center is the Lowell Project's only formal recreation area. Other, non-Project recreation facilities are also located near the Lowell Project, including the Lowell National Historical Park, Merrimack River Trail, Pawtucket Falls Overlook, boat access facilities on the Lowell Project impoundment, and the Rourke Brothers Boat Ramp. These and other non-Project facilities are not owned or operated by Boott, but are popular Merrimack River recreational areas. In addition, there are numerous informal access areas on Lowell Project lands that are used by the public to access the Merrimack River.

The Lowell Project area relevant to this survey is defined on the map. The information provided in this survey will inform the development of appropriate management measures for recreational resources at the Lowell Project.

Lowell Project Area Recreation Map



Q-1. What is the zip code of your primary residence? _______________

Q-2. What is your age? _______________

Q-3. Are you: Male ☐ Female ☐ Prefer not to answer ☐

Q-4. Regarding the Lowell Project area, do you consider yourself:

5. A regular visitor to this area (*3 or more times per year*)
6. An occasional visitor (*1-2 times per year*)
7. An infrequent visitor (*Less than 1 time per year*)

Q-5. During the last 12 months, which month(s) did you visit the Lowell Project area? *(select all that apply)*?

Jan ☐ Feb ☐ Mar ☐ Apr ☐ May ☐ Jun ☐ Jul ☐ Aug ☐ Sep ☐ Oct ☐ Nov ☐ Dec ☐

I have not visited in the last 12 months ☐

Q-6. Which of the following recreation areas at or near the Lowell Project did you utilize for recreation during the past 12 months? **(Please select all that apply)**

21. Lowell Heritage State Park
22. Merrimack River Trail
23. E.L. Field Powerhouse Visitor Center
24. NPS Walkway Tours
25. Riverwalk Ramble
26. Waterpower Walk
27. Heritage Hike
28. Northern Canal Walkway
29. Redevelopment Rove
30. Boat access facilities on the Lowell Project impoundment
31. Lowell Heritage State Park – Rourke Brothers Boat Ramp
32. Pawtucket Falls Overlook (Lowell, MA)
33. Chelmsford Boat Access (Chelmsford, MA)
34. Merrill Park (Hudson, NH)
35. Greeley Boat Ramp (Nashua, NH)
36. Depot St. Boat Ramp (Merrimack, NH)
37. Moore's Falls Conservation Area (Litchfield, NH)
38. Informal Shoreline Parking/Access Areas
39. None of the above
40. Other (Please list)

____
____
____

Q-7. On your last trip, about how many miles did you travel to get to the Lowell Project?

A. _________miles

Q-8. During the past 12 months, when did you visit the Lowell Project? **(Please select one)**

1. Only on weekdays (Monday – Friday)
2. Only on weekends (Saturday or Sunday) and/or holidays
3. Both weekdays AND weekends and/or holidays

Q-9. On previous visits to the Lowell Project have you stayed overnight (not including your own home)?

2. Yes 2. No

Q-10. At what type of accommodations do you usually stay? (**Please select one)**

6. RV/Auto/Tent Campground
7. Motel/hotel
8. Bed and Breakfast
9. Vacation or Rental Home
10. Other (Please specify: ____)

Q-11. What was the approximate size of your group during your last trip to the Lowell Project area?

A. _____________people

Q-12. Which of the following best describes your group during previous trips to the Lowell Project Area?

6. Individual
7. Adult group (over 21)
8. Youth group (under 21)
9. Family (with children)
10. Mixed group (groups with children, adults, and/or teens)

Q-13. On previous trips to the Lowell Project area, in which of the following activities have you or do you expect to participate? (**Please select all that apply**)

1. Bank fishing	12. Canoeing	24. RV camping
2. Boat fishing	13. Kayaking	25. Tent camping
3. Guided fishing experience	14. Commercial whitewater boating	26. Photography
4. Walking tour	15. Museum-going	27. Sightseeing
5. Hiking	16. Shopping and/or dining	28. Relaxing
6. Backpacking	17. Swimming	29. Sunbathing
7. Guided canal tours	18. Off-highway vehicle (dirt bike/ATV)	30. Dog walking
8. Historical/heritage site visits	19. Horseback riding	31. Painting/drawing
9. Running, jogging, and fitness	20. Off-road mountain biking	32. Other (please describe):

10. Rock climbing/bouldering	21. Road cycling
11. Picnicking	22. Adventure sports
	23. Geo-caching

Q-14. Of the activities you circled in **Q-13** above, what is the primary activity that you participated in during previous visits? (**Please write in the corresponding number from above**)

A. Primary activity # __________

Q-15. **You selected (Primary Activity Number) as the Primary activity in Question 14. Please rate the following:**

	Totally Unacceptable	Unacceptable	Neutral	Acceptable	Totally Acceptable
Challenge	1	2	3	4	5
Safety	1	2	3	4	5
Enjoyment	1	2	3	4	5
River/Canal Flow	1	2	3	4	5
Crowding	1	2	3	4	5
Overall Experience	1	2	3	4	5

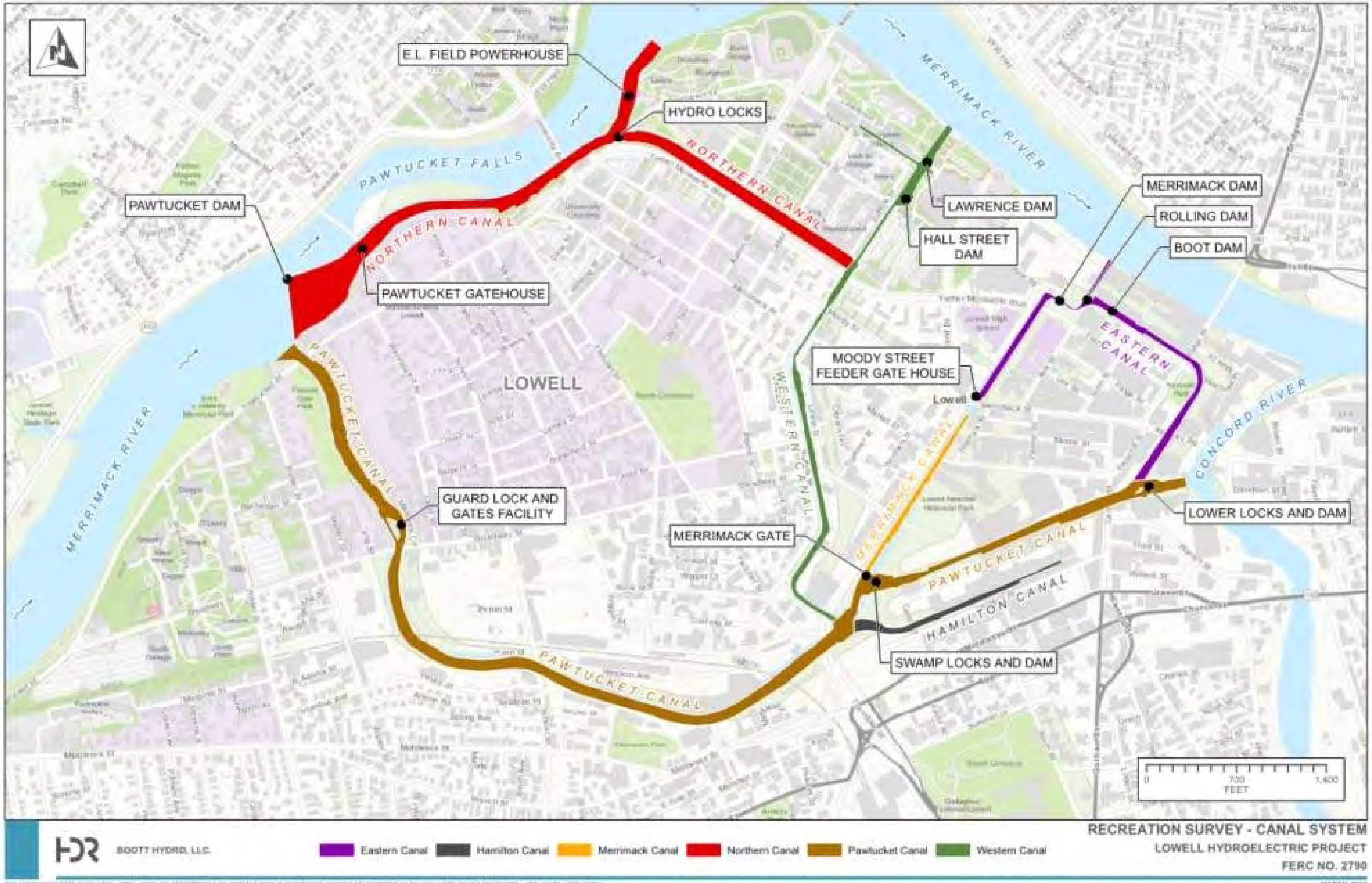
Q-16. Approximately how much money did you spend in preparation for or in association with your last recreational trip to the Lowell Project (meals, gas, lodging, equipment, etc.)?

A. $_____________

Q-17. **On previous visits to the Lowell Project, how would you rate the accumulation of waterborne trash in any of the canals shown in the below figure?**

	Totally Unacceptable	Unacceptable	Neutral	Acceptable	Totally Acceptable
Eastern Canal	1	2	3	4	5
Hamilton Canal	1	2	3	4	5
Merrimack Canal	1	2	3	4	5
Northern Canal	1	2	3	4	5
Pawtucket Canal	1	2	3	4	5
Western Canal	1	2	3	4	5

Lowell Canal System



Q-19. Thinking about your visit to the Lowell Heritage State Park…

(please use the following numerical scale to rate the recreation area)

1.) Totally Unacceptable
2.) Unacceptable
3.) Neutral
4.) Acceptable
5.) Totally Acceptable

Accessibility	
Parking	
Crowding	
Safety	
Condition of Recreation Facilities	
Available Amenities	
River/Canal Flow	
Overall Experience	

Q-20. Thinking about your visit to the Merrimack River Trail….

(please use the following numerical scale to rate the recreation area)

1.) Totally Unacceptable
2.) Unacceptable
3.) Neutral
4.) Acceptable
5.) Totally Acceptable

Accessibility	
Parking	
Crowding	
Safety	
Condition of Recreation Facilities	
Available Amenities	
River/Canal Flow	
Overall Experience	

Q-21. Thinking about your visit to the E.L. Field Powerhouse Visitor Center…

(please use the following numerical scale to rate the recreation area)

1.) Totally Unacceptable
2.) Unacceptable
3.) Neutral
4.) Acceptable
5.) Totally Acceptable

Accessibility	
Parking	
Crowding	
Safety	
Condition of Recreation Facilities	
Available Amenities	
River/Canal Flow	
Overall Experience	

Q-22. Thinking about your visit on the NPS Walkway Tours….

(please use the following numerical scale to rate the recreation area)

1.) Totally Unacceptable
2.) Unacceptable
3.) Neutral
4.) Acceptable
5.) Totally Acceptable

Accessibility	
Parking	
Crowding	
Safety	
Condition of Recreation Facilities	
Available Amenities	
River/Canal Flow	
Overall Experience	

Q-23. Thinking about your visit to the Riverwalk Ramble….

(please use the following numerical scale to rate the recreation area)

1.) Totally Unacceptable
2.) Unacceptable
3.) Neutral
4.) Acceptable
5.) Totally Acceptable

Accessibility	
Parking	
Crowding	
Safety	
Condition of Recreation Facilities	
Available Amenities	
River/Canal Flow	
Overall Experience	

Q-24. Thinking about your visit to the Waterpower Walk….

(please use the following numerical scale to rate the recreation area)

1.) Totally Unacceptable
2.) Unacceptable
3.) Neutral
4.) Acceptable
5.) Totally Acceptable

Accessibility	
Parking	
Crowding	
Safety	
Condition of Recreation Facilities	
Available Amenities	
River/Canal Flow	
Overall Experience	

Q-25. Thinking about your visit to the Heritage Hike….

(please use the following numerical scale to rate the recreation area)

1.) Totally Unacceptable
2.) Unacceptable
3.) Neutral
4.) Acceptable
5.) Totally Acceptable

Accessibility	
Parking	
Crowding	
Safety	
Condition of Recreation Facilities	
Available Amenities	
River/Canal Flow	
Overall Experience	

Q-26. Thinking about your visit to the Northern Canal Walkway….

(please use the following numerical scale to rate the recreation area)

1.) Totally Unacceptable
2.) Unacceptable
3.) Neutral
4.) Acceptable
5.) Totally Acceptable

Accessibility	
Parking	
Crowding	
Safety	
Condition of Recreation Facilities	
Available Amenities	
River/Canal Flow	
Overall Experience	

Q-27. Thinking about your visit to the Redevelopment Rove….

(please use the following numerical scale to rate the recreation area)

1.) Totally Unacceptable
2.) Unacceptable
3.) Neutral
4.) Acceptable
5.) Totally Acceptable

Accessibility	
Parking	
Crowding	
Safety	
Condition of Recreation Facilities	
Available Amenities	
River/Canal Flow	
Overall Experience	

Q-28. Thinking about your visit to boat access facilities on the Lowell Project impoundment…

(please use the following numerical scale to rate the recreation area)

1.) Totally Unacceptable
2.) Unacceptable
3.) Neutral
4.) Acceptable
5.) Totally Acceptable

Accessibility	
Parking	
Crowding	
Safety	
Condition of Recreation Facilities	
Available Amenities	
River/Canal Flow	
Overall Experience	

Q-29. Thinking about your visit to the Rourke Brothers Boat Ramp…

(please use the following numerical scale to rate the recreation area)

1.) Totally Unacceptable
2.) Unacceptable
3.) Neutral
4.) Acceptable
5.) Totally Acceptable

Accessibility	
Parking	
Crowding	
Safety	
Condition of Recreation Facilities	
Available Amenities	
River/Canal Flow	
Overall Experience	

Q-30. Thinking about your visit to the Pawtucket Falls Overlook…

(please use the following numerical scale to rate the recreation area)

1.) Totally Unacceptable
2.) Unacceptable
3.) Neutral
4.) Acceptable
5.) Totally Acceptable

Accessibility	
Parking	
Crowding	
Safety	
Condition of Recreation Facilities	
Available Amenities	
River/Canal Flow	
Overall Experience	

Q-31. Thinking about your visit to the Chelmsford Boat Access…

(please use the following numerical scale to rate the recreation area)

1.) Totally Unacceptable
2.) Unacceptable
3.) Neutral
4.) Acceptable
5.) Totally Acceptable

Accessibility	

Parking	
Crowding	
Safety	
Condition of Recreation Facilities	
Available Amenities	
River/Canal Flow	
Overall Experience	

Q-32. Thinking about your visit to the Merrill Park…

(please use the following numerical scale to rate the recreation area)

1.) Totally Unacceptable
2.) Unacceptable
3.) Neutral
4.) Acceptable
5.) Totally Acceptable

Accessibility	
Parking	
Crowding	
Safety	
Condition of Recreation Facilities	
Available Amenities	
River/Canal Flow	
Overall Experience	

Q-33. Thinking about your visit to the Greeley Boat Ramp…

(please use the following numerical scale to rate the recreation area)

1.) Totally Unacceptable
2.) Unacceptable
3.) Neutral
4.) Acceptable
5.) Totally Acceptable

Accessibility	
Parking	
Crowding	
Safety	
Condition of Recreation Facilities	
Available Amenities	
River/Canal Flow	
Overall Experience	

Q-34. Thinking about your visit to the Depot St. Boat Ramp…

(please use the following numerical scale to rate the recreation area)

1.) Totally Unacceptable
2.) Unacceptable
3.) Neutral
4.) Acceptable
5.) Totally Acceptable

Accessibility	
Parking	
Crowding	
Safety	
Condition of Recreation Facilities	
Available Amenities	
River/Canal Flow	
Overall Experience	

Q-35. Thinking about your visit to the Moore's Falls Conservation Area…

(please use the following numerical scale to rate the recreation area)

1.) Totally Unacceptable
2.) Unacceptable
3.) Neutral
4.) Acceptable
5.) Totally Acceptable

Accessibility	
Parking	
Crowding	
Safety	
Condition of Recreation Facilities	
Available Amenities	
River/Canal Flow	
Overall Experience	

Q-36. Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project.

4. Type of recreation enhancement:____

   Location(s):____

   ____

5. Type of recreation enhancement:____

   Location(s):____

   ____

6. Type of recreation enhancement:____

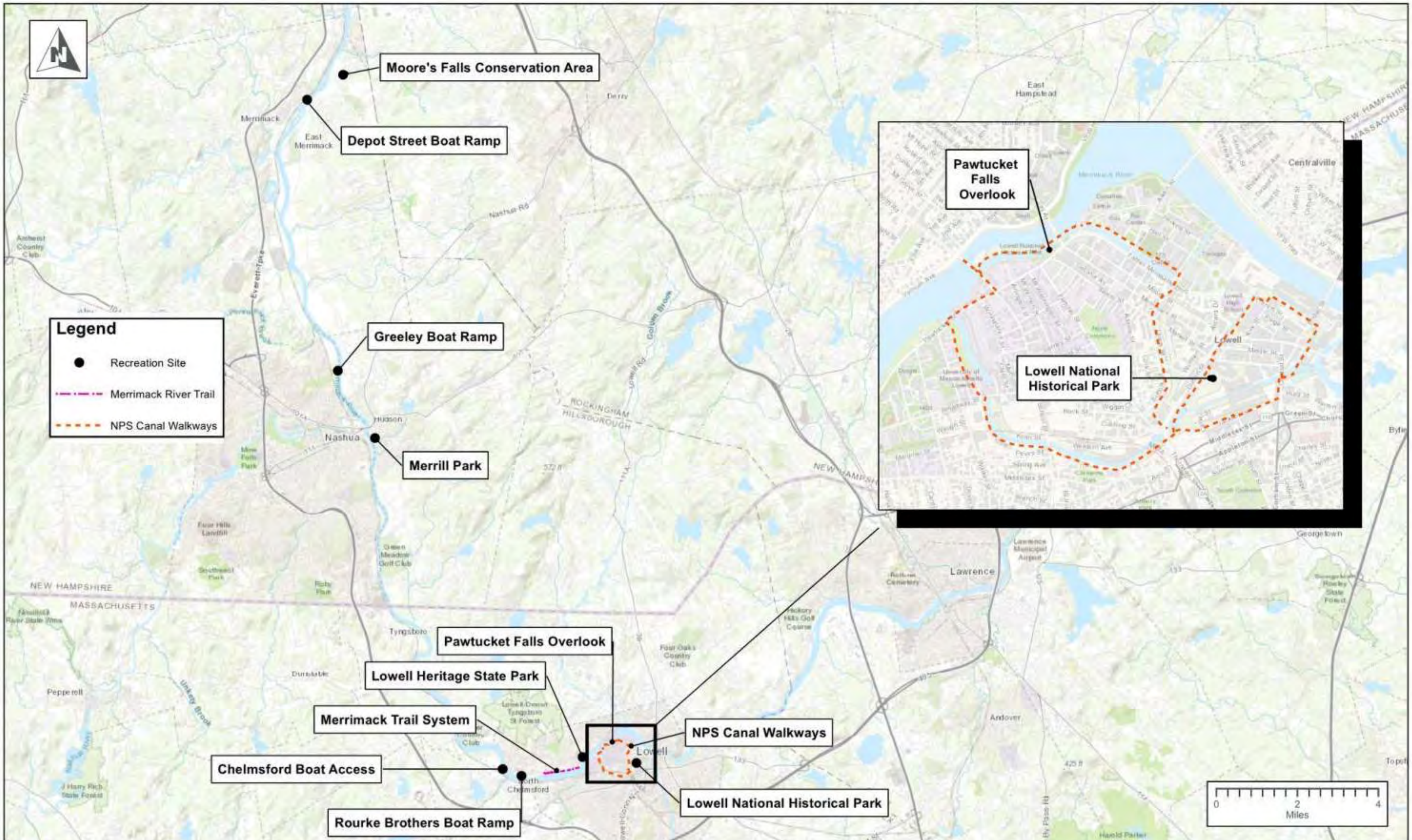
   Location(s):____

Q-37. Please share any other comments that you have regarding recreation at the Lowell Project:
____
____
____

Thank you for completing the Online Recreation Survey!

Appendix B - Recreation Inventory Map and Notes

Map of Recreation Inventory Areas



BOOTT HYDRO, LLC.

RECREATION SURVEY
LOWELL HYDROELECTRIC PROJECT
FERC NO. 2790
APRIL 2020

Recreation Inventory Notes

Chelmsford Boat Access
Recreation Inventory
December 16, 2019

Parking	Signage	Recreation Amenities	Condition of Recreation Amenities	Additional Features
- Parking lot for approximately 50 cars - Parking circle - Boat trailer only parking	- Signage with public launch information - Kiosk with boat access rules and regulations - Blank kiosk	- Boat ramp - River trail - Picnicking tables - Waste receptacles	- Structural damage to boat ramp - Picnic tables noted to need ongoing maintenance - Trash receptacles in good condition	- Baseball/softball fields

Photo 1 – Chelmsford Boat Access Kiosk

Photo 2 – Chelmsford Boat Access Ramp

Depot Street Boat Ramp
Recreation Inventory
December 16, 2019

Parking	Signage	Recreation Amenities	Condition of Recreation Amenities	Additional Features
- 6-8 car capacity parking lot - Emergency parking - Offstreet overflow parking	- Signage with public boat ramp information - Kiosk with boat access rules and regulations - Kiosk with information on the Landing Site of Reeds Ferry	- Boat ramp - Short trail to boat ramp with tunnel - Trash receptacles	- Boat ramp in good condition - Trail in good condition - Trash receptacles noted in good condition	- Grassy area for picnicking -

Photo 3 – Depot Street Boat Ramp Sign

Photo 4 – Depot Street Boat Ramp

Greeley Boat Ramp
Recreation Inventory
December 16, 2019

Parking	Signage	Recreation Amenities	Condition of Recreation Amenities	Additional Features
- Parking for 2 near boat ramp - Parking for 4 just above boat ramp	- Entry signage with park hours and rules - Poor, unreadable signage near boat ramp	- Boat ramp - Off-road trail	- Boat ramp reported in good condition - Trail noted in good condition	- Access road

Photo 5 – Access road to Greeley Boat Ramp

Photo 6 – Greeley Boat Ramp

Lowell Heritage State Park
Recreation Inventory
December 16, 2019

Parking	Signage	Recreation Amenities	Condition of Recreation Amenities	Additional Features
- 20-30 car parking lot - Street parking	- Signage with rules, directions, and park hours	- Outdoor stage with grassy lawn - Sand beach - Benches - Pavilion - Emergency boat ramp	- All recreation amenities reported in good condition	- Restrooms inside building - Waste receptacles

Photo 7 – Parking lot at Lowell Heritage State Park

Photo 8 – Outdoor stage at Lowell Heritage State Park

Photo 9 – Beach at Lowell Heritage State Park

Lowell National Historical Park (Visitor Center)
Recreation Inventory
December 16, 2019

Parking	Signage	Recreation Amenities	Condition of Recreation Amenities	Additional Features
- Ample free car parking lot (~100 spots) -	- "Bus, RV and Trailer Parking Only" - Lowell National Historical Park Visitor Center Sign - Visitor Center Sign with hours - Map of Lowell National Historical Park Features	- Standing exhibits with historical and hydropower information - Interactive equipment for education - Restrooms and water-fountain	- All recreation amenities reported in good condition	- Information front desk - Wheel chair ramp - Gift shop - Restrooms

Photo 10 – Standing educational exhibits and gift shop inside Lowell National Historical Park Visitor Center

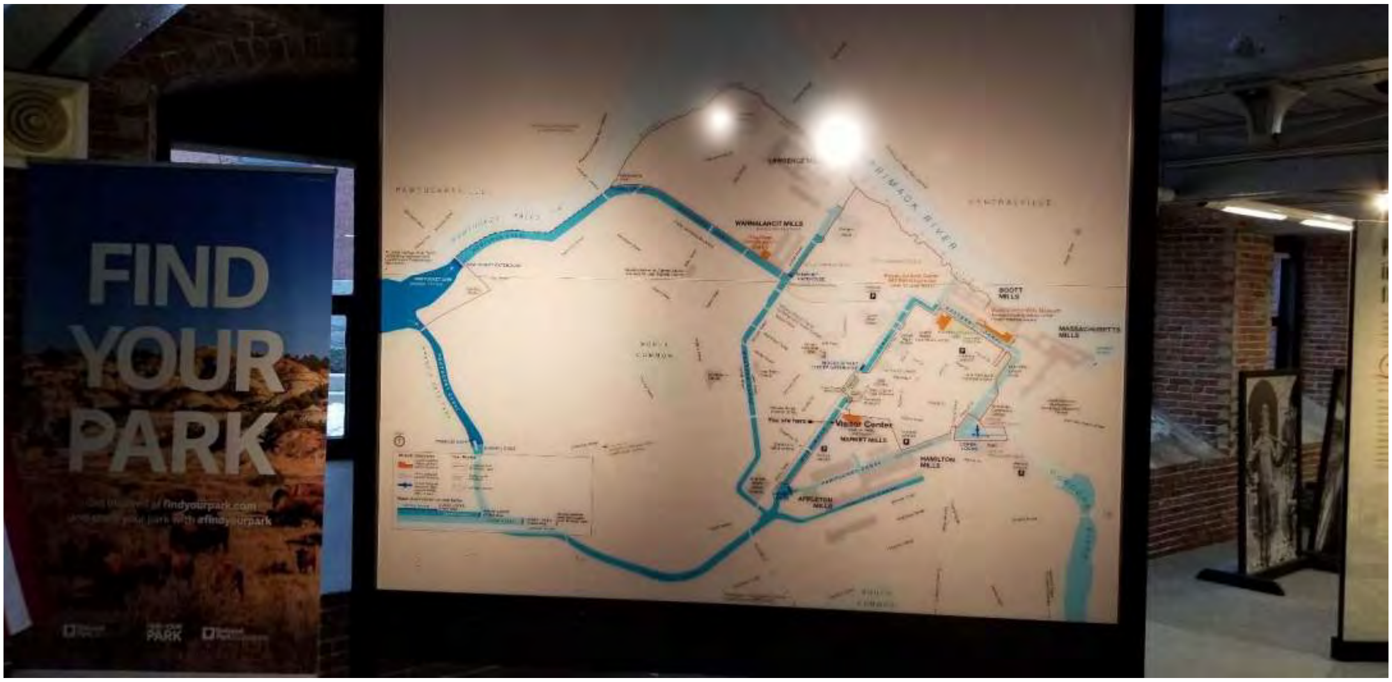


Photo 11 – Map of canal layout and Lowell National Historical Park Features (located inside Visitor Center)

Merrill Park
Recreation Inventory
December 16, 2019

Parking	Signage	Recreation Amenities	Condition of Recreation Amenities	Additional Features
- No formal park lot Dirt parking area for approximately 5 cars	- Entry sign to park	- Walking trail - Hand-carry launch area	- Parking area is minimal, could be graded, many deep ruts - Hand-carry launch and walking trail acceptable	- Bicycle motocross jump - Adjacent to graveyard (common area for dog walking)

Photo 12 – Entry sign to Merrill Park


Photo 13 –Access road to Merrill Park

Merrimack Trail System
Recreation Inventory
December 17, 2019

Parking	Signage	Recreation Amenities	Condition of Recreation Amenities	Additional Features
- Parking for approximately 20 cars - Street parking	- Welcome sign with rules and hours	- Trail to water - Walking trails - Benches - Trash receptacles - Bathrooms	- All recreation amenities reported in good condition	- Not applicable

Photo 14 – Walking Path

Moore's Falls Conservation Area
Recreation Inventory
December 16, 2019

Parking	Signage	Recreation Amenities	Condition of Recreation Amenities	Additional Features
- Parking lot for 7-11 cars	- Welcome kiosk with rules and information on young forest and shrubland - Welcome sign with rules - Caution signs regarding hunting and other uses of the area - Educational exhibits with environmental information	- Trails - Educational exhibits	- All recreation amenities reported in good condition	- Birdhouses

Photo 15 – Welcome Kiosk to Moore's Falls Conservation Area

Photo 16 – Birdhouses at Moore's Falls Conservation Area

National Park Service Canal Walkways
Recreation Inventory
December 17, 2019

Parking	Signage	Recreation Amenities	Condition of Recreation Amenities	Additional Features
- Parking available at NPS Visitor Center	- Information and direction signs - Educational exhibits and signs	- Canalways - Benches - Education signs - Lighting	- All recreation amenities reported in good condition	- Not applicable

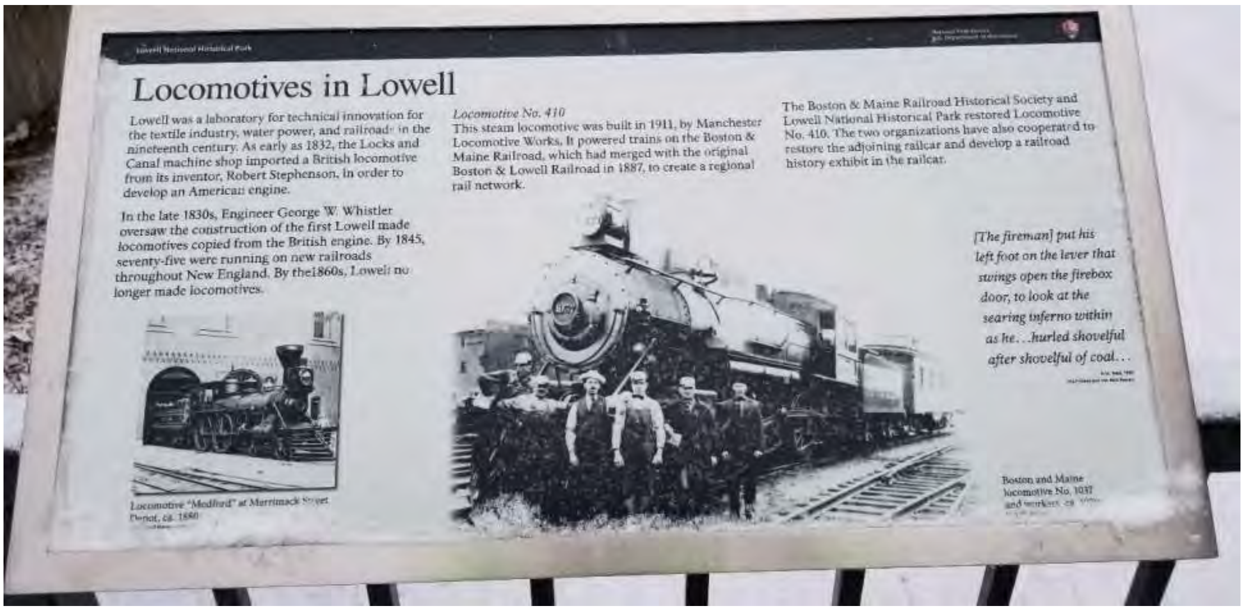


Photo 17 – Example photograph of educational signs

Photo 18 – Canalways and benches along Merrimack Canal Walk

Pawtucket Falls Overlook
Recreation Inventory
December 16, 2019

Parking	Signage	Recreation Amenities	Condition of Recreation Amenities	Additional Features
- Not applicable	- Educational signage	- Overlook area	- Good condition	- Not applicable

Photo 19 – Educational sign at the Pawtucket Falls Overlook


Photo 20 – View of dam and Pawtucket Falls from Pawtucket Falls Overlook

Rourke Brothers Boat Ramp
Recreation Inventory
December 16, 2019

Parking	Signage	Recreation Amenities	Condition of Recreation Amenities	Additional Features
- Parking for approximately 60 cars - Handicap parking/ADA-compliant	- Welcome sign - Kiosk with rules and regulations - Rourke Brothers Memorial Sign	- Boat ramp - Dock - Tables	- All recreation amenities reported in good condition	- Grassy picnic areas

Photo 21 – Kiosk with rules and regulations

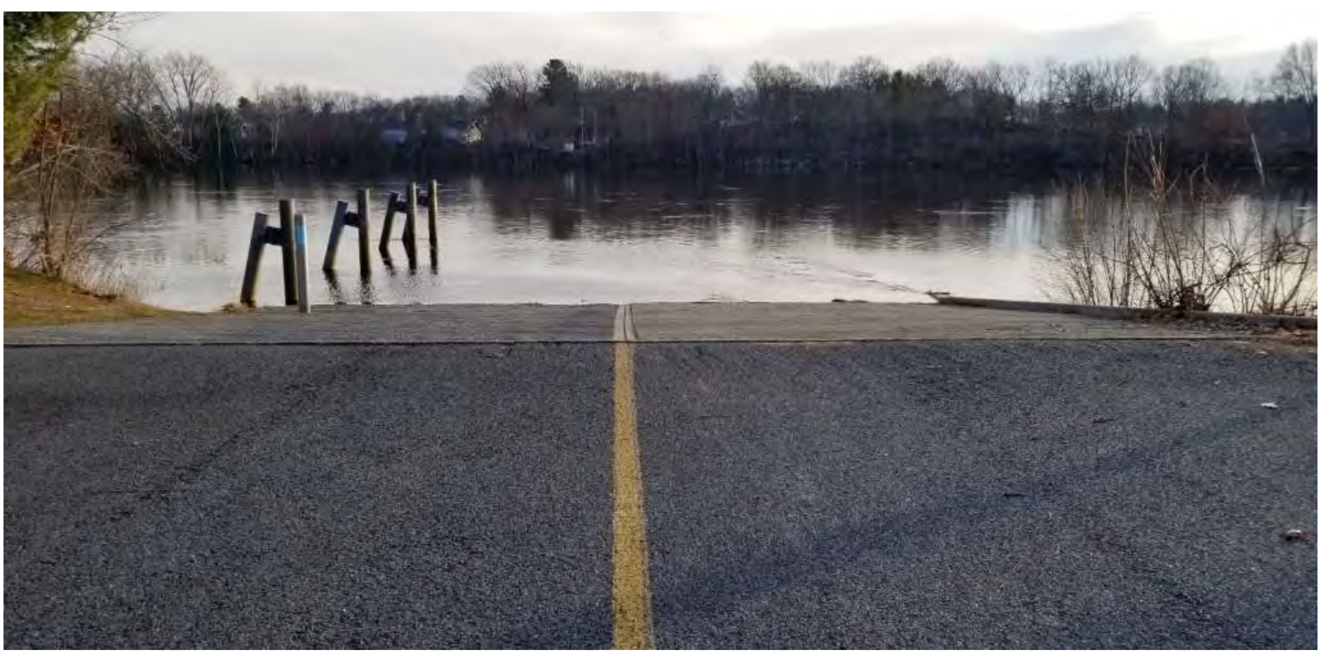


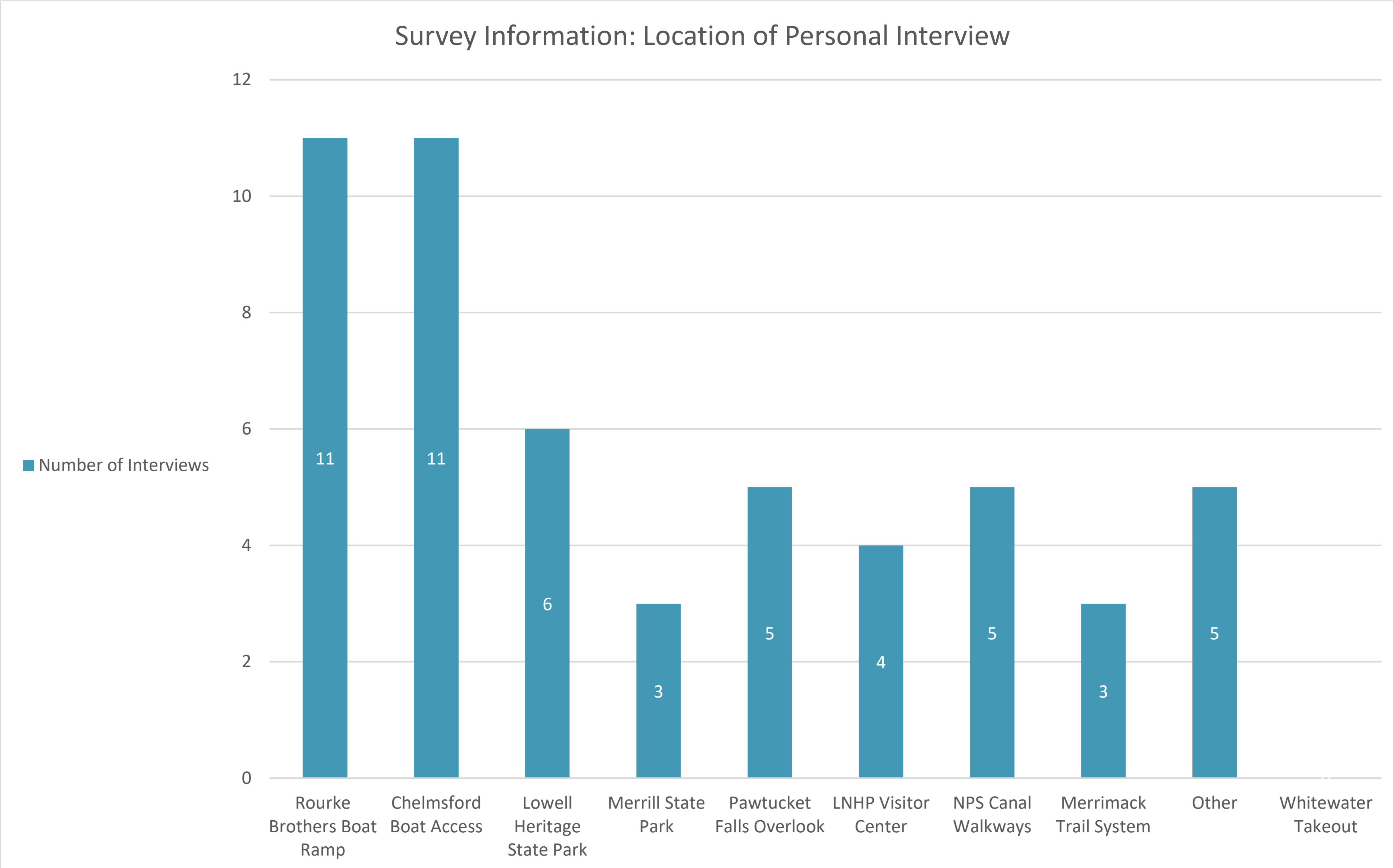
Photo 22 – Paved Rourke Brothers Boat Ramp

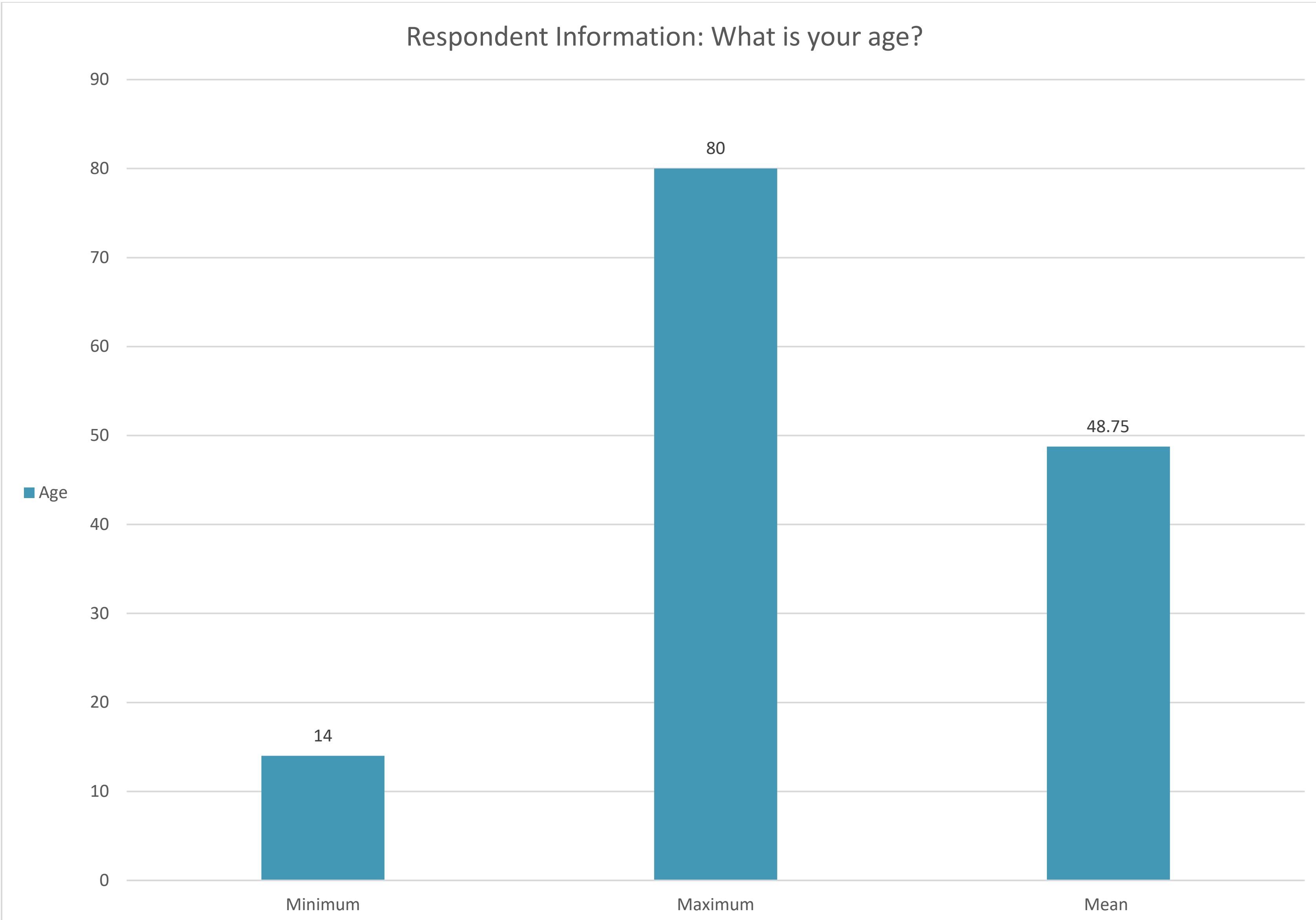
E.L. Field Powerhouse Visitor Center
Recreation Inventory
December 16, 2019

Parking	Signage	Recreation Amenities	Condition of Recreation Amenities	Additional Features
- **Large locked gated area available for parking** - **Asphalt/gravel parking area**	- Welcome sign	- Standing exhibits with historical and hydropower informatio**n** - Interactive and interpretive equipment for education	- Reported in good condition	- ADA-compliant elevator

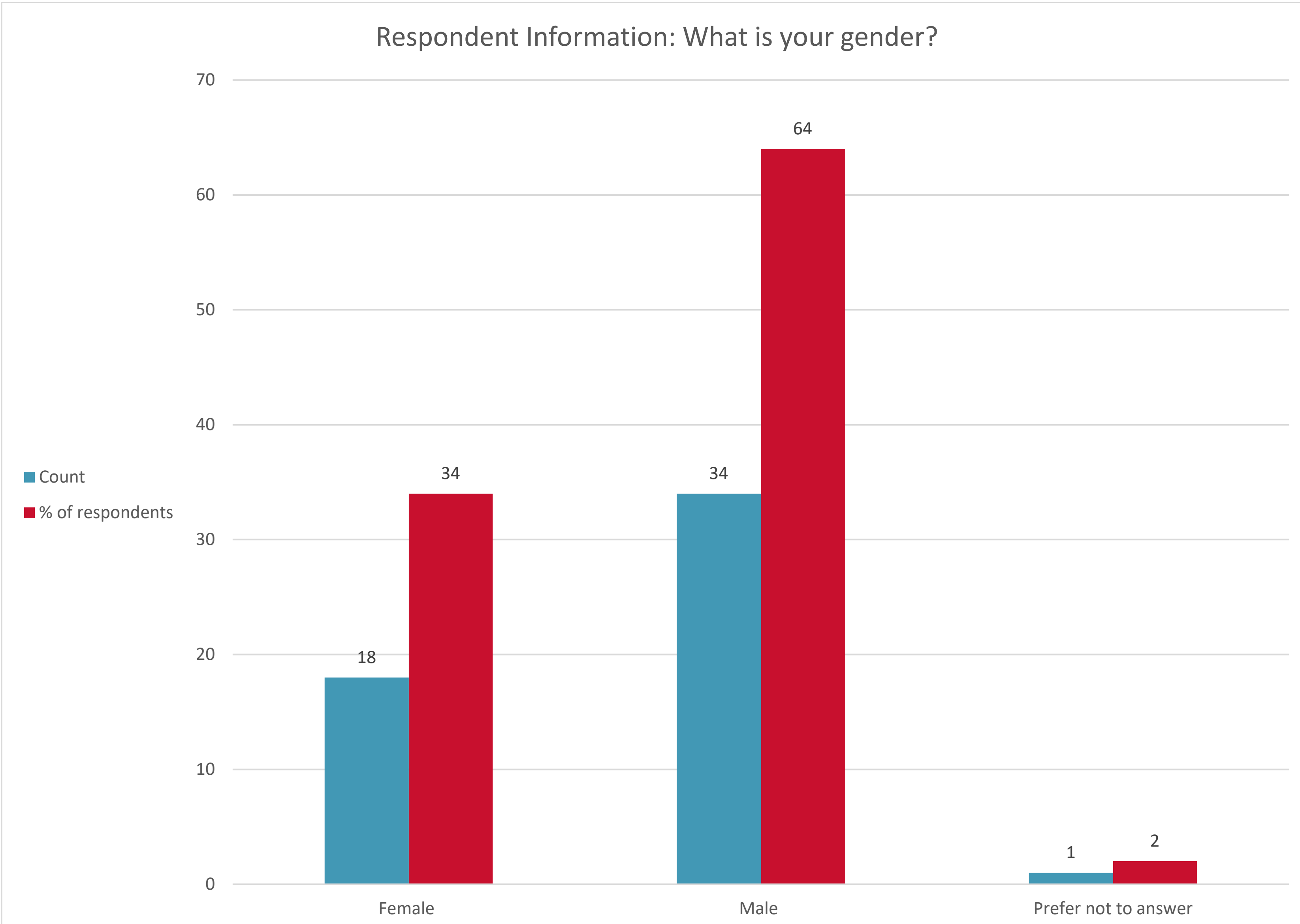
*****The E.L. Field Powerhouse Visitor Center was closed the days of inventory. Only the outside portions were included in this inventory.

Appendix C - Personal Interview/Visitor-Intercept Survey Data

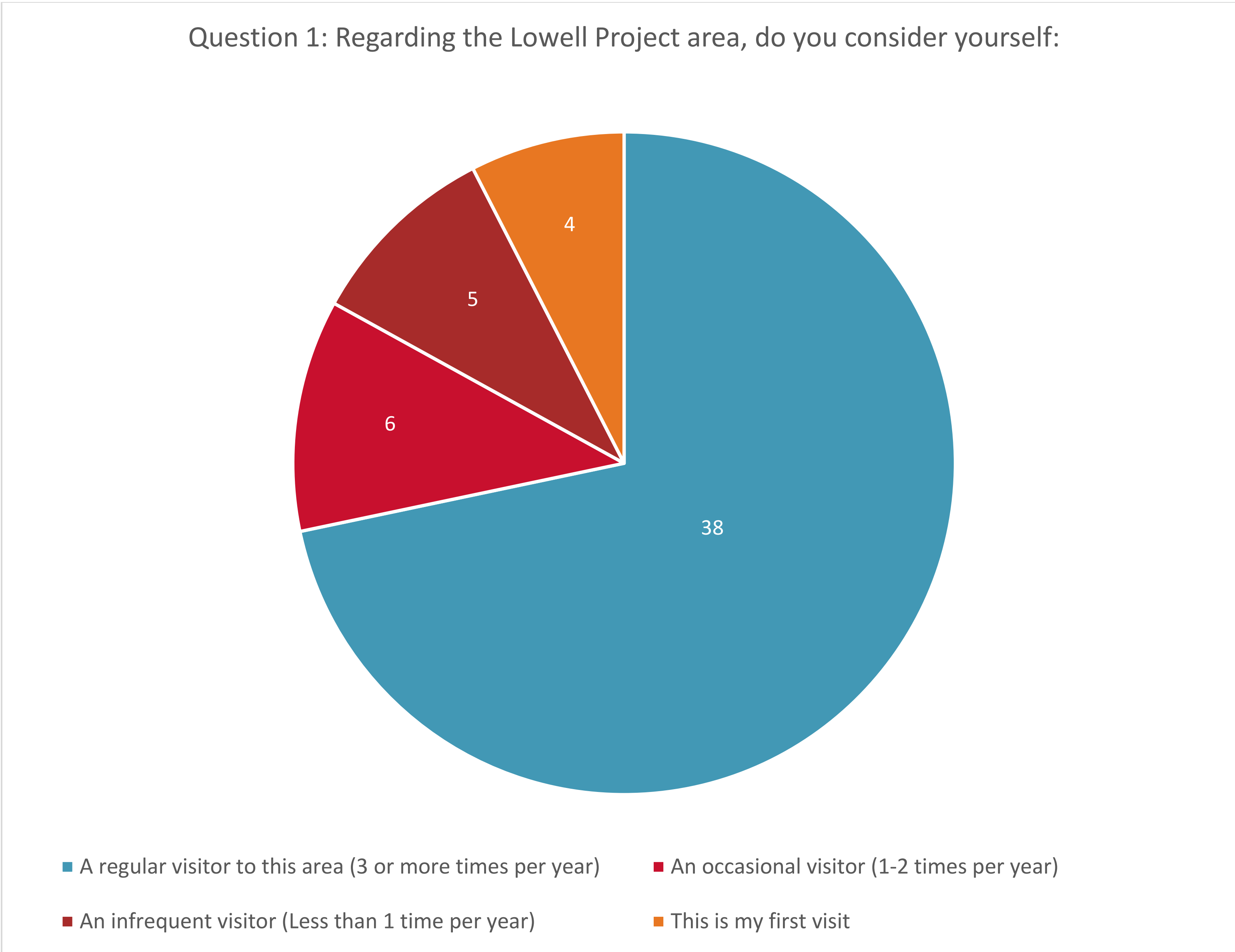

Survey Information: Location of Personal Interview
Number of Interviews
12
10
8
6
4
2
0
11
11
6
3
5
4
5
3
5
Rourke Brothers Boat Ramp
Chelmsford Boat Access
Lowell Heritage State Park
Merrill State Park
Pawtucket Falls Overlook
LNHP Visitor Center
NPS Canal Walkways
Merrimack Trail System
Other
Whitewater Takeout

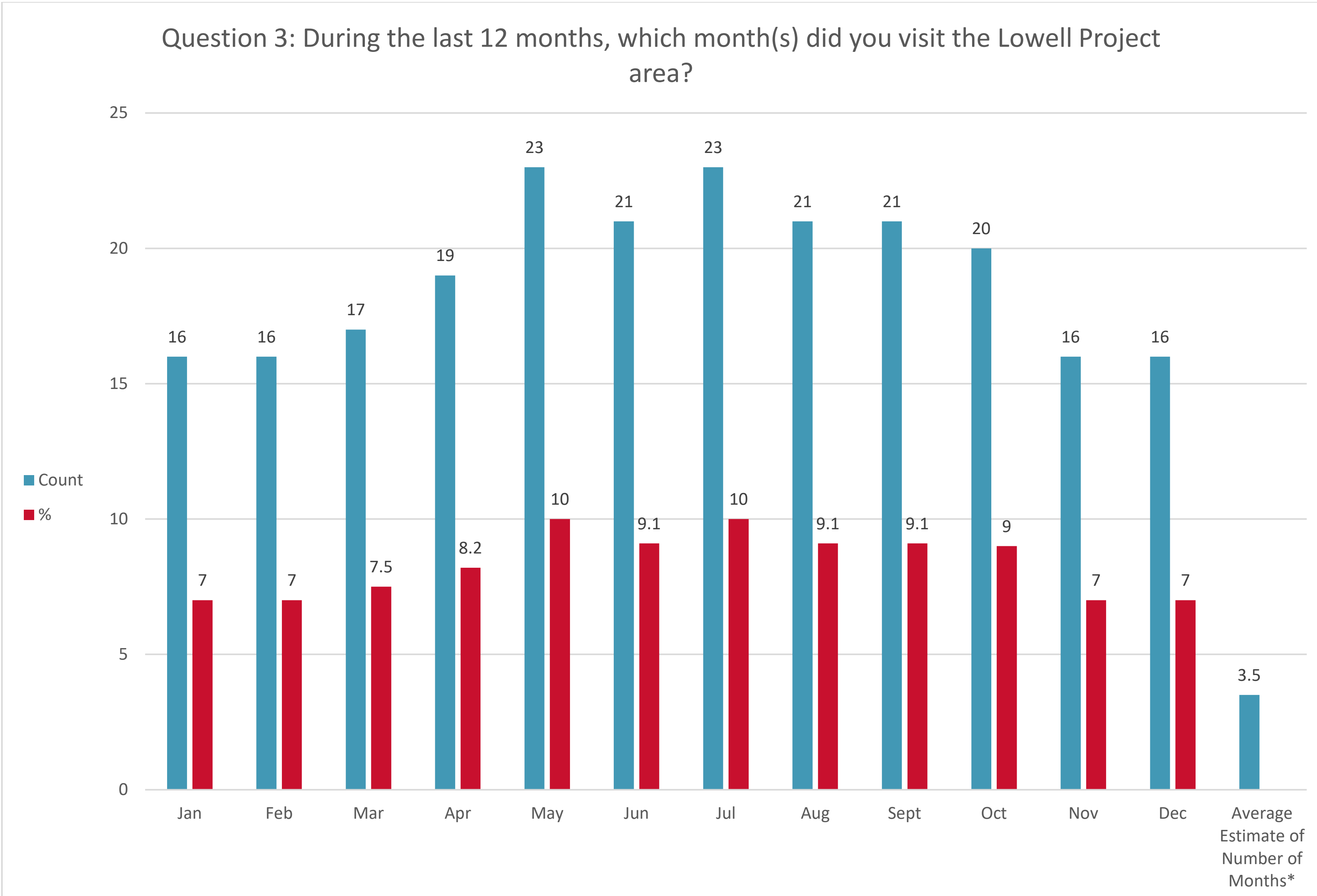


Respondent Information: What is your age?
Age
90
80
70
60
50
40
30
20
10
0
14
80
48.75
Minimum
Maximum
Mean

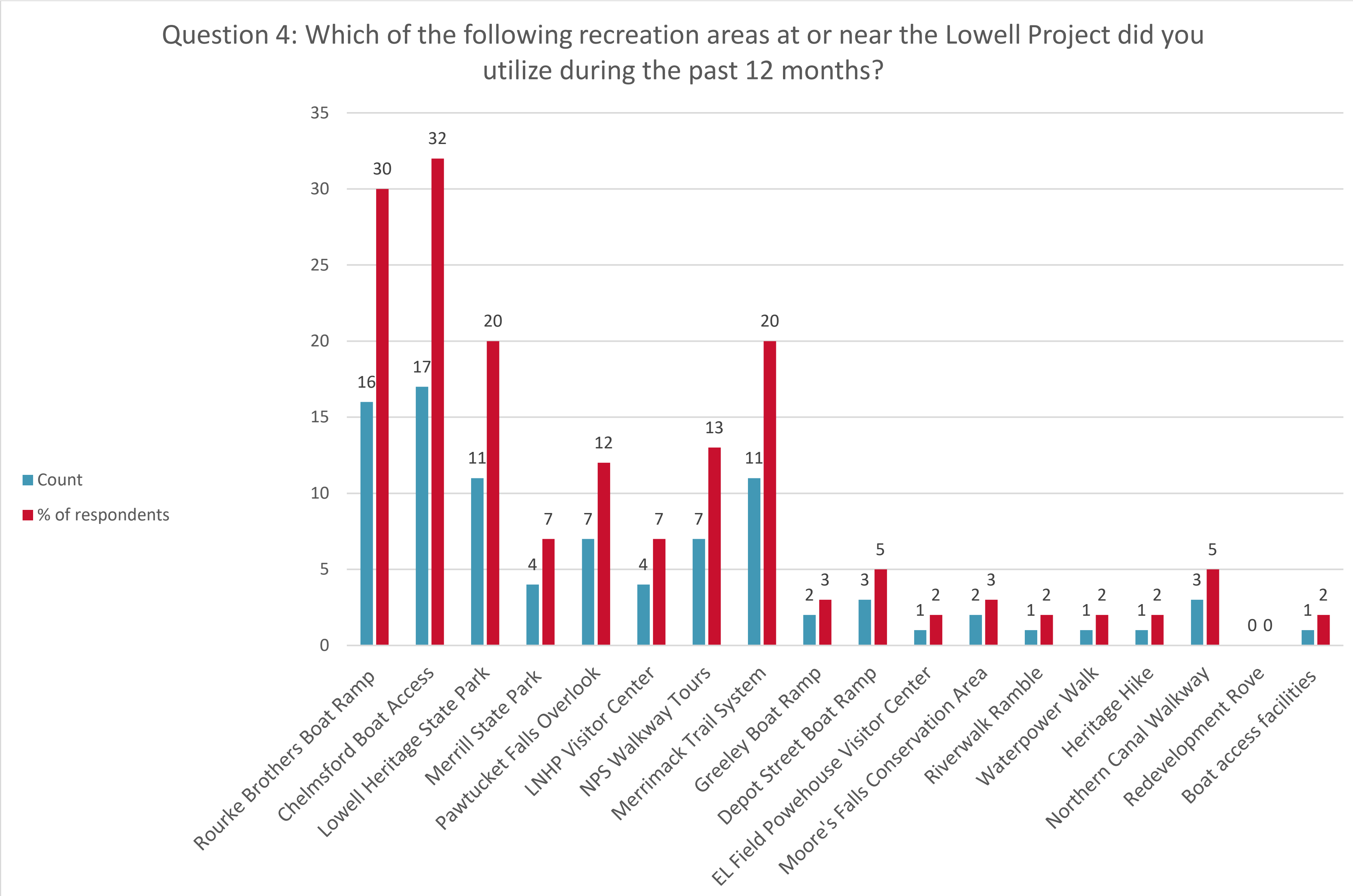


Respondent Information: What is your gender?
70
60
50
40
30
20
10
0
Count
% of respondents
18
34
34
64
1
2
Female
Male
Prefer not to answer

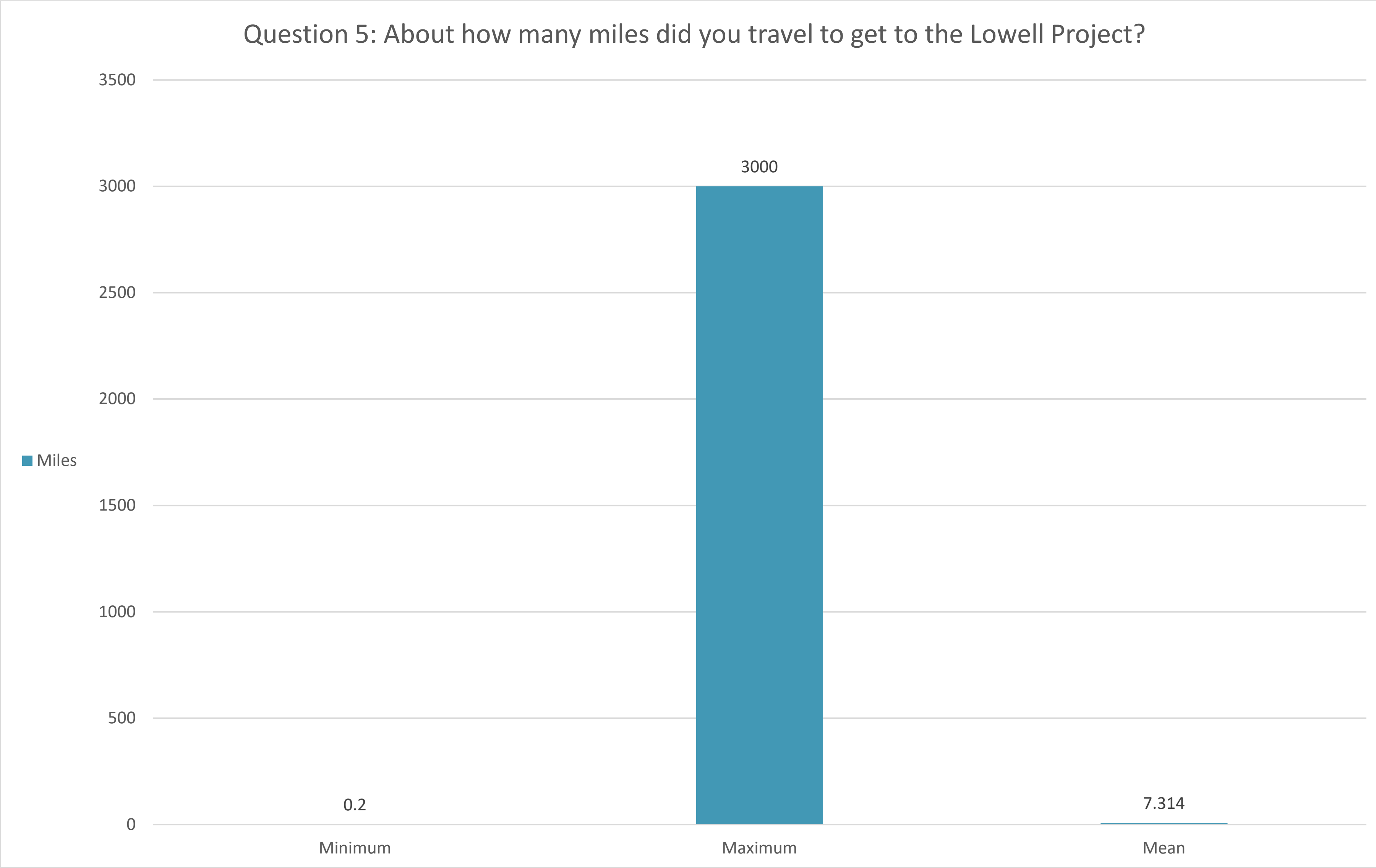

Question 1: Regarding the Lowell Project area, do you consider yourself:
4
5
6
38
A regular visitor to this area (3 or more times per year)
An occasional visitor (1-2 times per year)
An infrequent visitor (Less than 1 time per year)
This is my first visit



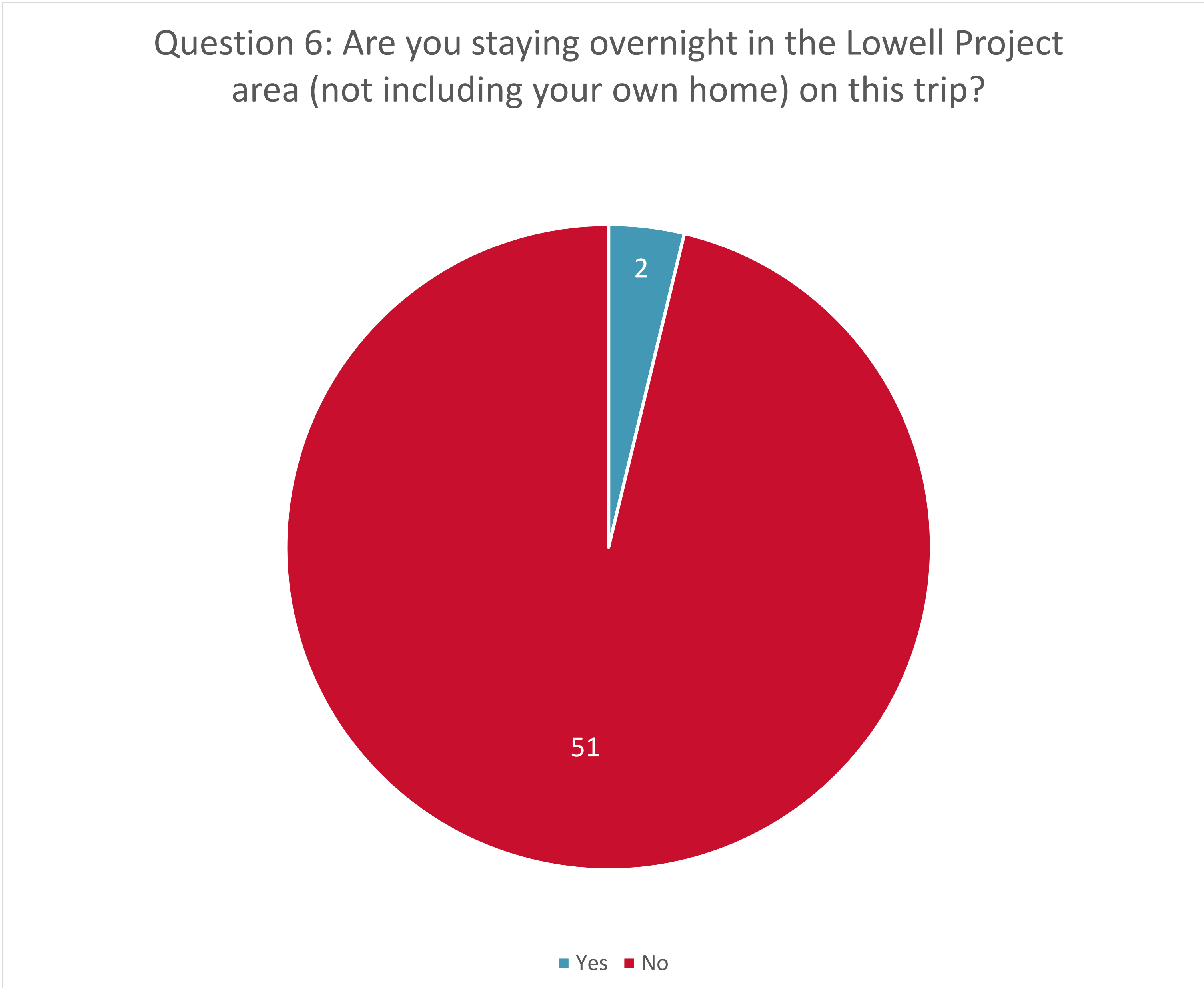
*A small number of respondents interpreted Question 3 as asking how many months during the last 12 months they visited the Project. This is the average of those responses.

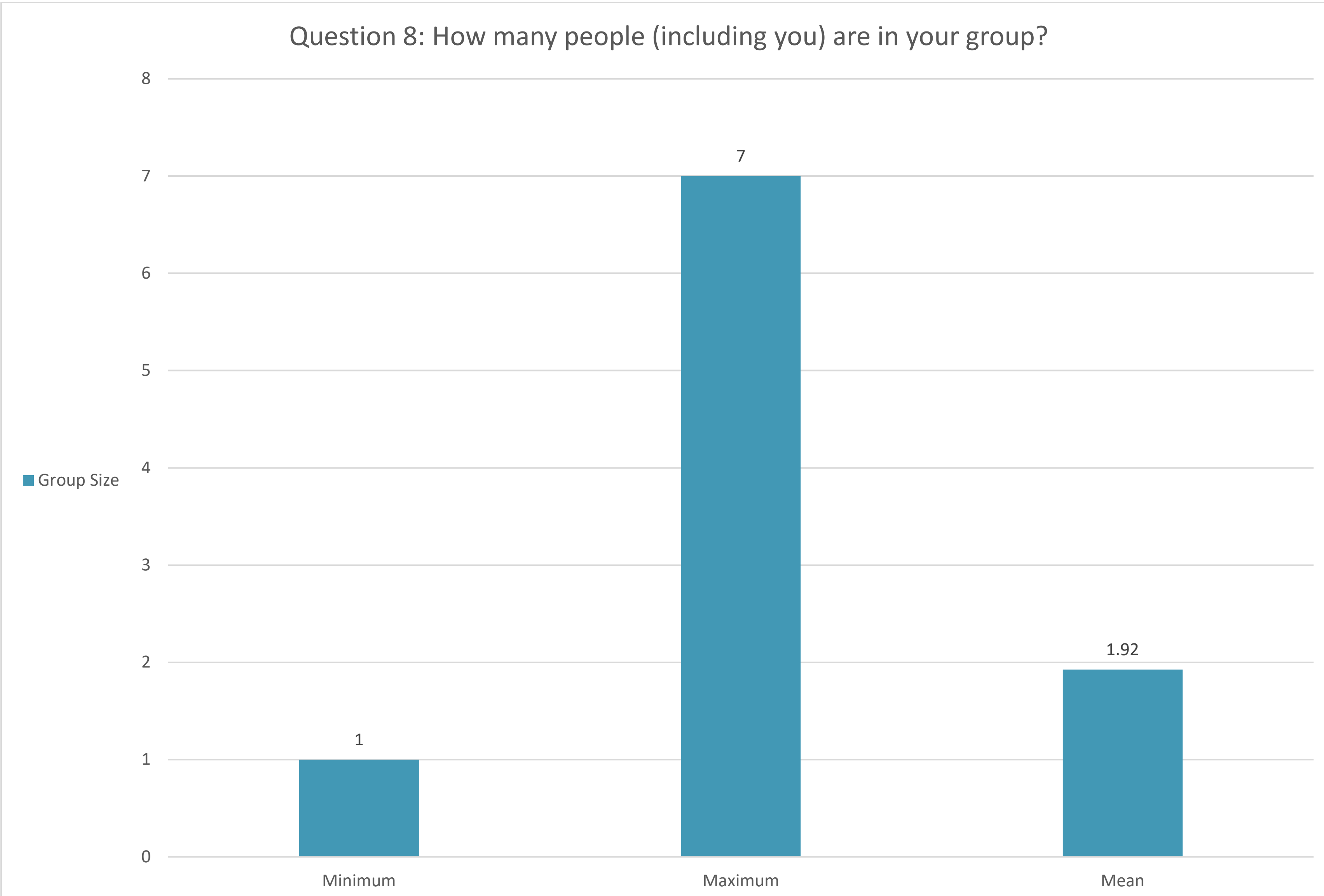


Question 4: Which of the following recreation areas at or near the Lowell Project did you utilize during the past 12 months?
Count
% of respondents
35
30
25
20
15
10
5
0
16
30
17
32
11
20
4
7
7
12
4
7
7
13
11
20
2
3
3
5
1
2
2
3
1
2
1
2
1
2
3
5
0 0
1
2
Rourke Brothers Boat Ramp
Chelmsford Boat Access
Lowell Heritage State Park
Merrill State Park
Pawtucket Falls Overlook
LNHP Visitor Center
NPS Walkway Tours
Merrimack Trail System
Greeley Boat Ramp
Depot Street Boat Ramp
EL Field Powehouse Visitor Center
Moore's Falls Conservation Area
Riverwalk Ramble
Waterpower Walk
Heritage Hike
Northern Canal Walkway
Redevelopment Rove
Boat access facilities

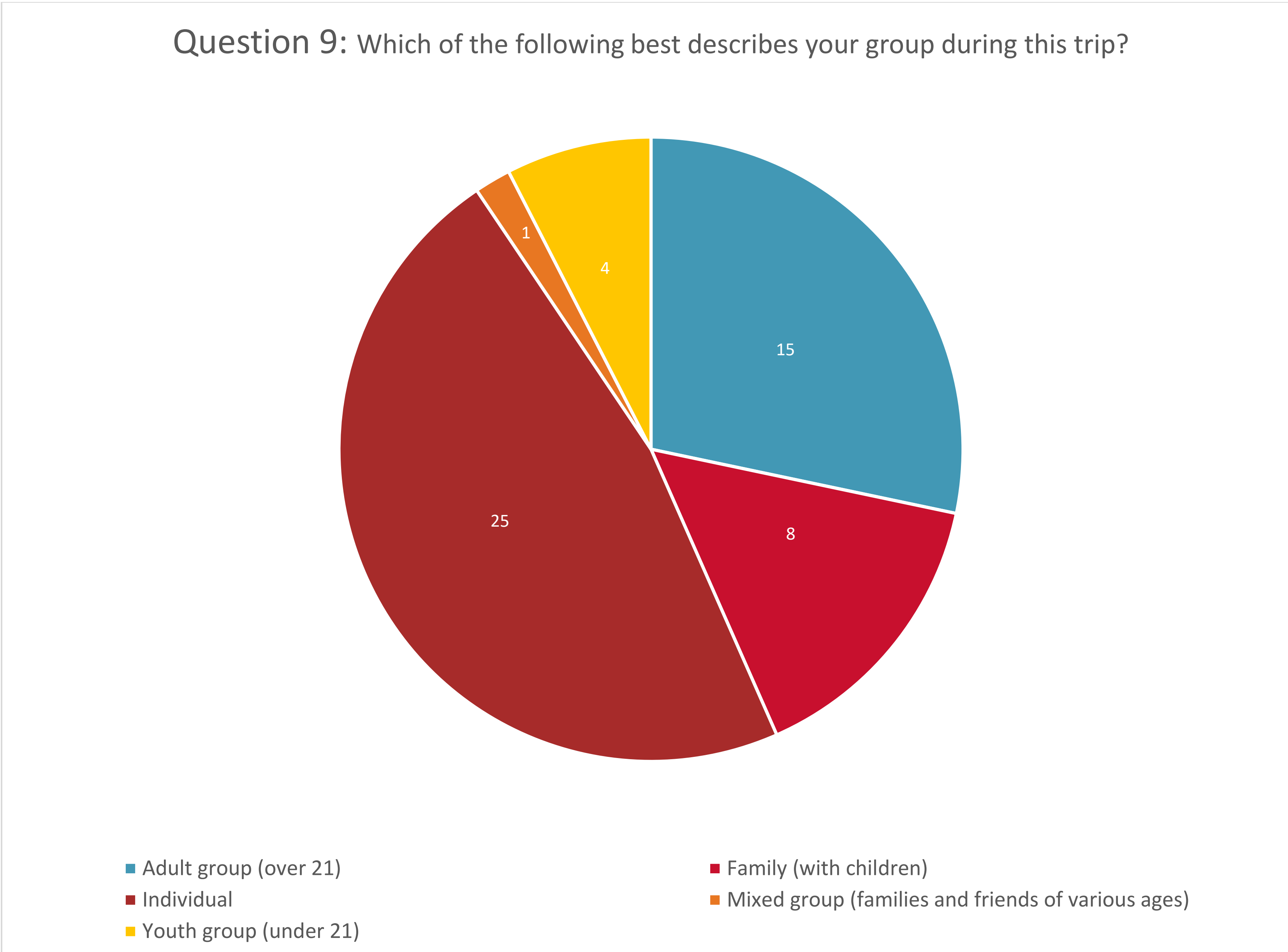


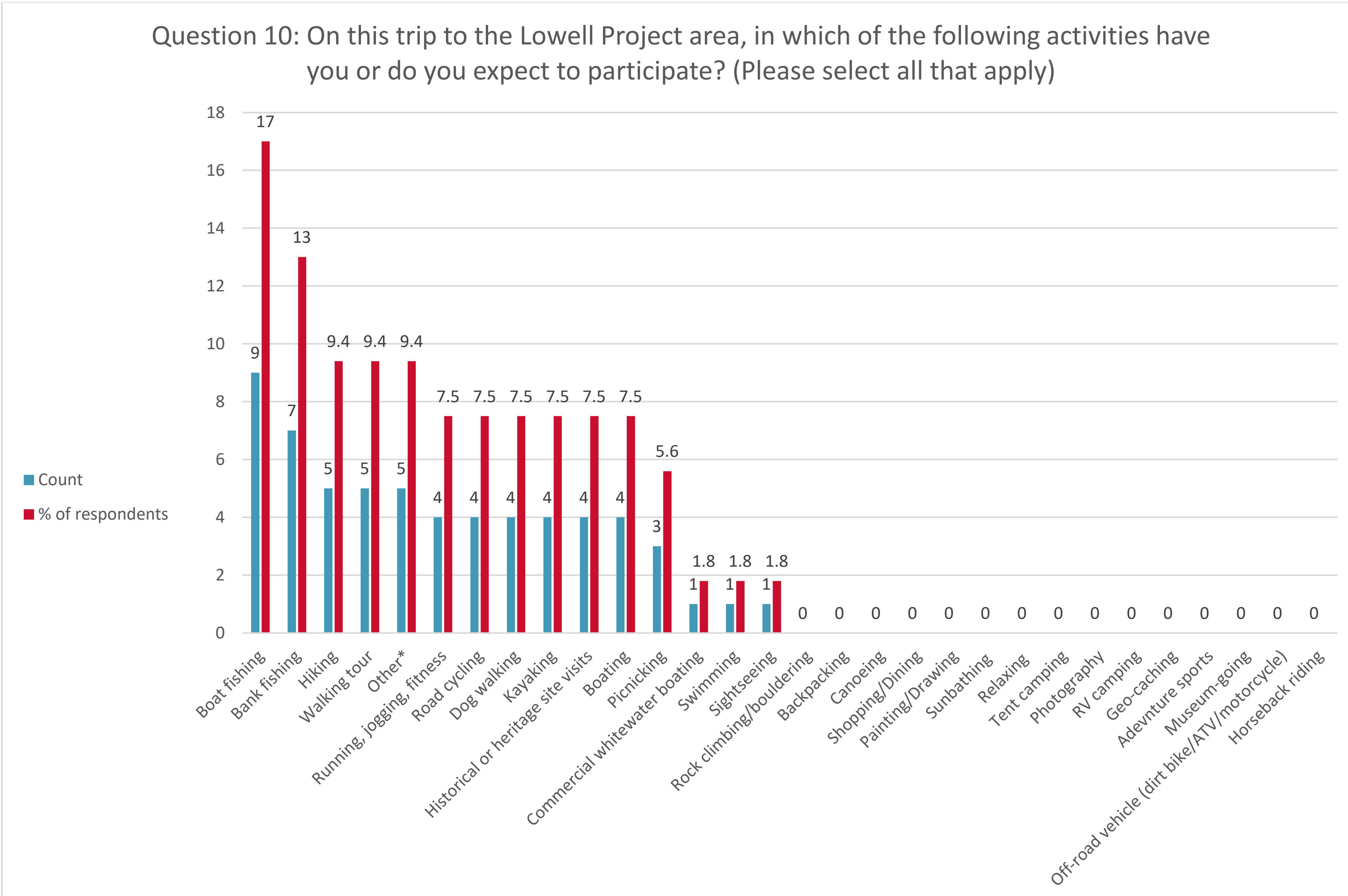
*The mean does not include the 3,000 miles as it would significantly skew the results. To see the full list of respondent residential zip codes and a representative map, see Appendix F.


Question 6: Are you staying overnight in the Lowell Project area (not including your own home) on this trip?
2
51
Yes
No

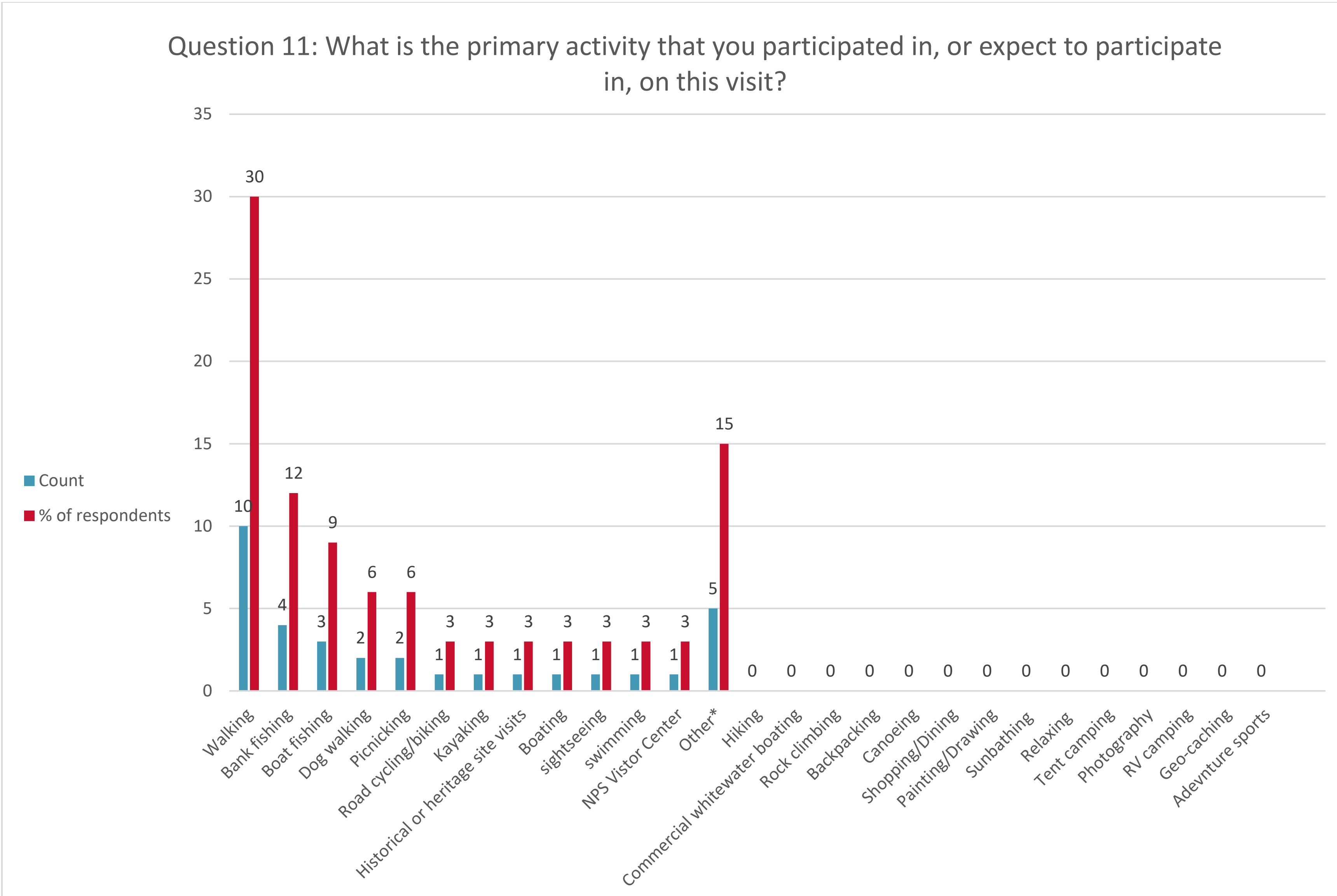


Question 8: How many people (including you) are in your group?
8
7
6
5
4
3
2
1
0
Group Size
1
7
1.92
Minimum
Maximum
Mean

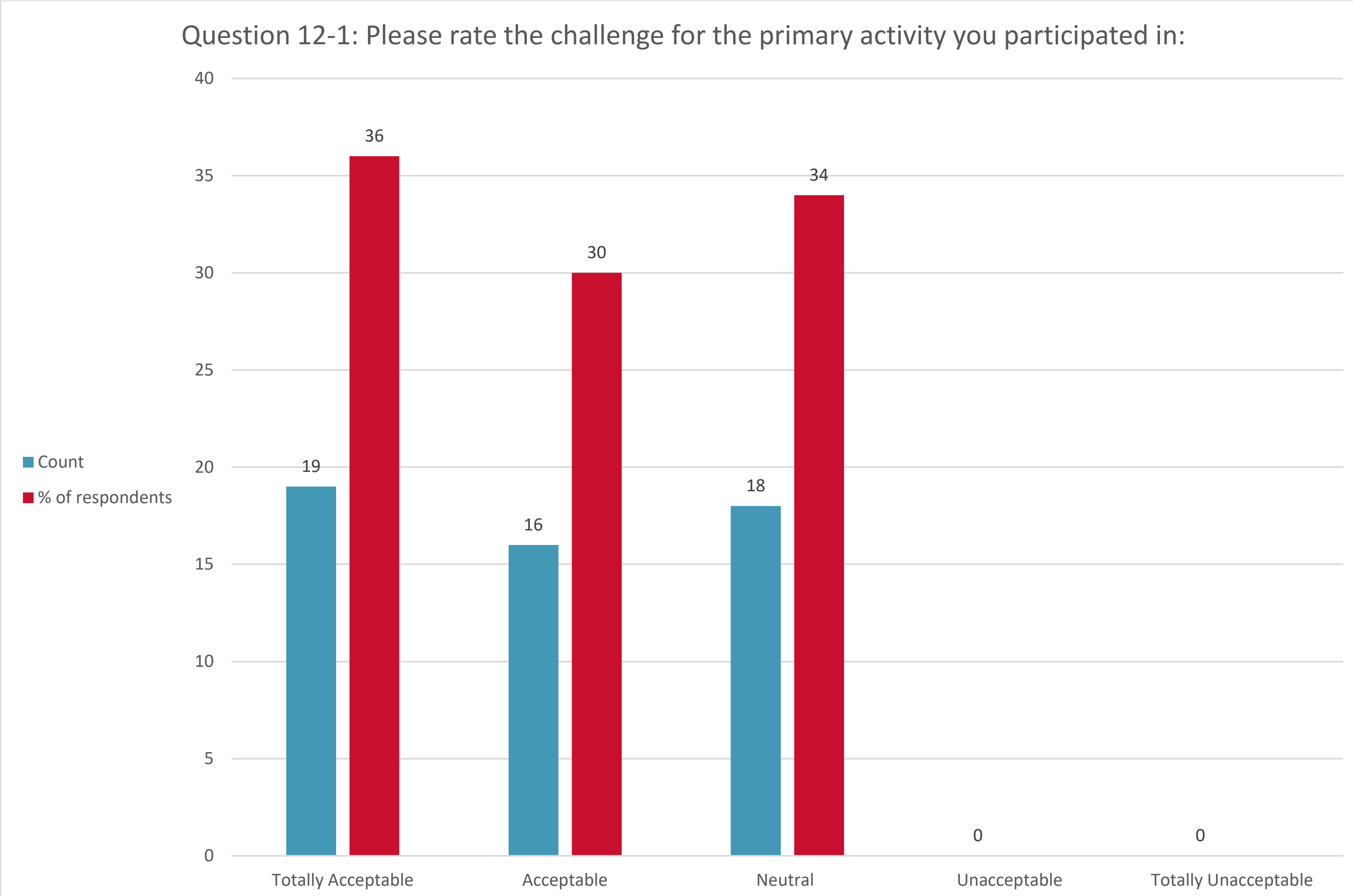

Question 9: Which of the following best describes your group during this trip?
15
8
25
1
4
Adult group (over 21)
Family (with children)
Individual
Mixed group (families and friends of various ages)
Youth group (under 21)



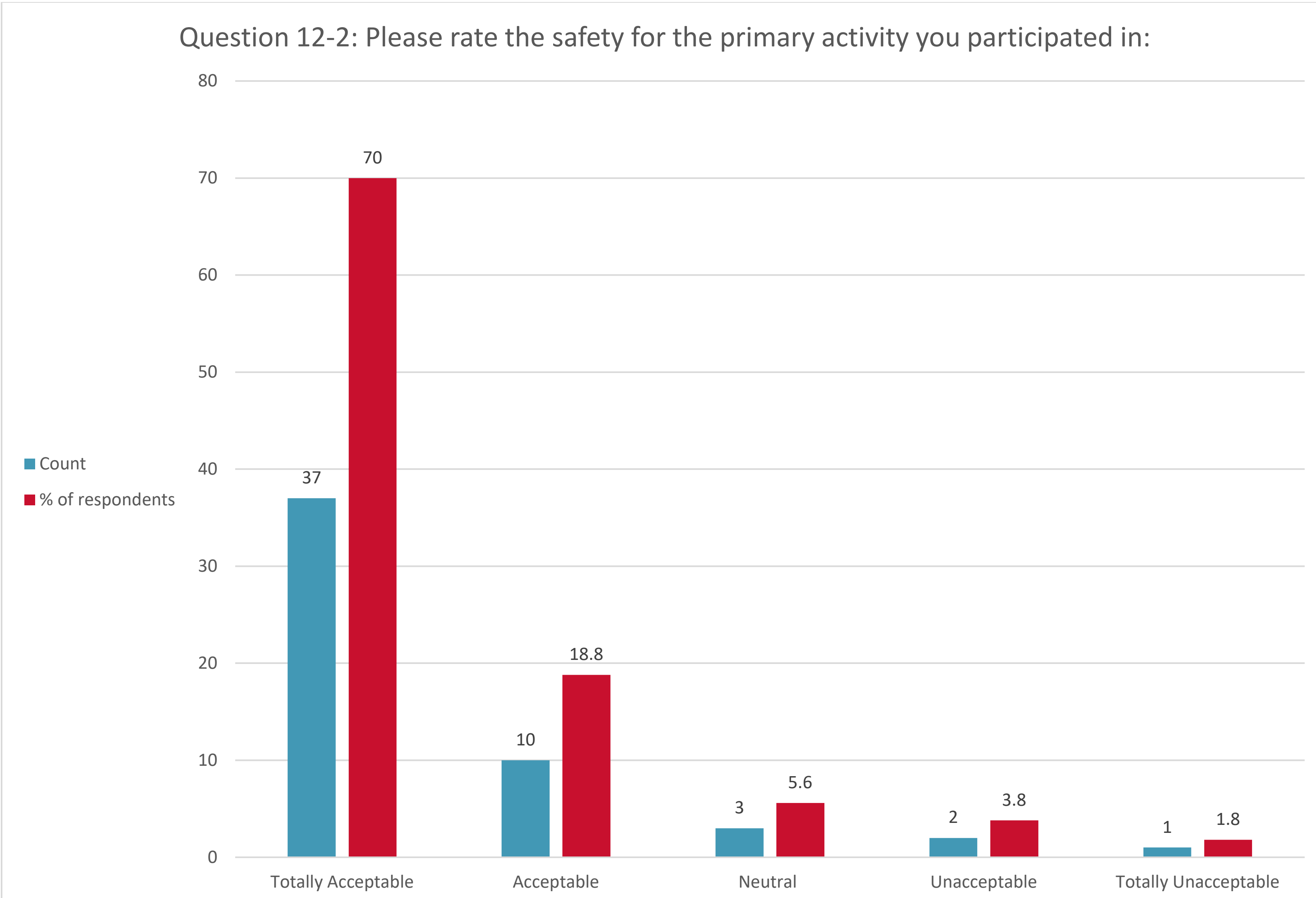
*Other activities included duck feeding, playground, jet skiing, rowing, and wake boarding.



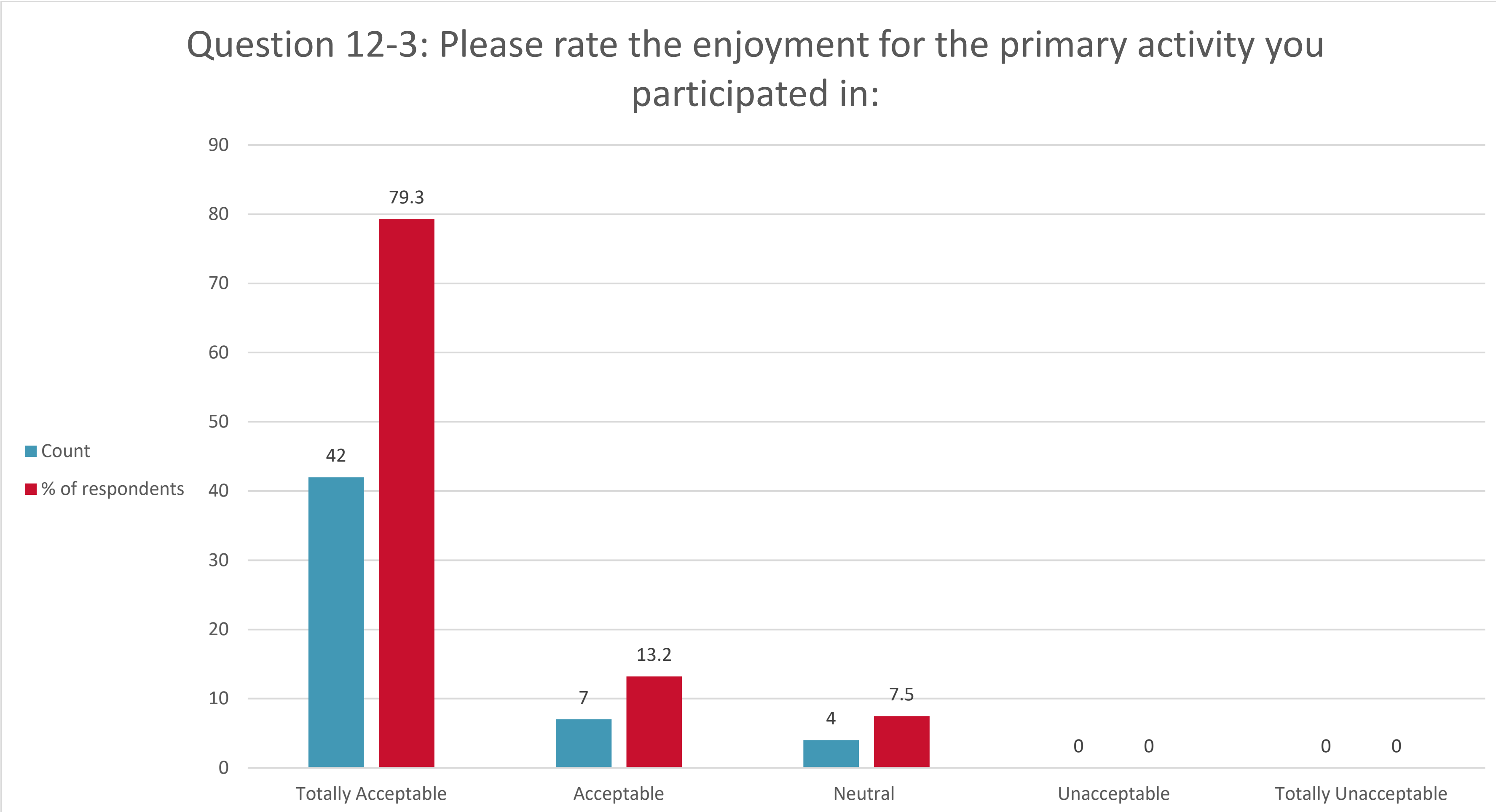
*Other activities included duck feeding, playground, jet skiing, rowing, and wake boarding.

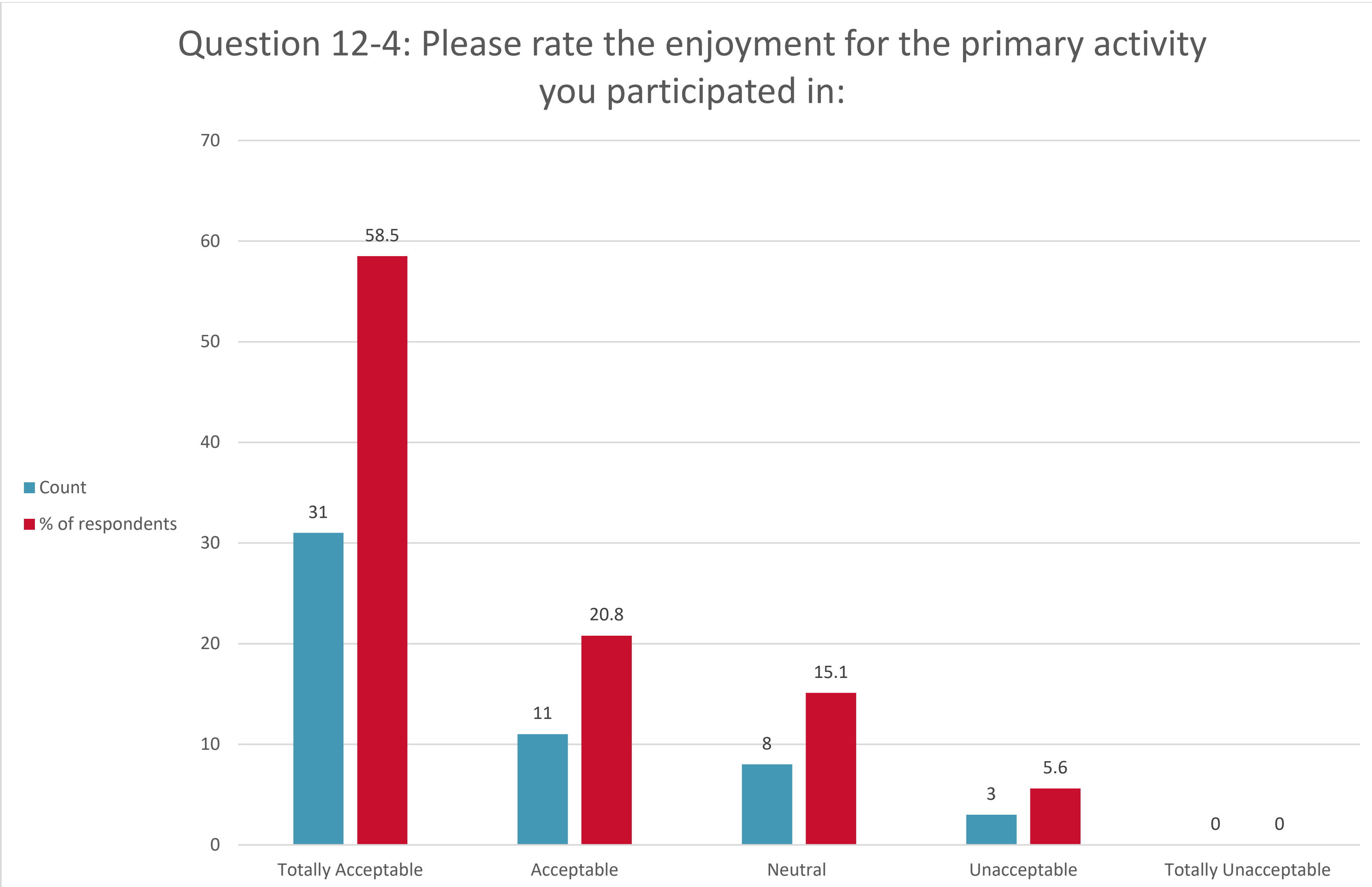


Question 12-1: Please rate the challenge for the primary activity you participated in:
40
35
30
25
20
15
10
5
0
Count
% of respondents
19
36
16
30
18
34
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

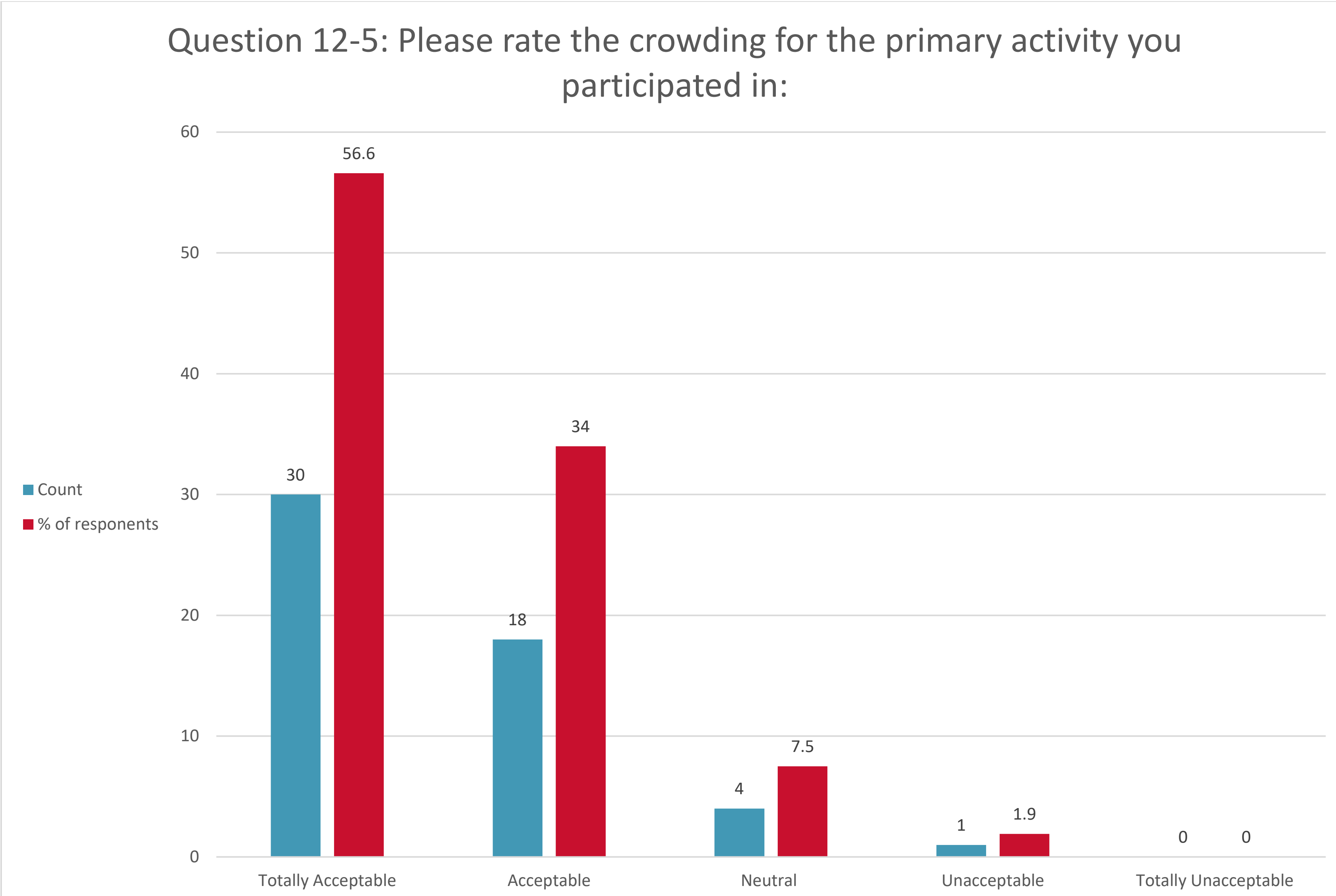


Question 12-2: Please rate the safety for the primary activity you participated in:
Count
% of respondents
80
70
60
50
40
30
20
10
0
70
37
18.8
10
5.6
3
3.8
2
1.8
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

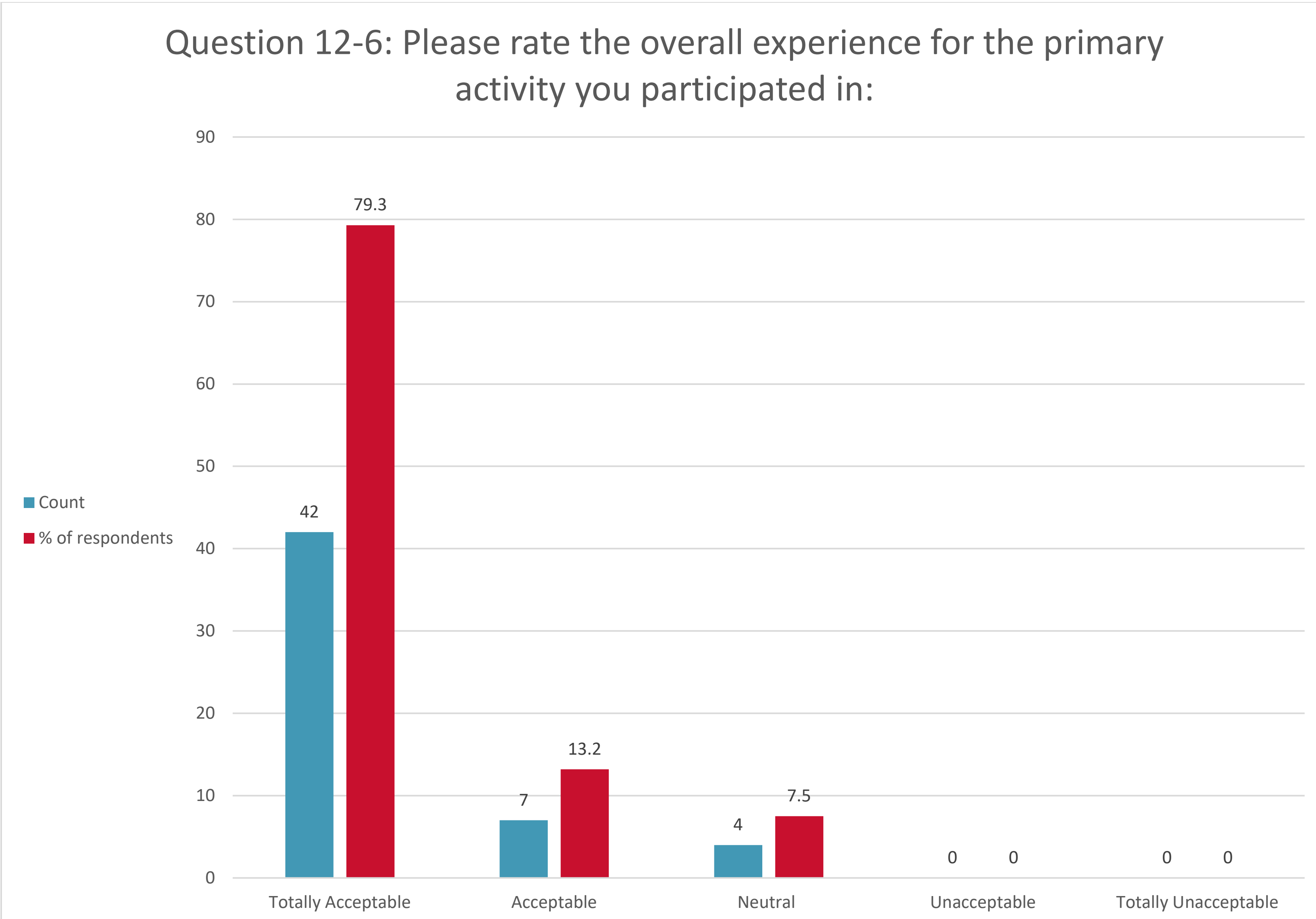

Question 12-3: Please rate the enjoyment for the primary activity you participated in:
Count
% of respondents
90
80
70
60
50
40
30
20
10
0
79.3
42
13.2
7
7.5
4
0
0
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable



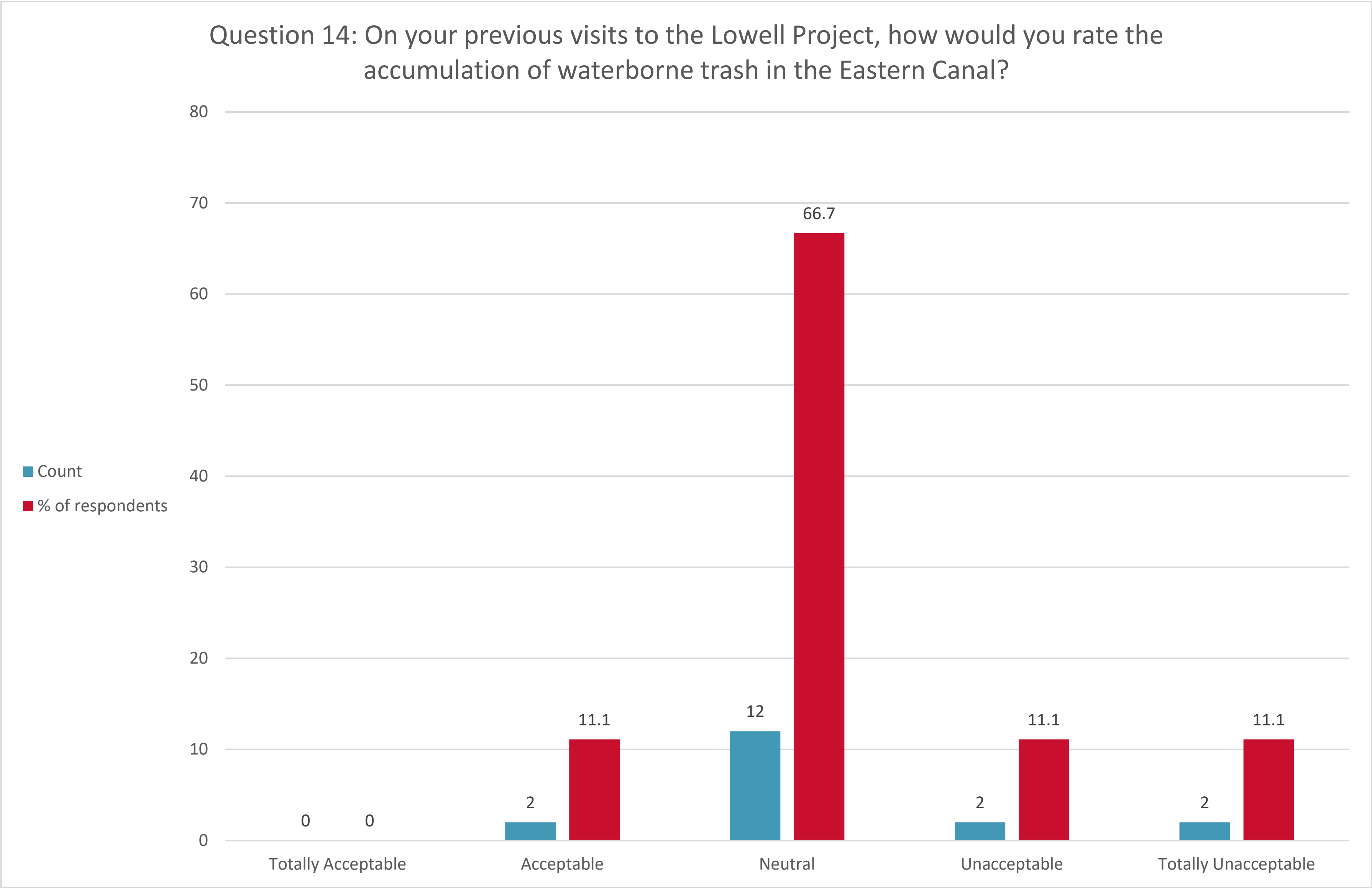
Question 12-4: Please rate the enjoyment for the primary activity you participated in:
Count
% of respondents
70
60
50
40
30
20
10
0
31
58.5
11
20.8
8
15.1
3
5.6
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable



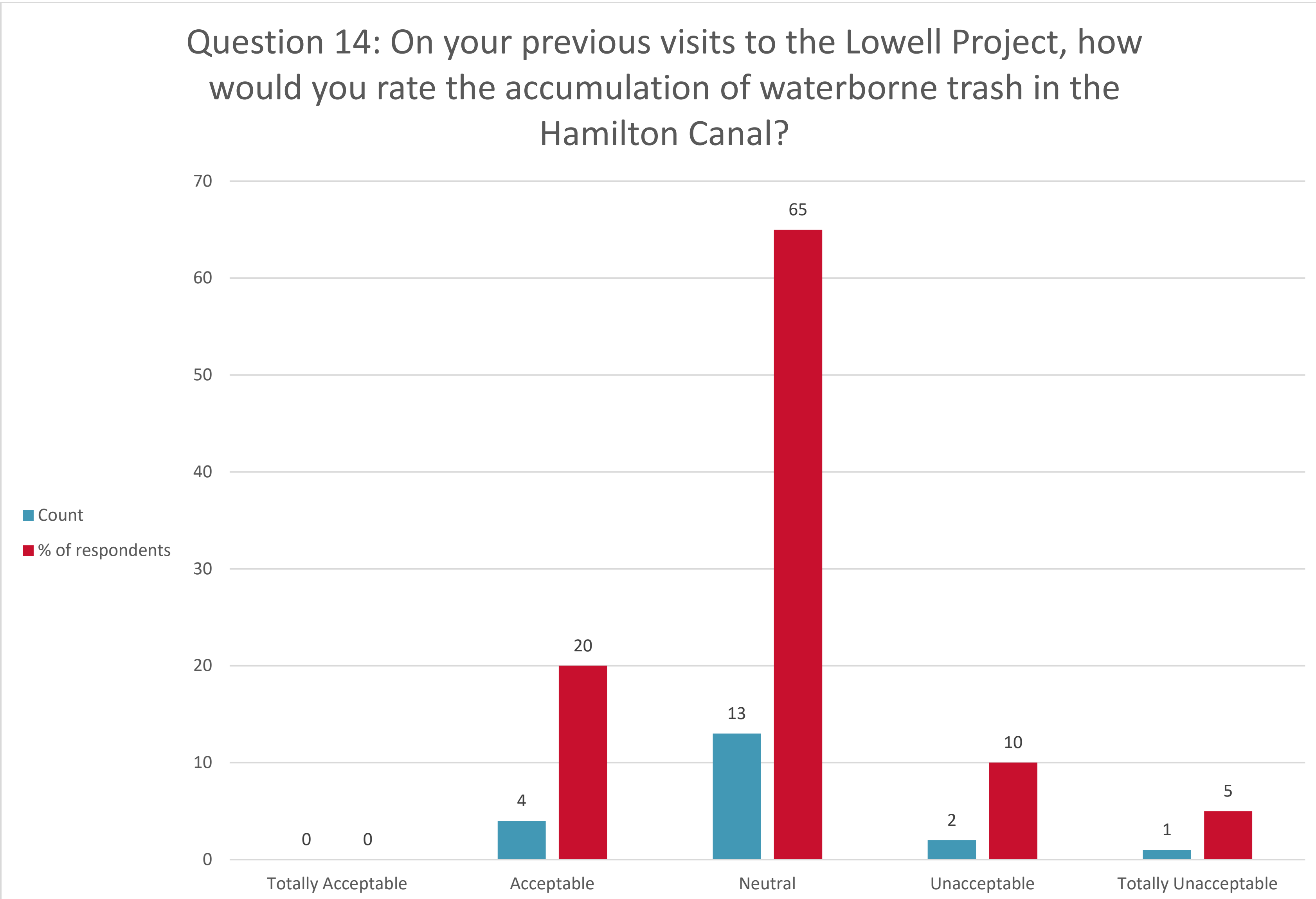
Question 12-5: Please rate the crowding for the primary activity you participated in:
Count
% of responents
60
50
40
30
20
10
0
56.6
30
34
18
7.5
4
1
1.9
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable



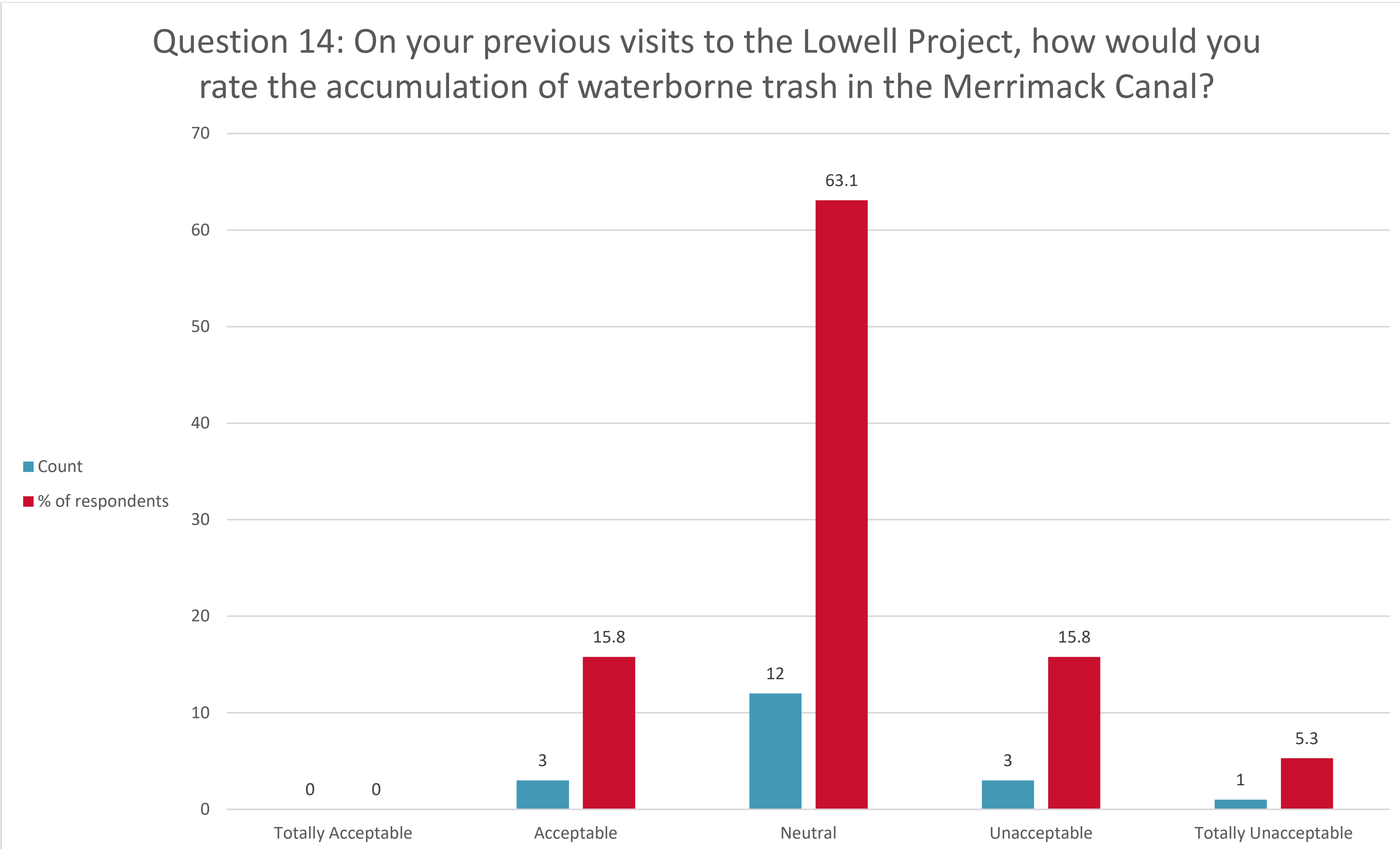
Question 12-6: Please rate the overall experience for the primary activity you participated in:
90
80
70
60
50
40
30
20
10
0
Count
% of respondents
42
79.3
7
13.2
4
7.5
0
0
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

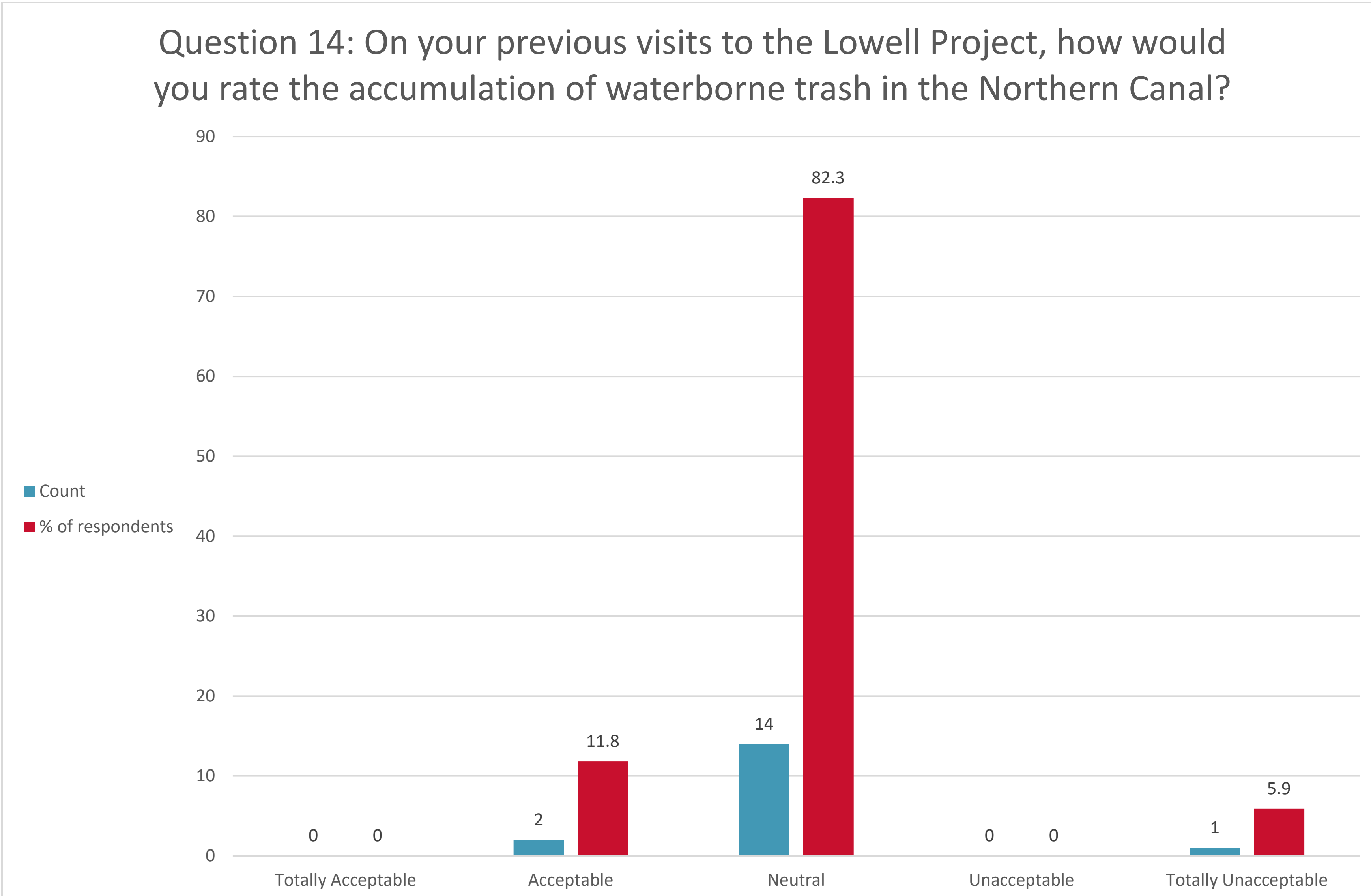


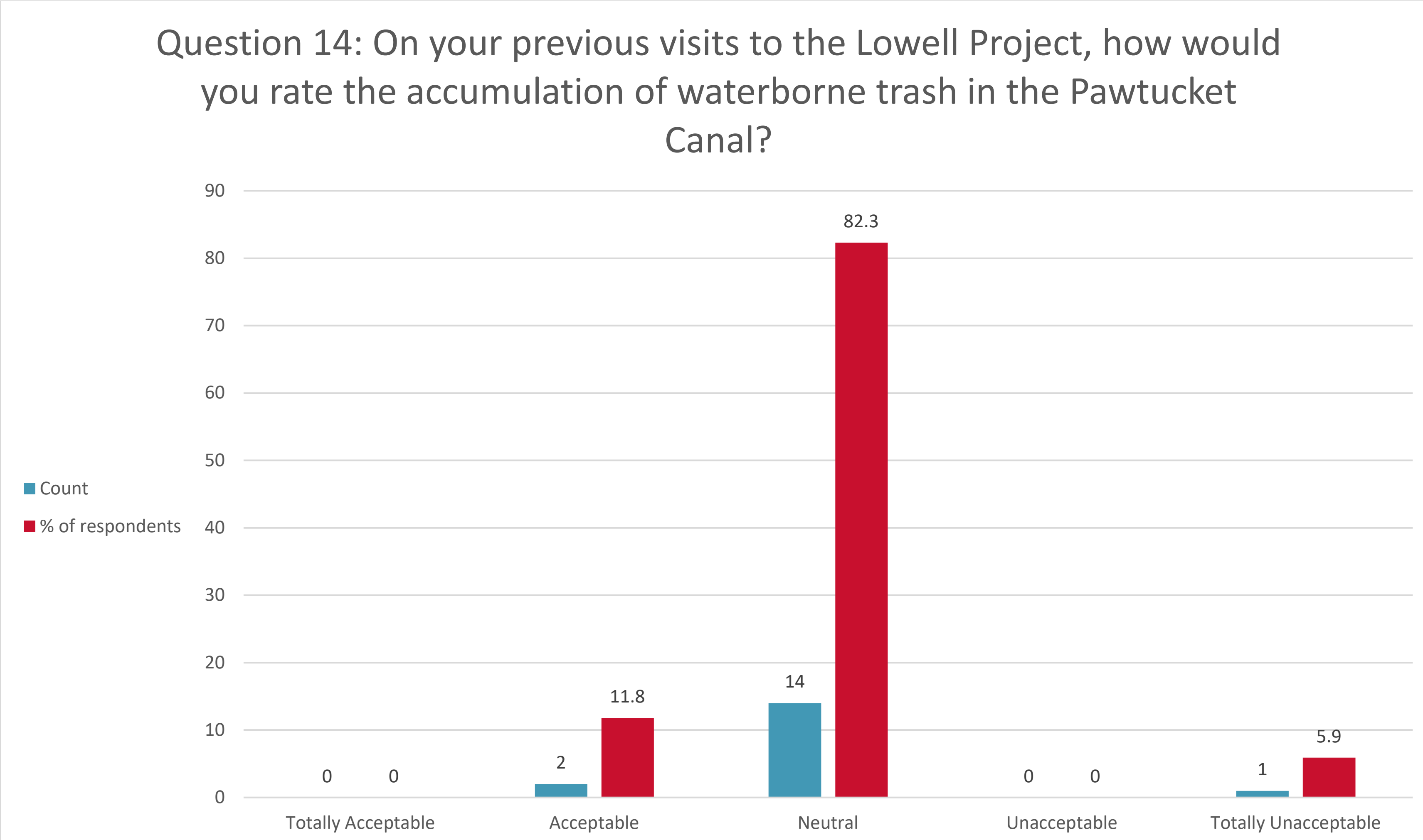
Question 14: On your previous visits to the Lowell Project, how would you rate the accumulation of waterborne trash in the Eastern Canal?
80
70
60
50
40
30
20
10
0
Count
% of respondents
0
0
2
11.1
12
66.7
2
11.1
2
11.1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable



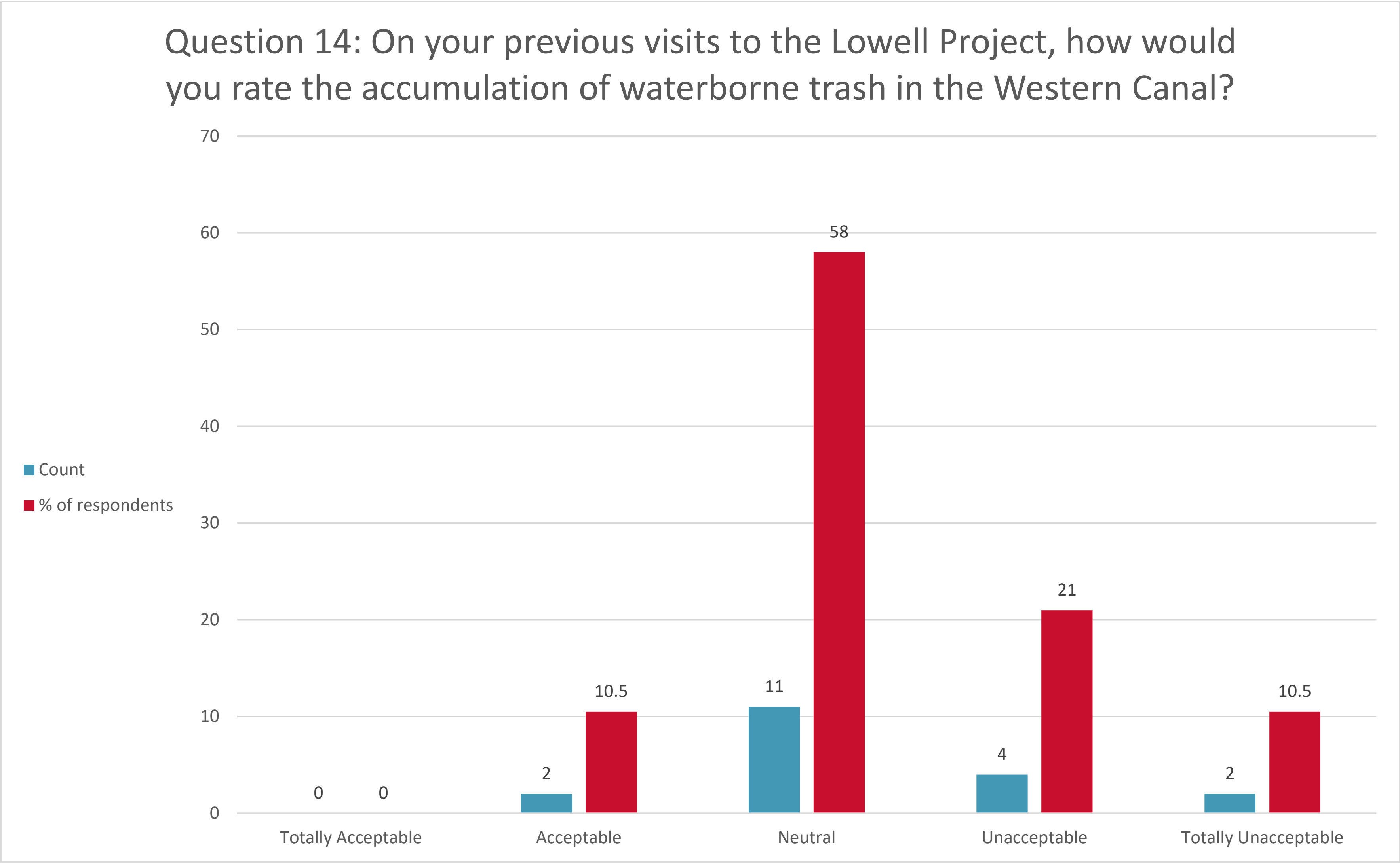
Question 14: On your previous visits to the Lowell Project, how would you rate the accumulation of waterborne trash in the Hamilton Canal?
70
60
50
40
30
20
10
0
Count
% of respondents
0
0
4
20
13
65
2
10
1
5
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 14: On your previous visits to the Lowell Project, how would you rate the accumulation of waterborne trash in the Merrimack Canal?
Count
% of respondents
70
60
50
40
30
20
10
0
63.1
15.8
12
3
0
0
15.8
3
5.3
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

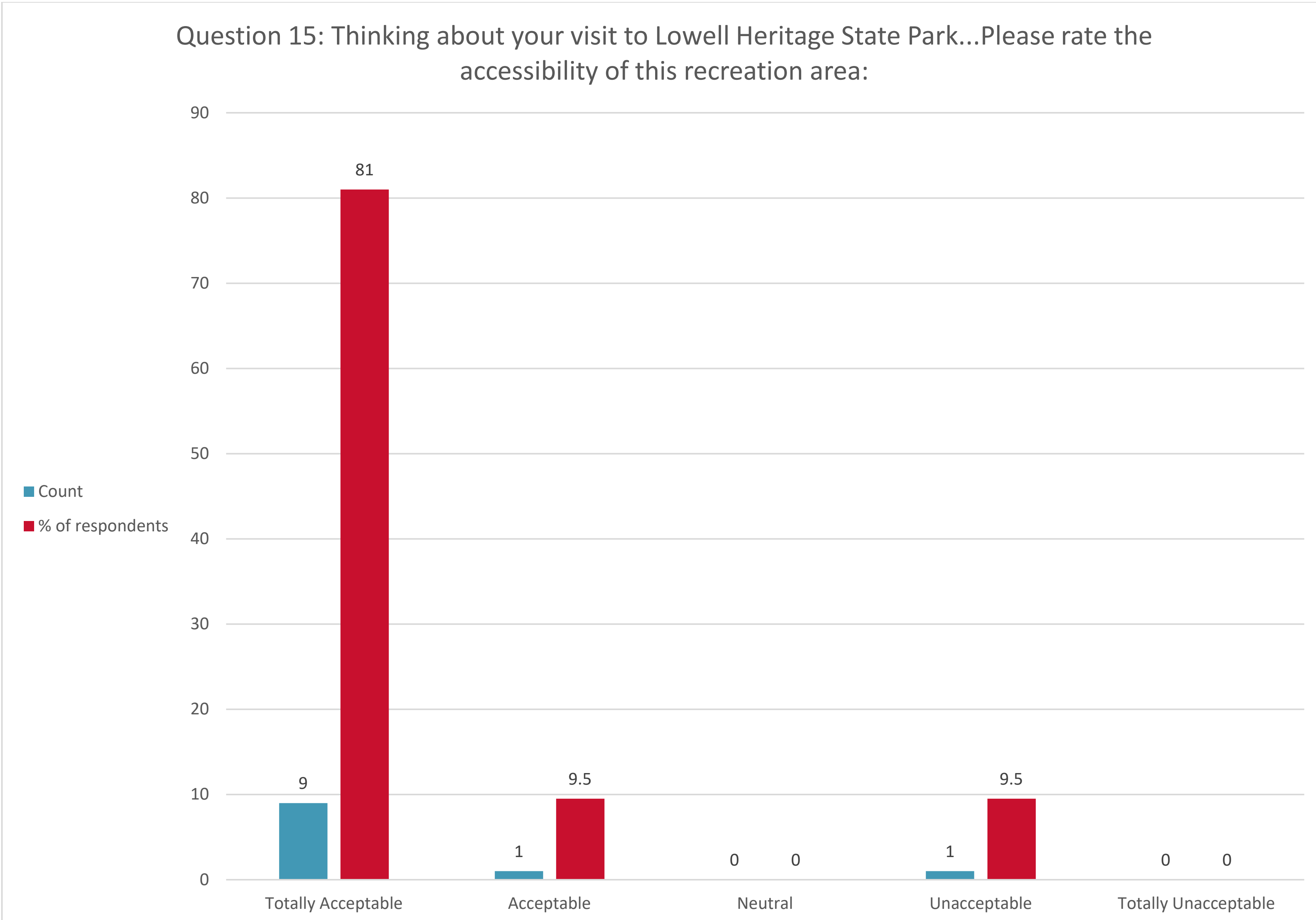

Question 14: On your previous visits to the Lowell Project, how would you rate the accumulation of waterborne trash in the Northern Canal?
Count
% of respondents
90
80
70
60
50
40
30
20
10
0
82.3
11.8
14
2
5.9
1
0
0
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

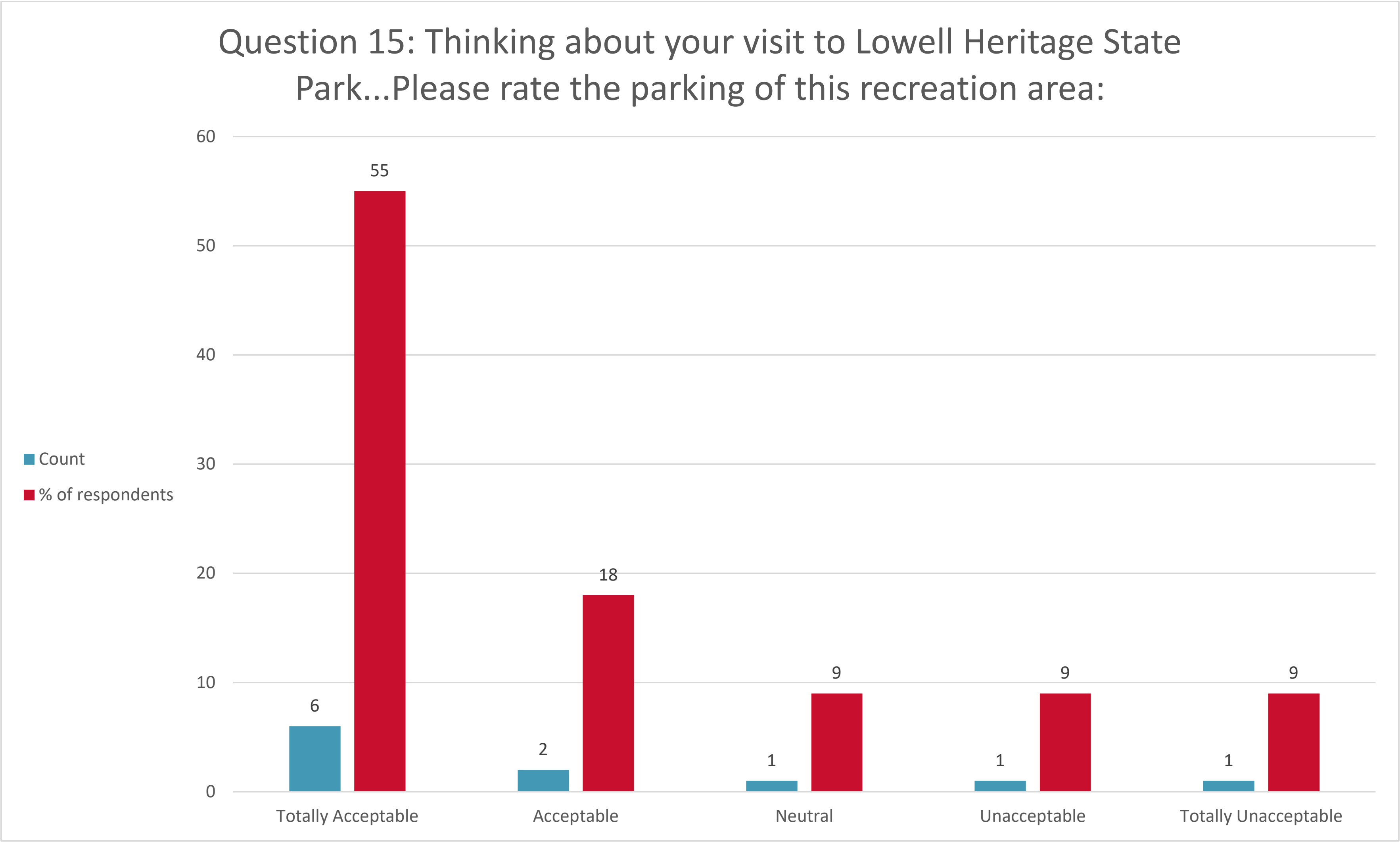


Question 14: On your previous visits to the Lowell Project, how would you rate the accumulation of waterborne trash in the Pawtucket Canal?
Count
% of respondents
90
80
70
60
50
40
30
20
10
0
82.3
11.8
14
2
5.9
1
0
0
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

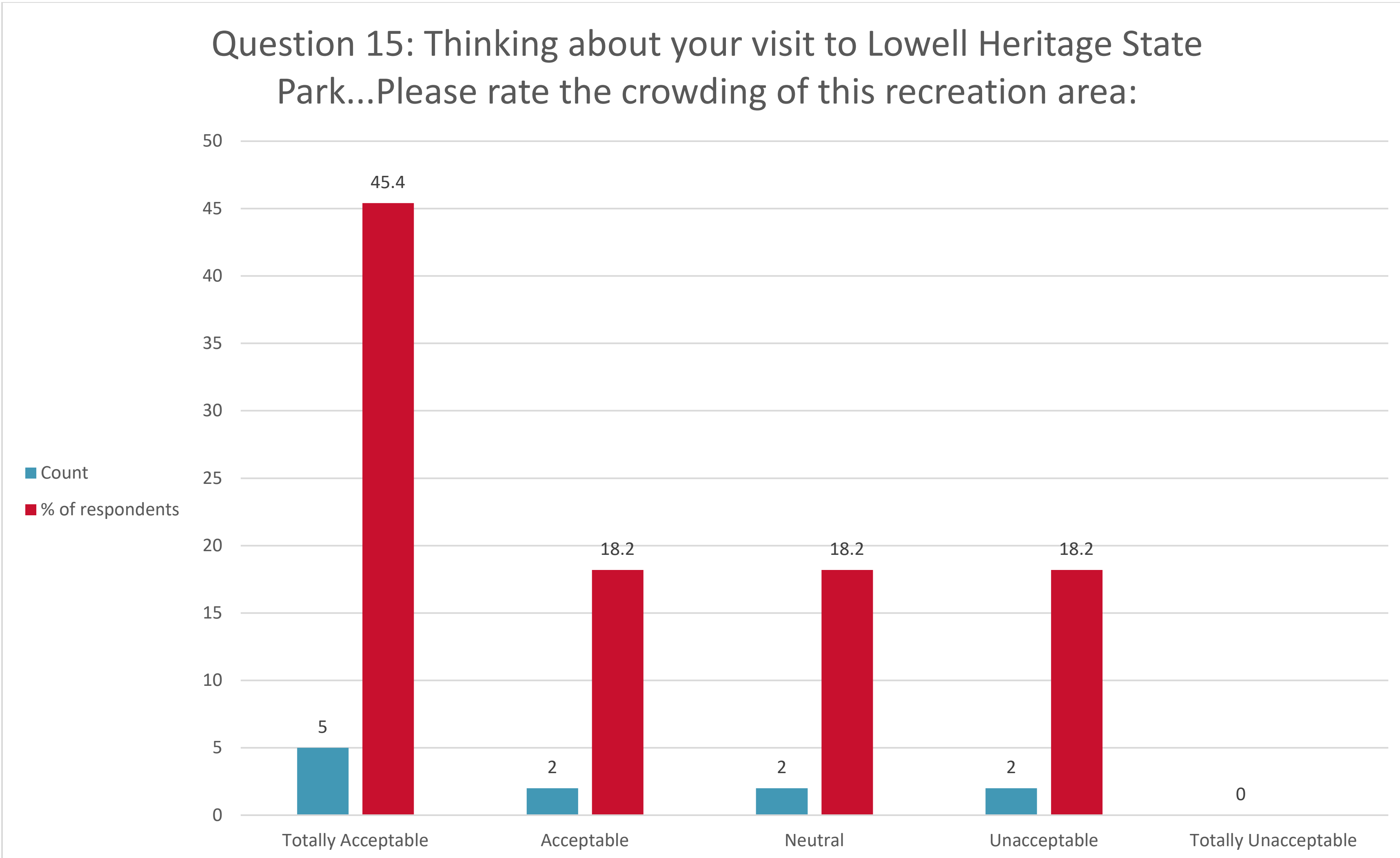


Question 14: On your previous visits to the Lowell Project, how would you rate the accumulation of waterborne trash in the Western Canal?
70
60
50
40
30
20
10
0
Count
% of respondents
0
0
2
10.5
11
58
4
21
2
10.5
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

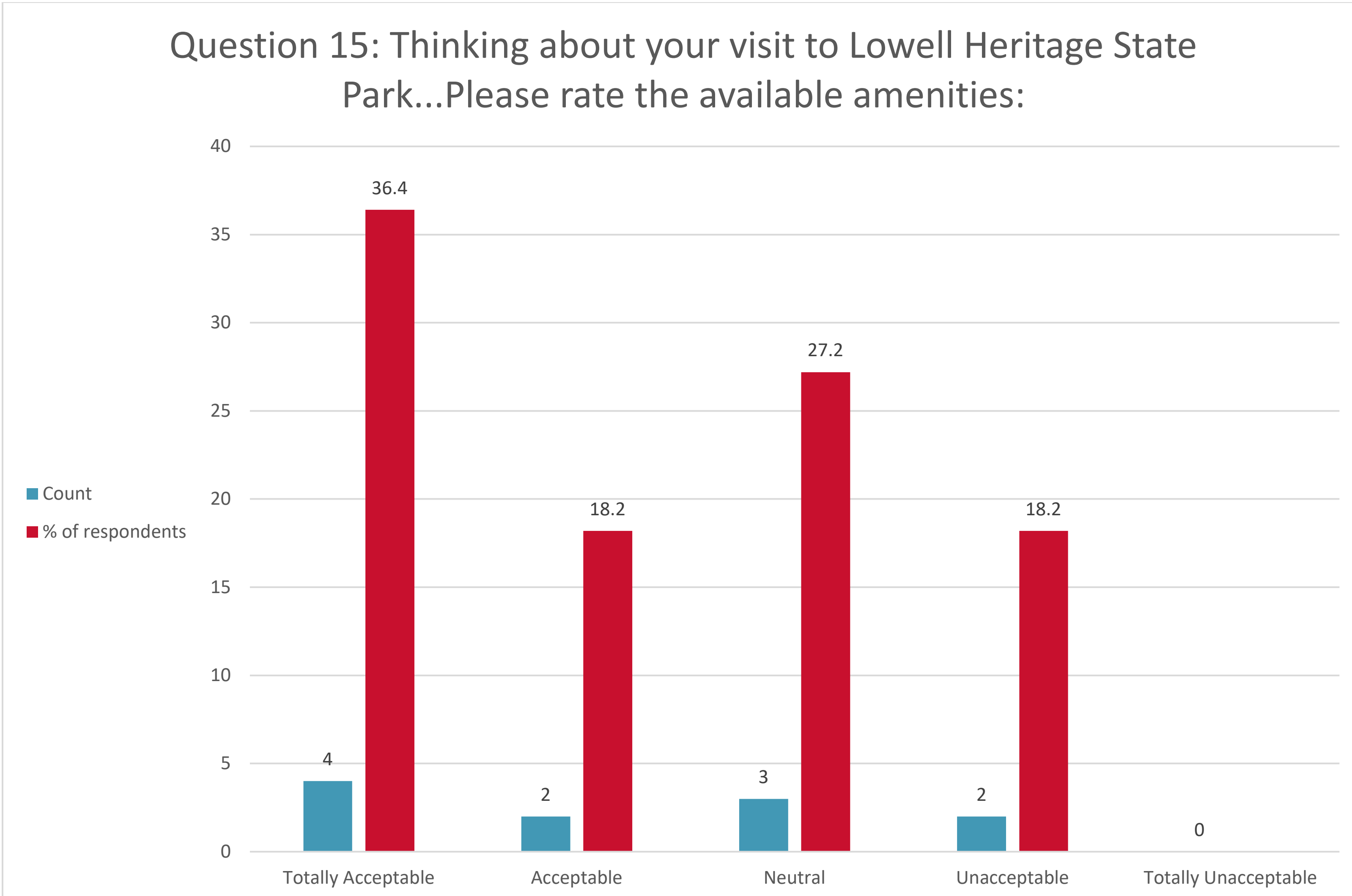

Question 15: Thinking about your visit to Lowell Heritage State Park...Please rate the accessibility of this recreation area:
90
80
70
60
50
40
30
20
10
0
81
9
9.5
1
0
0
1
9.5
0
0
Count
% of respondents
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable



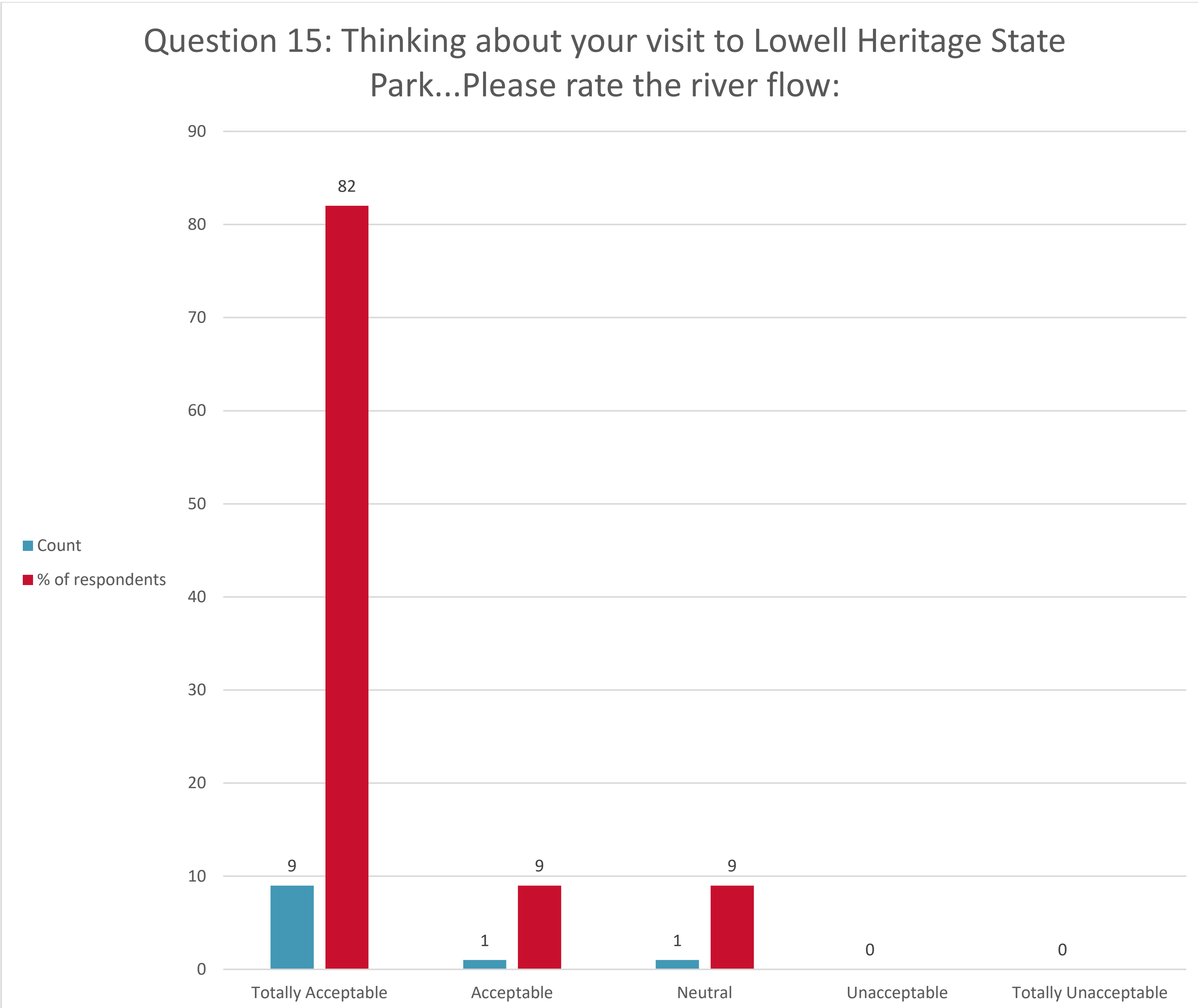
Question 15: Thinking about your visit to Lowell Heritage State Park...Please rate the parking of this recreation area:
Count
% of respondents
60
50
40
30
20
10
0
6
55
2
18
1
9
1
9
1
9
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable



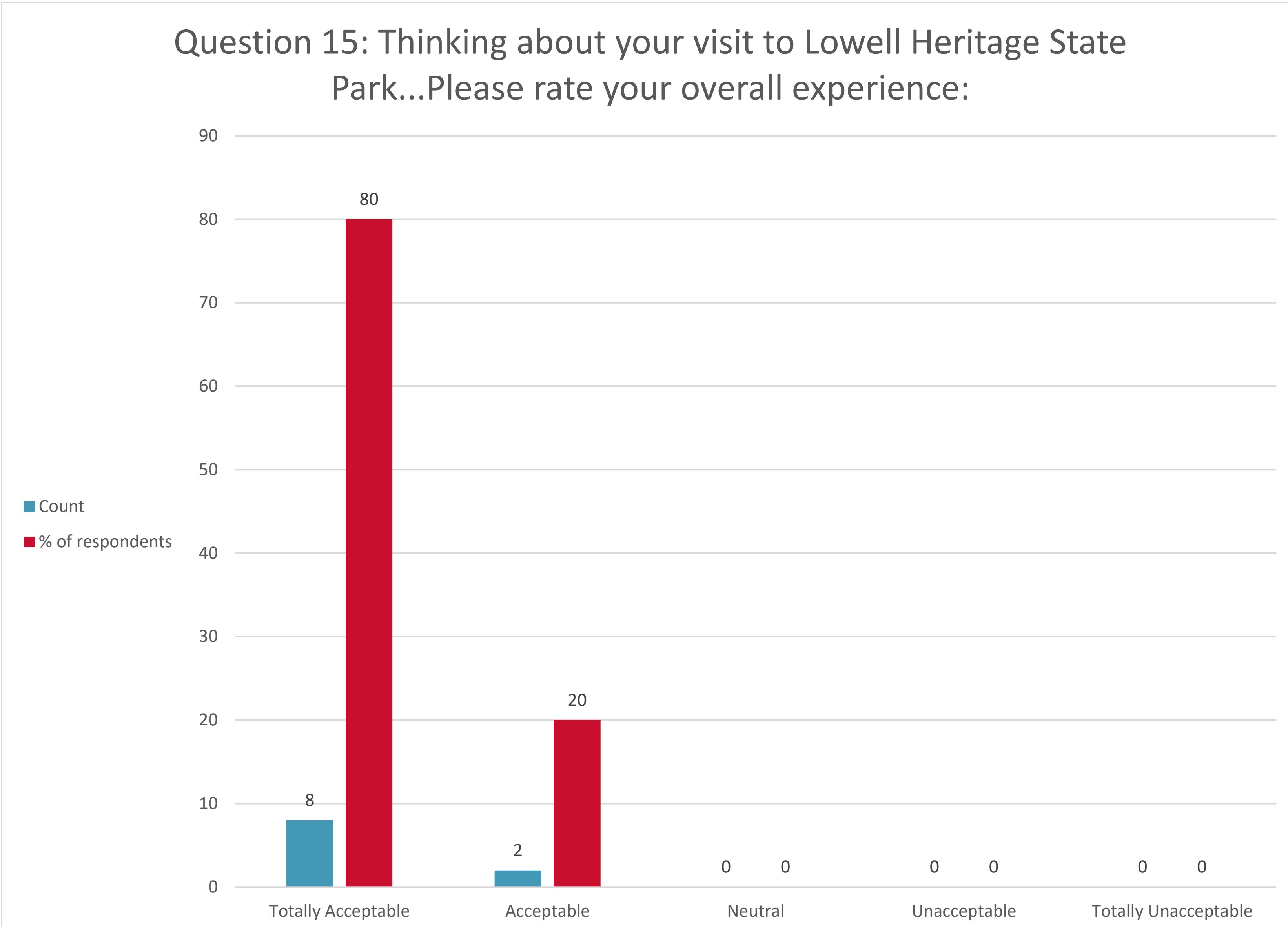
Question 15: Thinking about your visit to Lowell Heritage State Park...Please rate the crowding of this recreation area:
Count
% of respondents
50
45
40
35
30
25
20
15
10
5
0
45.4
5
18.2
2
18.2
2
18.2
2
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

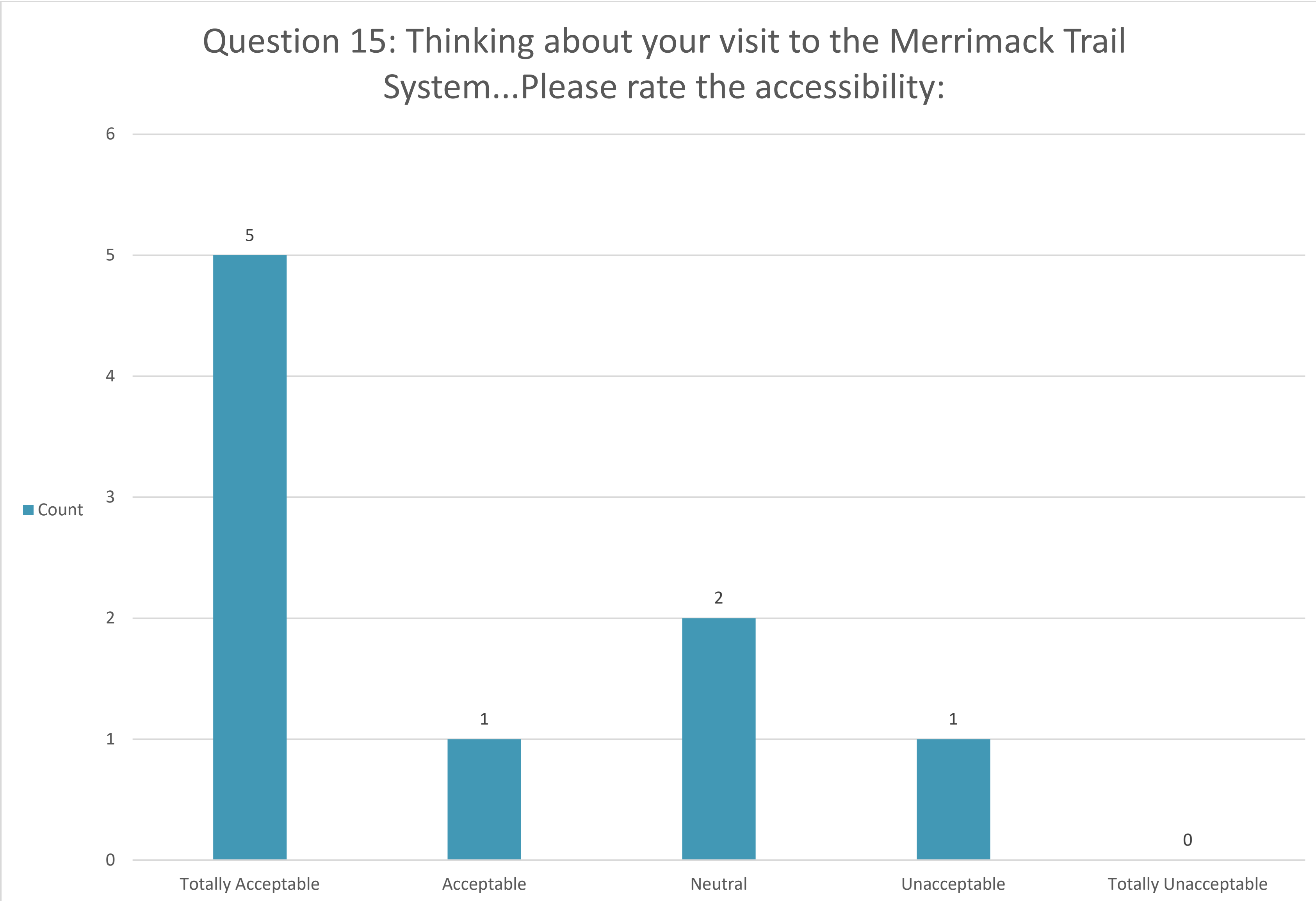


Question 15: Thinking about your visit to Lowell Heritage State Park...Please rate the available amenities:
Count
% of respondents
40
35
30
25
20
15
10
5
0
36.4
4
18.2
2
27.2
3
18.2
2
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

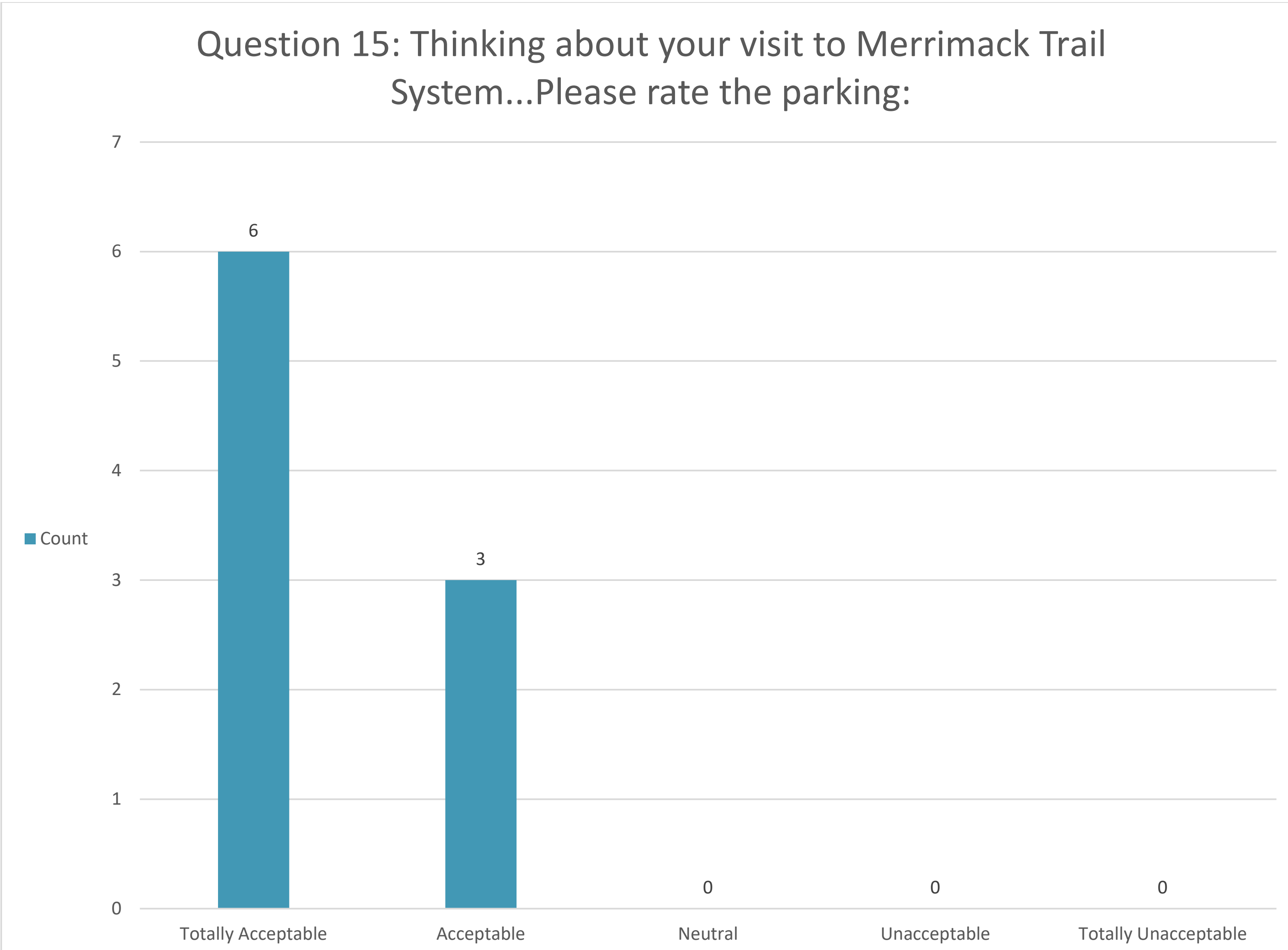


Question 15: Thinking about your visit to Lowell Heritage State Park...Please rate the river flow:
Count
% of respondents
90
80
70
60
50
40
30
20
10
0
82
9
9
1
9
1
9
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

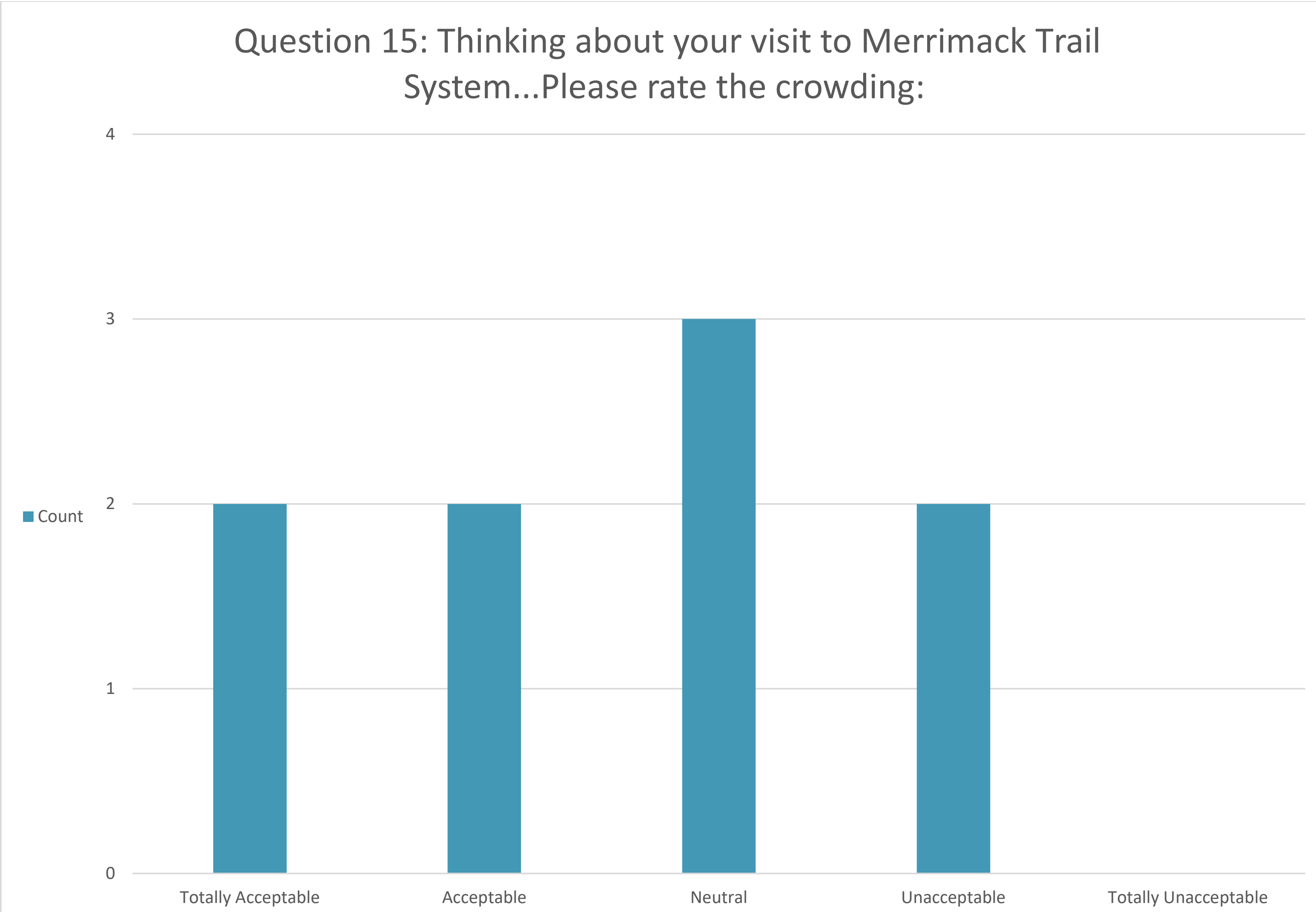

Question 15: Thinking about your visit to Lowell Heritage State Park...Please rate your overall experience:
90
80
70
60
50
40
30
20
10
0
Count
% of respondents
8
80
2
20
0
0
0
0
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable



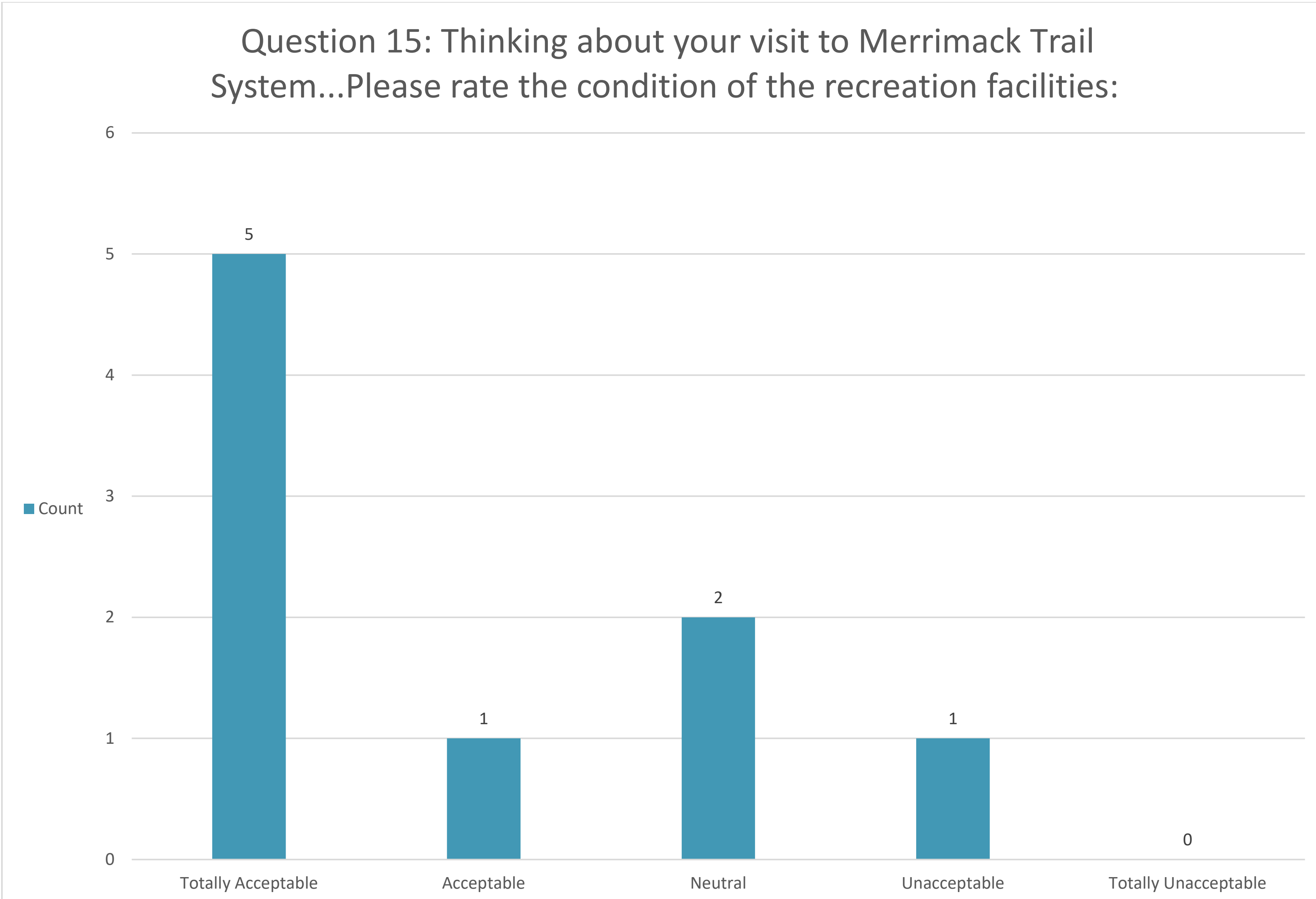
*Percentages not shown for respondent counts under ten.



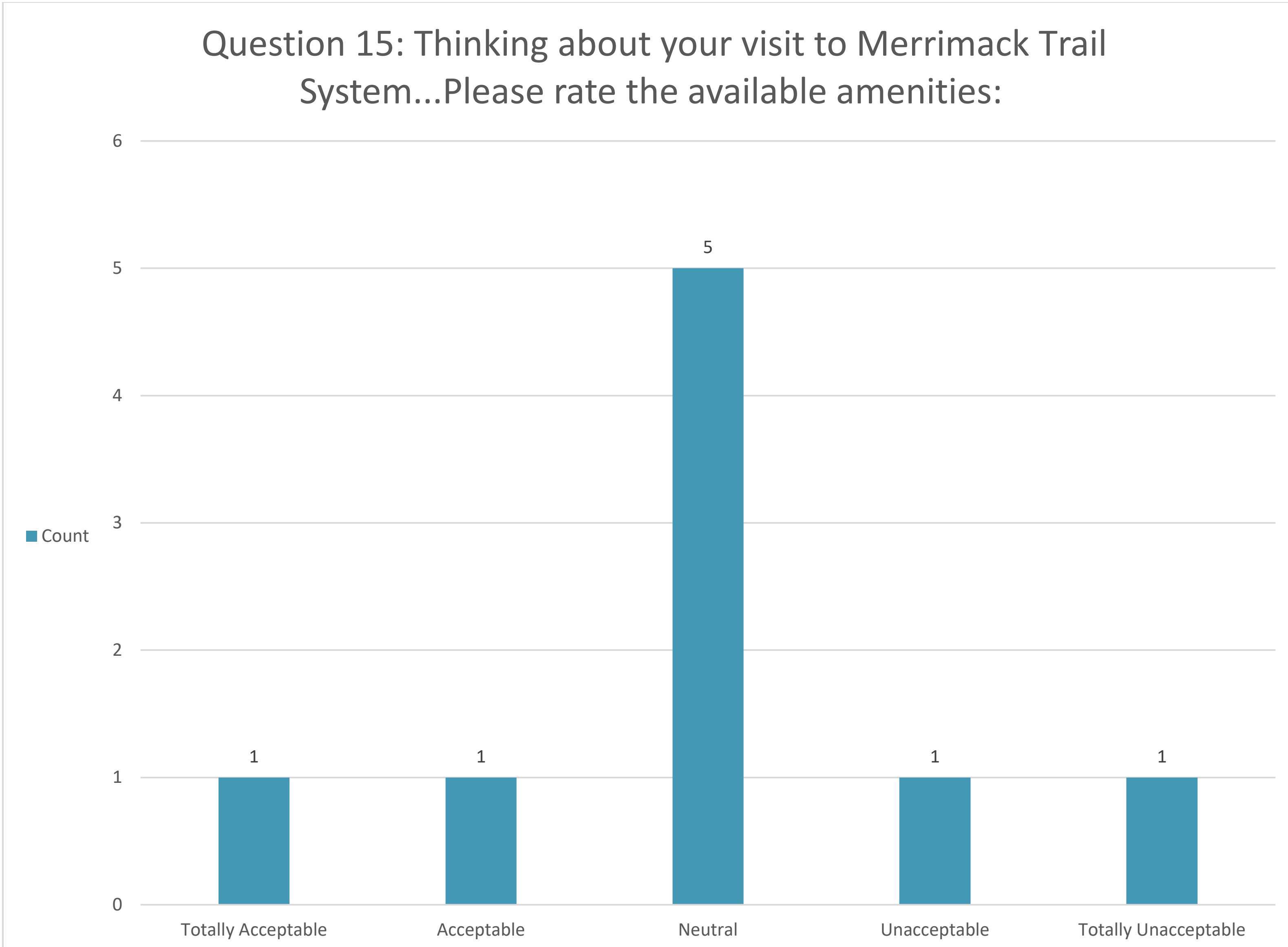
*Percentages not shown for respondent counts under ten.



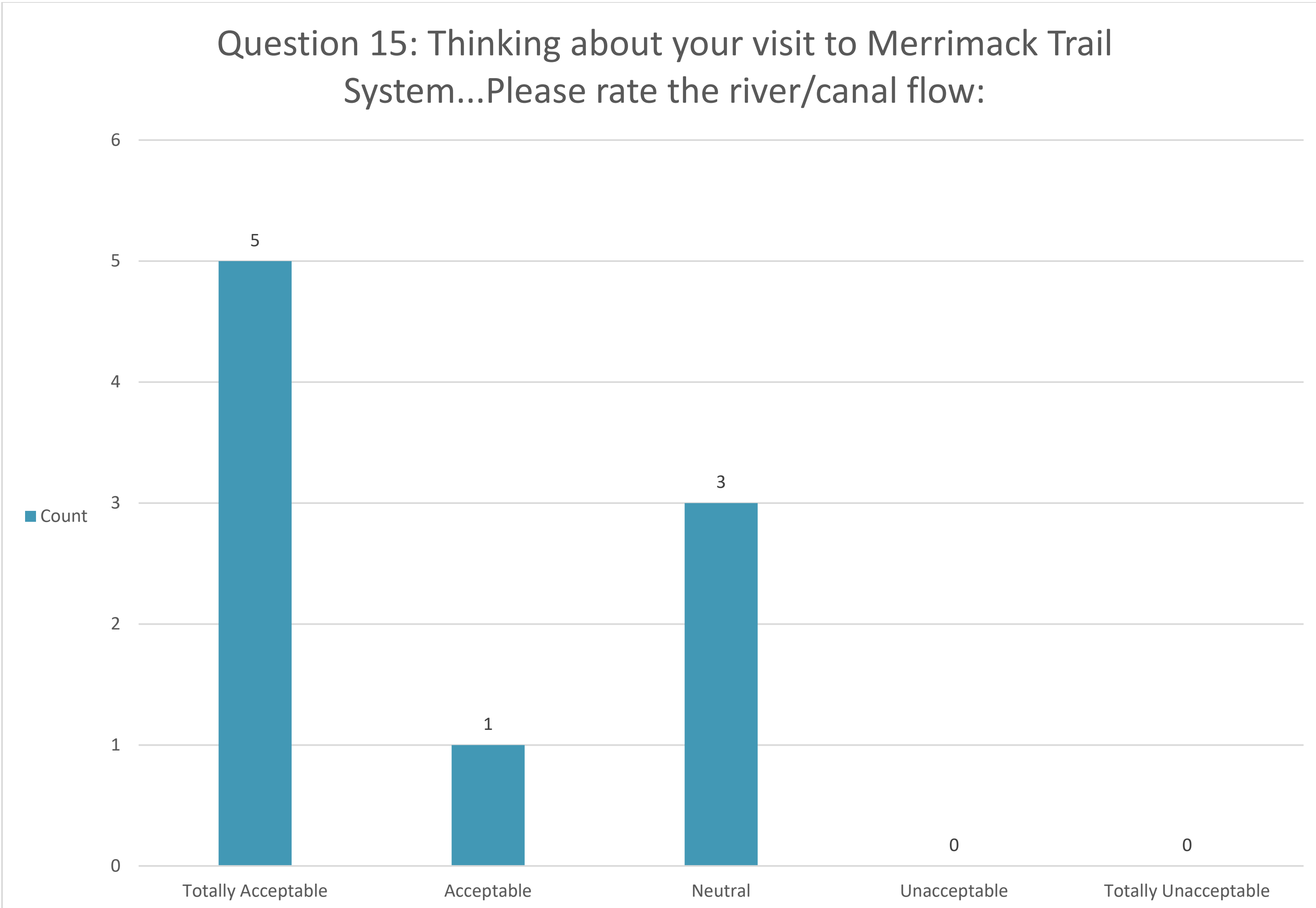
*Percentages not shown for respondent counts under ten.



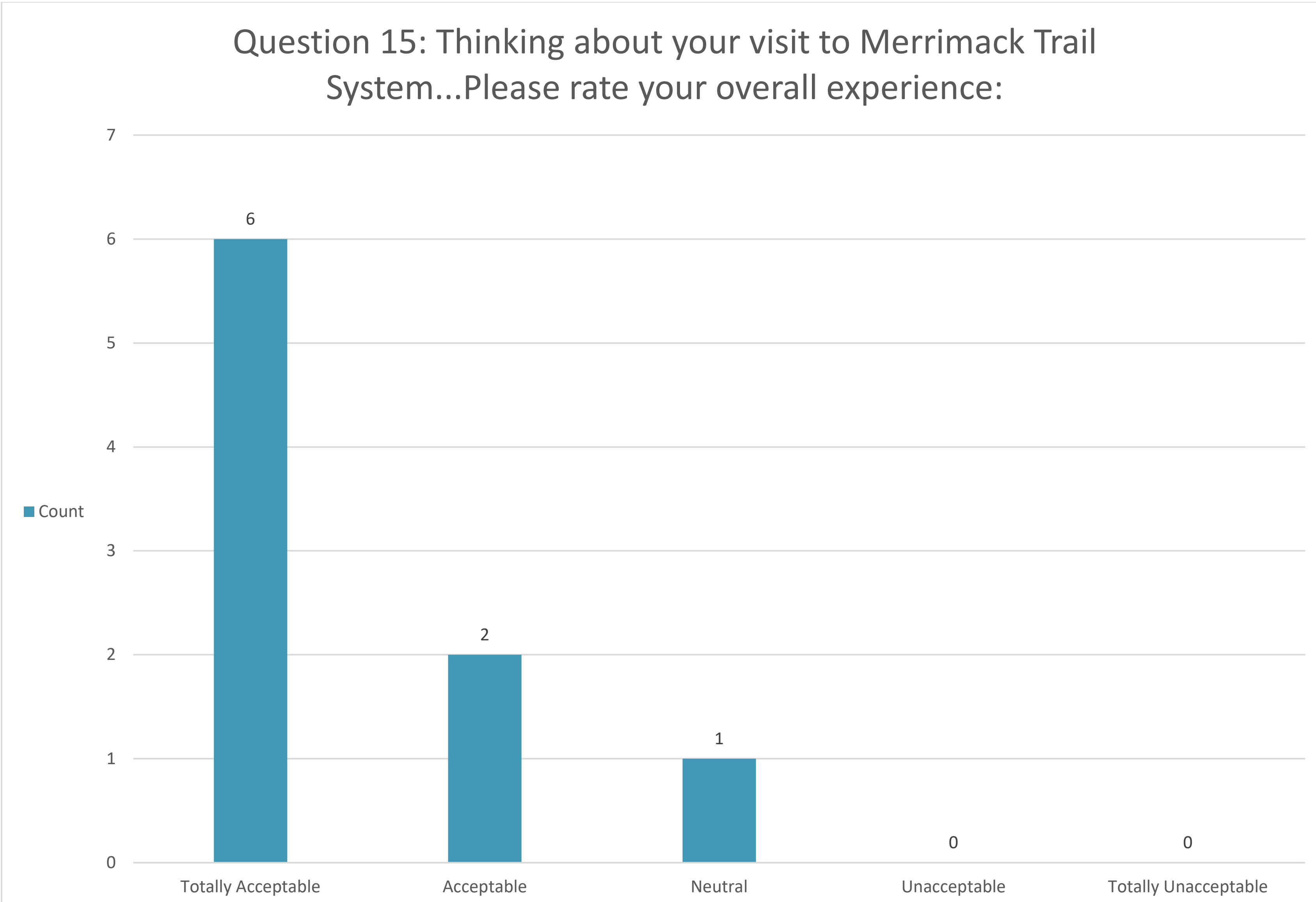
*Percentages not shown for respondent counts under ten.



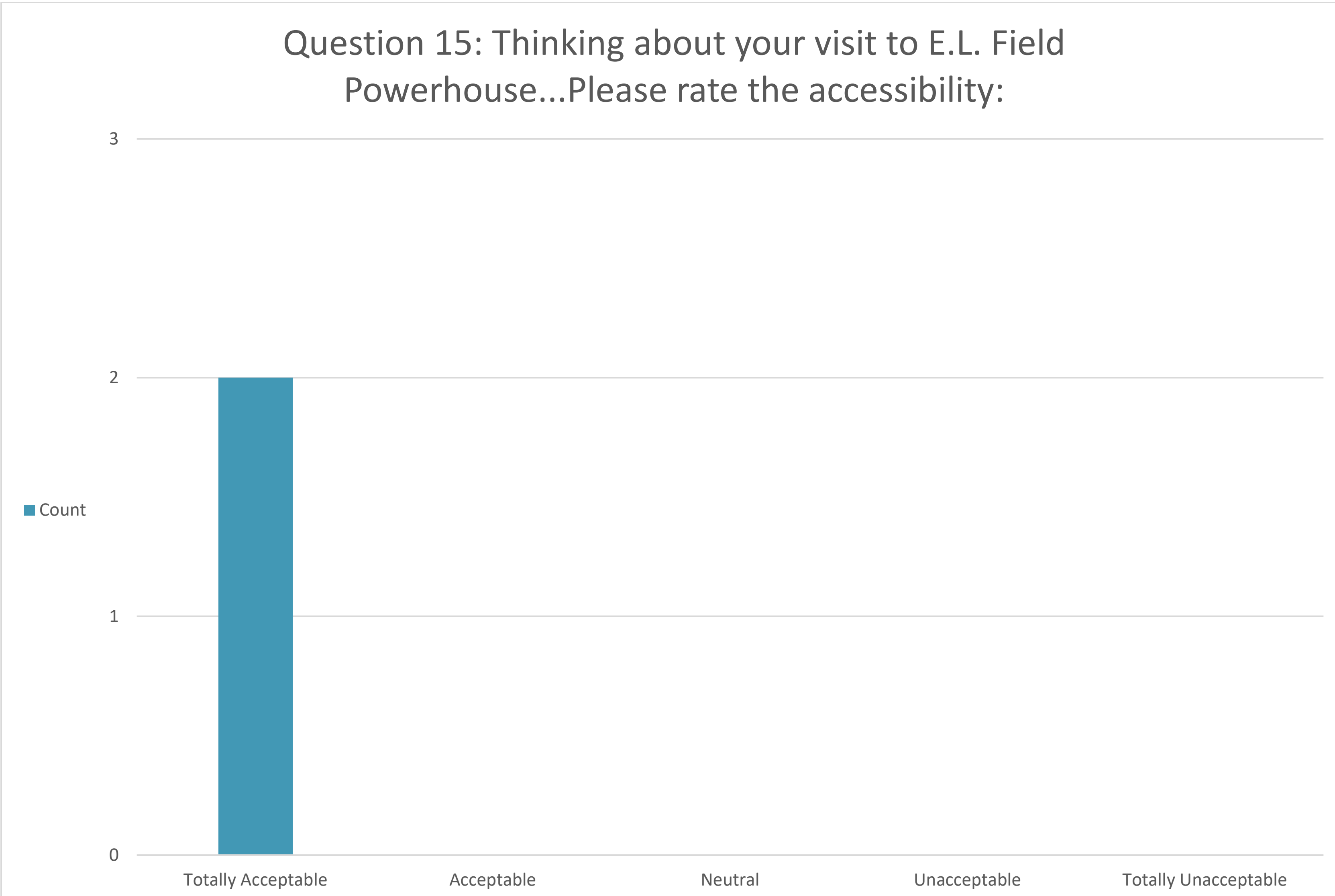
*Percentages not shown for respondent counts under ten.



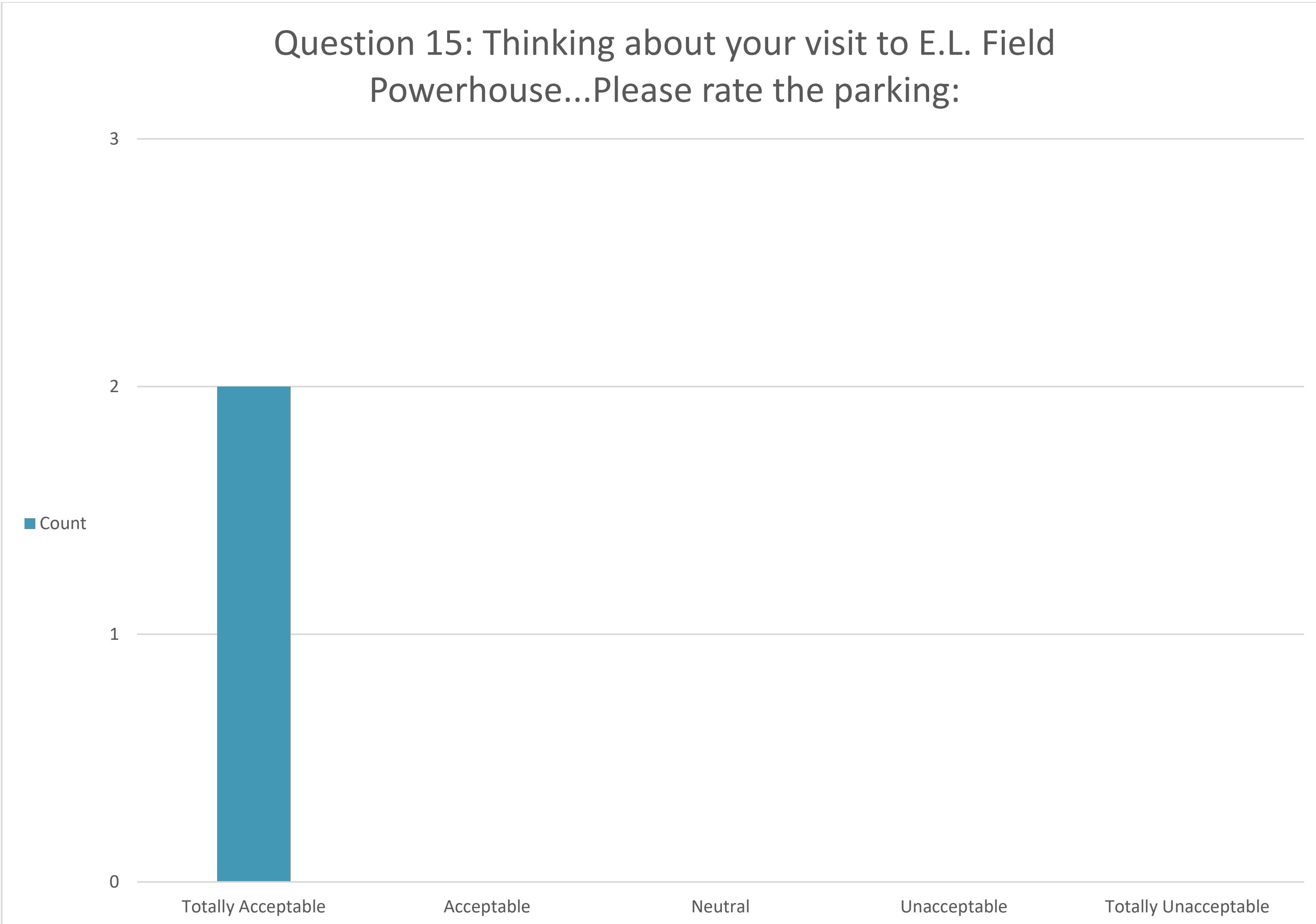
*Percentages not shown for respondent counts under ten.



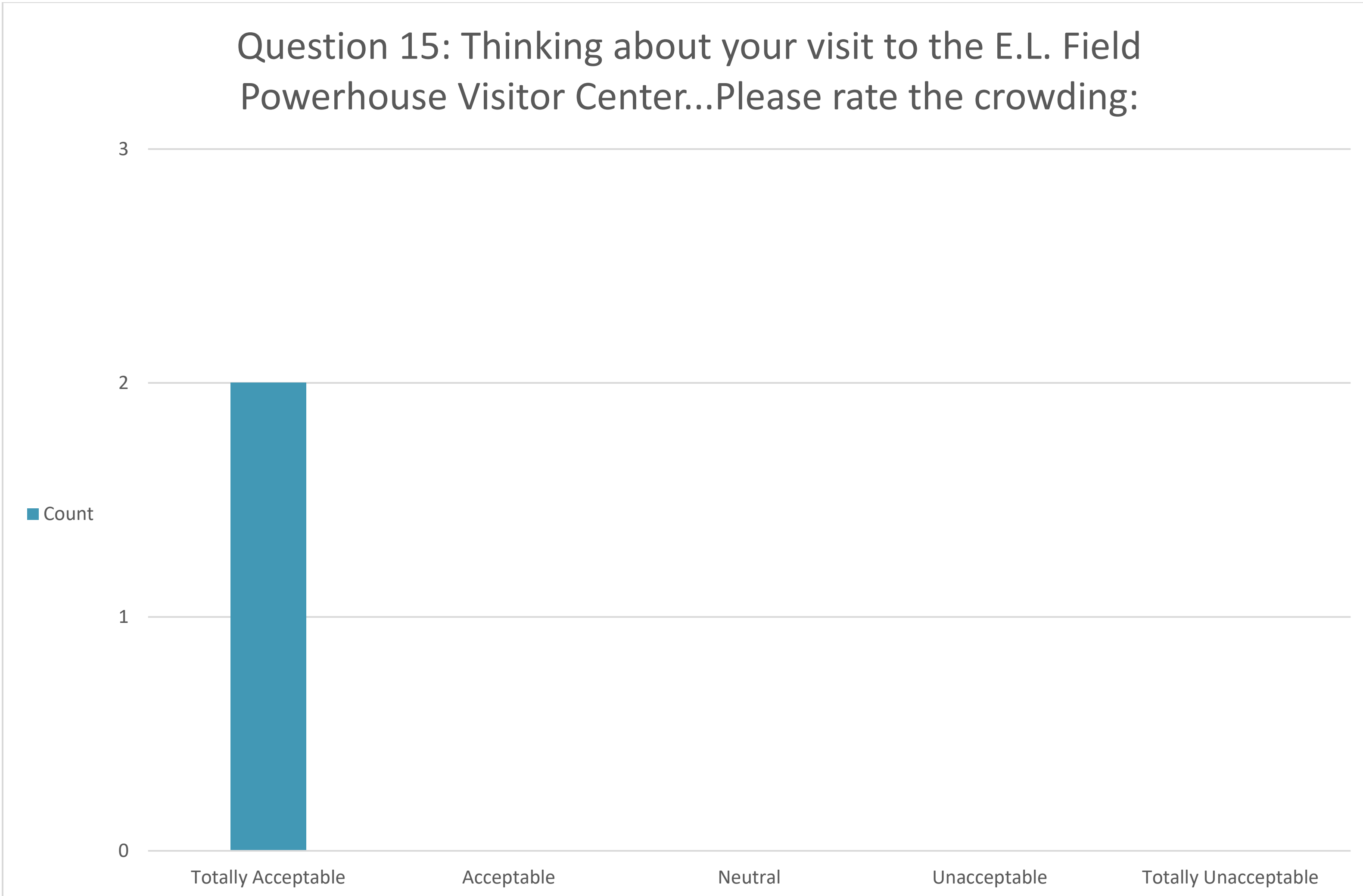
*Percentages not shown for respondent counts under ten.



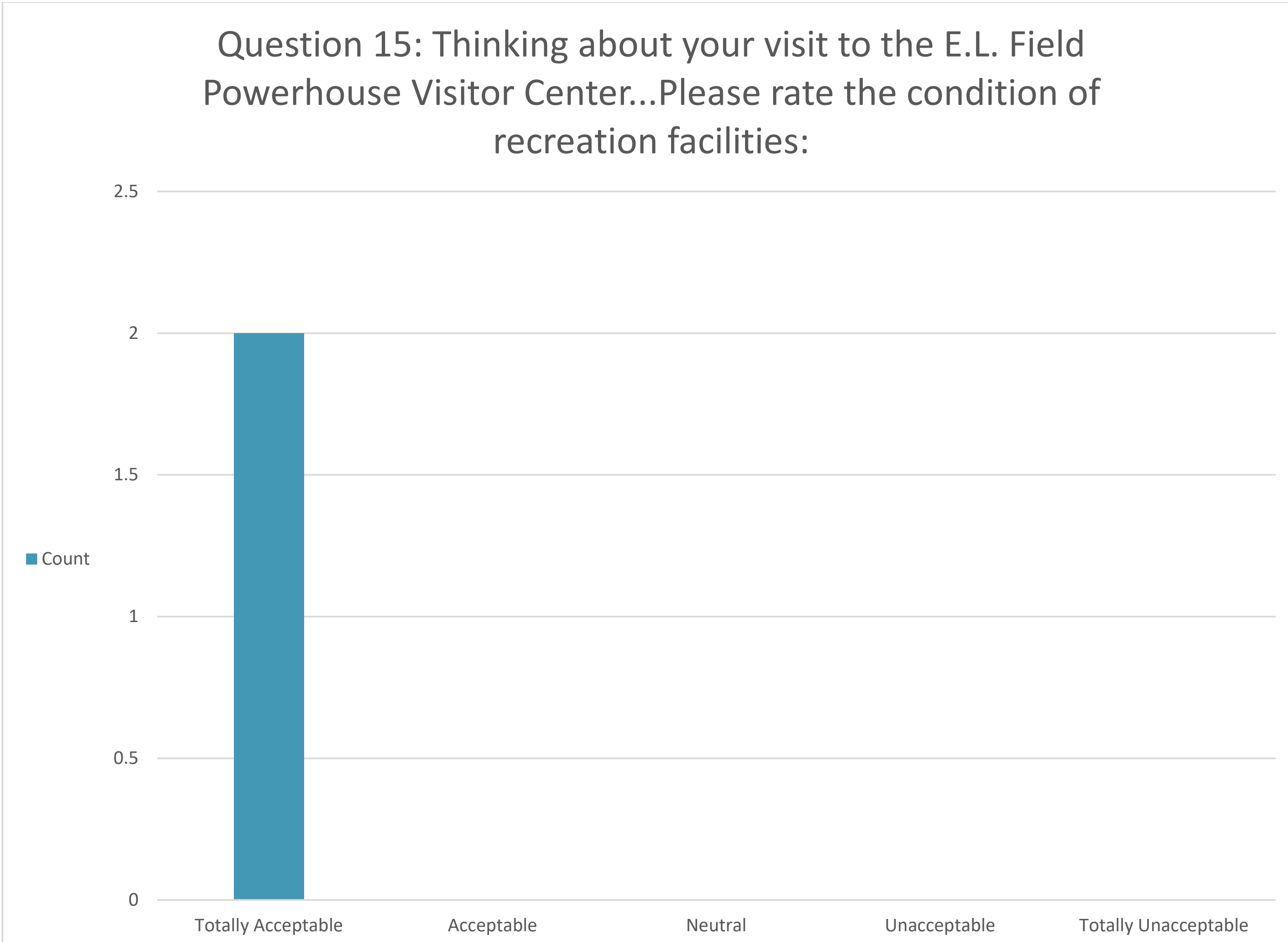
*Percentages not shown for respondent counts under ten.



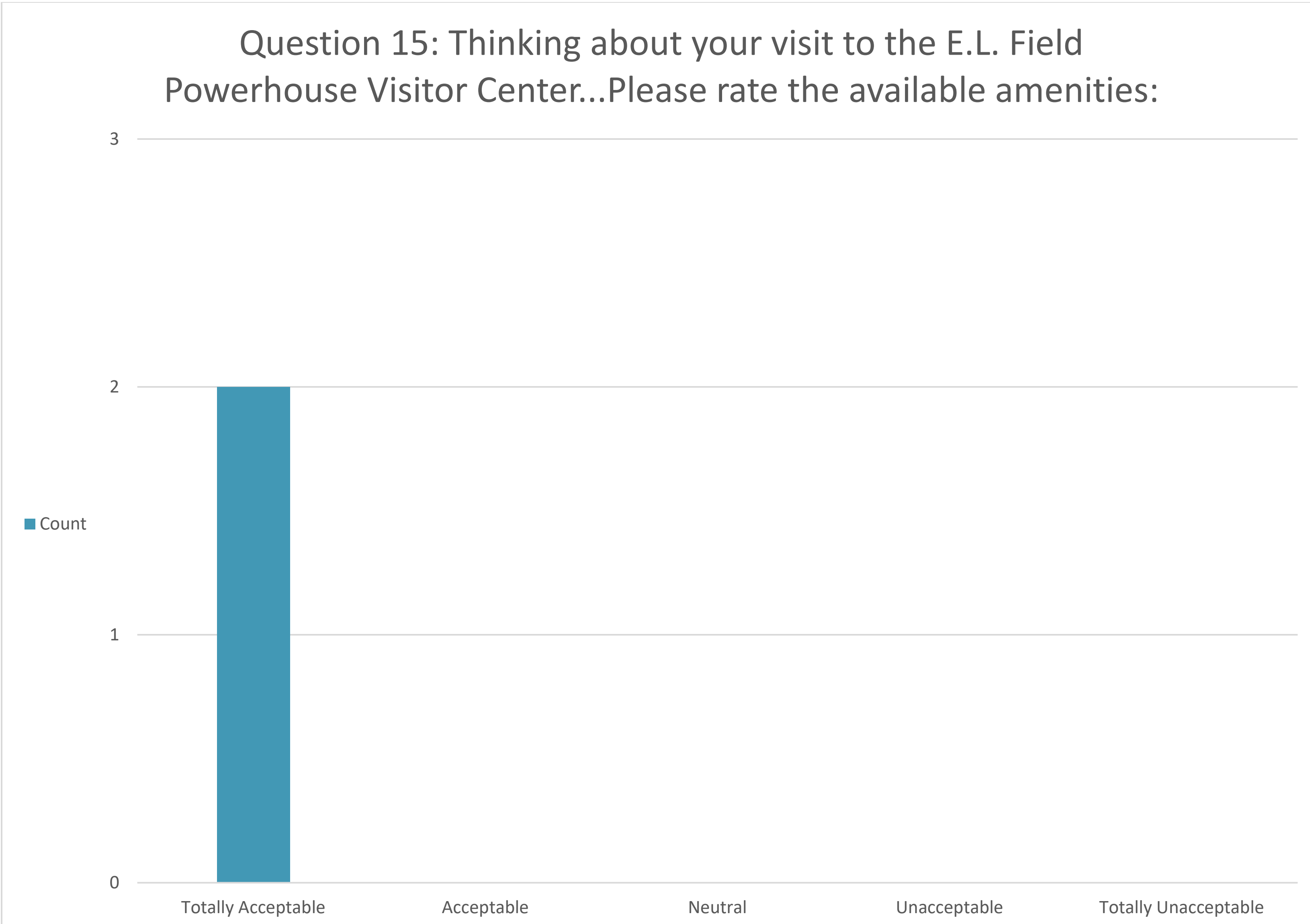
*Percentages not shown for respondent counts under ten.



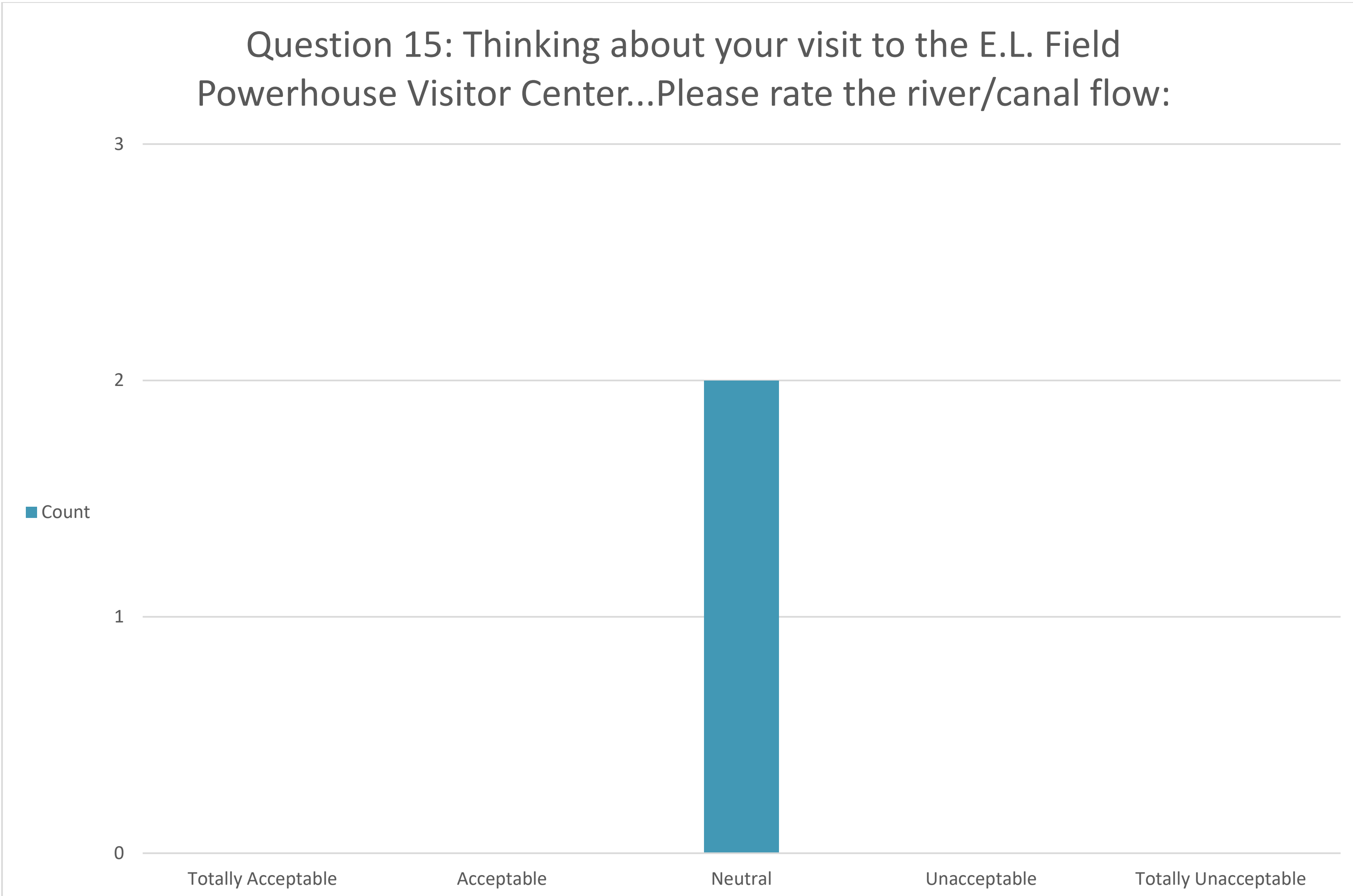
*Percentages not shown for respondent counts under ten.



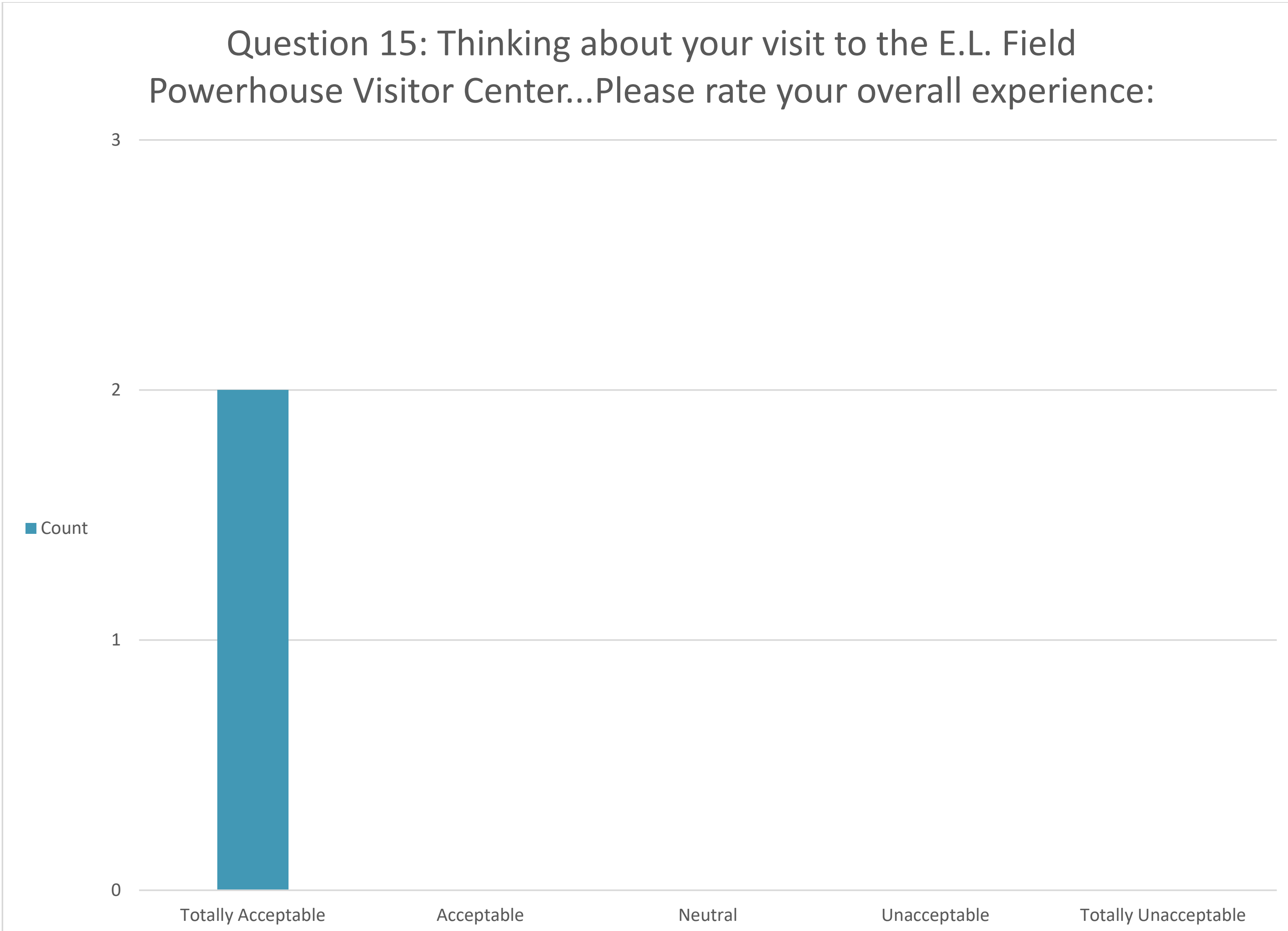
*Percentages not shown for respondent counts under ten.



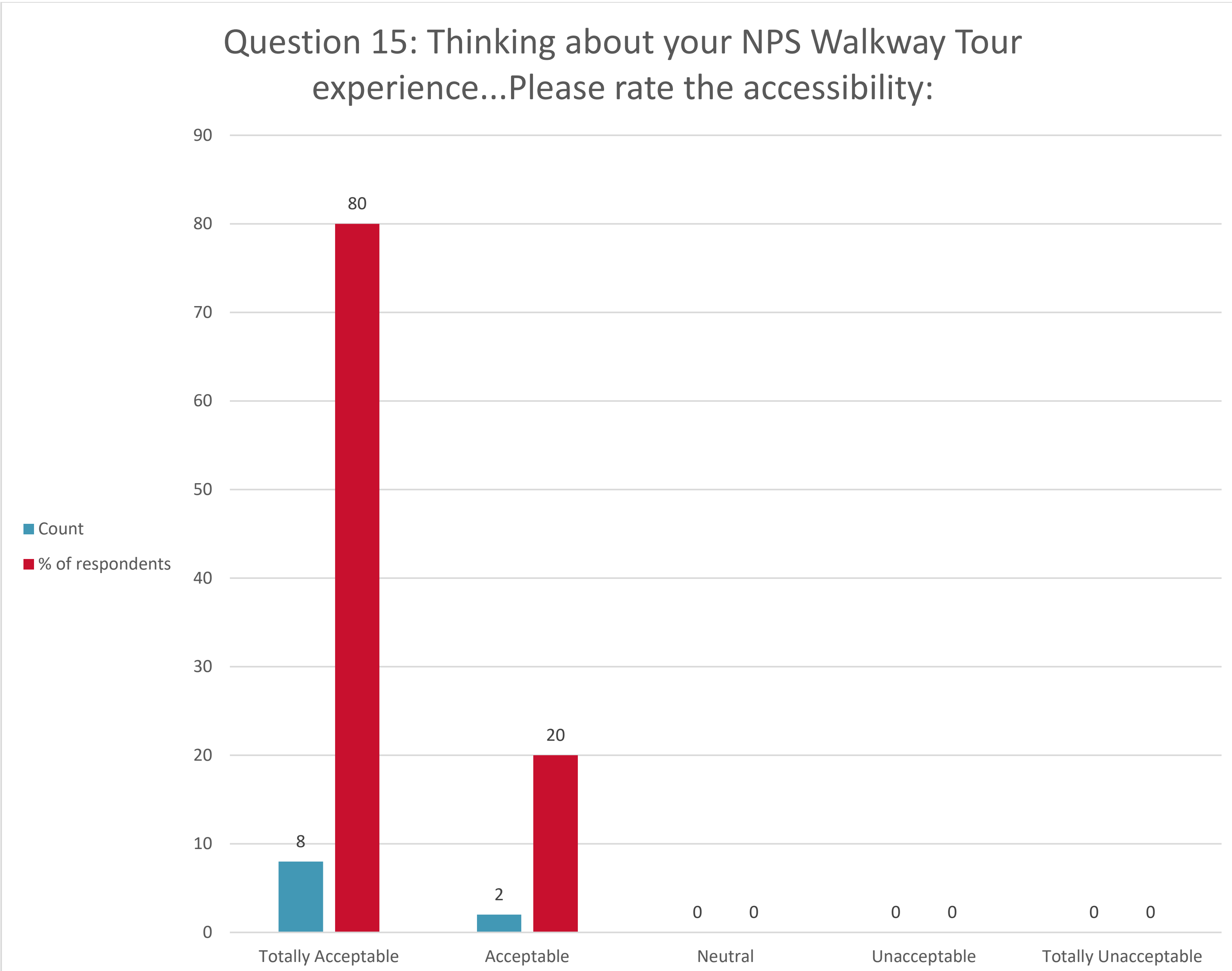
*Percentages not shown for respondent counts under ten.



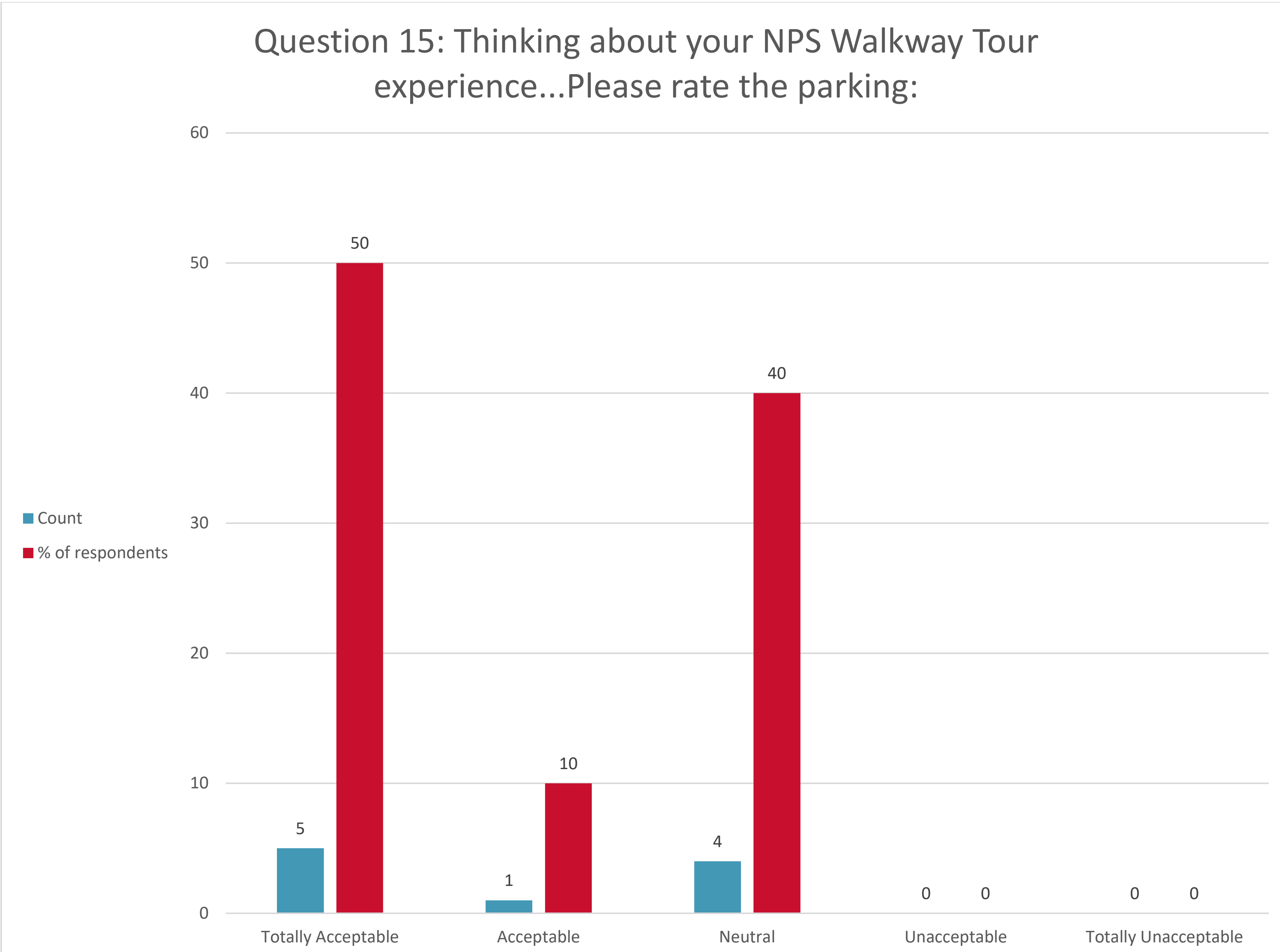
*Percentages not shown for respondent counts under ten.



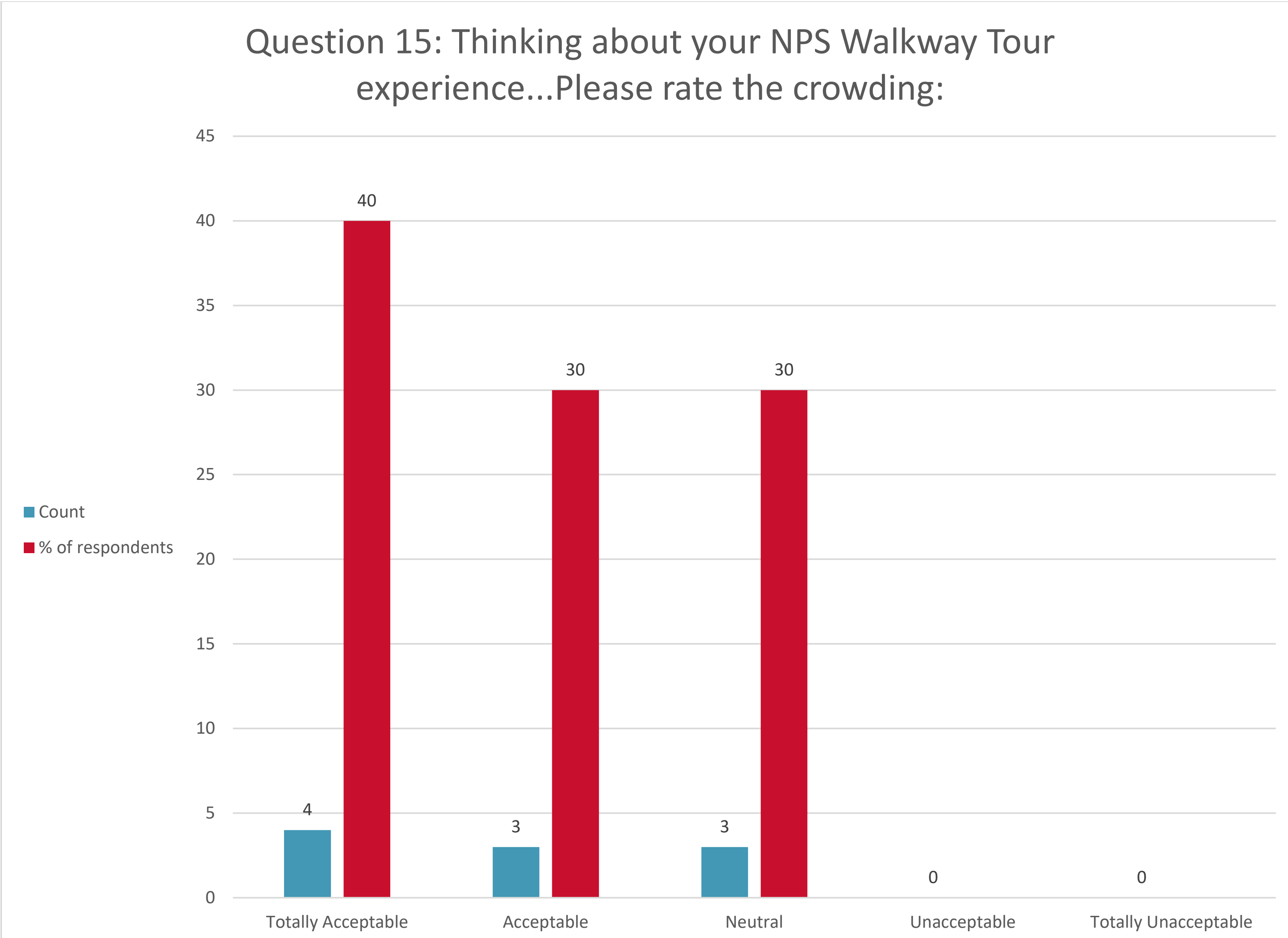
*Percentages not shown for respondent counts under ten.



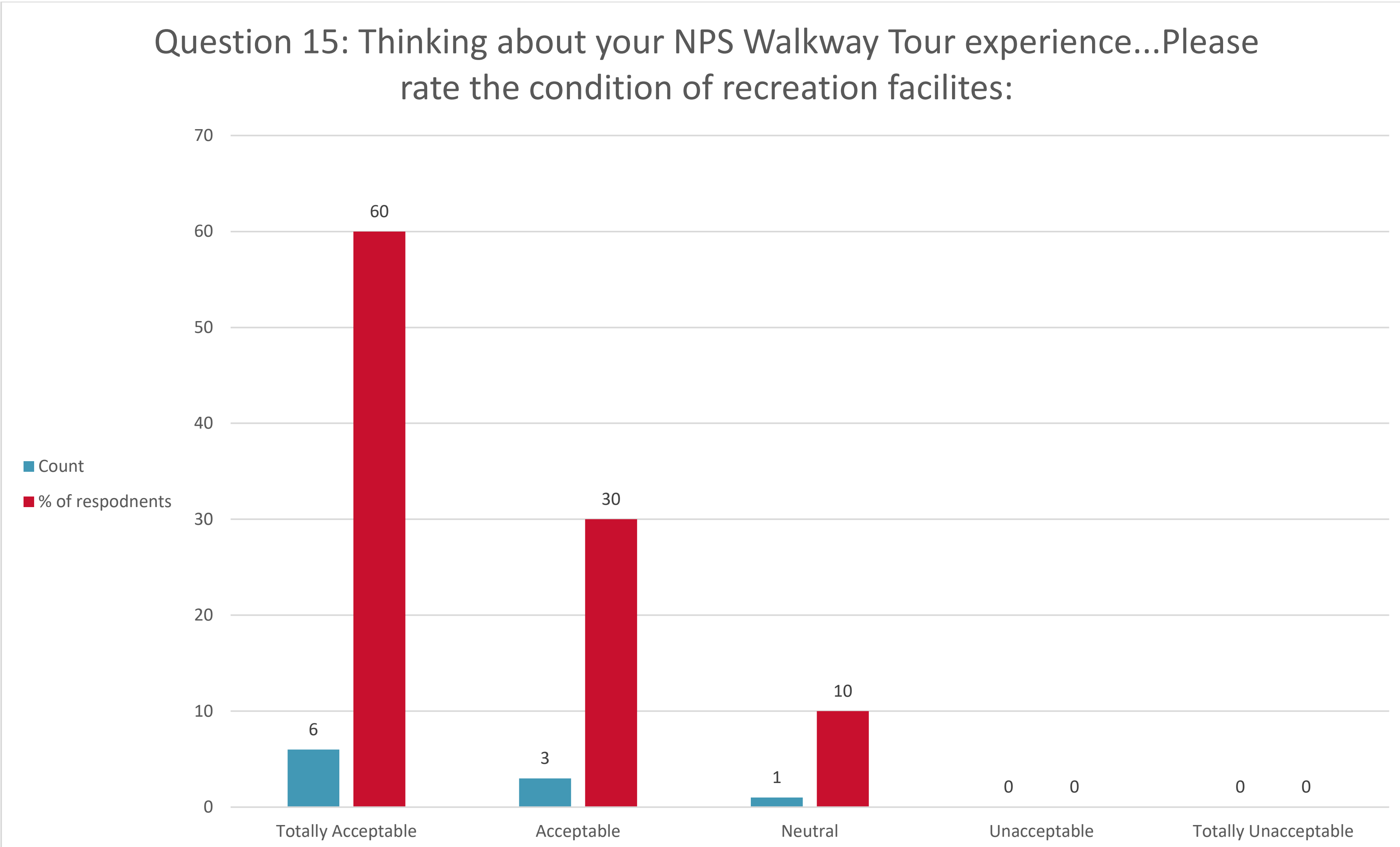
Question 15: Thinking about your NPS Walkway Tour experience...Please rate the accessibility:
90
80
70
60
50
40
30
20
10
0
Count
% of respondents
8
80
2
20
0
0
0
0
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable



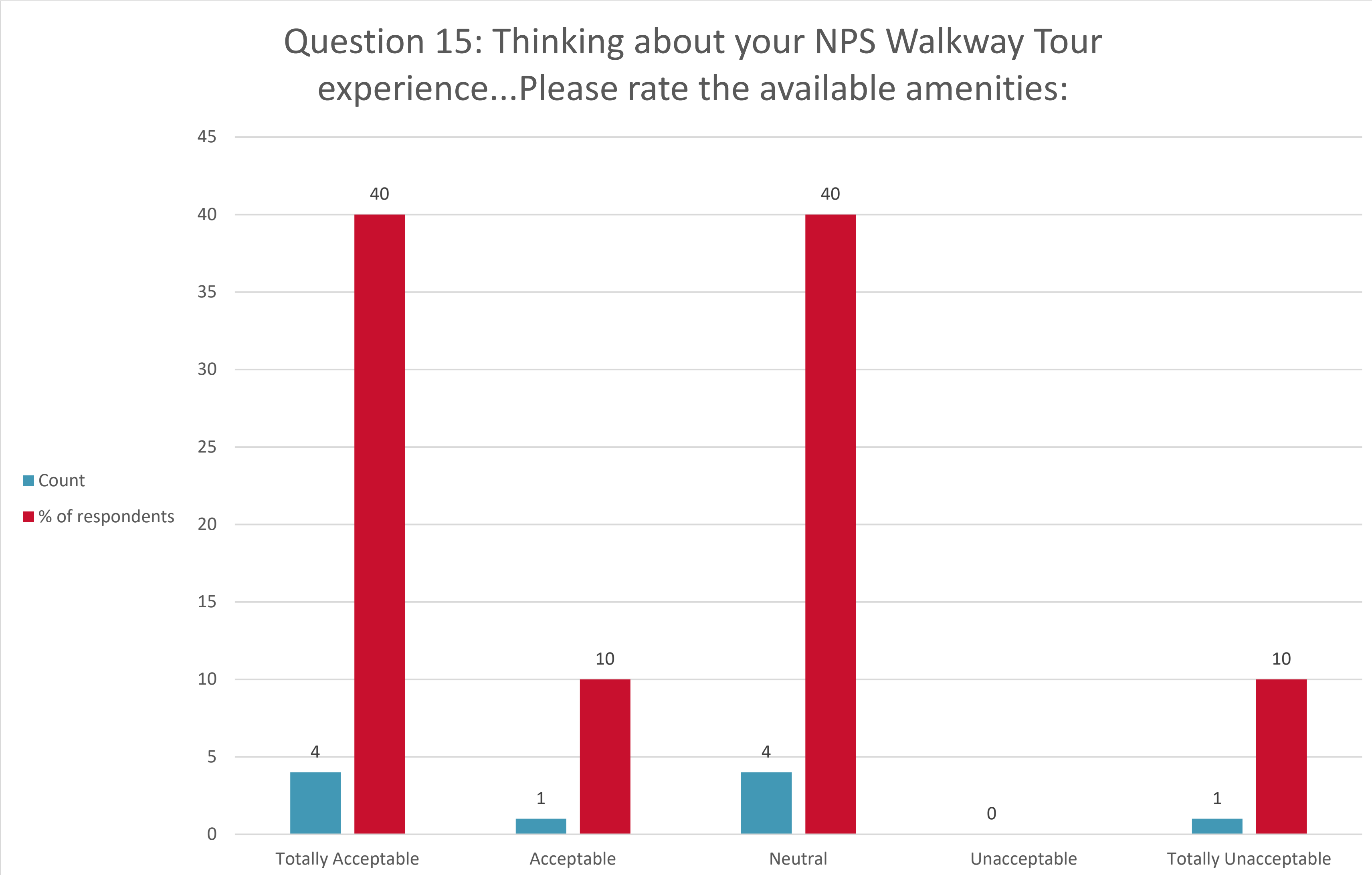
Question 15: Thinking about your NPS Walkway Tour experience...Please rate the parking:
60
50
40
30
20
10
0
Count
% of respondents
50
40
10
5
1
4
0
0
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable



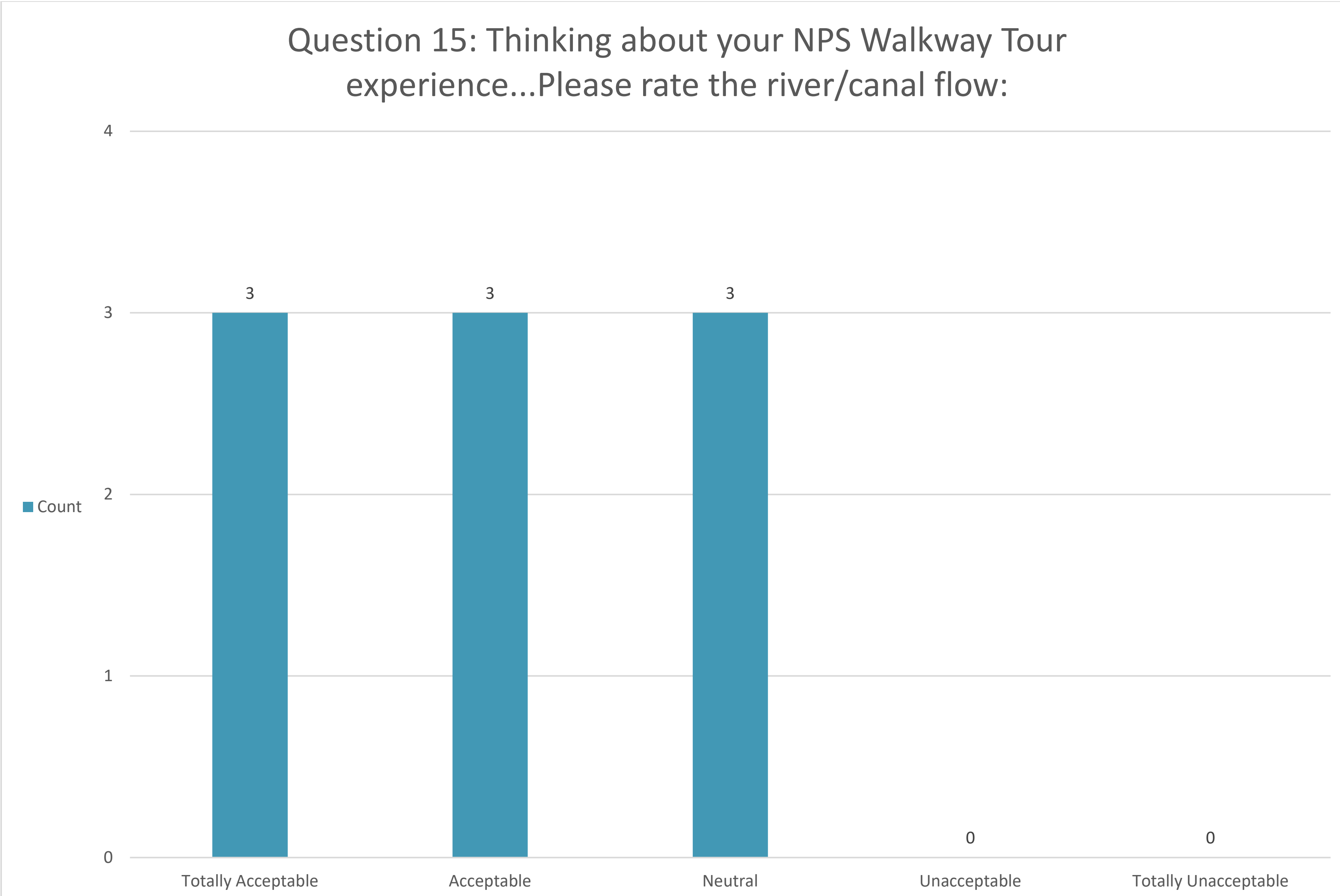
Question 15: Thinking about your NPS Walkway Tour experience...Please rate the crowding:
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
40
30
30
4
3
3
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable



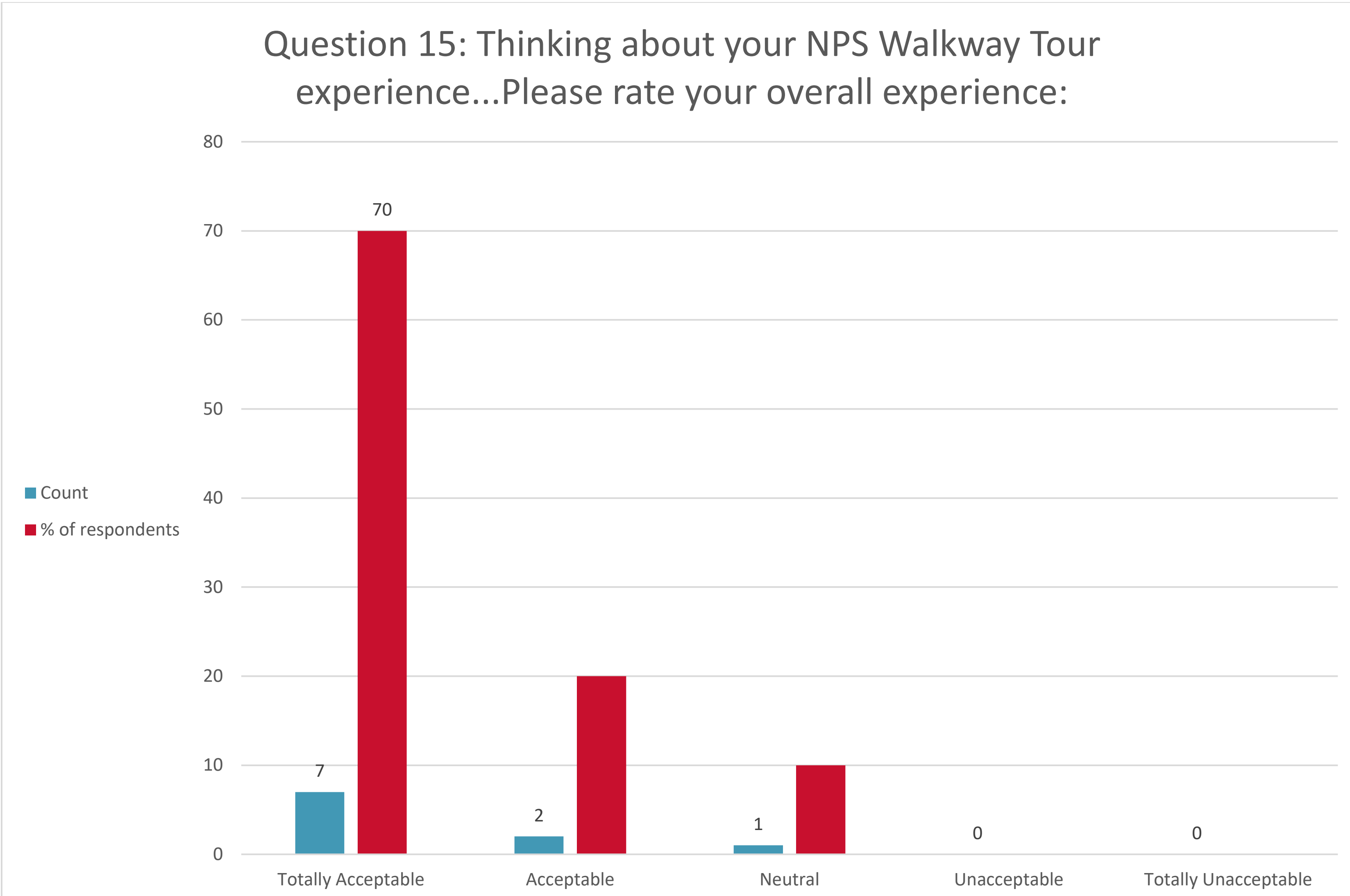
Question 15: Thinking about your NPS Walkway Tour experience...Please rate the condition of recreation facilites:
Count
% of respodnents
70
60
50
40
30
20
10
0
6
60
3
30
1
10
0
0
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

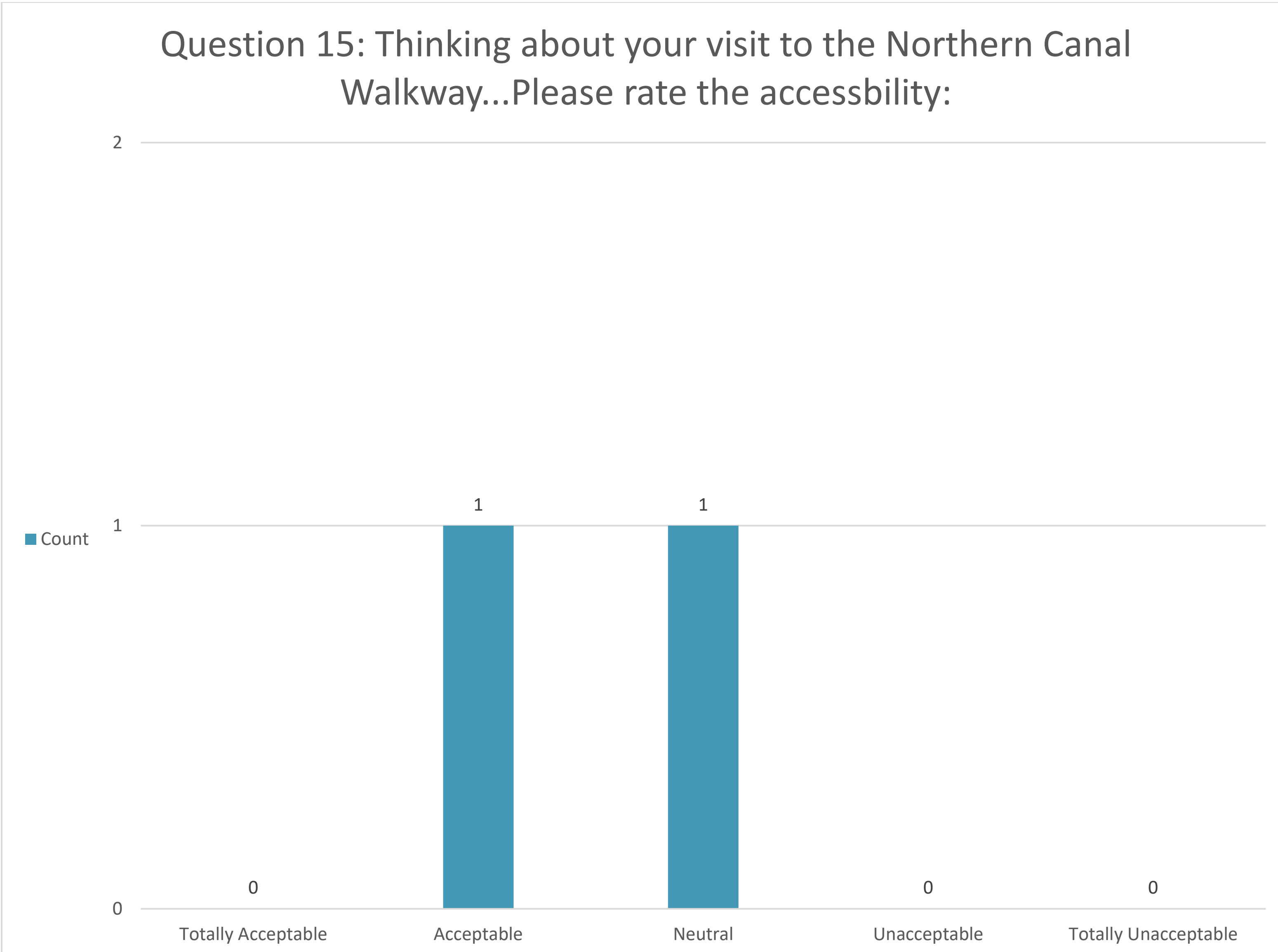


Question 15: Thinking about your NPS Walkway Tour experience...Please rate the available amenities:
Count
% of respondents
45
40
35
30
25
20
15
10
5
0
4
40
1
10
4
40
0
1
10
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

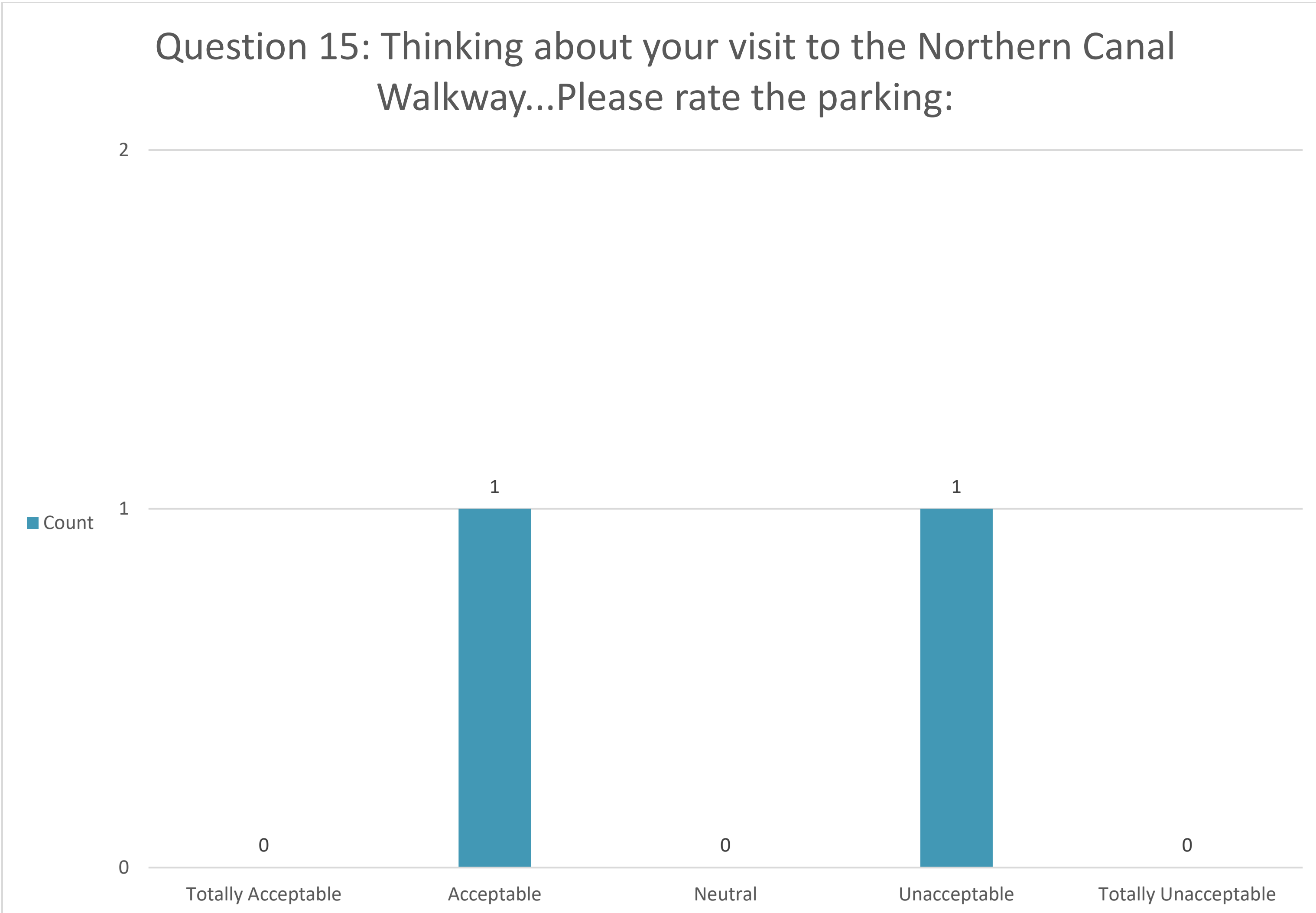


*Percentages not shown for respondent counts under ten.

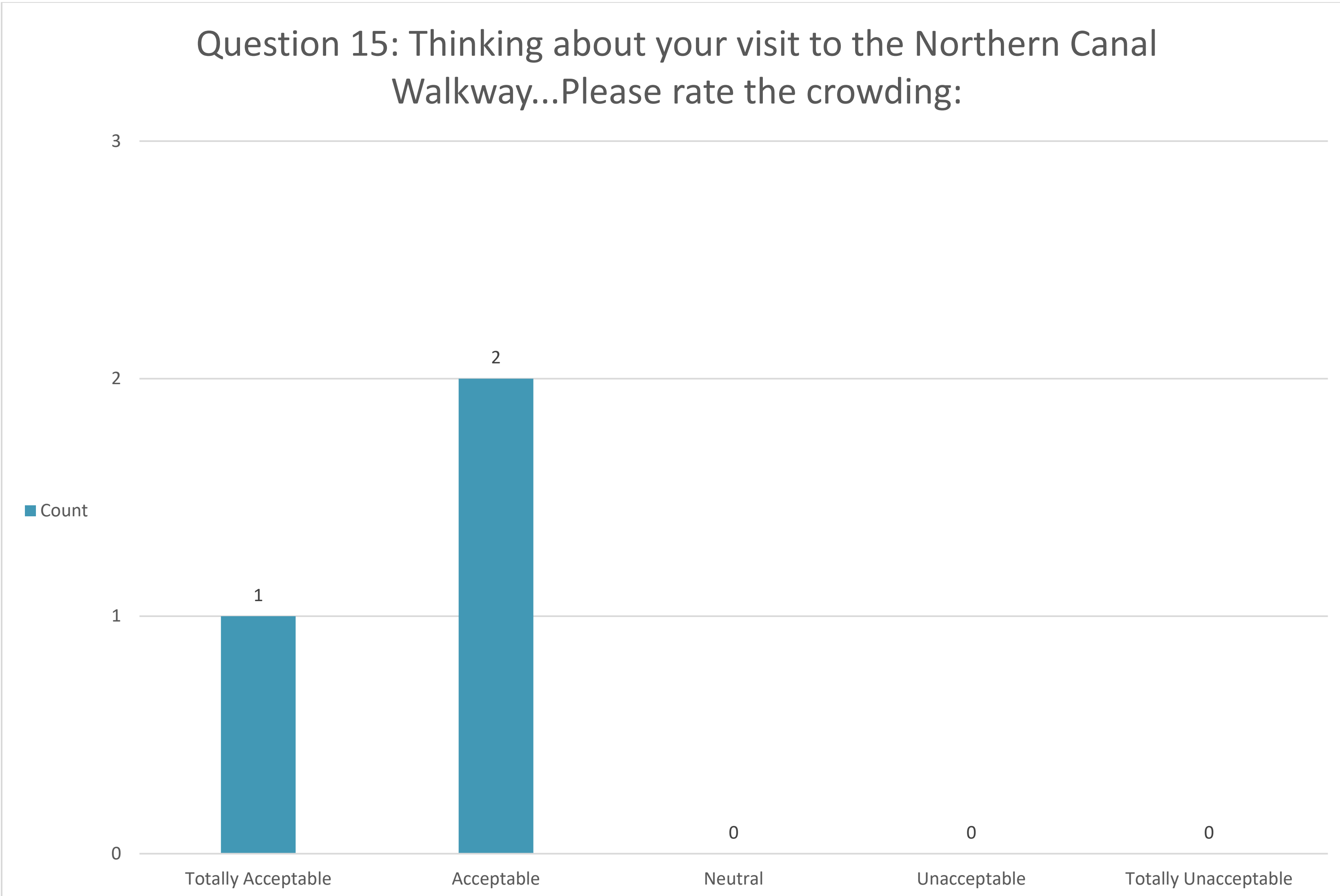

Question 15: Thinking about your NPS Walkway Tour experience...Please rate your overall experience:
Count
% of respondents
80
70
60
50
40
30
20
10
0
70
7
2
1
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable



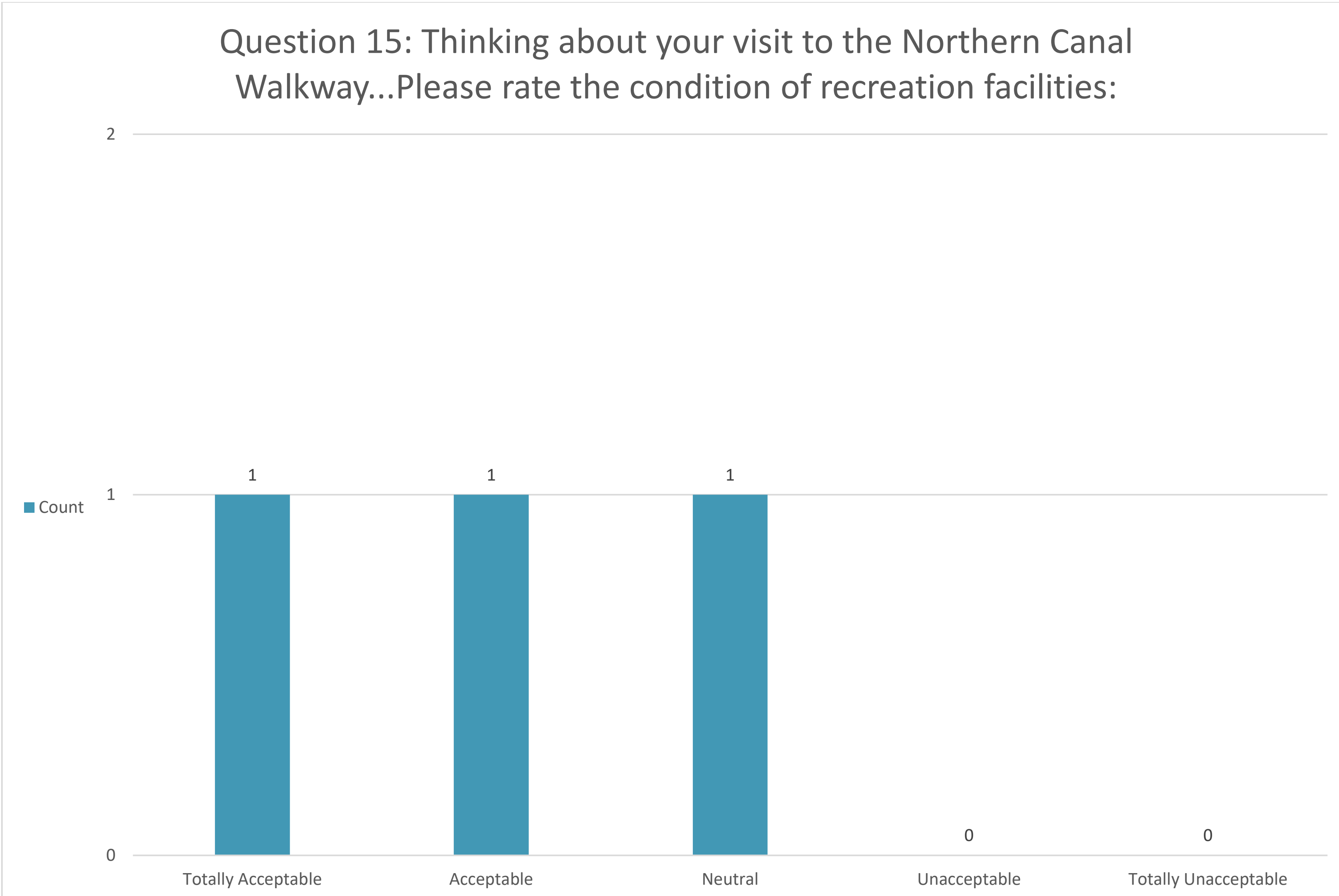
*Percentages not shown for respondent counts under ten.



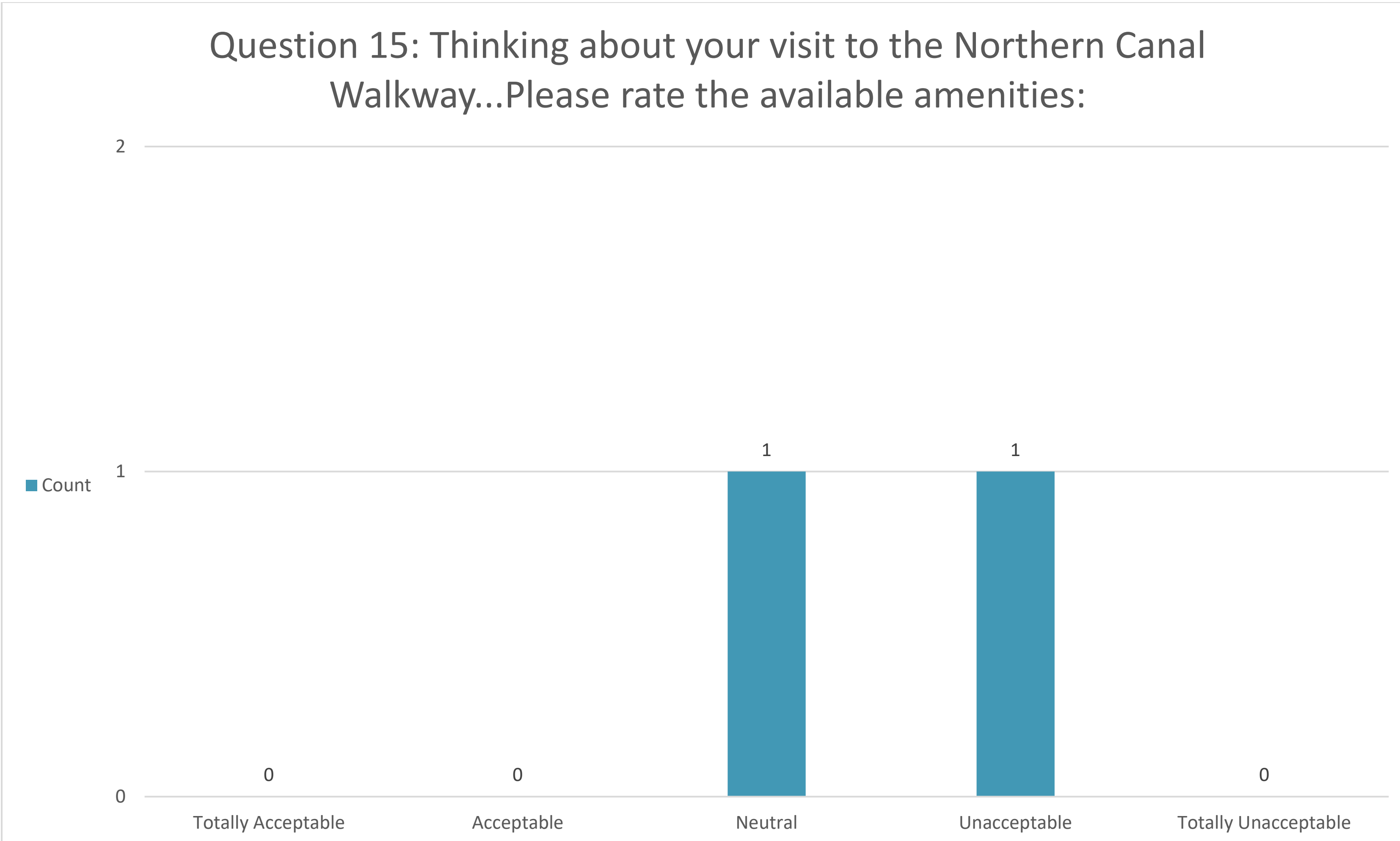
*Percentages not shown for respondent counts under ten.



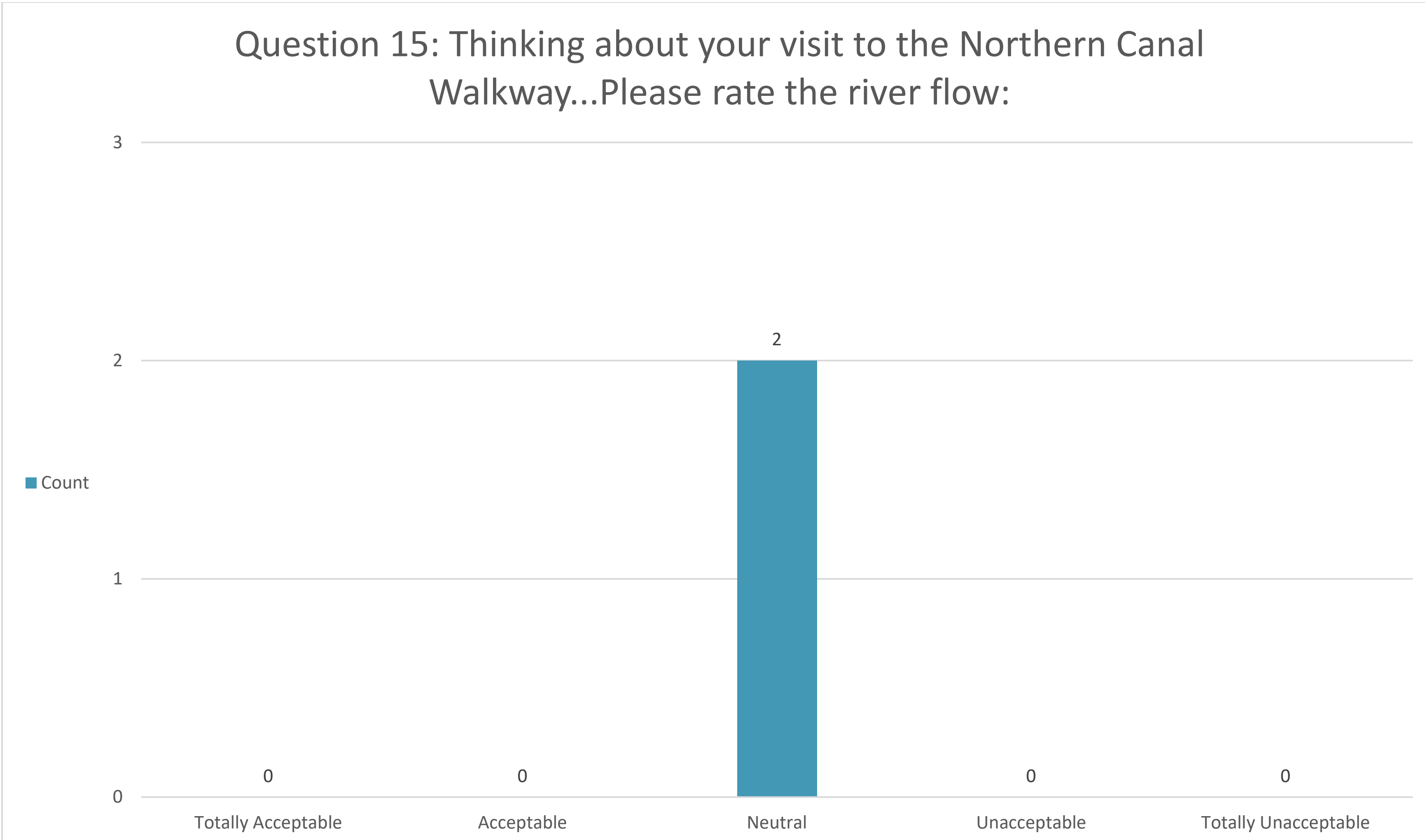
*Percentages not shown for respondent counts under ten.



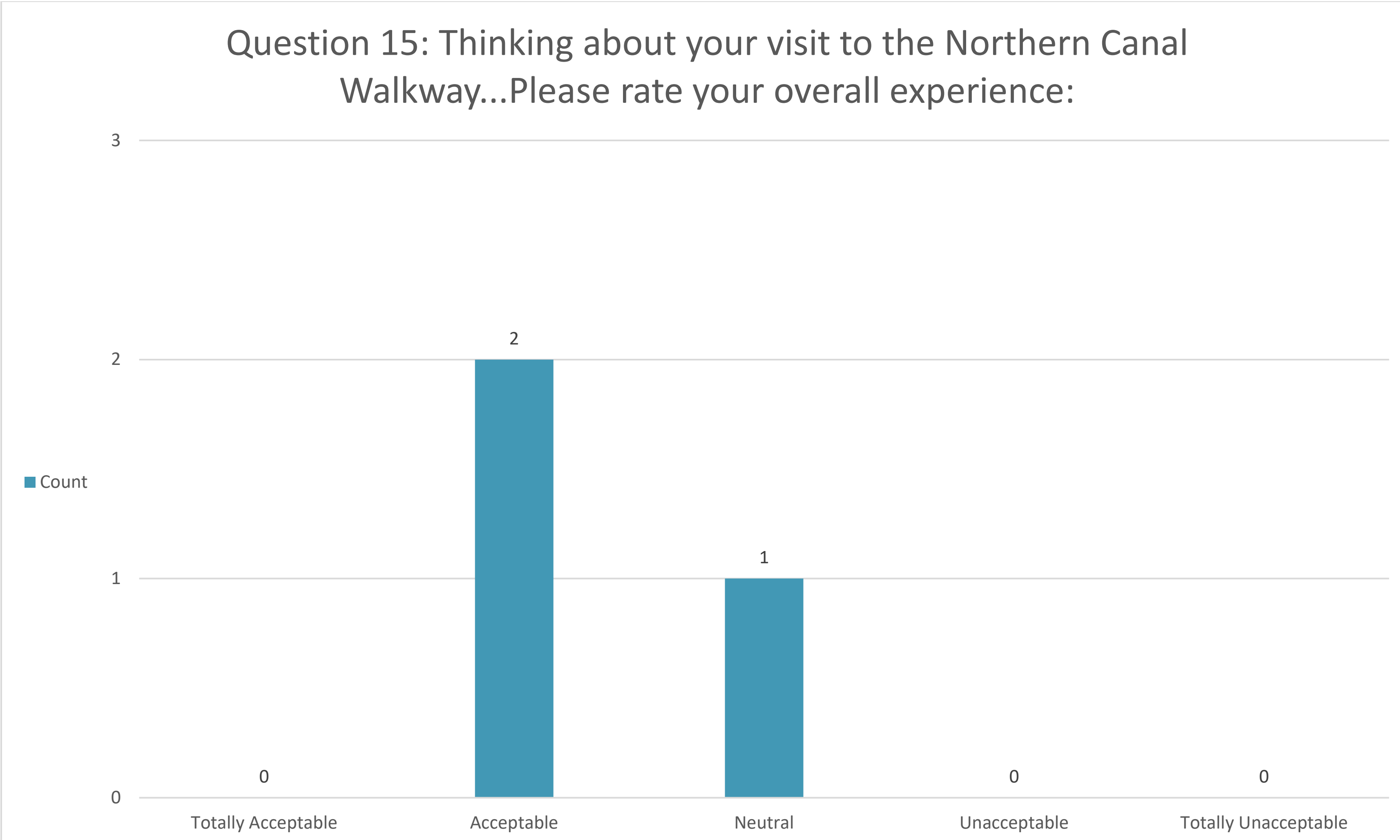
*Percentages not shown for respondent counts under ten.



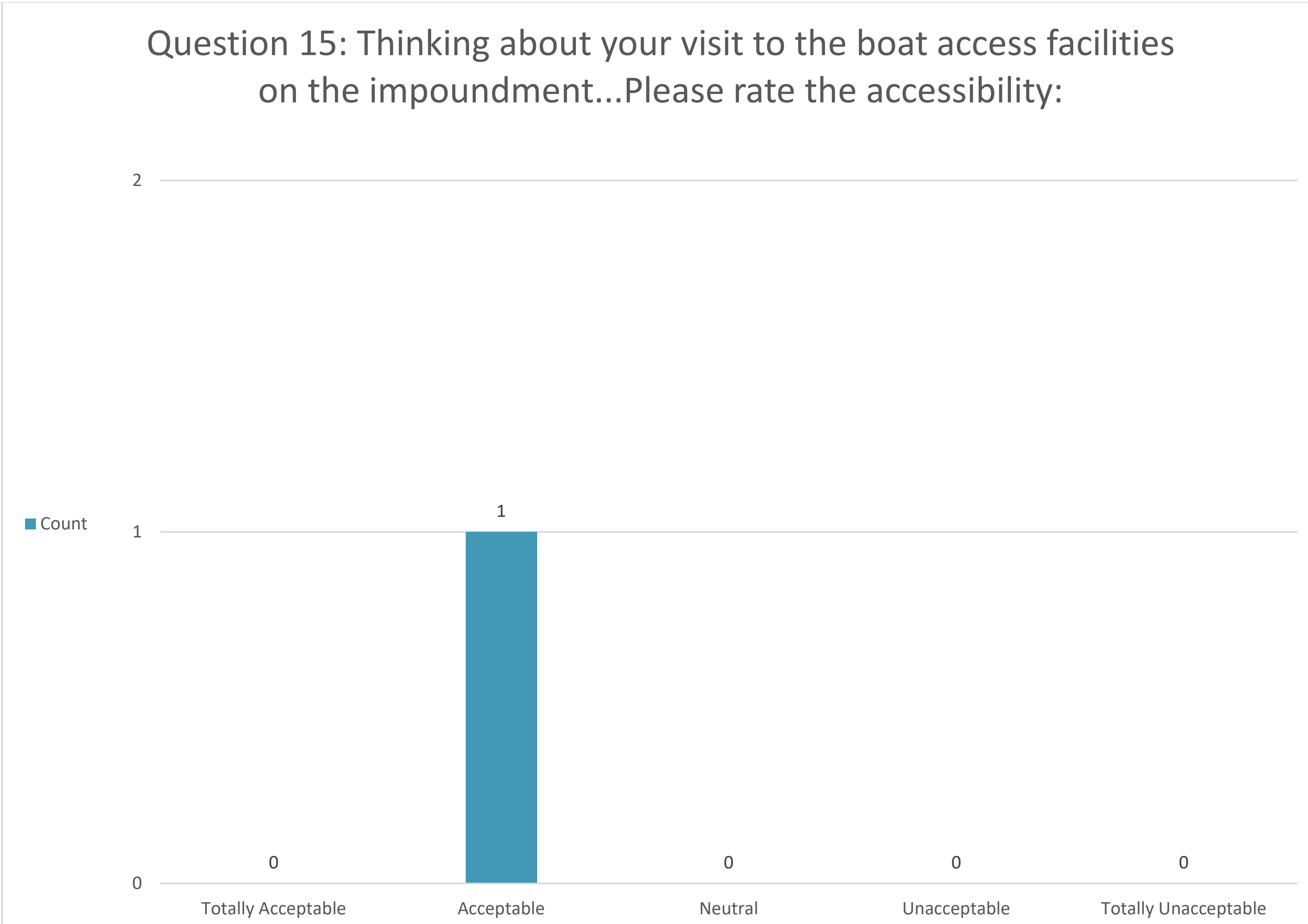
*Percentages not shown for respondent counts under ten.



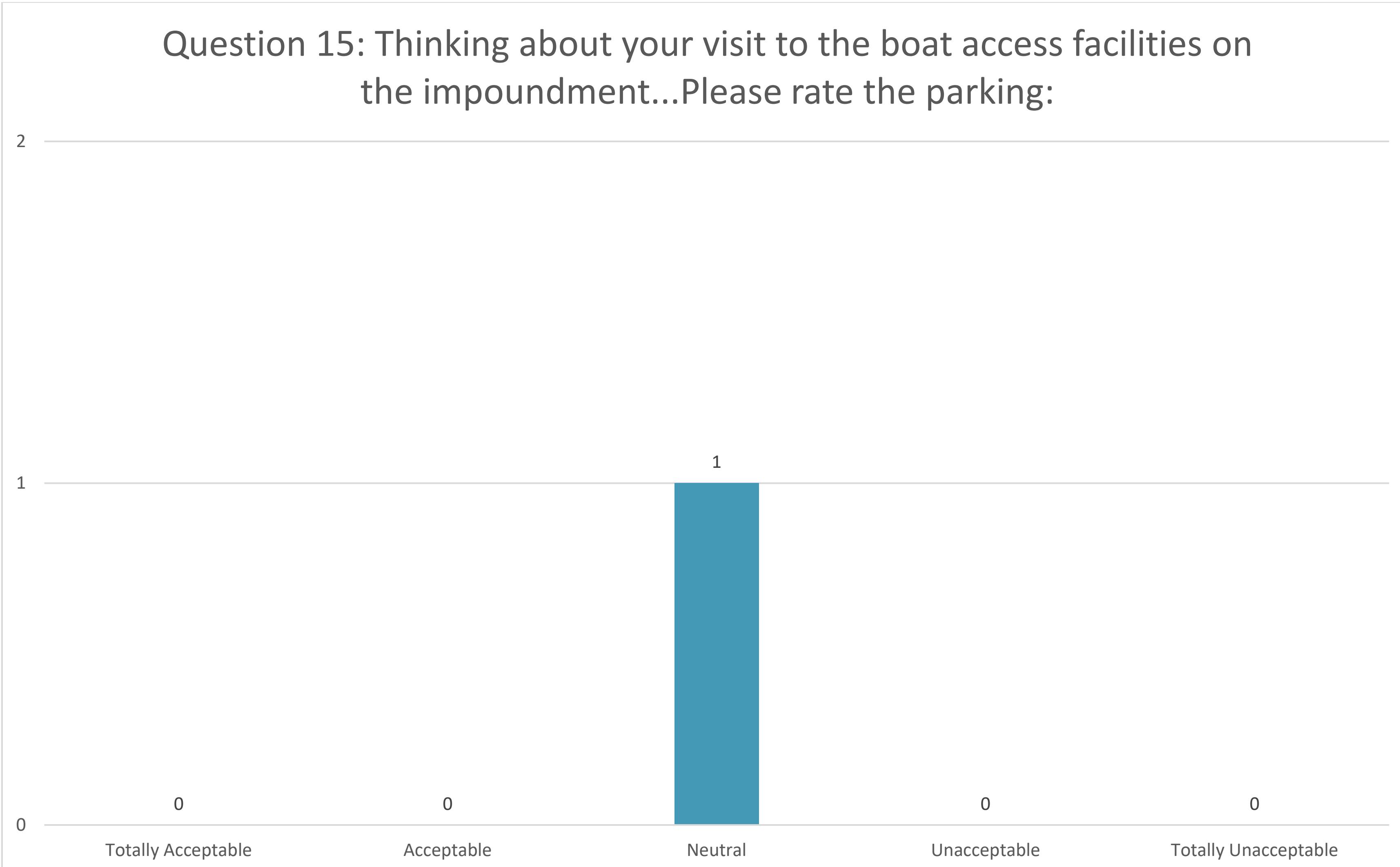
*Percentages not shown for respondent counts under ten.



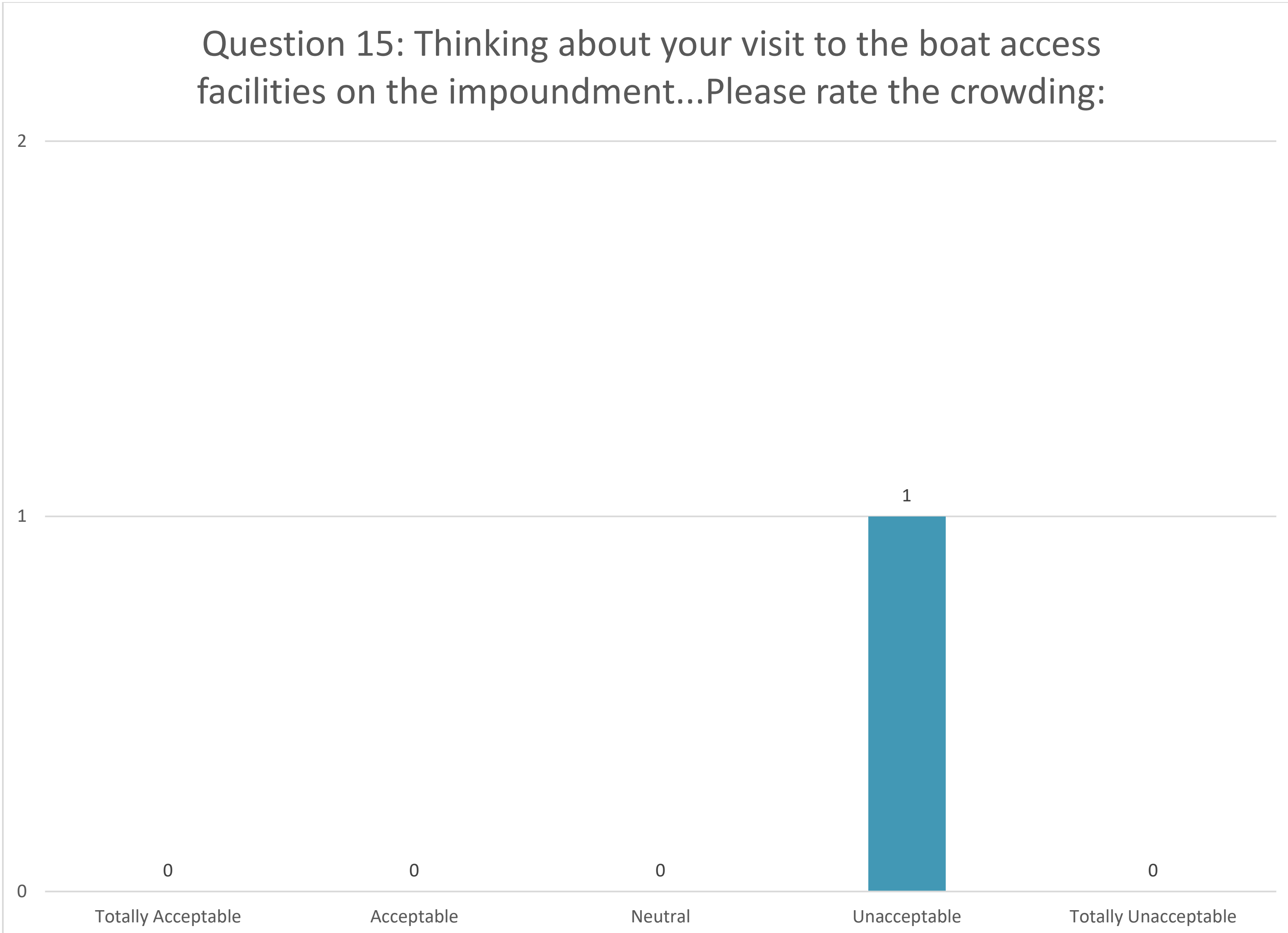
*Percentages not shown for respondent counts under ten.



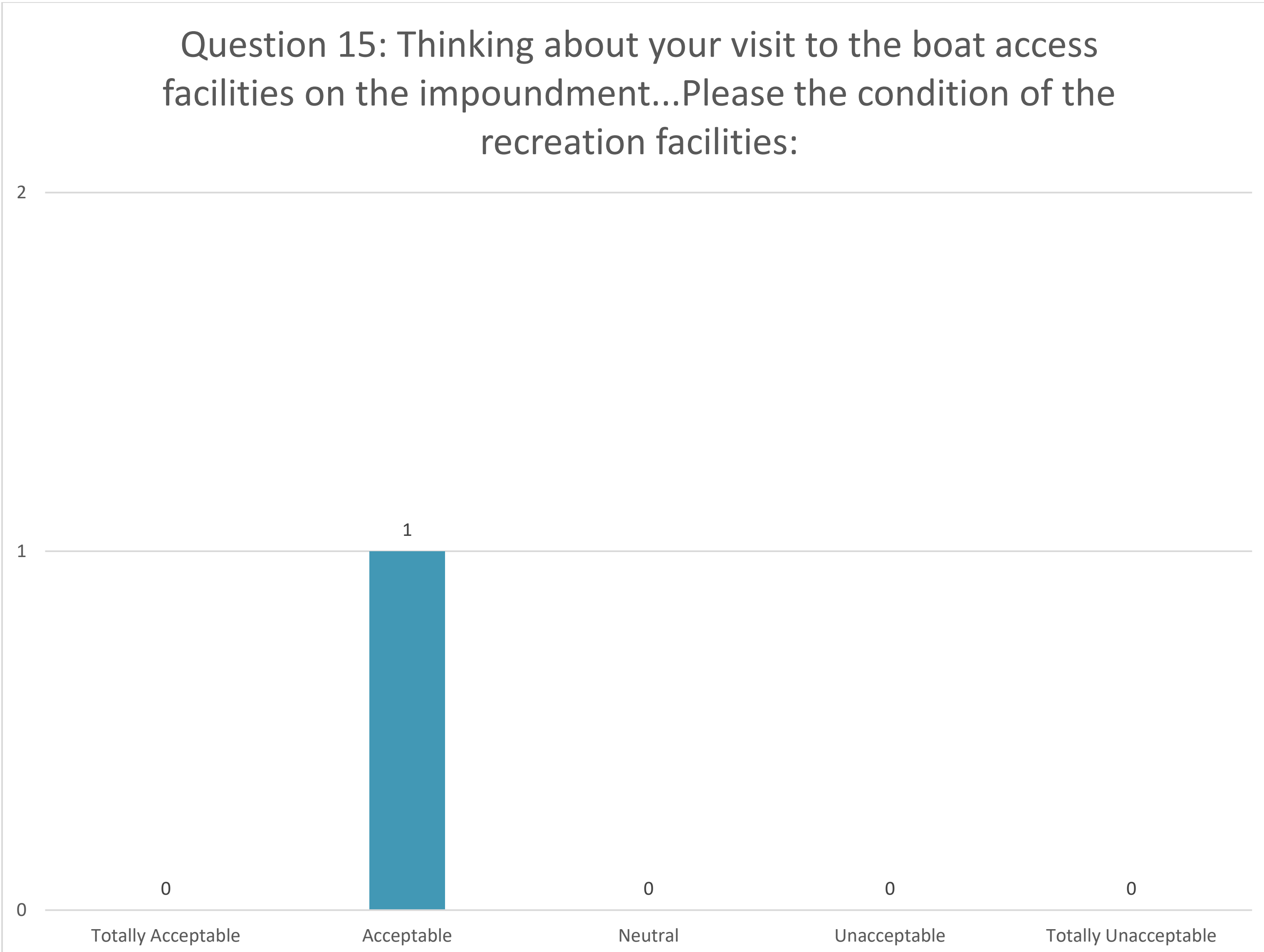
*Percentages not shown for respondent counts under ten.



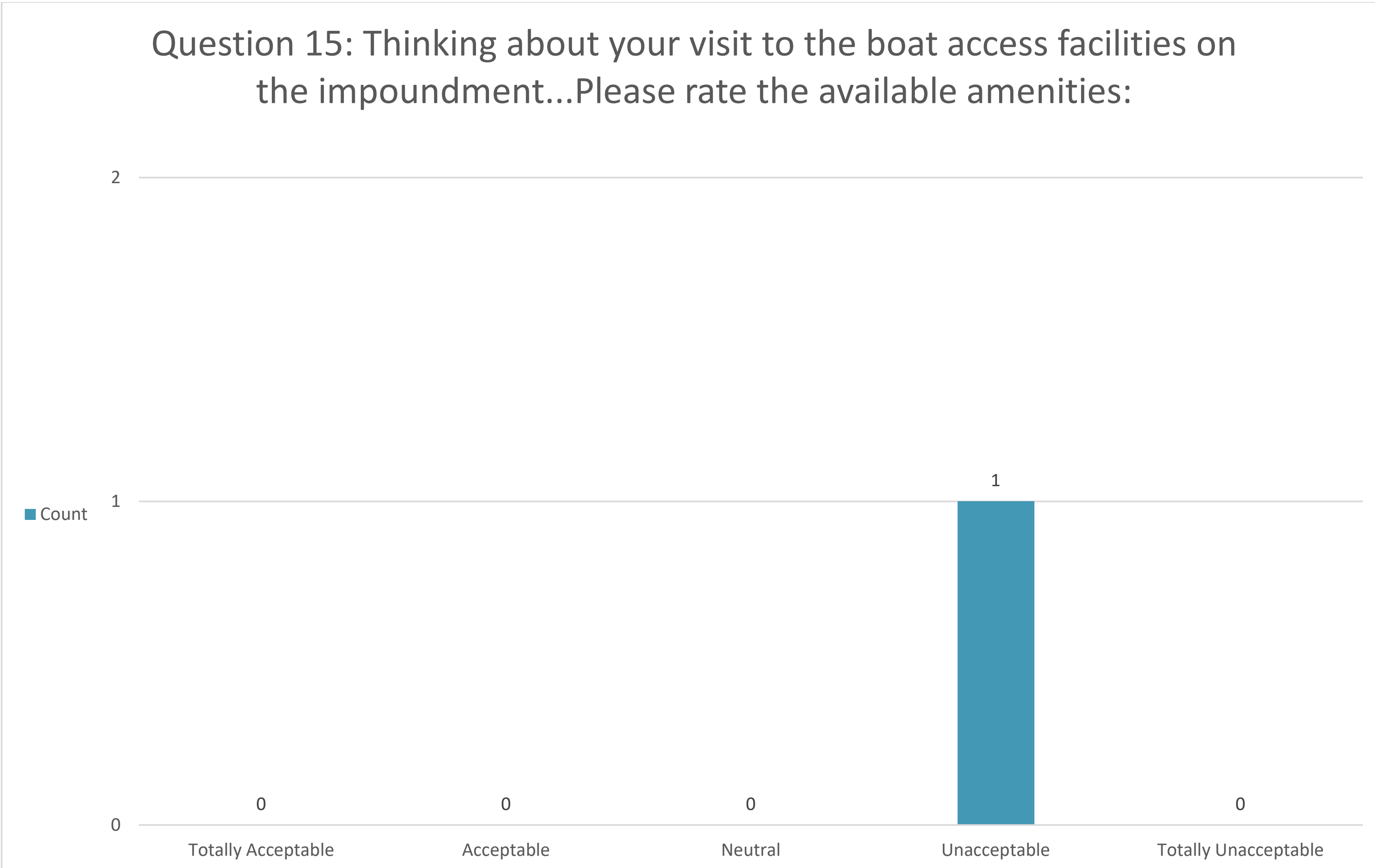
*Percentages not shown for respondent counts under ten.



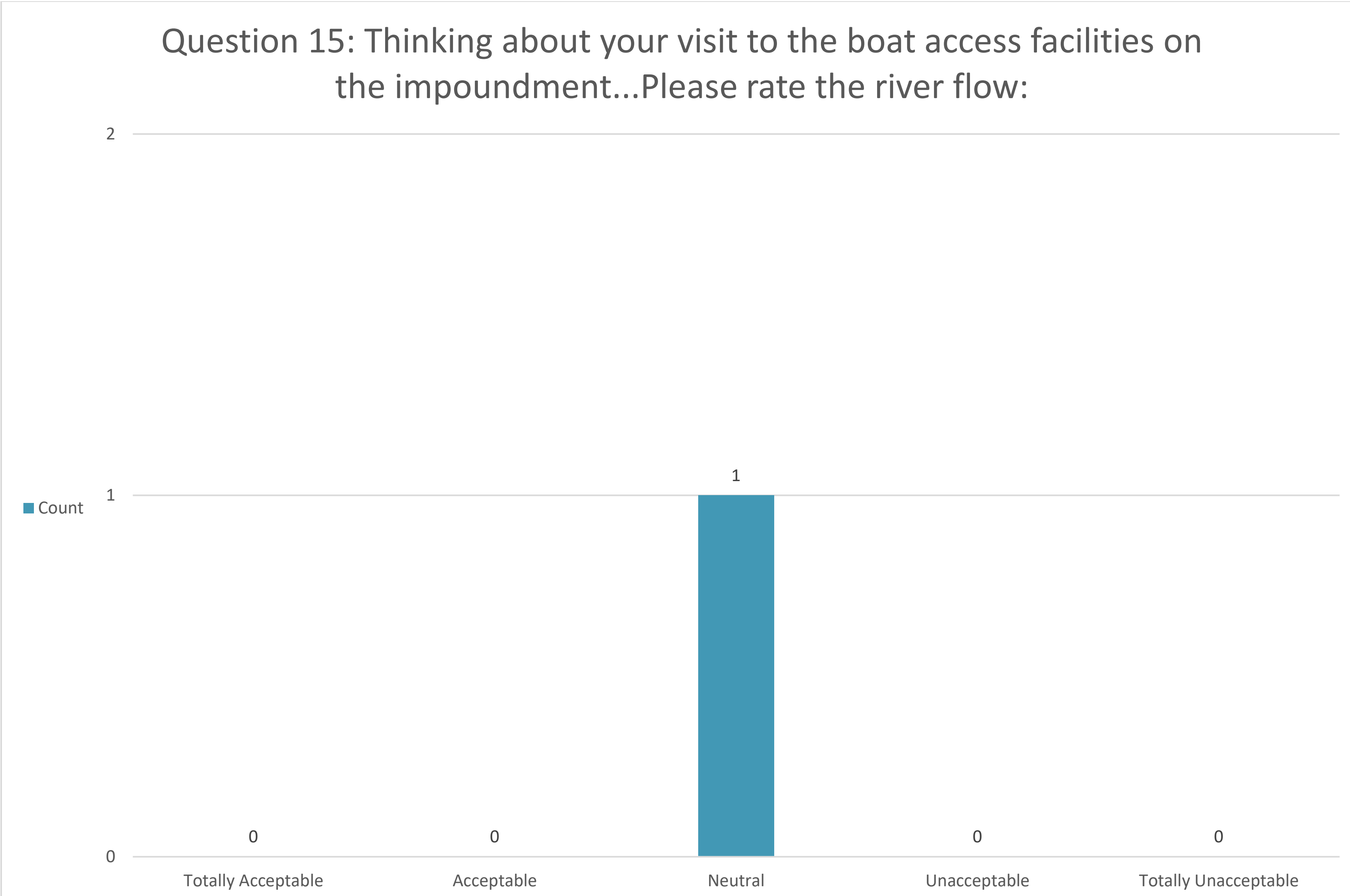
*Percentages not shown for respondent counts under ten.



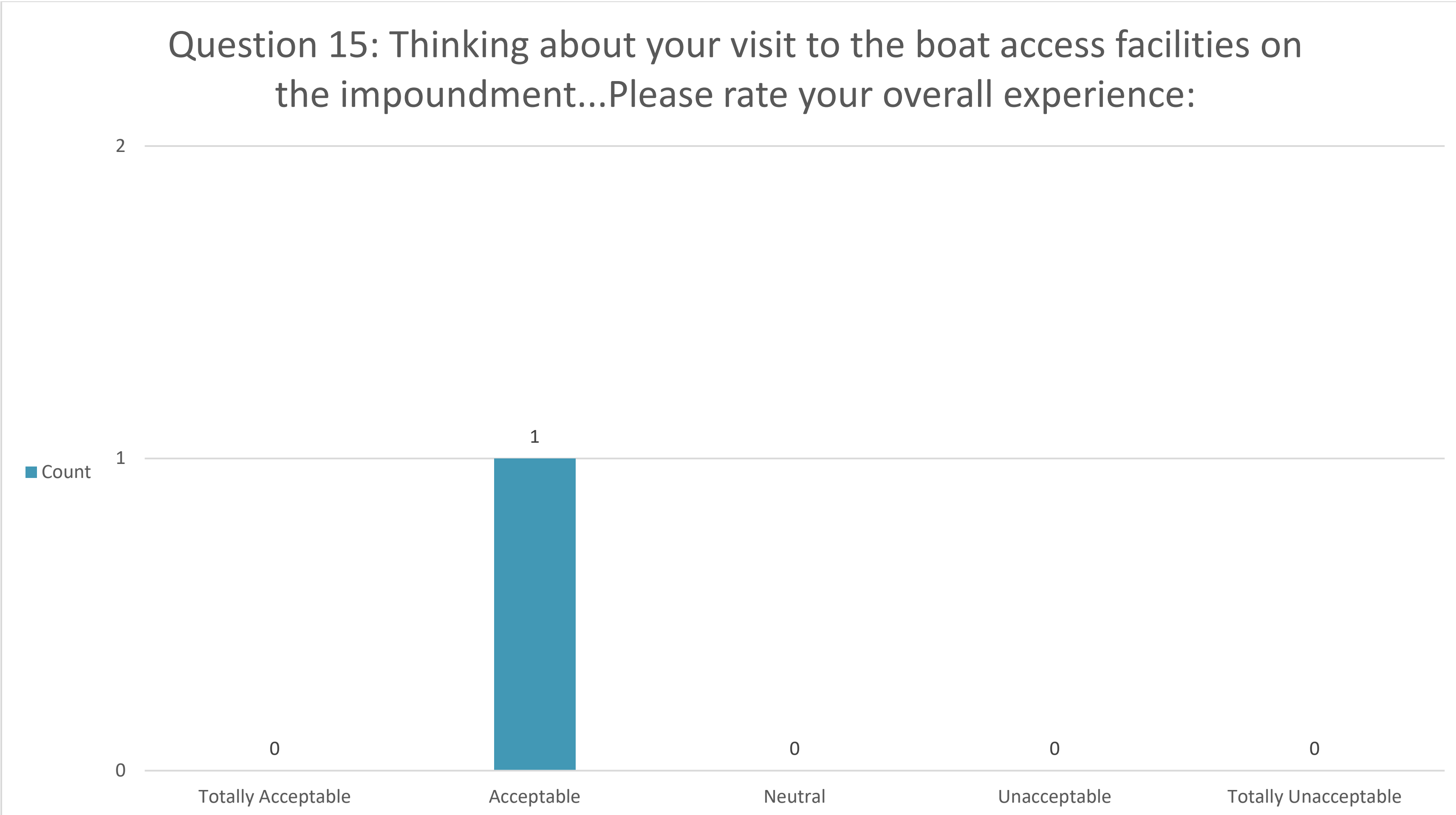
*Percentages not shown for respondent counts under ten.



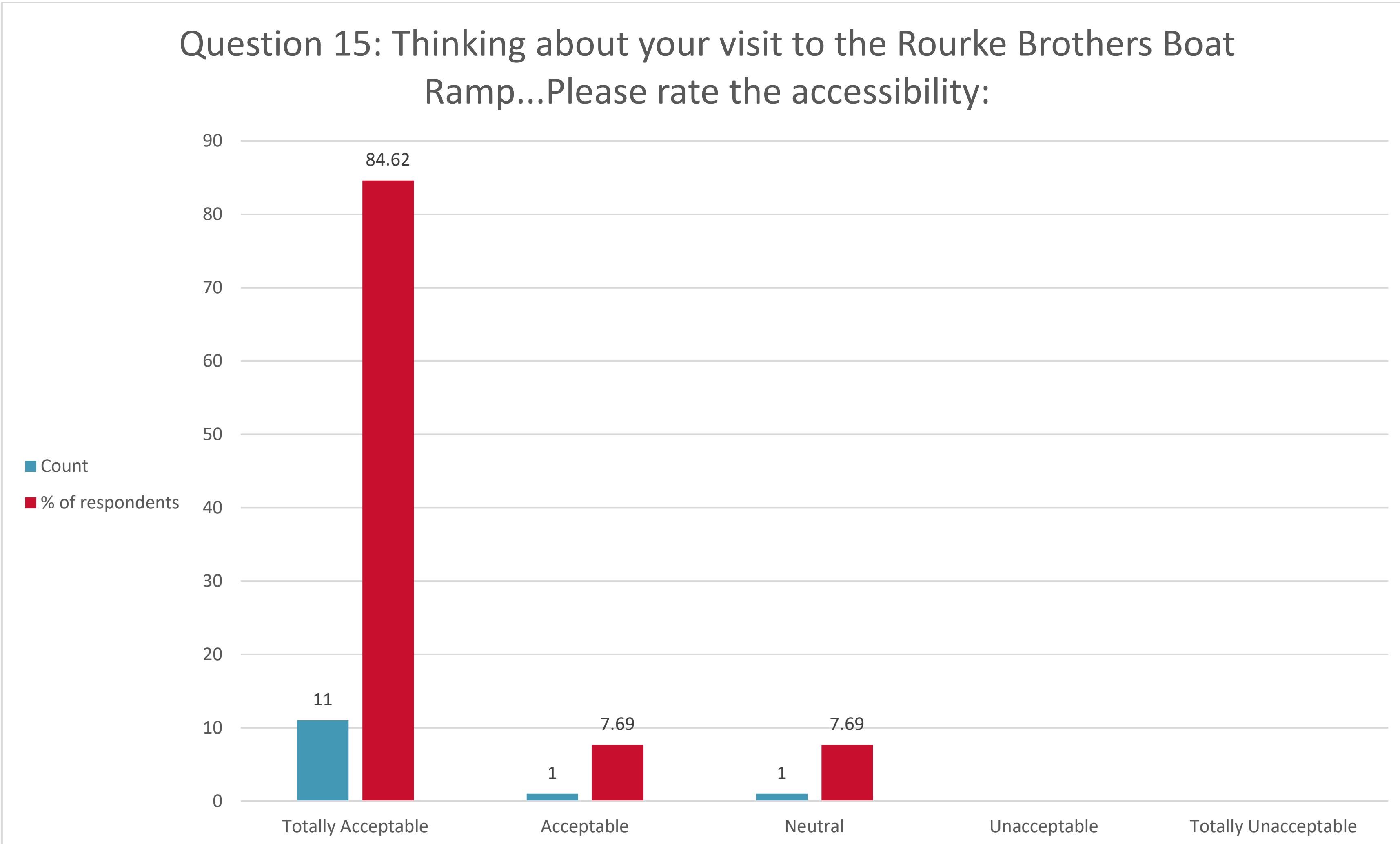
*Percentages not shown for respondent counts under ten.



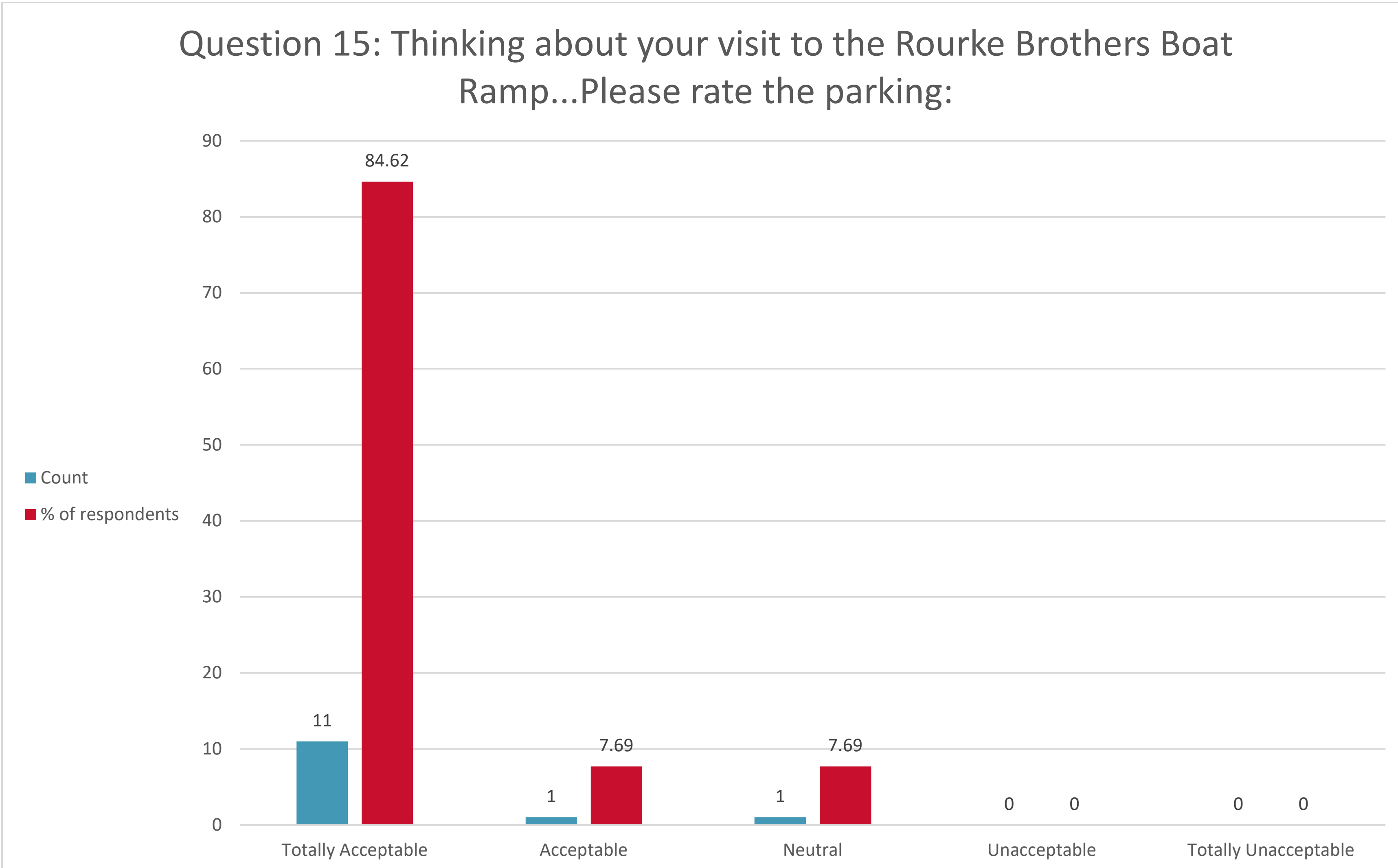
*Percentages not shown for respondent counts under ten.

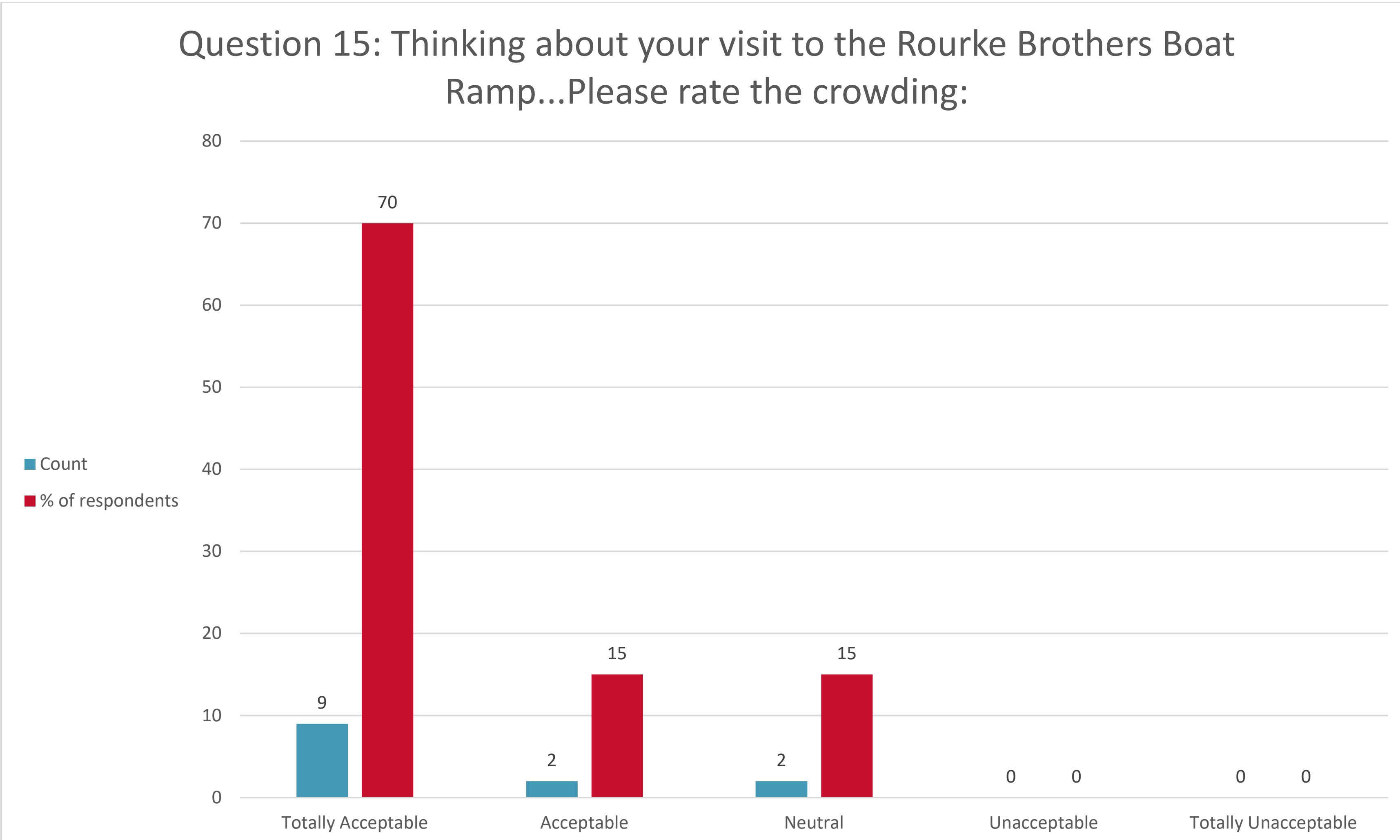


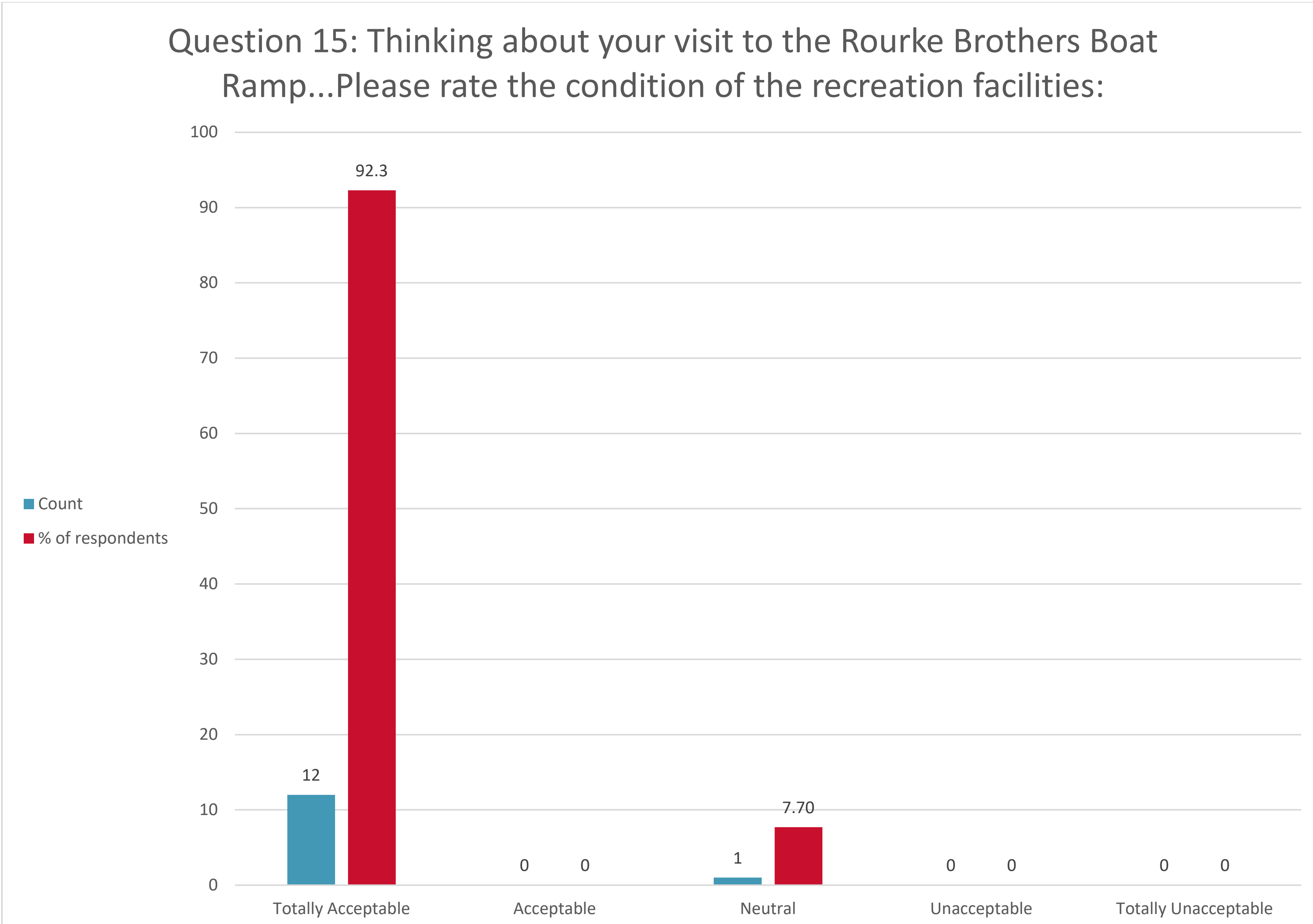
*Percentages not shown for respondent counts under ten.



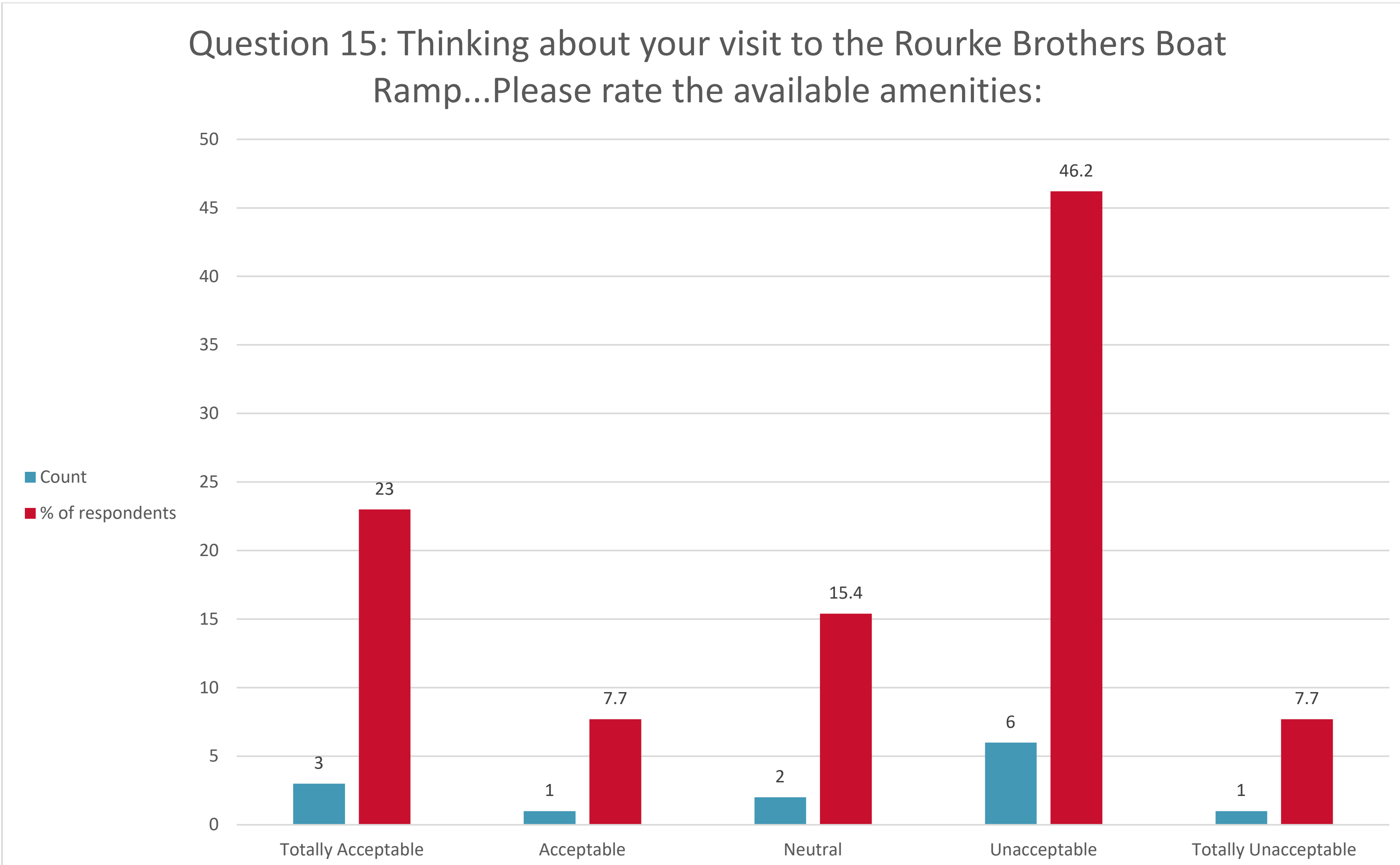
Question 15: Thinking about your visit to the Rourke Brothers Boat Ramp...Please rate the accessibility:
Count
% of respondents
90
80
70
60
50
40
30
20
10
0
84.62
11
7.69
1
7.69
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

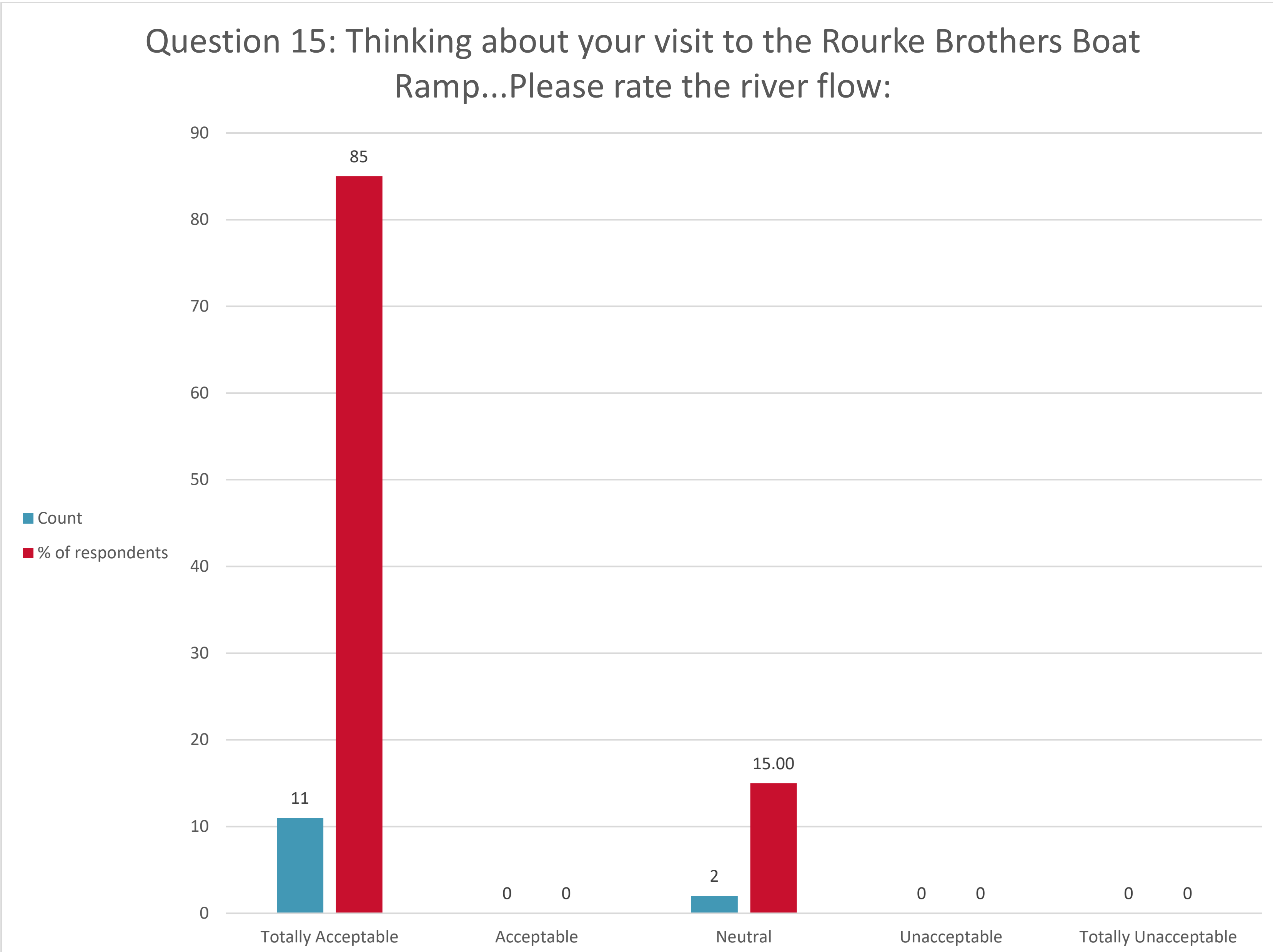

Question 15: Thinking about your visit to the Rourke Brothers Boat Ramp...Please rate the parking:
Count
% of respondents
90
80
70
60
50
40
30
20
10
0
84.62
11
7.69
1
7.69
1
0
0
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

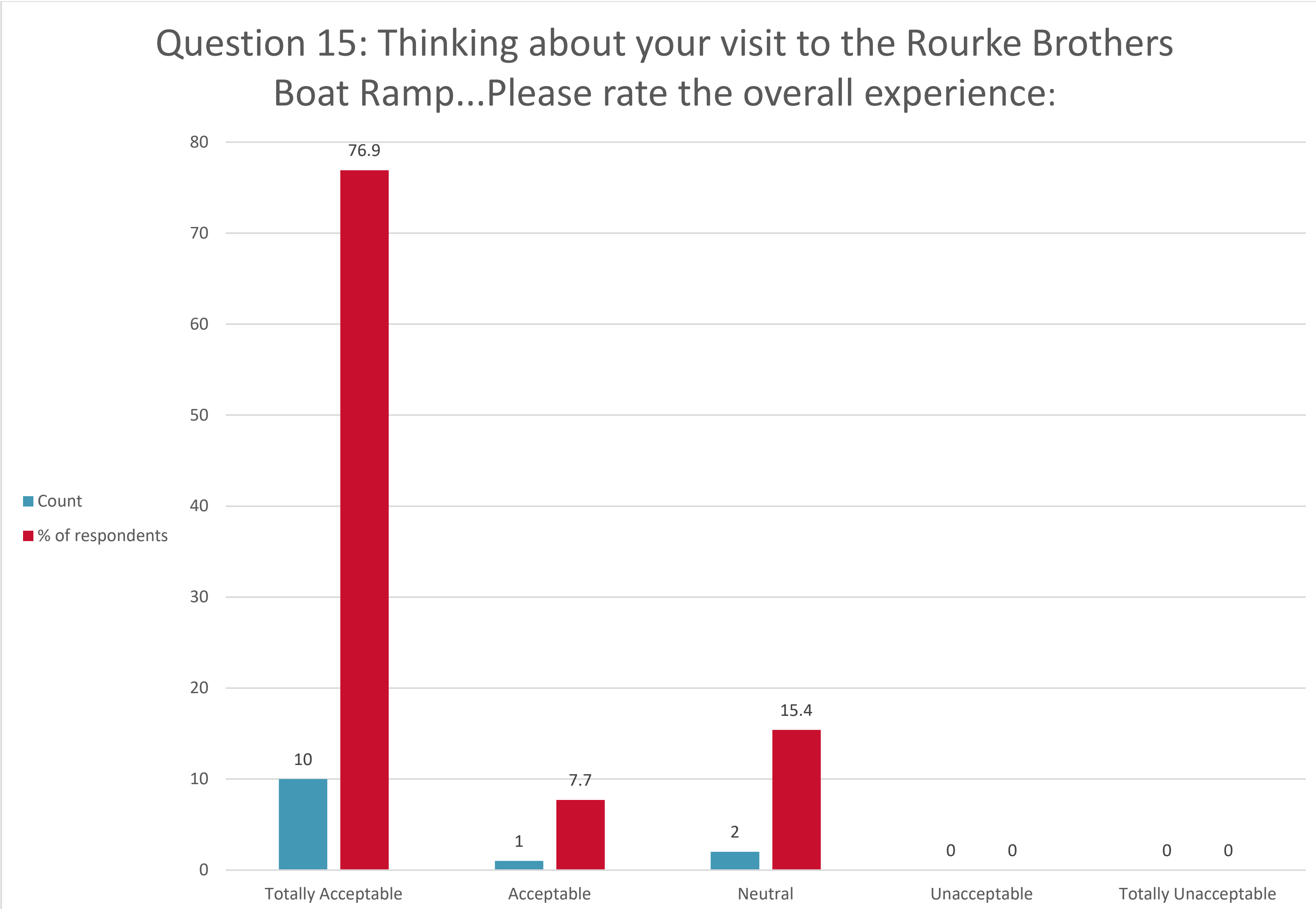

Question 15: Thinking about your visit to the Rourke Brothers Boat Ramp...Please rate the crowding:
80
70
60
50
40
30
20
10
0
Count
% of respondents
70
9
15
2
15
2
0
0
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

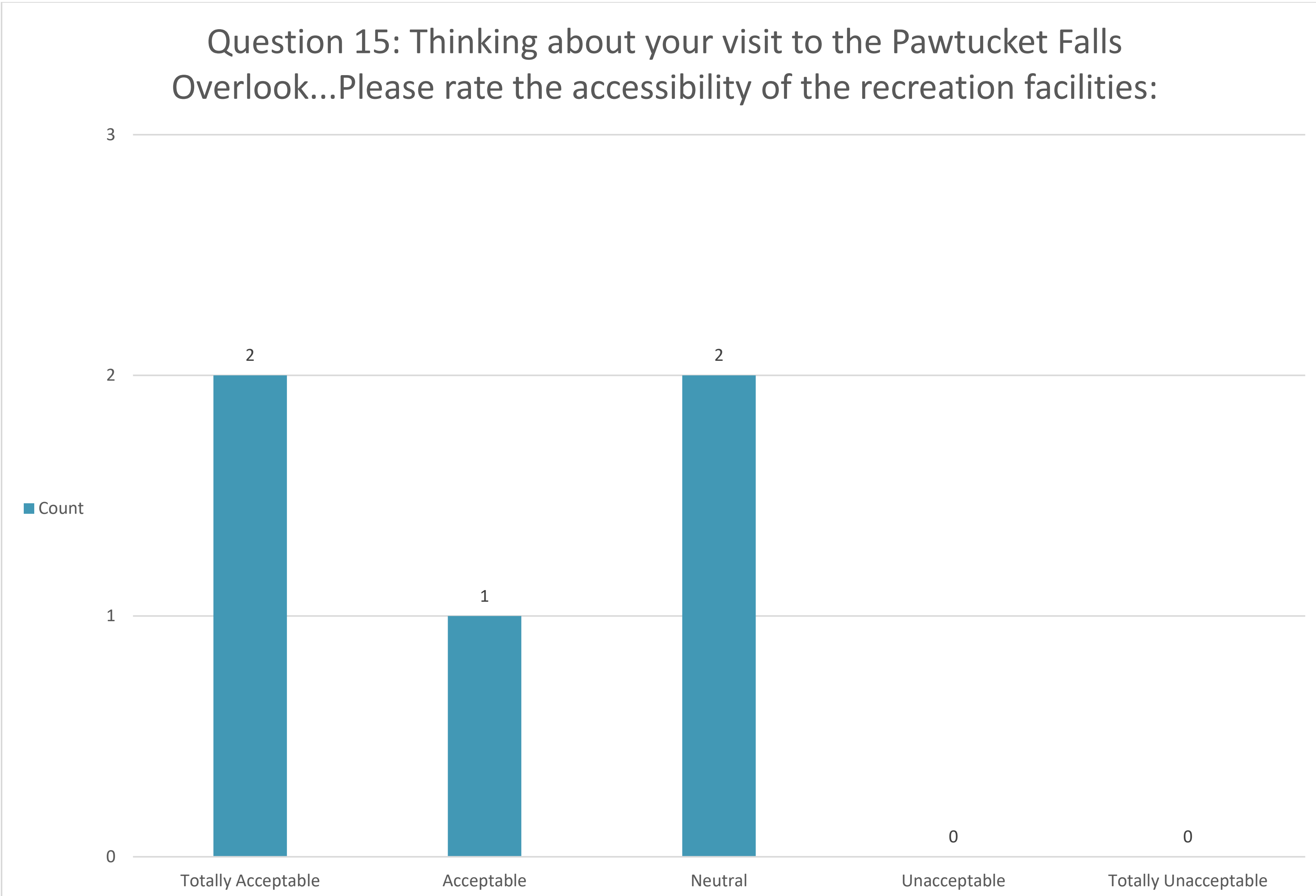


Question 15: Thinking about your visit to the Rourke Brothers Boat Ramp...Please rate the condition of the recreation facilities:
Count
% of respondents
100
90
80
70
60
50
40
30
20
10
0
92.3
12
0
0
1
7.70
0
0
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

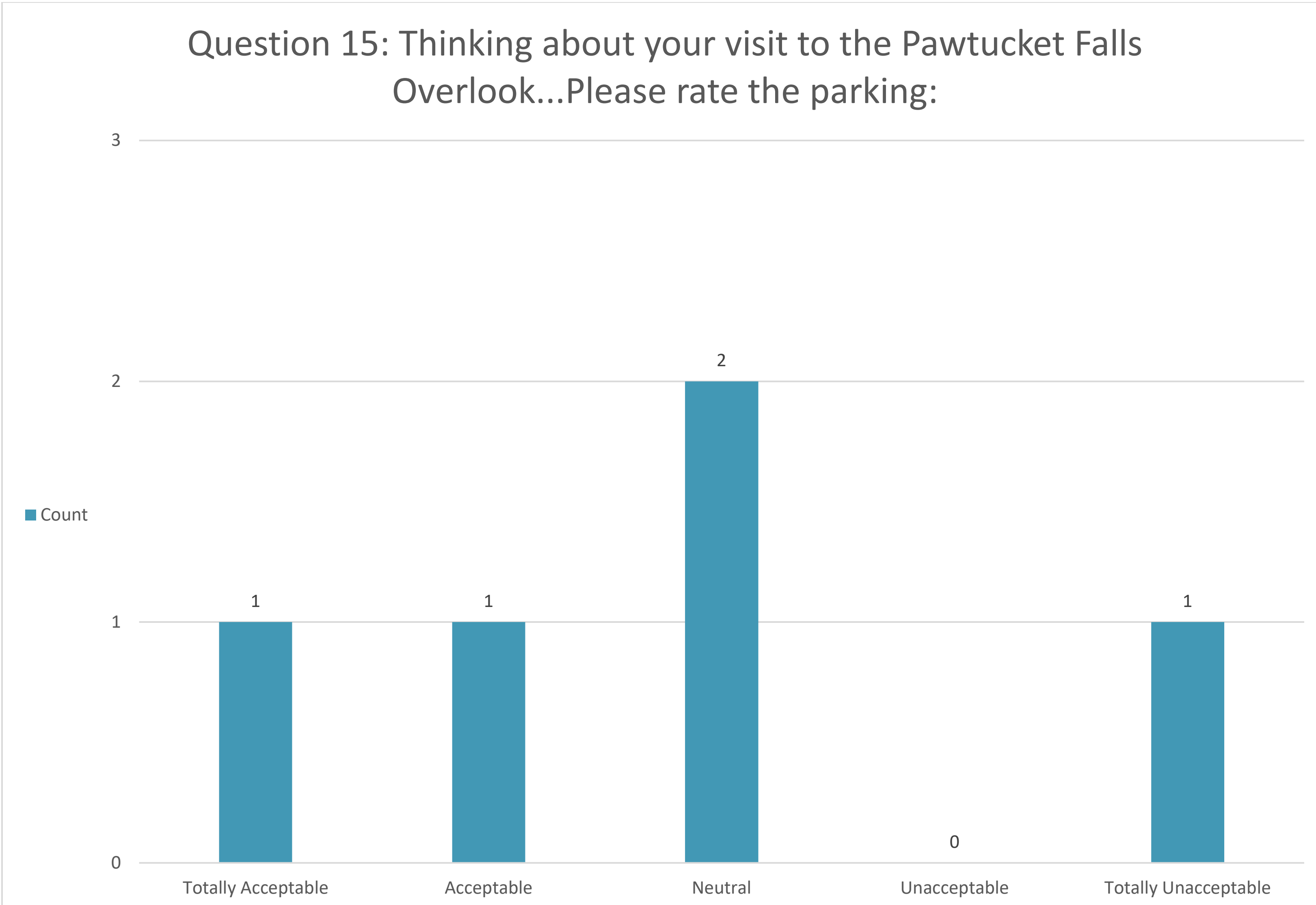

Question 15: Thinking about your visit to the Rourke Brothers Boat Ramp...Please rate the available amenities:
Count
% of respondents
50
45
40
35
30
25
20
15
10
5
0
3
23
1
7.7
2
15.4
6
46.2
1
7.7
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 15: Thinking about your visit to the Rourke Brothers Boat Ramp...Please rate the river flow:
90
80
70
60
50
40
30
20
10
0
85
11
0
0
2
15.00
0
0
0
0
Count
% of respondents
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

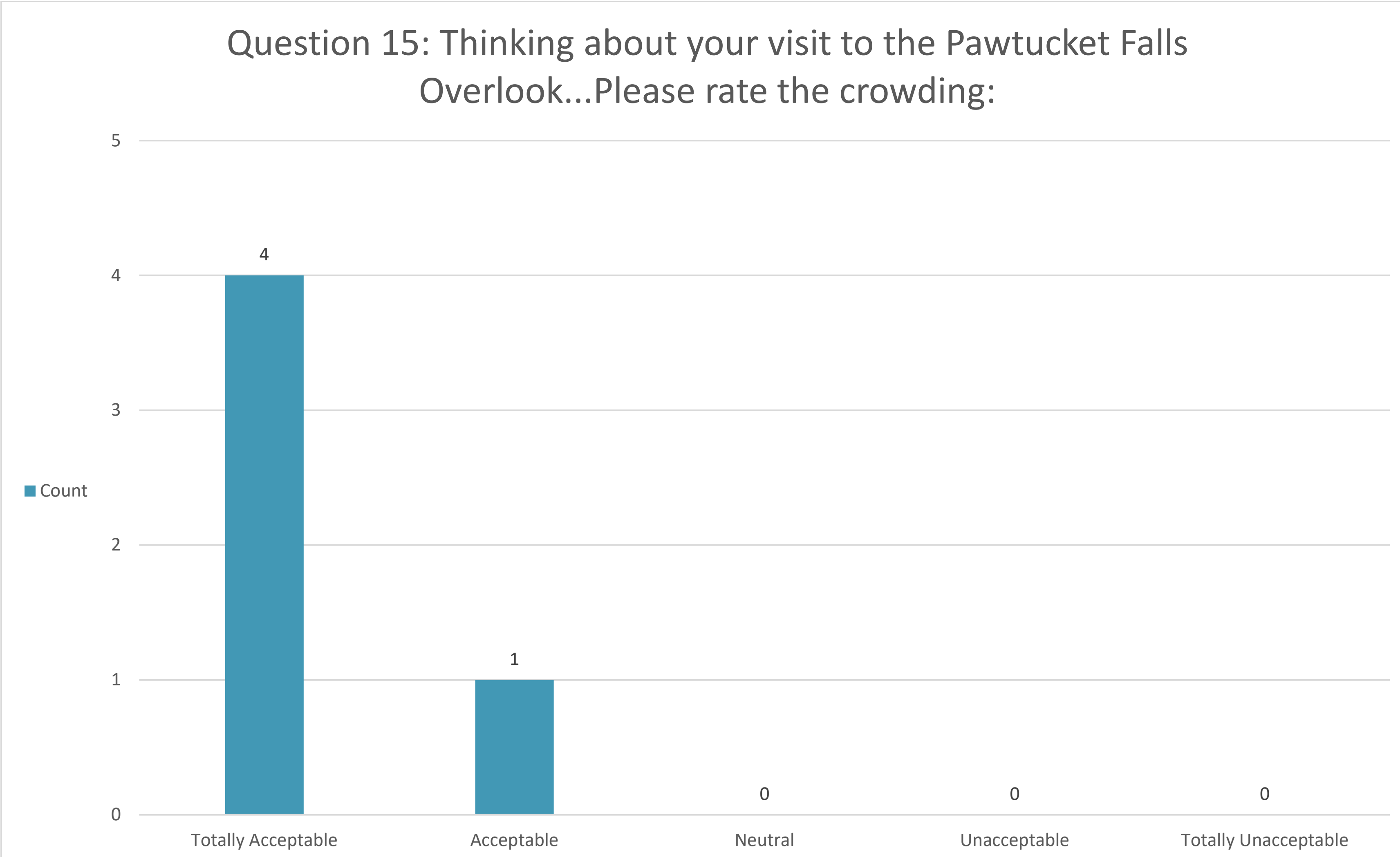

Question 15: Thinking about your visit to the Rourke Brothers Boat Ramp...Please rate the overall experience:
Count
% of respondents
80
70
60
50
40
30
20
10
0
76.9
10
7.7
1
15.4
2
0
0
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable



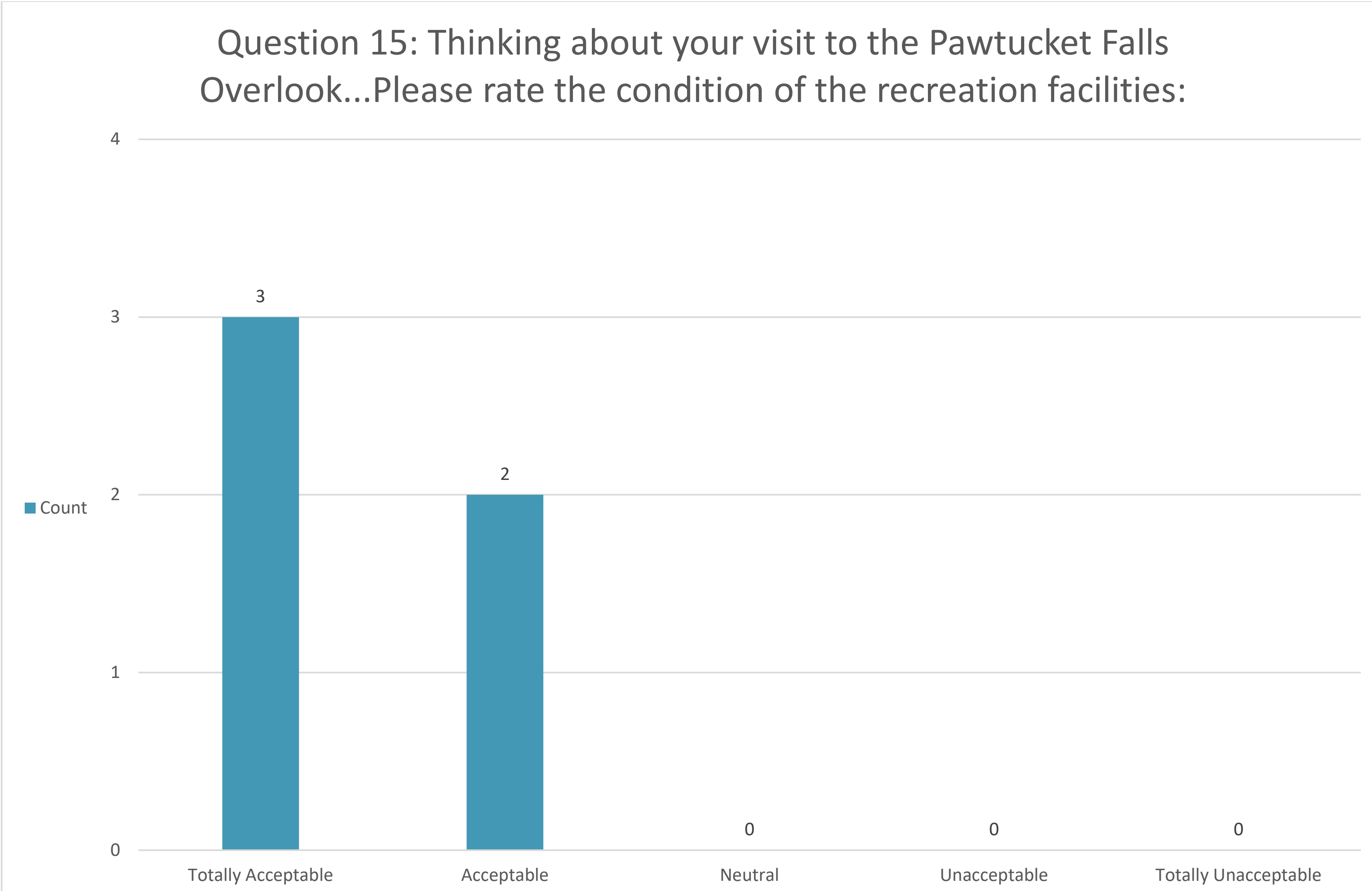
*Percentages not shown for respondent counts under ten.



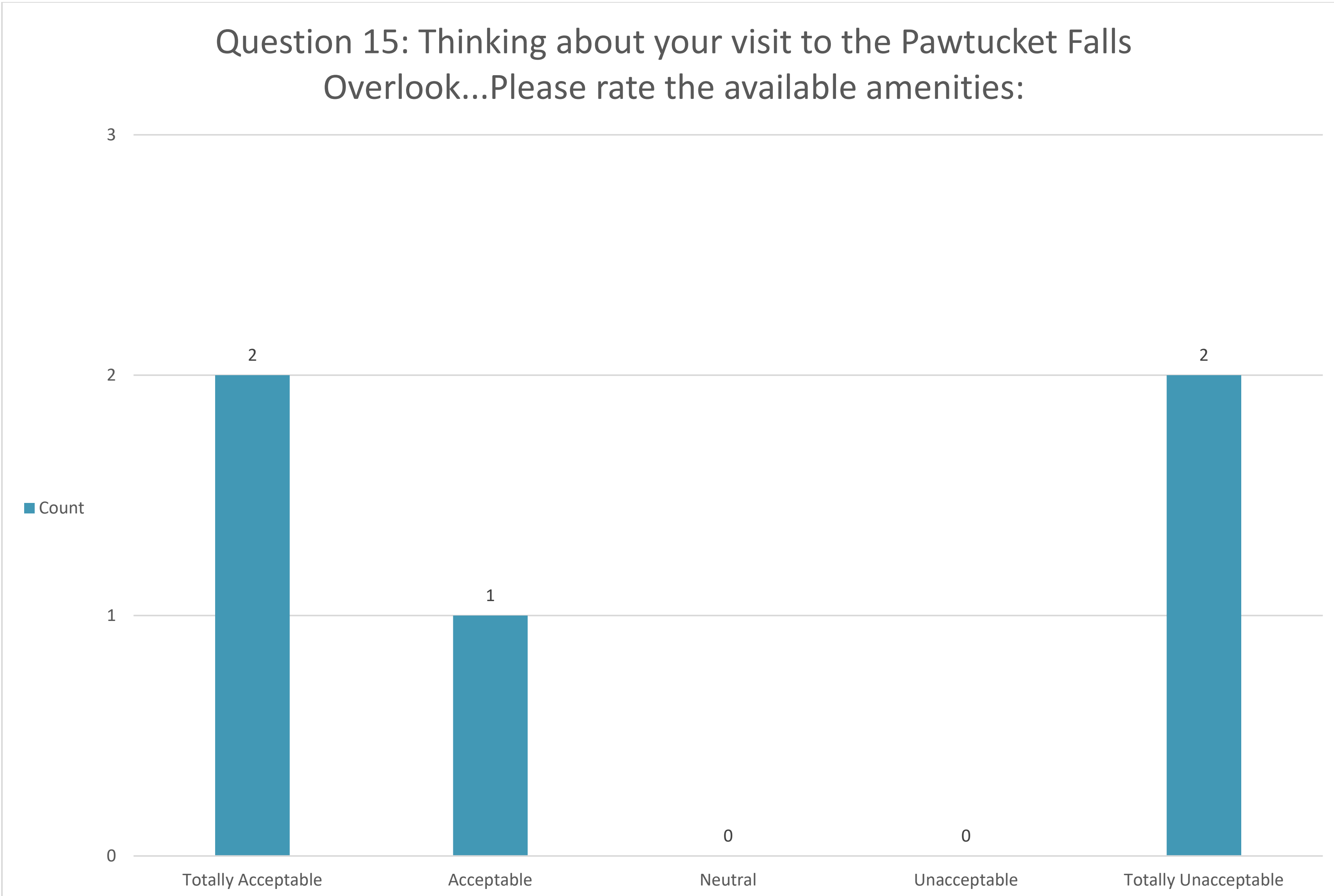
*Percentages not shown for respondent counts under ten.



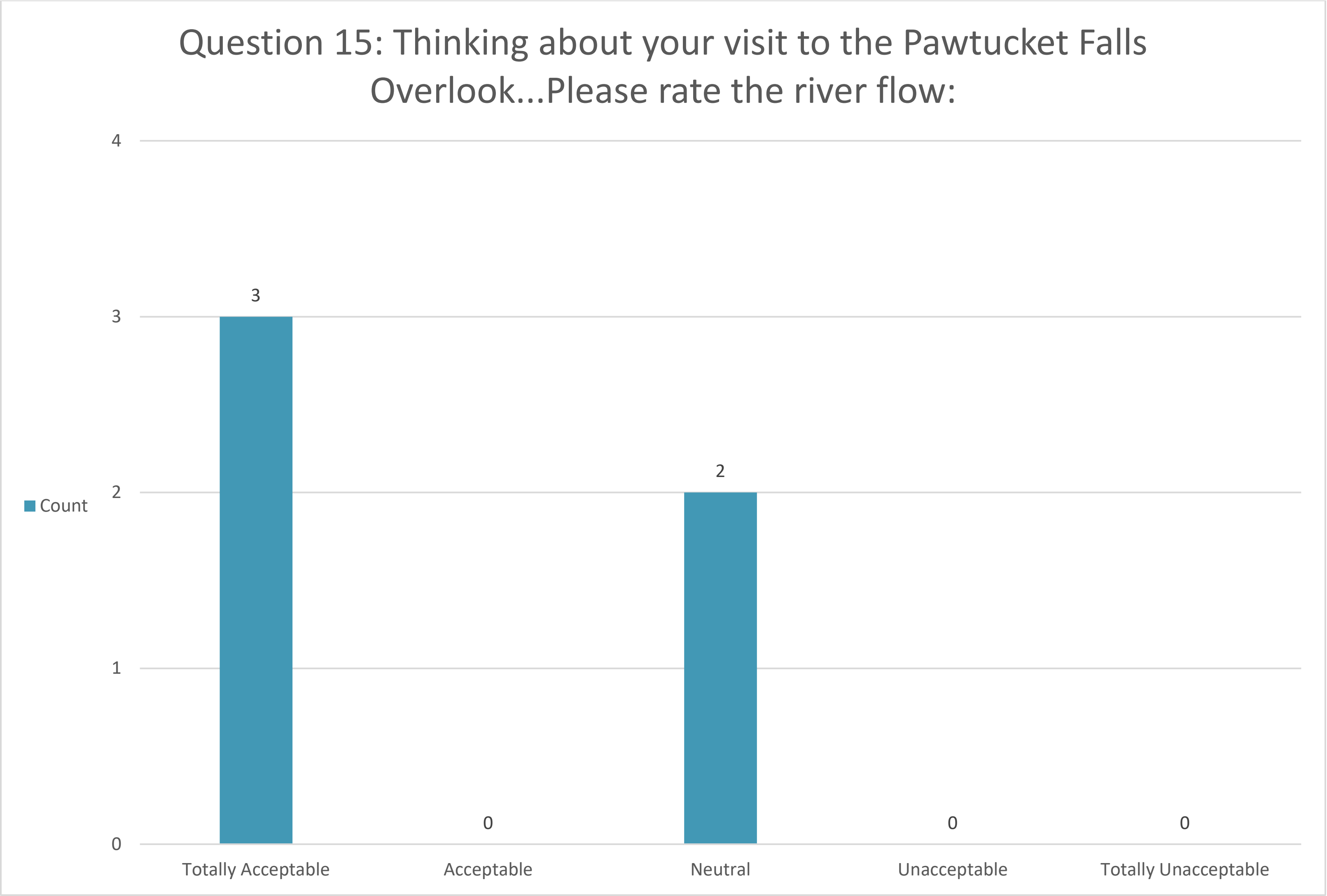
*Percentages not shown for respondent counts under ten.



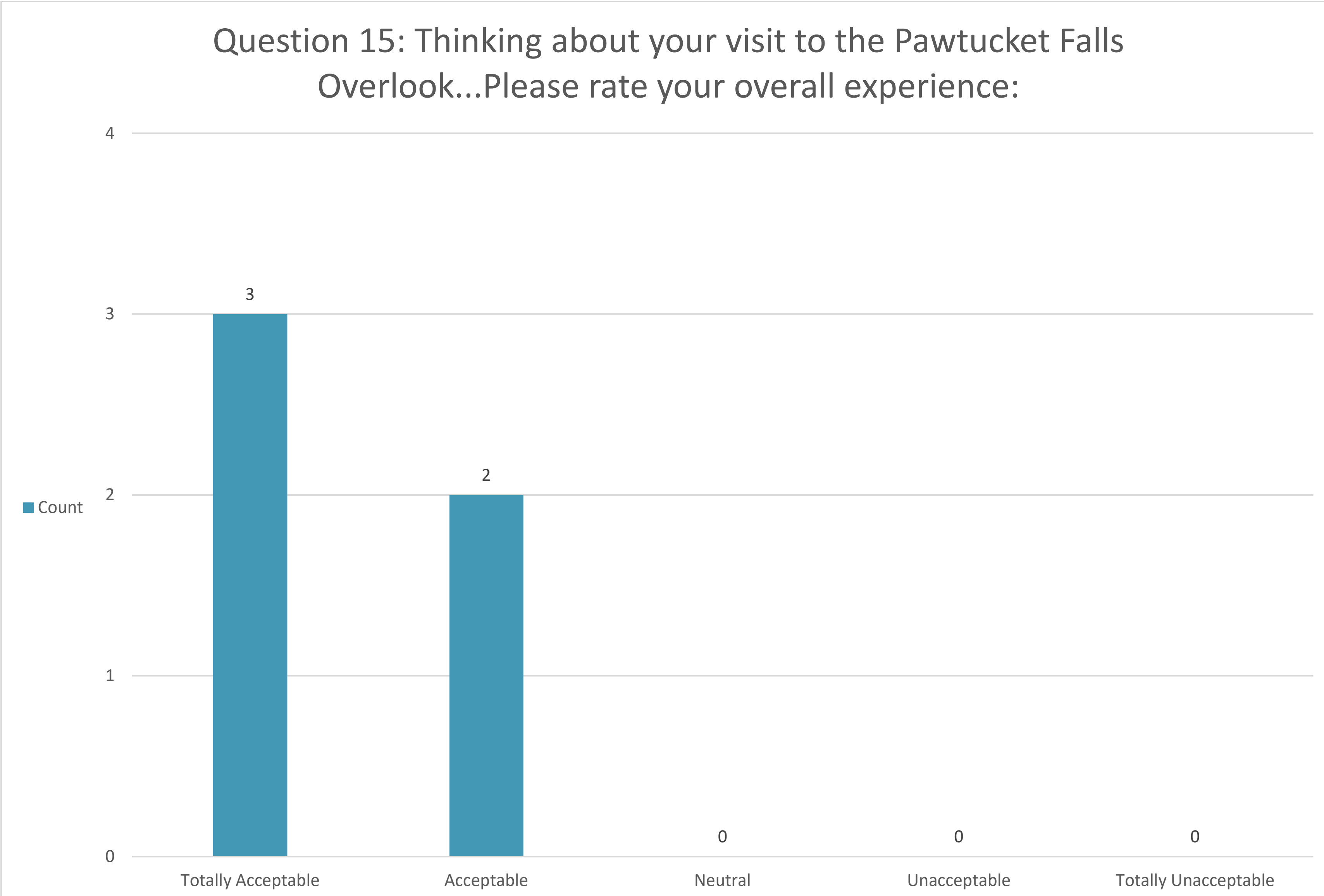
*Percentages not shown for respondent counts under ten.



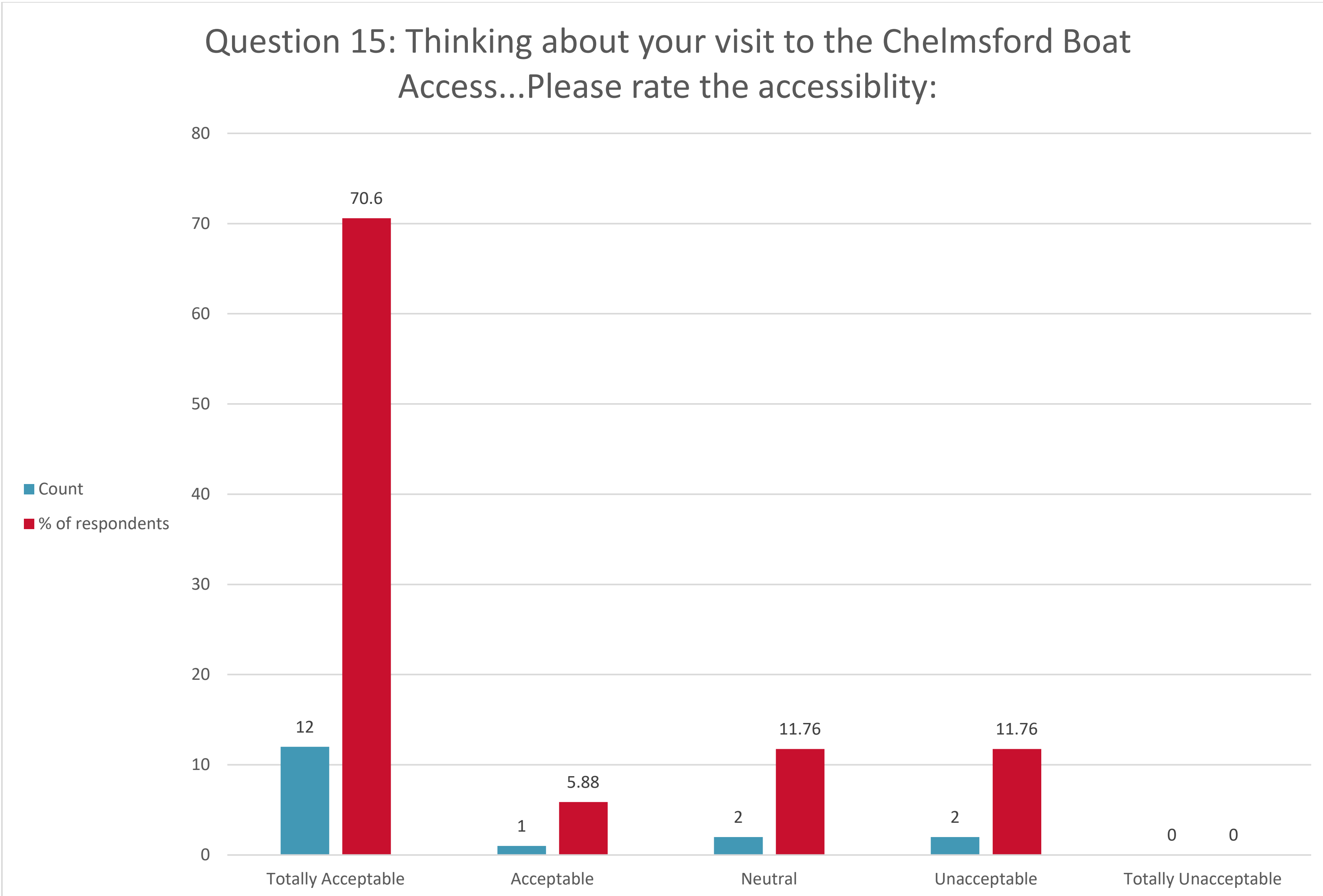
*Percentages not shown for respondent counts under ten.

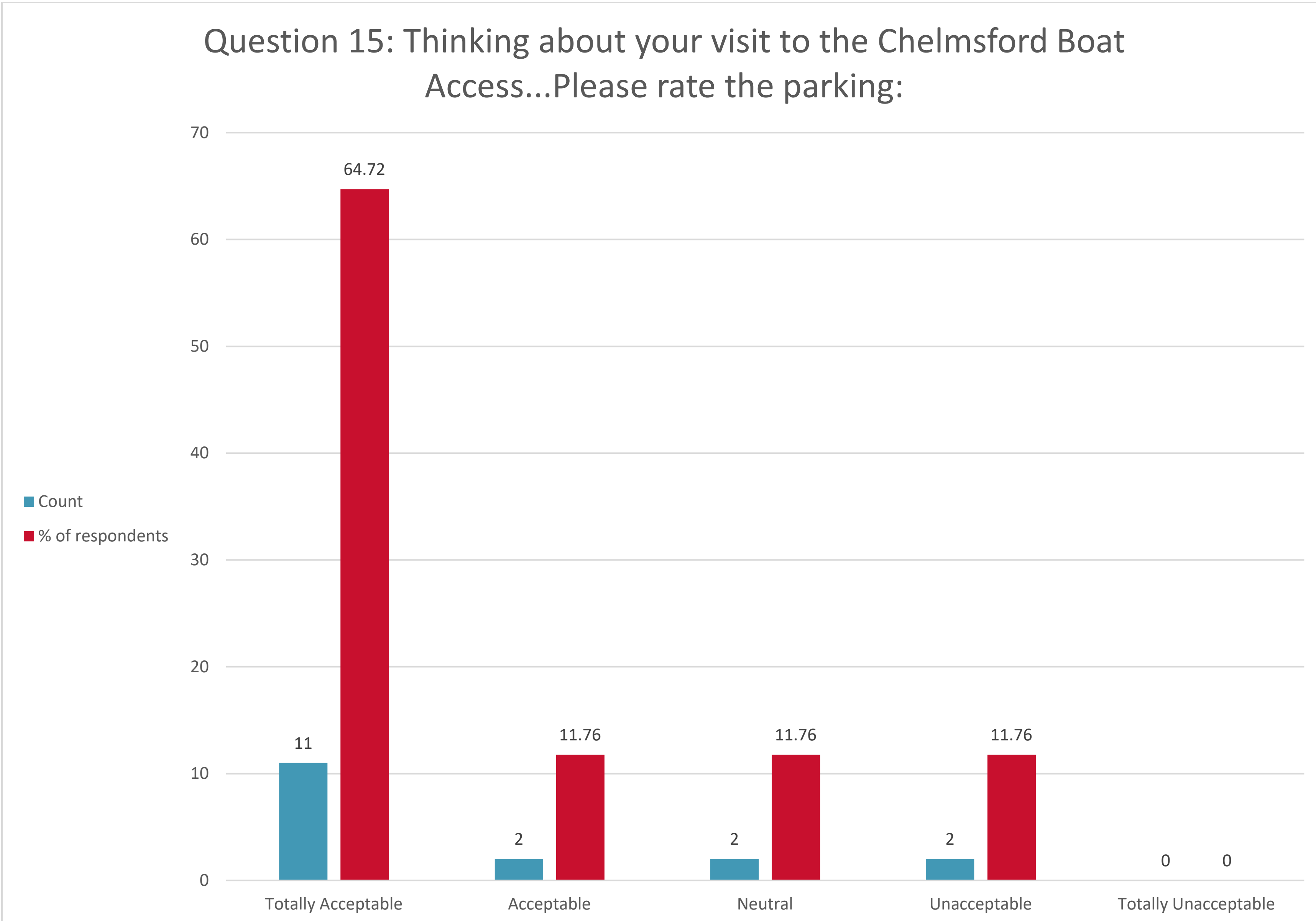


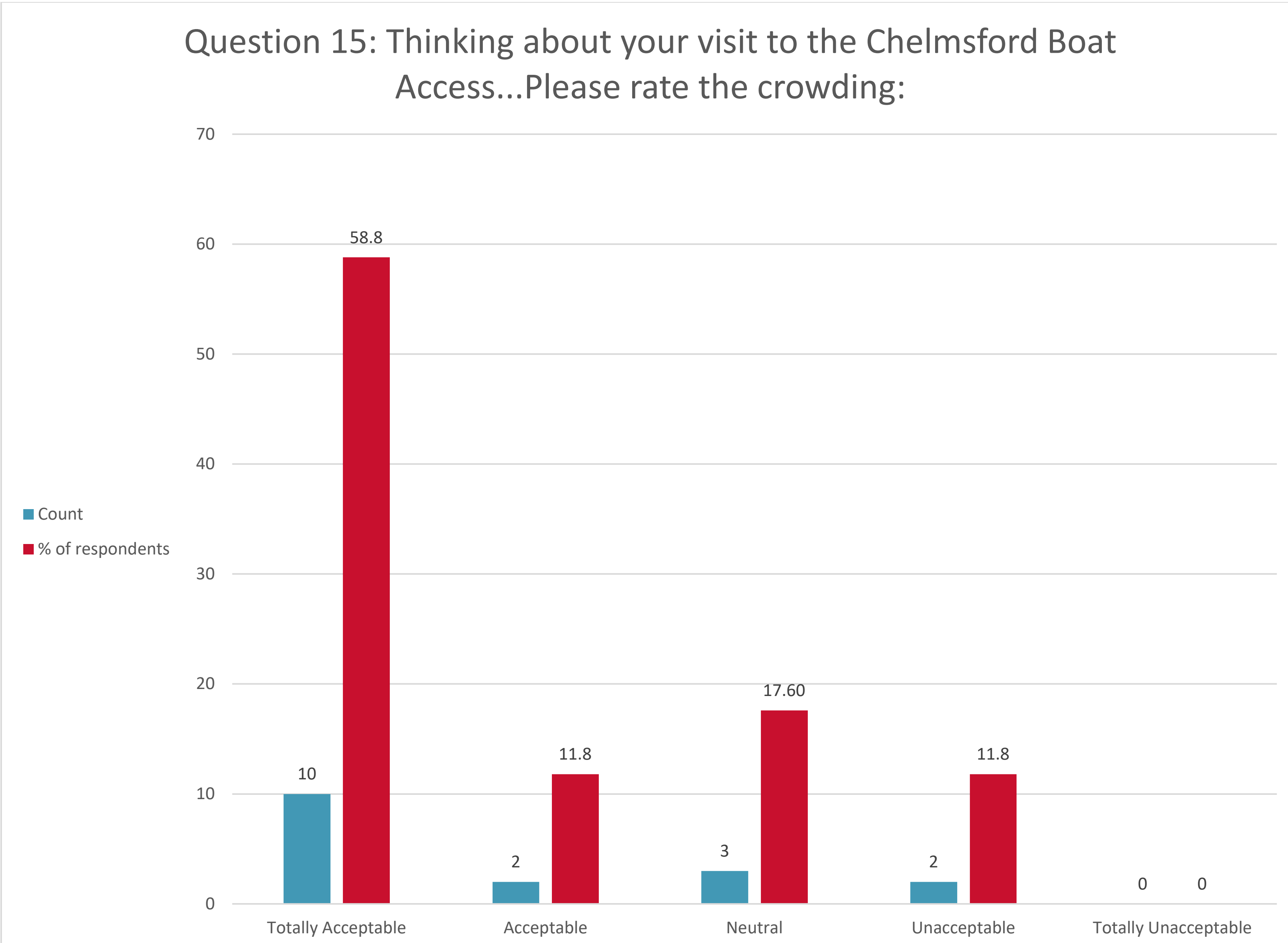
*Percentages not shown for respondent counts under ten.

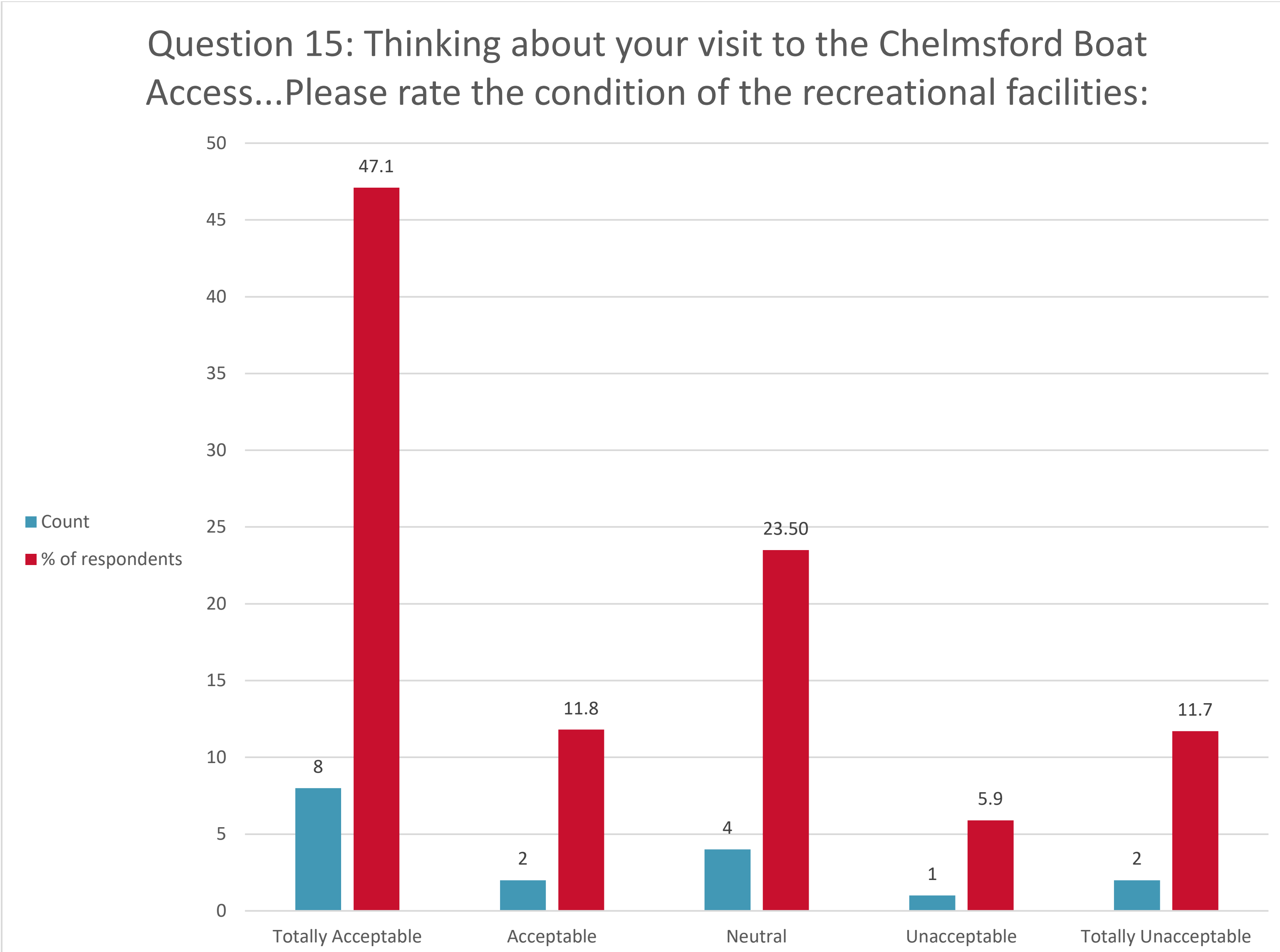


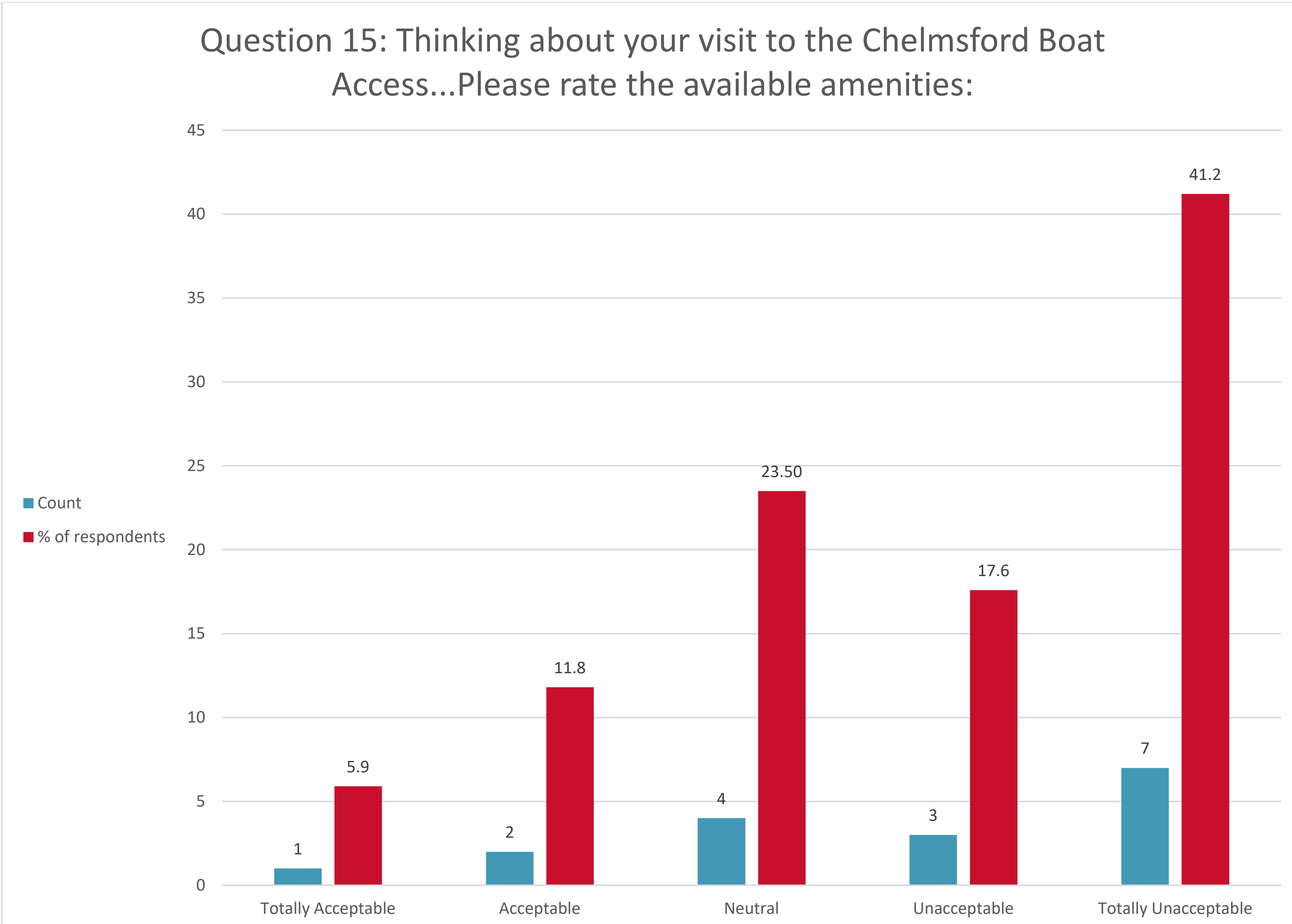
*Percentages not shown for respondent counts under ten.


Question 15: Thinking about your visit to the Chelmsford Boat Access...Please rate the accessiblity:
Count
% of respondents
80
70
60
50
40
30
20
10
0
70.6
12
5.88
1
11.76
2
11.76
2
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

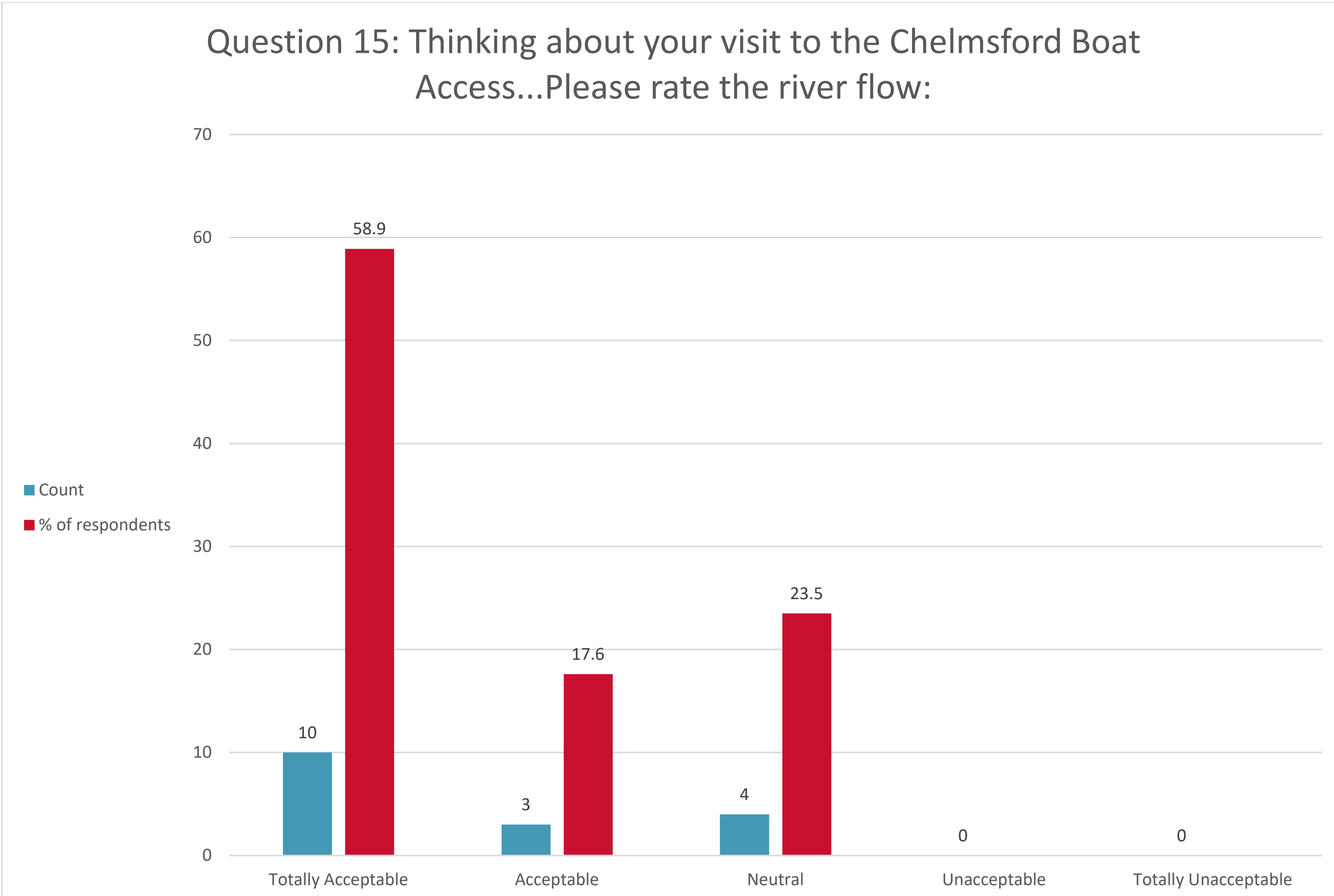

Question 15: Thinking about your visit to the Chelmsford Boat Access...Please rate the parking:
70
60
50
40
30
20
10
0
Count
% of respondents
64.72
11
11.76
2
11.76
2
11.76
2
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

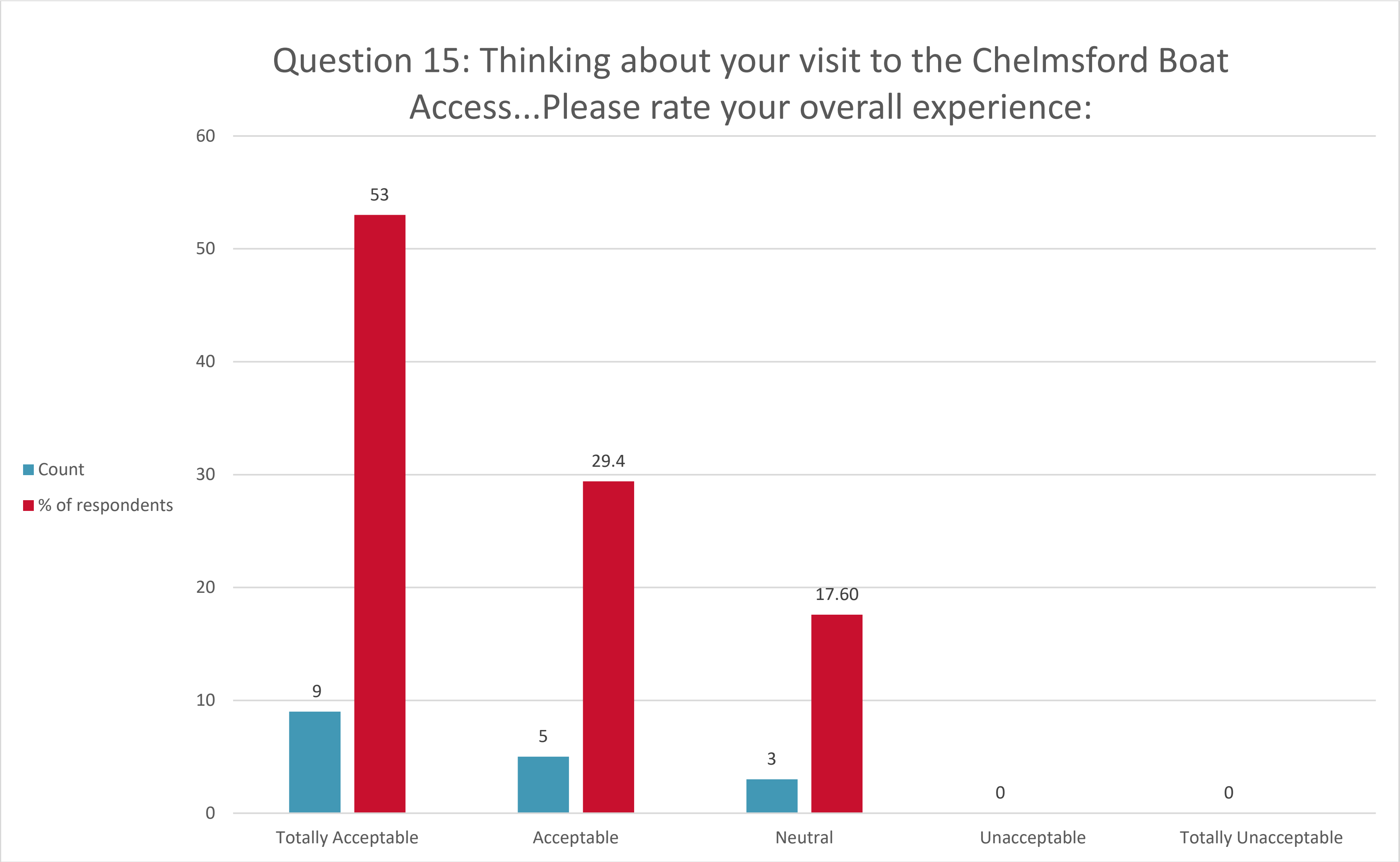

Question 15: Thinking about your visit to the Chelmsford Boat Access...Please rate the crowding:
70
60
50
40
30
20
10
0
Count
% of respondents
58.8
10
11.8
2
17.60
3
11.8
2
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 15: Thinking about your visit to the Chelmsford Boat Access...Please rate the condition of the recreational facilities:
Count
% of respondents
50
45
40
35
30
25
20
15
10
5
0
8
47.1
2
11.8
4
23.50
1
5.9
2
11.7
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

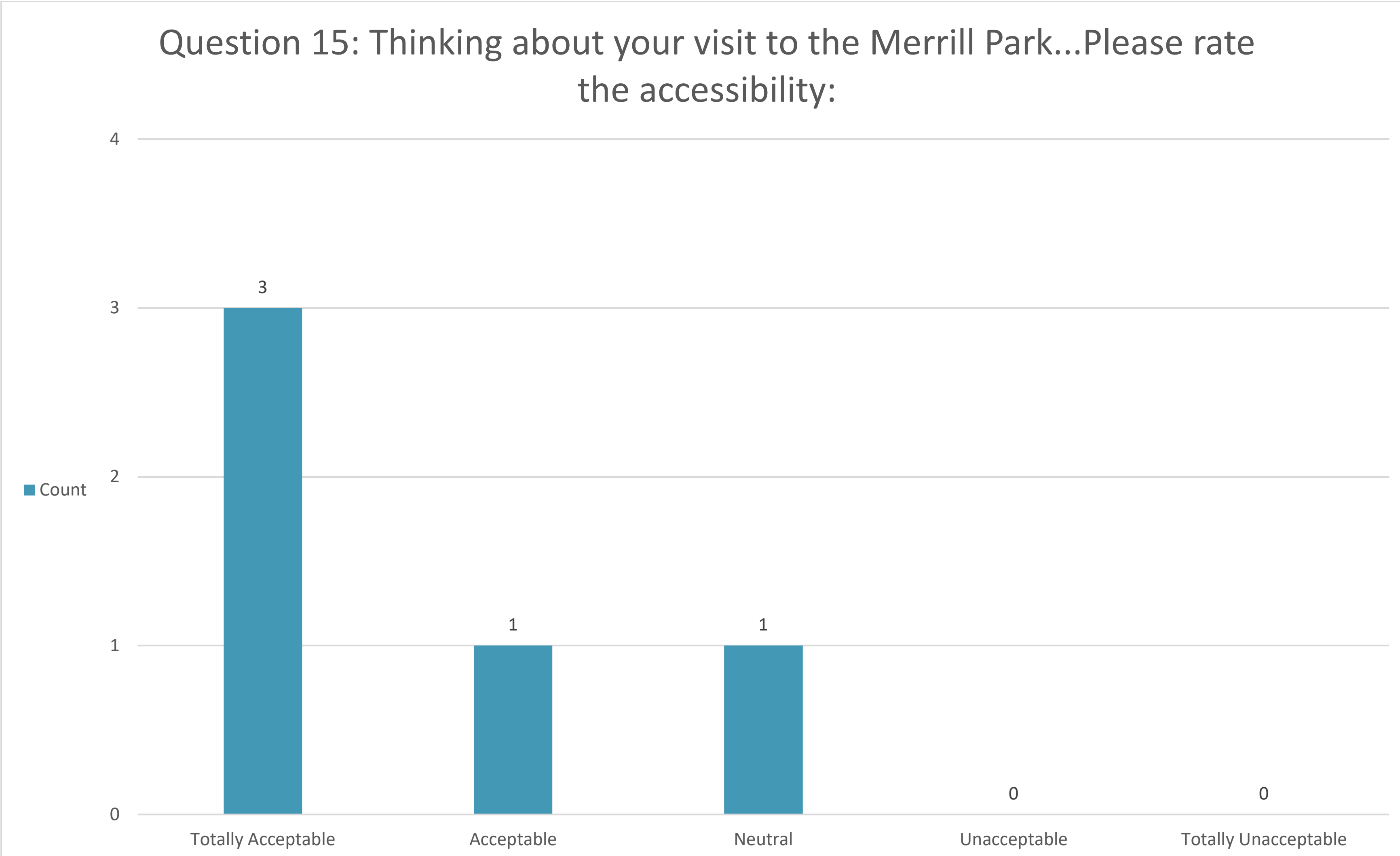


Question 15: Thinking about your visit to the Chelmsford Boat Access...Please rate the available amenities:
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
1
5.9
2
11.8
4
23.50
3
17.6
7
41.2
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

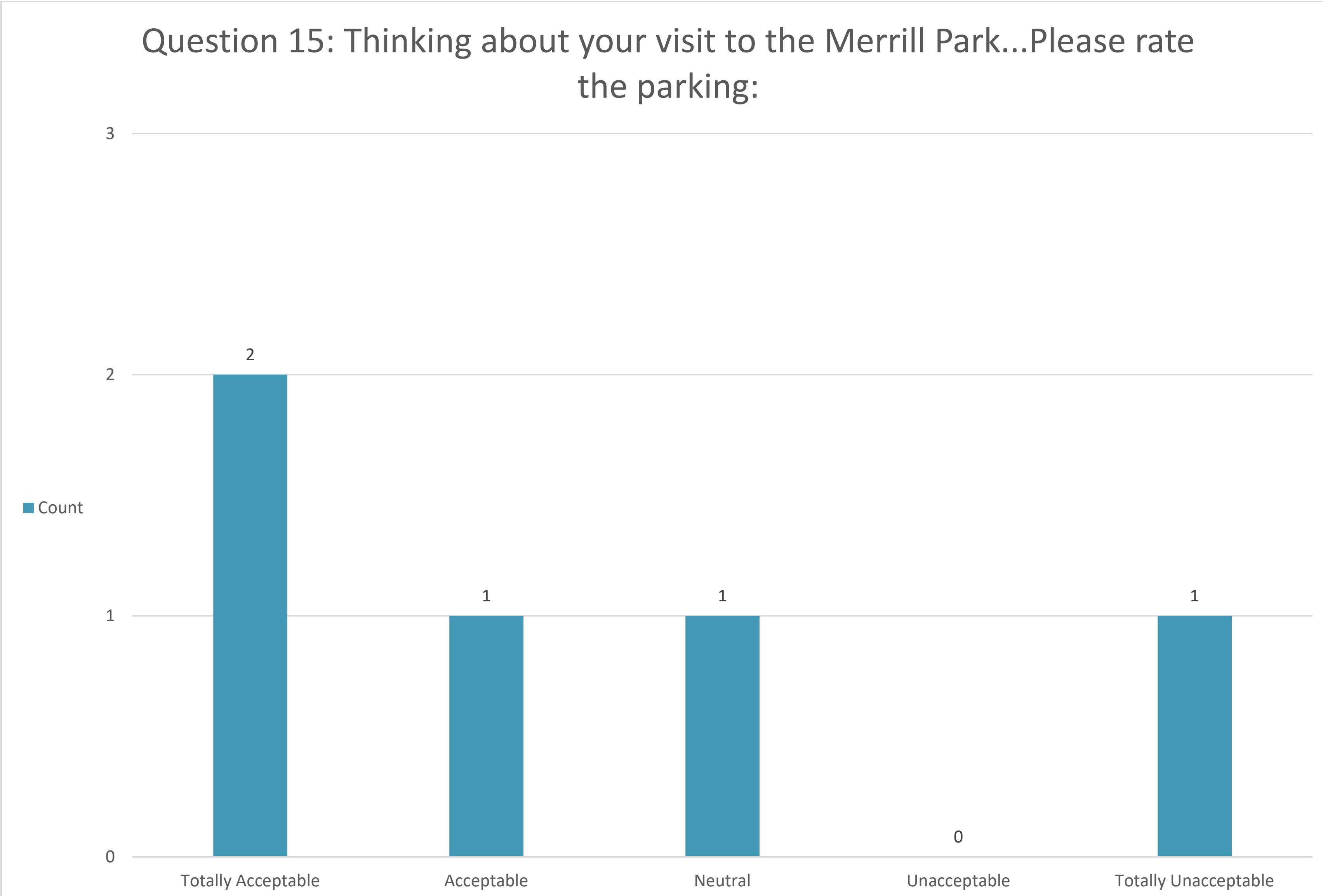

Question 15: Thinking about your visit to the Chelmsford Boat Access...Please rate the river flow:
Count
% of respondents
70
60
50
40
30
20
10
0
58.9
10
17.6
3
23.5
4
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable



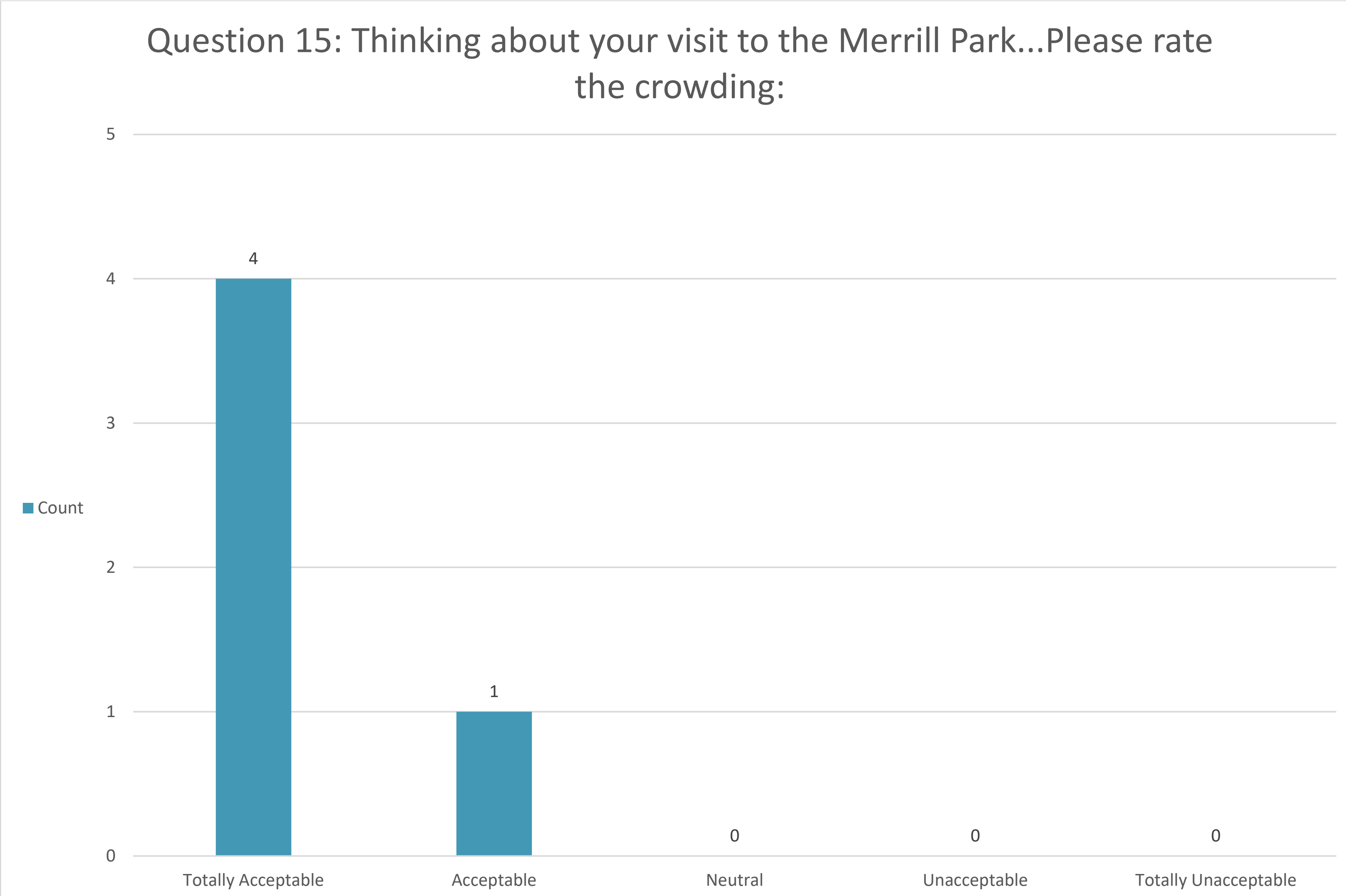
Question 15: Thinking about your visit to the Chelmsford Boat Access...Please rate your overall experience:
Count
% of respondents
60
50
40
30
20
10
0
53
29.4
17.60
9
5
3
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable



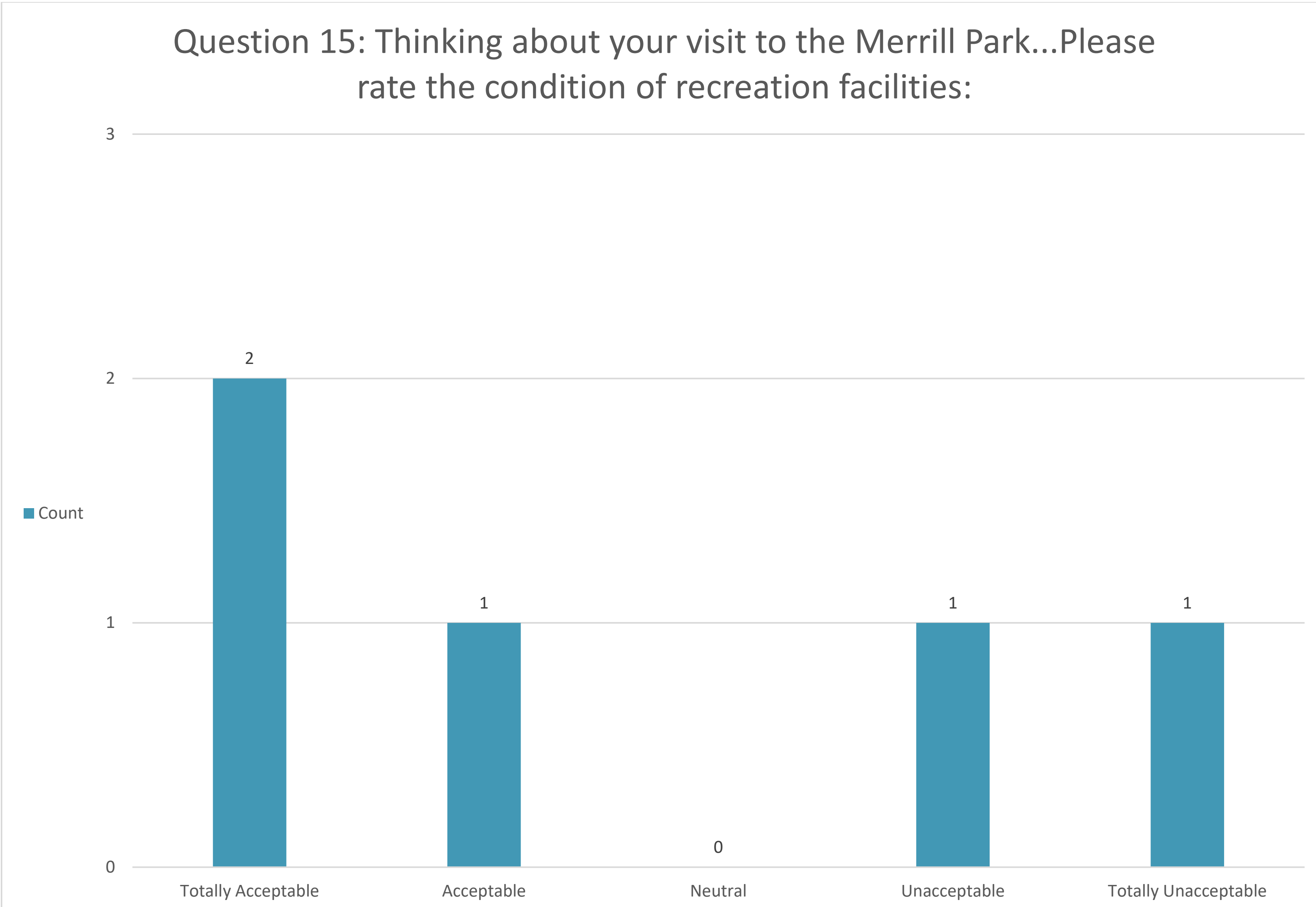
*Percentages not shown for respondent counts under ten.



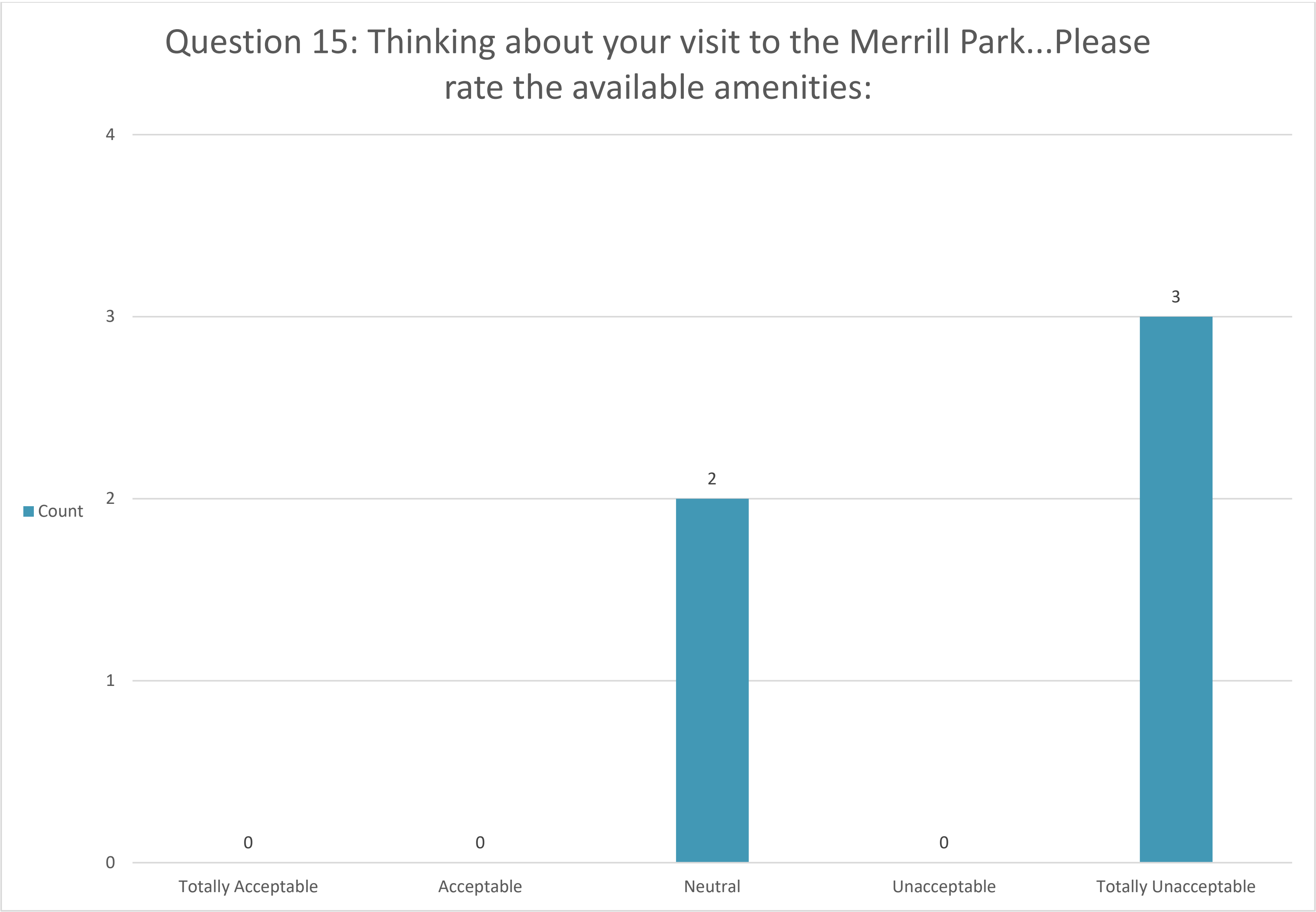
*Percentages not shown for respondent counts under ten.



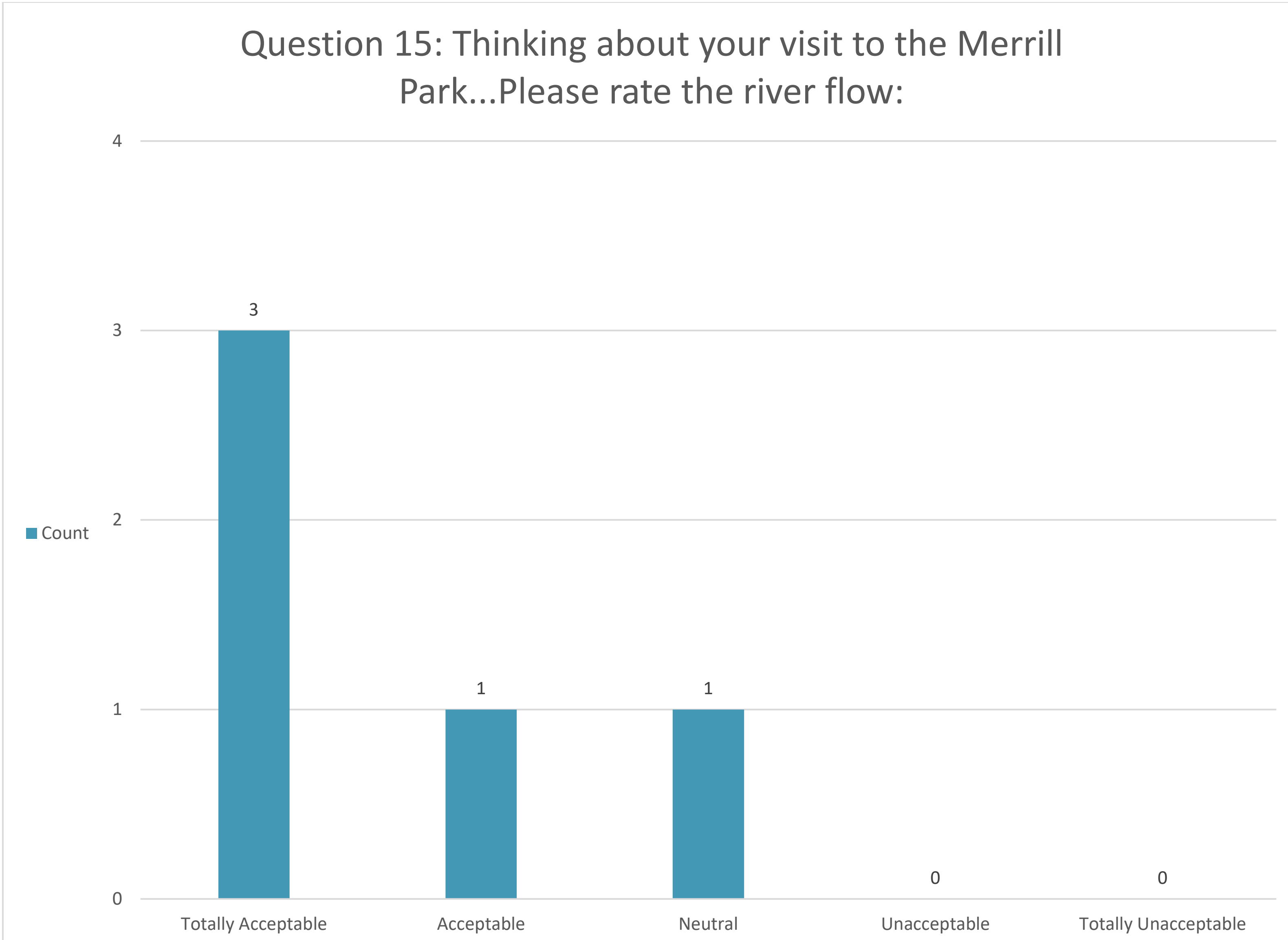
*Percentages not shown for respondent counts under ten.



*Percentages not shown for respondent counts under ten.



*Percentages not shown for respondent counts under ten.



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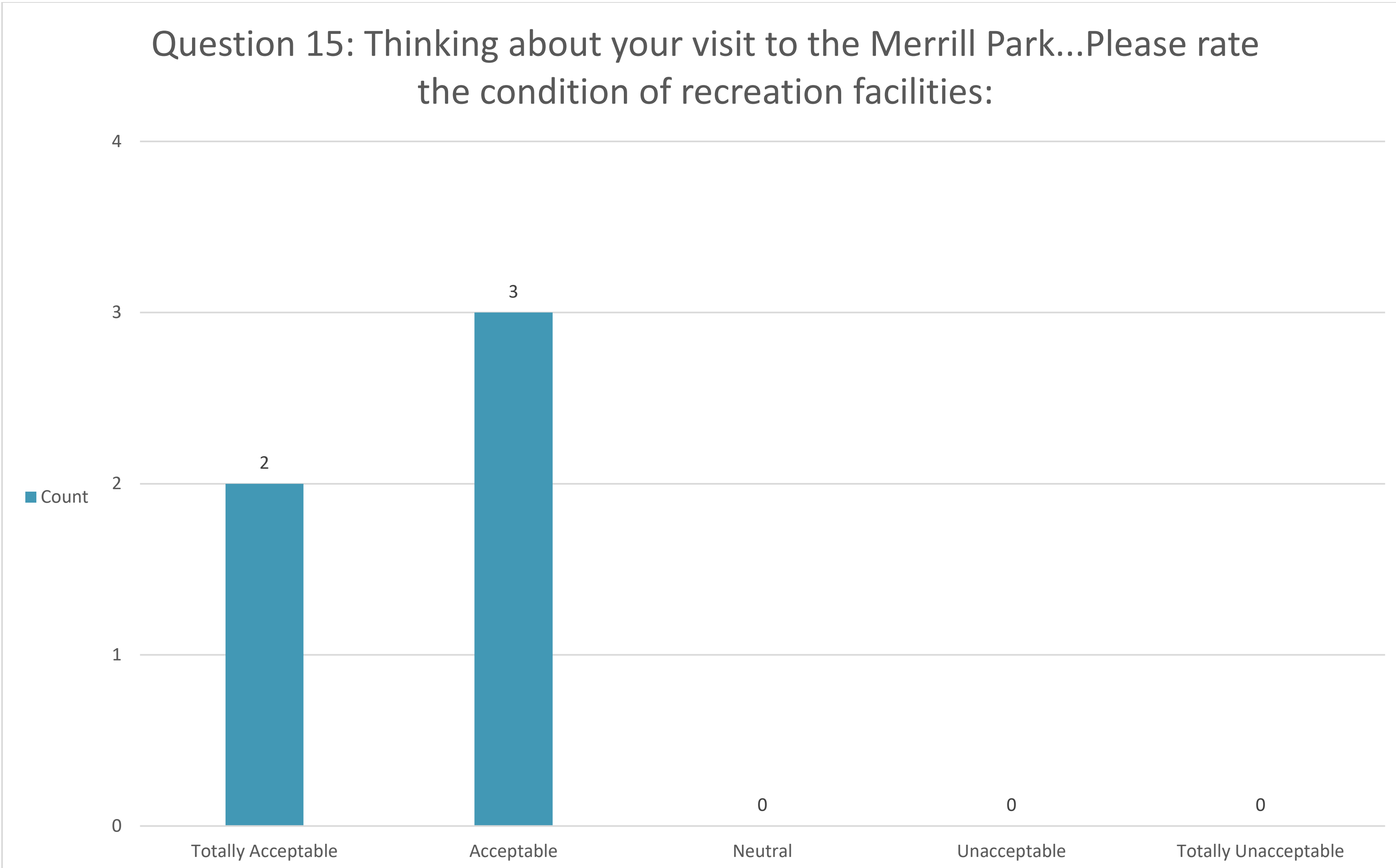
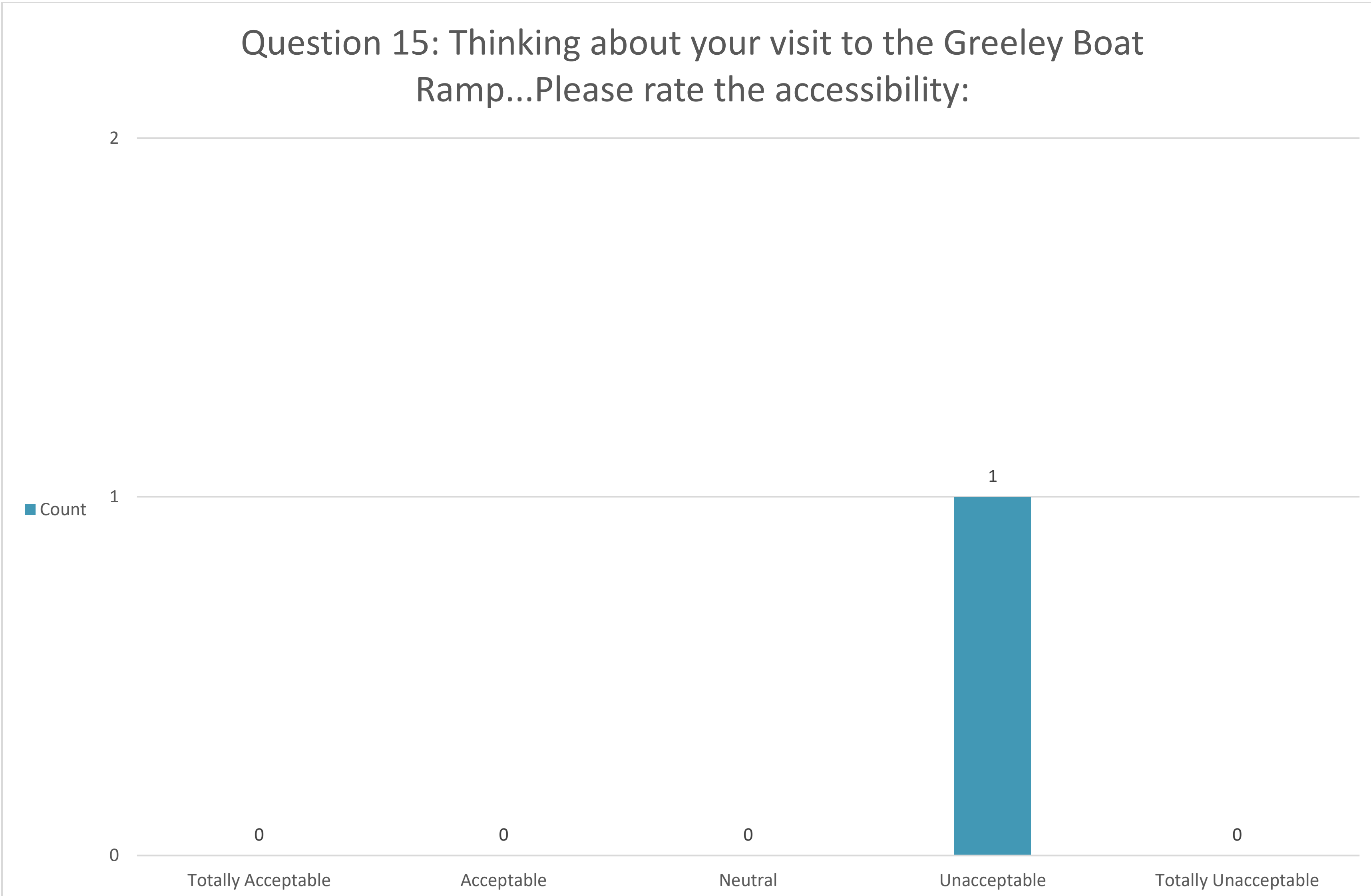
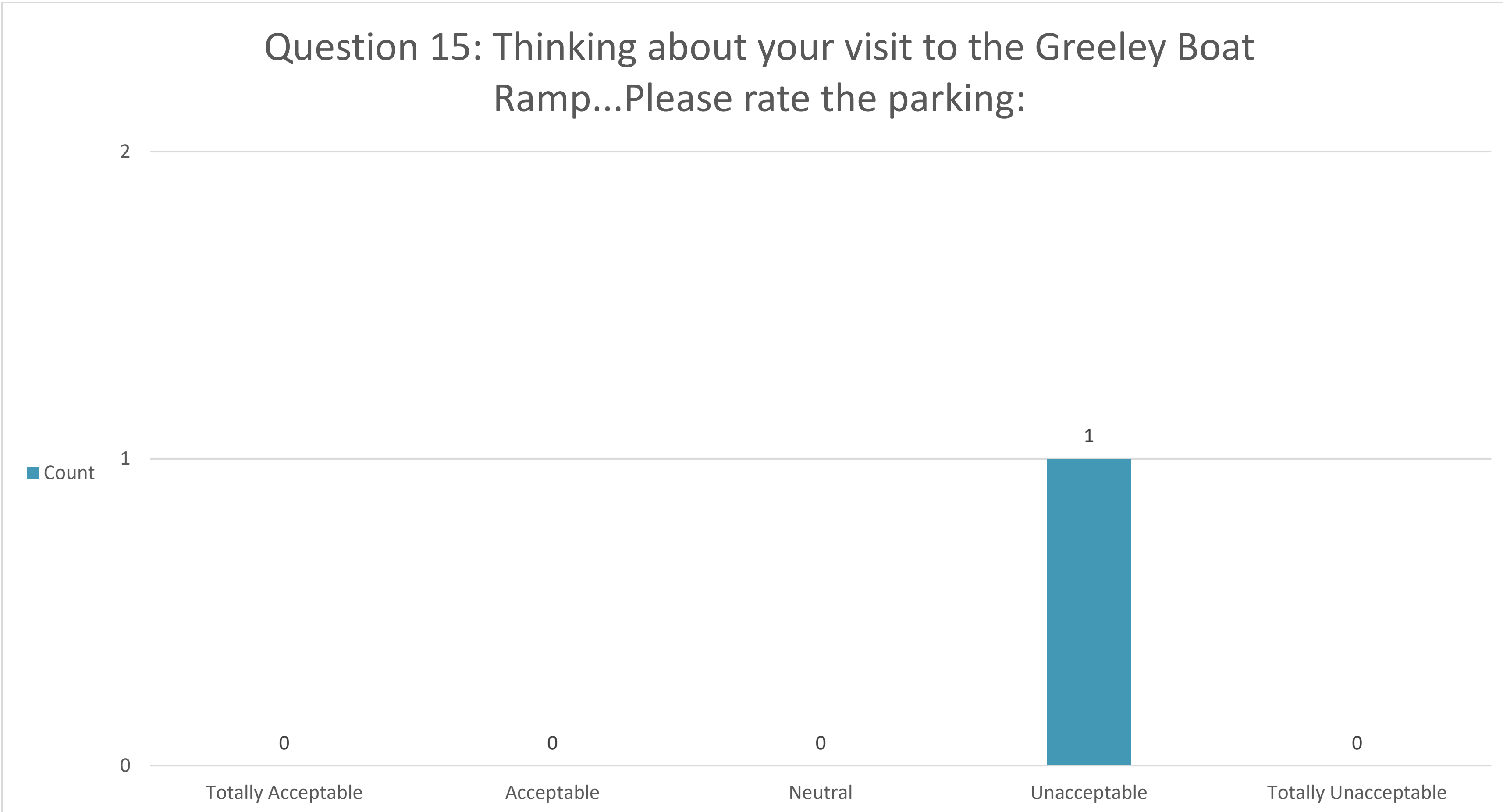


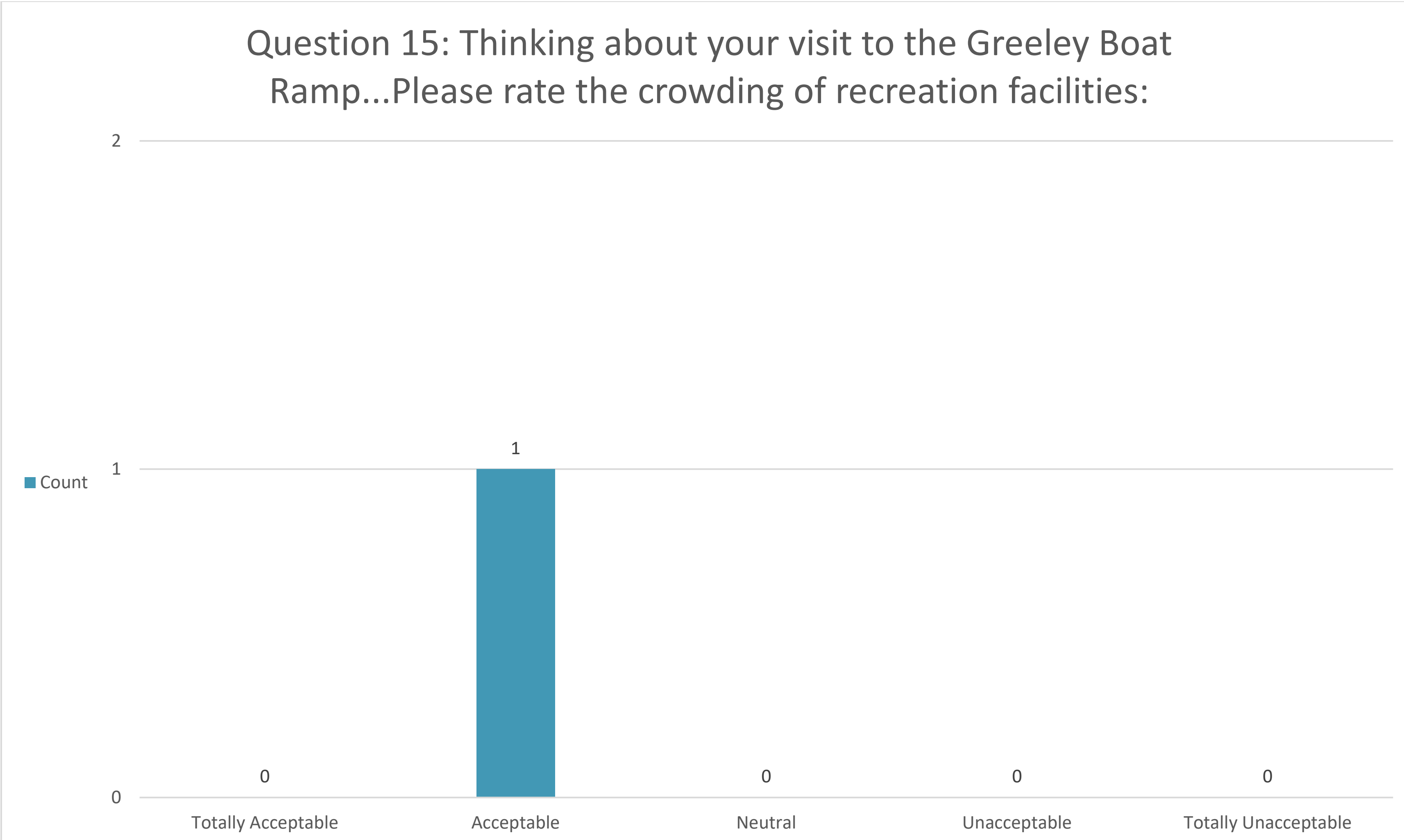
*Percentages not shown for respondent counts under ten.



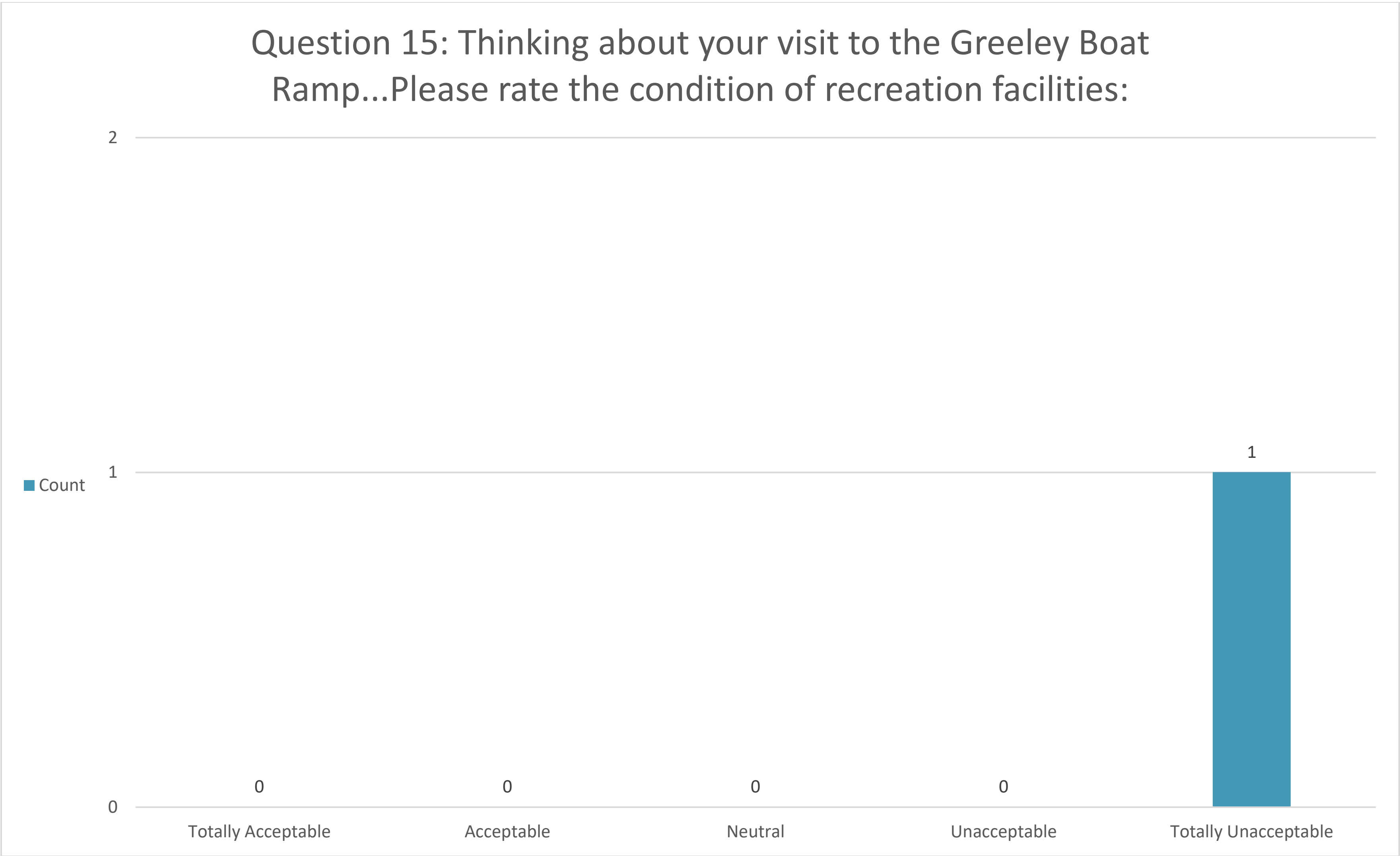
*Percentages not shown for respondent counts under ten.



*Percentages not shown for respondent counts under ten.



*Percentages not shown for respondent counts under ten.



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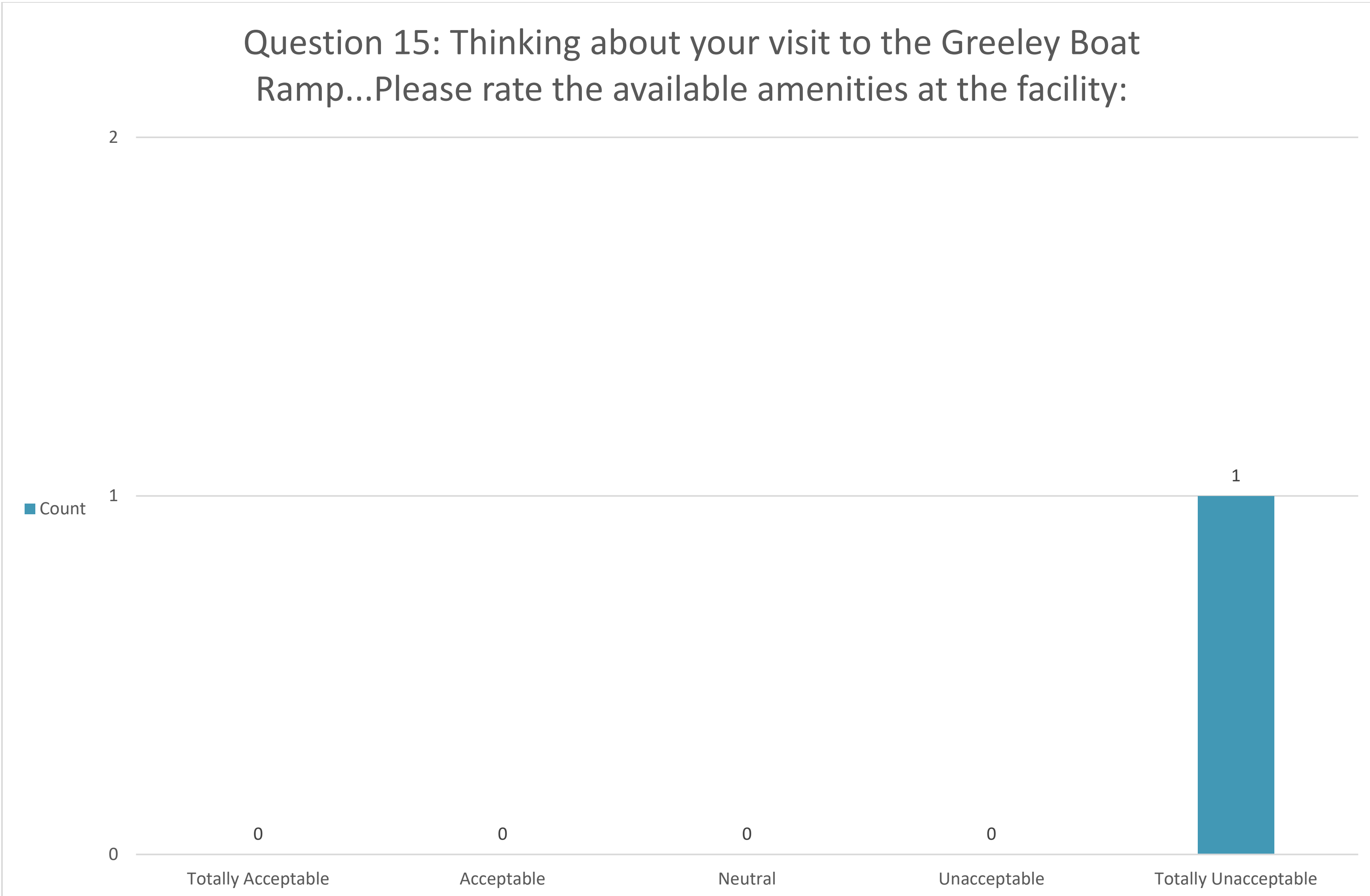
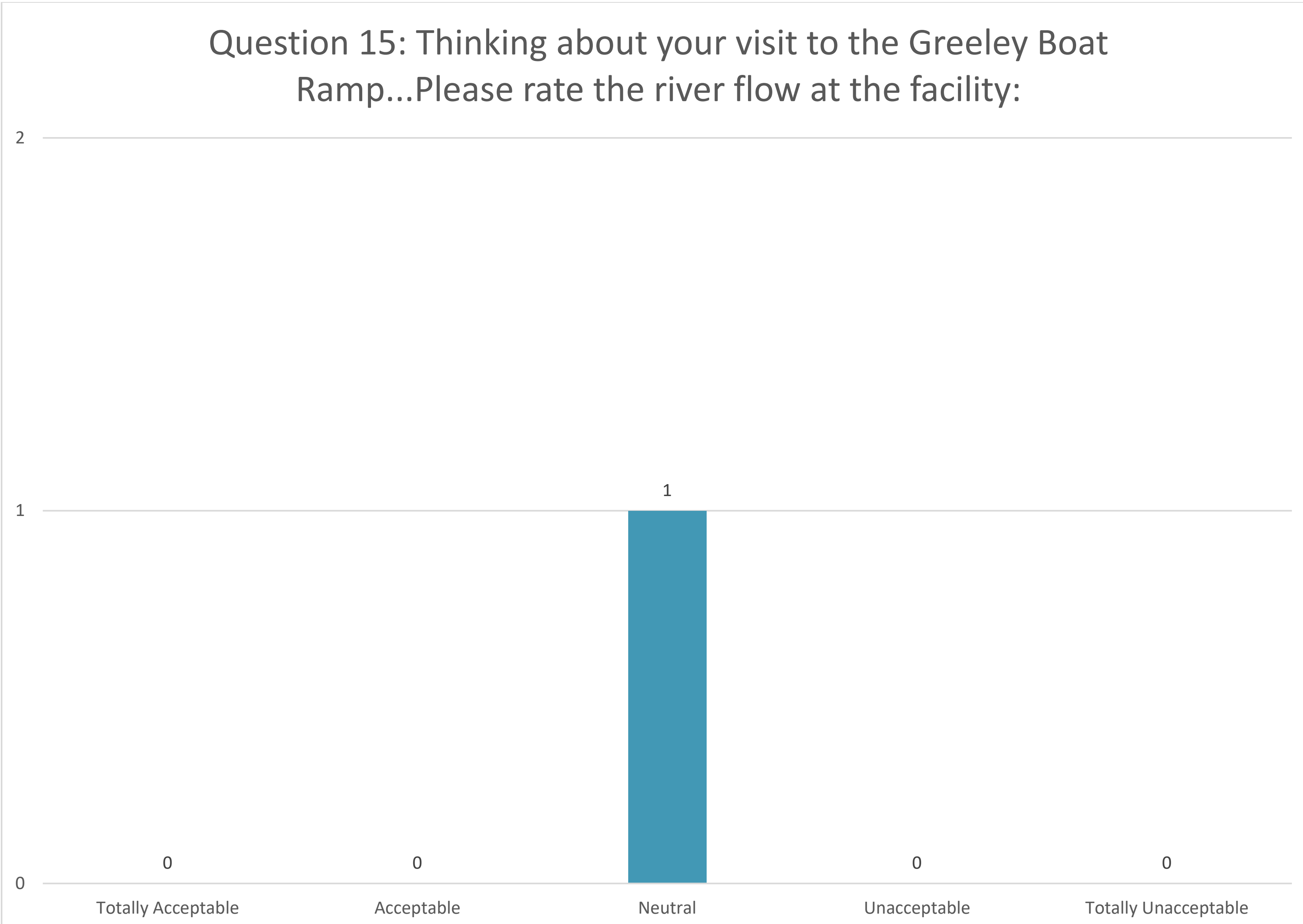
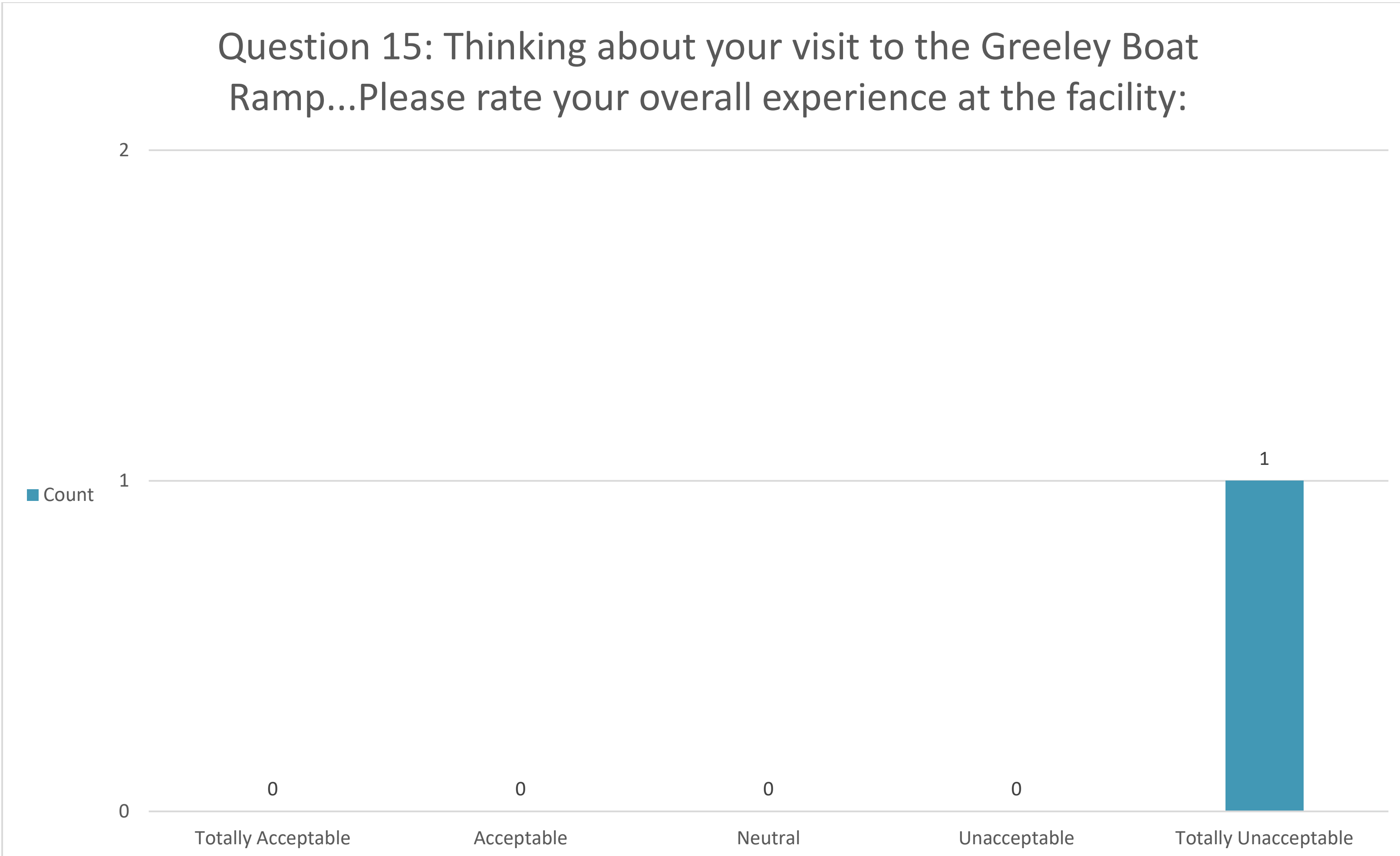


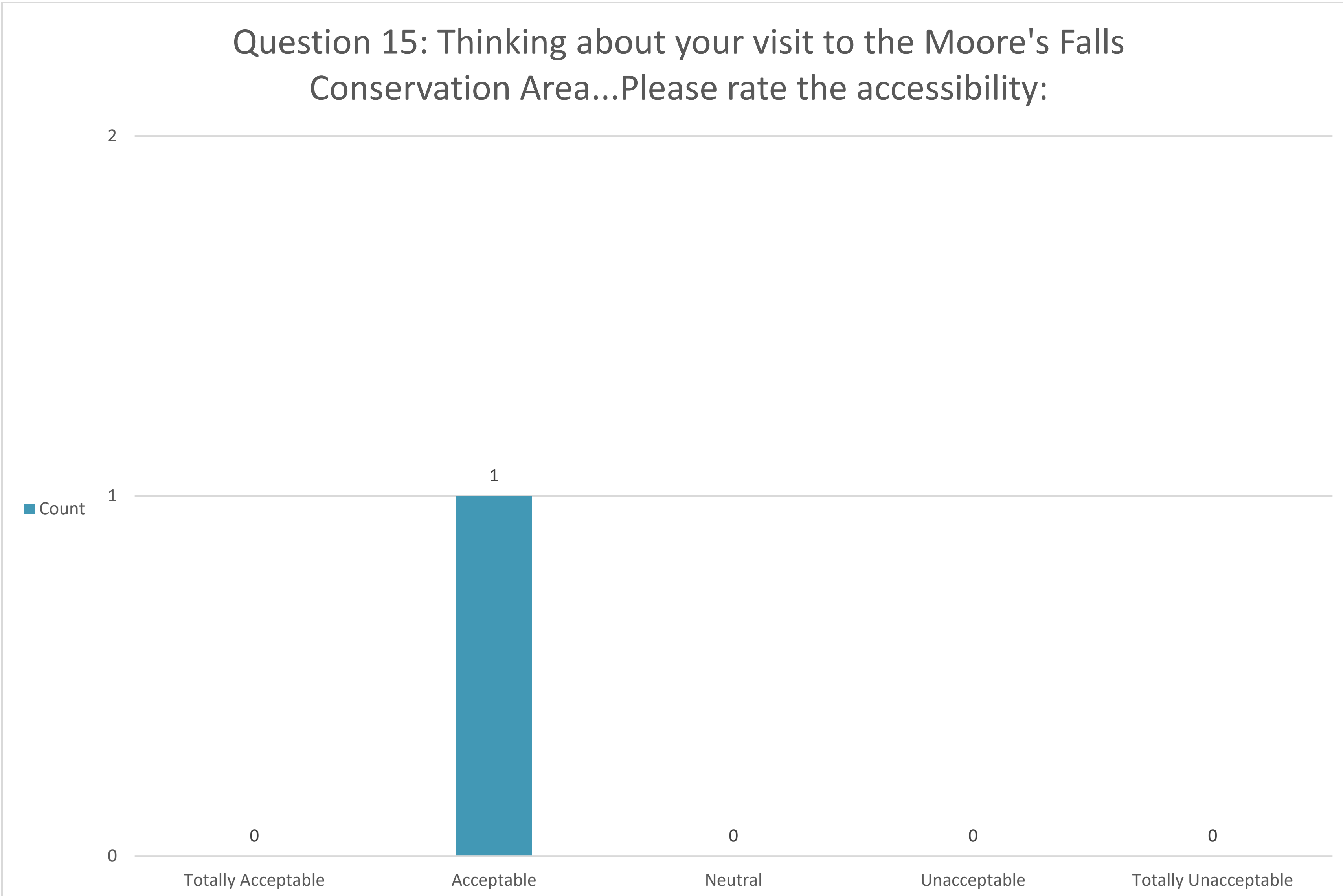
*Percentages not shown for respondent counts under ten.



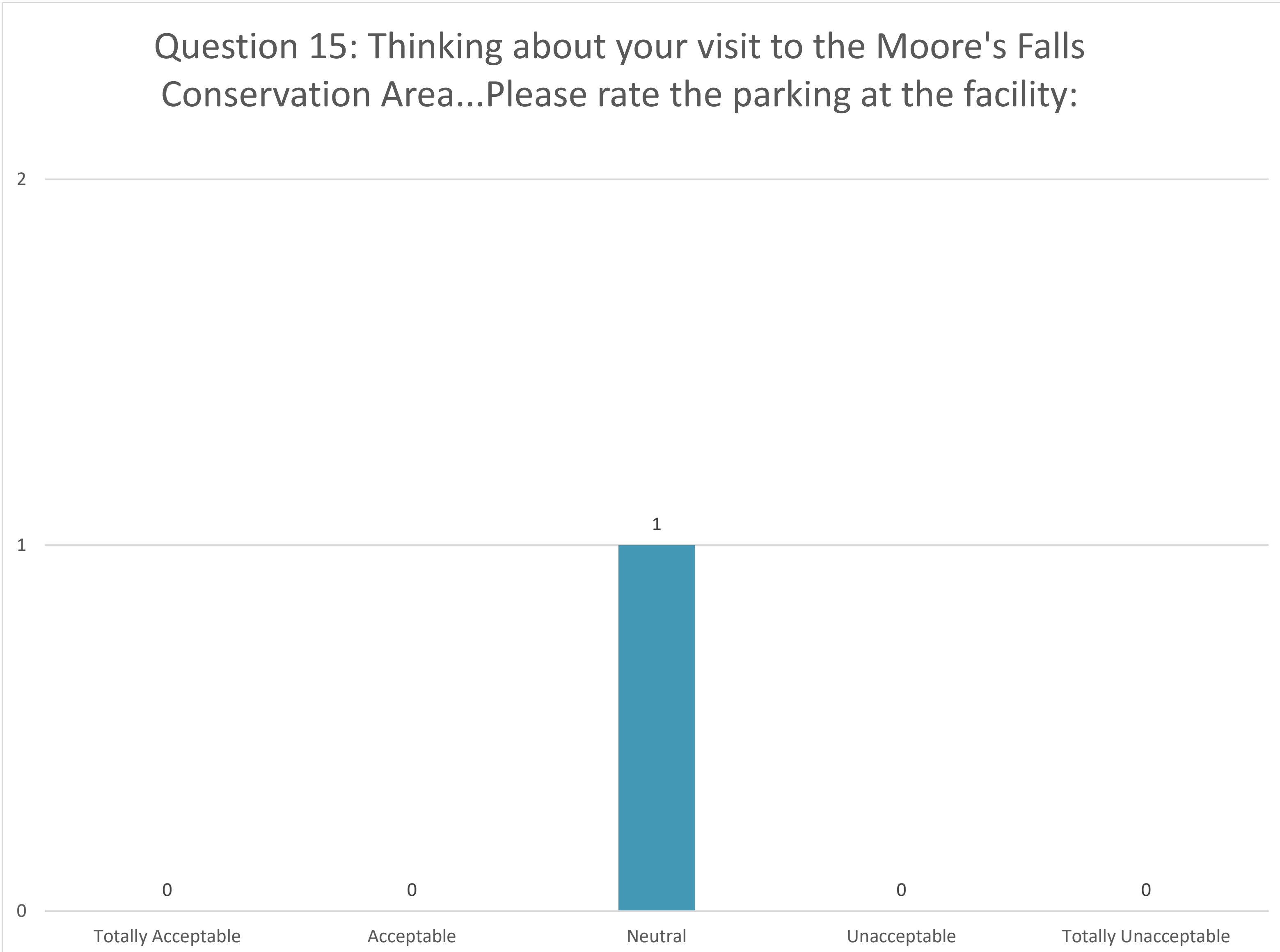
*Percentages not shown for respondent counts under ten.



*Percentages not shown for respondent counts under ten.



*Percentages not shown for respondent counts under ten.



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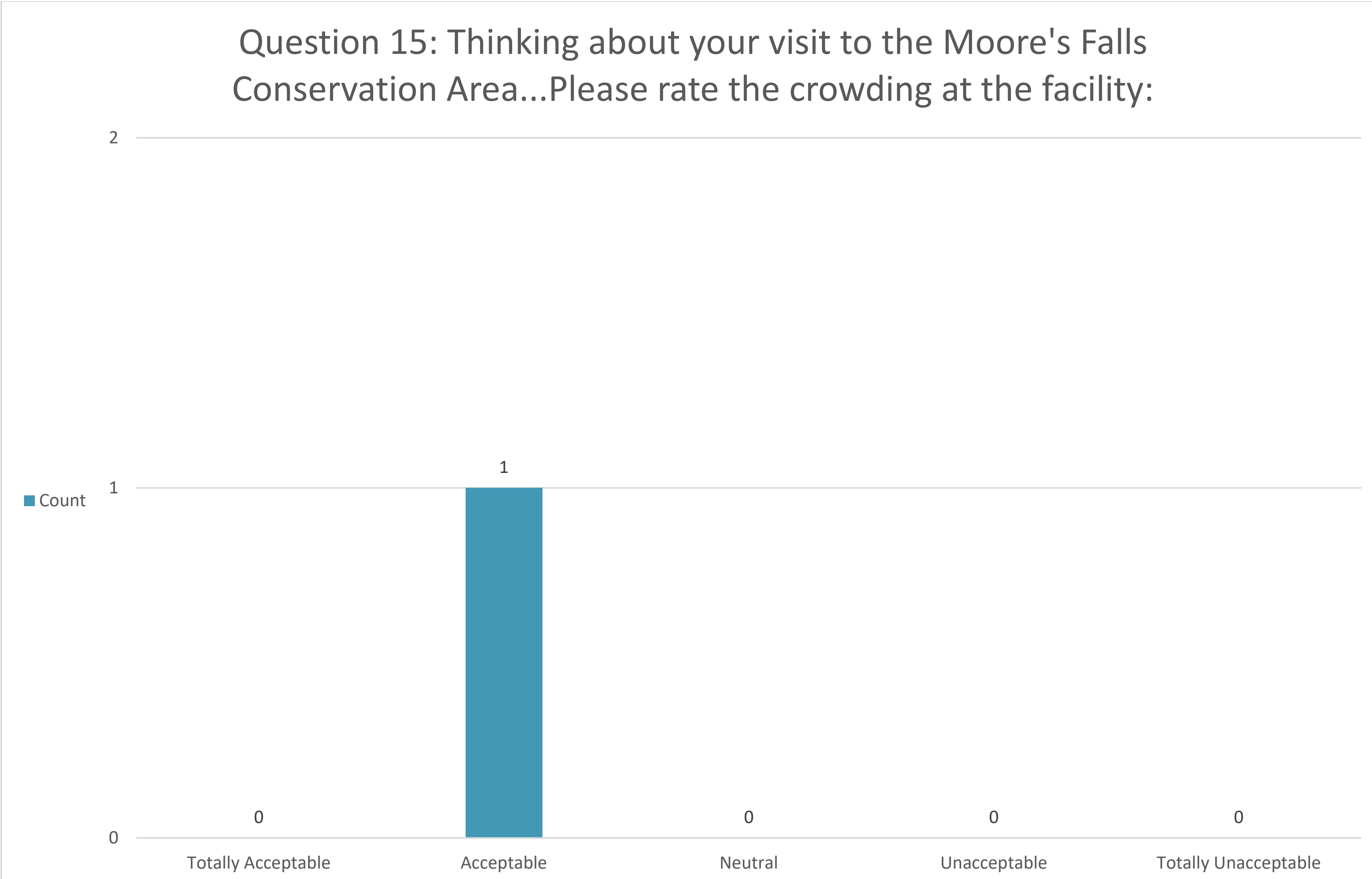
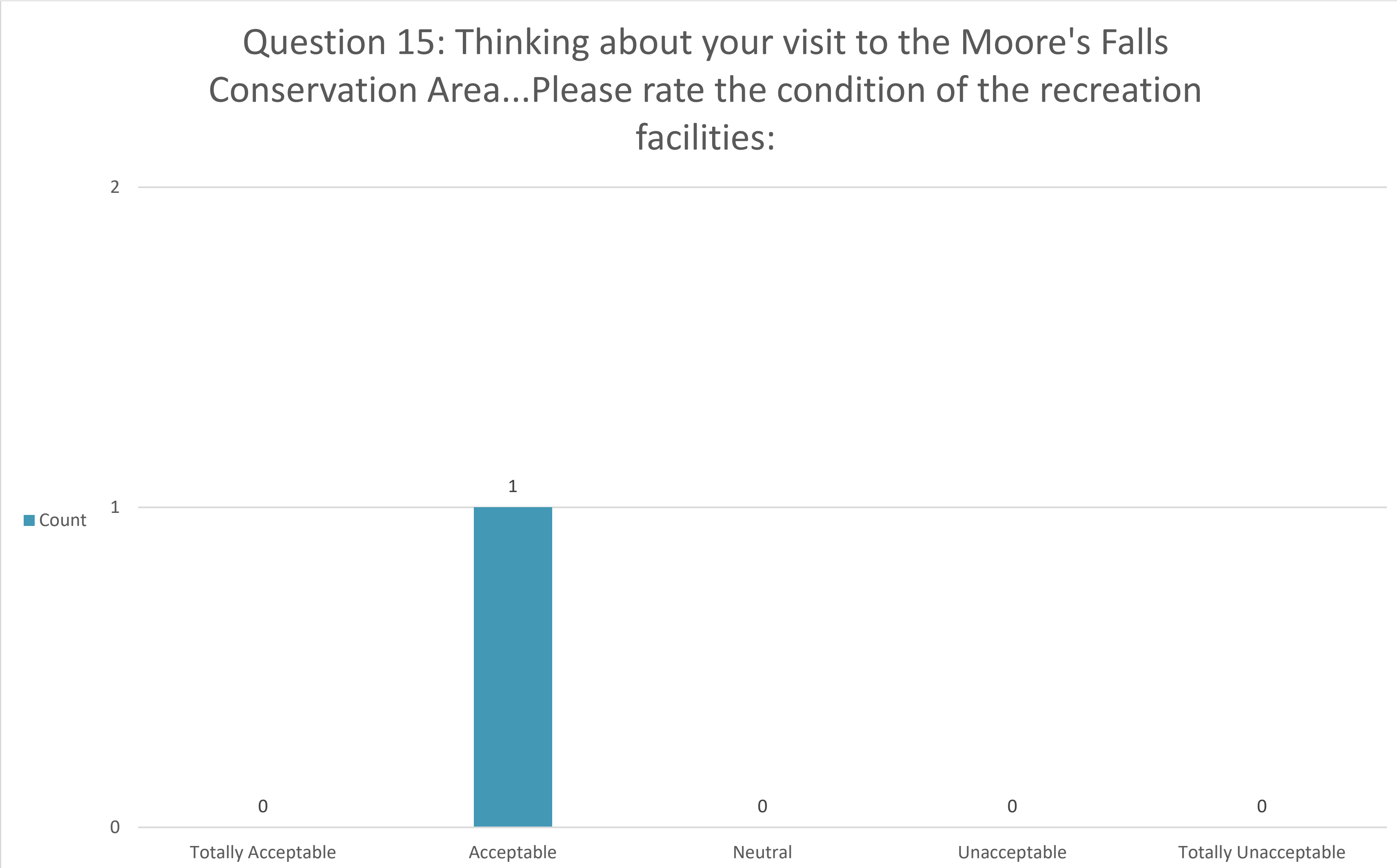
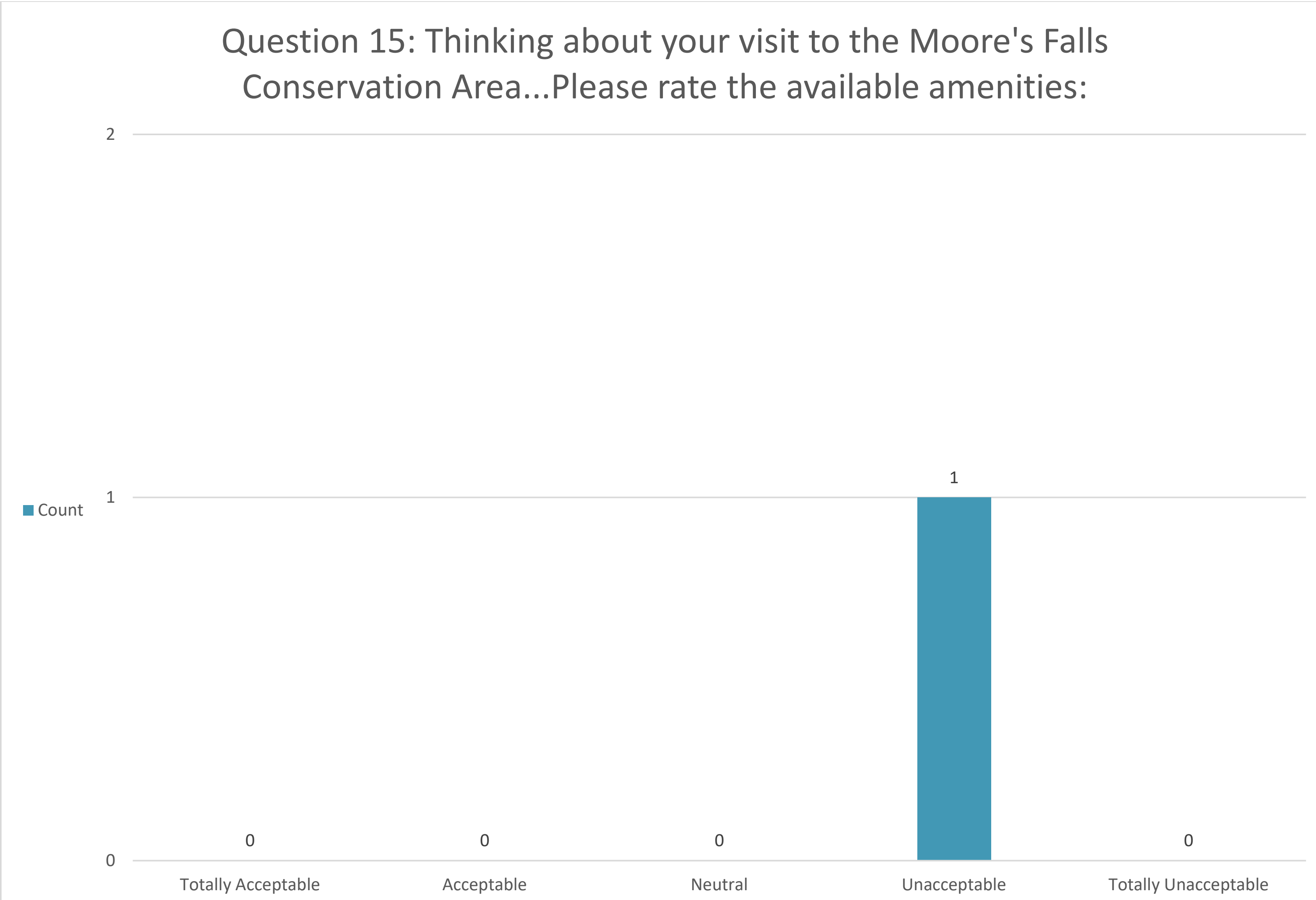


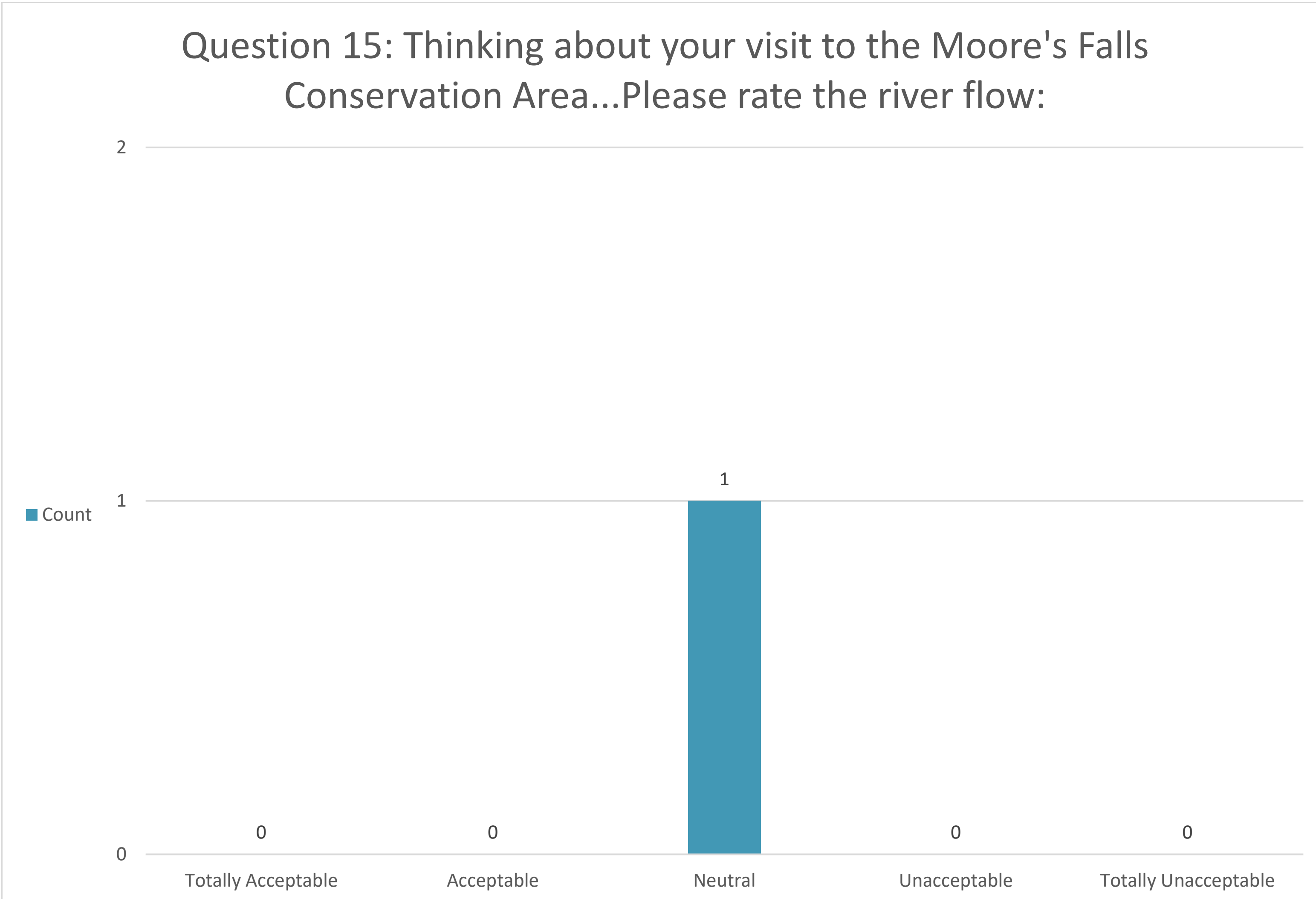
*Percentages not shown for respondent counts under ten.



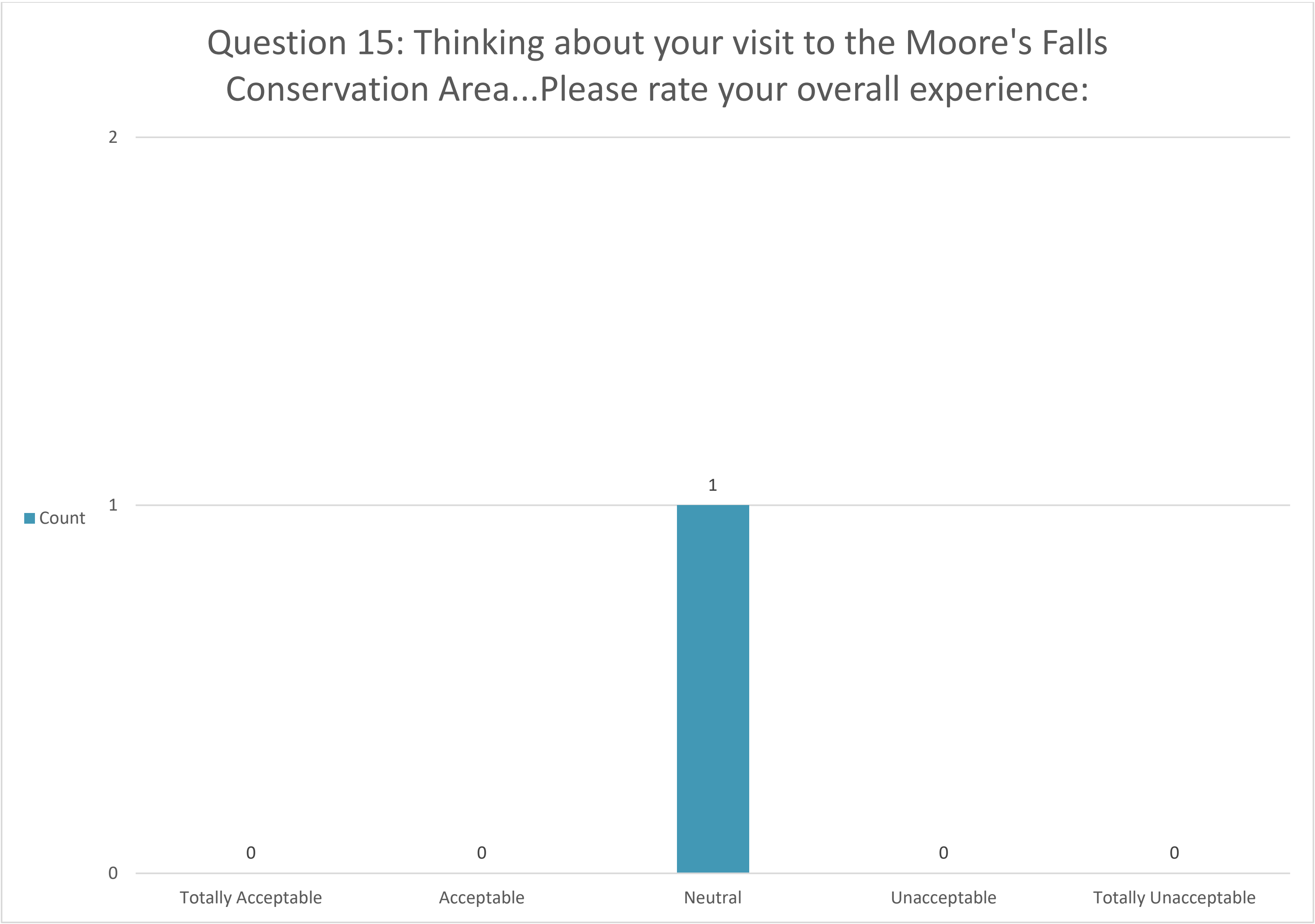
*Percentages not shown for respondent counts under ten.



*Percentages not shown for respondent counts under ten.



*Percentages not shown for respondent counts under ten.



*Percentages not shown for respondent counts under ten.

	Question 16: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Question 16: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Question 17: Please share any other comments that you have regarding recreation at the Lowell Project:
Recorded Date	**Q16. Type of Recreation Enhancement:**	**Q. 16 Location(s)**	**Q16. Type of Recreation Enhancement:**	**Q. 16 Location(s)**	**Q17. General comments**
5/26/2019 19:18	Bathroom, fix boat ramp	Chelmsford Boat Ramp			
5/26/2019 19:18	Better parking more; more cleanliness	Lowell Heritage State Park	Needs a bathroom	Rourke Brothers Boat Ramp	
5/26/2019 19:18	Bathroom would be nice	Rourke Brothers Boat Ramp			Very clean, Every year is cleaner!
5/26/2019 19:18	Better ramp	Chelmsford Boat Ramp			
5/26/2019 19:18	Fix sidewalks, add grills, add picnic tables	Lowell Heritage State Park			Need professionally experienced oversight of programs that are held here. Hold events on holidays. More park staff for events.
5/26/2019 19:18	Bike and walk lanes	Merrimack River trail	Signage for opening of gates	Northern canal walkway	Nice dam; aesthetically pleasing
5/26/2019 19:18	Dock sanding, longer ramp	Rourke Brothers Boat Ramp	Repave of ramp, dock, trash barrel	Chelmsford	More access on opposite side of river of rourke bros ramp
5/26/2019 19:18	More fishing piers	Rourke Brothers Boat Ramp			
5/26/2019 19:18	New boat launch- deteriorating, public bathroom	Chelmsford Boat Ramp	Bathroom	Rourke ramp; Canal walkways	Flooding upstream with obermeyer; safety with powered crafts- post safety regs
5/27/2019 21:51	When students row rowing they should park on the side of the side of the road				Need bathrooms; trash cans. Two more American Disabilities Act parking at the parking spot. Rowers take all the parking spots.
5/27/2019 21:51	Access to the water	Merrill Park			

	Question 16: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Question 16: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Question 17: Please share any other comments that you have regarding recreation at the Lowell Project:
Recorded Date	**Q16. Type of Recreation Enhancement:**	**Q. 16 Location(s)**	**Q16. Type of Recreation Enhancement:**	**Q. 16 Location(s)**	**Q17. General comments**
5/27/2019 21:51	Porta potty; trail should be widened; some type of advertisement;				
5/27/2019 21:51	Access to the beach and walkway	Chelmsford Boat Ramp			
5/27/2019 21:51	Improve the boat ramp	Chelmsford Boat Ramp			
5/27/2019 21:51	Porta Potty/ bathrooms on site of the boat launch	Chelmsford Boat Ramp			
5/27/2019 21:51					
5/27/2019 21:51	Some access points to the river esp folks want to launch a kayak or canoe	NPS walkway tours			
5/27/2019 21:51	Forest ranger presence	All			Great upkeep of rec facilities
5/27/2019 21:51	Bathroom hours extended until 9pm	Merrimack Trail System			Sometimes the music is too loud.
6/12/2019 7:41					
6/12/2019 7:41					Docks
6/12/2019 7:41					Bathrooms
6/12/2019 7:41					Rope swing to swim.
6/12/2019 7:41					

	Question 16: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Question 16: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Question 17: Please share any other comments that you have regarding recreation at the Lowell Project:
Recorded Date	**Q16. Type of Recreation Enhancement:**	**Q. 16 Location(s)**	**Q16. Type of Recreation Enhancement:**	**Q. 16 Location(s)**	**Q17. General comments**
6/12/2019 7:41	More bathrooms; litter looks bad	Merrimack Trail System			
6/12/2019 7:42					
6/12/2019 7:42					
6/12/2019 7:42					
6/12/2019 7:42	Improve boat ramp and bathroom facilities	Chelmsford Boat Ramp			
6/12/2019 7:42	Trash can	Rourke Brothers Boat Ramp			
6/12/2019 7:42	Rent paddleboards	Chelmsford Boat Ramp			
7/26/2019 19:47	Turning lane into facility	Rourke Brothers Boat Ramp			Considers rourke bros third in the state; really nice
7/26/2019 19:47	Porta potty	Rourke Brothers Boat Ramp			
7/26/2019 19:47	Trash can	Pawtucket Overlook and Canal Walkways			
7/26/2019 19:47	Porta potty and trash can	Chelmsford Boat Ramp			
7/26/2019 19:48					
8/26/2019 10:55					

	Question 16: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Question 16: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Question 17: Please share any other comments that you have regarding recreation at the Lowell Project:
Recorded Date	**Q16. Type of Recreation Enhancement:**	**Q. 16 Location(s)**	**Q16. Type of Recreation Enhancement:**	**Q. 16 Location(s)**	**Q17. General comments**
8/26/2019 10:55					"Informational panels great
8/26/2019 10:55	Paving, add flowering trees, higher barrier	Merrimack Trail System			
8/26/2019 10:55	Clean up trash in canal	Pawtucket Falls Overlook			
8/26/2019 10:55	Lifeguards during summer	Lowell Heritage State Park			
8/26/2019 10:55	Porta potty	Rourke Brothers Boat Ramp			
8/26/2019 10:55	Tray barrel and porta potty	Rourke Brothers Boat Ramp			
10/13/2019 19:46	Update bathrooms				
10/13/2019 19:46	Roads in and out need work and parking	Chelmsford Boat Launch			
10/31/2019 15:17	Blacktop the path occasionally	Merrimack Trail System			Walkway tours = visitor center
10/31/2019 15:17	Maintenance of benches, signs, add signage of existing facilities	Canal Walkway			
10/31/2019 15:17	More tables	Lowell Heritage State Park			
10/31/2019 15:17	Permanent bathroom or porta potty	Rourke Brothers Boat Ramp	Trashcan	Rourke brothers	

	Question 16: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Question 16: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Question 17: Please share any other comments that you have regarding recreation at the Lowell Project:
Recorded Date	**Q16. Type of Recreation Enhancement:**	**Q. 16 Location(s)**	**Q16. Type of Recreation Enhancement:**	**Q. 16 Location(s)**	**Q17. General comments**
10/31/2019 15:17	Benches, trash can	Pawtucket Falls Overlook			
10/31/2019 15:17	Numbering of trees for emergency reasons	Lowell Heritage State Park	Volunteer ranger Dogs on leash	Lowell Heritage State Park	Policing good on weekends
10/31/2019 15:17					Trash at dam
10/31/2019 15:17	More benches in some areas; better signage at intersections				Set up volunteer rangers

Appendix D - Field Reconnaissance Data

Field Reconnaissance Data

Personal Interviews and Field Reconnaissance Date	Location	Weather Conditions	Time (Military)	Approximate Vehicles Observed	Estimated Number of Recreationists Observed	Observed Recreational Activities
May 25, 2019	Chelmsford Boat Access	Cloudy/partially sunny	8:04 – 9:06	• 3 cars	2	• Hiking • Boating
May 25, 2019	Merrill Park	Cloudy/partially sunny	9:30 – 10:30	• 0	1	• Walking
May 25, 2019	Rourke Brothers Boat Ramp	Cloudy/partially sunny	11:03 – 11:57	• 10 cars • 8 cars with trailers	16	• Boating • Kayaking • Paddle board
May 25, 2019	Merrimack Trail System	Cloudy/partially sunny	12:10 – 1:07	• 0	100	• Boating • Running, jogging, hiking
May 25, 2019	Pawtucket Falls Overlook	Cloudy/partially sunny	1:58 – 2:57	• 0	8	• Boating • Hiking
May 25, 2019	Lowell Heritage State Park	Cloudy/partially sunny	3:14 – 4:11	• Not recorded	150	• Hiking • Running, jogging, and fitness • Dog walking • Boating
May 25, 2019	NPS Canal Walkways	Cloudy/partially sunny	4:50 – 5:50	• N/A	30	• Picnicking
May 26, 2019	Lowell Heritage State Park	Sunny, 70s	8:30 – 9:30	• 30 cars	90	• Boating • Hiking • Bicycling • Picnicking • Running, jogging, and fitness • Dogwalking
May 26, 2019	Pawtucket Falls Overlook	Sunny, 70s	9:41 – 9:45	• 0	4	• Hiking/walking
May 26, 2019	Lowell National Historical Park Visitor Center	Sunny, 70s	10:57 – 12:02	• 20 cars	35	• Park attendance
May 26, 2019	NPS Canal Walkways	Sunny, 70s	12:10 – 13:18	• N/A	40	• Walking

Personal Interviews and Field Reconnaissance Date	Location	Weather Conditions	Time (Military)	Approximate Vehicles Observed	Estimated Number of Recreationists Observed	Observed Recreational Activities
May 26, 2019	Chelmsford Boat Access	Sunny, 70s	14:10 – 15:10	• 7 cars • 5 cars with boat trailers		• Boating
May 26, 2019	Merrimack Trail System	Sunny, 70s	17:09 – 18:10	• 60 cars (not including overflow parking)	175	• Hiking/Walking
May 27, 2019	Lowell National Historical Park Visitor Center	Sunny, 70s	8:30 – 9:30	• 0	2	• Park attendance
May 27, 2019	Merrimack Trail System	Sunny, 70s	9:55 – 11:00	• 20 rowing boats	250	• A regatta for the Massachusetts Public Schools Rowing Association • Hiking, walking, bicycling
May 27, 2019	Rourke Brothers Boat Ramp	Sunny, 70s	11:56 – 12:59	• 25 cars • 3 boats • 1 Moped • 1 car trailer	10	• Boating • Dog walking
May 27, 2019	Chelmsford Boat Access	Sunny, 70s	15:38 – 16:42	• 5 jet skis • 7 boat trailers	26	• Boating • Hiking, walking • Dog walking
May 27, 2019	Pawtucket Falls Overlook	Sunny, 70s	16:59 – 18:00	• 0	1	• Hiking/Walking
May 28, 2019	Rourke Brothers Boat Ramp	Overcast, 50s	8:05 – 9:08	• 2 cars	2	• Hiking/walking
May 28, 2019	NPS Canal Walkways	Overcast, 50s	9:20 – 10:30	• 0	14	• Park attendance • Fishing
May 28, 2019	Merrimack Trail System	Overcast, 50s	10:45 – 11:45	• 15 cars	29	• Hiking/walking • Fishing • Running/jogging
May 28, 2019	Lowell Heritage State Park	Overcast, 50s	11:48 – 12:45	• 3	2	• Dog walking • Hiking/walking • Running/Jogging

Personal Interviews and Field Reconnaissance Date	Location	Weather Conditions	Time (Military)	Approximate Vehicles Observed	Estimated Number of Recreationists Observed	Observed Recreational Activities
May 28, 2019	Pawtucket Falls Overlook	Overcast, 50s	12:53 – 13:56	• 1 car	1	• Walking
May 28, 2019	Chelmsford Boat Access	Overcast, 50s	14:27 – 15:24	• 1 car	0	• N/A
May 28, 2019	Lowell National Historical Park Visitor Center	Overcast, 50s	17:50 – 18:00	• 0	0	• Park was closed
June, 07, 2019	Rourke Brothers Boat Ramp	Sunny, 80s	8:00 – 9:01	• 2 cars	2	• Bicycling
June, 07, 2019	Merrill Park	Sunny, 80s	9:24 – 10:24	• 0	0	• N/A
June, 07, 2019	Chelmsford Boat Access	Sunny, 80s	10:54 – 12:00	• 4 cars	4	• Boating • Fishing
June, 07, 2019	Lowell National Historical Park Visitor Center	Sunny, 80s	12:15 – 13:18	• 0	36	• Park attendance
June, 07, 2019	NPS Canal Walkways	Sunny, 80s	13:18 – 14:20	• 0	40	• Walking • Bicycling
June, 07, 2019	Pawtucket Falls Overlook	Sunny, 80s	14:20 – 15:20	• 1 cars	2	• Walking
June, 07, 2019	Lowell Heritage State Park	Sunny, 80s	15:29 – 16:30	• 5 cars	40	• Hiking/walking • Picnicking • Bicycling • Boating
June, 07, 2019	Merrimack Trail System	Sunny, 80s	16:30 – 17:30	• 35 cars	60	• Hiking/walking • Picnicking • Boating • Fishing • Skateboarding • Paddle boarding
June, 07, 2019	Rourke Brothers Boat Ramp	Sunny, 80s	17:40 – 18:00	• 9 cars	10	• Boating • Walking

Personal Interviews and Field Reconnaissance Date	Location	Weather Conditions	Time (Military)	Approximate Vehicles Observed	Estimated Number of Recreationists Observed	Observed Recreational Activities
June 10, 2019	Merrimack Trail System	Sunny, 80s	8:08 – 9:08	• 30 cars	40	• Fishing • Running/jogging • Hiking/walking
June 10, 2019	Lowell Heritage State Park	Sunny, 80s	9:08 – 10:06	• 40 cars	60	• Running/jogging • Hiking/walking • Bicycling
June 10, 2019	Pawtucket Falls Overlook	Sunny, 80s	10:19 – 11:17	• 4 cars	2	• Walking
June 10, 2019	Rourke Brothers Boat Ramp	Sunny, 80s	11:28 – 12:26	• 13 cars	12	• Boating
June 10, 2019	Merrill Park	Sunny, 80s	13:15 – 14:13	• 0 cars	2	• Boating • Bicycling
June 10, 2019	Chelmsford Boat Access	Sunny, 80s	14:45 – 15:53	• 5 cars	8	• Boating • Fishing
June 10, 2019	Lowell National Historical Park Visitor Center	Sunny, 80s	16:10 – 17:09	• 0 cars	8	• Park attendance
June 10, 2019	NPS Canal Walkways	Sunny, 80s	17:09 – 18:09	• 0 cars	20	• Hiking/walking • Fishing
June 15, 2019	Rourke Brothers Boat Ramp	Sunny, 70s	8:00 – 9:00	• 3 cars	3	• Boating
June 15, 2019	Merrill Park	Sunny, 70s	9:25 – 10:25	• 0	2	• Bicycling
June 15, 2019	Chelmsford Boat Access	Sunny, 70s	11:10 – 12:13	• 1 boat trailer	5	• Boating • Fishing • Softball tournament
June 15, 2019	NPS Canal Walkways	Sunny, 70s	13:10 – 14:10	• 0	15	• Hiking/walking • Picnicking
June 15, 2019	Pawtucket Falls Overlook	Sunny, 70s	14:32 – 15:35	• 0	3	• Hiking/walking
June 15, 2019	Merrimack Trail System	Sunny, 70s	15:47 – 16:48	• 100	100	• Hiking/walking • Bicycling • Picnicking • Fishing • Boating • Running

Personal Interviews and Field Reconnaissance Date	Location	Weather Conditions	Time (Military)	Approximate Vehicles Observed	Estimated Number of Recreationists Observed	Observed Recreational Activities
June 15, 2019	Rourke Brothers Boat Ramp	Sunny, 70s	17:00 – 18:00	• 14 cars	30	• Boating • Jet skiing • Dog walking
June 16, 2019	Rourke Brothers Boat Ramp	Rainy, 60s	8:00 – 9:03	• 1 boat trailer • 1 car	1	• Dog walker
June 16, 2019	Lowell Heritage State Park	Rainy, 60s	9:23 – 10:23	• 8 cars	55	• Running/jogging • Hiking/walking • Bicycling • Picnicking
June 16, 2019	Lowell National Historical Park Visitor Center	Rainy, 60s	10:30 – 11:30	• 0	7	• Hiking/walking
June 16, 2019	NPS Canal Walking	Rainy, 60s	11:37 – 12:37	• 0	4	• Walking
June 16, 2019	Merrill Park	Rainy, 60s	13:21 – 14:28	• 1 car	2	• Dog walking
June 16, 2019	Chelmsford Boat Access	Rainy, 60s	15:10 – 16:10	• N/A	N/A	• N/A
June 16, 2019	Pawtucket Falls Overlook	Rainy, 60s	16:21 – 17:21	• 0	2	• Walking • Dog walking
June 16, 2019	Merrimack Trail System	Rainy, 60s	17:25 – 18:00	• 8	10	• Sitting in cars (raining) • Walking
July 10, 2019	Merrimack Trail System	Cloudy and Sunny, 60s	8:15 – 9:15	• 7 cars	8	• Hiking/walking
July 10, 2019	Merrill Park	Cloudy and Sunny, 60s	9:55 – 10:55	• 0	0	• N/A
July 10, 2019	Chelmsford Boat Access	Cloudy and Sunny, 60s	11:25 – 12:25	• 3 cars	5	• N/A
July 10, 2019	Pawtucket Falls Overlook	Cloudy and Sunny, 60s	13:15 – 14:15	• 0	0	• N/A
July 10, 2019	NPS Canal Walkways	Cloudy and Sunny, 60s	14:40 – 15:40	• 5	50	• Hiking/Walking • Bicycling • Swimming
July 10, 2019	Whitewater takeout	Cloudy and Sunny, 60s	15:52 – 16:50	• 0	0	• N/A
July 10, 2019	Rourke Brothers Boat Ramp	Cloudy and Sunny, 60s	16:50 – 18:00	• 8 cars	7	• Boating

Personal Interviews and Field Reconnaissance Date	Location	Weather Conditions	Time (Military)	Approximate Vehicles Observed	Estimated Number of Recreationists Observed	Observed Recreational Activities
July 19, 2019	Rourke Brothers Boat Ramp	Overcast, 70s	8:00 – 9:00	• 5 cars	2	• Dog walking • Bicycling • Fishing
July 19, 2019	Pawtucket Falls Overlook	Overcast, 70s	9:35 – 10:44	• 0	0	• N/A
July 19, 2019	Lowell National Historical Park Visitor Center	Overcast, 70s	10:58 – 11:58	• 0	9	• N/A
July 19, 2019	NPS Canal Walkways	Overcast, 70s	12:24 – 13:20	• 0	10	• N/A
July 19, 2019	Merrimack Trail System	Overcast, 70s	13:38 – 14:42	• 20 cars	50	• Boating • Running/jogging • Hiking/walking • Bicycling • Dog walking
July 19, 2019	Merrill Park	Overcast, 70s	15:25 – 16:25	• 1 car	8	• Bicycling
July 19, 2019	Whitewater Takeout	Overcast, 70s	17:00 – 18:00	• 0	0	• N/A
July 27, 2019	Merrimack Trail System	Sunny, 80s	8:07 – 9:06	• 40 cars	80	• Dog walker • Picnicking • Bicycling • Hiking/walking • Running/jogging
July 27, 2019	Merrill Park	Sunny, 80s	9:45 – 10:45	• 1	2	• Dog walker • Jet ski
July 27, 2019	Chelmsford Boat Access	Sunny, 80s	11:06 –12:07	• 2 cars • 4 boat trailers	10	• Picnicking • Boating • Softball tournaments
July 27, 2019	Rourke Brothers Boat Ramp	Sunny, 80s	12:19 – 13:20	• 20 cars	15	• Boating • Fishing • Bicycling • Picnicking
July 27, 2019	Pawtucket Falls Overlook	Sunny, 80s	14:02 – 15:02	• 0	0	• N/A
July 27, 2019	Whitewater Takeout	Sunny, 80s	15:10 – 16:10	• 0	0	• N/A
July 27, 2019	Lowell Heritage State Park	Sunny, 80s	16:20 – 17:20	• 30 cars	70	• Boating

Personal Interviews and Field Reconnaissance Date	Location	Weather Conditions	Time (Military)	Approximate Vehicles Observed	Estimated Number of Recreationists Observed	Observed Recreational Activities
						• Picnicking • Hiking/walking • Dog walking • Swimming
July 27, 2019	Rourke Brothers Boat Ramp	Sunny, 80s	18:00 – 19:00	• 14 cars • 6 trailers • 3 boaters	3	• Boating • Walking
July 28, 2019	Lowell National Historical Park Visitor Center	Sunny, 70s	8:30 – 9:30	• 0	7	• Park attendance
July 28, 2019	NPS Canal Walkways	Sunny, 70s	9:35 – 10:35	• 0	10	• Walking
July 28, 2019	Pawtucket Falls Overlook	Sunny, 70s	10:52 – 11:52	• 0	0	• N/A
July 28, 2019	Chelmsford Boat Access	Sunny, 70s	12:10 – 13:10	• 5 boat trailers	10	• Running/hiking • Boating • Bicycling
July 28, 2019	Merrill Park	Sunny, 70s	13:45 – 14:45	• 0	3	• Boating (not at Merrill Park, but observed from Merrill Park) • Fishing
July 28, 2019	Rourke Brothers Boat Ramp	Sunny, 70s	15:05 – 16:05	• 15 boat trailers	23	• Boating • Bicycling • Sailboating • Jet skiing
July 28, 2019	Lowell Heritage State Park	Sunny, 70s	16:25 – 17:25	• 35 cars	100	• Swimming • Running/jogging • Hiking/walking • Picnicking • Bicycling • Skateboarding • Dog walking
August 6, 2019	Merrimack Trail System	Sunny, 80s	8:10 – 9:10	• 50 cars	70	• Boating • Fishing • Running/jogging • Hiking/walking • Bicycling • Picnicking

Personal Interviews and Field Reconnaissance Date	Location	Weather Conditions	Time (Military)	Approximate Vehicles Observed	Estimated Number of Recreationists Observed	Observed Recreational Activities
						• Dog walking
August 6, 2019	Merrill Park	Sunny, 80s	09:45 – 10:45	• 0	0	• N/A
August 6, 2019	Chelmsford Boat Access	Sunny, 80s	11:20 – 12:20	• 3 cars	3	• Picnicking
August 6, 2019	Pawtucket Falls Overlook	Sunny, 80s	13:15 – 14:15	• 0	4	• Hiking/walking
August 6, 2019	Rourke Brothers Boat Ramp	Sunny, 80s	14:31 – 15:32	• 7 cars • 2 boat trailers	5	• Jet ski • Boating • Bicycling
August 6, 2019	Lowell Heritage State Park	Sunny, 80s	16:00 – 17:00	• 20 cars	60	• Picnicking • Swimming
August 6, 2019	Lowell National Historical Park Visitor Center	Sunny, 80s	17:21 – 18:00	• 0	11	• Park attendance
August 18, 2019	Lowell Heritage State Park	Cloudy, 80s	8:07 – 9:07	• 20 cars	90	• Running/jogging • Hiking/walking • Picnicking • Boating • Dog walkers
August 18, 2019	Chelmsford Boat Access	Cloudy, 80s	9:20 – 10:30	• 1 car • 1 trailer	4	• Softball tournament • Boating
August 18, 2019	Merrill Park	Cloudy, 80s	11:10 – 12:10	• 1 car	2	• Picnicking
August 18, 2019	Merrimack Trail System	Cloudy, 80s	12:45 – 13:45	• 50 cars	125	• Running/jogging • Hiking/walking • Bicycling
August 18, 2019	Lowell National Historical Park Visitor Center	Cloudy, 80s	14:35 – 15:35	• 0	21	• Park attendance
August 18, 2019	Pawtucket Falls Overlook	Cloudy, 80s	15:56 – 16:56	• 0	2	• Hiking/walking
August 18, 2019	Rourke Brothers Boat Ramp	Cloudy, 80s	17:09 – 18:00	• 11 cars • 8 boat trailers	14	• Boating • Fishing
August 21, 2019	Lowell Heritage State Park	Overcast, Rainy, 70s	8:00 – 9:00	• 15 cars	55	• Running/jogging • Hiking/walking • Dog walking
August 21, 2019	NPS Canal Walkways	Overcast, Rainy, 70s	9:15 – 10:15	• 0	30	• Walking • Dog walking

Personal Interviews and Field Reconnaissance Date	Location	Weather Conditions	Time (Military)	Approximate Vehicles Observed	Estimated Number of Recreationists Observed	Observed Recreational Activities
						• Picnicking
August 21, 2019	Merrill Park	Overcast, Rainy, 70s	10:55 – 11:55	• 0	0	• N/A
August 21, 2019	Pawtucket Falls Overlook	Overcast, Rainy, 70s	12:30 – 13:30	• 0	2	• Dog walking
August 21, 2019	Rourke Brothers Boat Ramp	Overcast, Rainy, 70s	14:20 – 15:20	• 6 cars • 2 boat trailers	0	• Boating
August 21, 2019	Chelmsford Boat Access	Overcast, Rainy, 70s	15:30 – 16:30	• 0	0	• N/A
August 21, 2019	Merrimack Trail System	Overcast, Rainy, 70s	16:50 – 17:50	• 15 cars	40	• Running/jogging • Hiking/walking • Bicycling • Dog walking
August 24, 2019	Pawtucket Falls Overlook	Sunny, 70s	9:30 – 10:30	• 0	0	• N/A
August 24, 2019	Merrill Park	Sunny, 70s	11:20 – 12:20	• 0	0	• N/A
August 24, 2019	Chelmsford Boat Access	Sunny, 70s	12:45 – 13:45	• 10 cars • 6 trailers	18	• Boating • Bicycling
August 24, 2019	Lowell National Historical Park Visitor Center	Sunny, 70s	14:45 – 15:45	• 0	49	• Park attendance
August 24, 2019	NPS Canal Walkways	Sunny, 70s	16:00 – 17:00	• 0	12	• Walking • Picnicking
August 24, 2019	Rourke Brothers Boat Ramp	Sunny, 70s	17:15 – 18:00	• 4 cars • 5 trailers	8	• Boating • Fishing • Bicycling
September 14, 2019	Rourke Brothers Boat Ramp	Cloudy, rainy, 60s	8:15 – 9:15	• 2 cars	2	• Walking
September 14, 2019	Pawtucket Falls Overlook	Cloudy, rainy, 60s	9:25 –10:25	• 0	0	• N/A
September 14, 2019	Merrill Park	Cloudy, rainy, 60s	11:02–12:05	• 3 cars	3	• Picnicking
September 14, 2019	Chelmsford Boat Access	Cloudy, rainy, 60s	12:35 –13:35	• 0	2	• Fishing • Softball tournament
September 14, 2019	NPS Canal Walkways	Cloudy, rainy, 60s	14:45 – 15:45	• 0	1	• Running/jogging
September 14, 2019	Lowell Heritage State Park	Cloudy, rainy, 60s	16:08 – 17:08	• 2 cars	23	• Hiking/walking
September 14, 2019	Merrimack Trail System	Cloudy, rainy, 60s	17:18 – 18:00	• 10 cars	7	• Hiking/walking

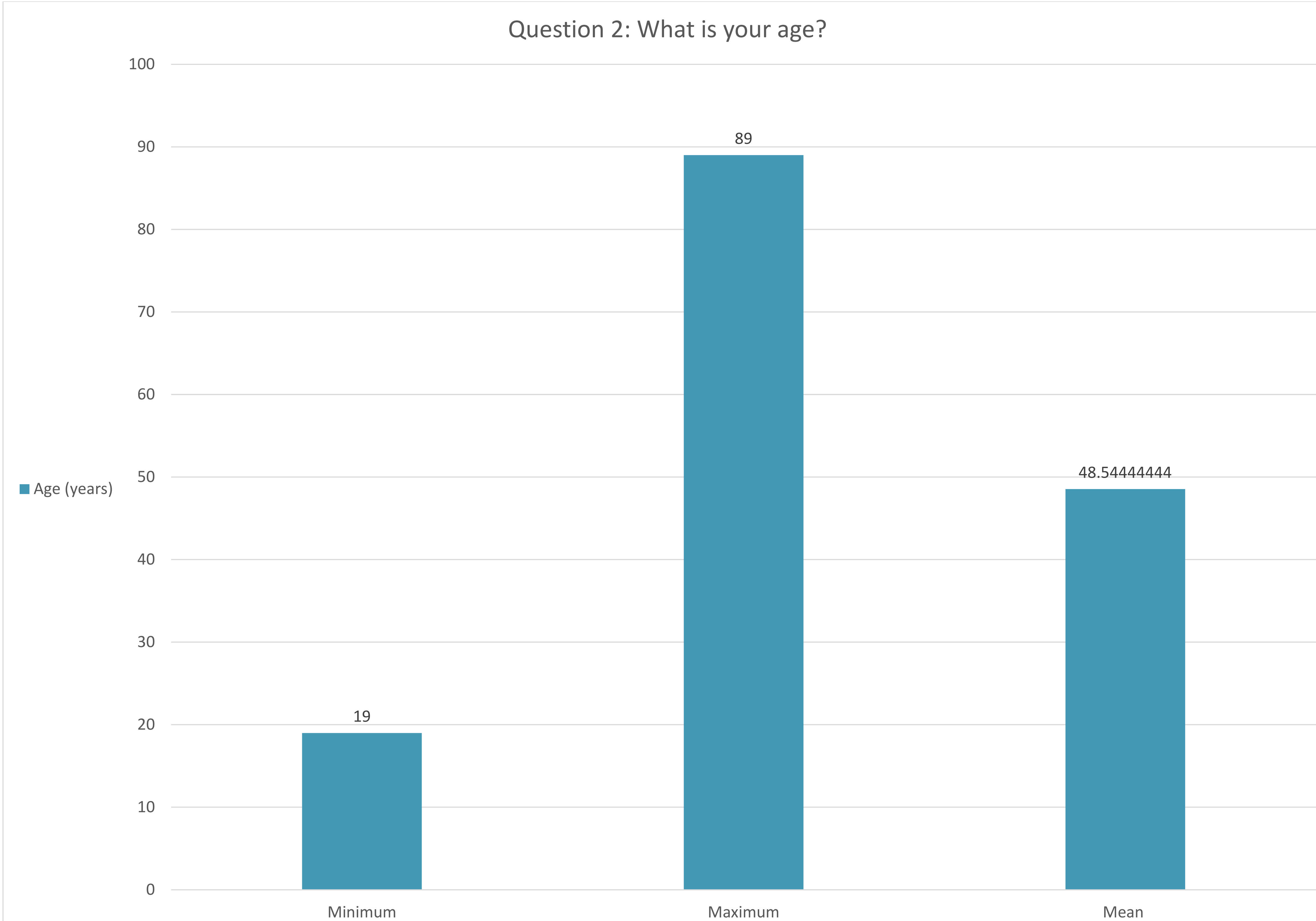
Personal Interviews and Field Reconnaissance Date	Location	Weather Conditions	Time (Military)	Approximate Vehicles Observed	Estimated Number of Recreationists Observed	Observed Recreational Activities
September 19, 2019	Merrimack Trail System	Sunny, cool, 60s	8:00 – 9:00	• 0	54	• Fishing • Running/jogging • Hiking/walking
September 19, 2019	Rourke Brothers Boat Ramp	Sunny, cool, 60s	9:00 – 10:00	• 5 cars • 2 boat trailers	6	• Boating • Fishing
September 19, 2019	Merrill Park	Sunny, cool, 60s	10:30 – 11:30	• 1	2	• Hiking/walking
September 19, 2019	Chelmsford Boat Access	Sunny, cool, 60s	12:00 – 13:00	• 5 cars	1	• Picnicking • Fishing
September 19, 2019	Lowell National Historical Park Visitor Center	Sunny, cool, 60s	13:20 – 14:20	• 0	17	• Park attendance
September 19, 2019	Pawtucket Falls Overlook	Sunny, cool, 60s	15:05 – 16:05	• 0	0	• N/A
September 19, 2019	Lowell Heritage State Park	Sunny, cool, 60s	16:24 – 17:24	• Not Recorded	50	• Hiking/walking • Running/jogging • Bicycling
September 19, 2019	Rourke Brothers Boat Ramp	Sunny, cool, 60s	17:30 – 18:00	• 4 cars • 2 boat trailers	3	• Fishing • Boating
September 22, 2019	Rourke Brothers Boat Ramp	Sunny, 70s – 80s	8:00 – 9:00	• 3 cars • 4 boat trailers	5	• Boating • Fishing
September 22, 2019	Pawtucket Falls Overlook	Sunny, 70s – 80s	9:30 – 10:30	• 0	0	• N/A
September 22, 2019	Merrill Park	Sunny, 70s – 80s	11:00 – 12:00	• 2 trucks	4	• Hiking/walking
September 22, 2019	Chelmsford Boat Access	Sunny, 70s – 80s	12:25 – 13:25	• 6 cars • 5 boat trailers	8	• Boating
September 22, 2019	Lowell National Historical Park Visitor Center	Sunny, 70s – 80s	13:40 – 14:40	• 0	20	• Park attendance • Power outage occurred
September 22, 2019	NPS Canal Walkways	Sunny, 70s – 80s	15:00 – 16:00	• 0	13	• Hiking/walking • Running/jogging • Bicycling
September 22, 2019	Lowell Heritage State Park	Sunny, 70s – 80s	16:10 – 17:10	• 15 cars • 1 boat docked	70	• Swimming • Running/jogging • Hiking/walking • Bicycling • Dog walking
September 22, 2019	Merrimack Trail System	Sunny, 70s – 80s	17:17 – 18:00	• Not recorded	30	• Fishing • Running/jogging

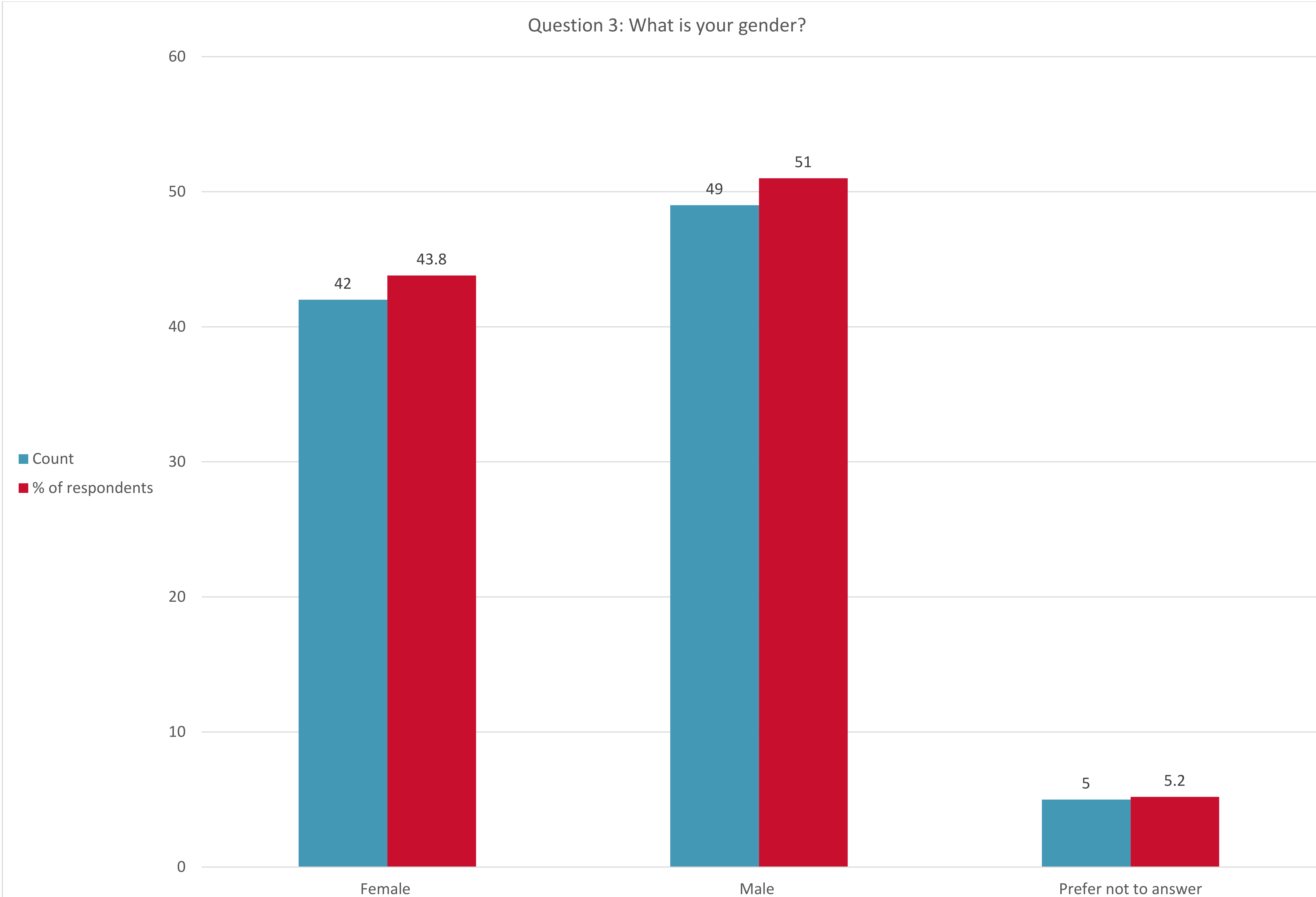
Personal Interviews and Field Reconnaissance Date	Location	Weather Conditions	Time (Military)	Approximate Vehicles Observed	Estimated Number of Recreationists Observed	Observed Recreational Activities
						• Hiking/walking • Bicycling
September 25, 2019	Merrill Park	Sunny, 70s	8:40 – 9:40	• 1 car	1	• Hiking/walking
September 25, 2019	Lowell Heritage State Park	Sunny, 70s	10:20 – 11:20	• Not recorded	60	• Running/jogging • Hiking/walking • Bicycling
September 25, 2019	Pawtucket Falls Overlook	Sunny, 70s	11:25 – 12:25	• 3 cars	0	• N/A
September 25, 2019	Lowell National Historical Park Visitor Center	Sunny, 70s	13:10 – 14:10	• 0	10	• Park attendance
September 25, 2019	NPS Canal Walkways	Sunny, 70s	14:30 – 15:45	• 0	60	• Hiking/walking
September 25, 2019	Rourke Brothers Boat Ramp	Sunny, 70s	16:20 – 17:20	• 4 cars	4	• N/A
September 25, 2019	Merrimack Trail System	Sunny, 70s	17:23 – 18:00	• 45 cars	50	• Fishing • Running/jogging • Hiking/walking
October 9, 2019	Lowell Heritage State Park	Cloudy, windy, 50s	8:20 – 9:20	• 15 cars	19	• Hiking/walking • Running/jogging • Dog walking
October 9, 2019	Rourke Brothers Boat Ramp	Cloudy, windy, 50s	9:30 – 10:30	• 3 cars	1	• Dog walking
October 9, 2019	Merrill Park	Cloudy, windy, 50s	11:09 – 12:09	• 0	0	• N/A
October 9, 2019	NPS Canal Walkways	Cloudy, windy, 50s	12:59 – 13:59	• 0	13	• Hiking/walking
October 9, 2019	Chelmsford Boat Access	Cloudy, windy, 50s	14:46 – 15: 46	• 2 cars	1	• Hiking/walking
October 9, 2019	Pawtucket Falls Overlook	Cloudy, windy, 50s	16:03 – 17:00	• 0	0	• N/A
October 9, 2019	Merrimack Trail System	Cloudy, windy, 50s	17: 11 – 18:00	• 20 cars • 3 boats	32	• Hiking/walking • Running/Jogging • Boating
October 15, 2019	Merrill Park	Sunny, cool, 40-50s	8:10 – 9:10	• 0	0	• N/A
October 15, 2019	Lowell Heritage State Park	Sunny, cool, 40-50s	9:35 – 10:35	• 2 cars	40	• Running/jogging • Hiking/walking • Bicycling
October 15, 2019	Pawtucket Falls Overlook	Sunny, cool, 40-50s	10:40 –11:40	• 0	0	• N/A

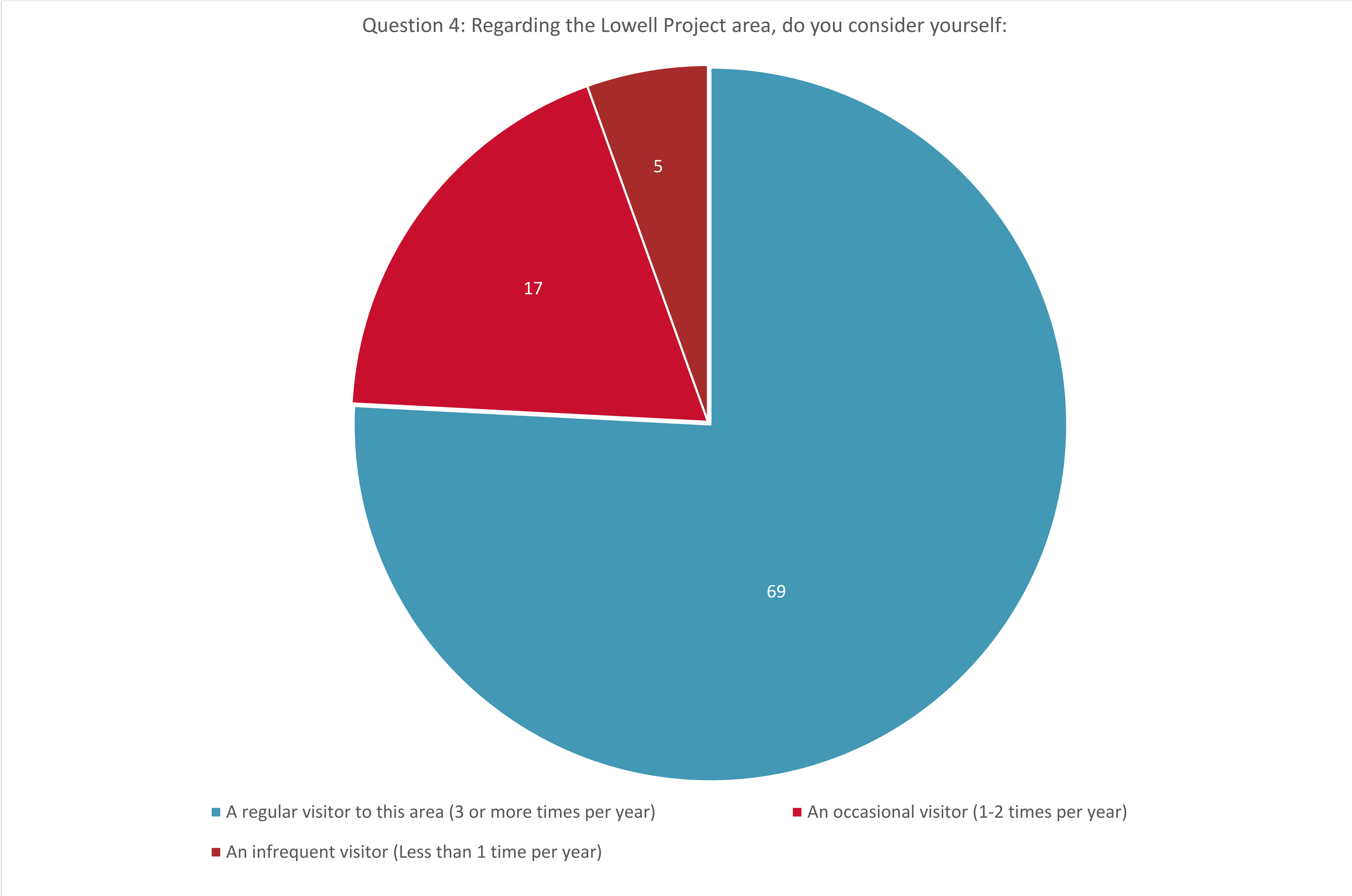
Personal Interviews and Field Reconnaissance Date	Location	Weather Conditions	Time (Military)	Approximate Vehicles Observed	Estimated Number of Recreationists Observed	Observed Recreational Activities
October 15, 2019	Lowell National Historical Park Visitor Center	Sunny, cool, 40-50s	11:49 – 12:49	• 0	32	• Park attendance
October 15, 2019	NPS Canal Walkways	Sunny, cool, 40-50s	12:49 – 13:49	• 0	35	• Hiking/walking
October 15, 2019	Chelmsford Boat Access	Sunny, cool, 40-50s	14:39 – 15:39	• 3 cars	3	• Boating
October 15, 2019	Rourke Brothers Boat Ramp	Sunny, cool, 40-50s	15:50 – 16:50	• 6 cars	6	• Walking/hiking • Boating
October 15, 2019	Merrimack Trail System	Sunny, cool, 40-50s	16:53 – 17:53	• 0	65	• Running/jogging • Hiking/walking • Bicycling • Fishing • Picnicking
October 19, 2019	Rourke Brothers Boat Ramp	Sunny, 40-50s	8:00 – 9:00	• 8 cars	8	• Not recorded
October 19, 2019	Chelmsford Boat Access	Sunny, 40-50s	9:07 – 10:07	• 2 cars	4	• Hiking/walking
October 19, 2019	Merrill Park	Sunny, 40-50s	10:26 – 11:26	• 1 car	3	• Hiking/walking • Fishing
October 19, 2019	Merrimack Trail System	Sunny, 40-50s	11:49 – 12:49	• 0	64	• Running/jogging • Hiking/walking
October 19, 2019	Lowell National Historical Park Visitor Center	Sunny, 40-50s	13:23 – 14:23	• 0	47	• Park attendance
October 19, 2019	Pawtucket Falls Overlook	Sunny, 40-50s	14:32 – 15:32	• 0	2	• Fishing
October 19, 2019	NPS Canal Walkways	Sunny, 40-50s	15:35 –16:35	• 0	58	• Bicycling • Hiking/walking
October 19, 2019	Lowell Heritage State Park	Sunny, 40-50s	16:48 – 17:58	• 0	75	• Running/jogging • Hiking/walking • Bicycling • Picnicking • Boating
October 27, 2019	Pawtucket Falls Overlook	Rainy, cloudy, 50s	8:21 – 9:21	• 0		• Hiking/walking
October 27, 2019	Merrill Park	Rainy, cloudy, 50s	9:49 – 10:49	• 1 car		• Hiking/walking
October 27, 2019	Chelmsford Boat Access	Rainy, cloudy, 50s	11:27 – 12:17	• 1 car		• Boating

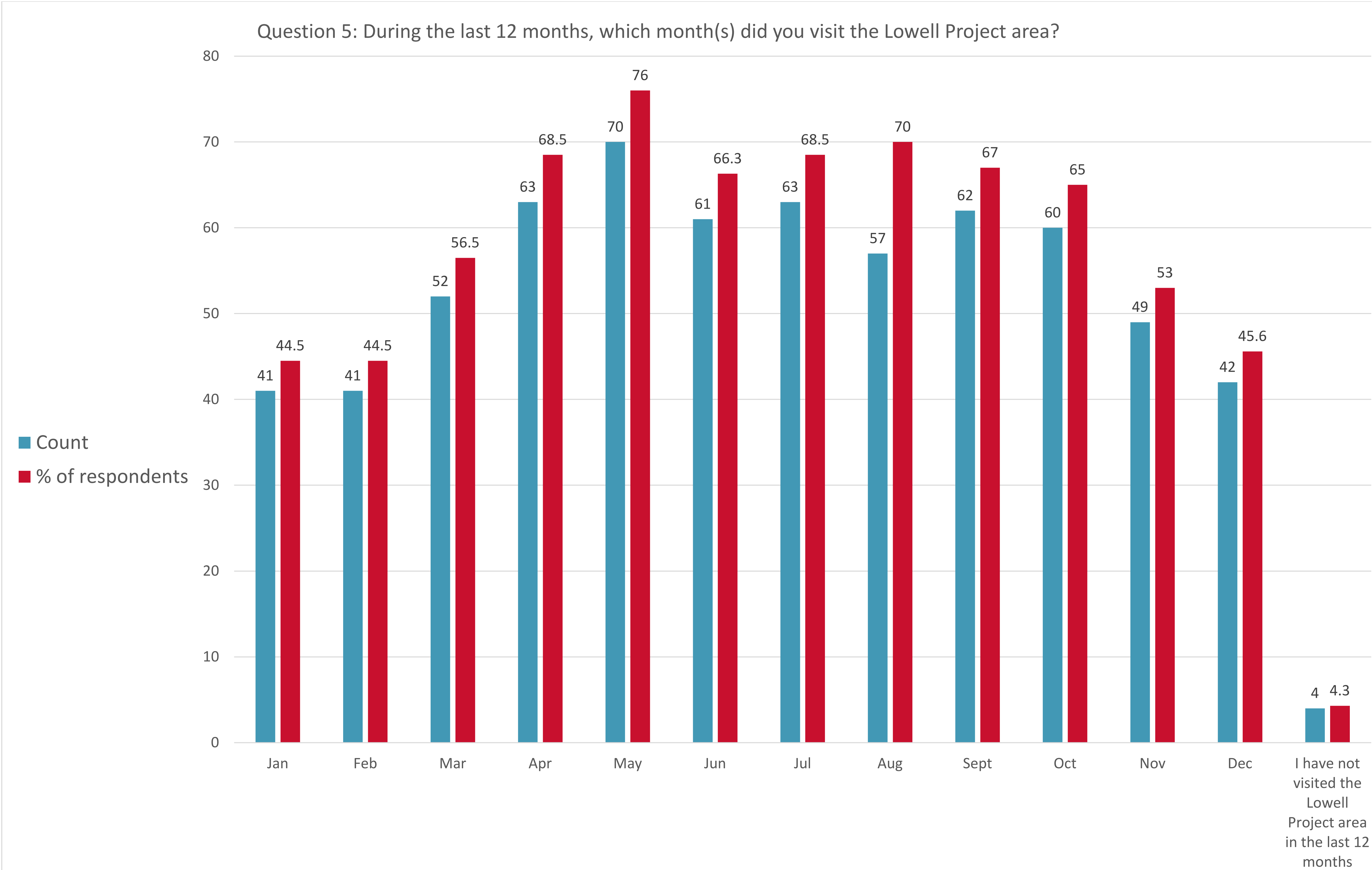
Personal Interviews and Field Reconnaissance Date	Location	Weather Conditions	Time (Military)	Approximate Vehicles Observed	Estimated Number of Recreationists Observed	Observed Recreational Activities
October 27, 2019	Lowell National Historical Park Visitor Center	Rainy, cloudy, 50s	12:31 – 13:31	• 0	13	• Park attendance
October 27, 2019	NPS Canal Walkways	Rainy, cloudy, 50s	14:03 – 15:03	• 0		• Hiking/walking
October 27, 2019	Rourke Brothers Boat Ramp	Rainy, cloudy, 50s	15:20 – 16:20	• 0	0	• N/A
October 27, 2019	Merrimack Trail System	Rainy, cloudy, 50s	16:30 – 17:30	• 4 cars	2	• Hiking/walking
October 27, 2019	Lowell Heritage State Park	Rainy, cloudy, 50s	17:32 – 18:00	• 0	0	• N/A

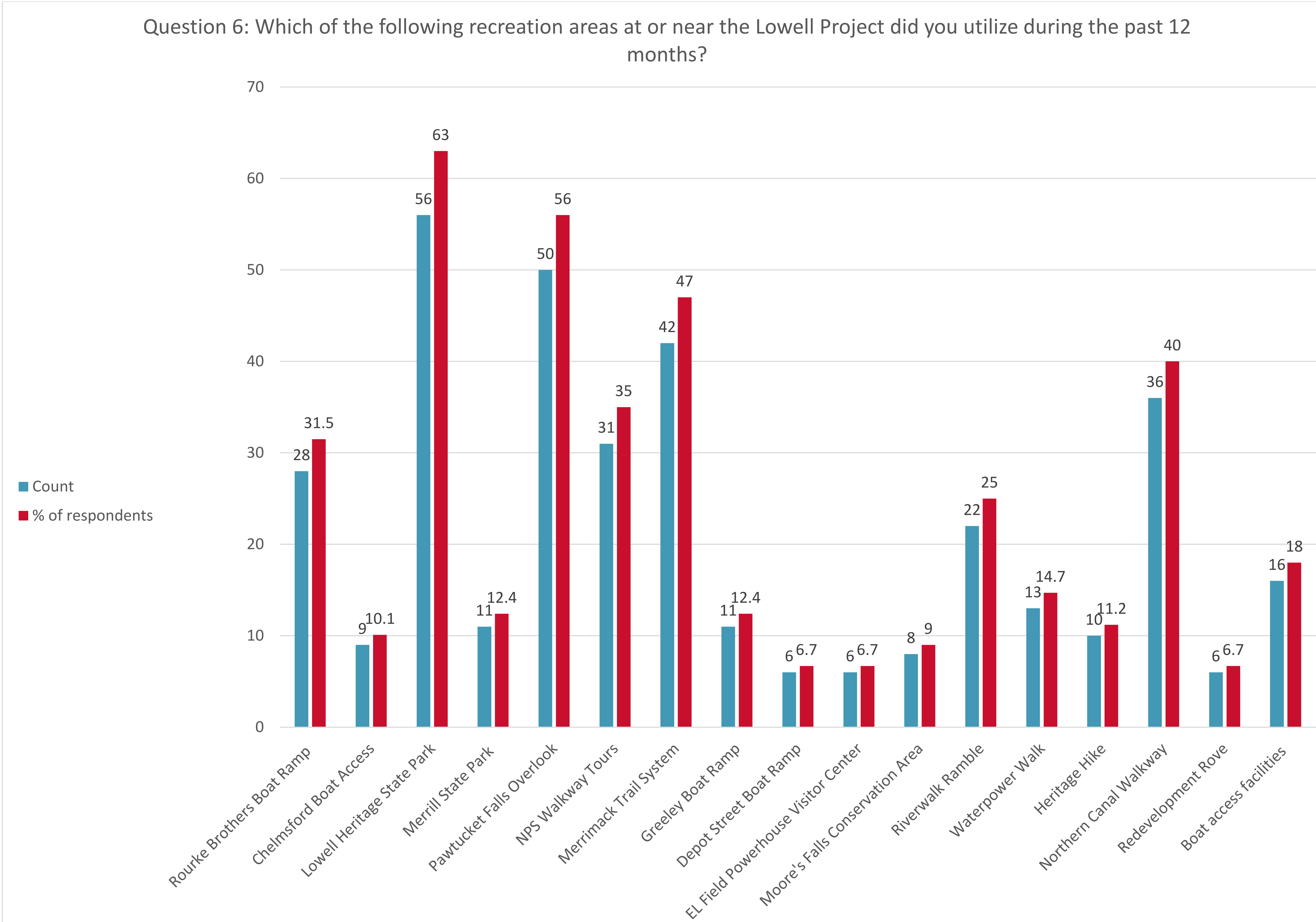
Appendix E - Online Recreation Survey Data


Question 2: What is your age?
100
90
80
70
60
50
40
30
20
10
0
Age (years)
19
89
48.54444444
Minimum
Maximum
Mean

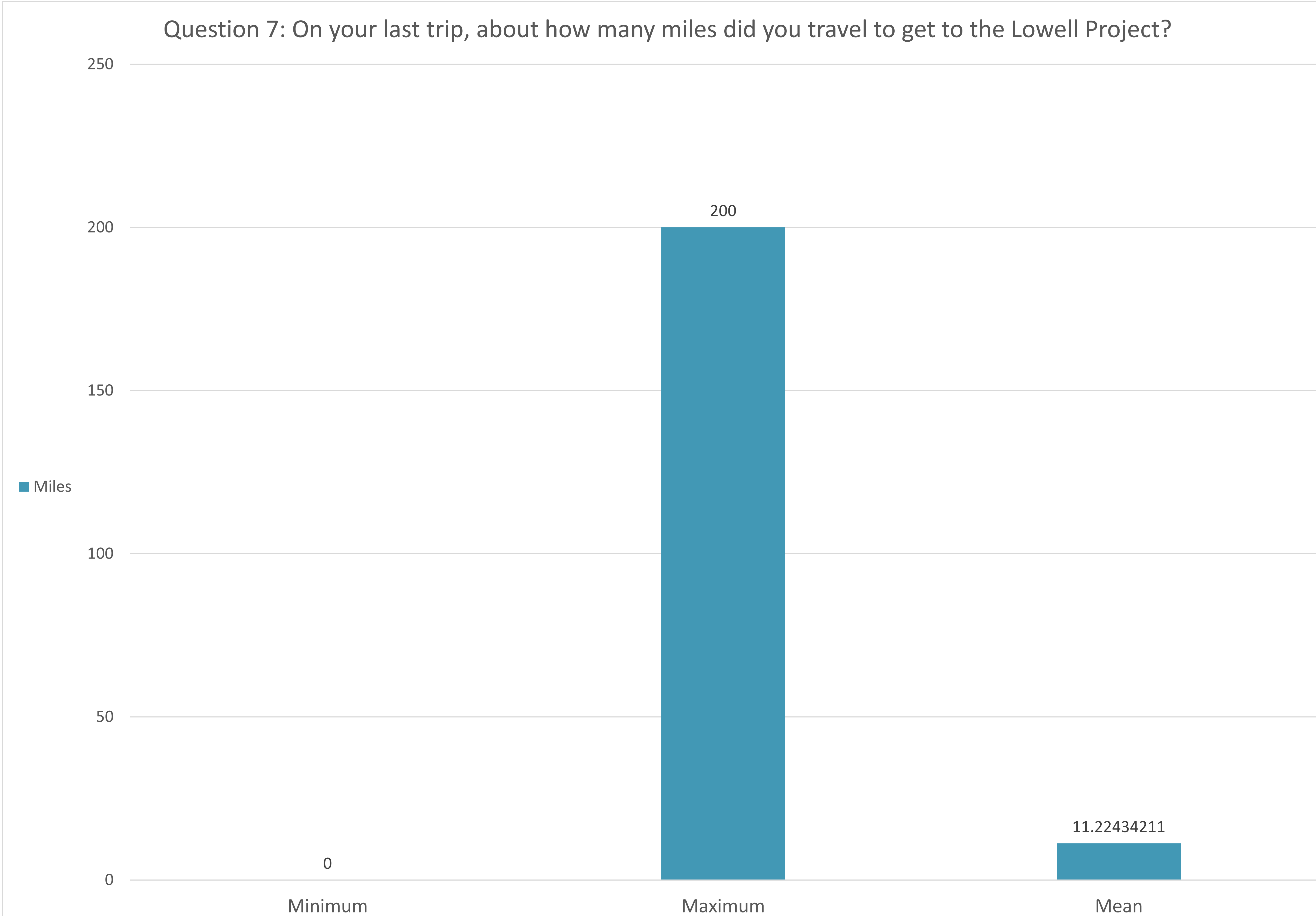

Question 3: What is your gender?
60
50
40
30
20
10
0
Count
% of respondents
42
43.8
49
51
5
5.2
Female
Male
Prefer not to answer

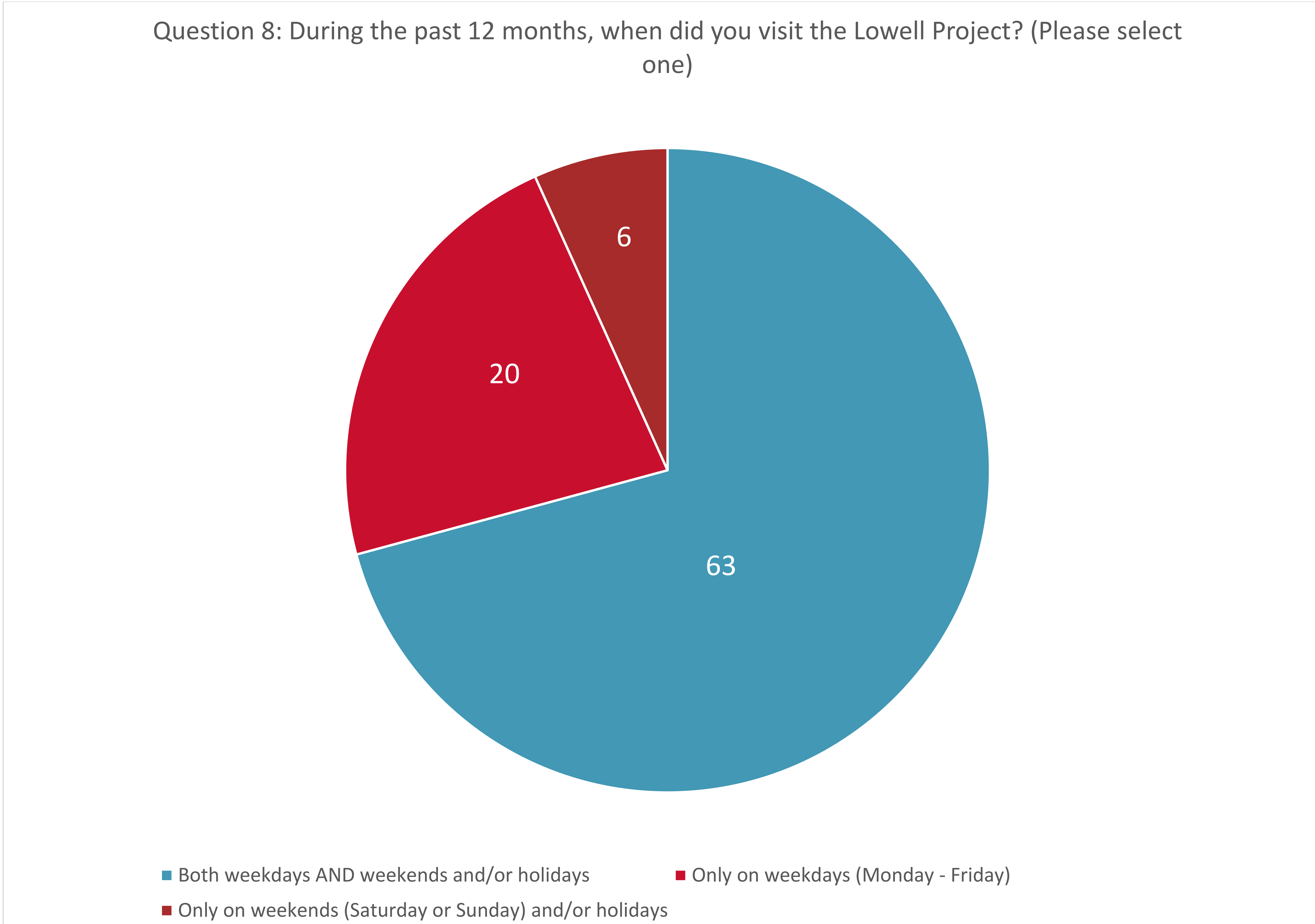

Question 4: Regarding the Lowell Project area, do you consider yourself:
5
17
69
A regular visitor to this area (3 or more times per year)
An occasional visitor (1-2 times per year)
An infrequent visitor (Less than 1 time per year)

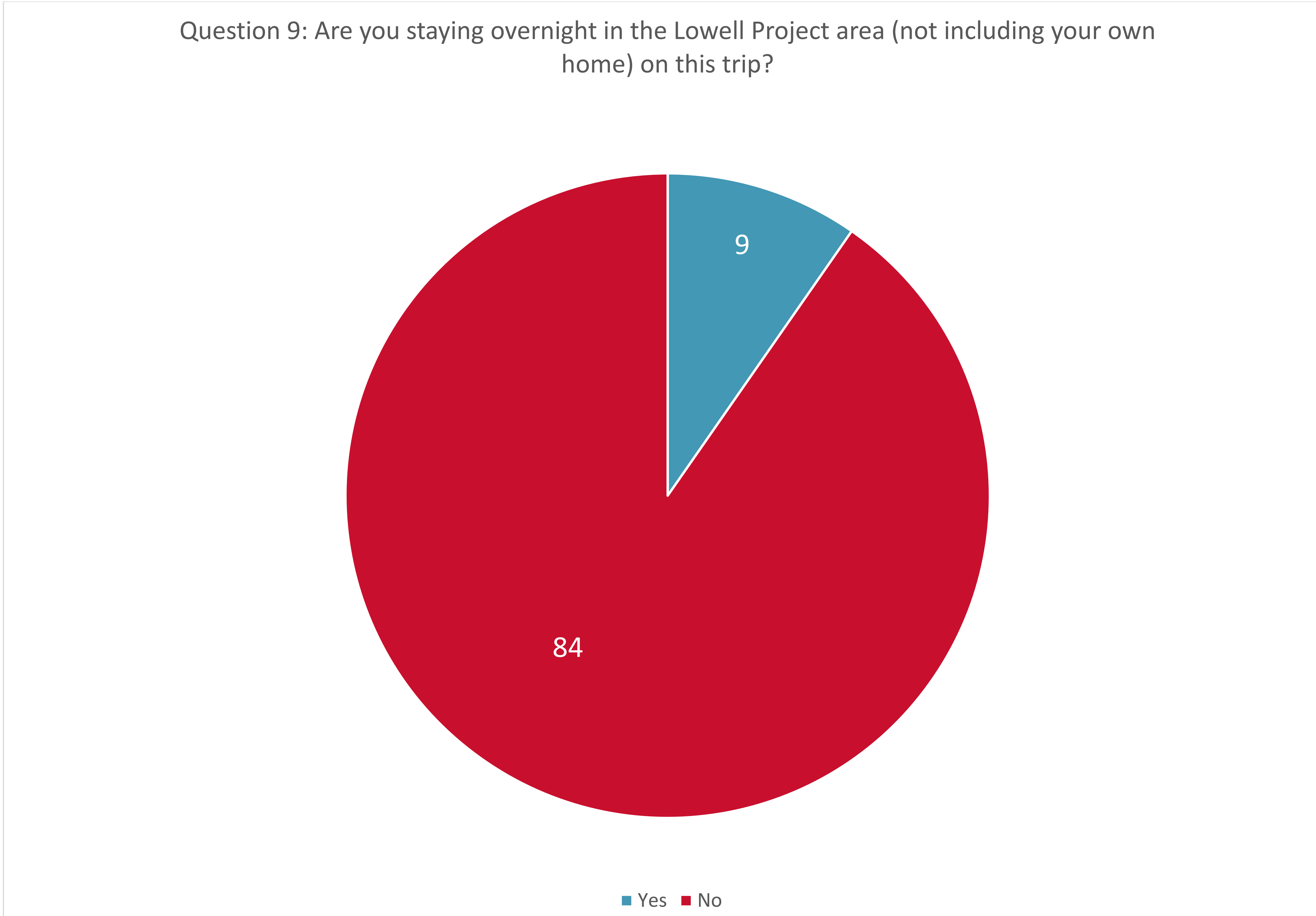

Question 5: During the last 12 months, which month(s) did you visit the Lowell Project area?
Count
% of respondents
80
70
60
50
40
30
20
10
0
41
44.5
41
44.5
52
56.5
63
68.5
70
76
61
66.3
63
68.5
57
70
62
67
60
65
49
53
42
45.6
4
4.3
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
I have not visited the Lowell Project area in the last 12 months

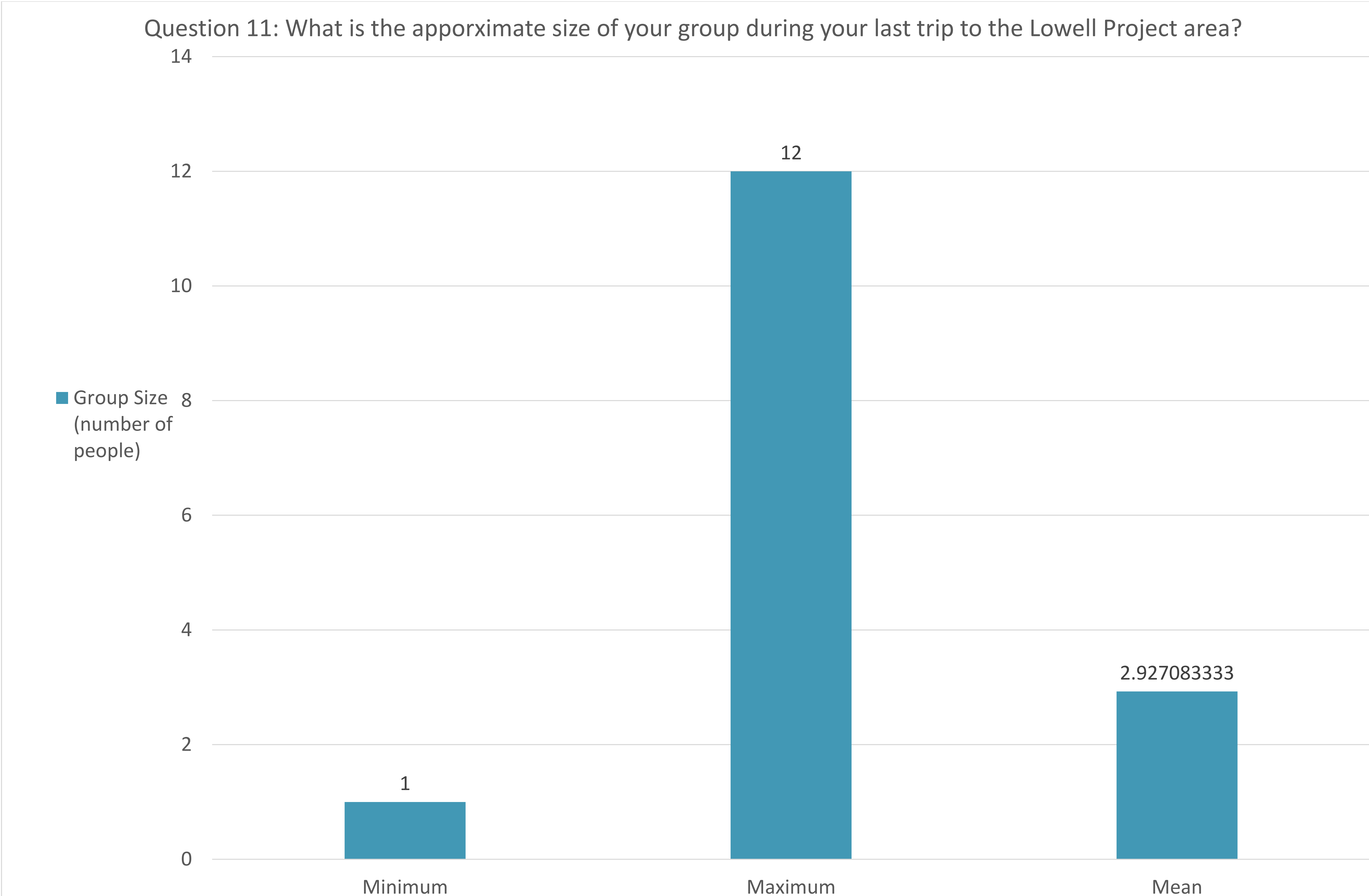


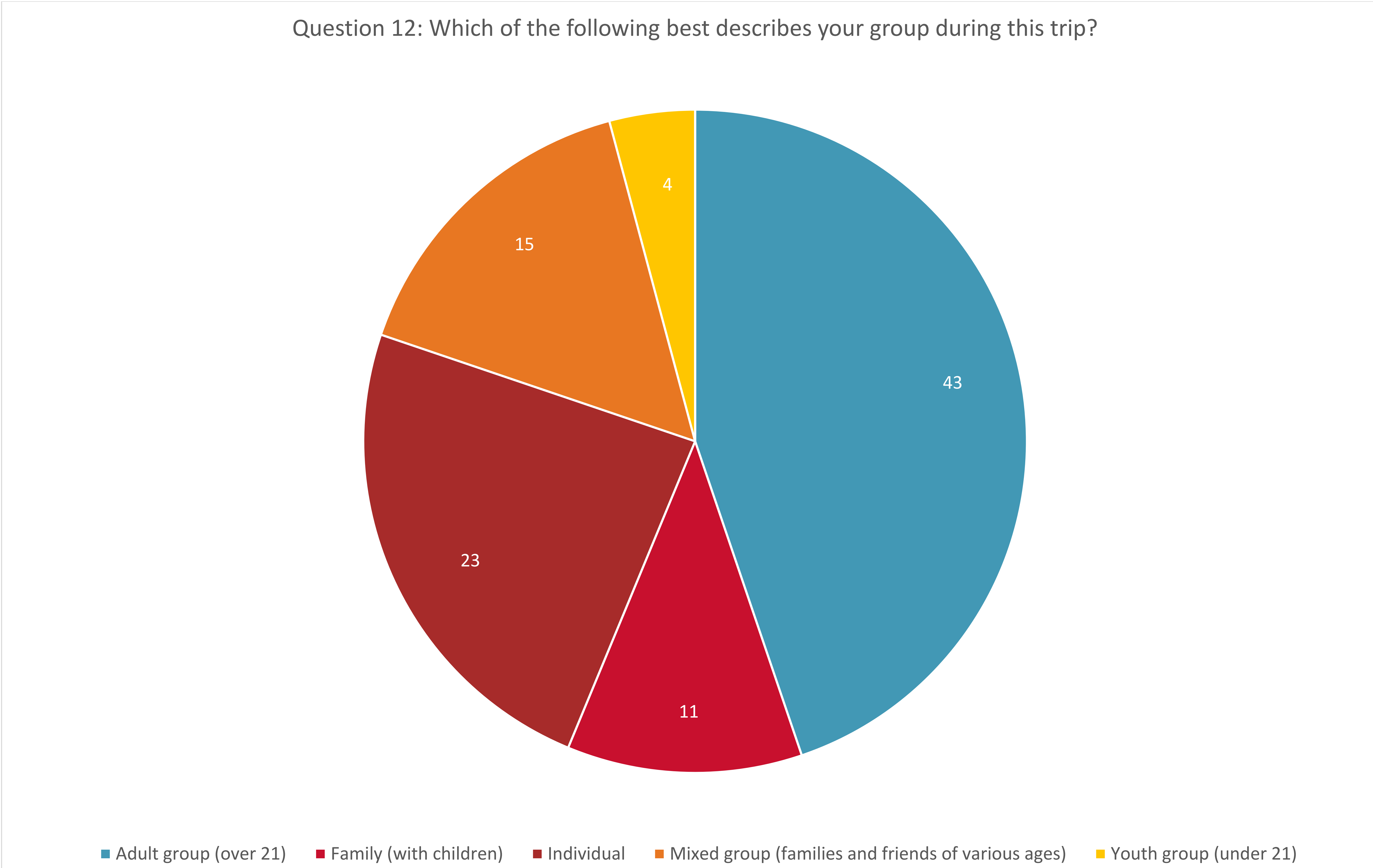
Question 6: Which of the following recreation areas at or near the Lowell Project did you utilize during the past 12 months?
Count
% of respondents
70
60
50
40
30
20
10
0
28
31.5
9
10.1
56
63
11
12.4
50
56
31
35
42
47
11
12.4
6
6.7
6
6.7
8
9
22
25
13
14.7
10
11.2
36
40
6
6.7
16
18
Rourke Brothers Boat Ramp
Chelmsford Boat Access
Lowell Heritage State Park
Merrill State Park
Pawtucket Falls Overlook
NPS Walkway Tours
Merrimack Trail System
Greeley Boat Ramp
Depot Street Boat Ramp
EL Field Powerhouse Visitor Center
Moore's Falls Conservation Area
Riverwalk Ramble
Waterpower Walk
Heritage Hike
Northern Canal Walkway
Redevelopment Rove
Boat access facilities

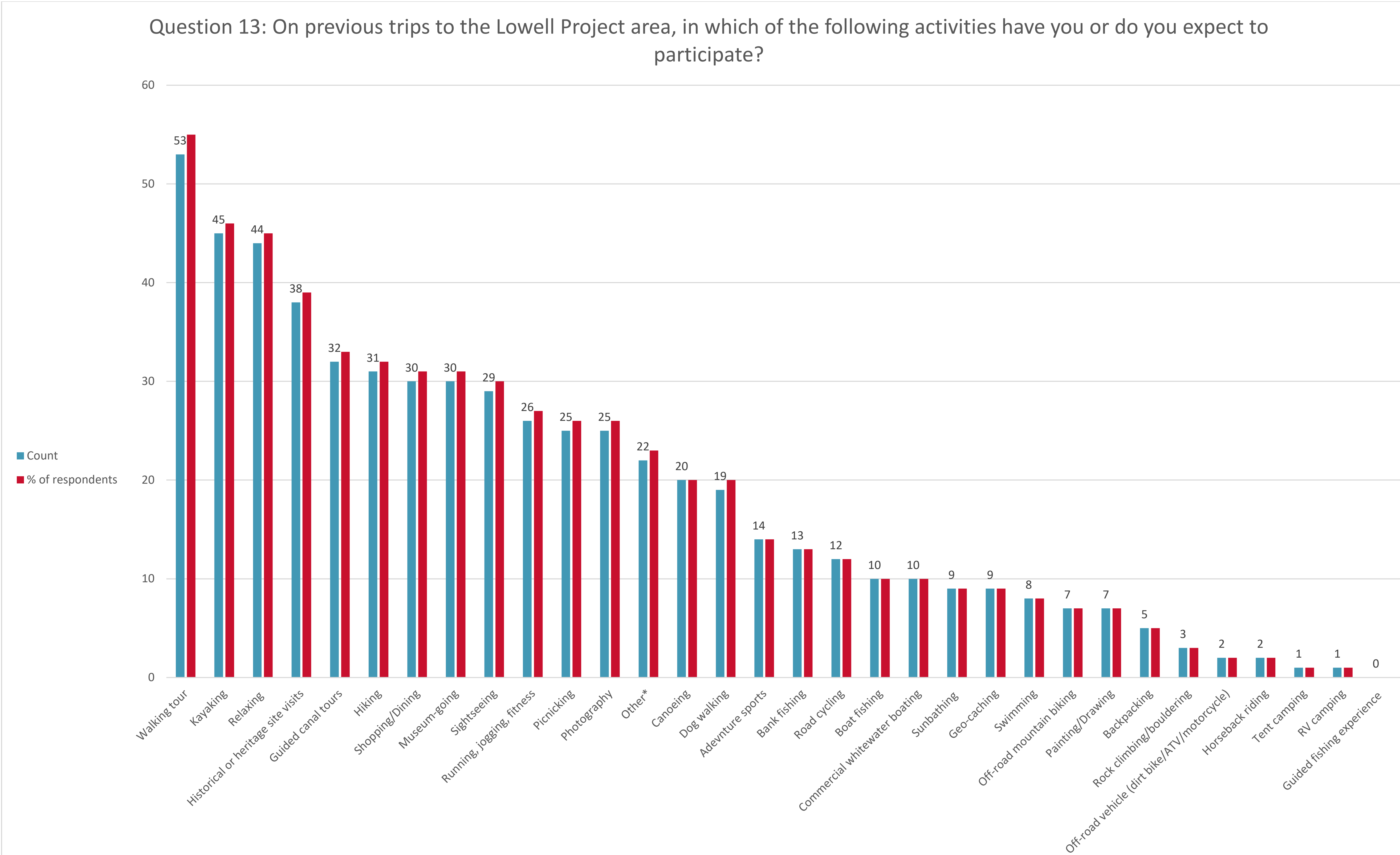

Question 7: On your last trip, about how many miles did you travel to get to the Lowell Project?
250
200
150
100
50
0
Miles
200
0
11.22434211
Minimum
Maximum
Mean


Question 8: During the past 12 months, when did you visit the Lowell Project? (Please select one)
6
20
63
Both weekdays AND weekends and/or holidays
Only on weekdays (Monday - Friday)
Only on weekends (Saturday or Sunday) and/or holidays

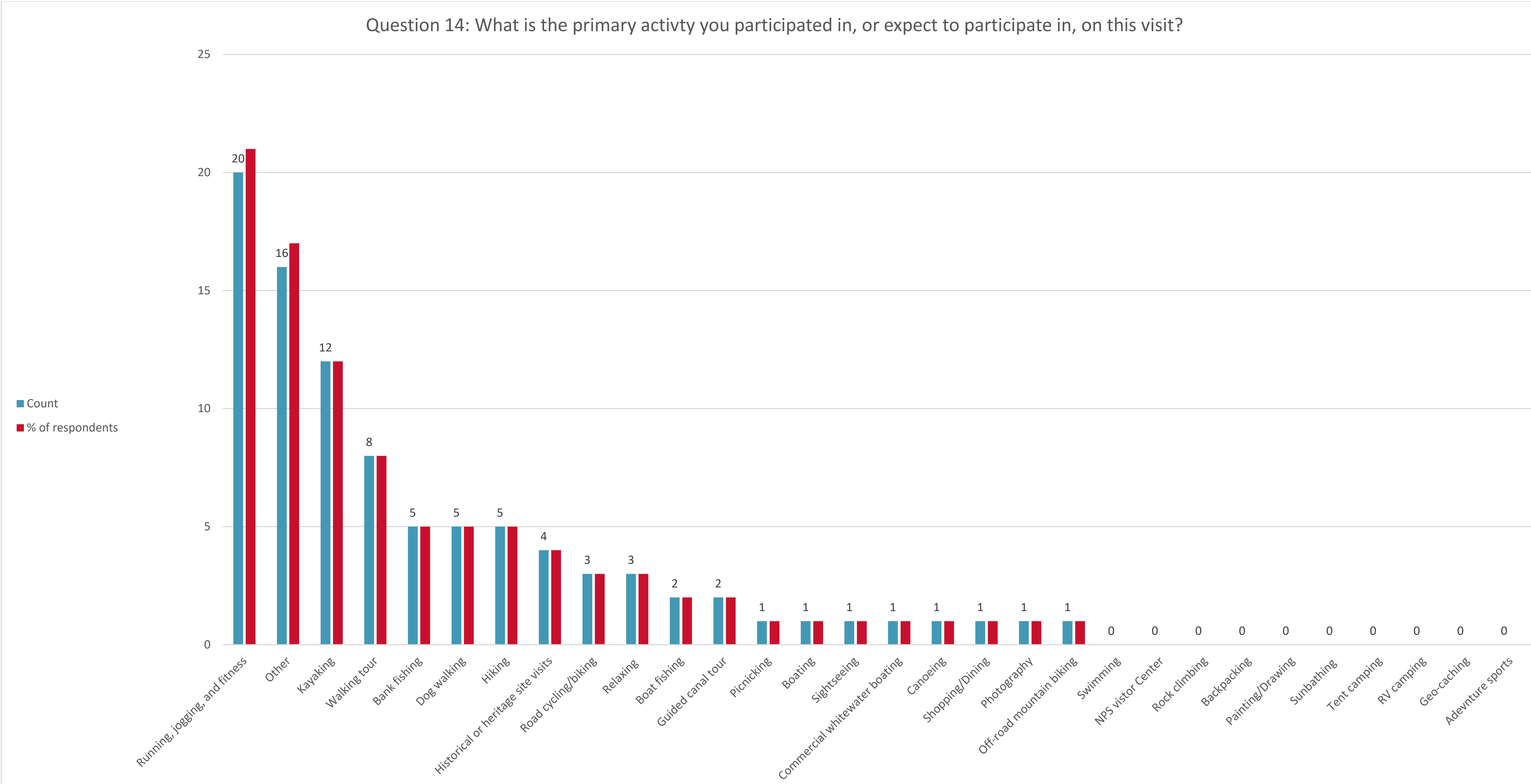

Question 9: Are you staying overnight in the Lowell Project area (not including your own home) on this trip?
9
84
Yes
No


Question 11: What is the apporximate size of your group during your last trip to the Lowell Project area?
14
12
10
8
6
4
2
0
Group Size (number of people)
1
12
2.927083333
Minimum
Maximum
Mean

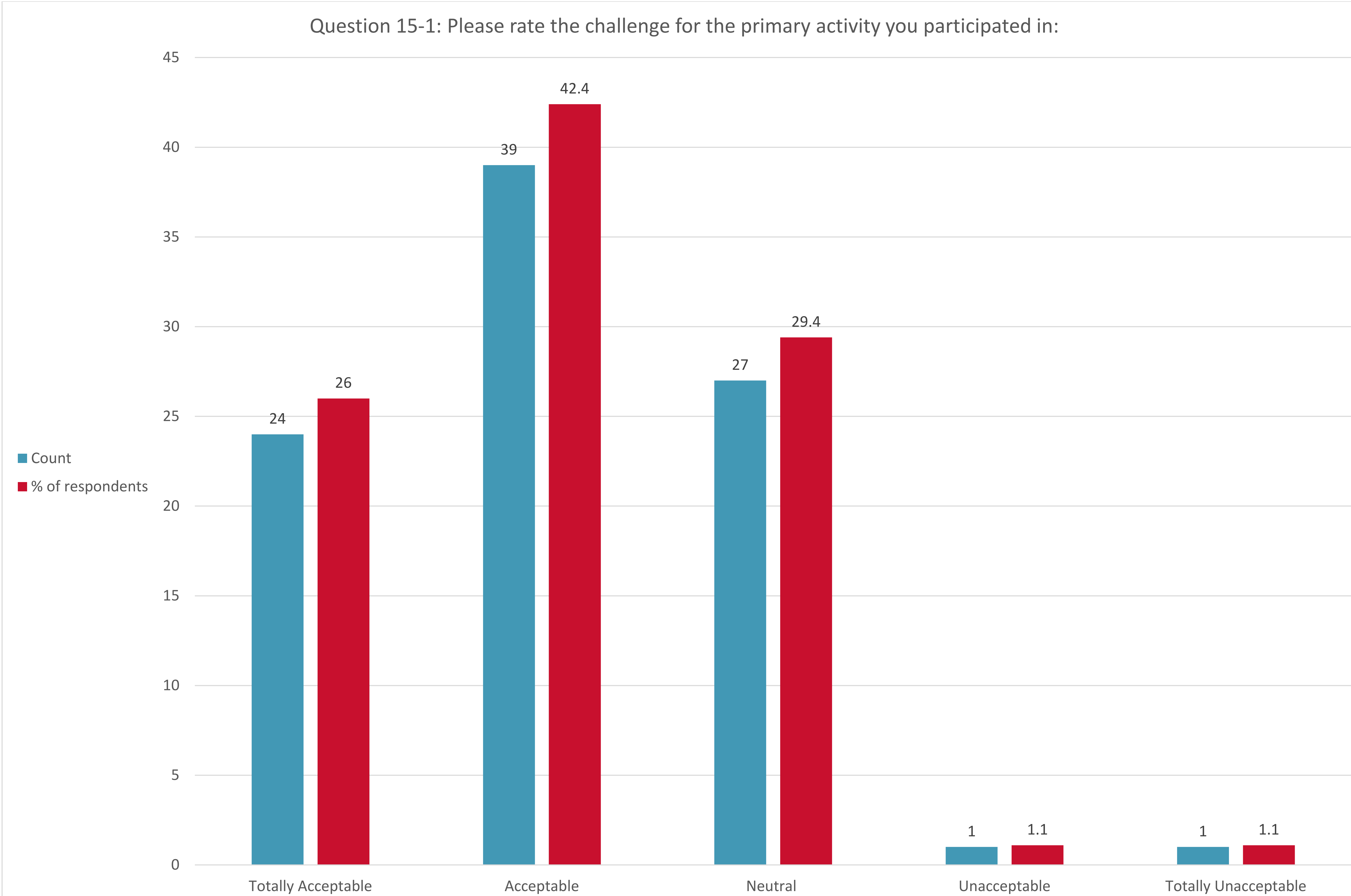

Question 12: Which of the following best describes your group during this trip?
43
11
23
15
4
Adult group (over 21)
Family (with children)
Individual
Mixed group (families and friends of various ages)
Youth group (under 21)

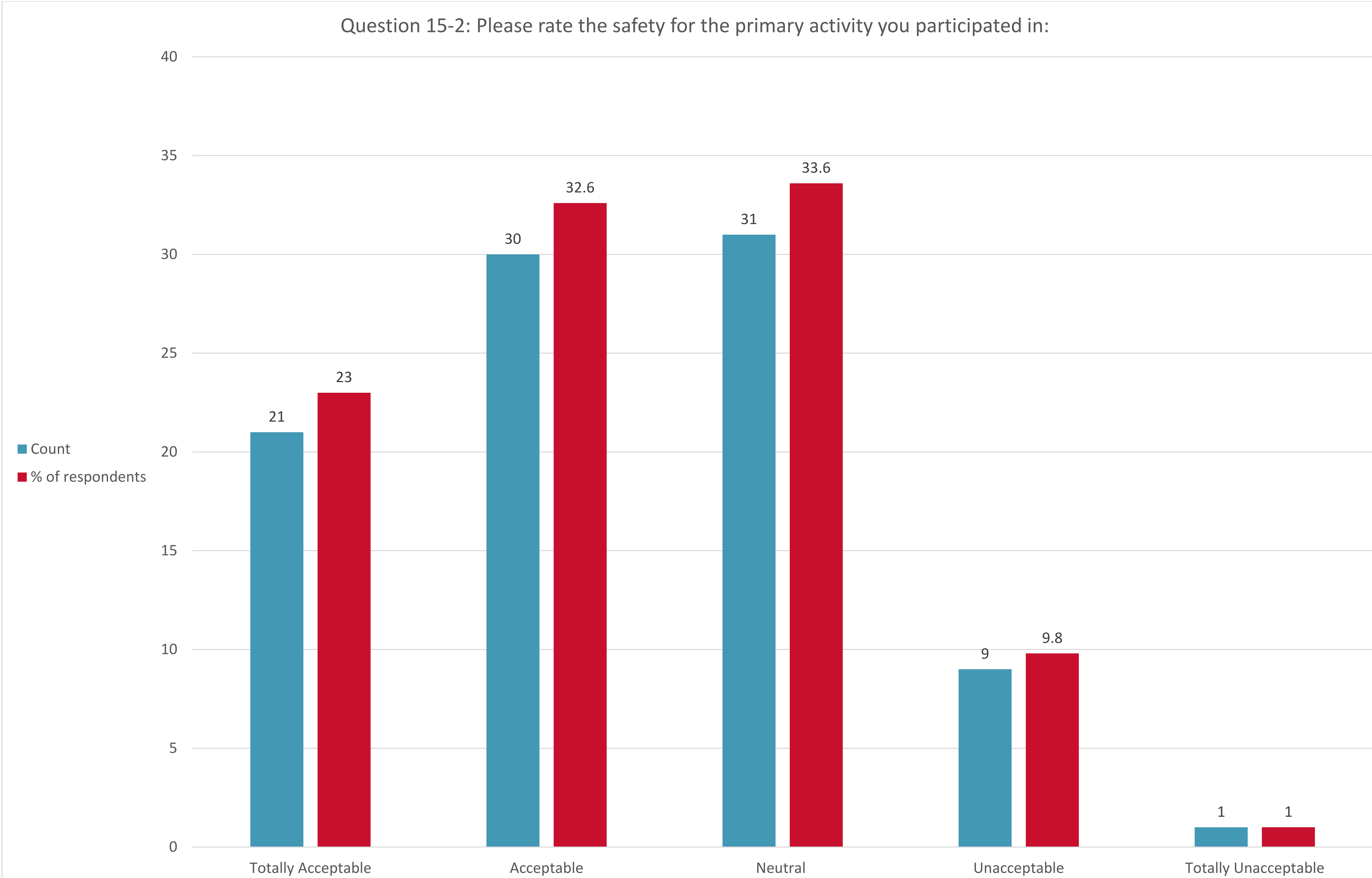


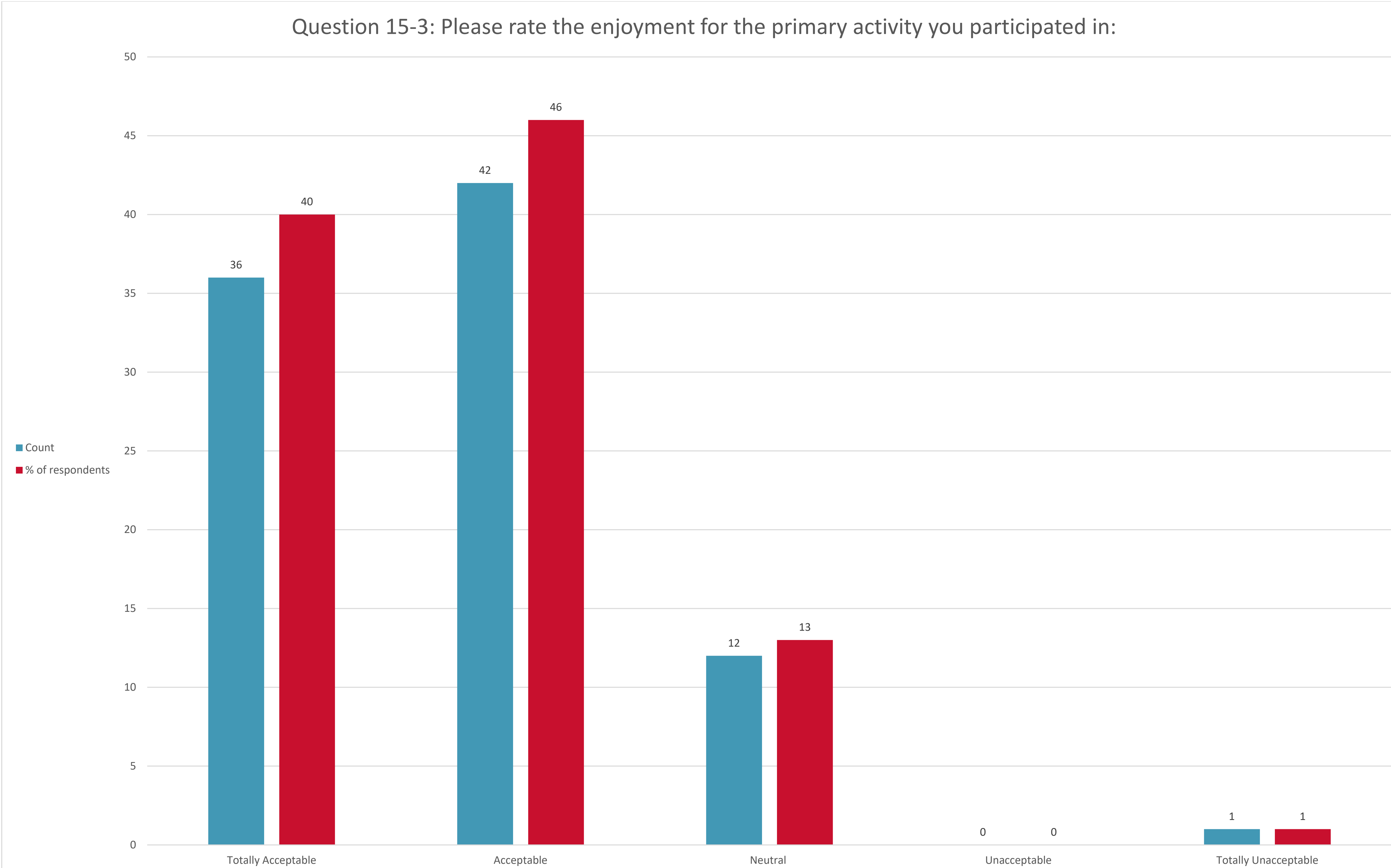
*Other responses included personal whitewater rafting or canoeing, hammocking, birding, attending festivals, and sport boating.

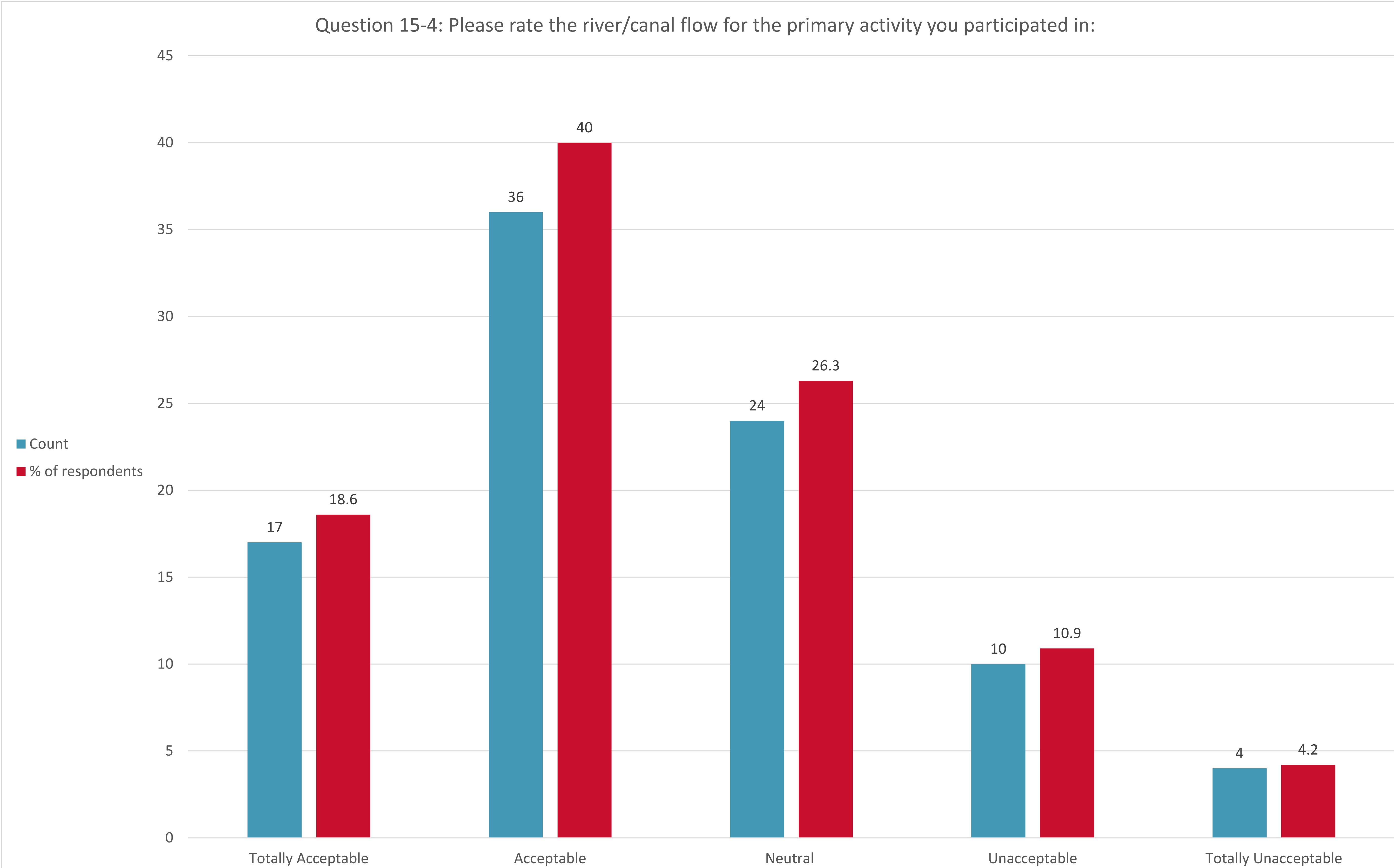


Question 14: What is the primary activty you participated in, or expect to participate in, on this visit?
Count
% of respondents
25
20
15
10
5
0
20
16
12
8
5
5
5
4
3
3
2
2
1
1
1
1
1
1
1
1
0
0
0
0
0
0
0
0
0
0
Running, jogging, and fitness
Other
Kayaking
Walking tour
Bank fishing
Dog walking
Hiking
Historical or heritage site visits
Road cycling/biking
Relaxing
Boat fishing
Guided canal tour
Picnicking
Boating
Sightseeing
Commercial whitewater boating
Canoeing
Shopping/Dining
Photography
Off-road mountain biking
Swimming
NPS vistor Center
Rock climbing
Backpacking
Painting/Drawing
Sunbathing
Tent camping
RV camping
Geo-caching
Adevnture sports

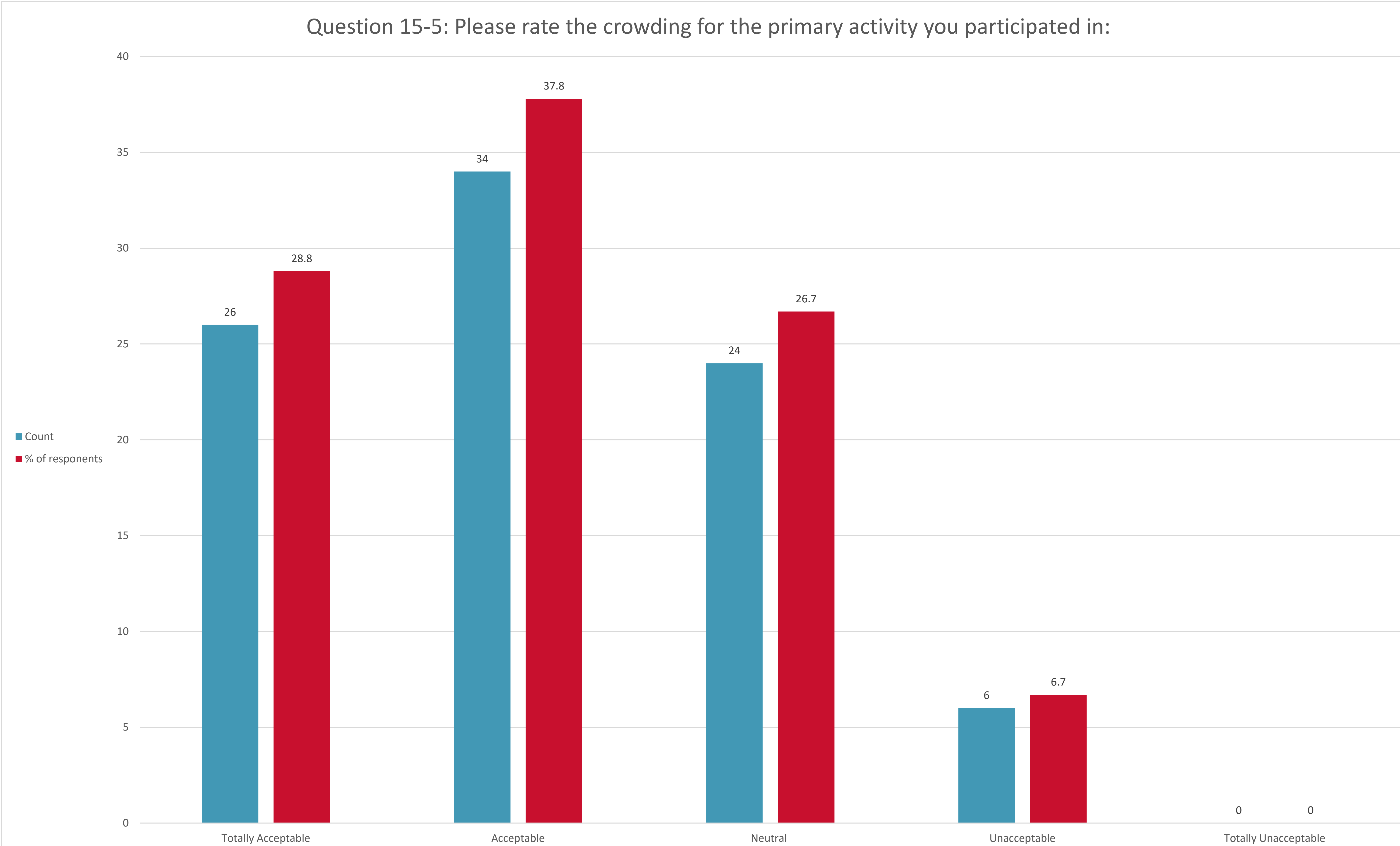

Question 15-1: Please rate the challenge for the primary activity you participated in:
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
24
26
39
42.4
27
29.4
1
1.1
1
1.1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

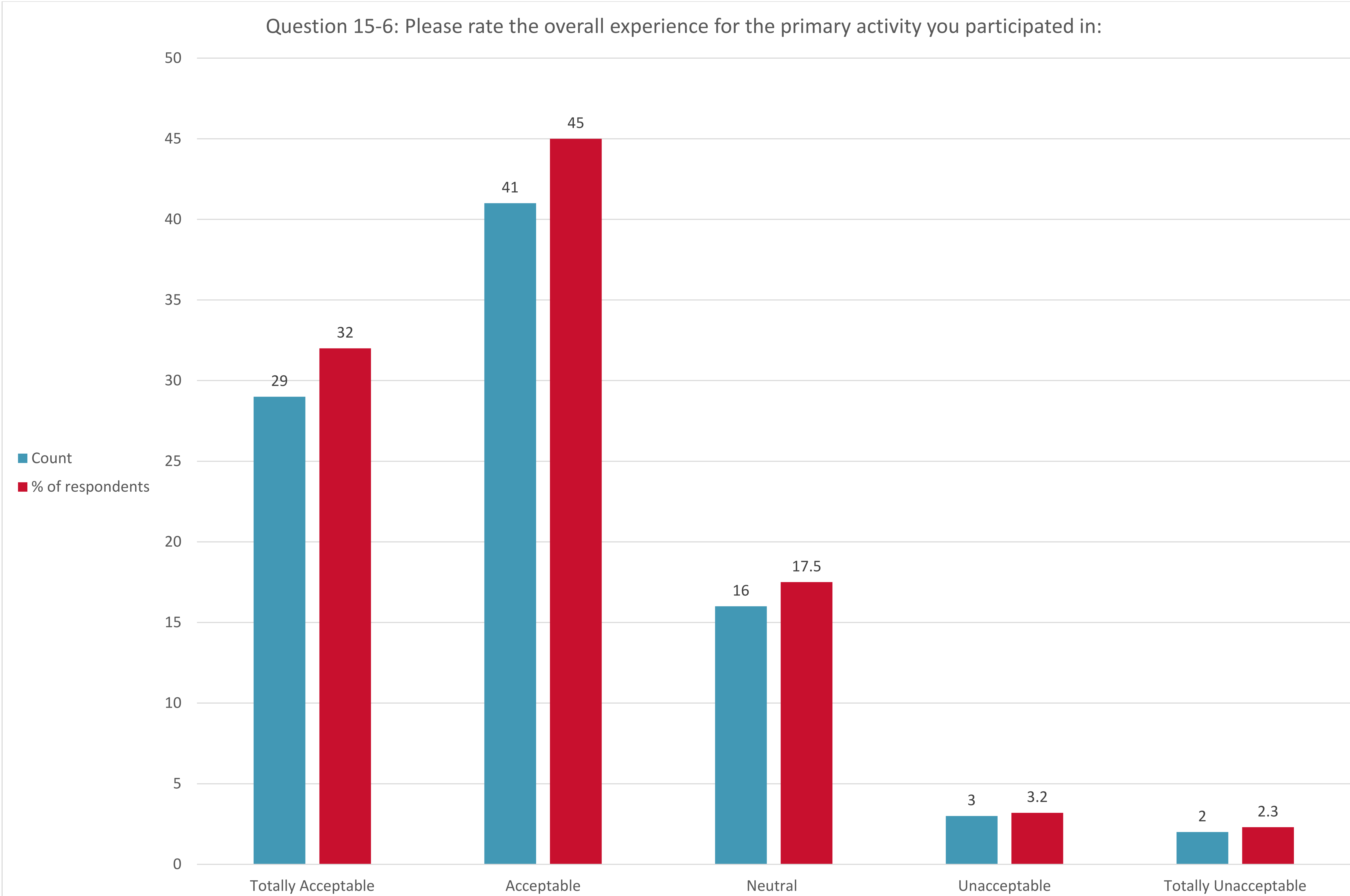

Question 15-2: Please rate the safety for the primary activity you participated in:
40
35
30
25
20
15
10
5
0
Count
% of respondents
21
23
30
32.6
31
33.6
9
9.8
1
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

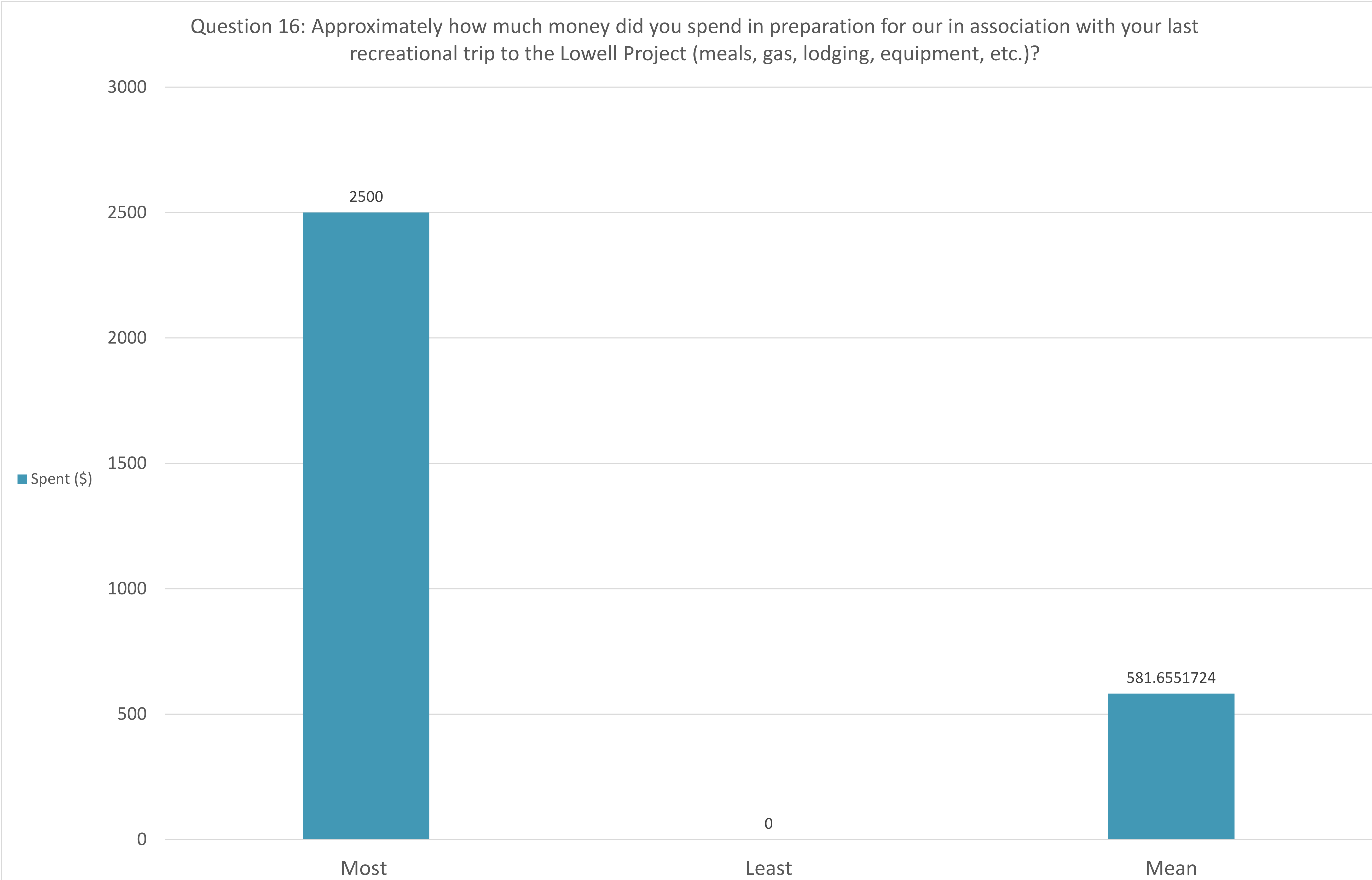

Question 15-3: Please rate the enjoyment for the primary activity you participated in:
Count
% of respondents
50
45
40
35
30
25
20
15
10
5
0
36
40
42
46
12
13
0
0
1
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

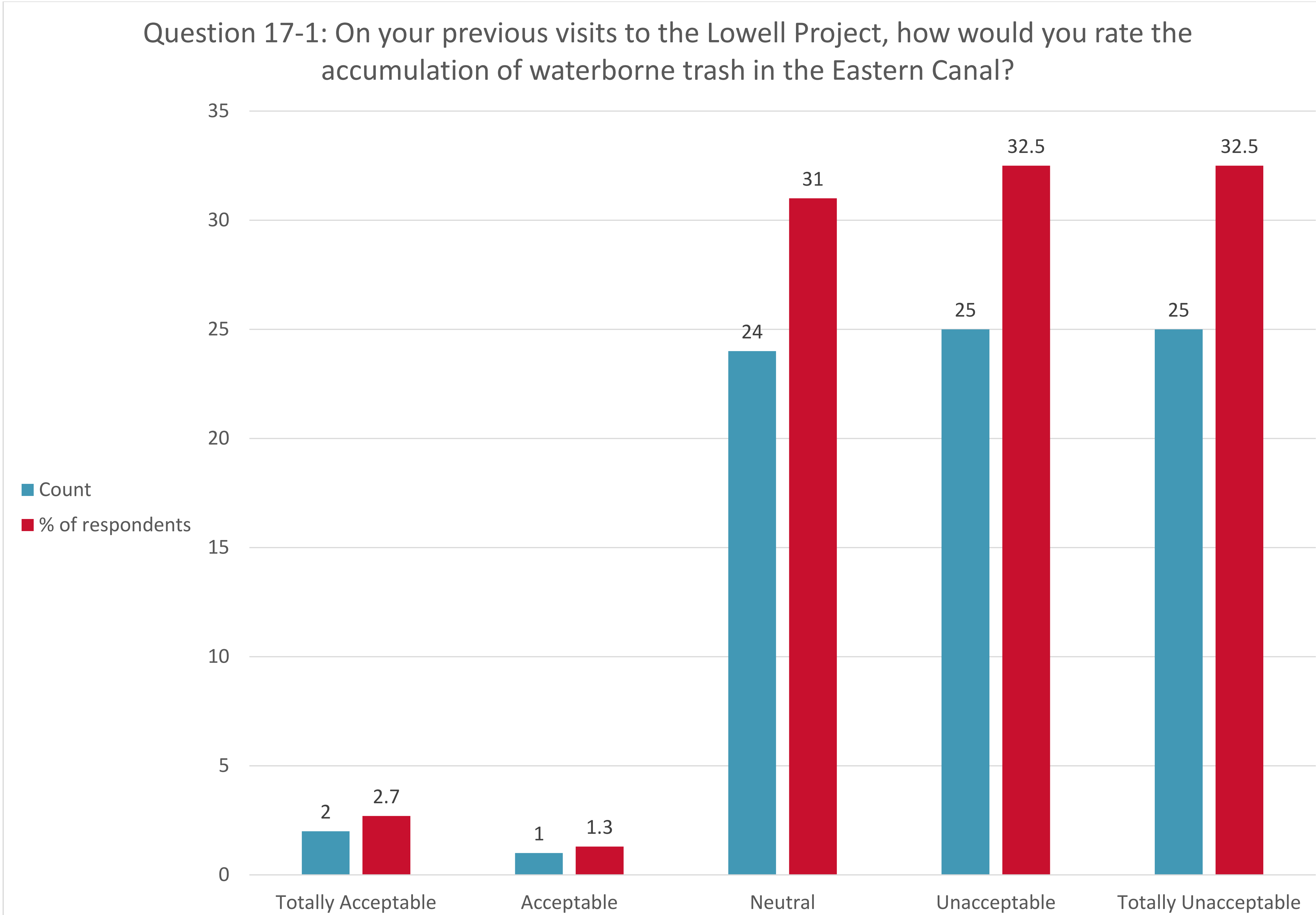


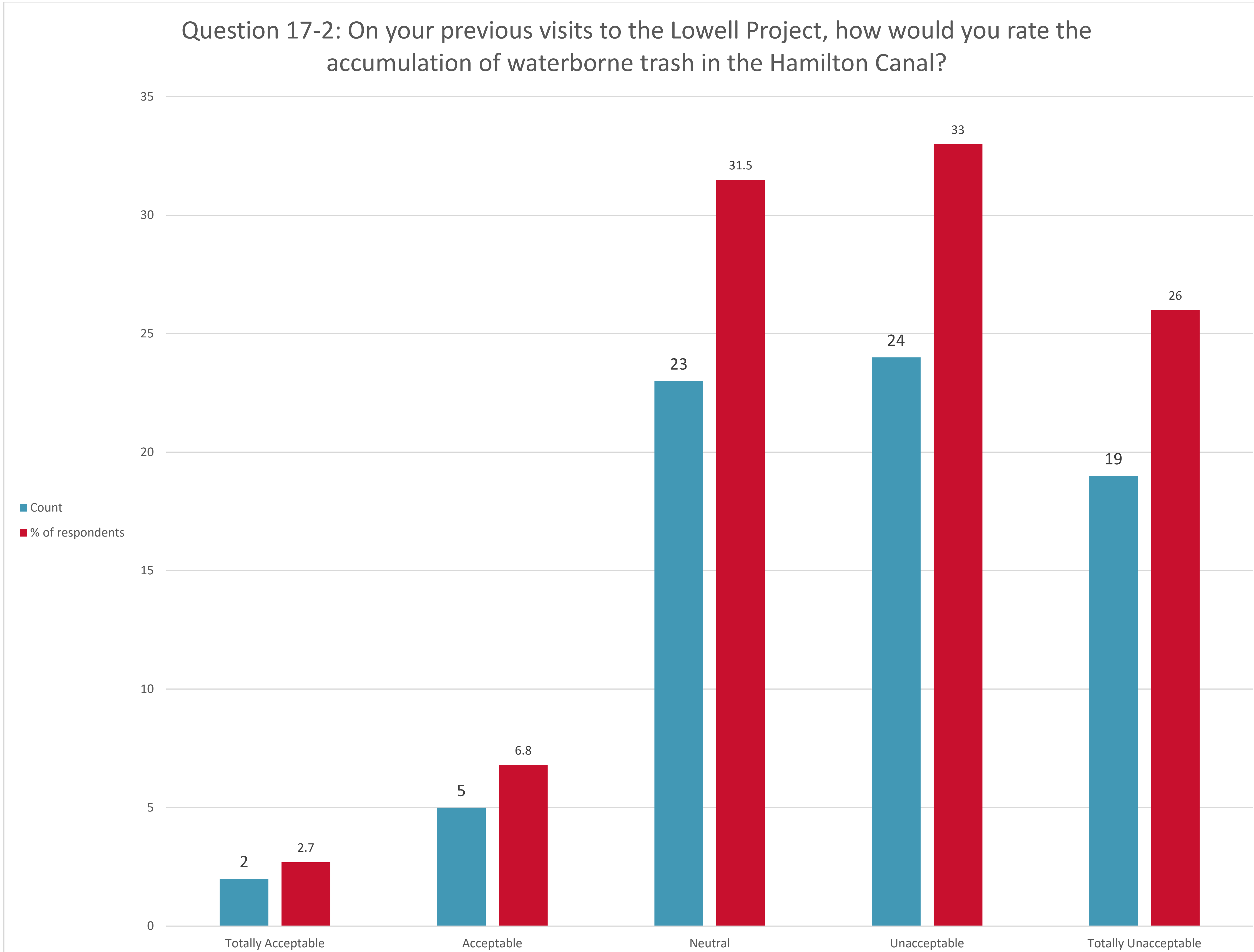
Question 15-4: Please rate the river/canal flow for the primary activity you participated in:
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
17
18.6
36
40
24
26.3
10
10.9
4
4.2
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

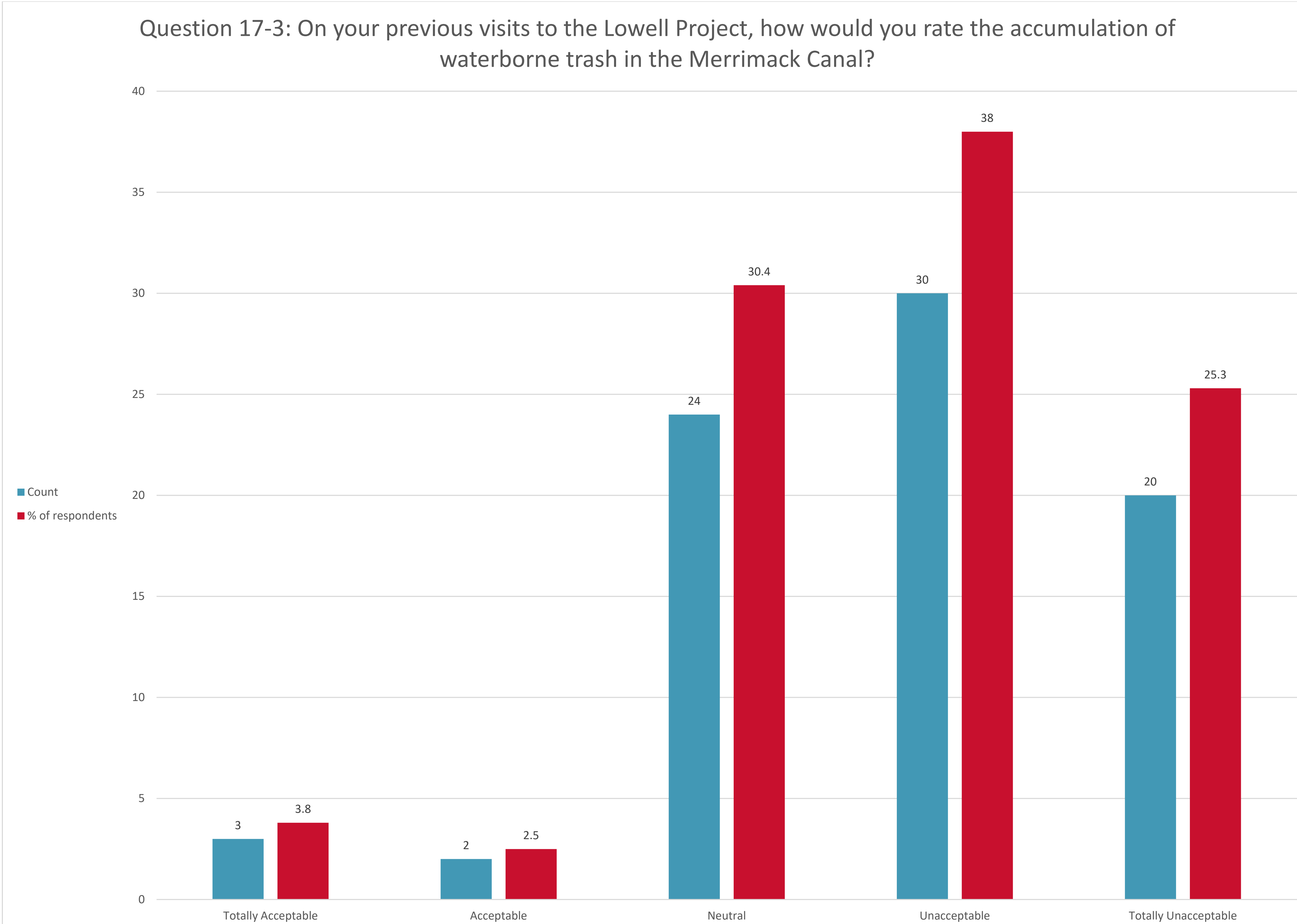

Question 15-5: Please rate the crowding for the primary activity you participated in:
40
35
30
25
20
15
10
5
0
Count
% of responents
26
28.8
34
37.8
24
26.7
6
6.7
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

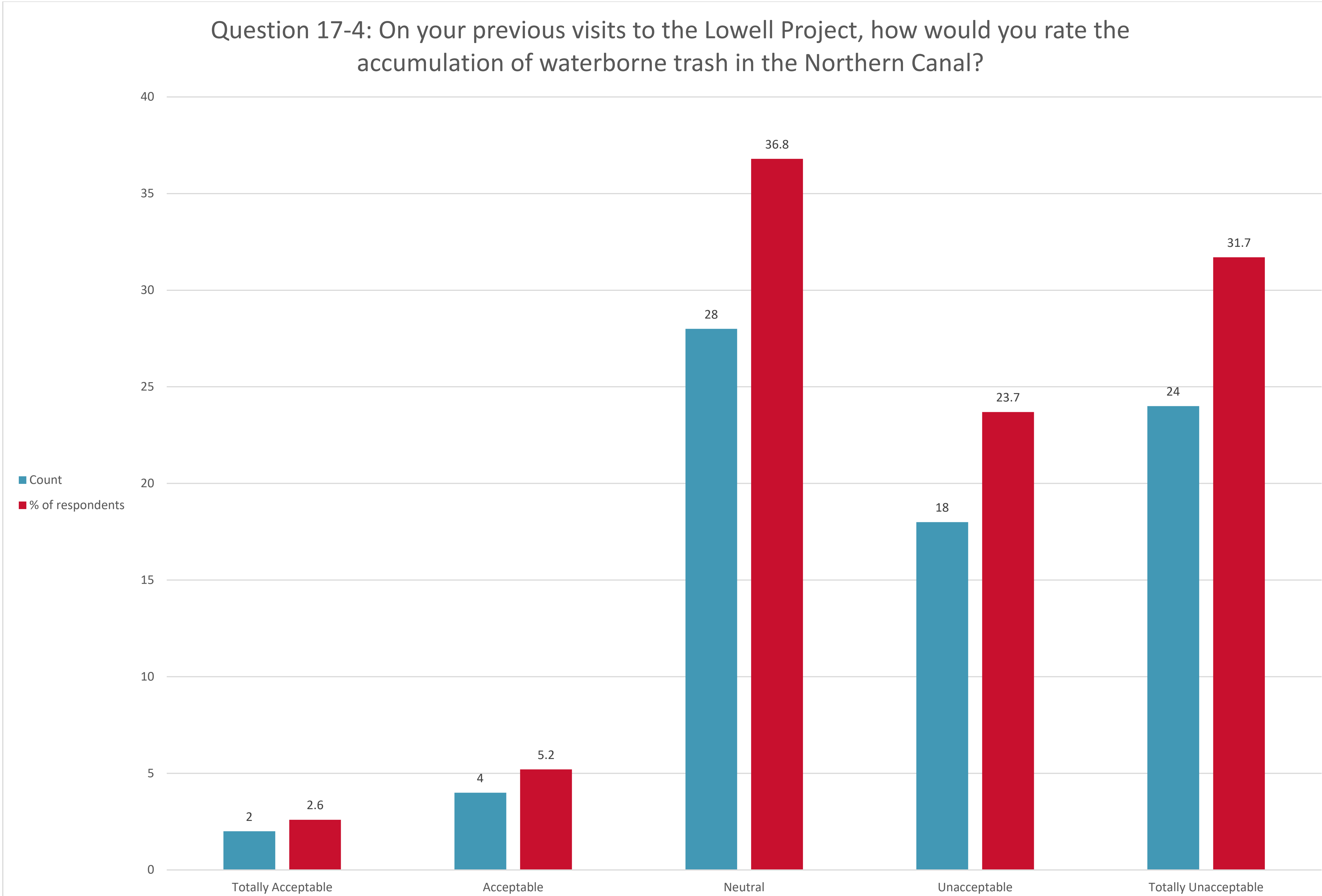

Question 15-6: Please rate the overall experience for the primary activity you participated in:
50
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
29
32
41
45
16
17.5
3
3.2
2
2.3
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

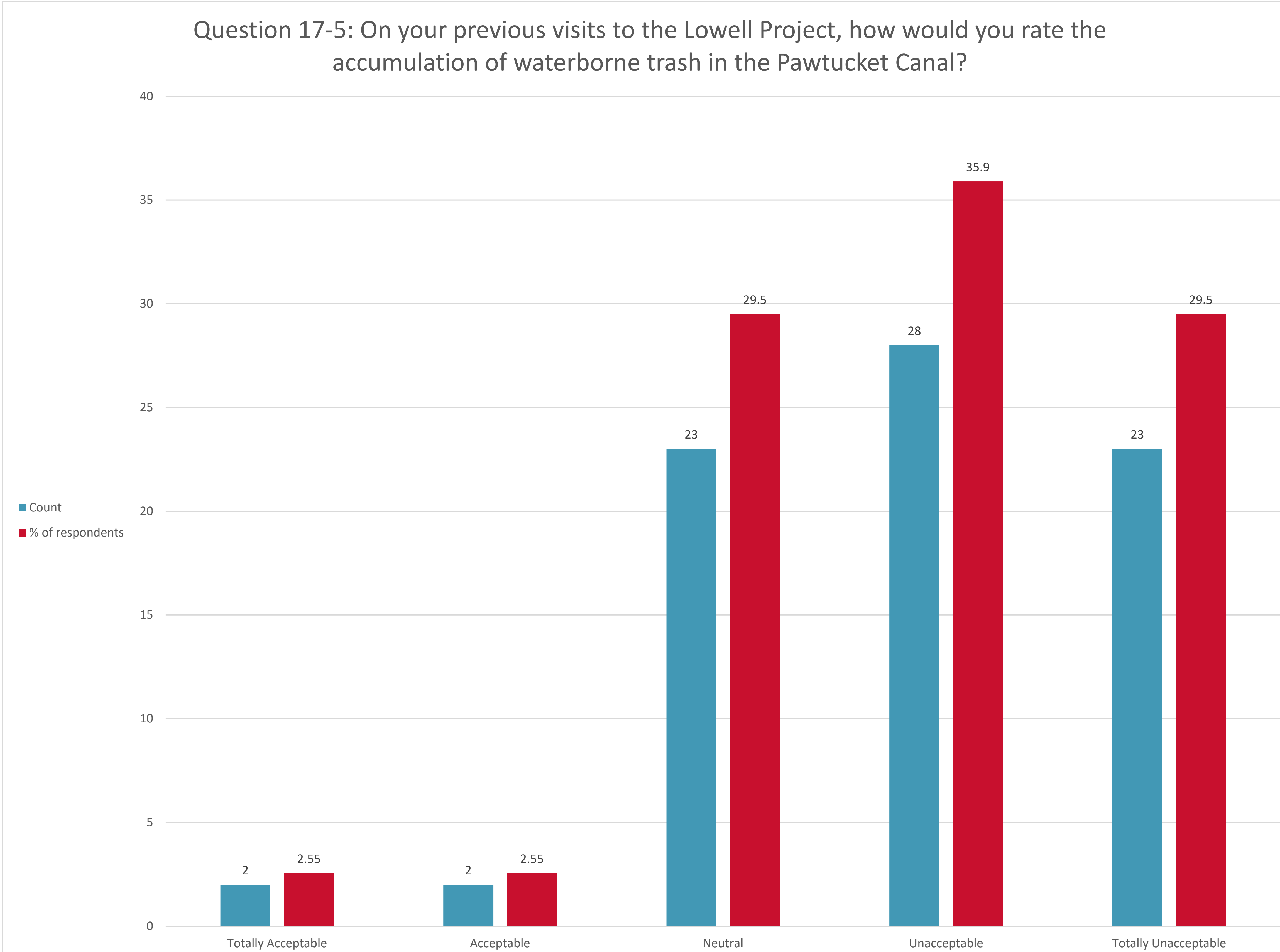

Question 16: Approximately how much money did you spend in preparation for our in association with your last recreational trip to the Lowell Project (meals, gas, lodging, equipment, etc.)?
3000
2500
2000
1500
1000
500
0
Spent ($)
2500
0
581.6551724
Most
Least
Mean


Question 17-1: On your previous visits to the Lowell Project, how would you rate the accumulation of waterborne trash in the Eastern Canal?
35
30
25
20
15
10
5
0
Count
% of respondents
2
2.7
1
1.3
24
31
25
32.5
25
32.5
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

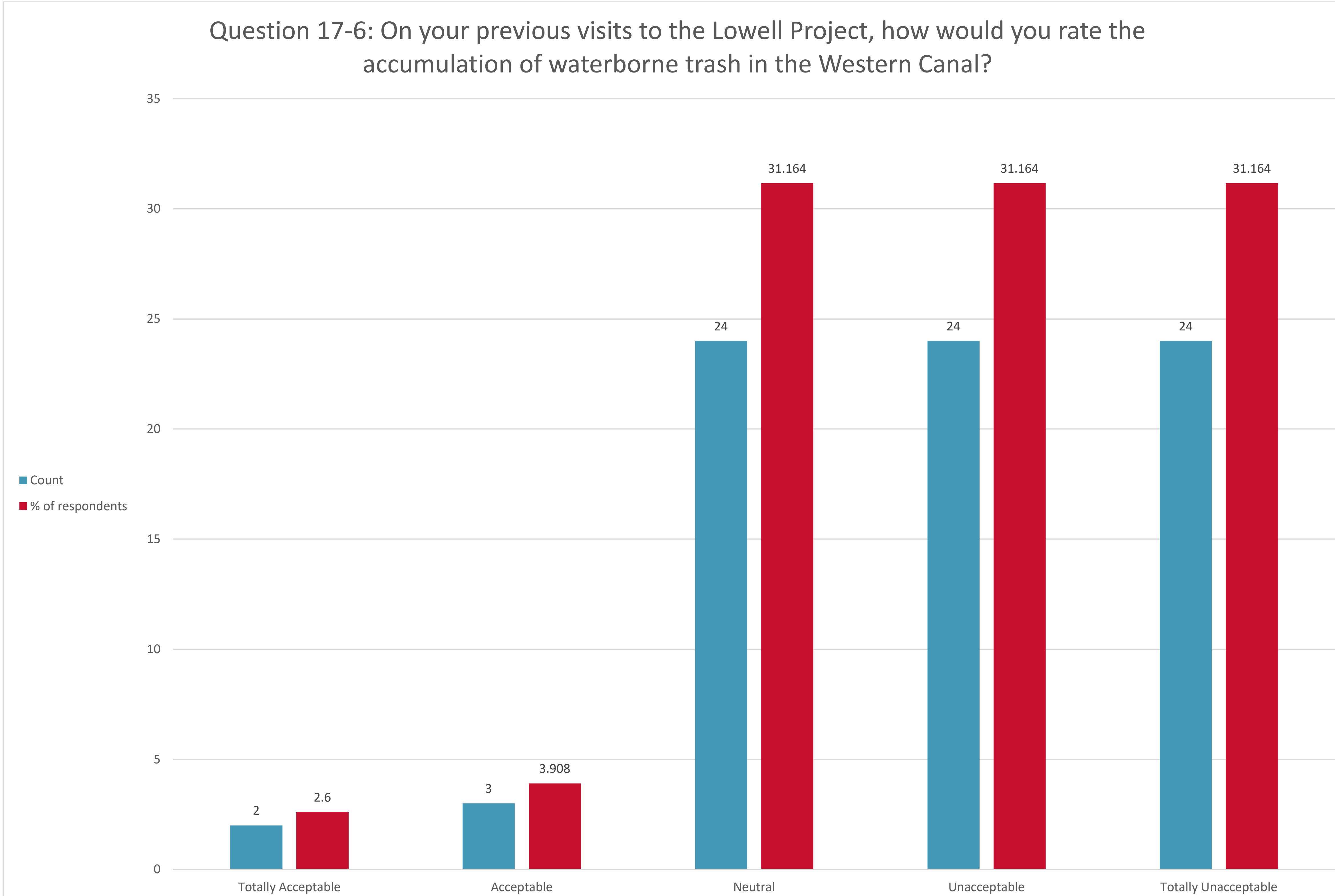

Question 17-2: On your previous visits to the Lowell Project, how would you rate the accumulation of waterborne trash in the Hamilton Canal?
35
30
25
20
15
10
5
0
Count
% of respondents
2
2.7
5
6.8
23
31.5
24
33
19
26
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

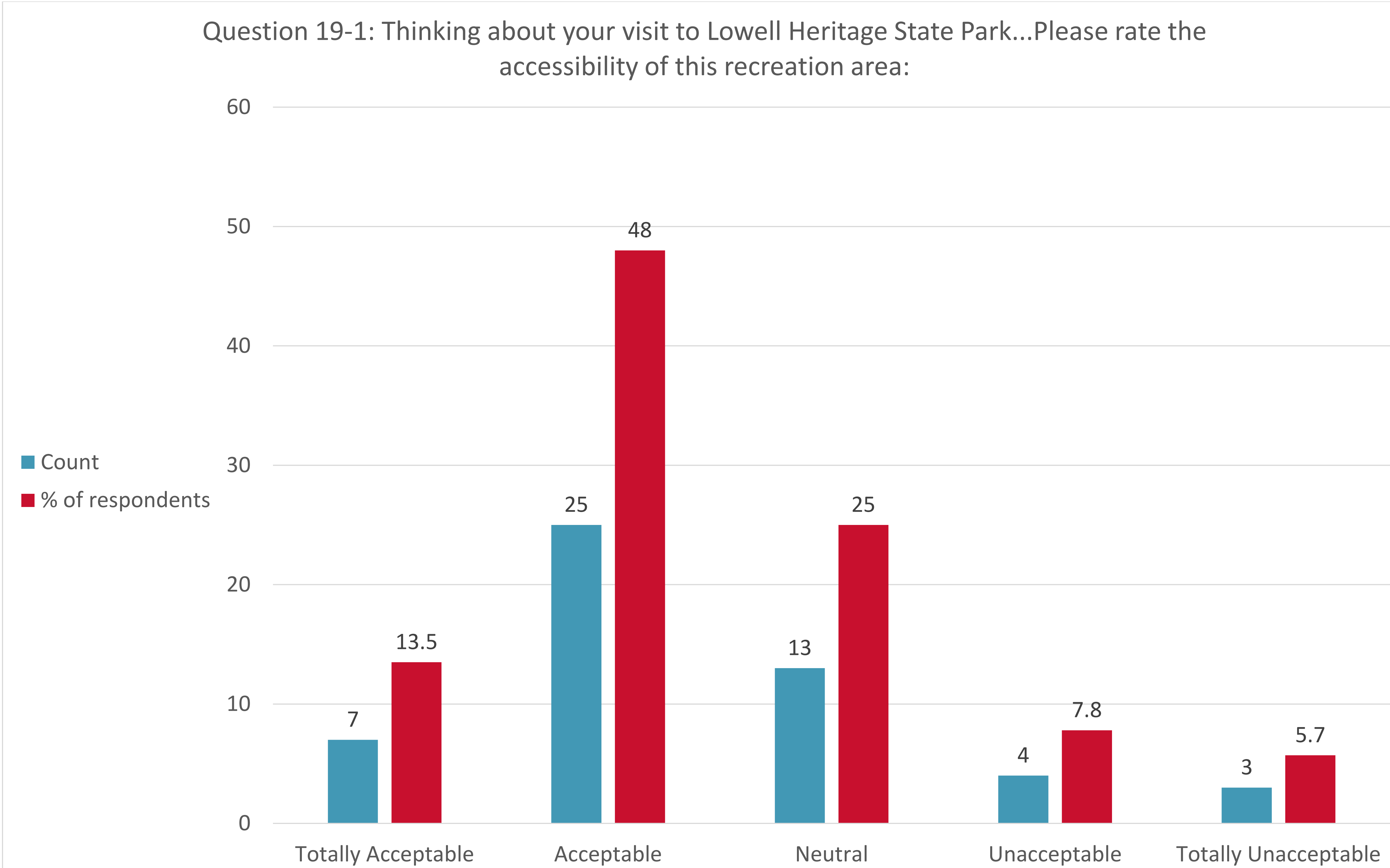

Question 17-3: On your previous visits to the Lowell Project, how would you rate the accumulation of waterborne trash in the Merrimack Canal?
Count
% of respondents
40
35
30
25
20
15
10
5
0
3
3.8
2
2.5
24
30.4
30
38
20
25.3
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 17-4: On your previous visits to the Lowell Project, how would you rate the accumulation of waterborne trash in the Northern Canal?
Count
% of respondents
0
5
10
15
20
25
30
35
40
2
2.6
4
5.2
28
36.8
18
23.7
24
31.7
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

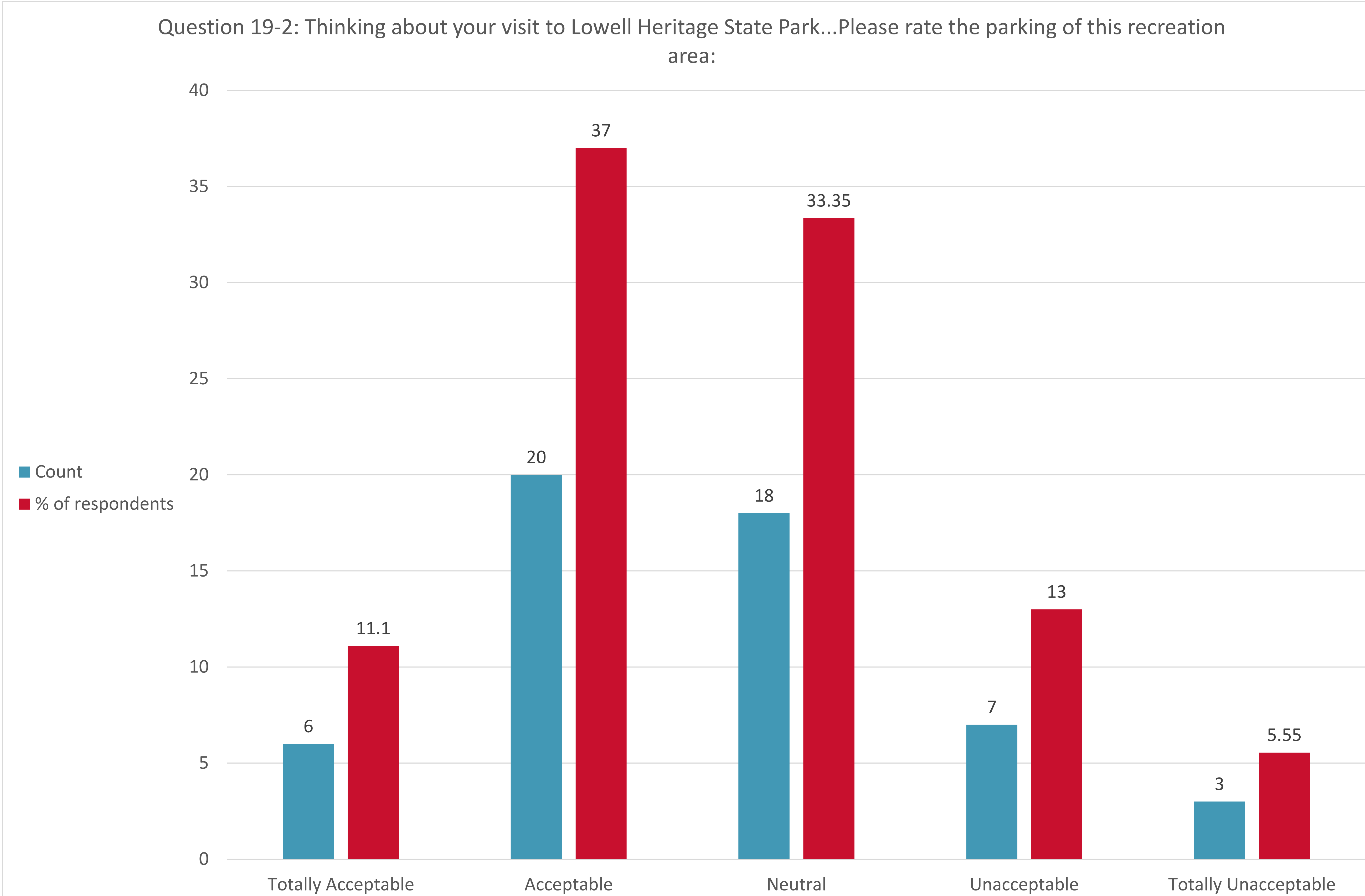


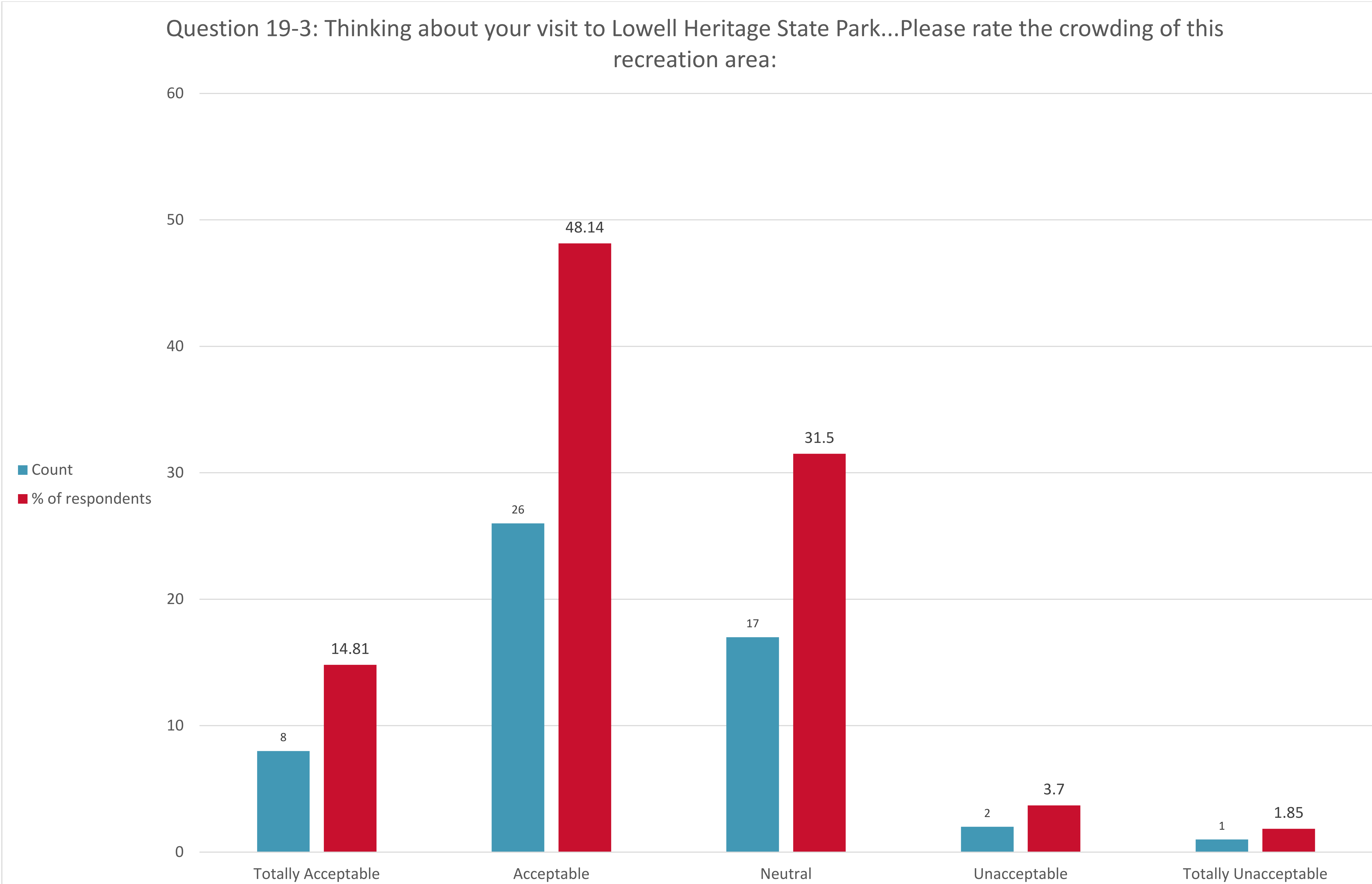
Question 17-5: On your previous visits to the Lowell Project, how would you rate the accumulation of waterborne trash in the Pawtucket Canal?
Count
% of respondents
40
35
30
25
20
15
10
5
0
2
2.55
2
2.55
23
29.5
28
35.9
23
29.5
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

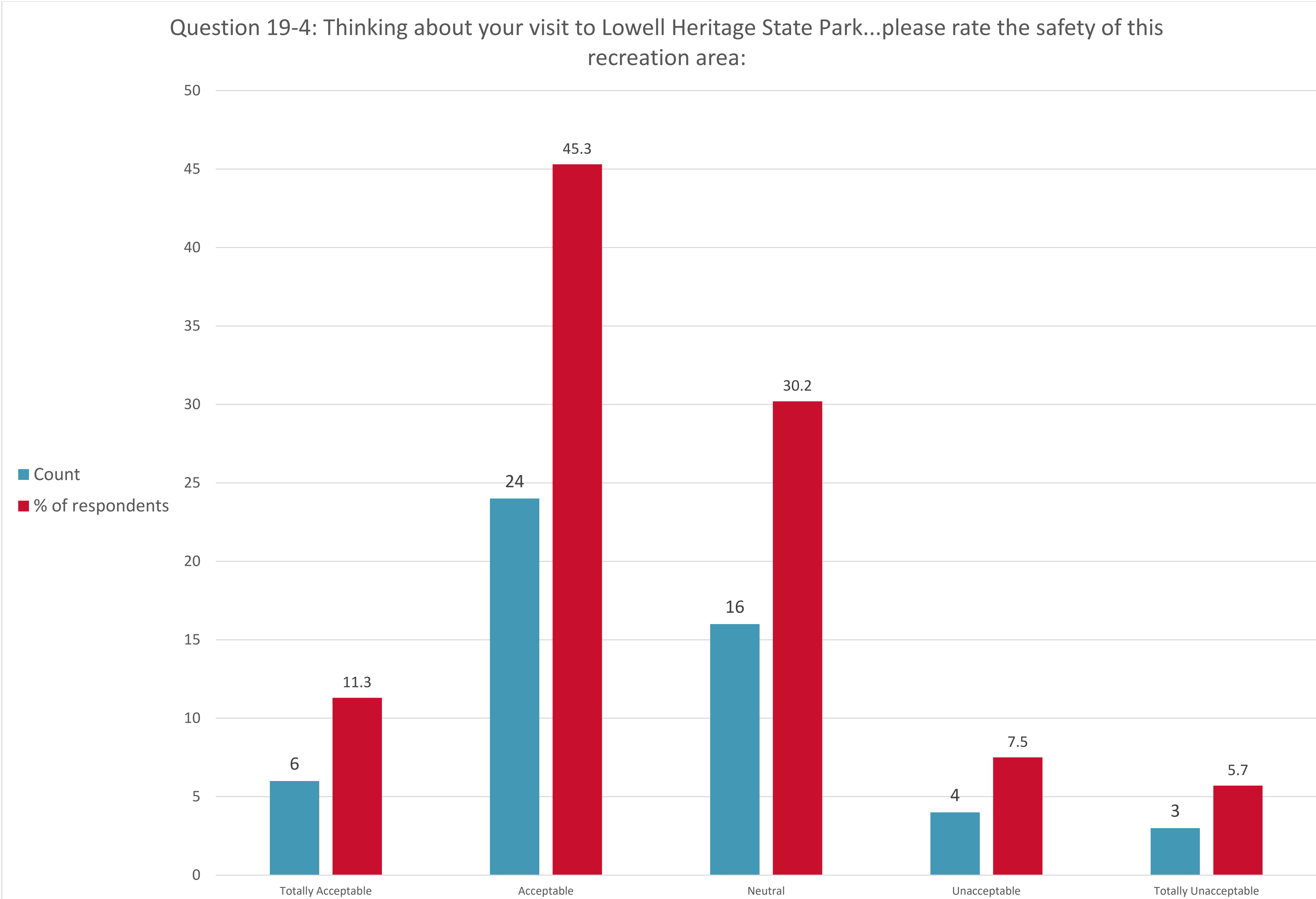

Question 17-6: On your previous visits to the Lowell Project, how would you rate the accumulation of waterborne trash in the Western Canal?
35
30
25
20
15
10
5
0
Count
% of respondents
2
2.6
3
3.908
24
31.164
24
31.164
24
31.164
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

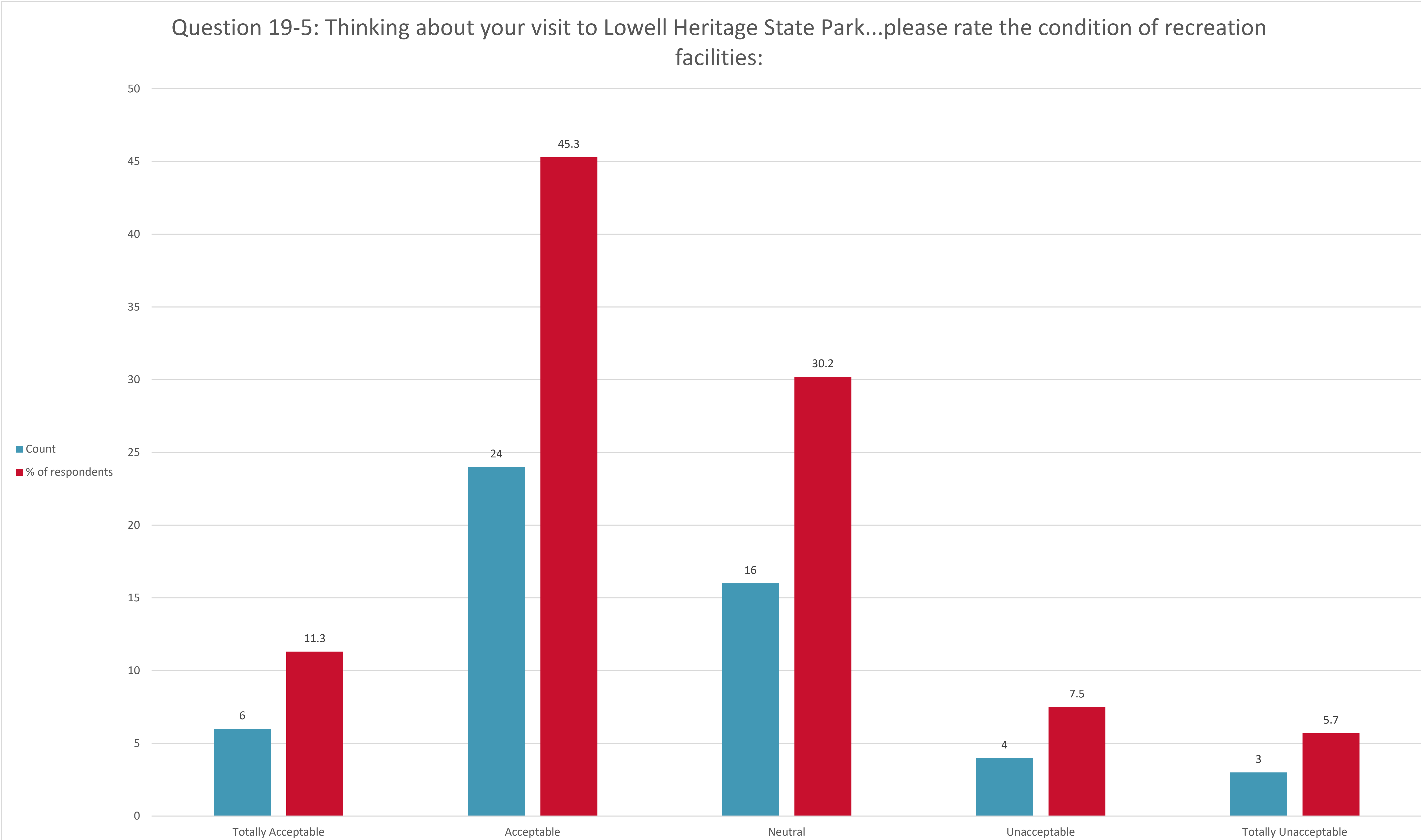


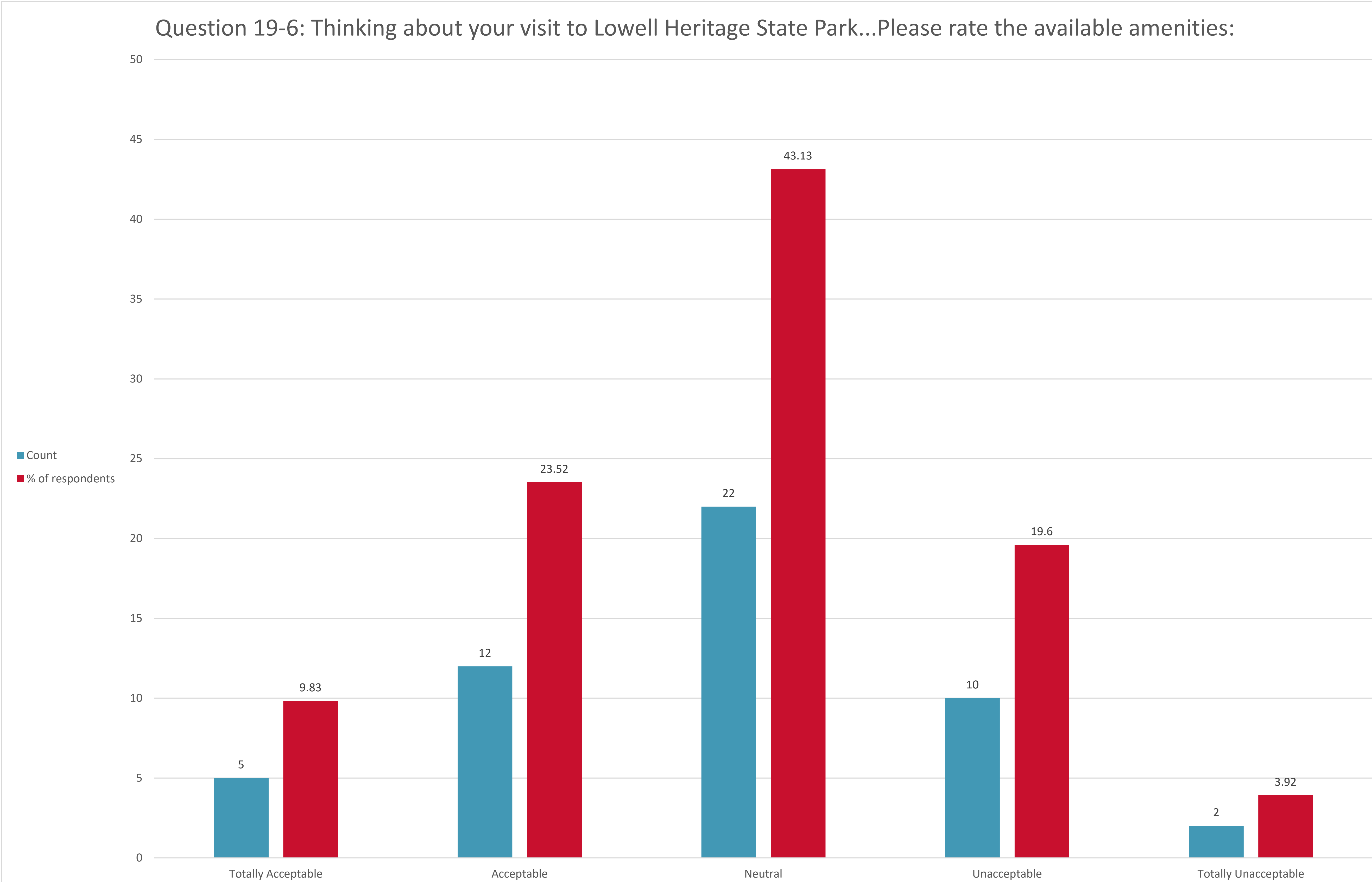
Question 19-1: Thinking about your visit to Lowell Heritage State Park...Please rate the accessibility of this recreation area:
60
50
40
30
20
10
0
Count
% of respondents
7
13.5
25
48
13
25
4
7.8
3
5.7
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

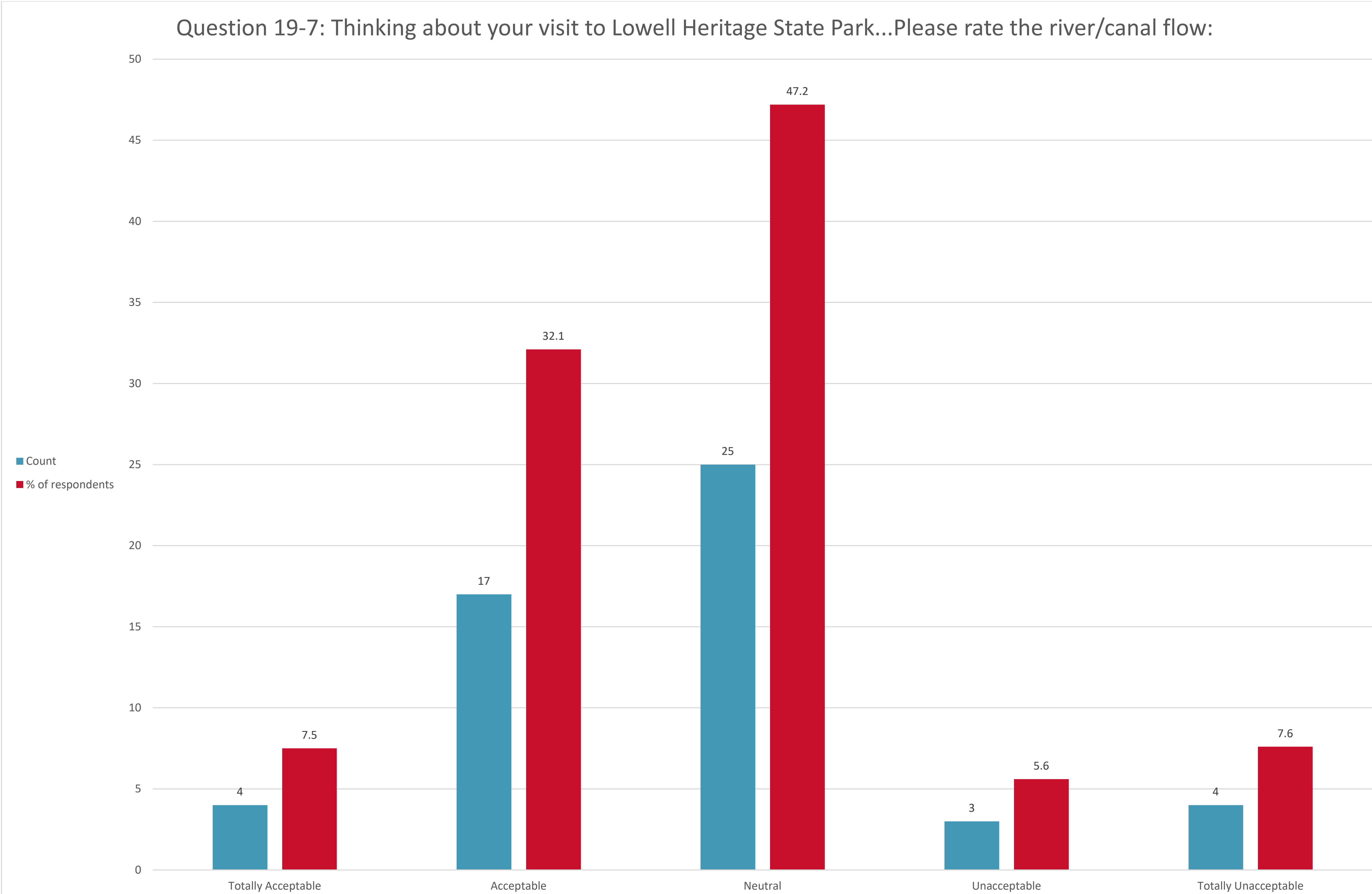

Question 19-2: Thinking about your visit to Lowell Heritage State Park...Please rate the parking of this recreation area:
40
35
30
25
20
15
10
5
0
Count
% of respondents
6
11.1
20
37
18
33.35
7
13
3
5.55
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

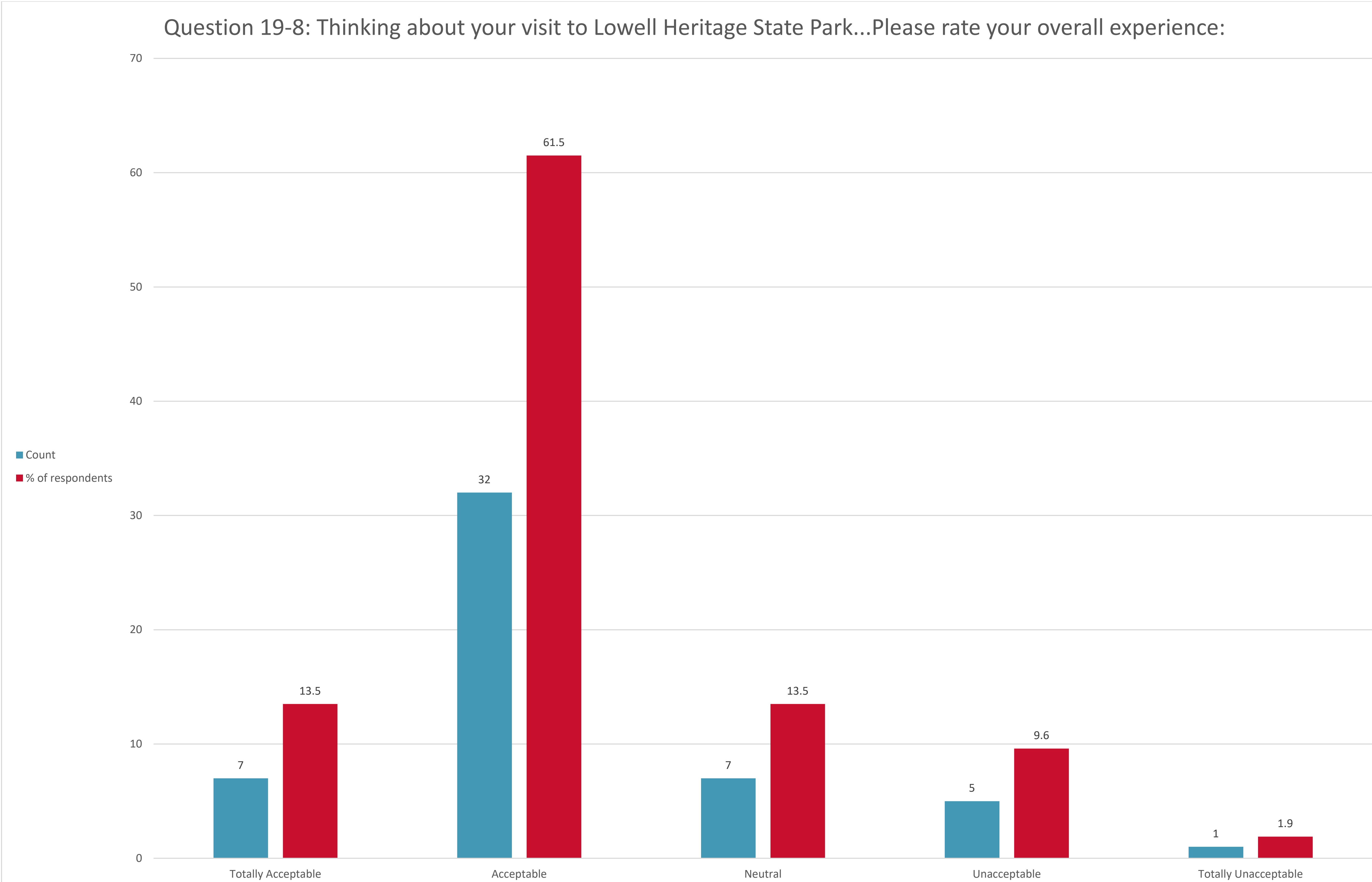

Question 19-3: Thinking about your visit to Lowell Heritage State Park...Please rate the crowding of this recreation area:
60
50
40
30
20
10
0
Count
% of respondents
8
14.81
26
48.14
17
31.5
2
3.7
1
1.85
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

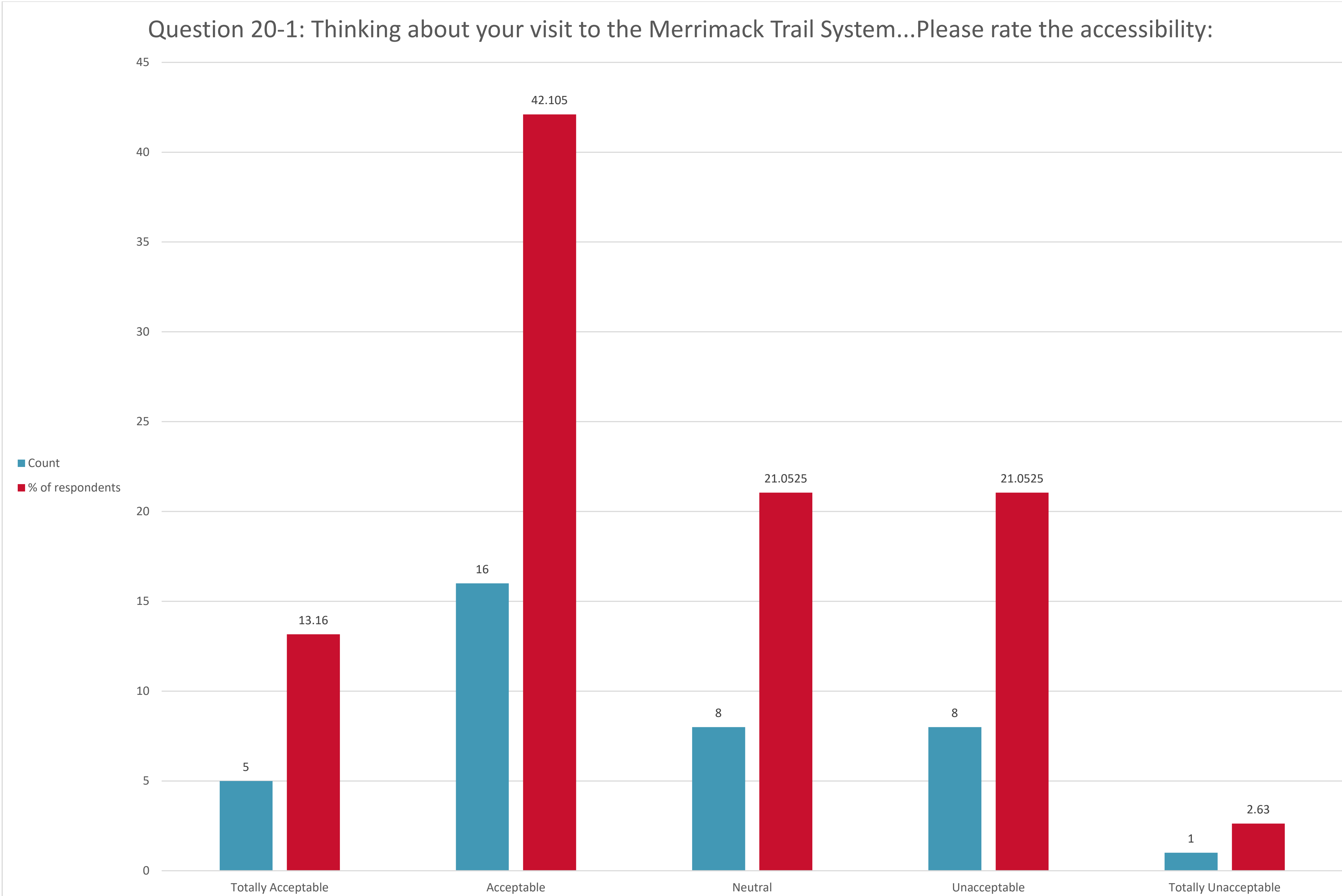

Question 19-4: Thinking about your visit to Lowell Heritage State Park...please rate the safety of this recreation area:
Count
% of respondents
0
5
10
15
20
25
30
35
40
45
50
6
11.3
24
45.3
16
30.2
4
7.5
3
5.7
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 19-5: Thinking about your visit to Lowell Heritage State Park...please rate the condition of recreation facilities:
50
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
6
11.3
24
45.3
16
30.2
4
7.5
3
5.7
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

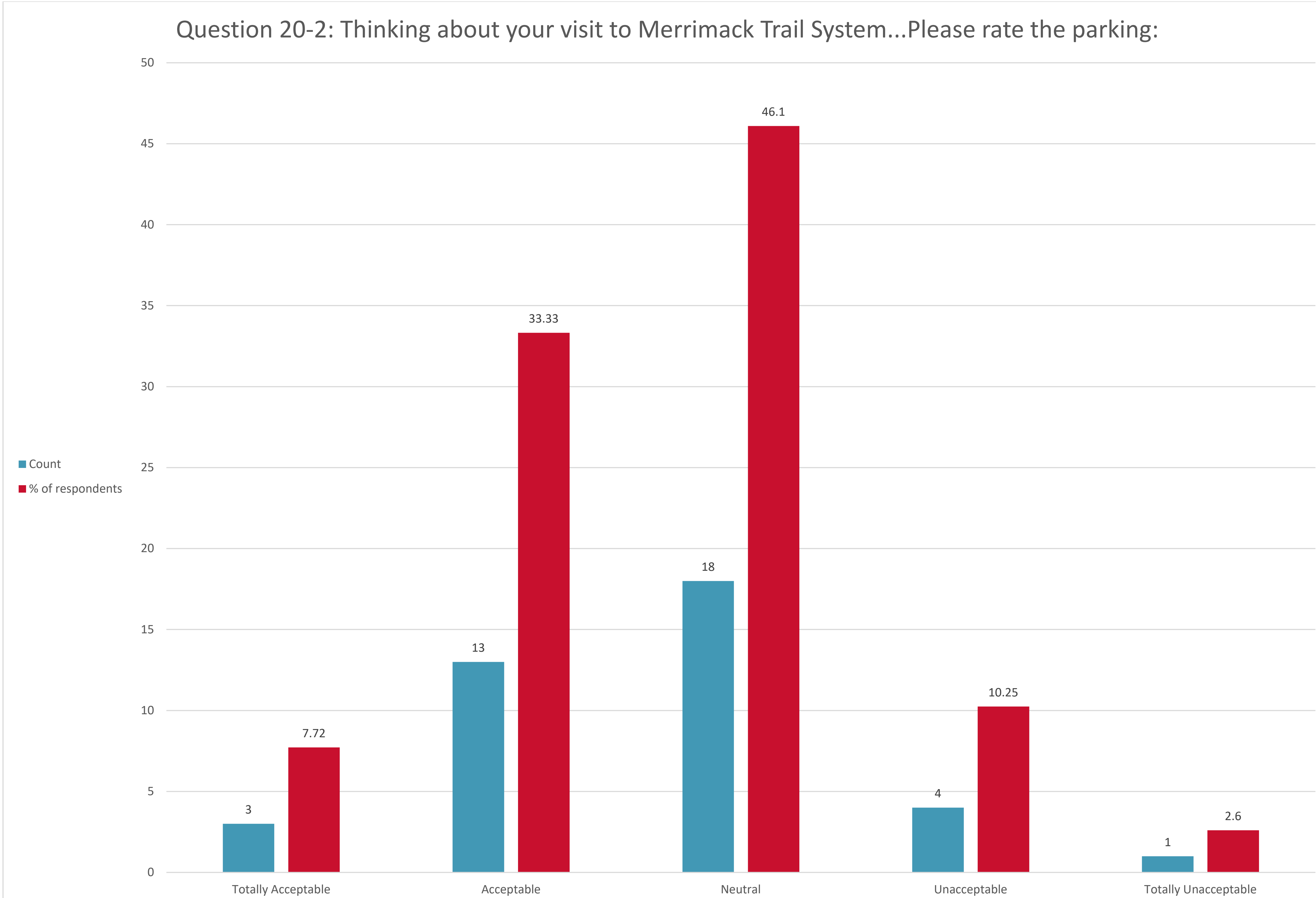

Question 19-6: Thinking about your visit to Lowell Heritage State Park...Please rate the available amenities:
50
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
5
9.83
12
23.52
22
43.13
10
19.6
2
3.92
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

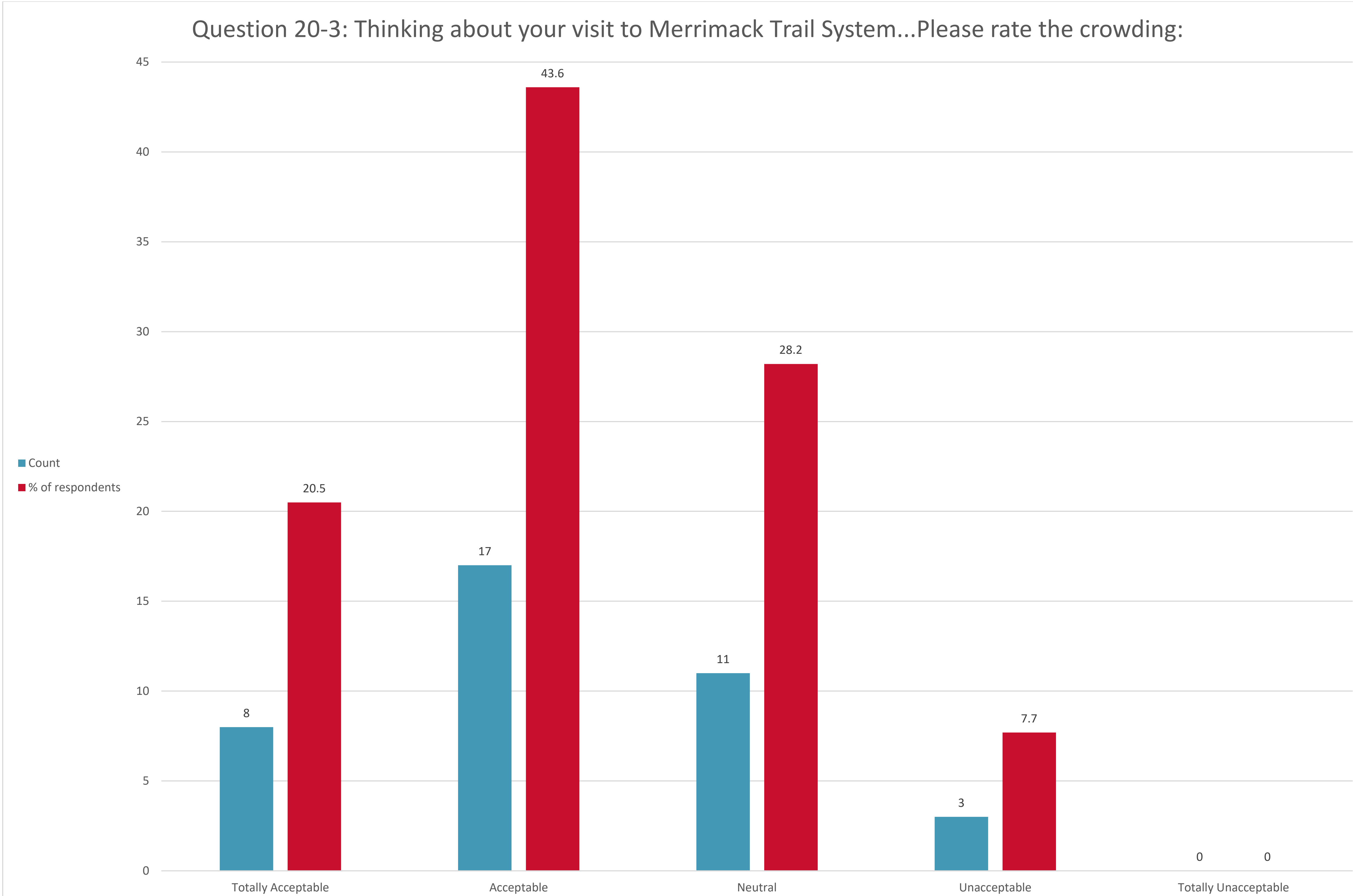

Question 19-7: Thinking about your visit to Lowell Heritage State Park...Please rate the river/canal flow:
50
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
4
7.5
17
32.1
25
47.2
3
5.6
4
7.6
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

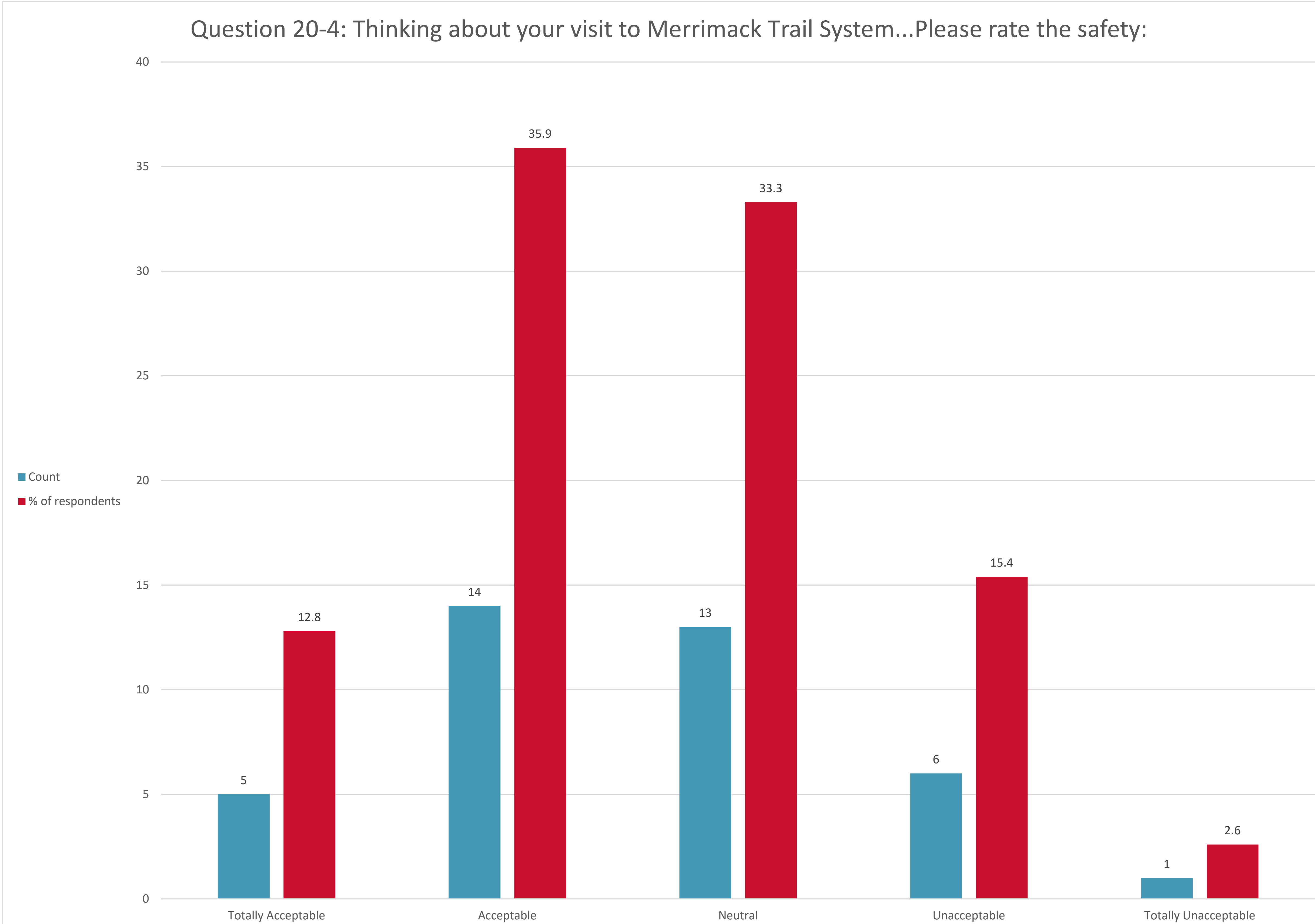

Question 19-8: Thinking about your visit to Lowell Heritage State Park...Please rate your overall experience:
70
60
50
40
30
20
10
0
Count
% of respondents
7
13.5
32
61.5
7
13.5
5
9.6
1
1.9
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

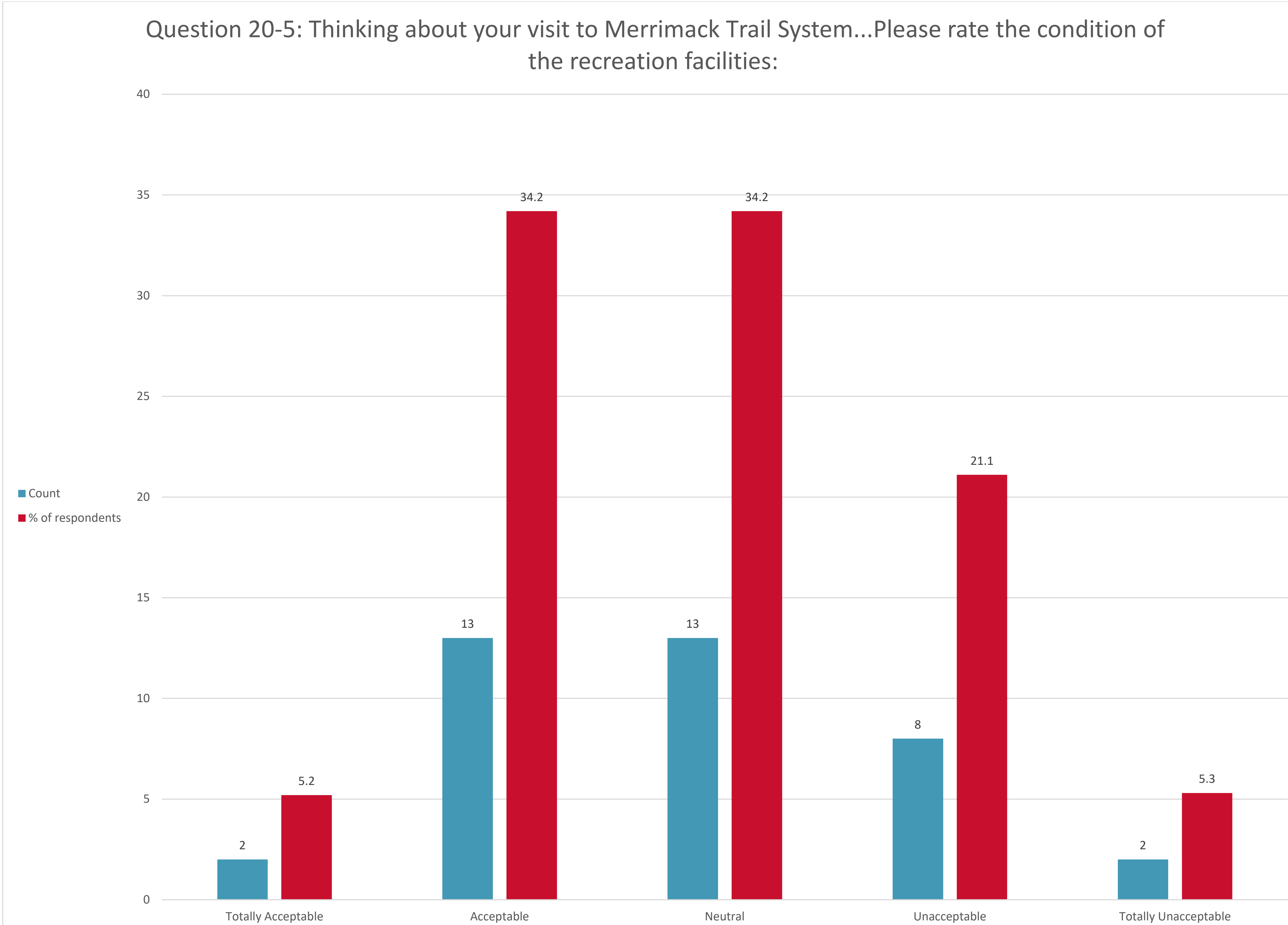


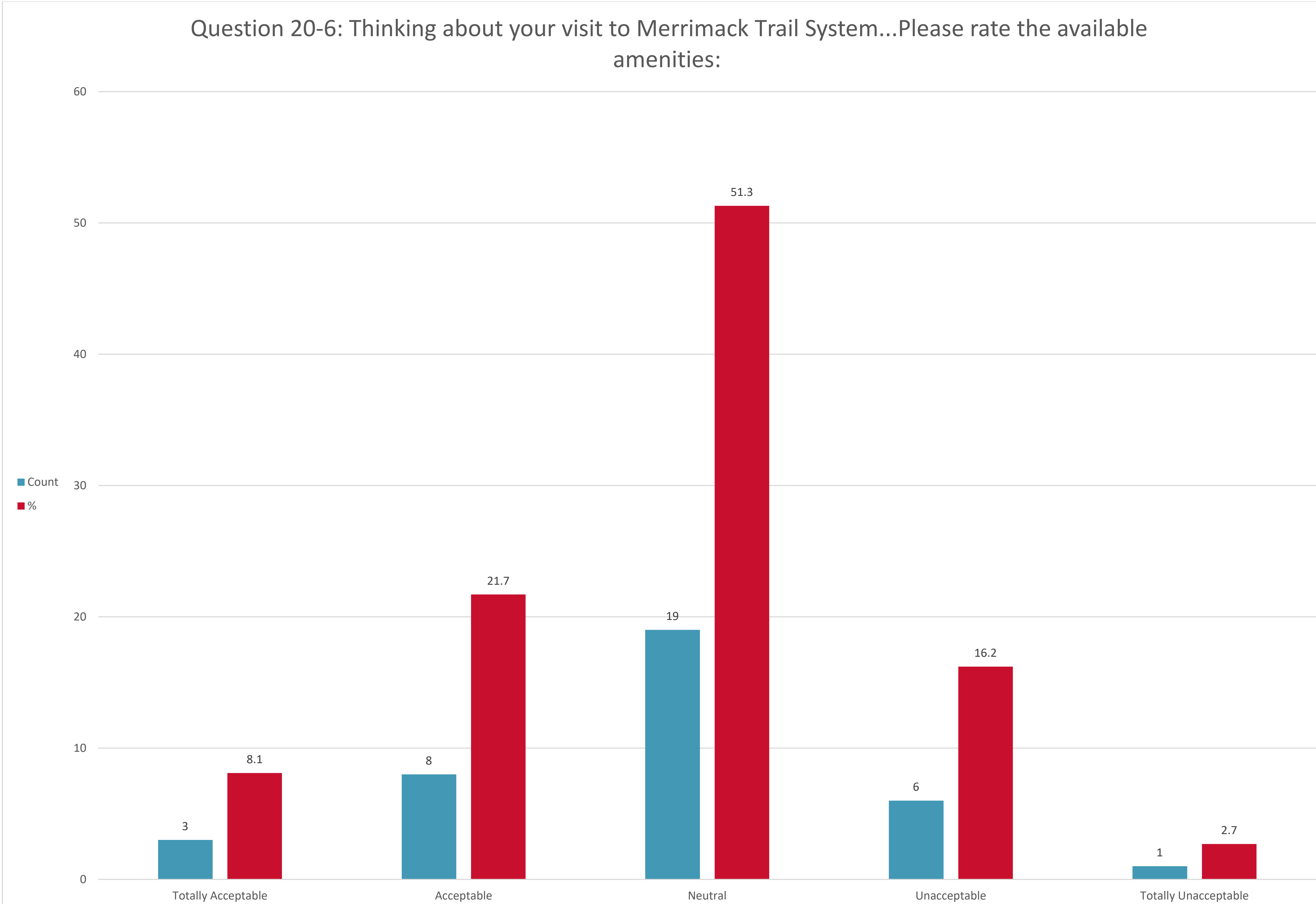
Question 20-1: Thinking about your visit to the Merrimack Trail System...Please rate the accessibility:
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
42.105
16
13.16
5
21.0525
8
21.0525
8
2.63
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 20-2: Thinking about your visit to Merrimack Trail System...Please rate the parking:
Count
% of respondents
0
5
10
15
20
25
30
35
40
45
50
3
7.72
13
33.33
18
46.1
4
10.25
1
2.6
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

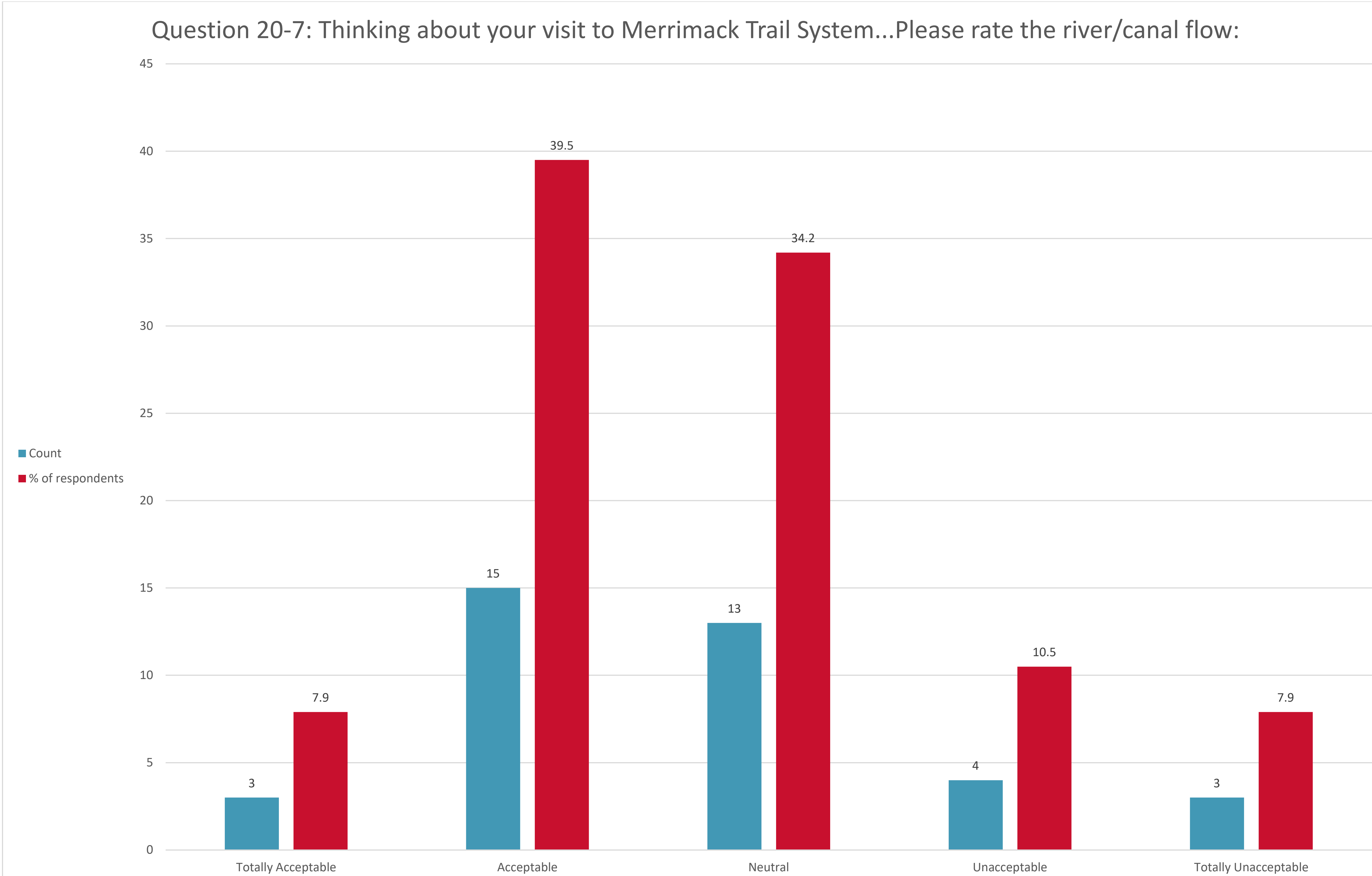

Question 20-3: Thinking about your visit to Merrimack Trail System...Please rate the crowding:
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
8
20.5
17
43.6
11
28.2
3
7.7
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

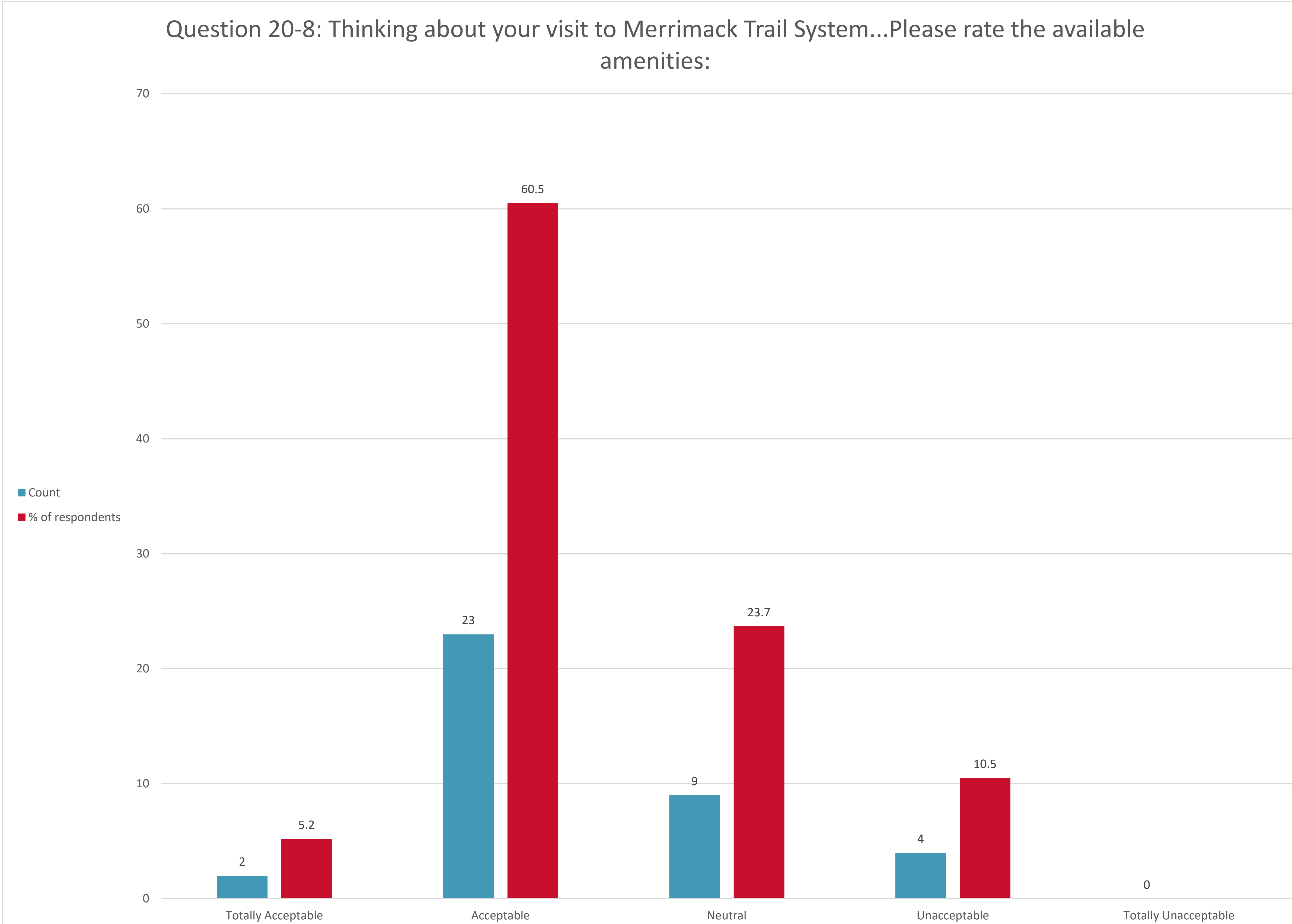

Question 20-4: Thinking about your visit to Merrimack Trail System...Please rate the safety:
40
35
30
25
20
15
10
5
0
Count
% of respondents
35.9
33.3
12.8
14
13
15.4
5
6
2.6
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 20-5: Thinking about your visit to Merrimack Trail System...Please rate the condition of the recreation facilities:
Count
% of respondents
40
35
30
25
20
15
10
5
0
2
5.2
13
34.2
13
34.2
8
21.1
2
5.3
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

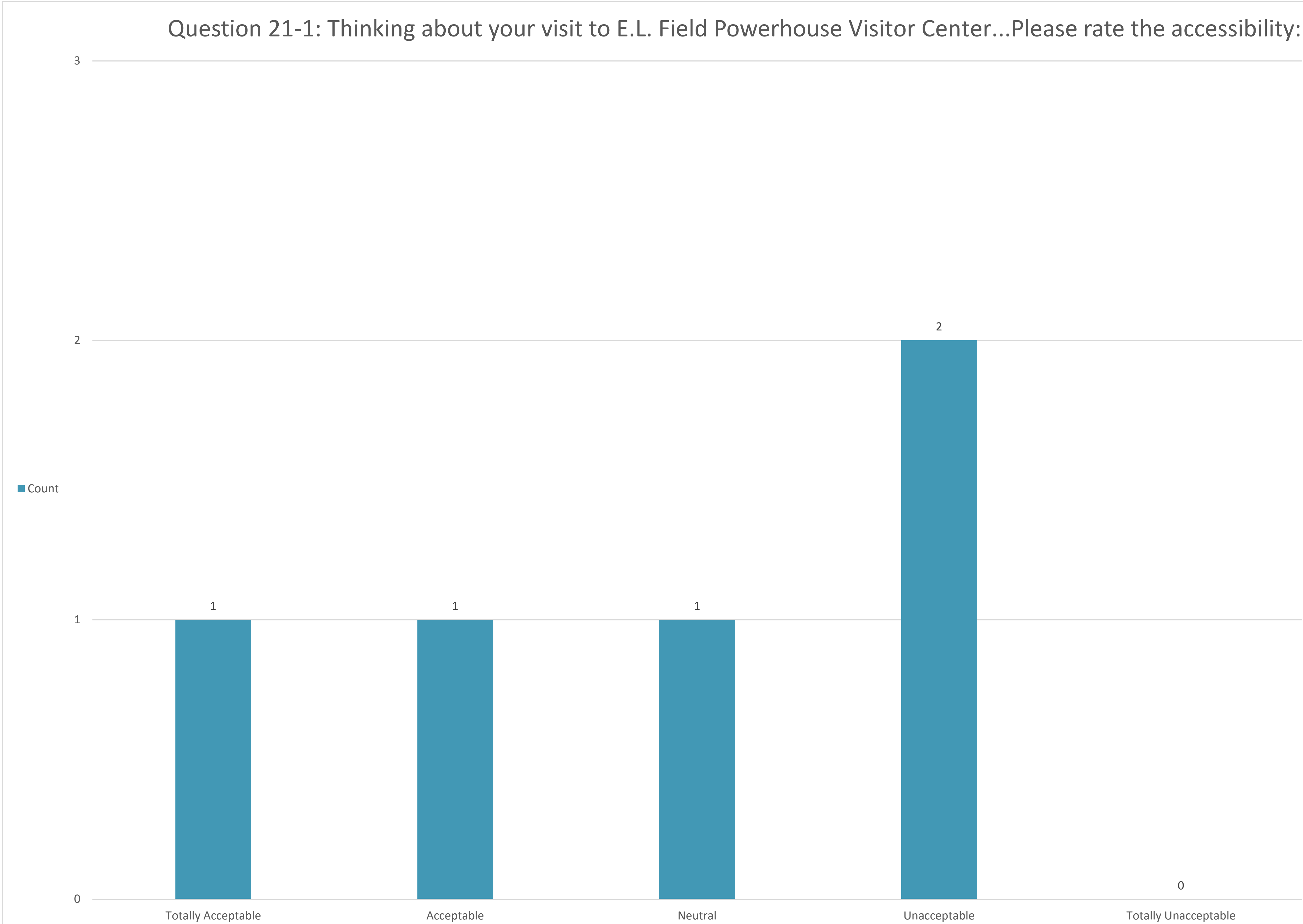


Question 20-6: Thinking about your visit to Merrimack Trail System...Please rate the available amenities:
60
50
40
30
20
10
0
Count
%
51.3
21.7
19
16.2
8.1
8
6
3
2.7
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

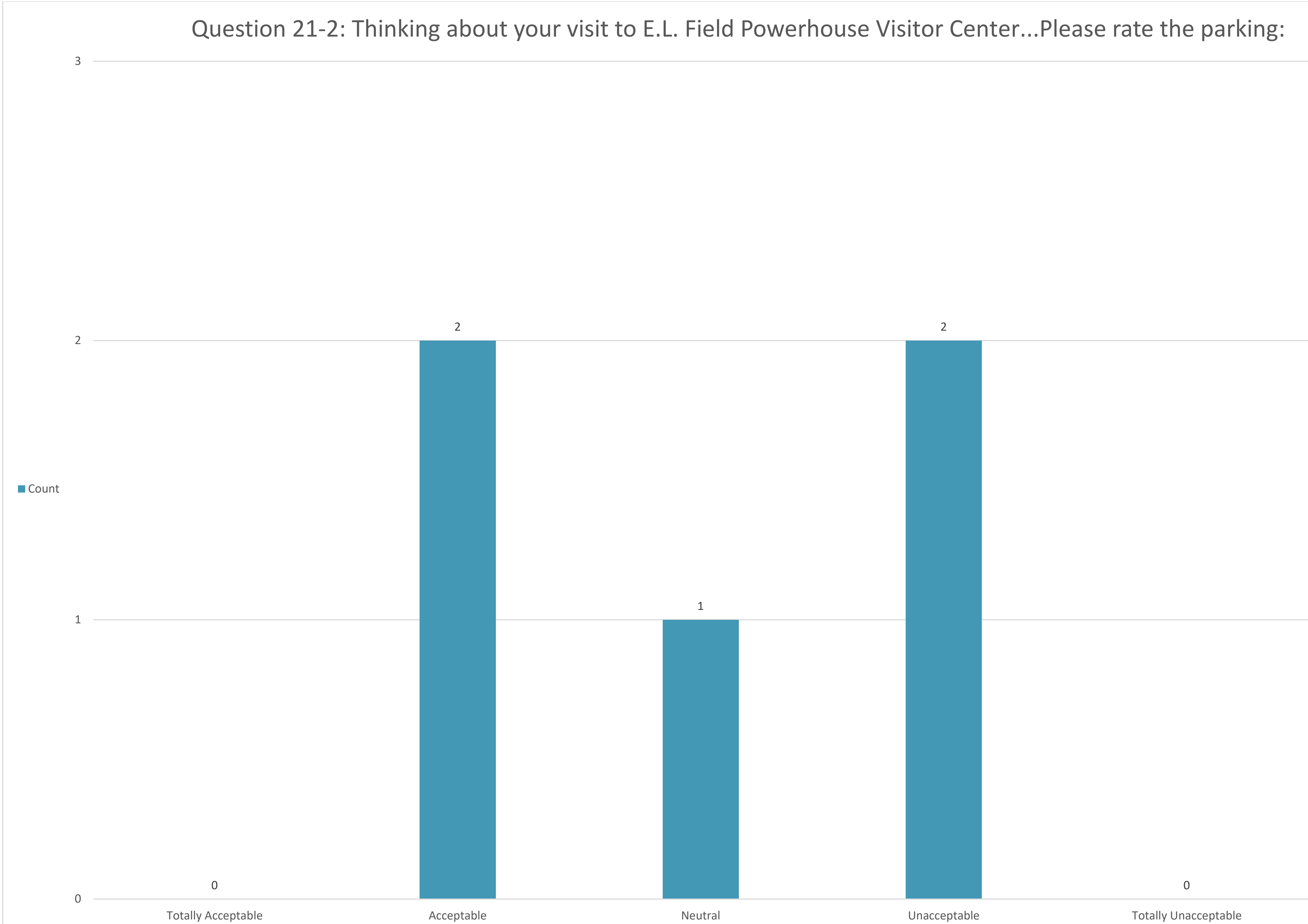

Question 20-7: Thinking about your visit to Merrimack Trail System...Please rate the river/canal flow:
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
3
7.9
15
39.5
13
34.2
4
10.5
3
7.9
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

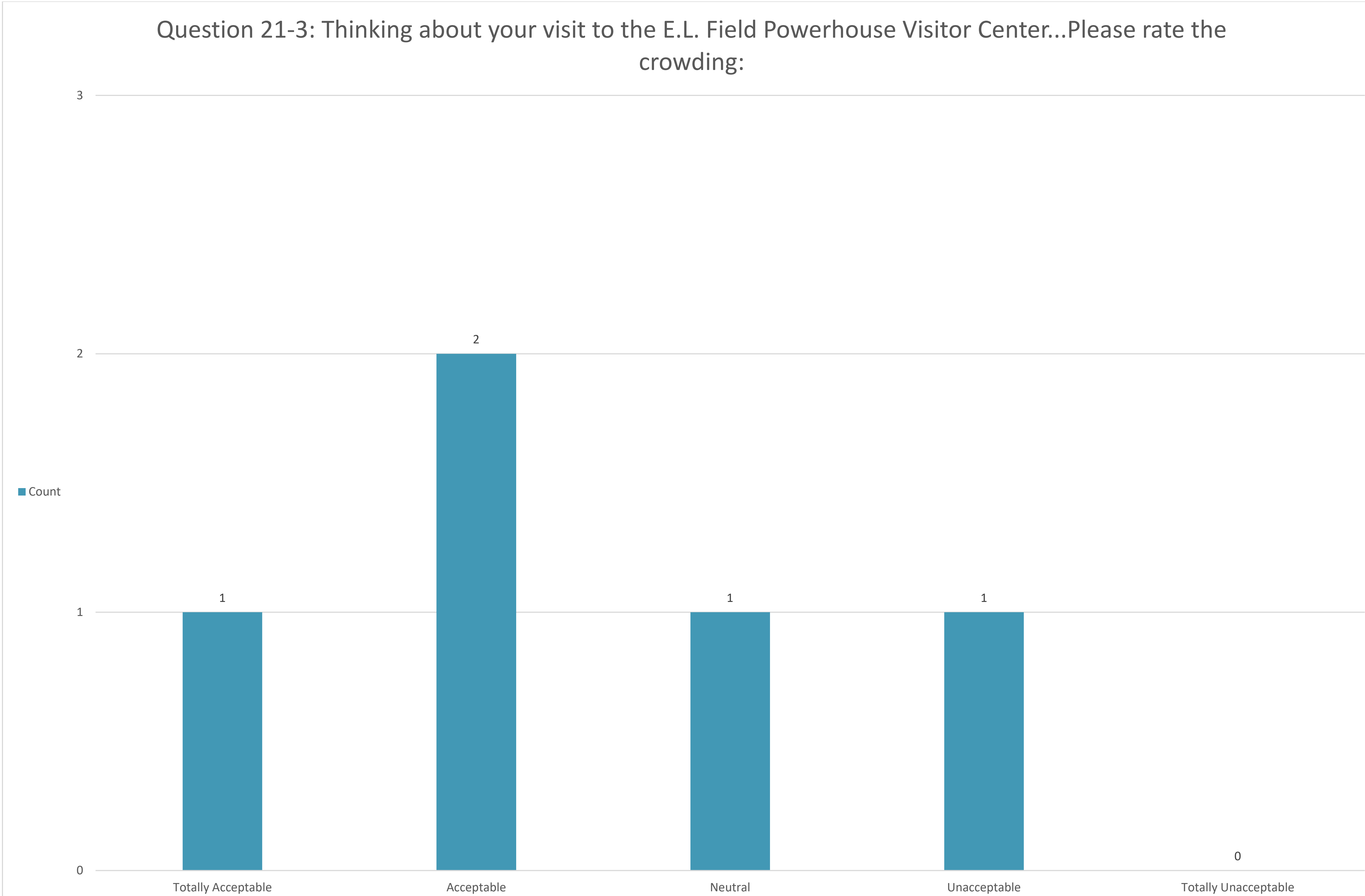


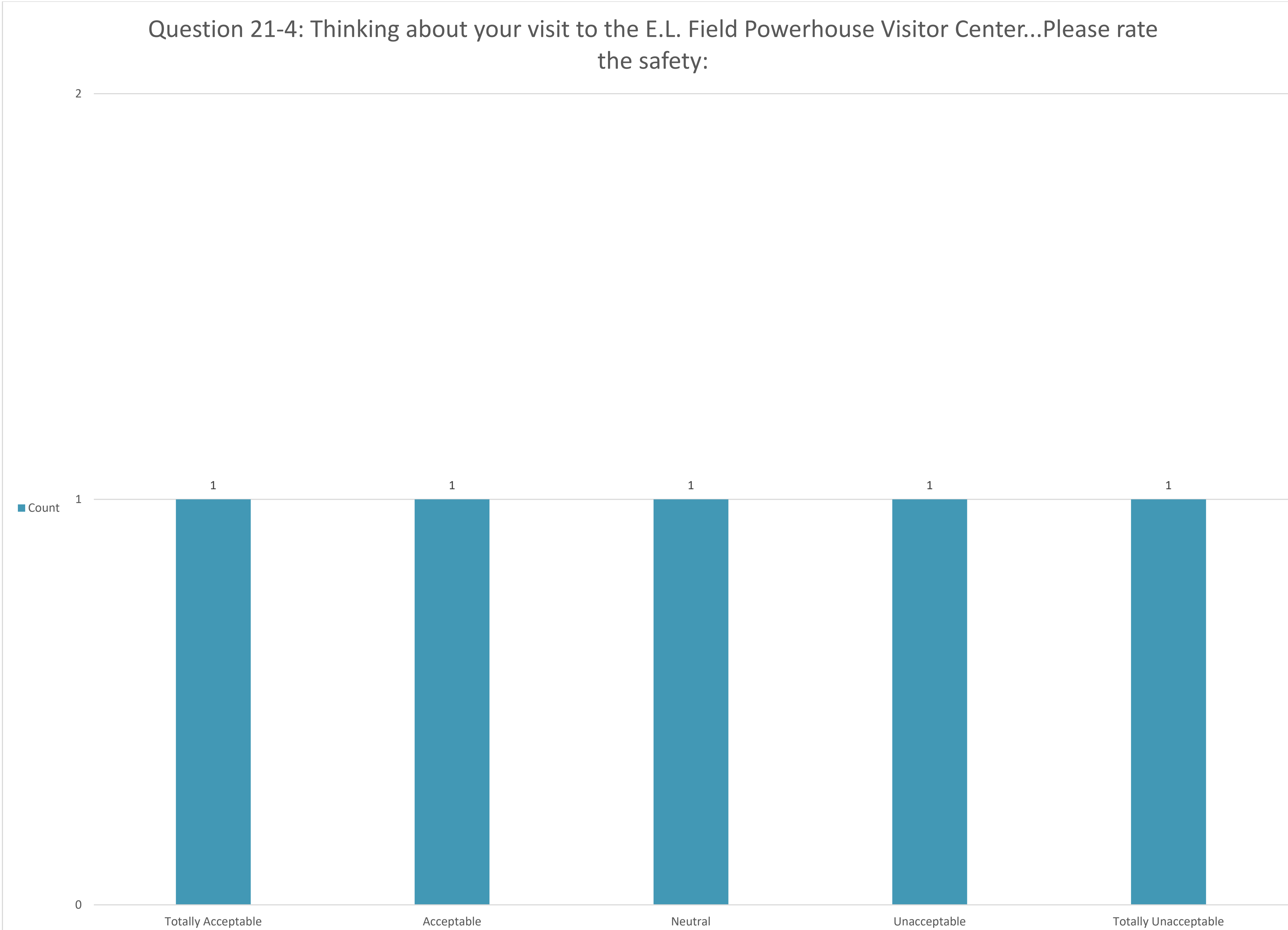
Question 20-8: Thinking about your visit to Merrimack Trail System...Please rate the available amenities:
70
60
50
40
30
20
10
0
Count
% of respondents
60.5
23
23.7
9
10.5
2
5.2
4
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

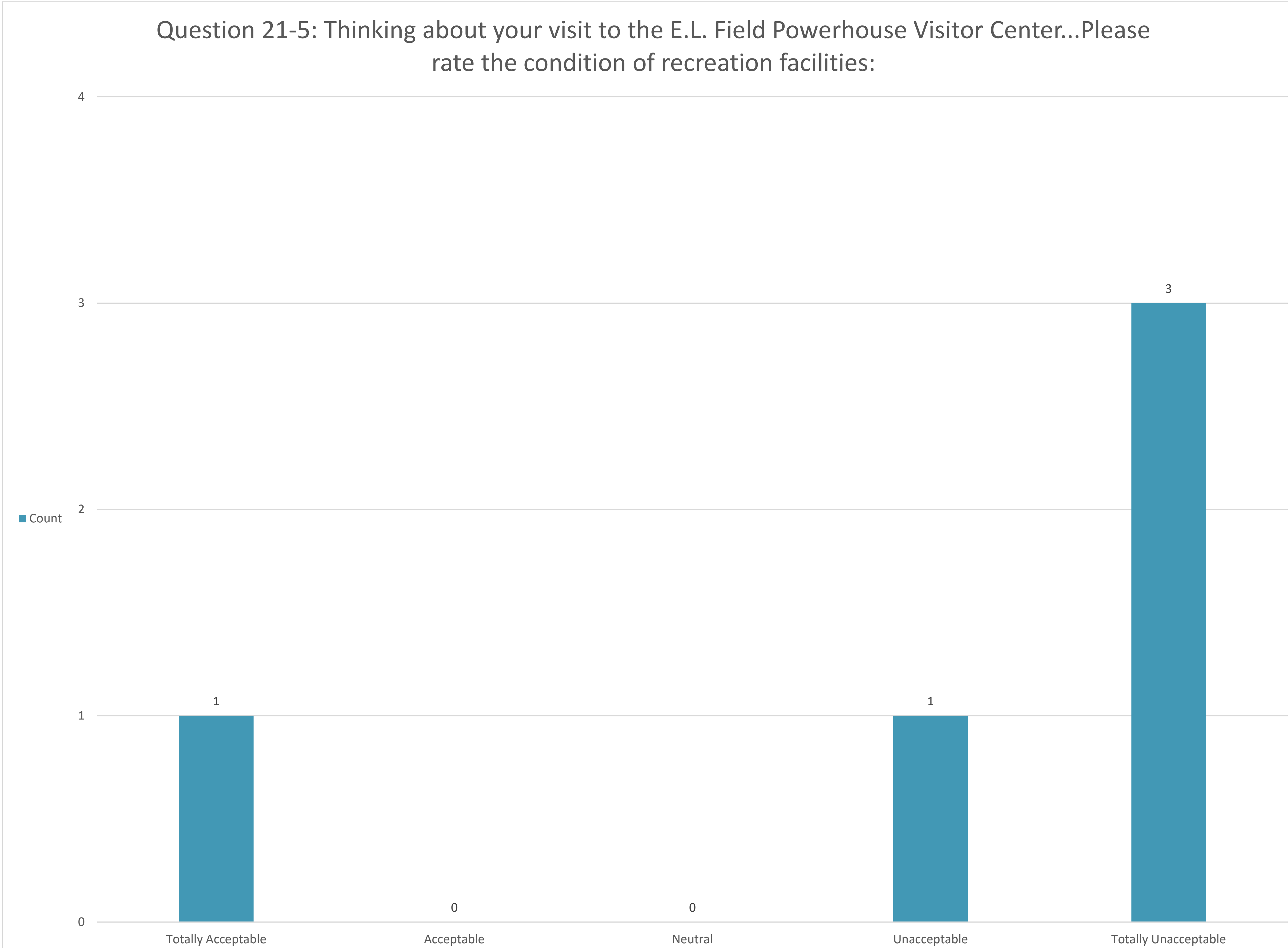


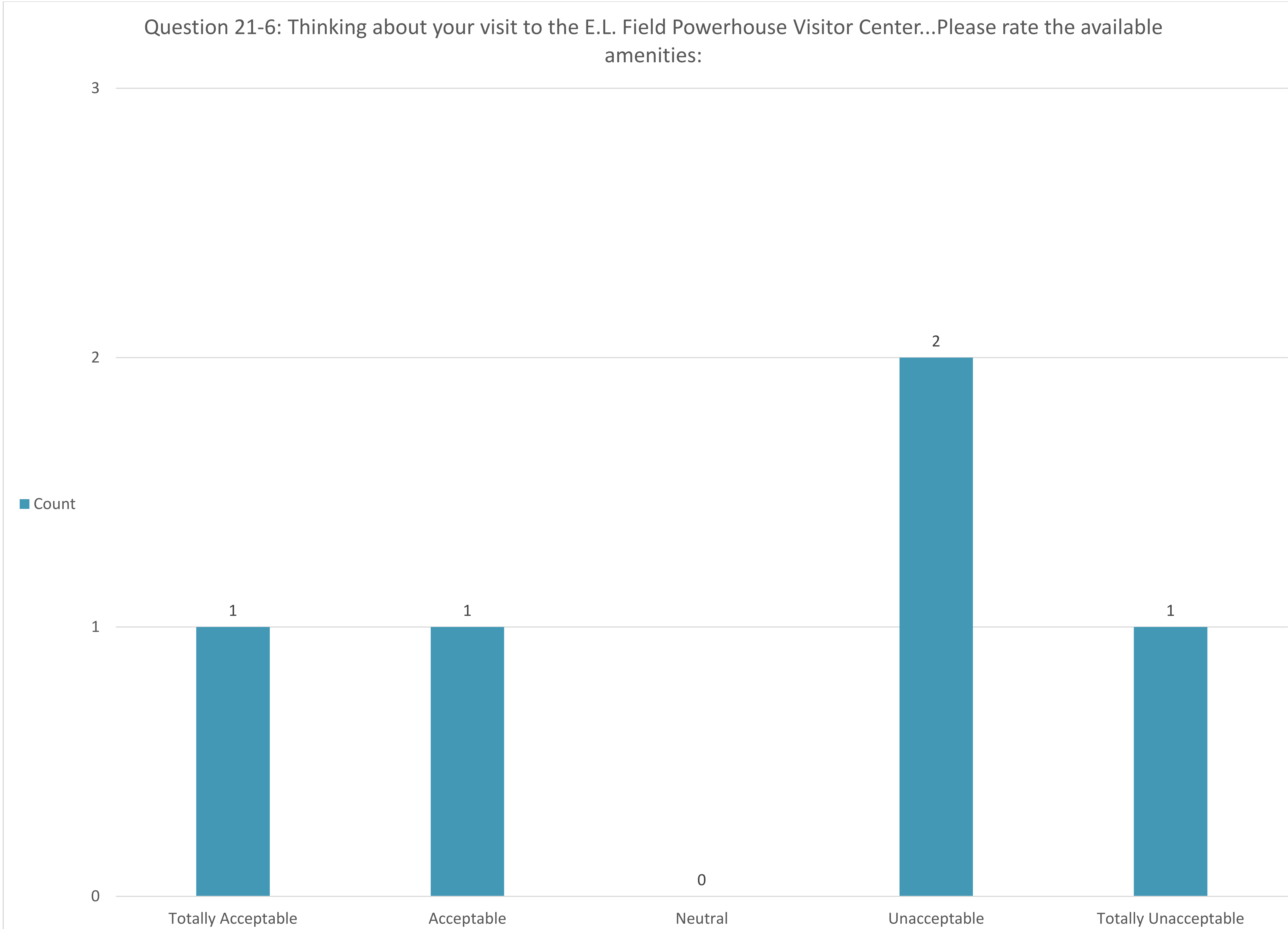
Question 21-1: Thinking about your visit to E.L. Field Powerhouse Visitor Center...Please rate the accessibility:
3
2
1
0
Count
1
1
1
2
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

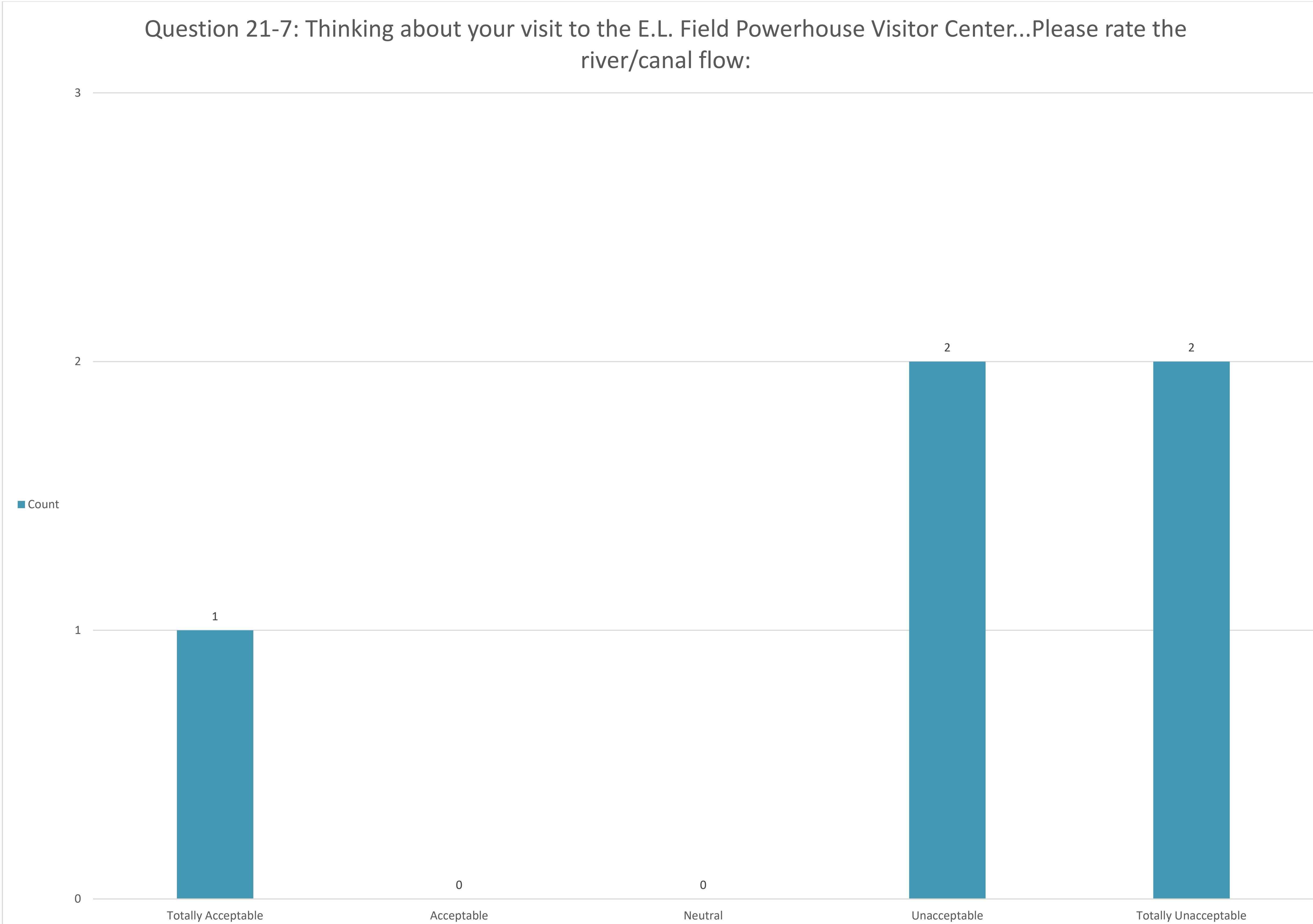

Question 21-2: Thinking about your visit to E.L. Field Powerhouse Visitor Center...Please rate the parking:
3
2
1
0
Count
0
2
1
2
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

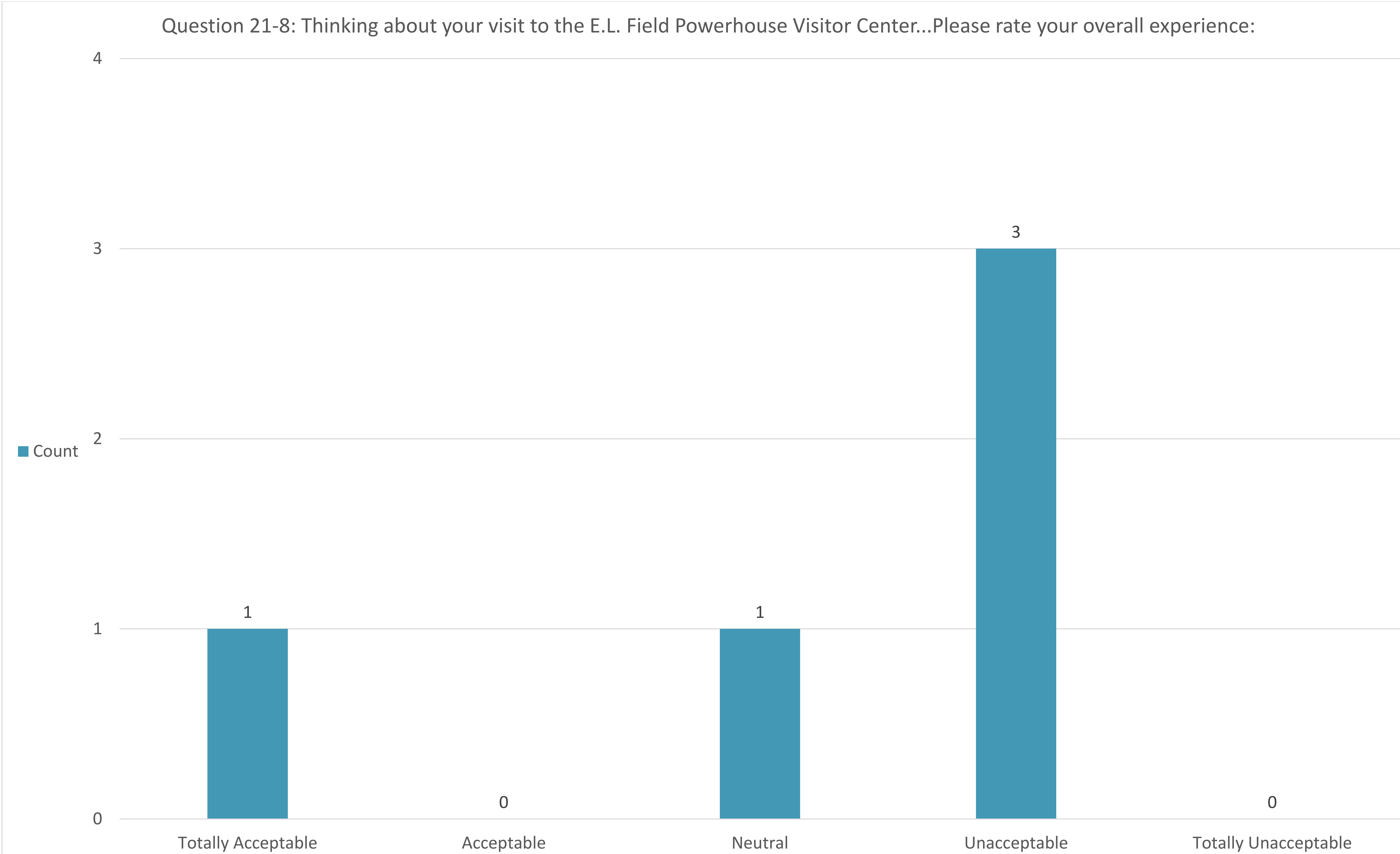

Question 21-3: Thinking about your visit to the E.L. Field Powerhouse Visitor Center...Please rate the crowding:
3
2
1
0
Count
1
2
1
1
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 21-4: Thinking about your visit to the E.L. Field Powerhouse Visitor Center...Please rate the safety:
2
1
0
Count
1
1
1
1
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

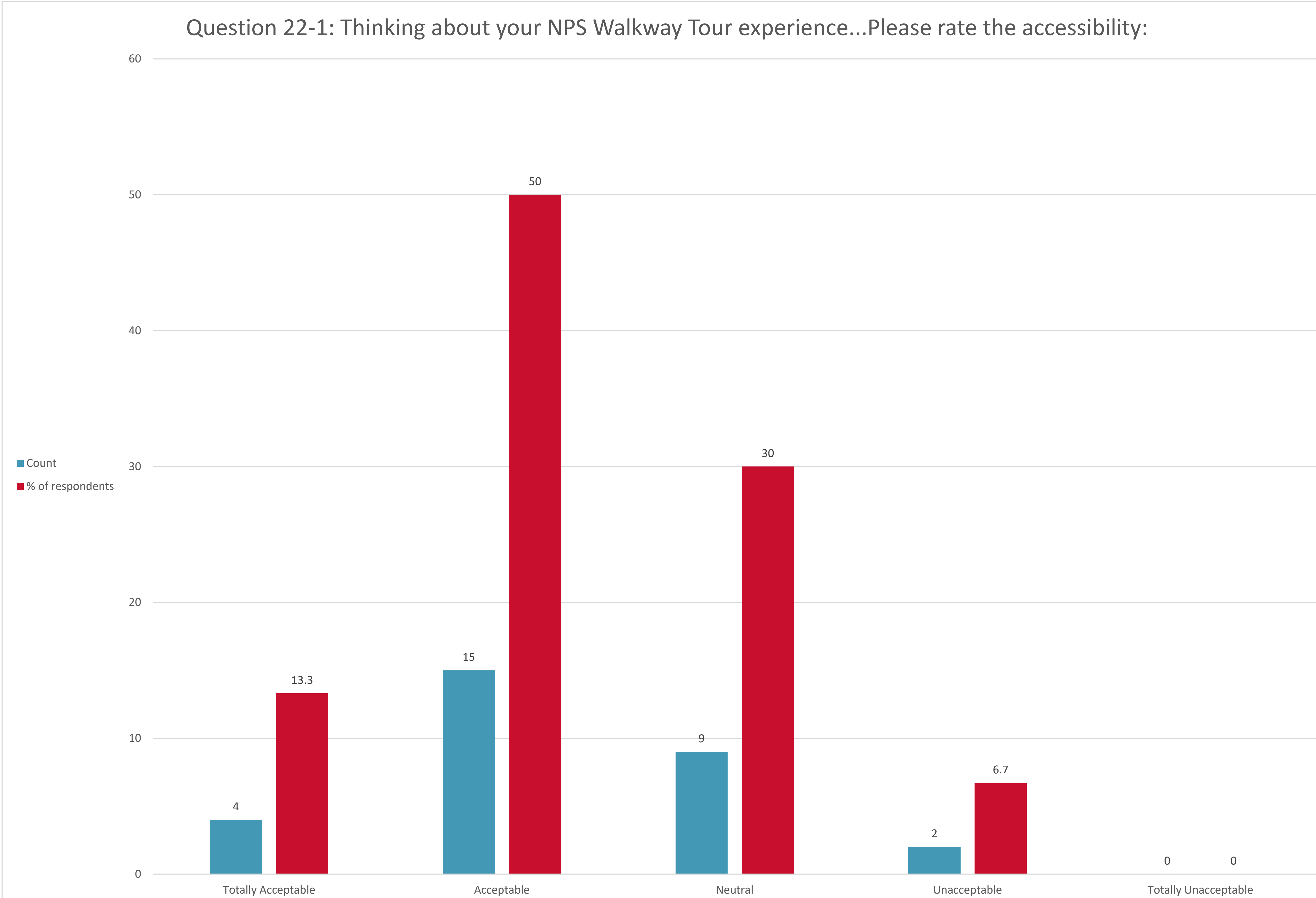

Question 21-5: Thinking about your visit to the E.L. Field Powerhouse Visitor Center...Please rate the condition of recreation facilities:
Count
0
1
2
3
4
1
0
0
1
3
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

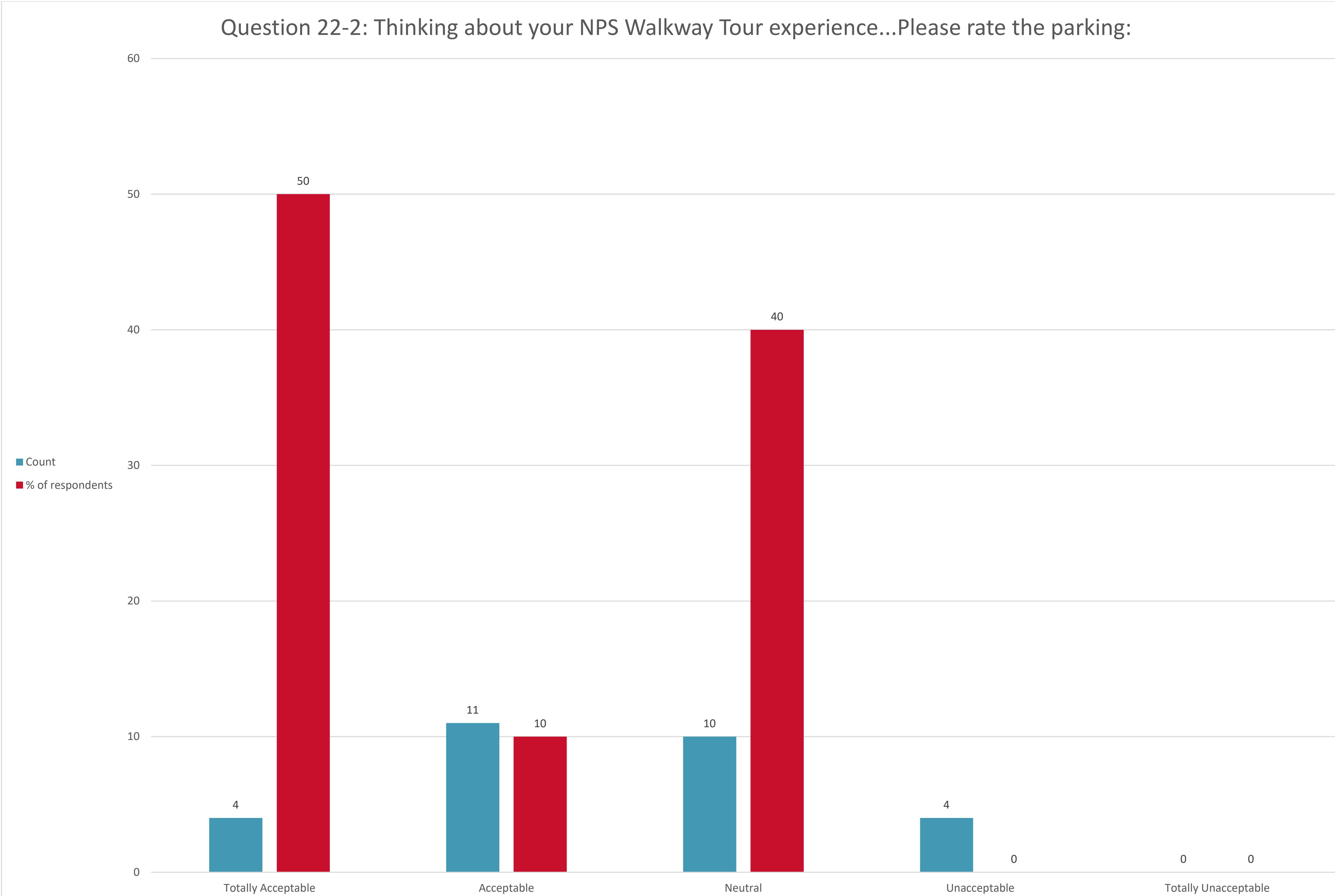

Question 21-6: Thinking about your visit to the E.L. Field Powerhouse Visitor Center...Please rate the available amenities:
Count
3
2
1
0
1
1
0
2
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

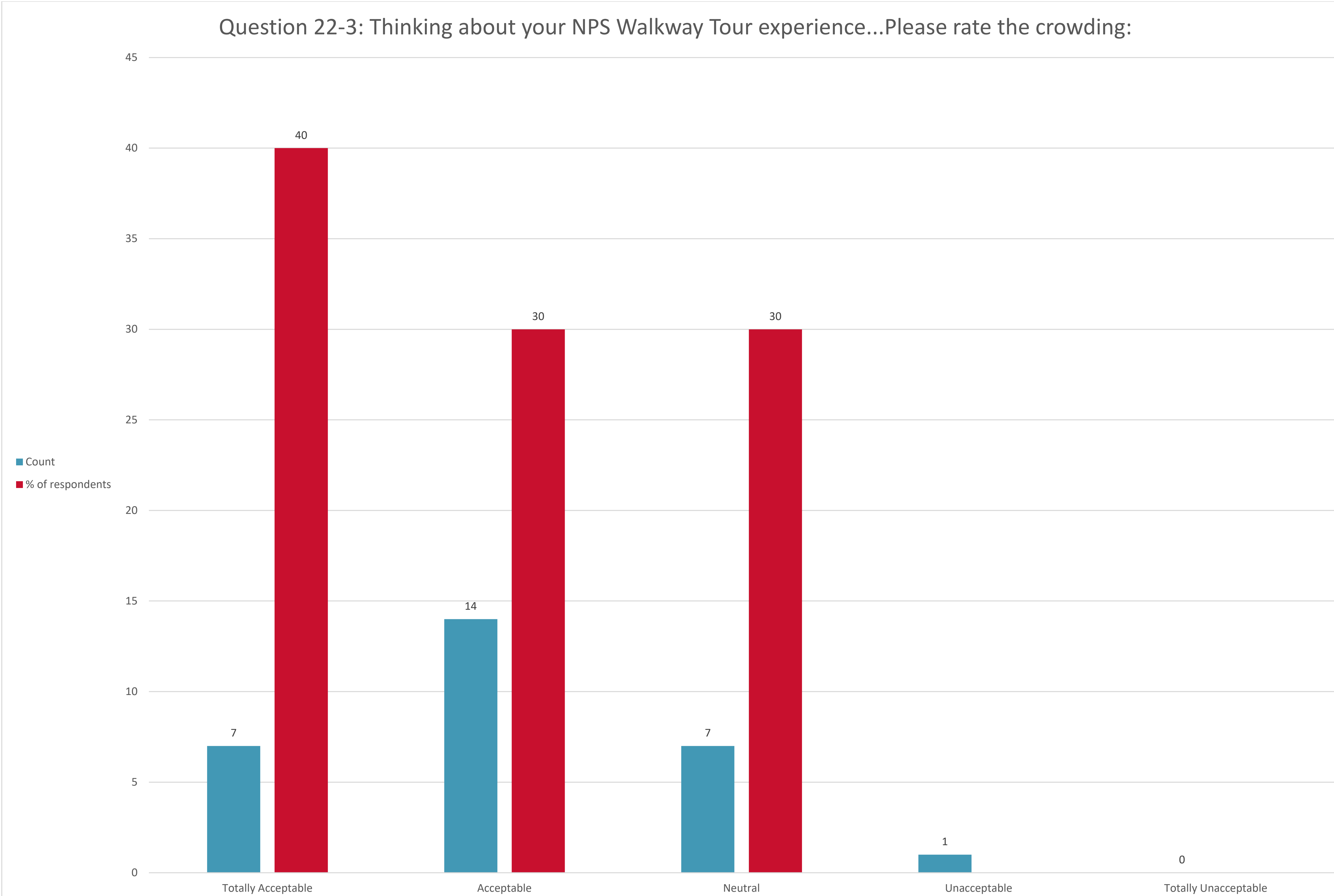

Question 21-7: Thinking about your visit to the E.L. Field Powerhouse Visitor Center...Please rate the river/canal flow:
3
2
1
0
Count
1
0
0
2
2
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable



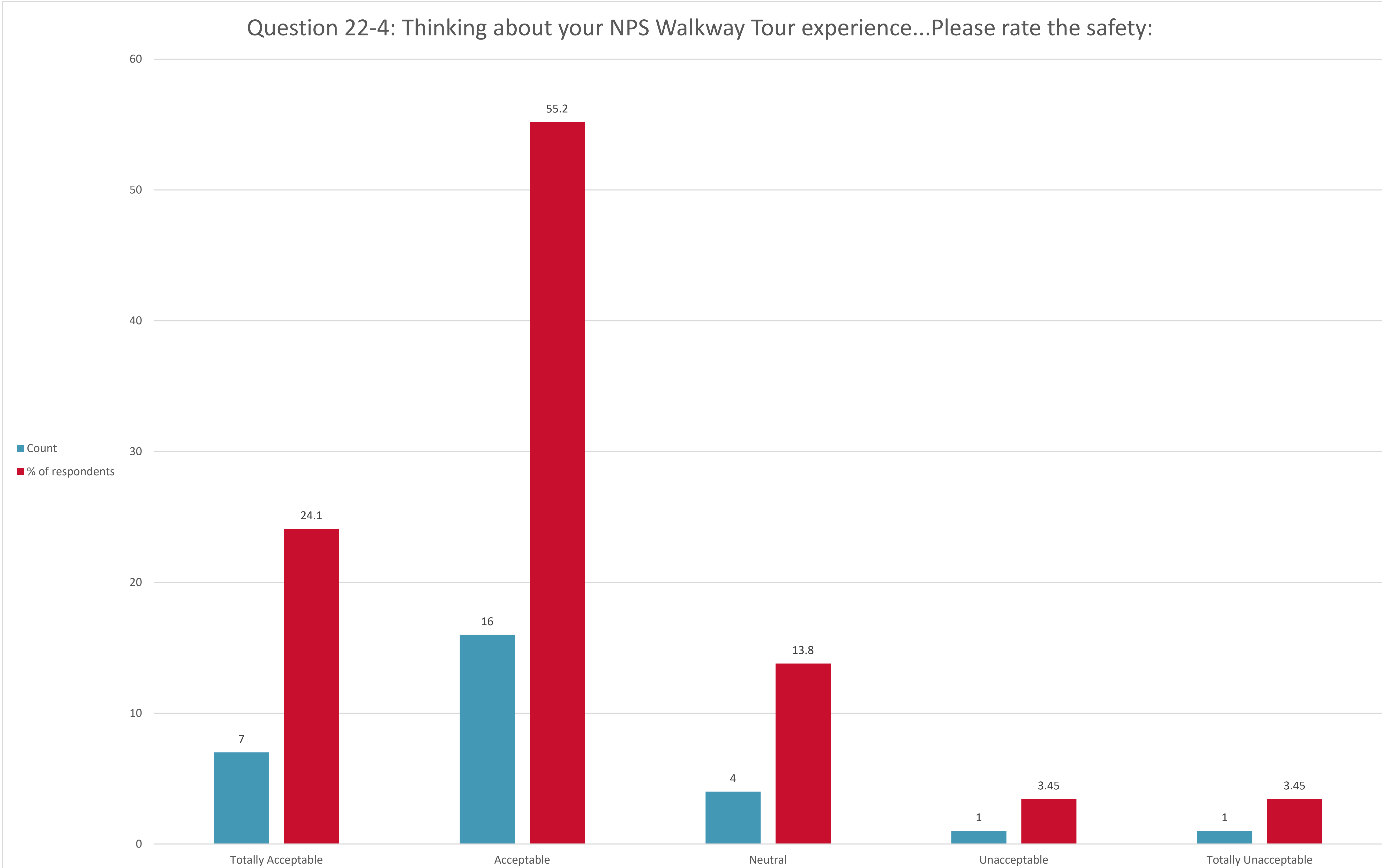
Question 21-8: Thinking about your visit to the E.L. Field Powerhouse Visitor Center...Please rate your overall experience:
Count
4
3
2
1
0
1
0
1
3
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 22-1: Thinking about your NPS Walkway Tour experience...Please rate the accessibility:
60
50
40
30
20
10
0
Count
% of respondents
4
13.3
15
50
9
30
2
6.7
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 22-2: Thinking about your NPS Walkway Tour experience...Please rate the parking:
60
50
40
30
20
10
0
50
40
11
10
10
4
4
0
0
0
Count
% of respondents
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

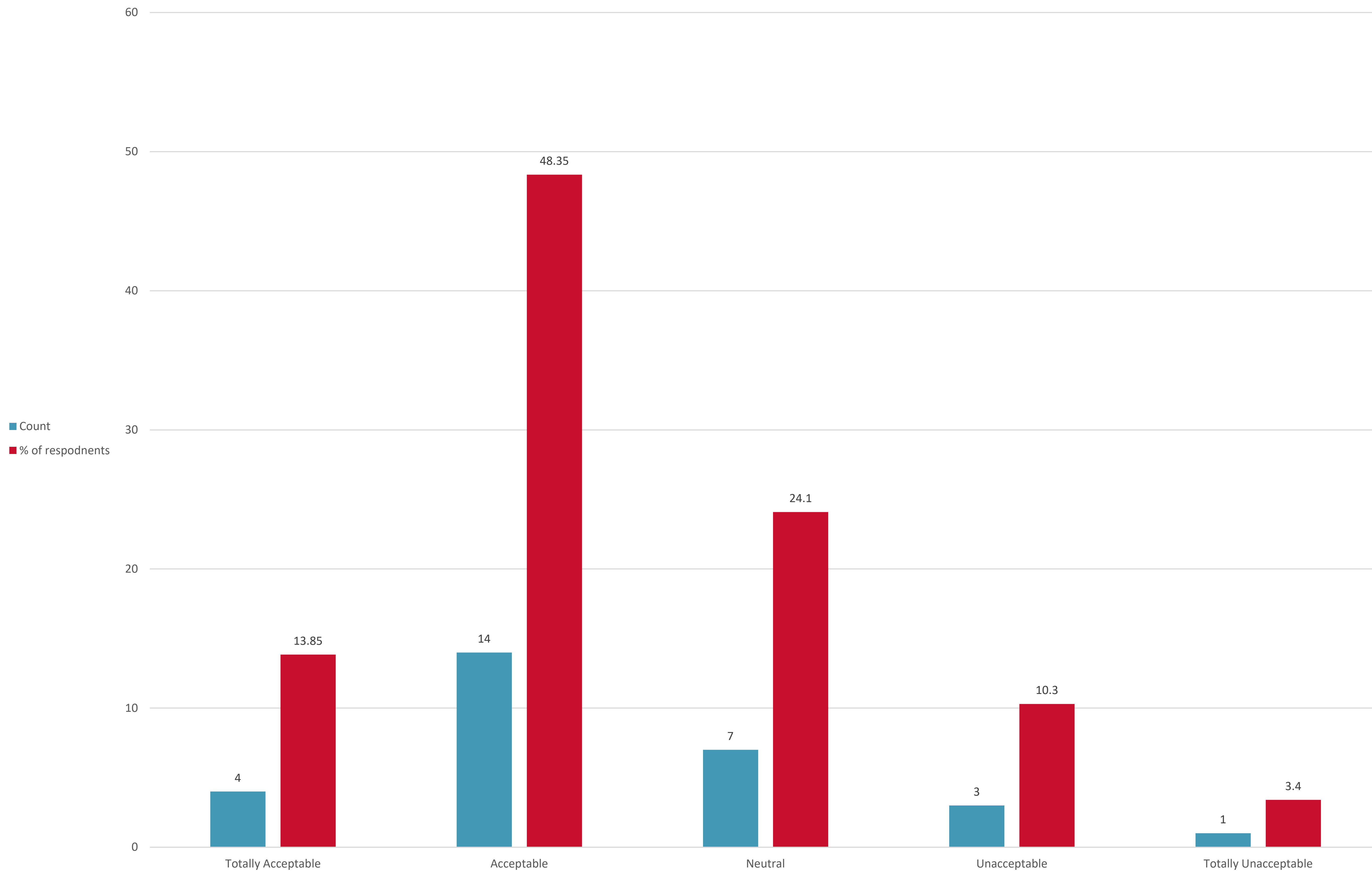


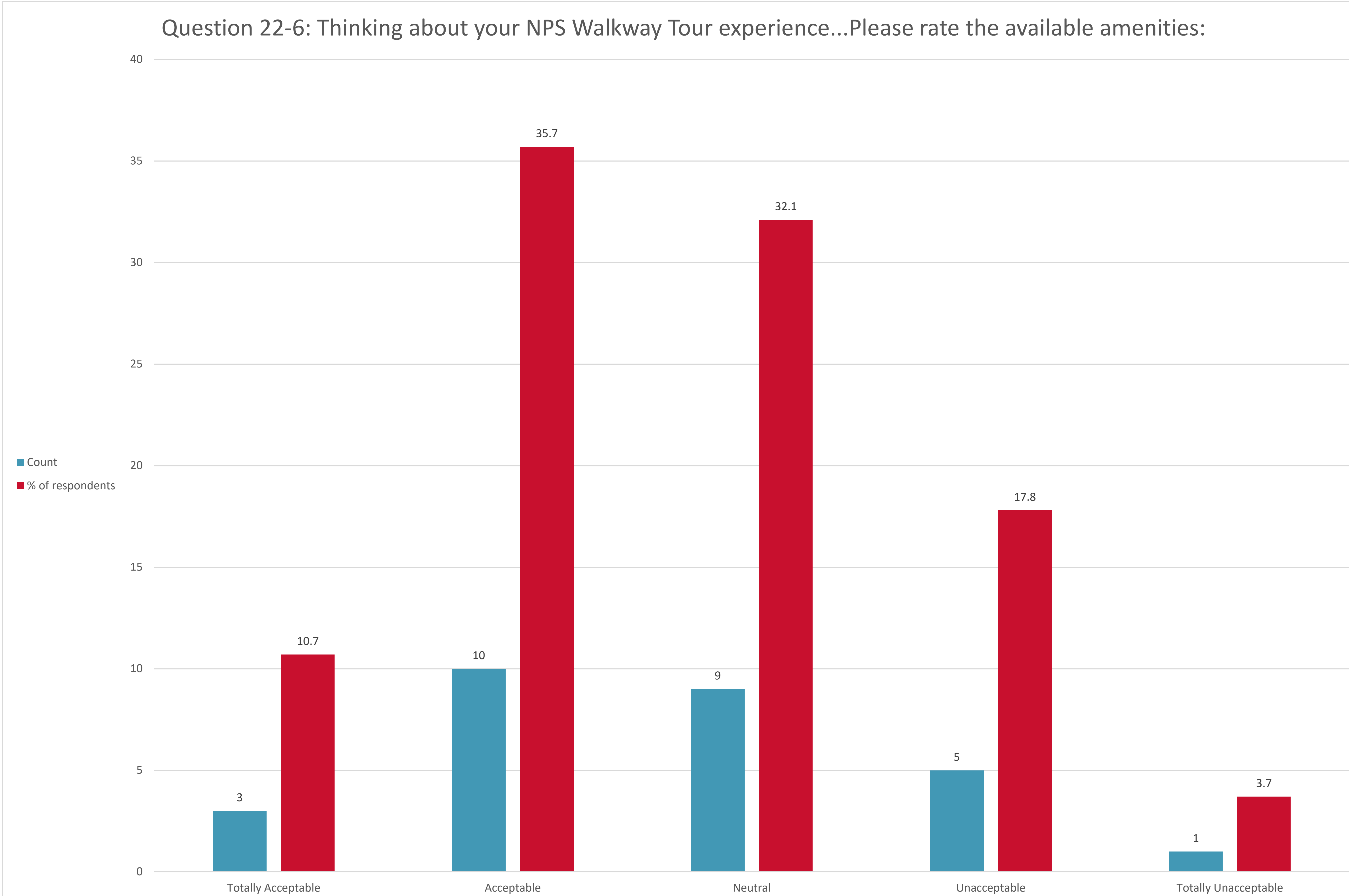
Question 22-3: Thinking about your NPS Walkway Tour experience...Please rate the crowding:
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
40
30
30
14
7
7
1
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

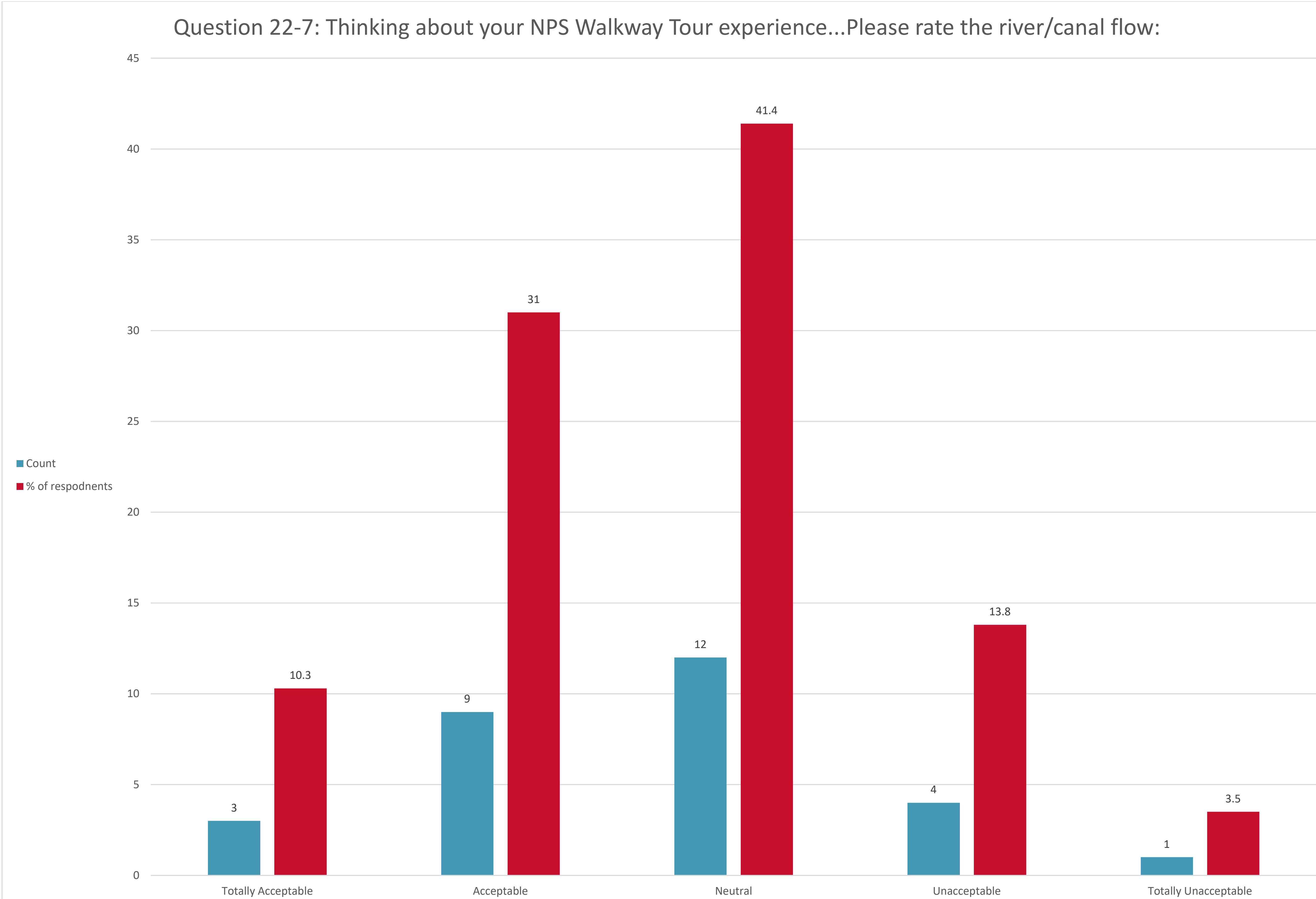


Question 22-4: Thinking about your NPS Walkway Tour experience...Please rate the safety:
60
50
40
30
20
10
0
Count
% of respondents
7
24.1
16
55.2
4
13.8
1
3.45
1
3.45
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

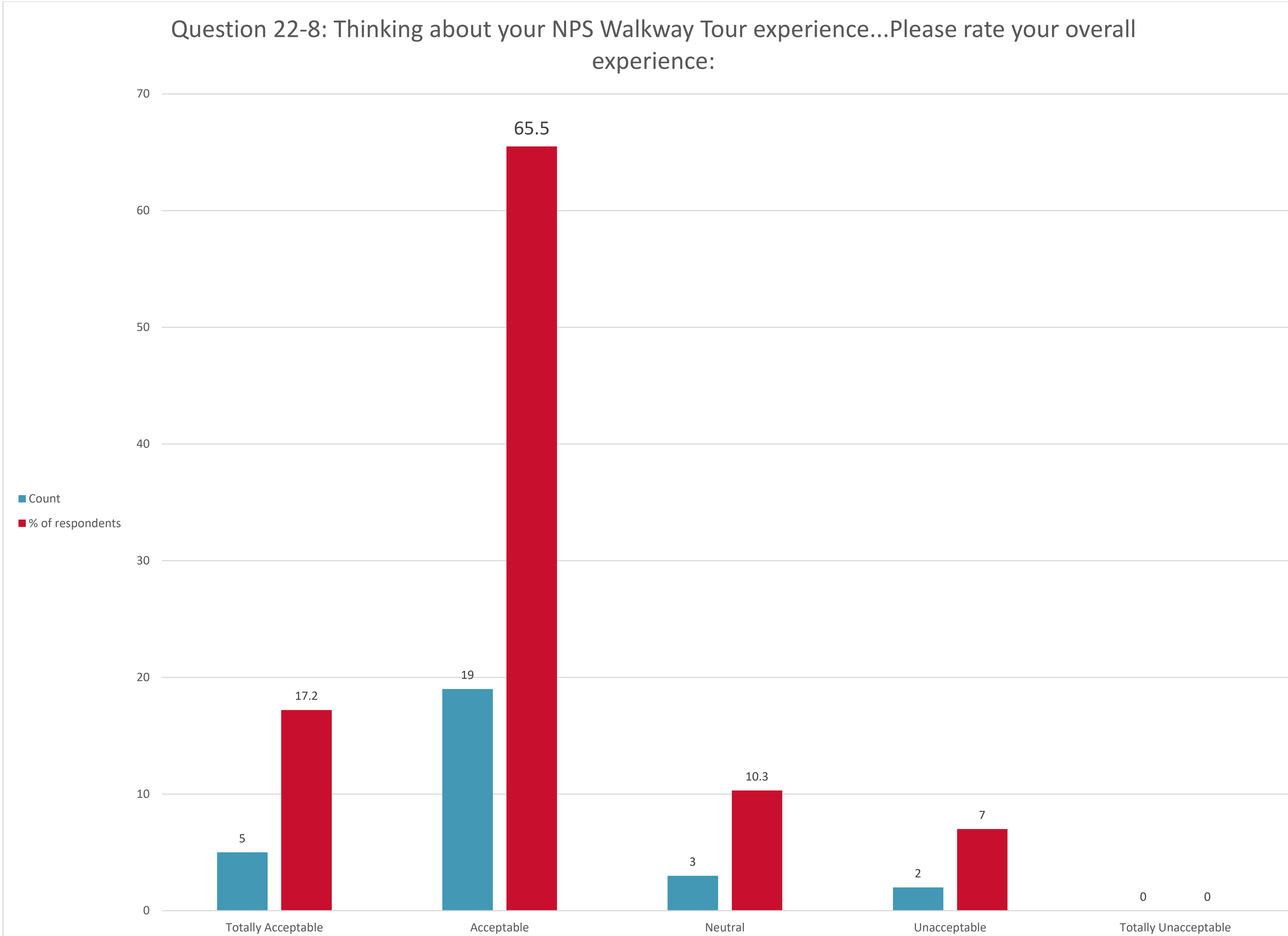
Question 22-5: Thinking about your NPS Walkway Tour experience...Please rate the condition of recreation facilites:

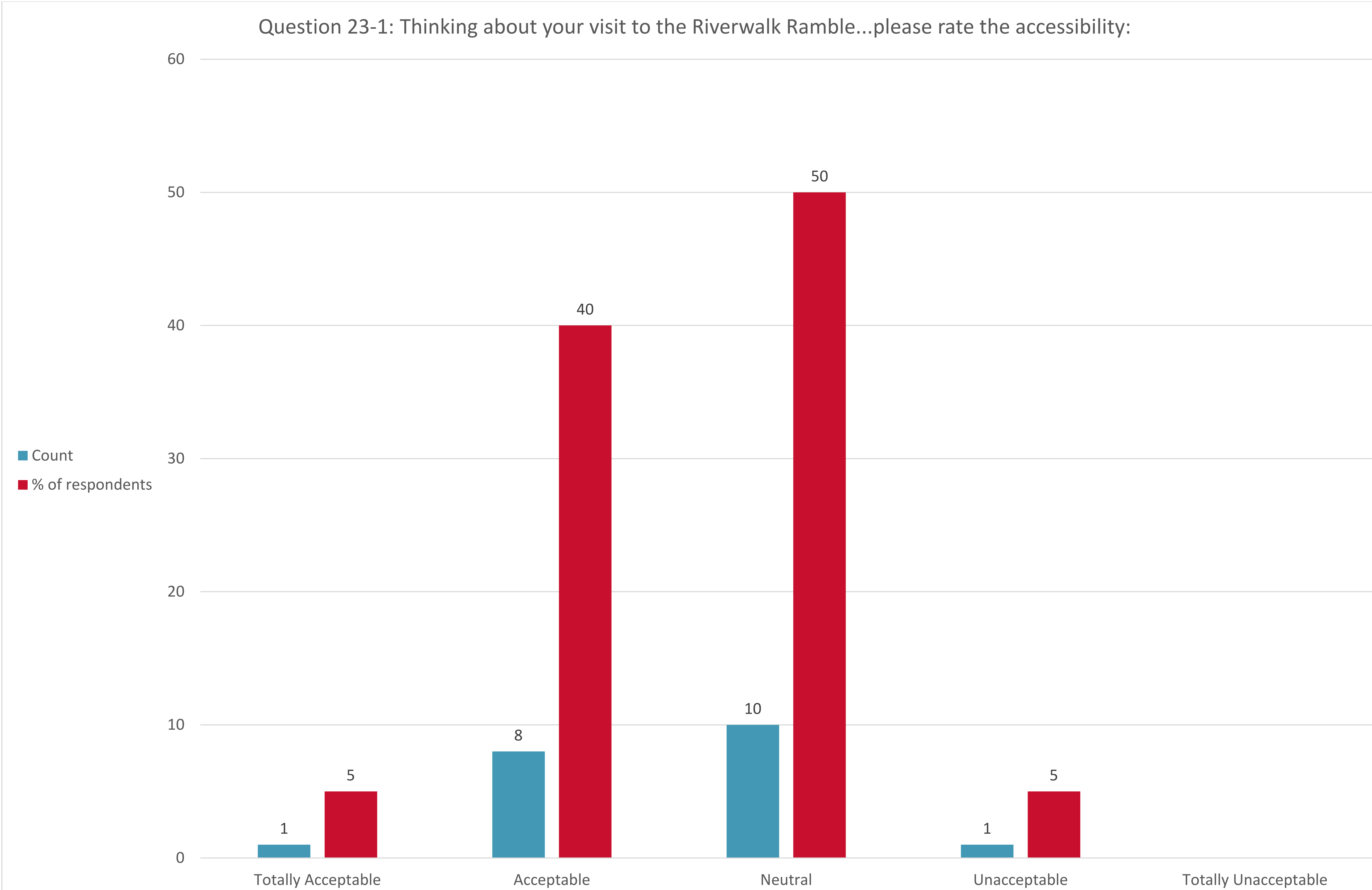



Question 22-6: Thinking about your NPS Walkway Tour experience...Please rate the available amenities:
40
35
30
25
20
15
10
5
0
Count
% of respondents
35.7
32.1
17.8
10.7
10
9
5
3
3.7
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

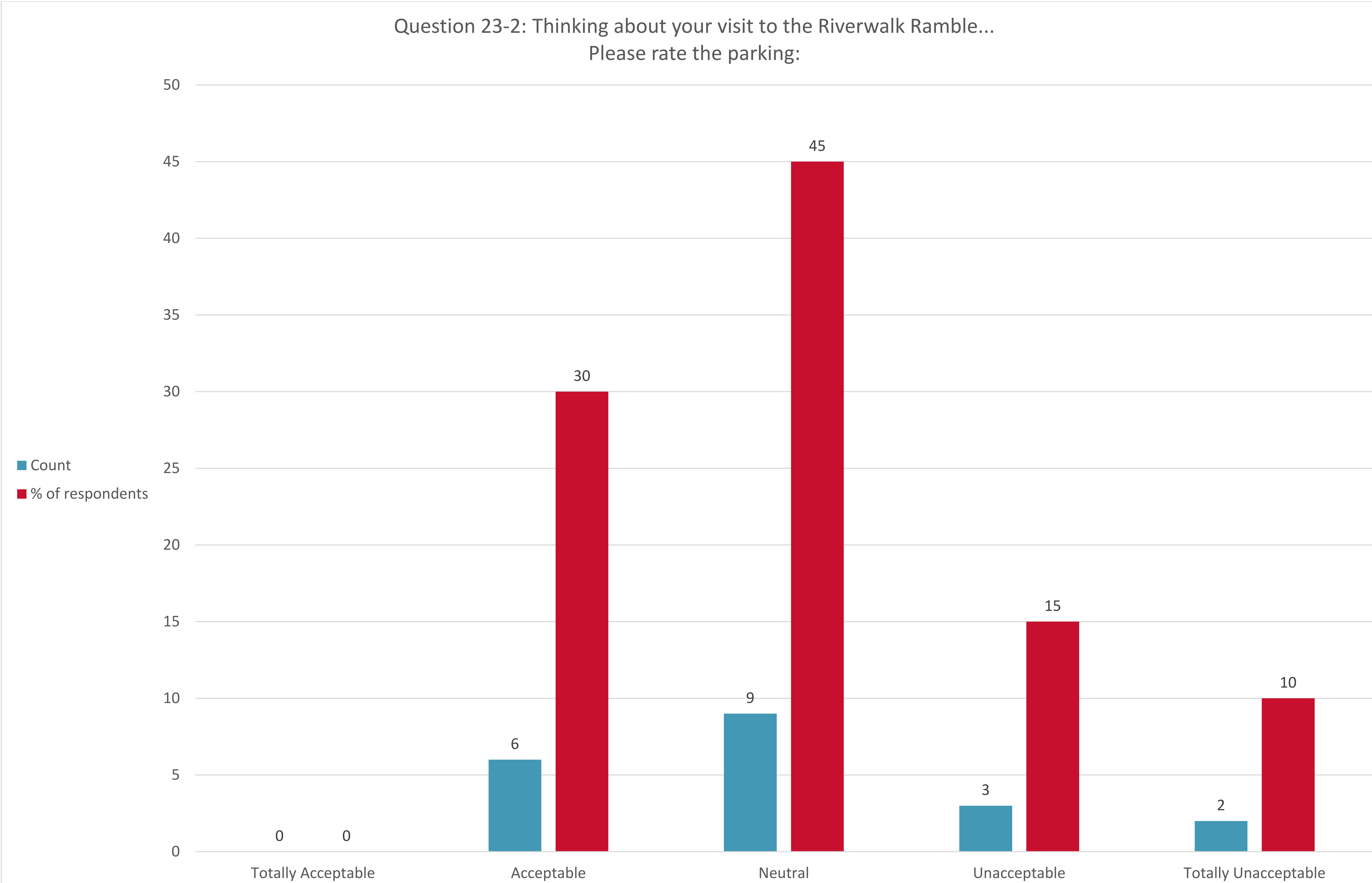


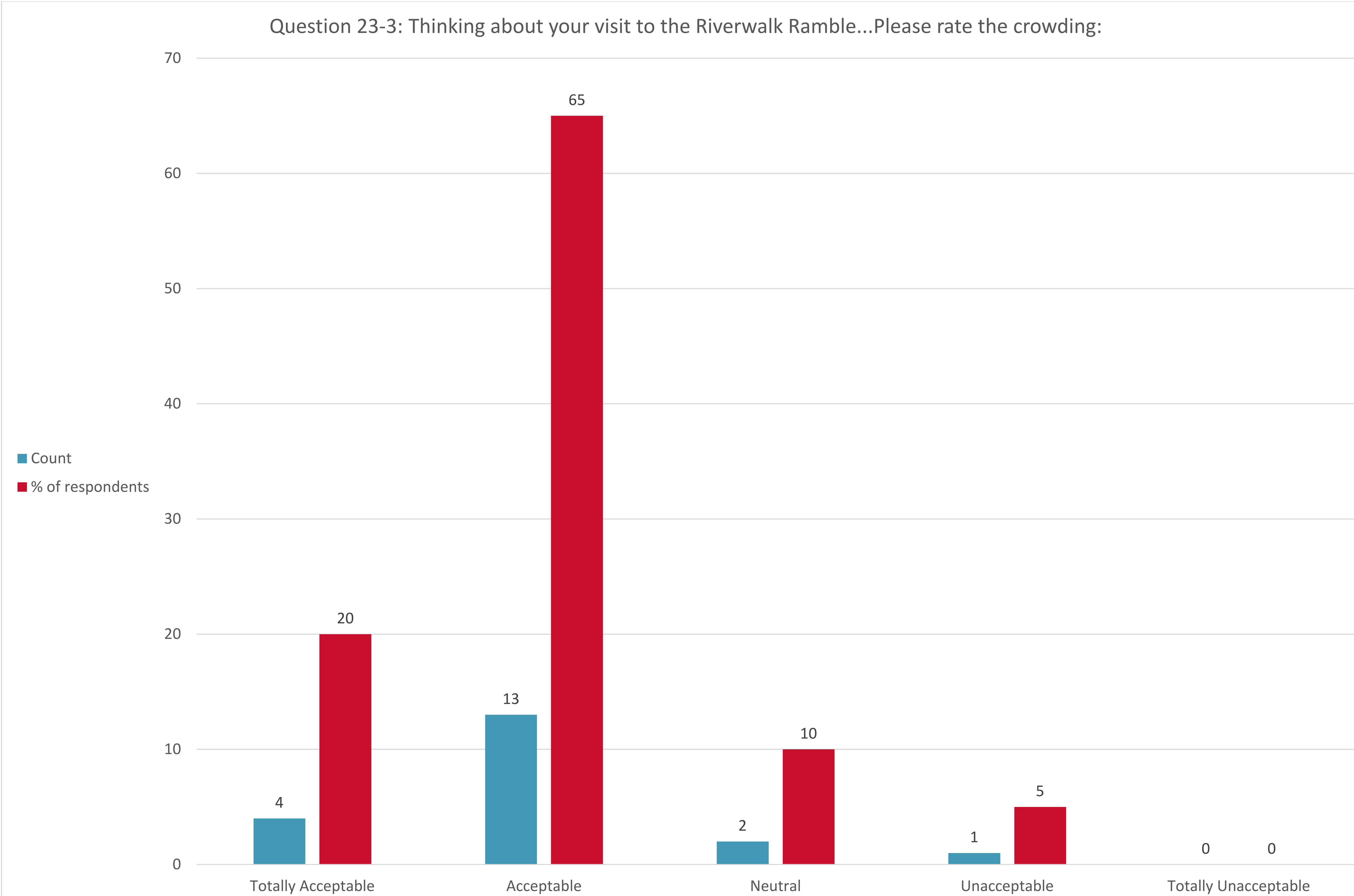
Question 22-7: Thinking about your NPS Walkway Tour experience...Please rate the river/canal flow:
45
40
35
30
25
20
15
10
5
0
Count
% of respodnents
3
10.3
9
31
12
41.4
4
13.8
1
3.5
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

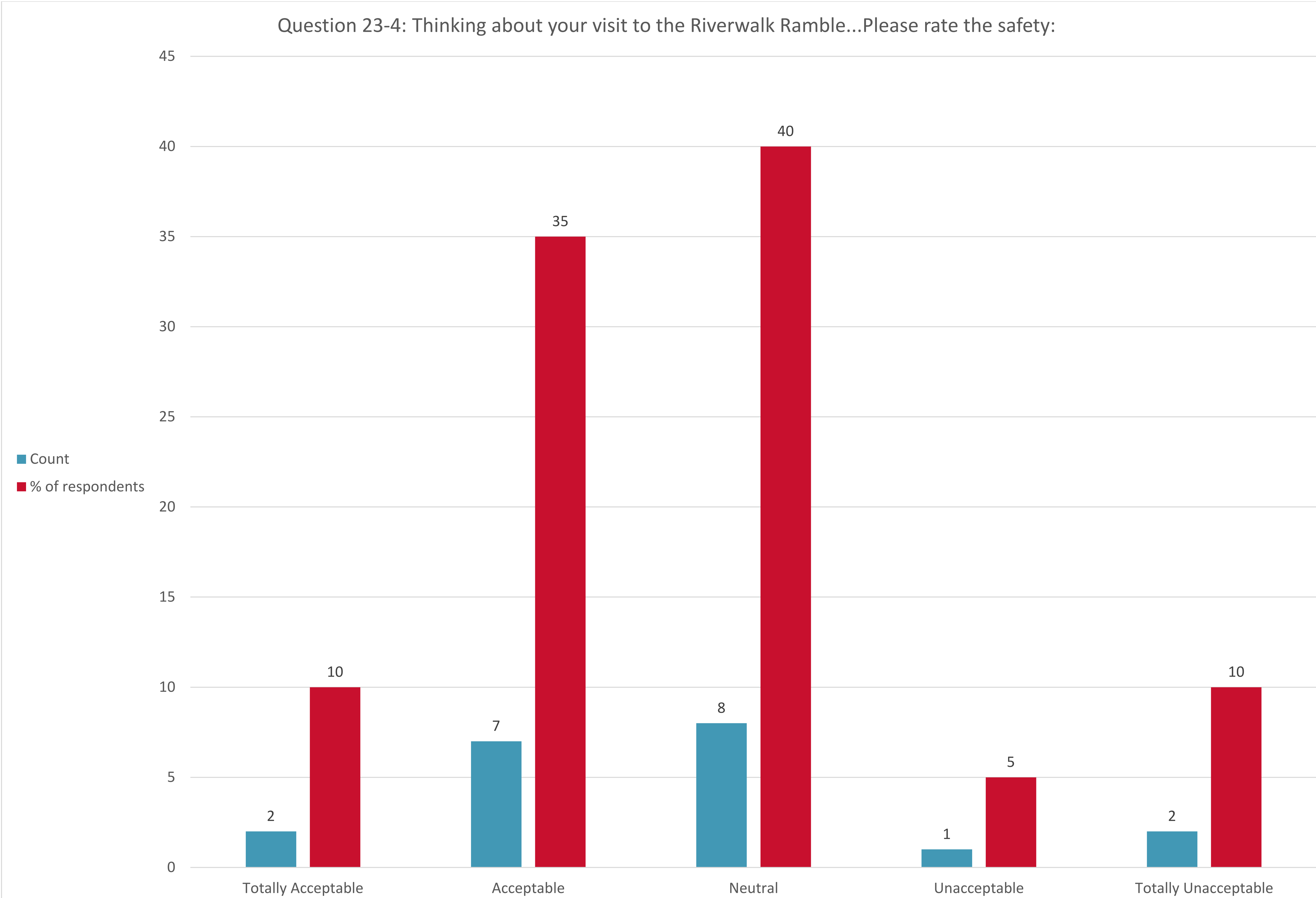

Question 22-8: Thinking about your NPS Walkway Tour experience...Please rate your overall experience:
70
60
50
40
30
20
10
0
Count
% of respondents
65.5
19
17.2
5
10.3
3
7
2
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

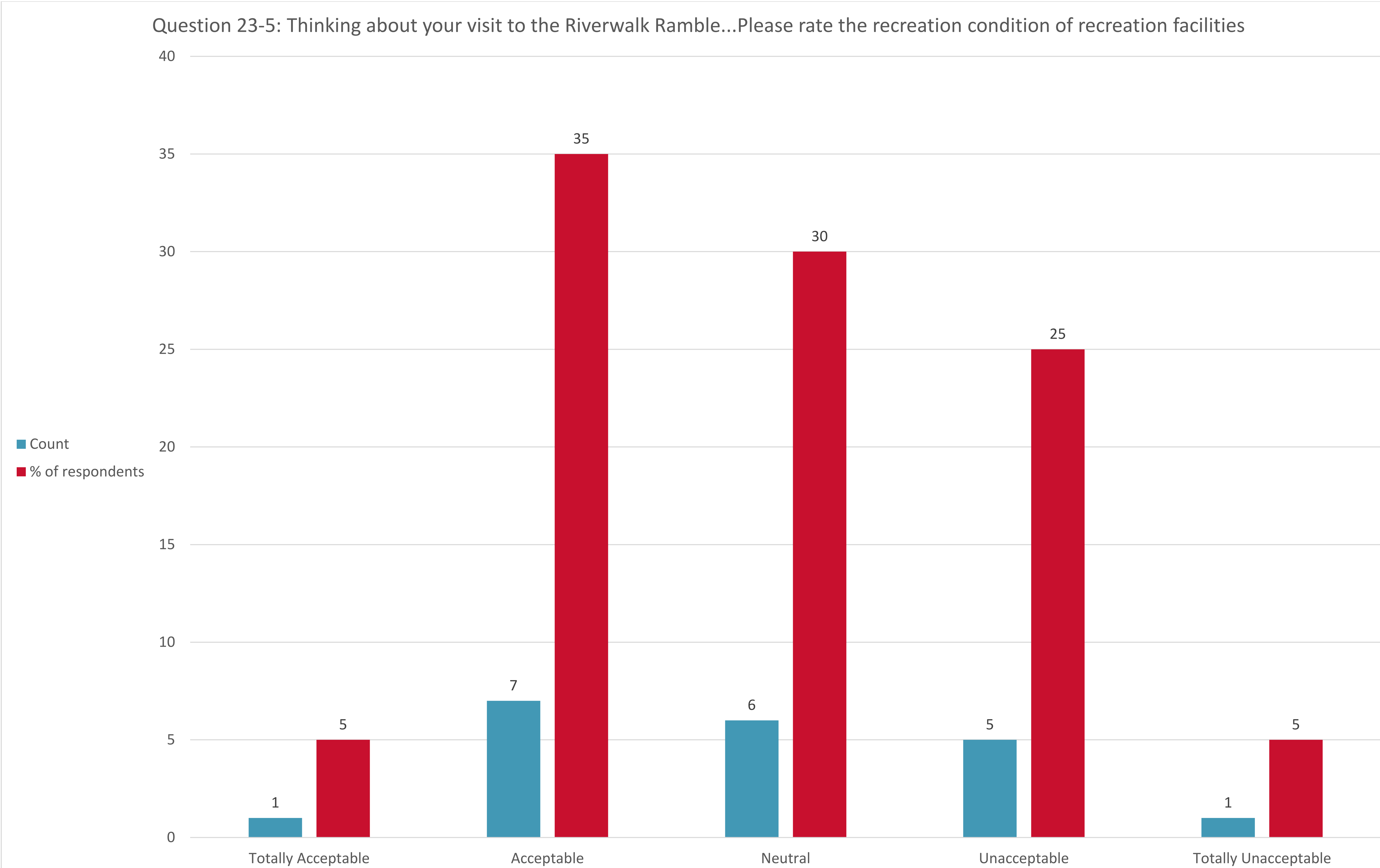


Question 23-1: Thinking about your visit to the Riverwalk Ramble...please rate the accessibility:
60
50
40
30
20
10
0
Count
% of respondents
1
5
8
40
10
50
1
5
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

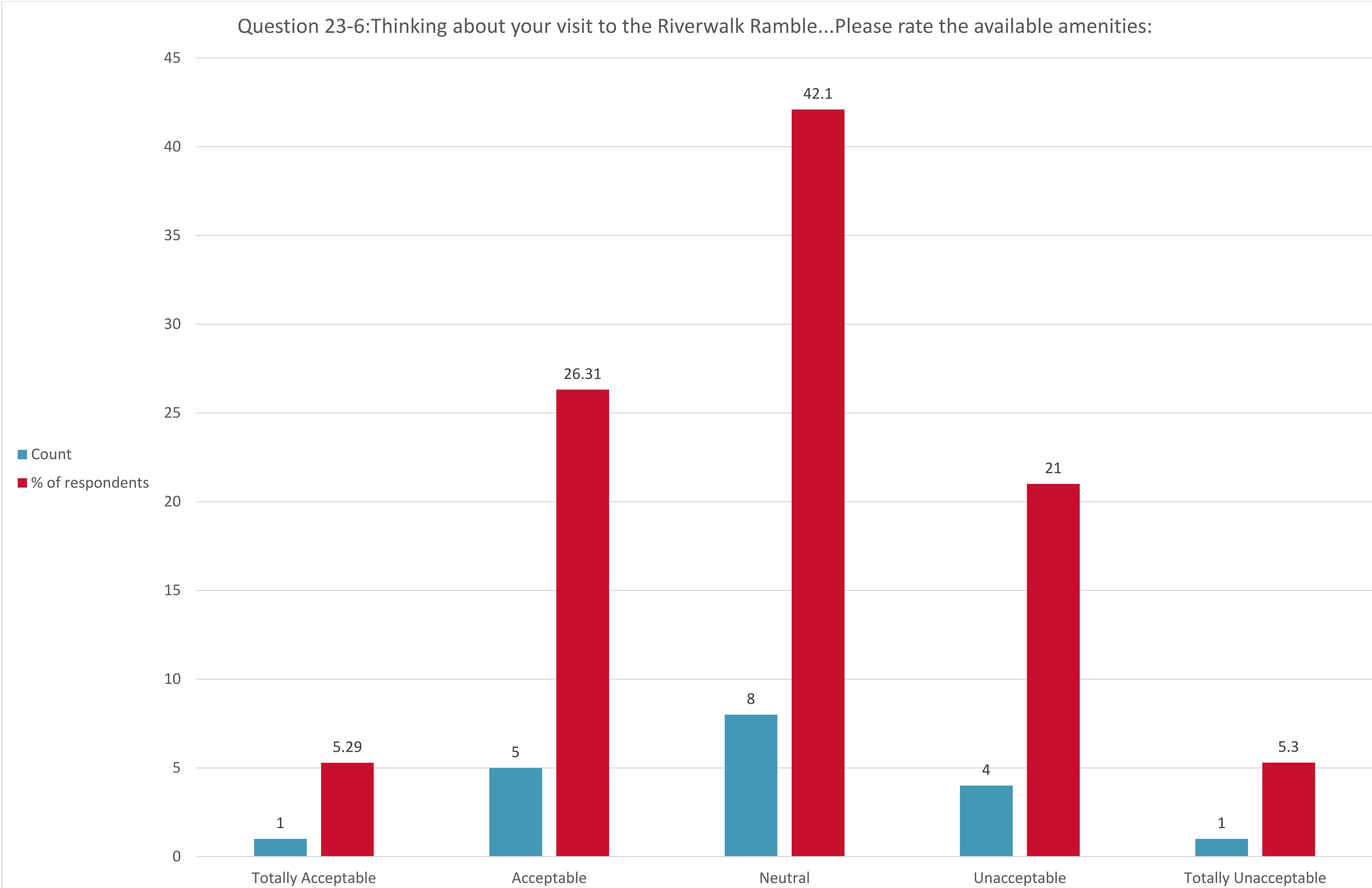

Question 23-2: Thinking about your visit to the Riverwalk Ramble...
Please rate the parking:
Count
% of respondents
50
45
40
35
30
25
20
15
10
5
0
0
0
6
30
9
45
3
15
2
10
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

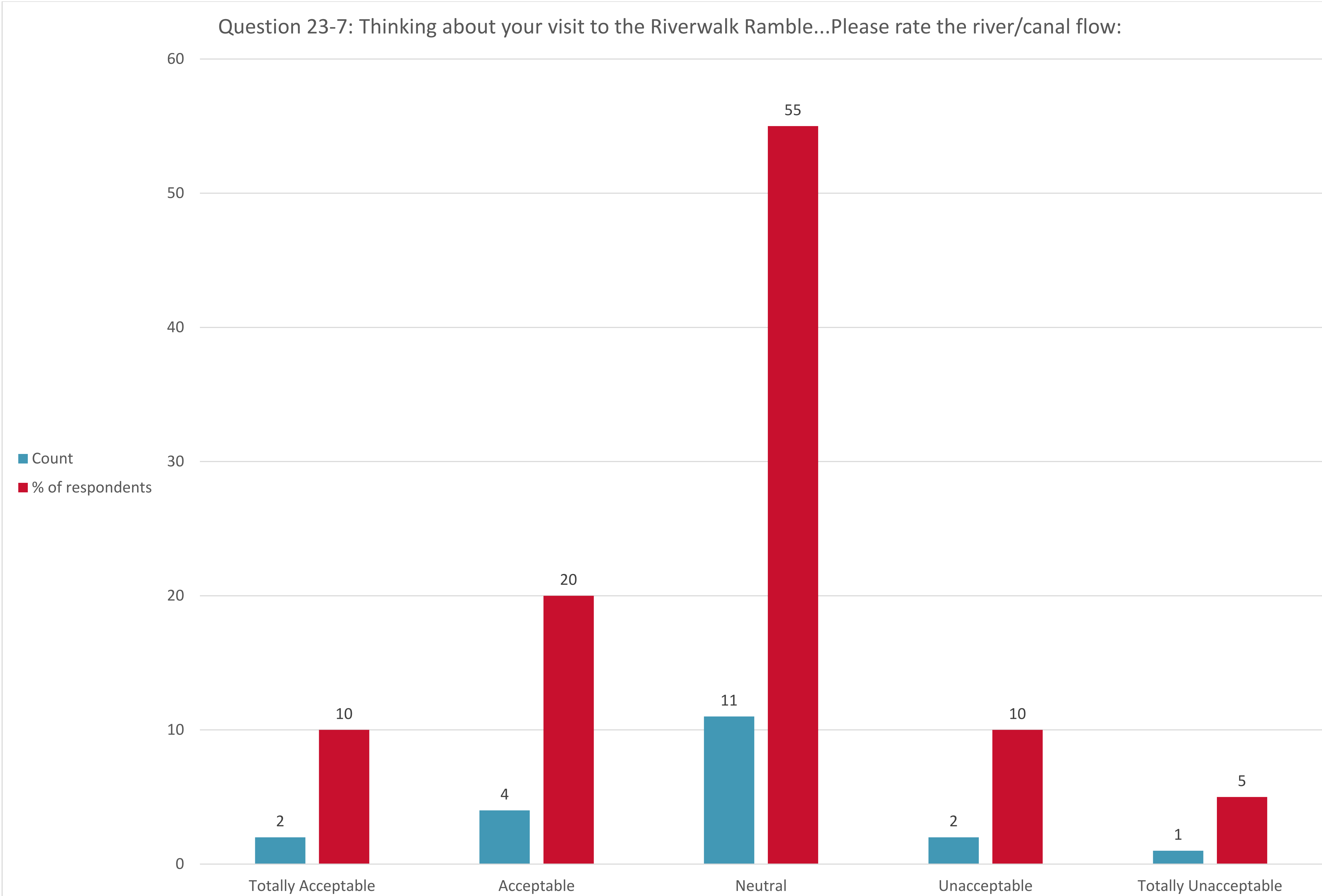

Question 23-3: Thinking about your visit to the Riverwalk Ramble...Please rate the crowding:
70
60
50
40
30
20
10
0
Count
% of respondents
65
20
13
4
10
2
5
1
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

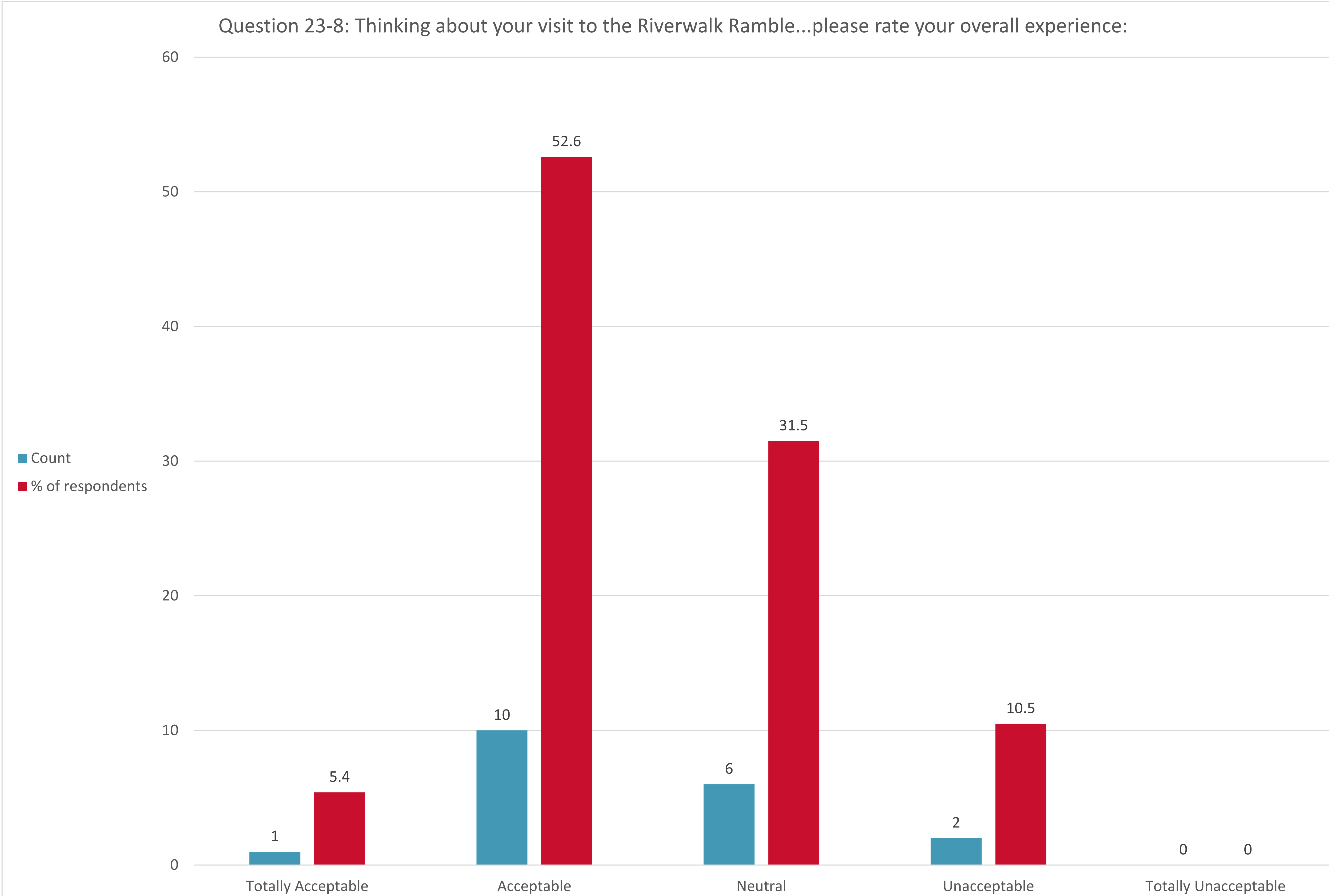

Question 23-4: Thinking about your visit to the Riverwalk Ramble...Please rate the safety:
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
2
10
7
35
8
40
1
5
2
10
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

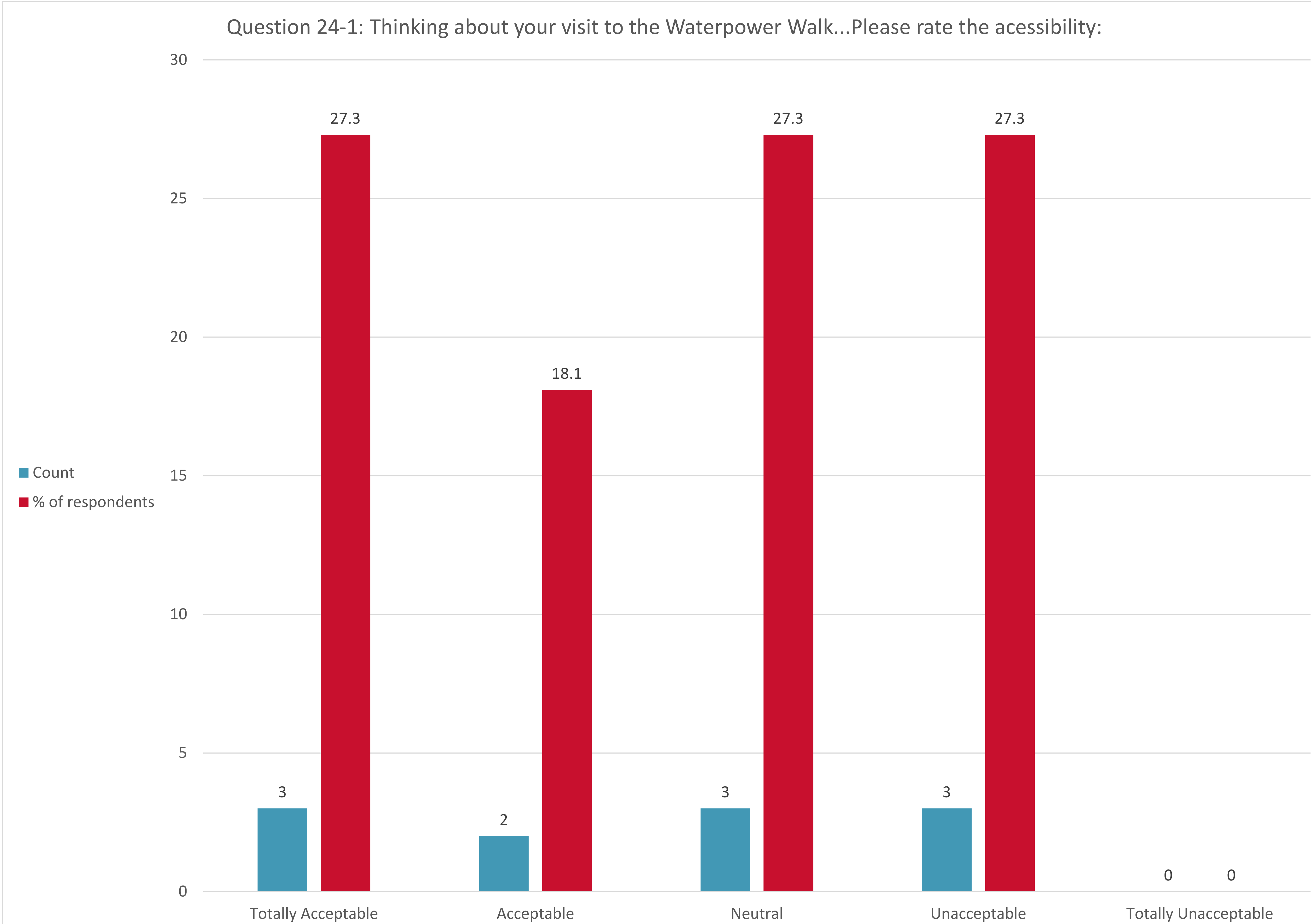


Question 23-5: Thinking about your visit to the Riverwalk Ramble...Please rate the recreation condition of recreation facilities
40
35
30
25
20
15
10
5
0
Count
% of respondents
1
5
7
35
6
30
5
25
1
5
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

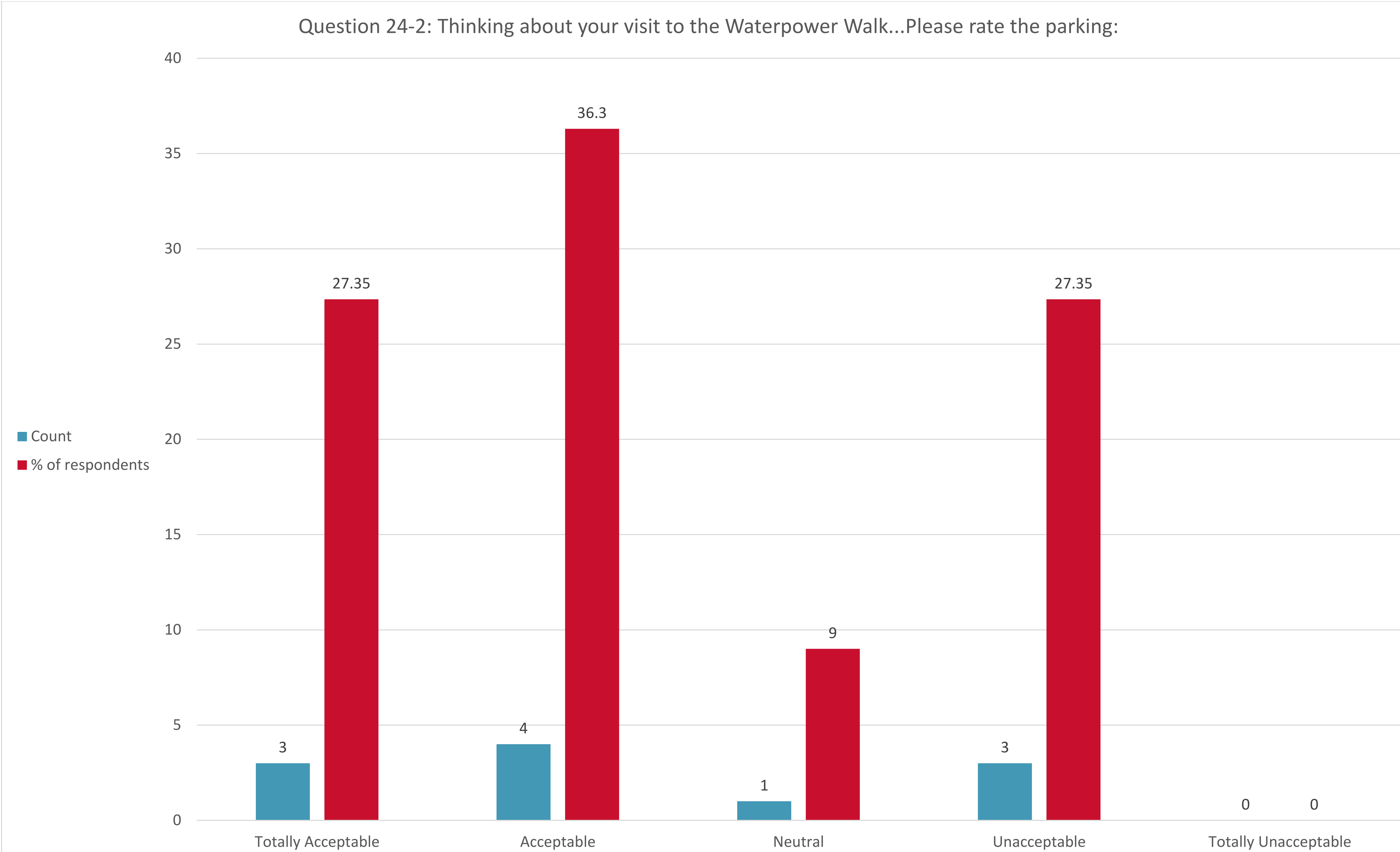

Question 23-6:Thinking about your visit to the Riverwalk Ramble...Please rate the available amenities:
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
1
5.29
5
26.31
8
42.1
4
21
1
5.3
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

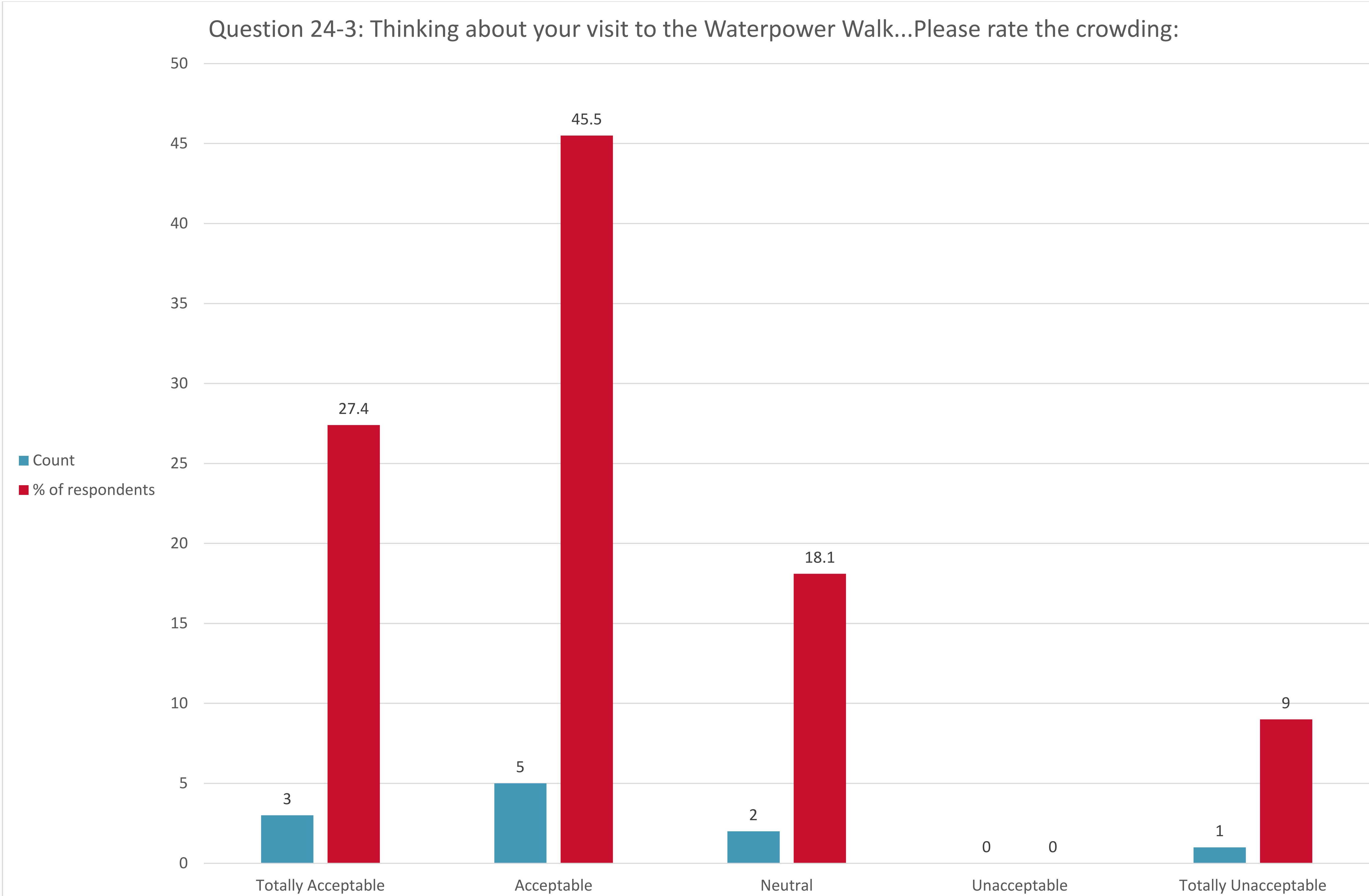

Question 23-7: Thinking about your visit to the Riverwalk Ramble...Please rate the river/canal flow:
Count
% of respondents
60
50
40
30
20
10
0
2
10
4
20
11
55
2
10
1
5
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

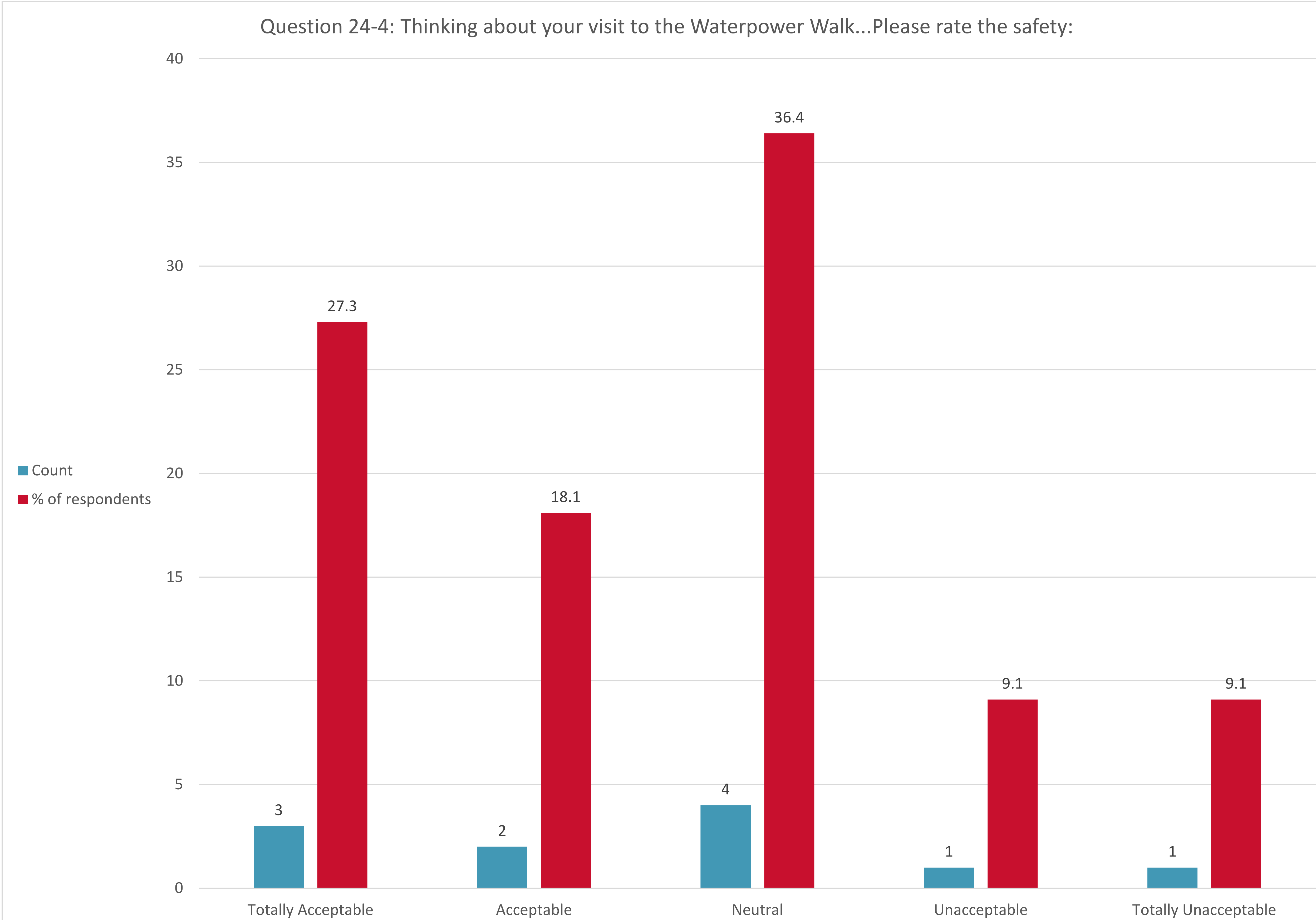

Question 23-8: Thinking about your visit to the Riverwalk Ramble...please rate your overall experience:
60
50
40
30
20
10
0
Count
% of respondents
52.6
31.5
10.5
5.4
10
6
2
1
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

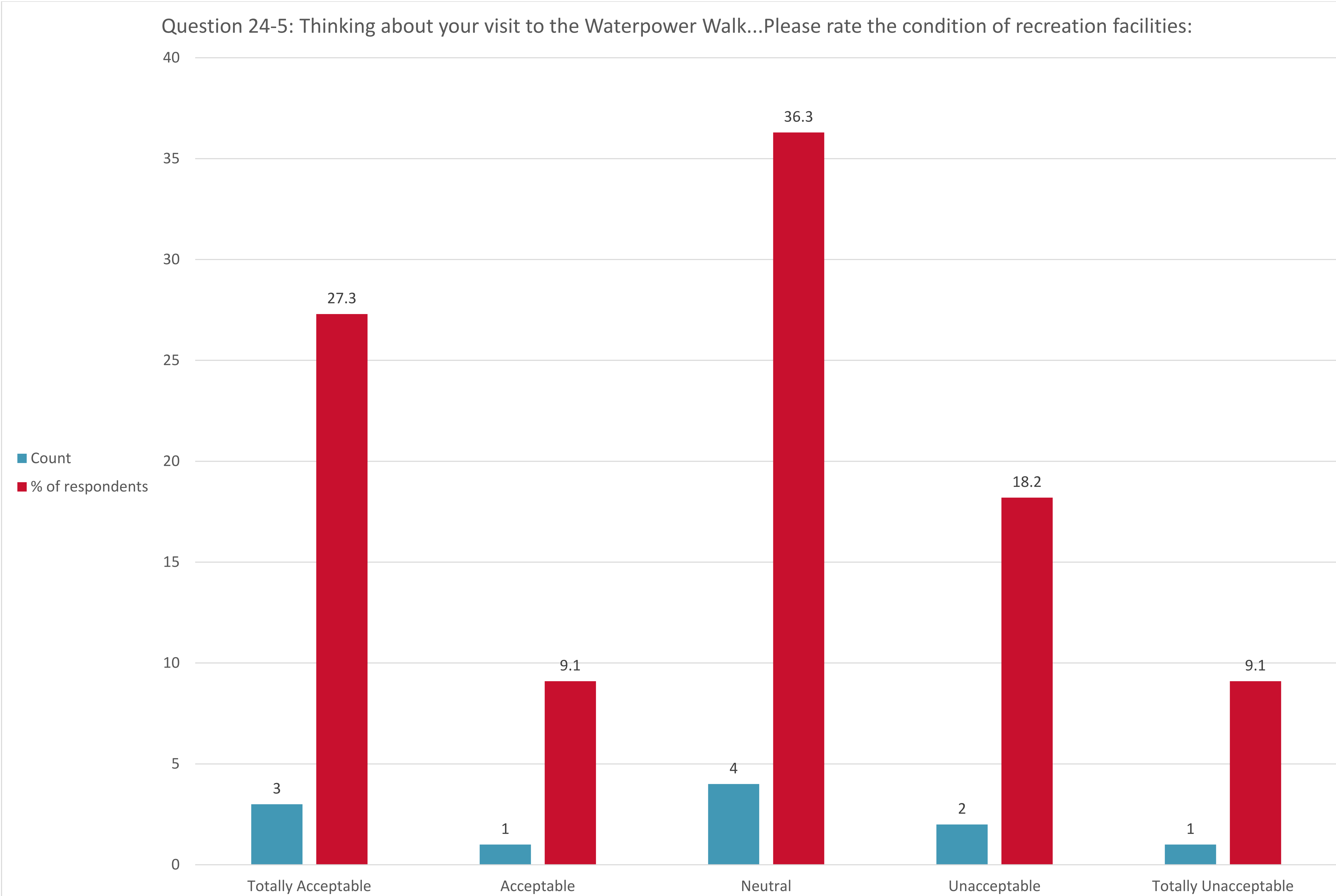


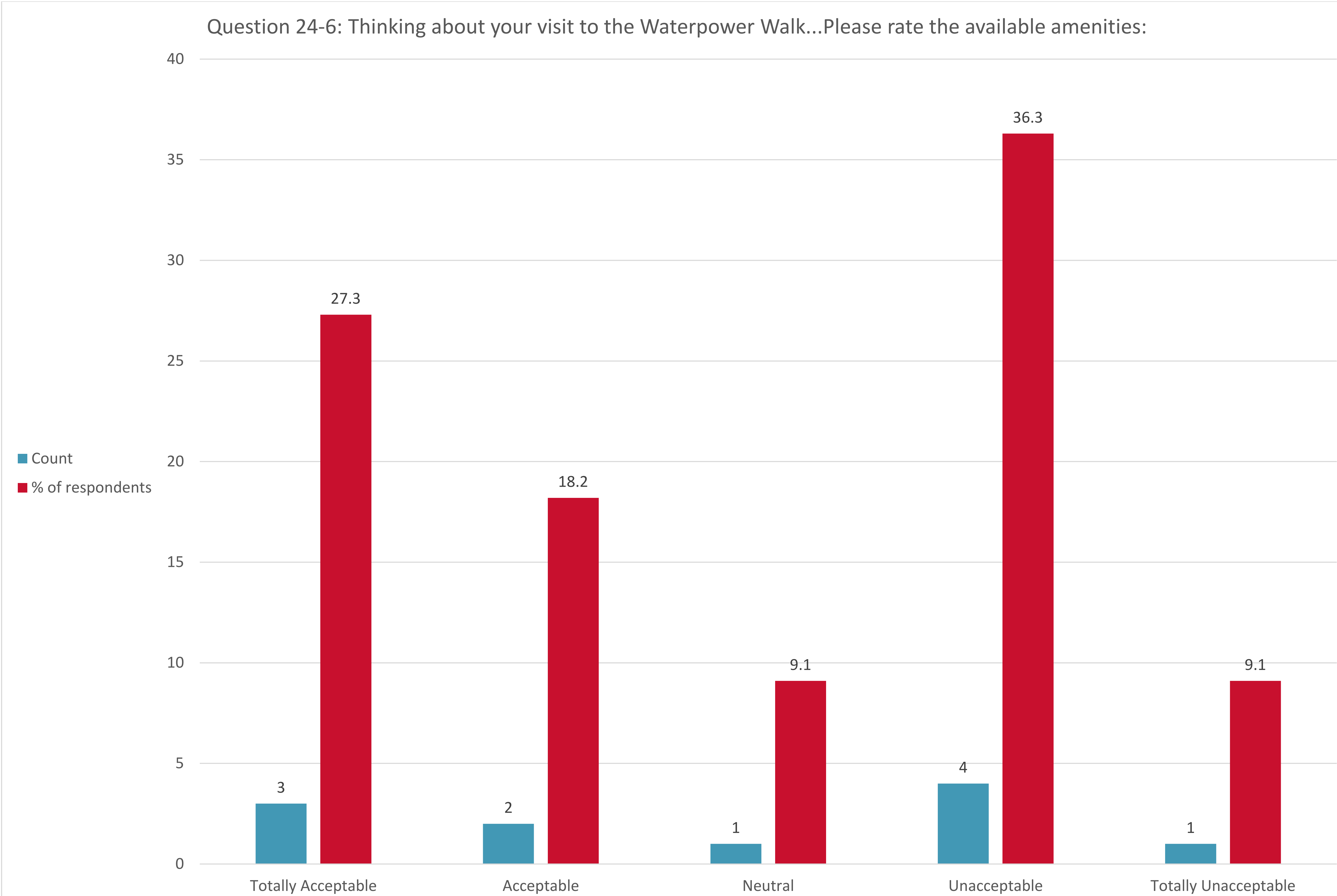
Question 24-1: Thinking about your visit to the Waterpower Walk...Please rate the acessibility:
30
25
20
15
10
5
0
Count
% of respondents
27.3
18.1
27.3
27.3
3
2
3
3
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

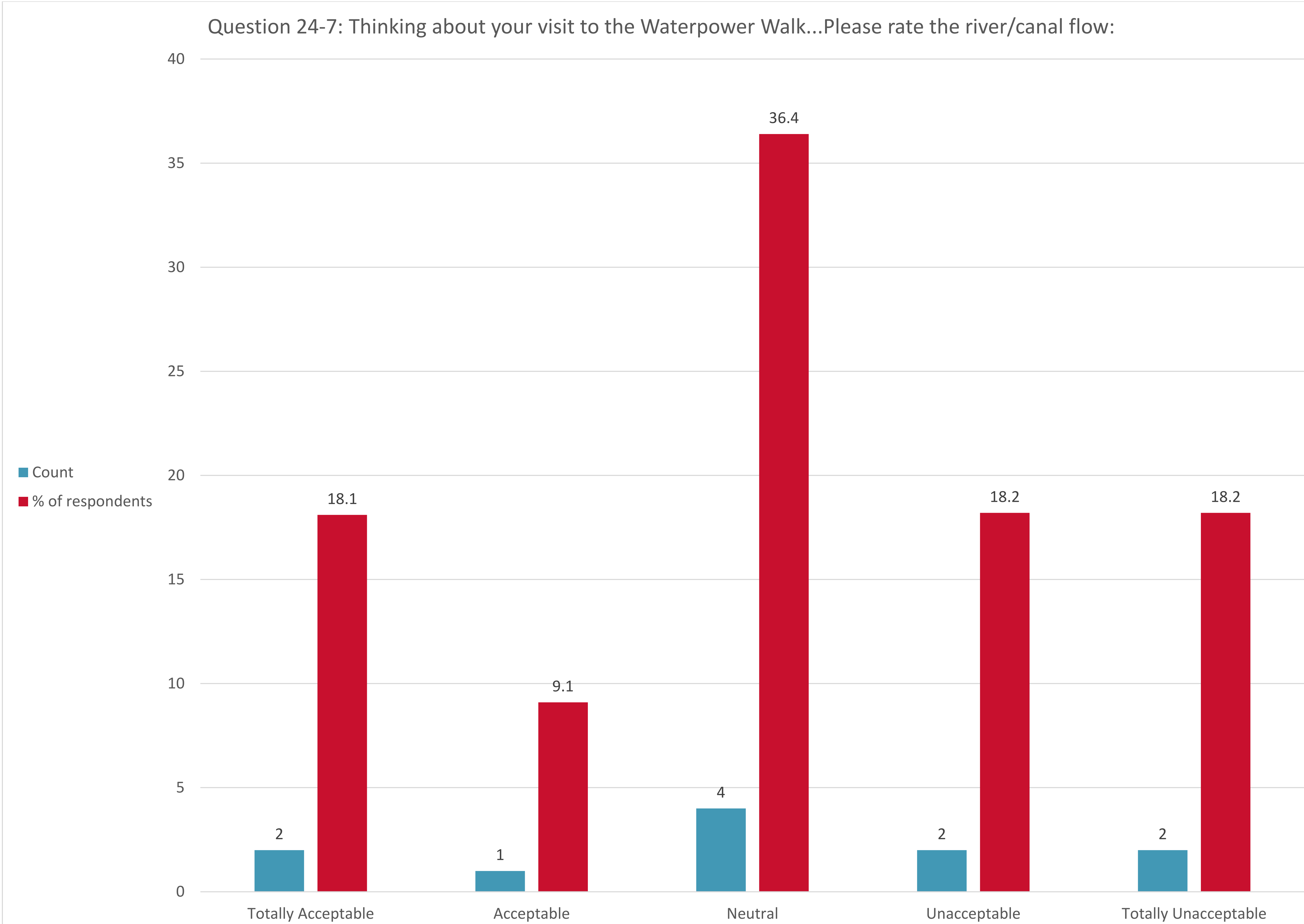

Question 24-2: Thinking about your visit to the Waterpower Walk...Please rate the parking:
Count
% of respondents
40
35
30
25
20
15
10
5
0
27.35
36.3
9
27.35
3
4
1
3
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 24-3: Thinking about your visit to the Waterpower Walk...Please rate the crowding:
Count
% of respondents
50
45
40
35
30
25
20
15
10
5
0
27.4
45.5
18.1
9
3
5
2
0
0
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

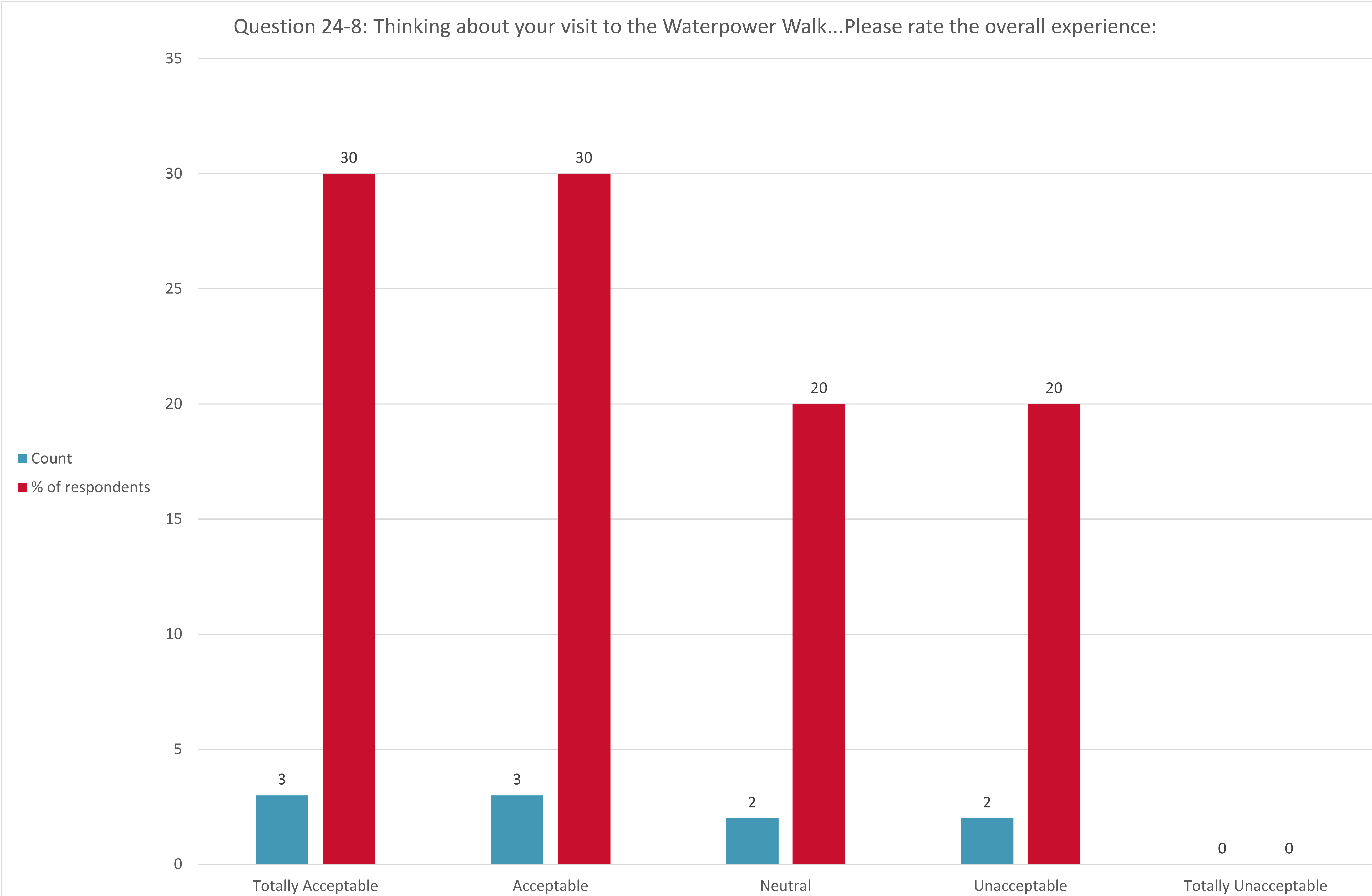

Question 24-4: Thinking about your visit to the Waterpower Walk...Please rate the safety:
40
35
30
25
20
15
10
5
0
Count
% of respondents
27.3
18.1
36.4
9.1
9.1
3
2
4
1
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

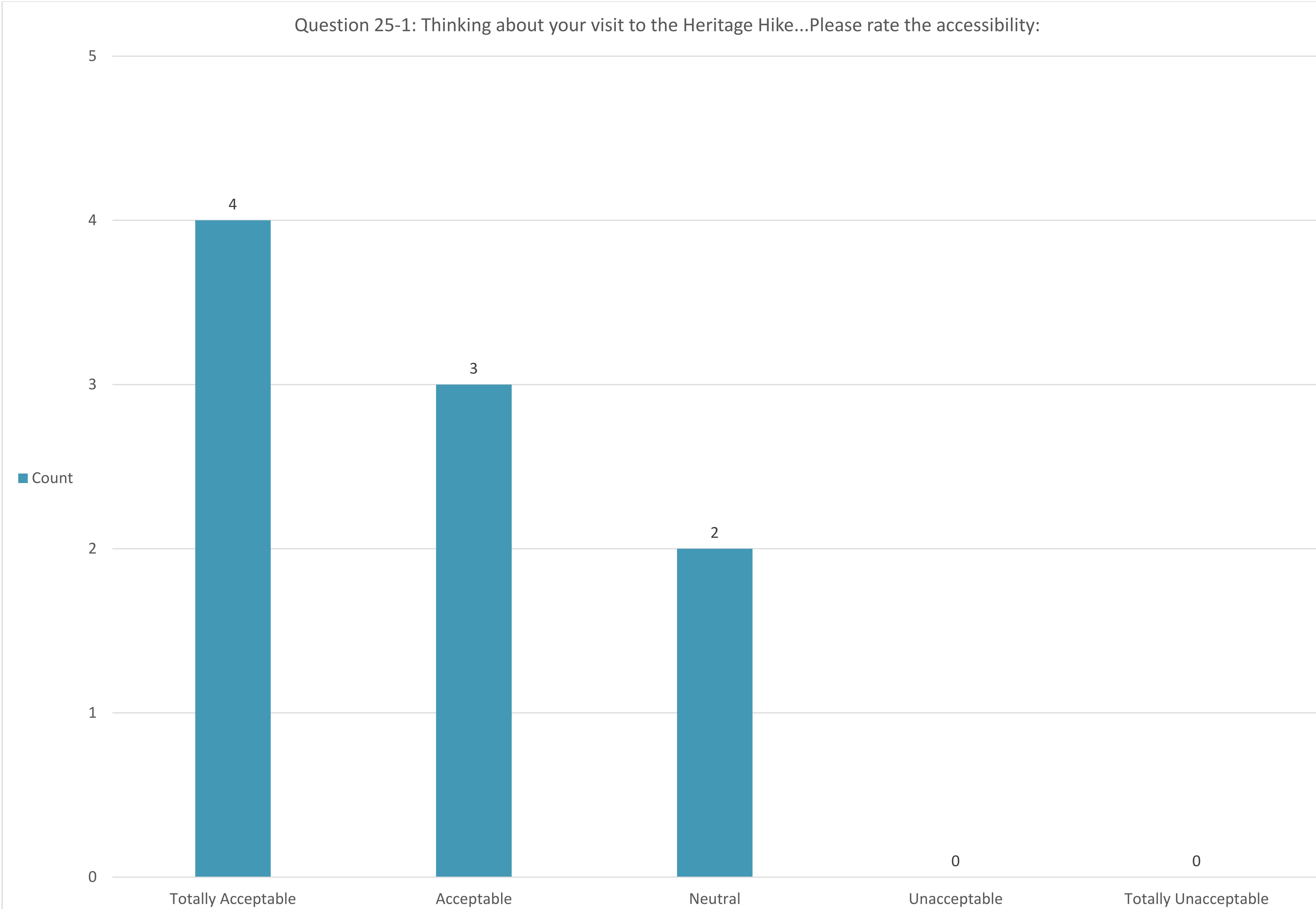

Question 24-5: Thinking about your visit to the Waterpower Walk...Please rate the condition of recreation facilities:
Count
% of respondents
40
35
30
25
20
15
10
5
0
3
27.3
1
9.1
4
36.3
2
18.2
1
9.1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

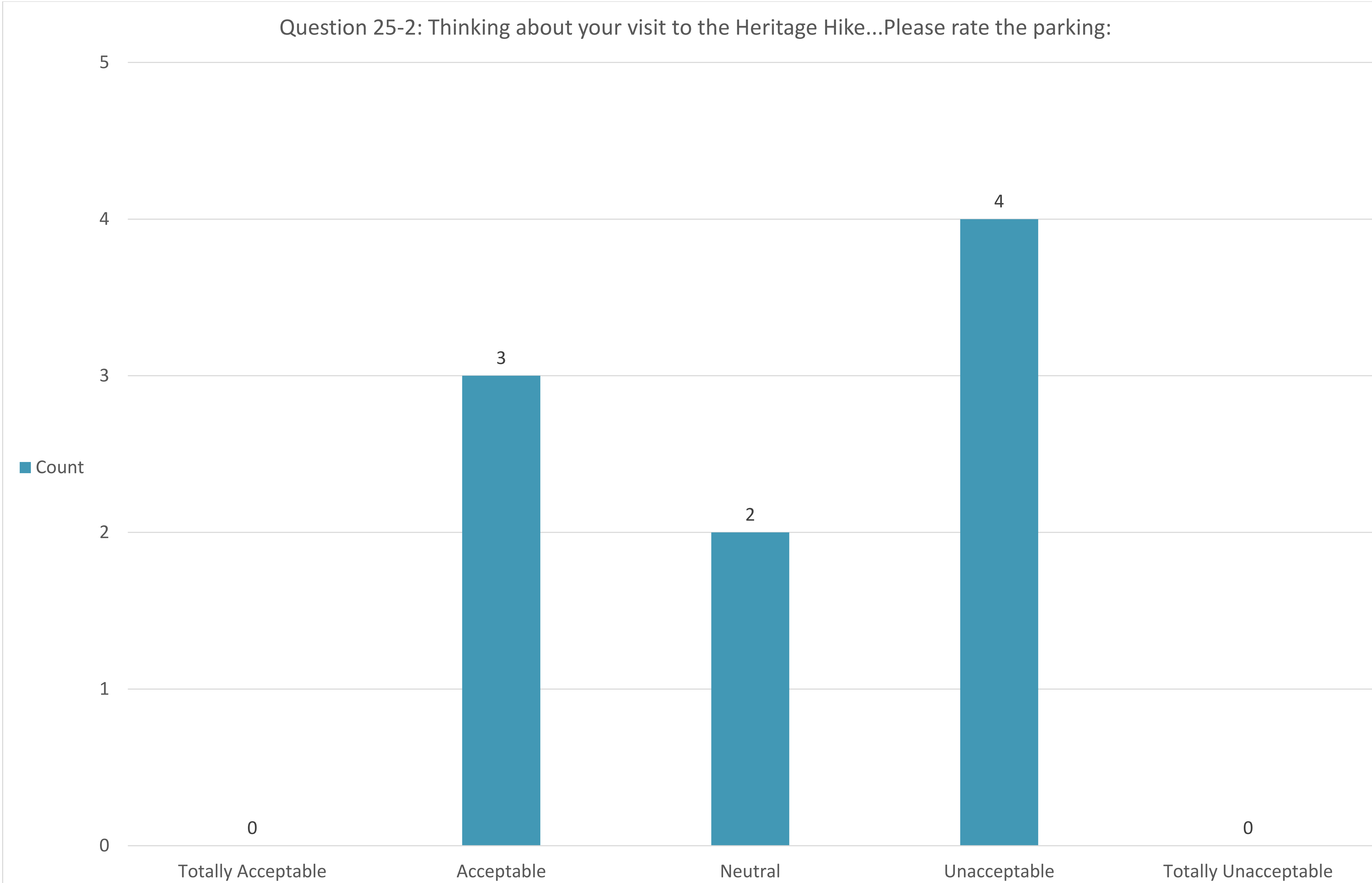

Question 24-6: Thinking about your visit to the Waterpower Walk...Please rate the available amenities:
40
35
30
25
20
15
10
5
0
Count
% of respondents
3
27.3
2
18.2
1
9.1
4
36.3
1
9.1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

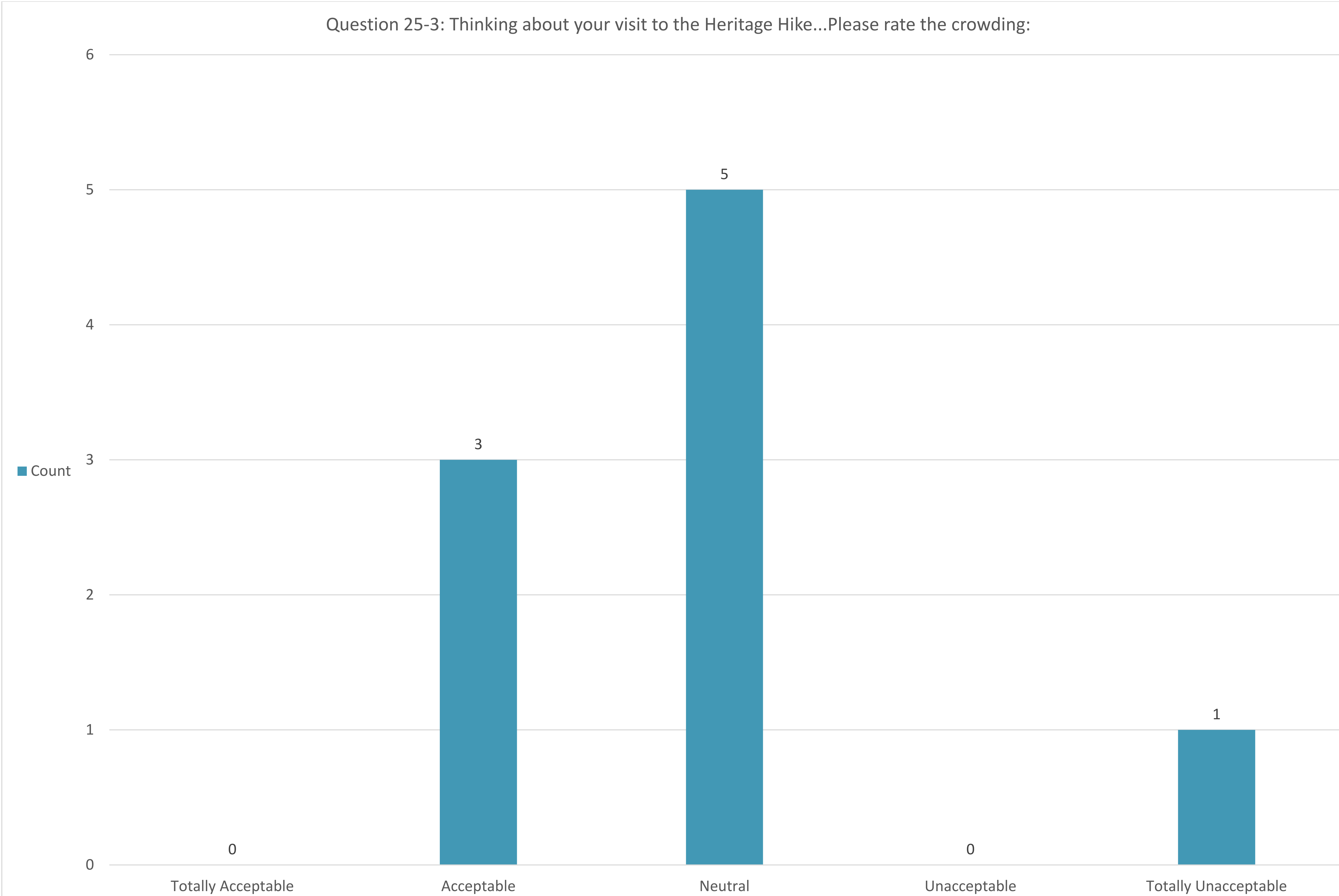


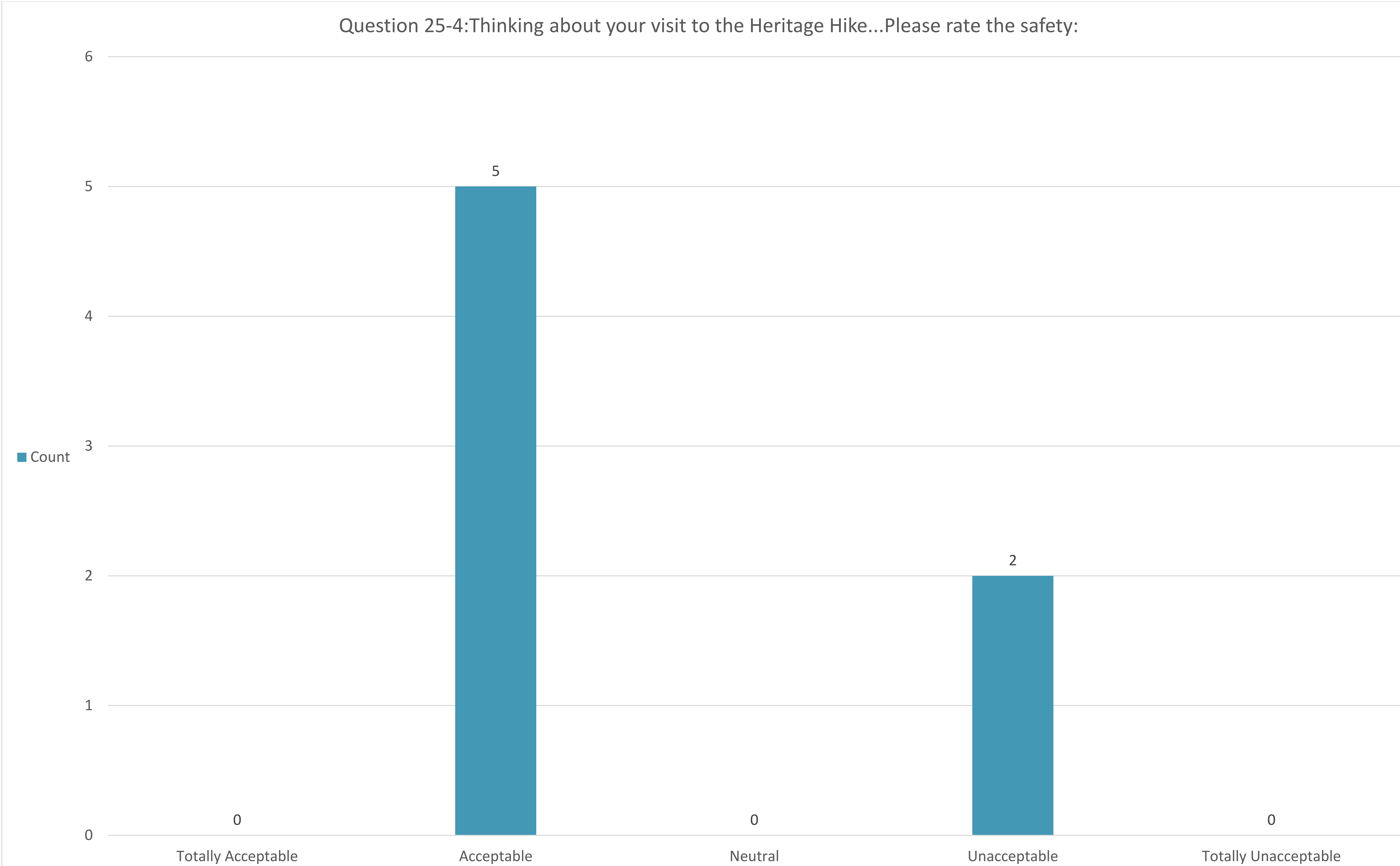
Question 24-7: Thinking about your visit to the Waterpower Walk...Please rate the river/canal flow:
Count
% of respondents
40
35
30
25
20
15
10
5
0
2
18.1
1
9.1
4
36.4
2
18.2
2
18.2
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

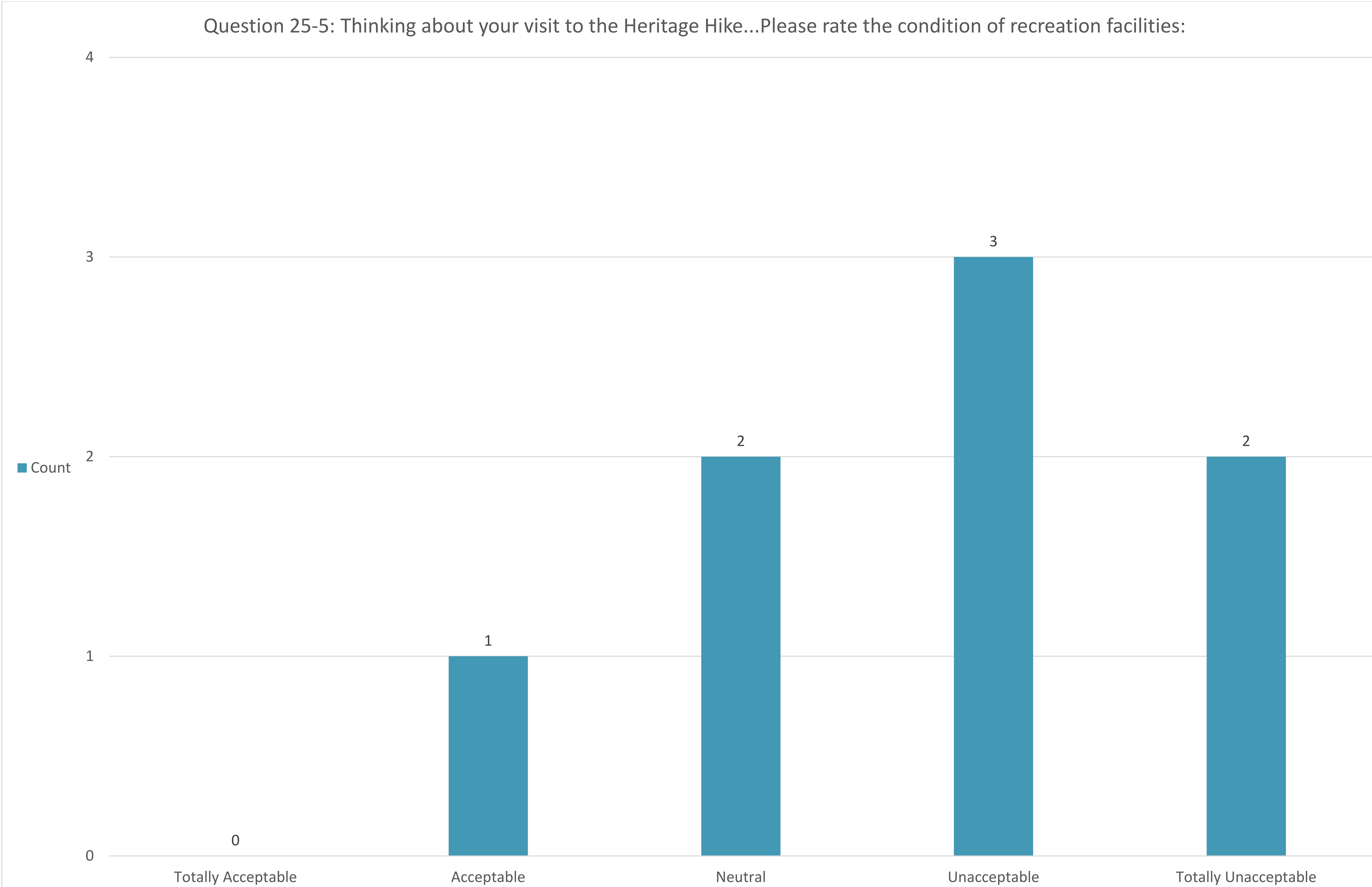

Question 24-8: Thinking about your visit to the Waterpower Walk...Please rate the overall experience:
35
30
25
20
15
10
5
0
Count
% of respondents
3
30
3
30
2
20
2
20
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 25-1: Thinking about your visit to the Heritage Hike...Please rate the accessibility:
5
4
3
2
1
0
Count
4
3
2
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

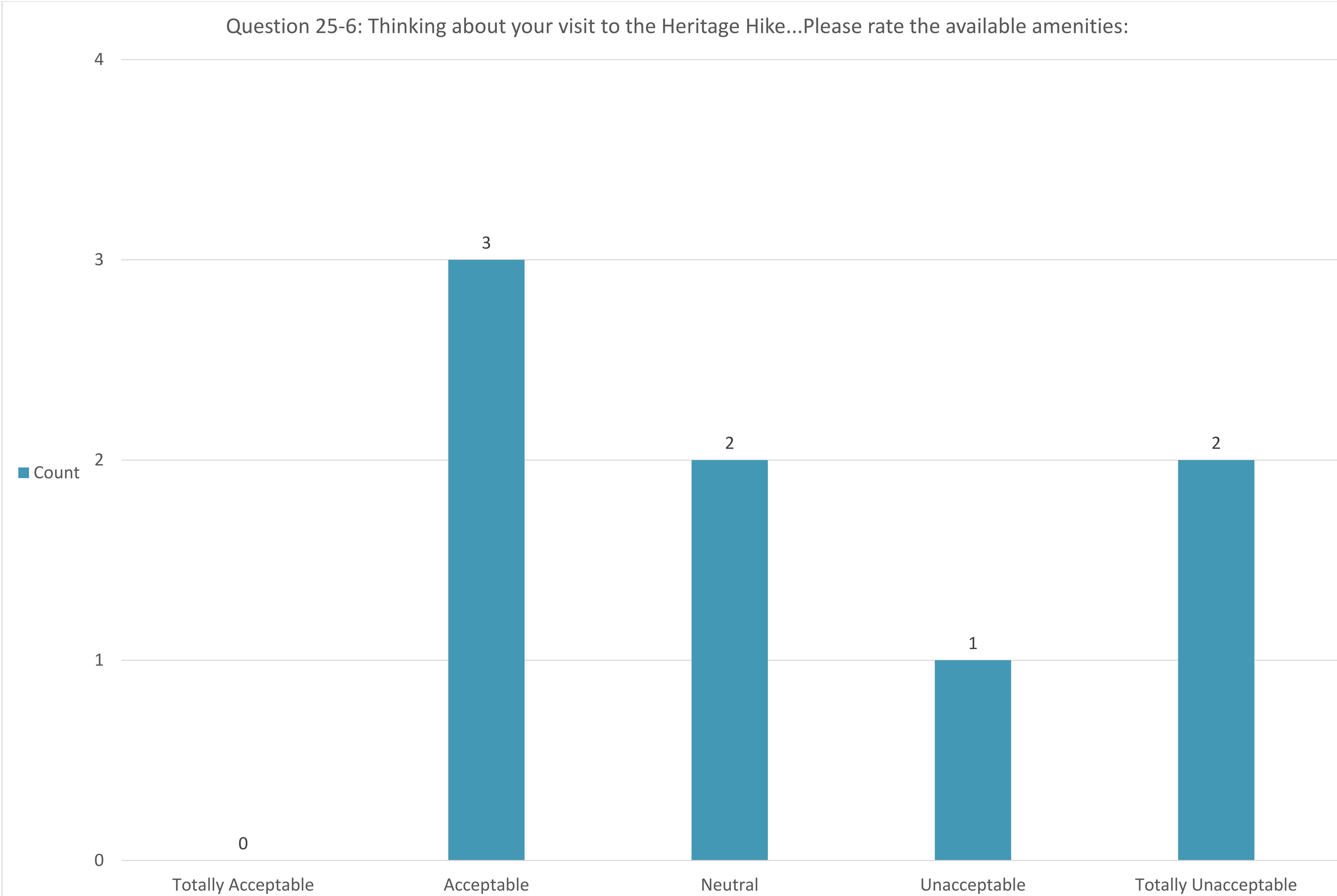

Question 25-2: Thinking about your visit to the Heritage Hike...Please rate the parking:
Count
5
4
3
2
1
0
0
3
2
4
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 25-3: Thinking about your visit to the Heritage Hike...Please rate the crowding:
Count
0
1
2
3
4
5
6
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable
0
3
5
0
1

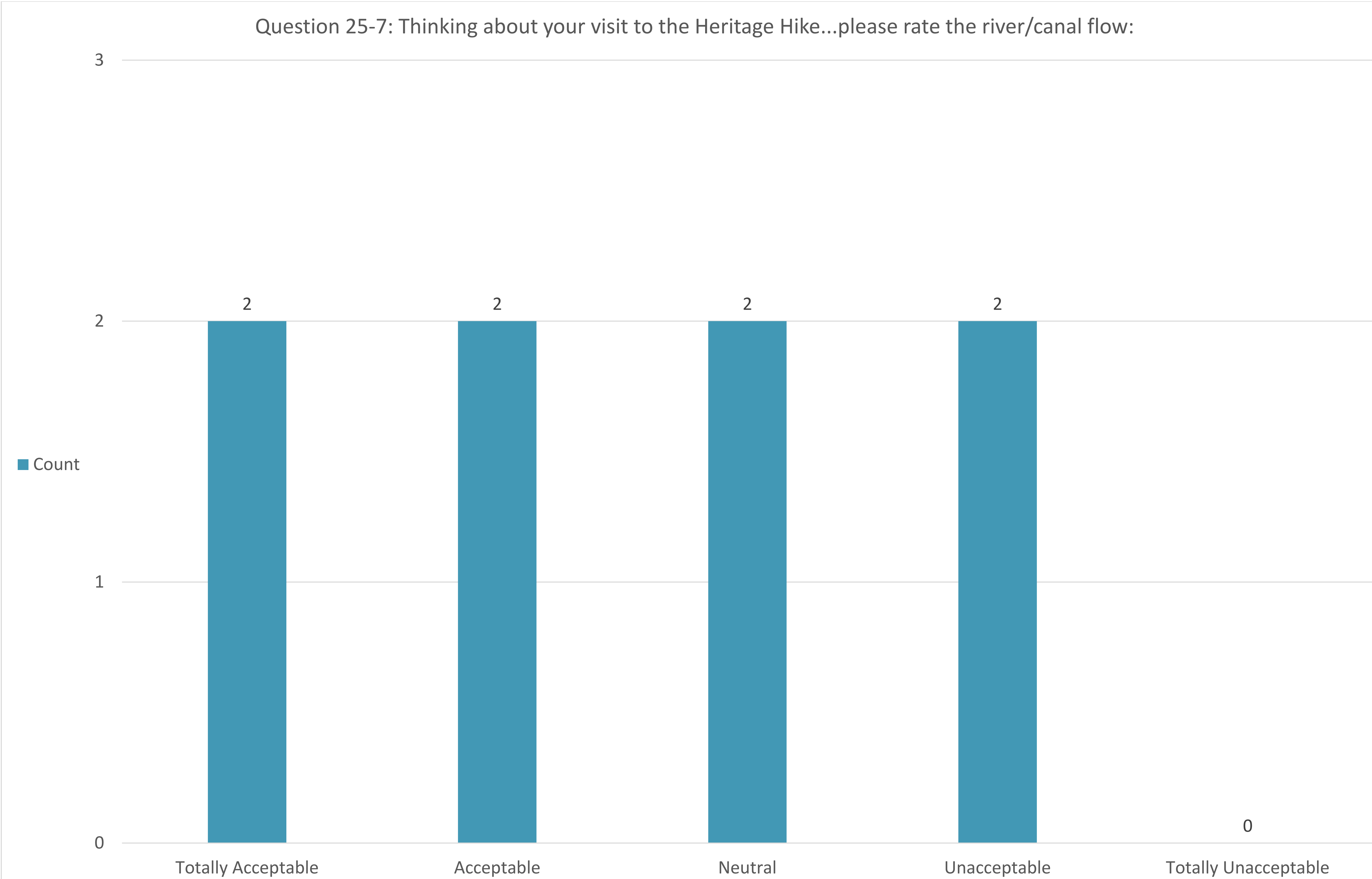

Question 25-4:Thinking about your visit to the Heritage Hike...Please rate the safety:
6
5
4
3
2
1
0
Count
5
2
0
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

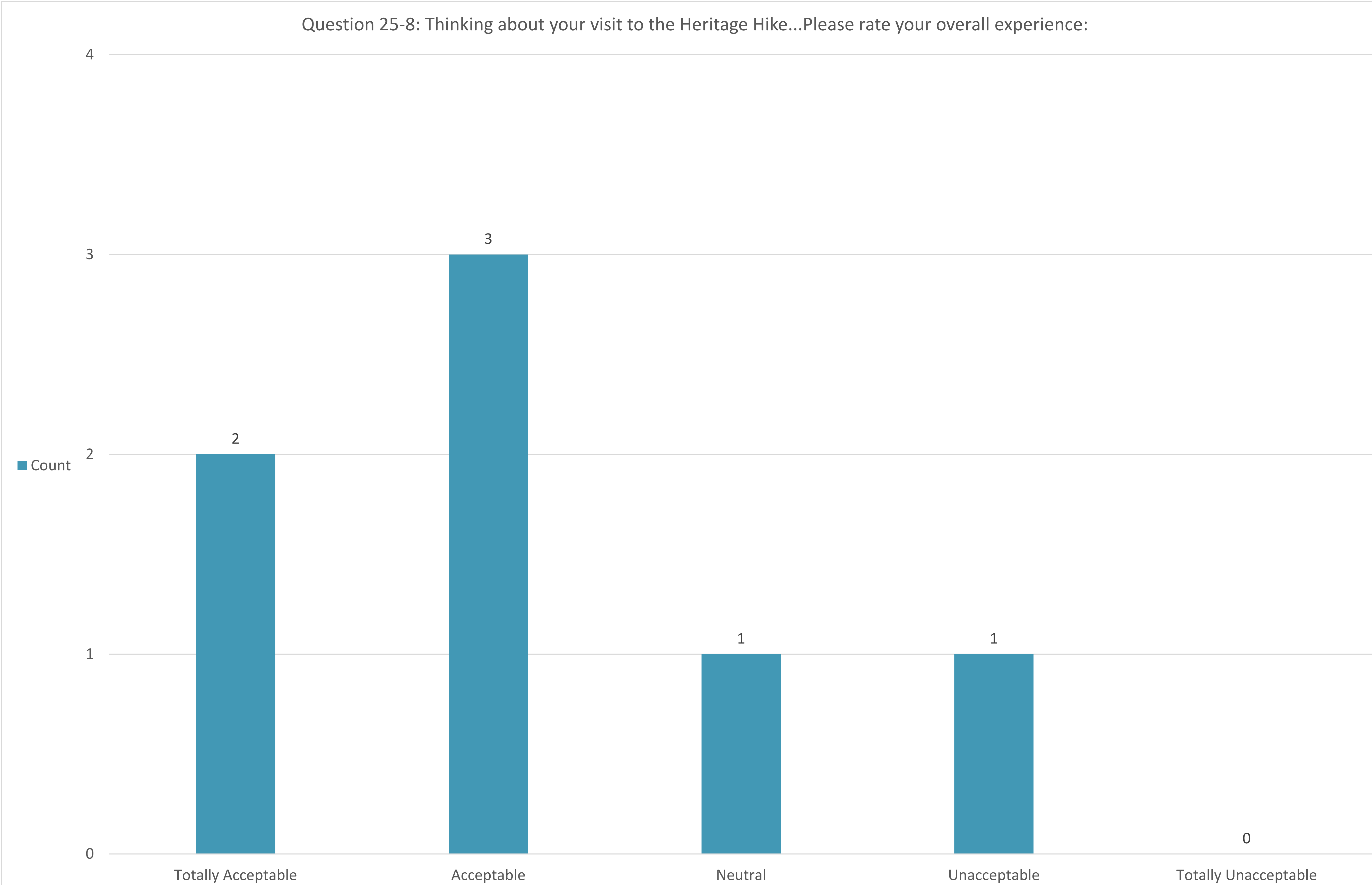


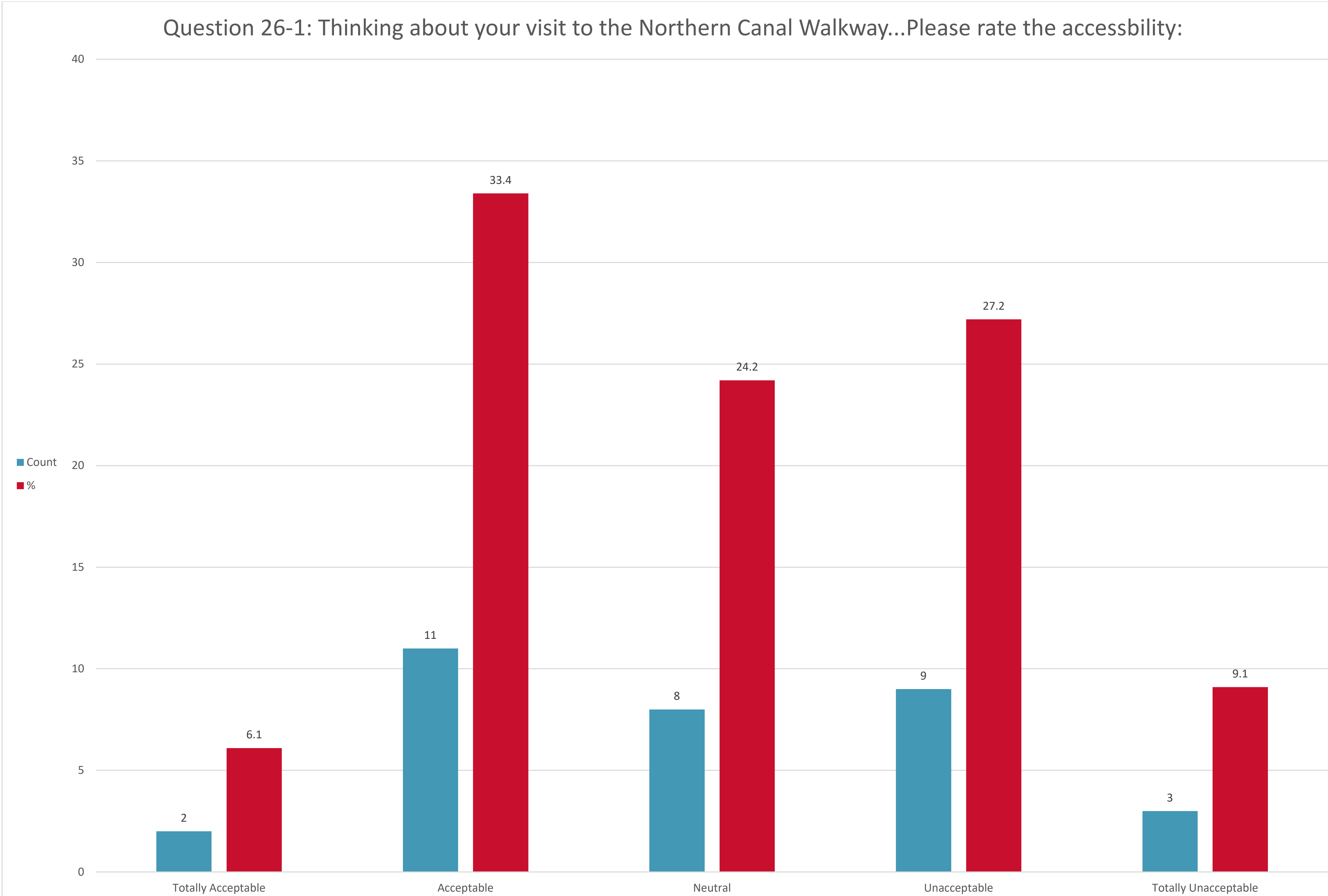
Question 25-5: Thinking about your visit to the Heritage Hike...Please rate the condition of recreation facilities:
4
3
2
1
0
Count
0
1
2
3
2
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

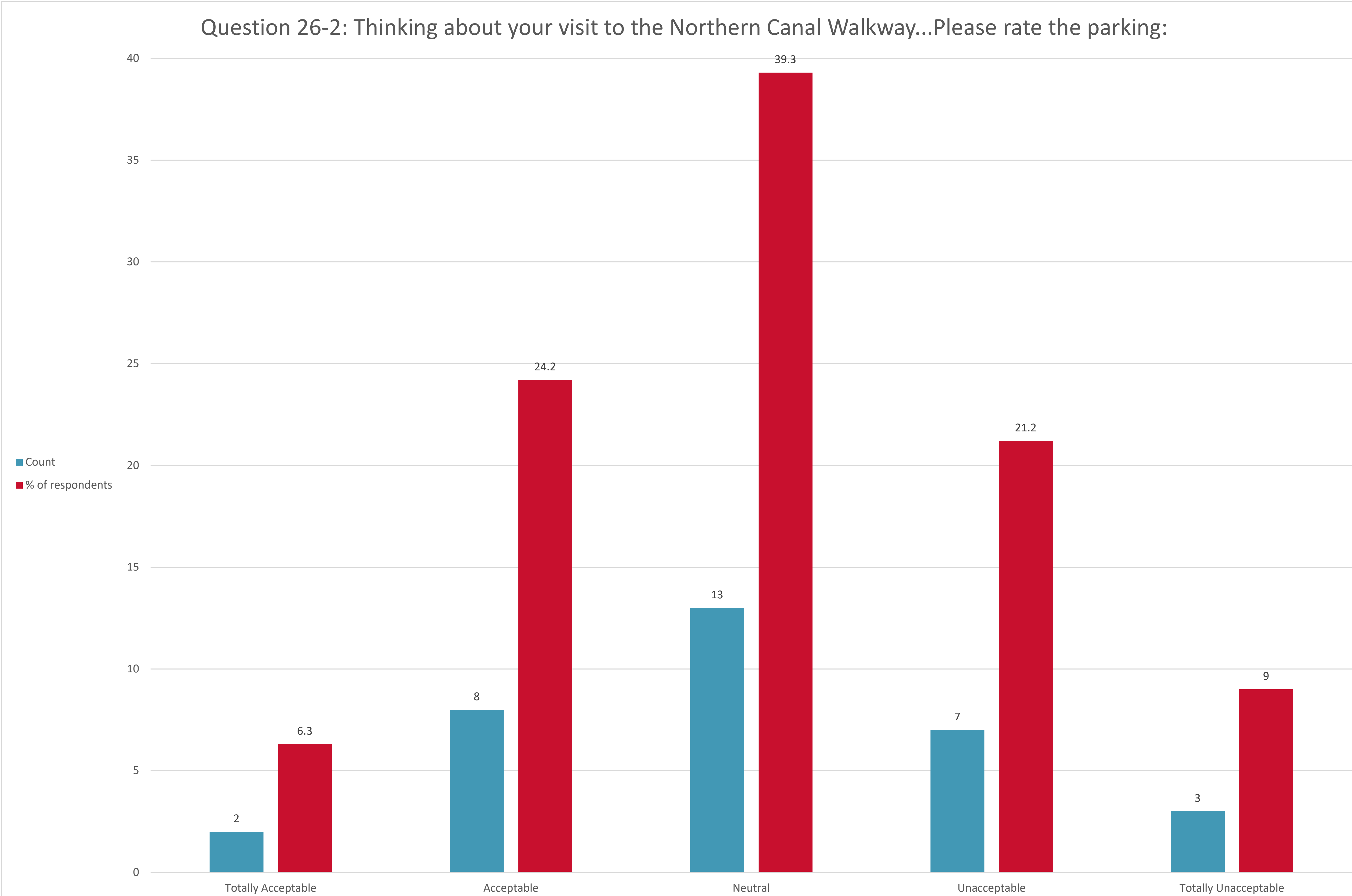


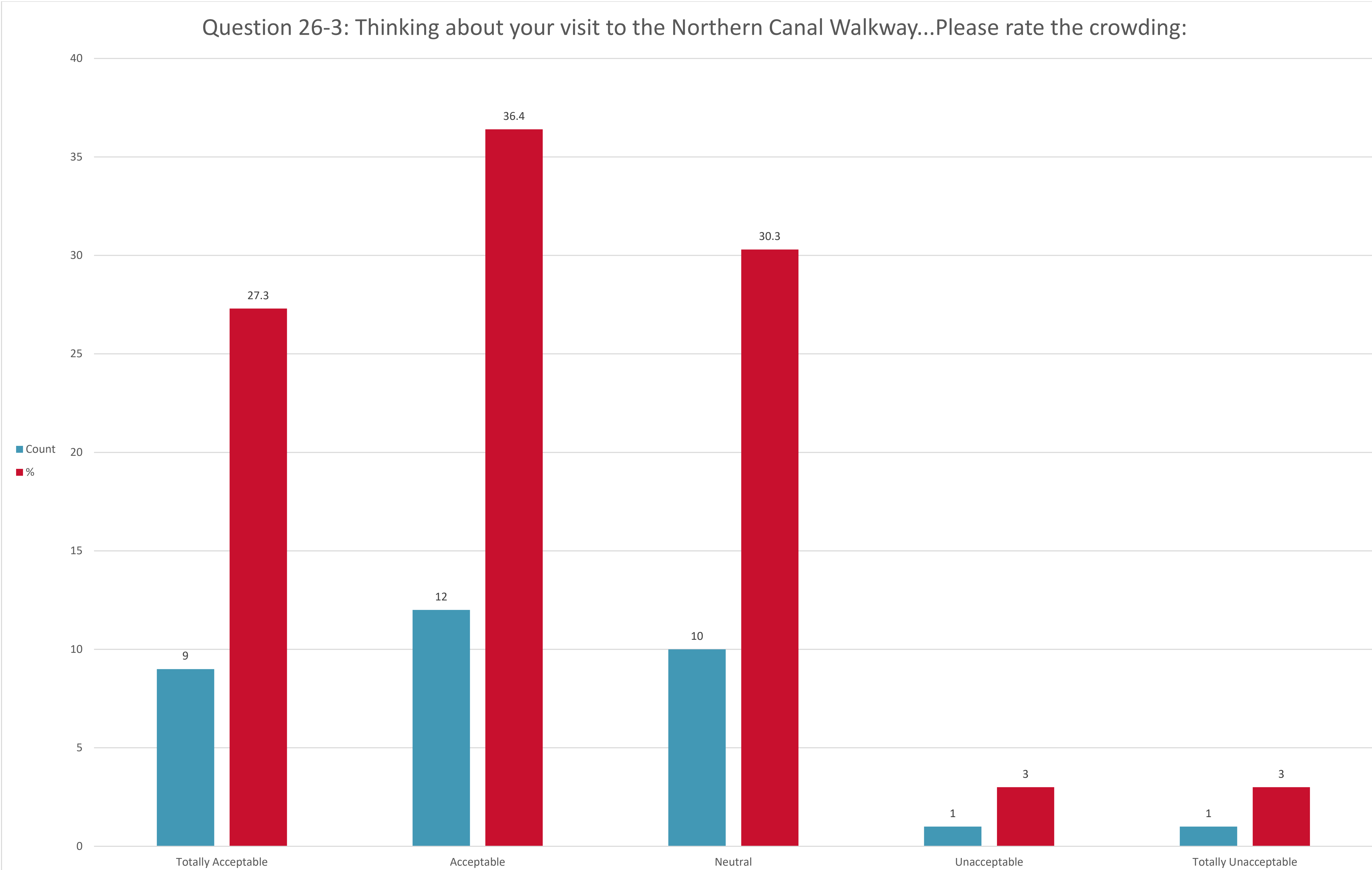
Question 25-6: Thinking about your visit to the Heritage Hike...Please rate the available amenities:
Count
4
3
2
1
0
0
3
2
1
2
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

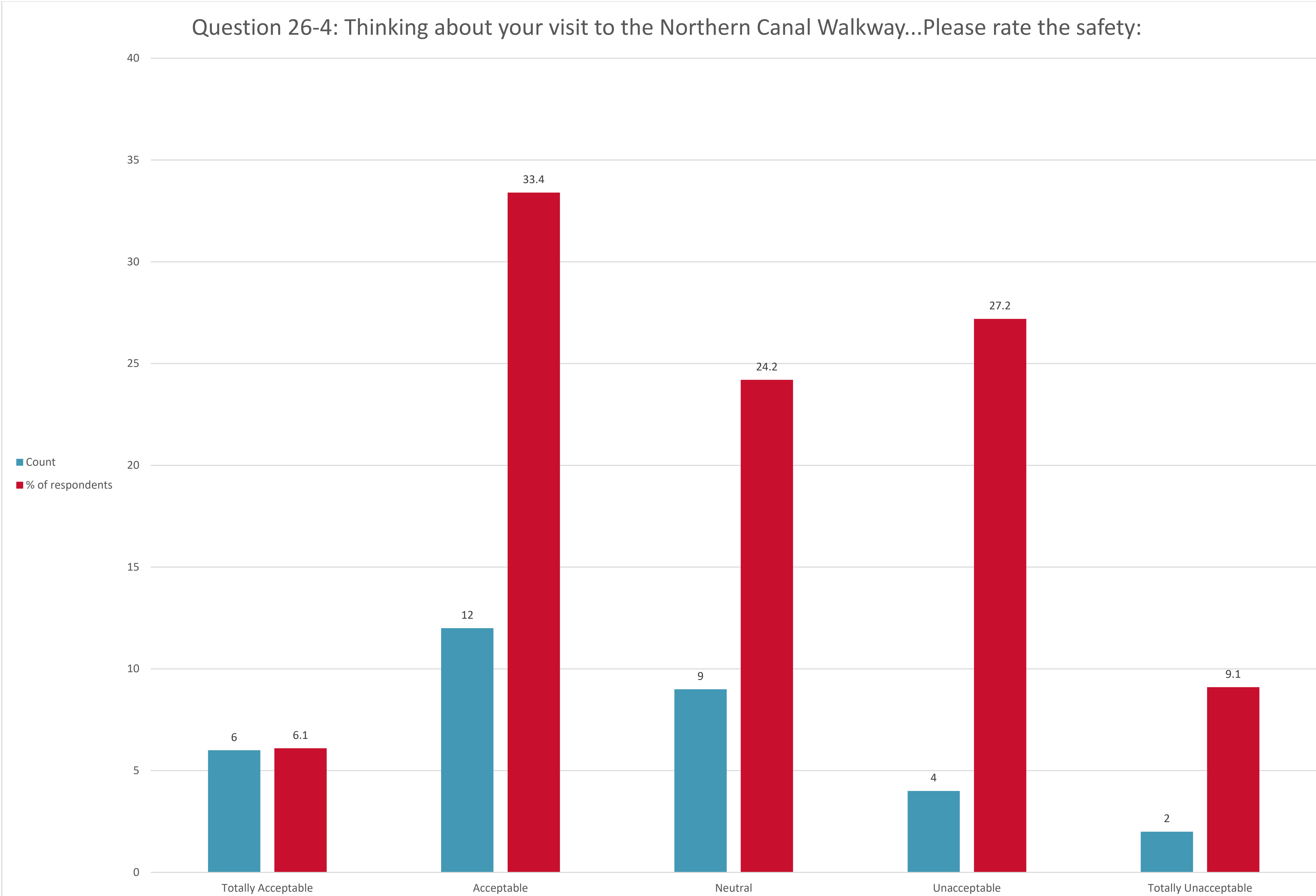

Question 25-7: Thinking about your visit to the Heritage Hike...please rate the river/canal flow:
3
2
1
0
Count
2
2
2
2
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 25-8: Thinking about your visit to the Heritage Hike...Please rate your overall experience:
4
3
2
1
0
Count
2
3
1
1
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

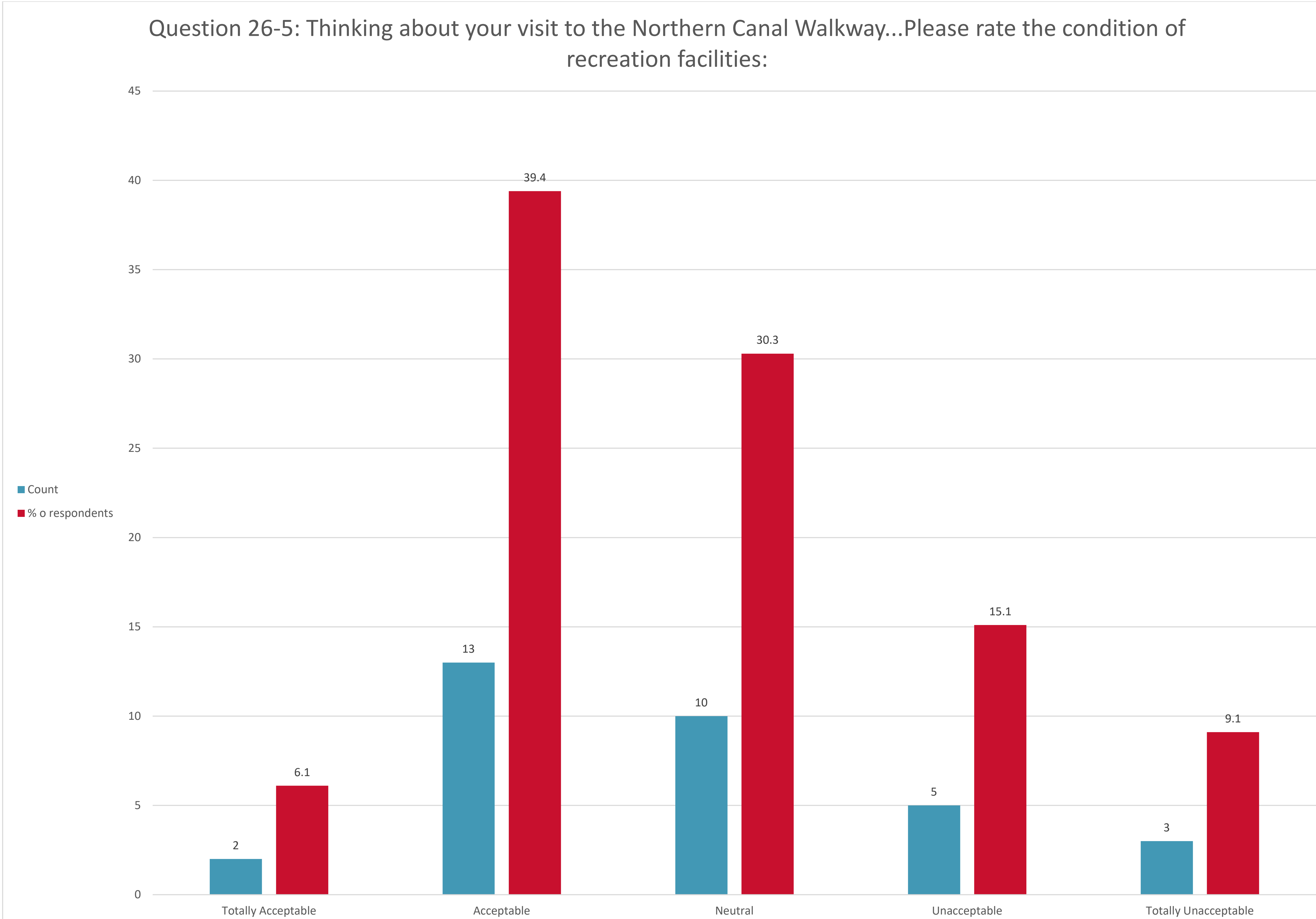

Question 26-1: Thinking about your visit to the Northern Canal Walkway...Please rate the accessbility:
Count
%
0
5
10
15
20
25
30
35
40
2
6.1
11
33.4
8
24.2
9
27.2
3
9.1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

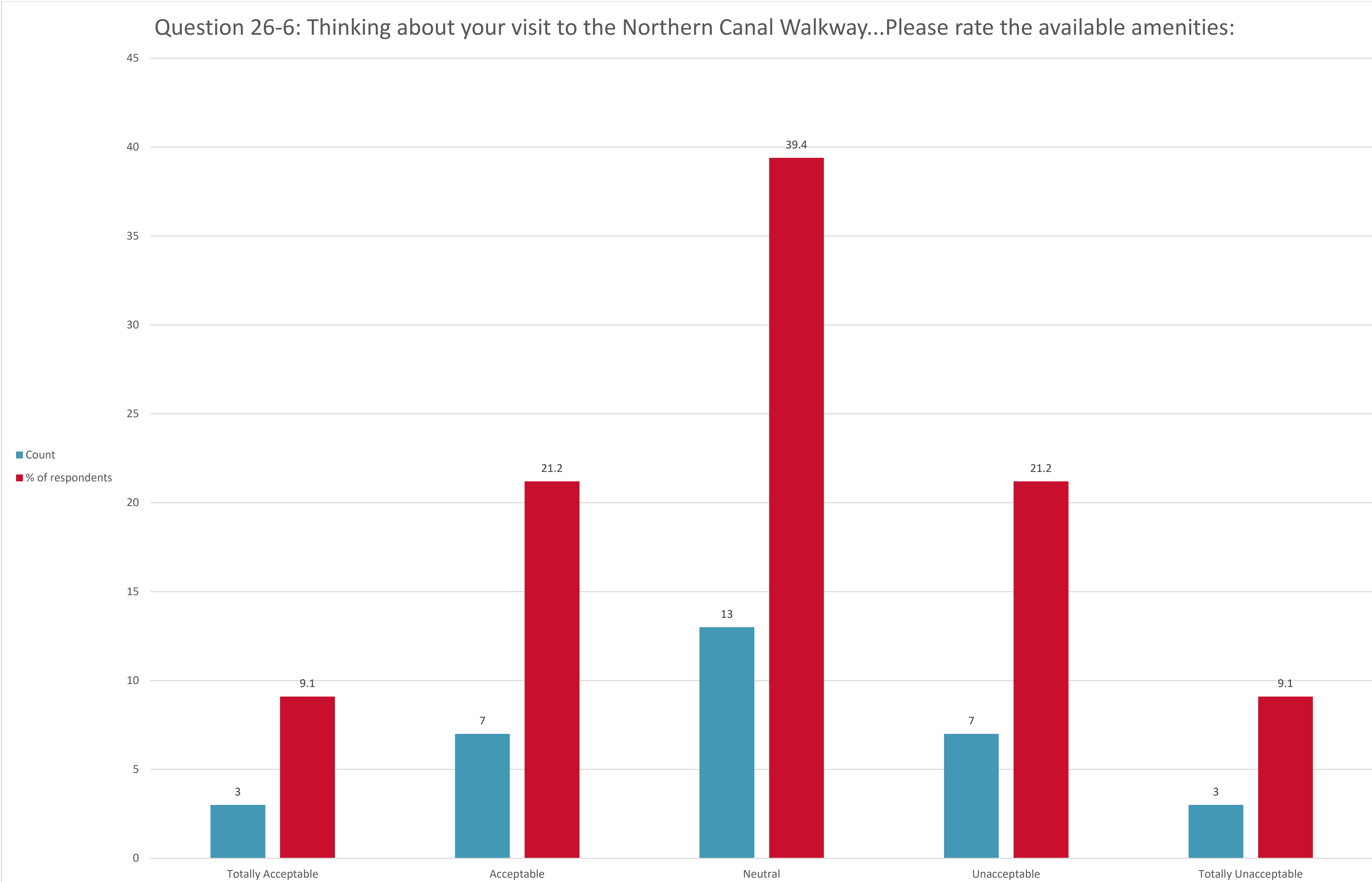

Question 26-2: Thinking about your visit to the Northern Canal Walkway...Please rate the parking:
Count
% of respondents
40
35
30
25
20
15
10
5
0
2
6.3
8
24.2
13
39.3
7
21.2
3
9
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

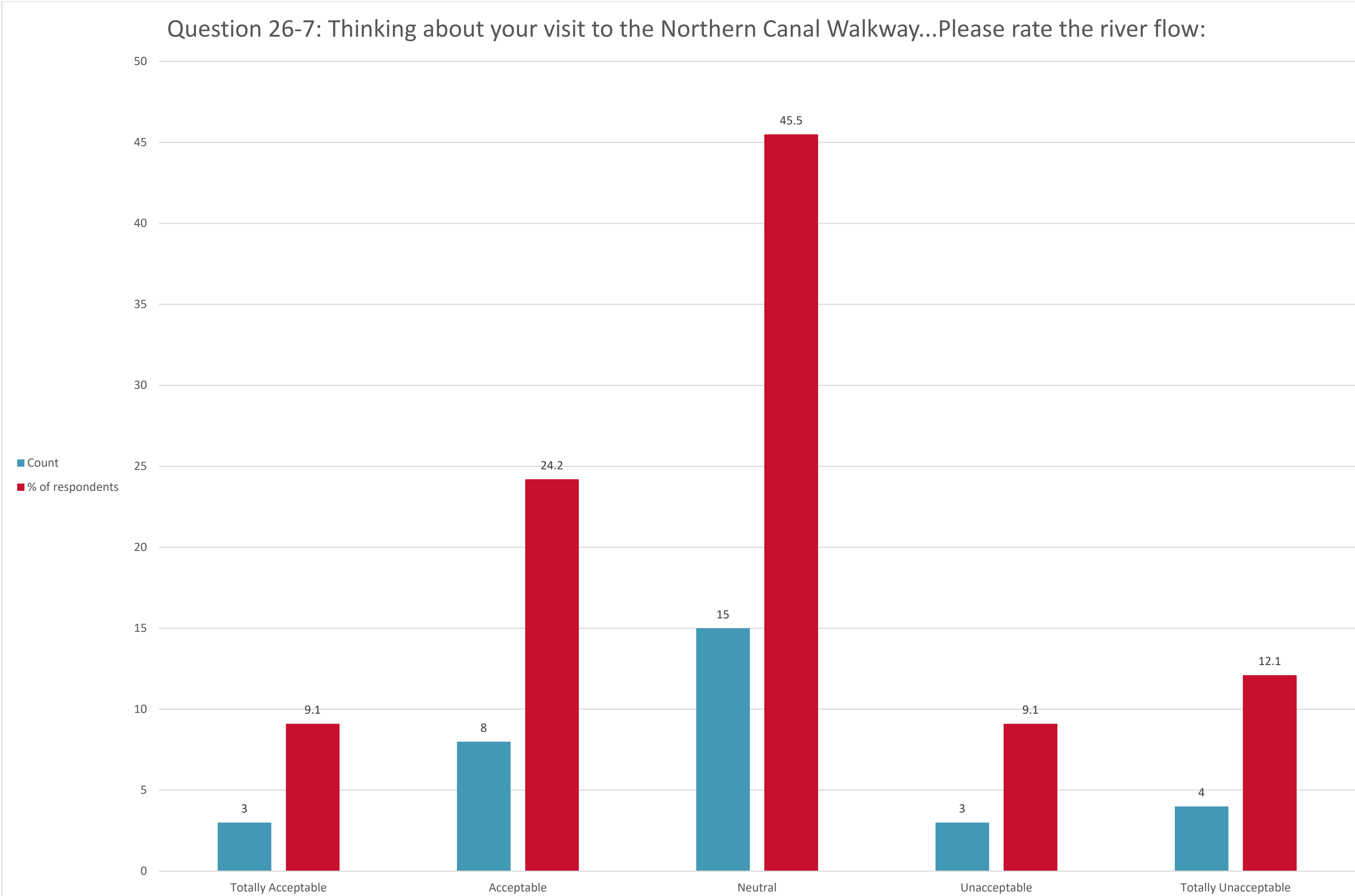

Question 26-3: Thinking about your visit to the Northern Canal Walkway...Please rate the crowding:
40
35
30
25
20
15
10
5
0
Count
%
27.3
36.4
30.3
9
12
10
1
3
1
3
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

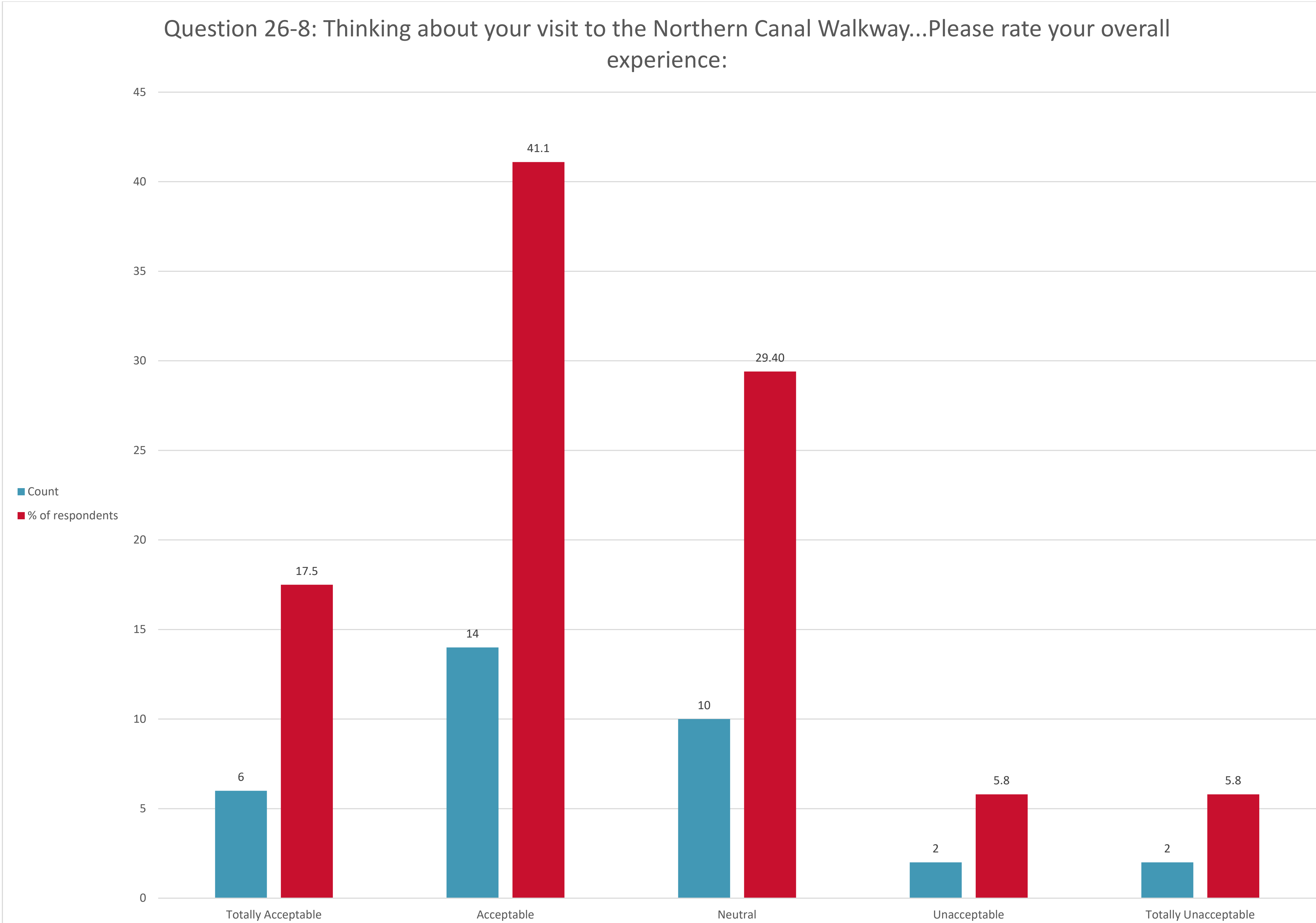


Question 26-4: Thinking about your visit to the Northern Canal Walkway...Please rate the safety:
Count
% of respondents
0
5
10
15
20
25
30
35
40
6
6.1
12
33.4
9
24.2
4
27.2
2
9.1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

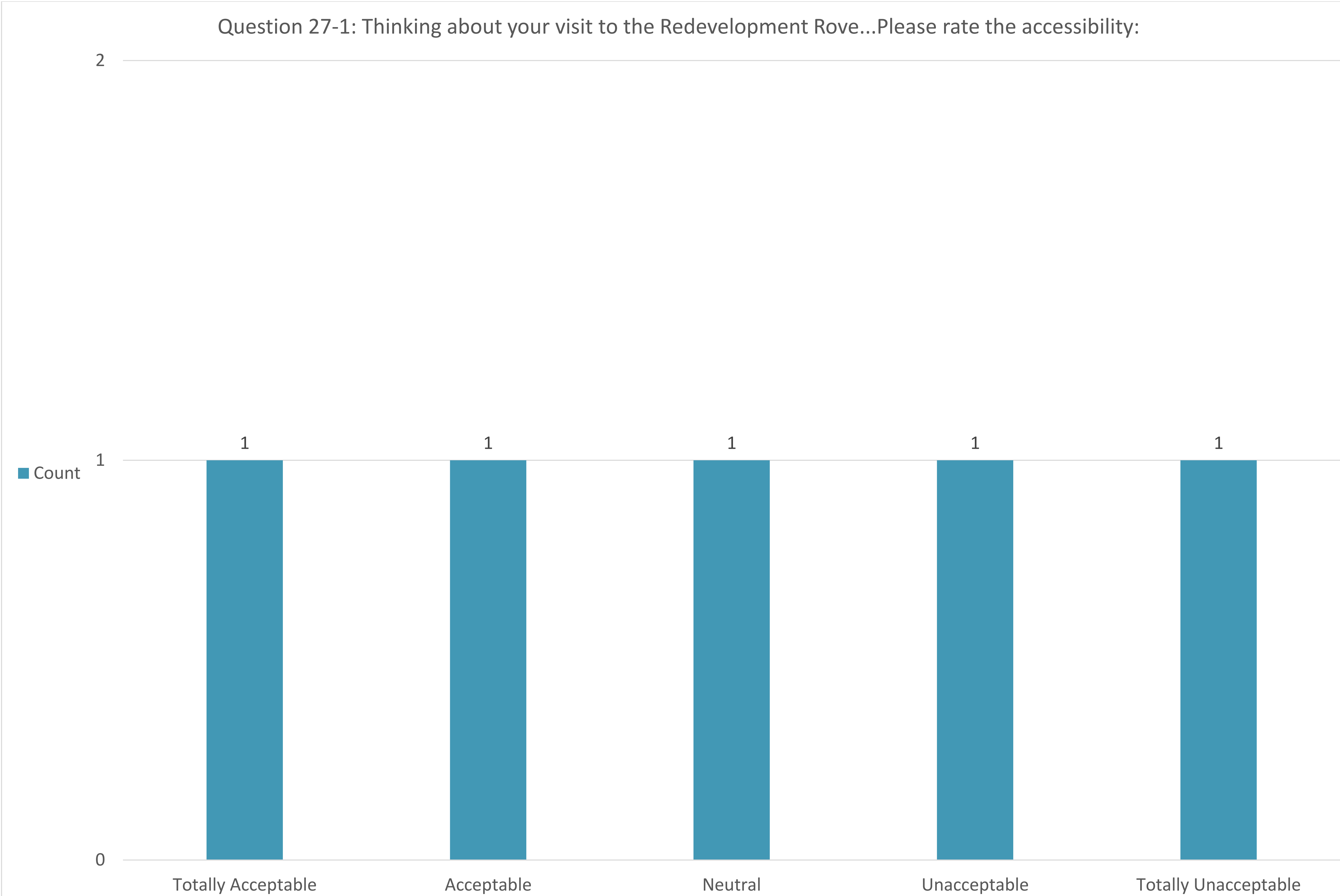

Question 26-5: Thinking about your visit to the Northern Canal Walkway...Please rate the condition of recreation facilities:
45
40
35
30
25
20
15
10
5
0
Count
% o respondents
2
6.1
13
39.4
10
30.3
5
15.1
3
9.1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 26-6: Thinking about your visit to the Northern Canal Walkway...Please rate the available amenities:
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
3
9.1
7
21.2
13
39.4
7
21.2
3
9.1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 26-7: Thinking about your visit to the Northern Canal Walkway...Please rate the river flow:
Count
% of respondents
50
45
40
35
30
25
20
15
10
5
0
3
9.1
8
24.2
15
45.5
3
9.1
4
12.1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

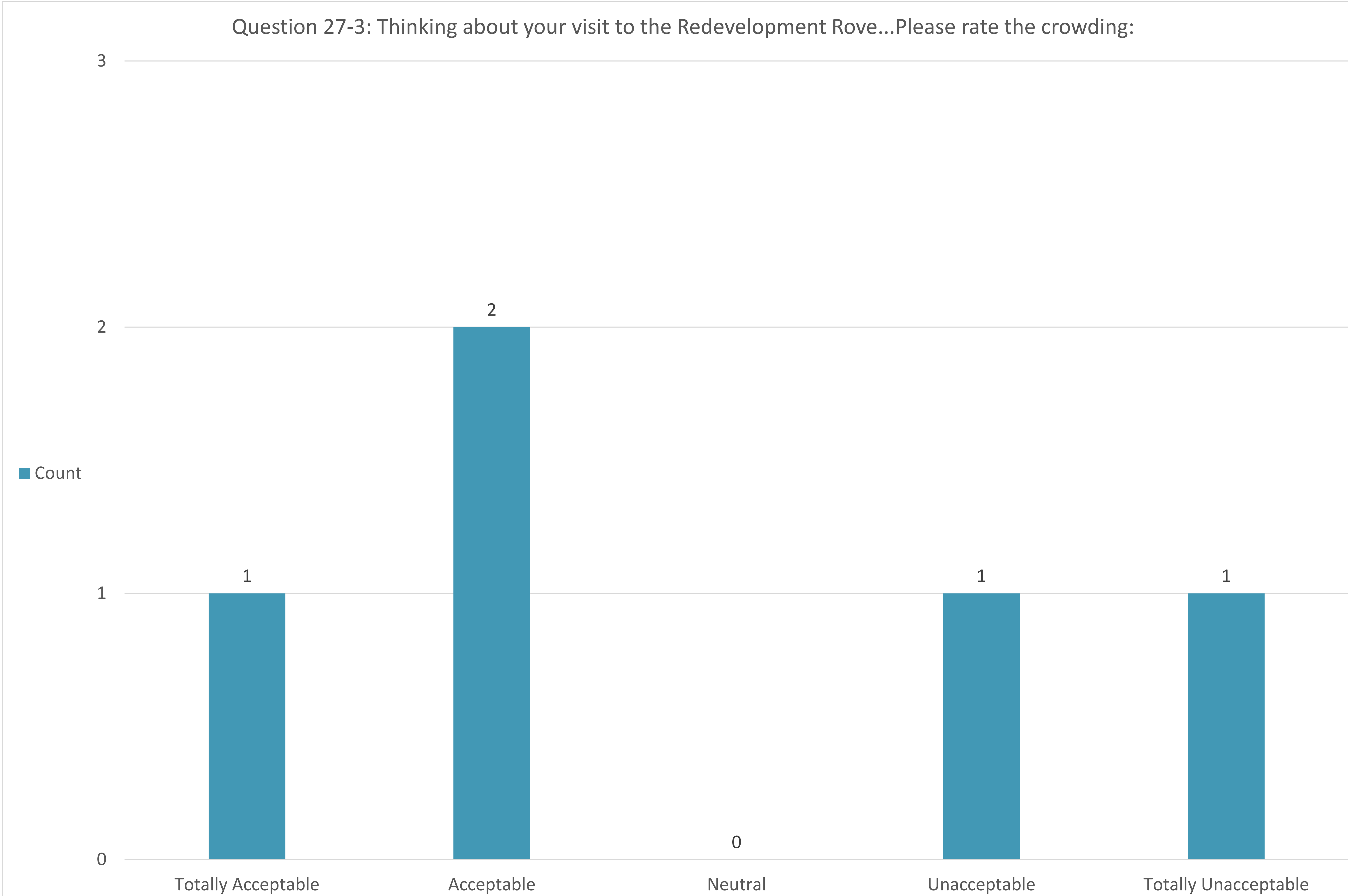


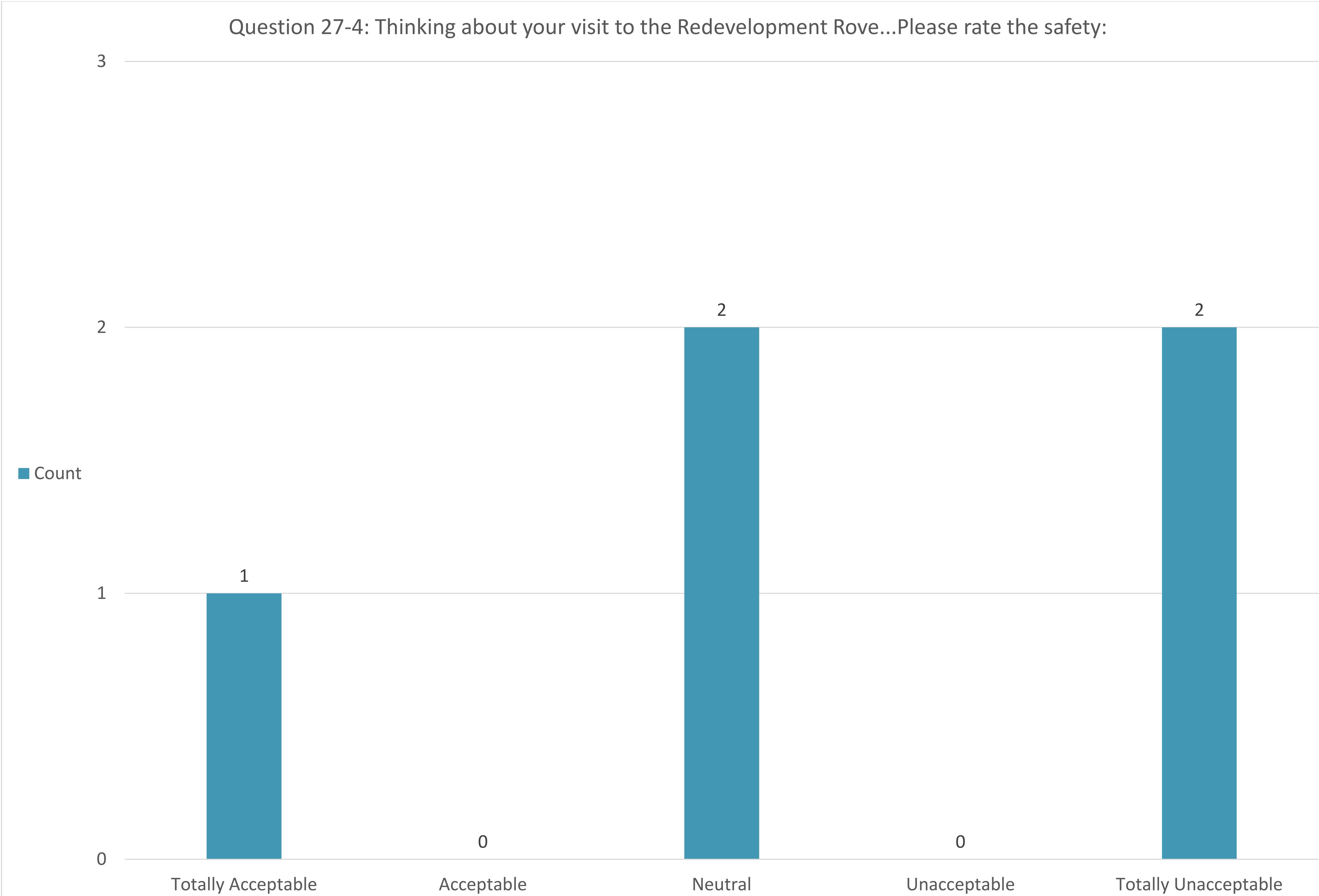
Question 26-8: Thinking about your visit to the Northern Canal Walkway...Please rate your overall experience:
Count
% of respondents
45
40
35
30
25
20
15
10
5
0
6
17.5
14
41.1
10
29.40
2
5.8
2
5.8
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

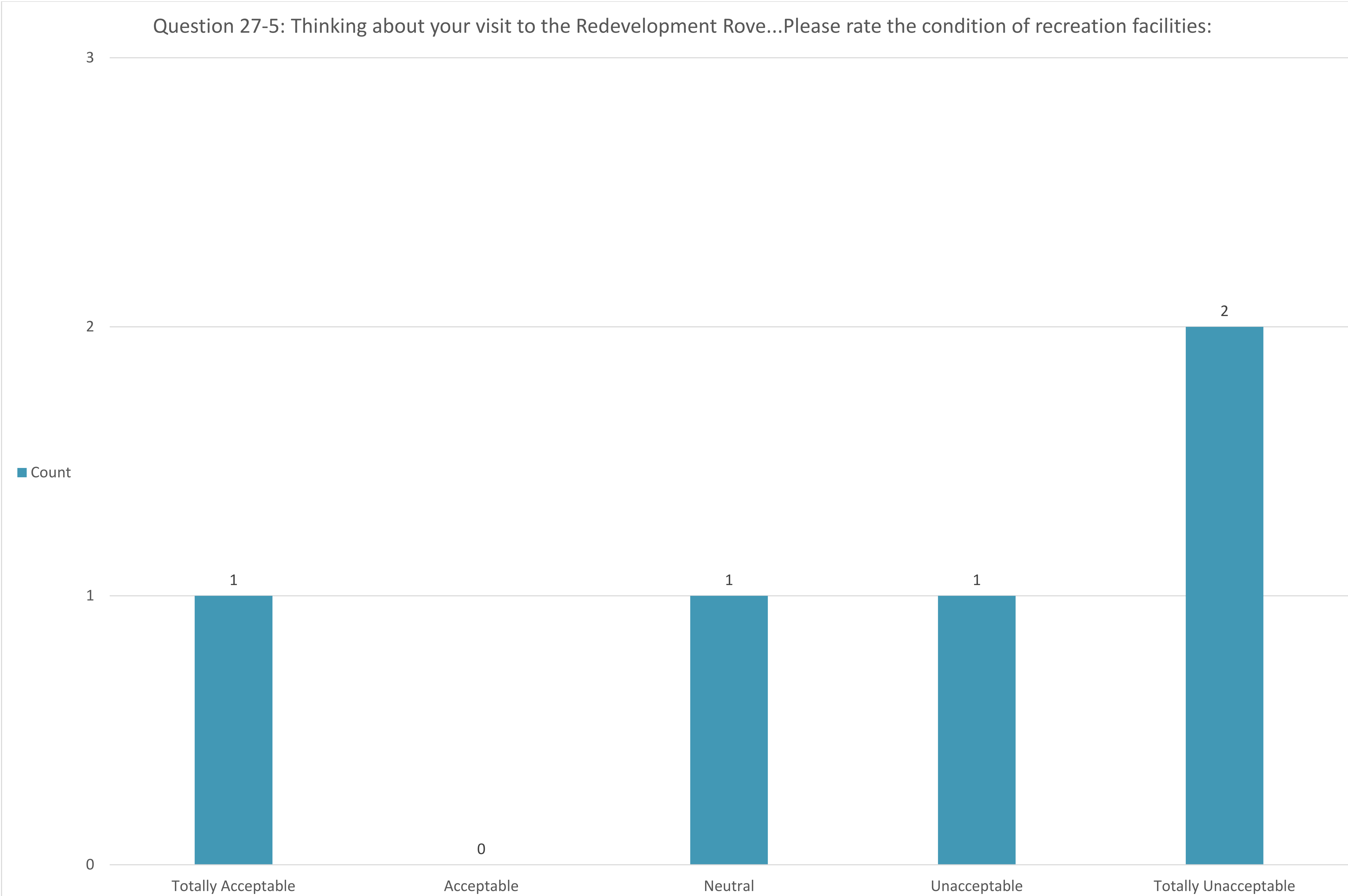


Question 27-1: Thinking about your visit to the Redevelopment Rove...Please rate the accessibility:
2
1
0
Count
1
1
1
1
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

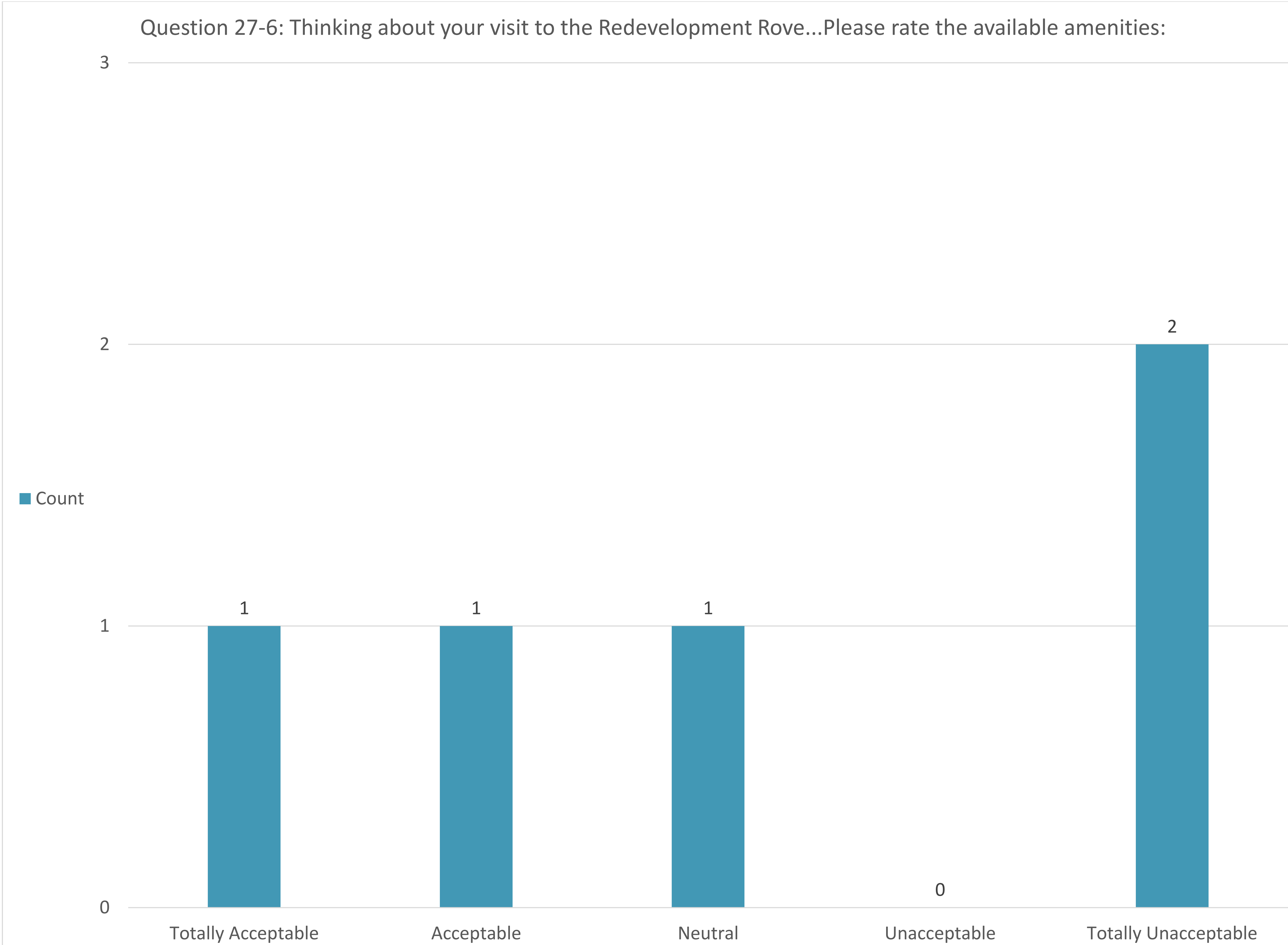

Question 27-2: Thinking about your visit to the Redevelopment Rove...Please rate the parking:
3
2
1
0
Count
0
1
1
2
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

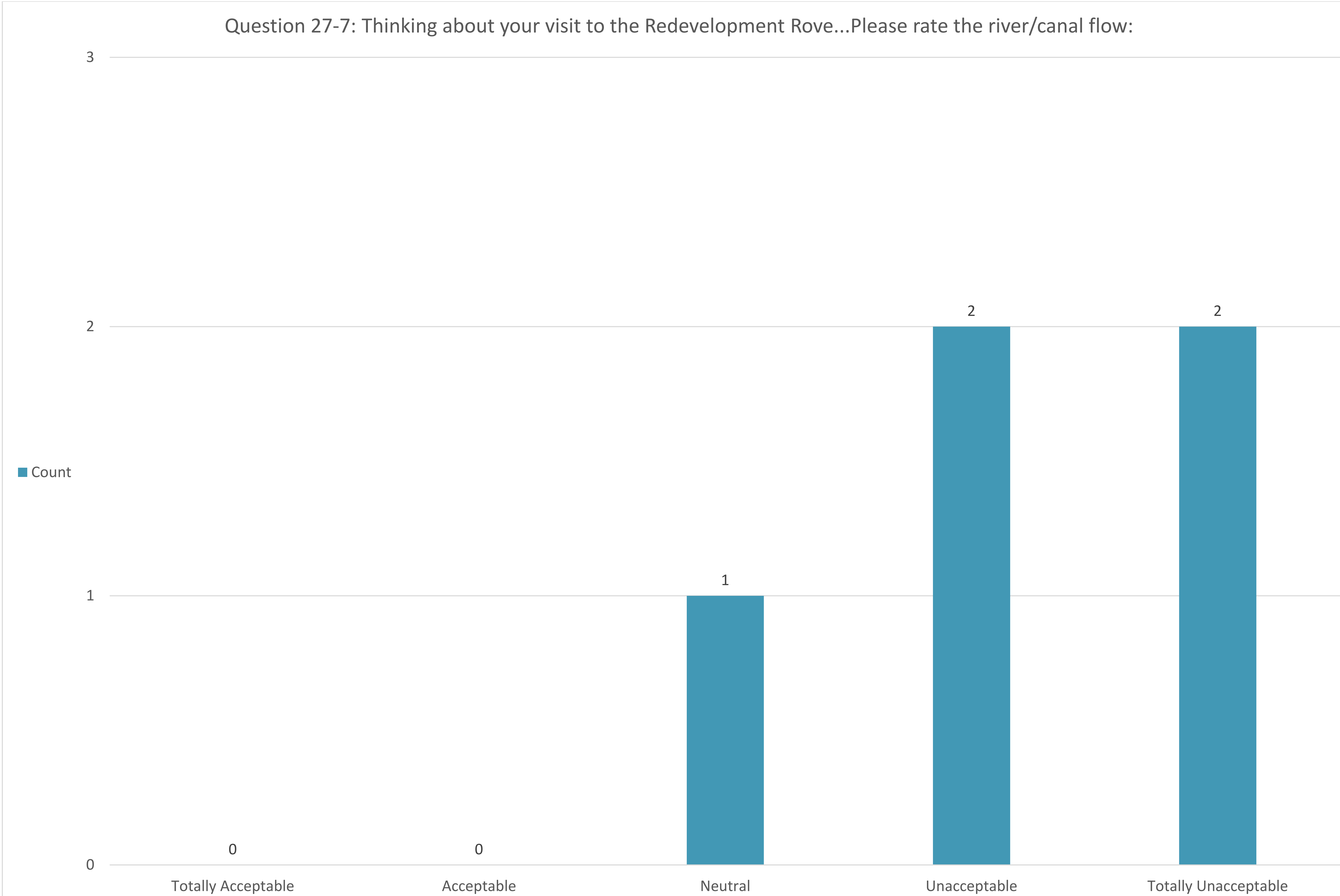

Question 27-3: Thinking about your visit to the Redevelopment Rove...Please rate the crowding:
3
2
1
0
Count
1
2
0
1
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 27-4: Thinking about your visit to the Redevelopment Rove...Please rate the safety:
3
2
1
0
Count
1
0
2
0
2
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

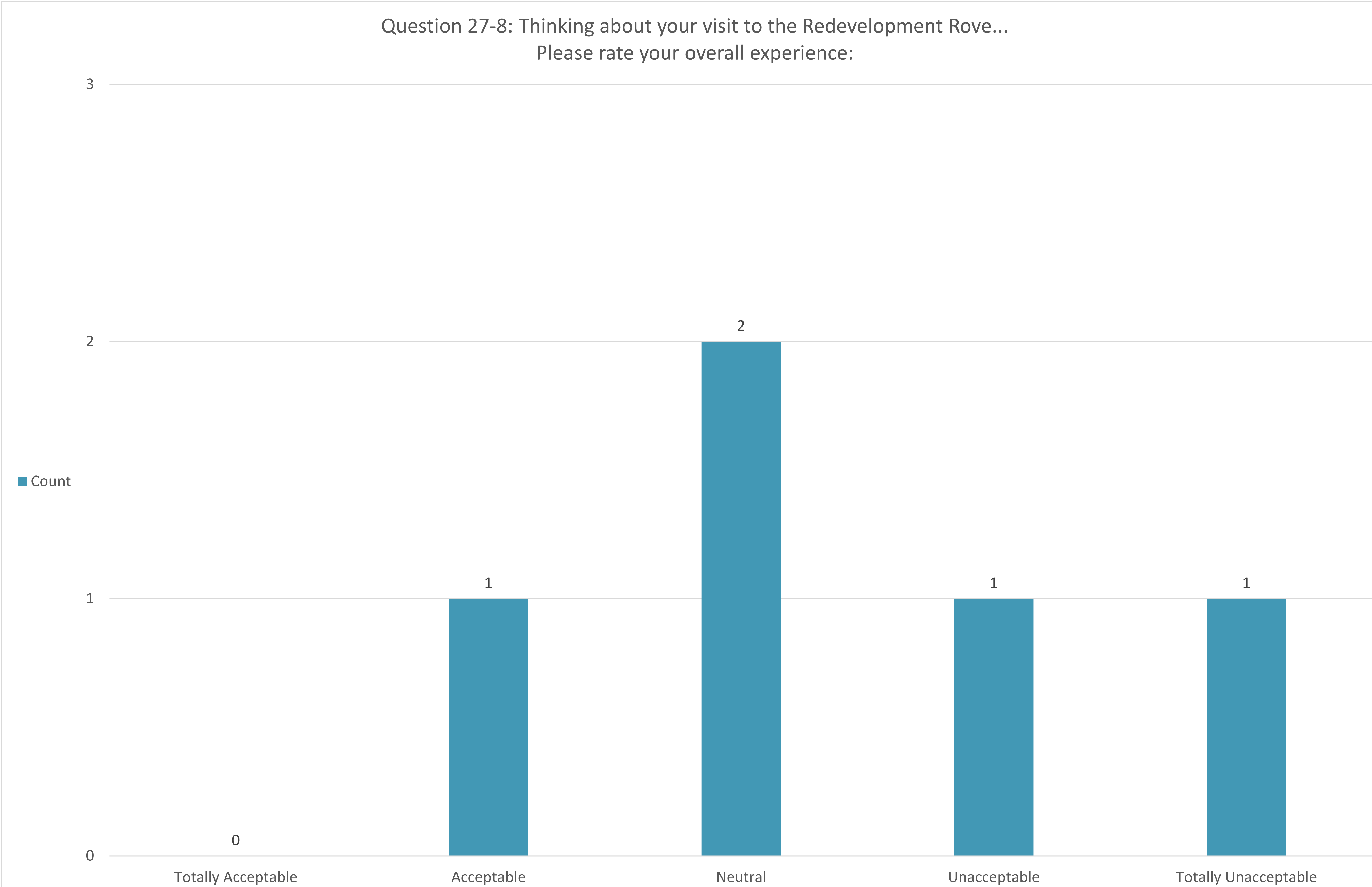


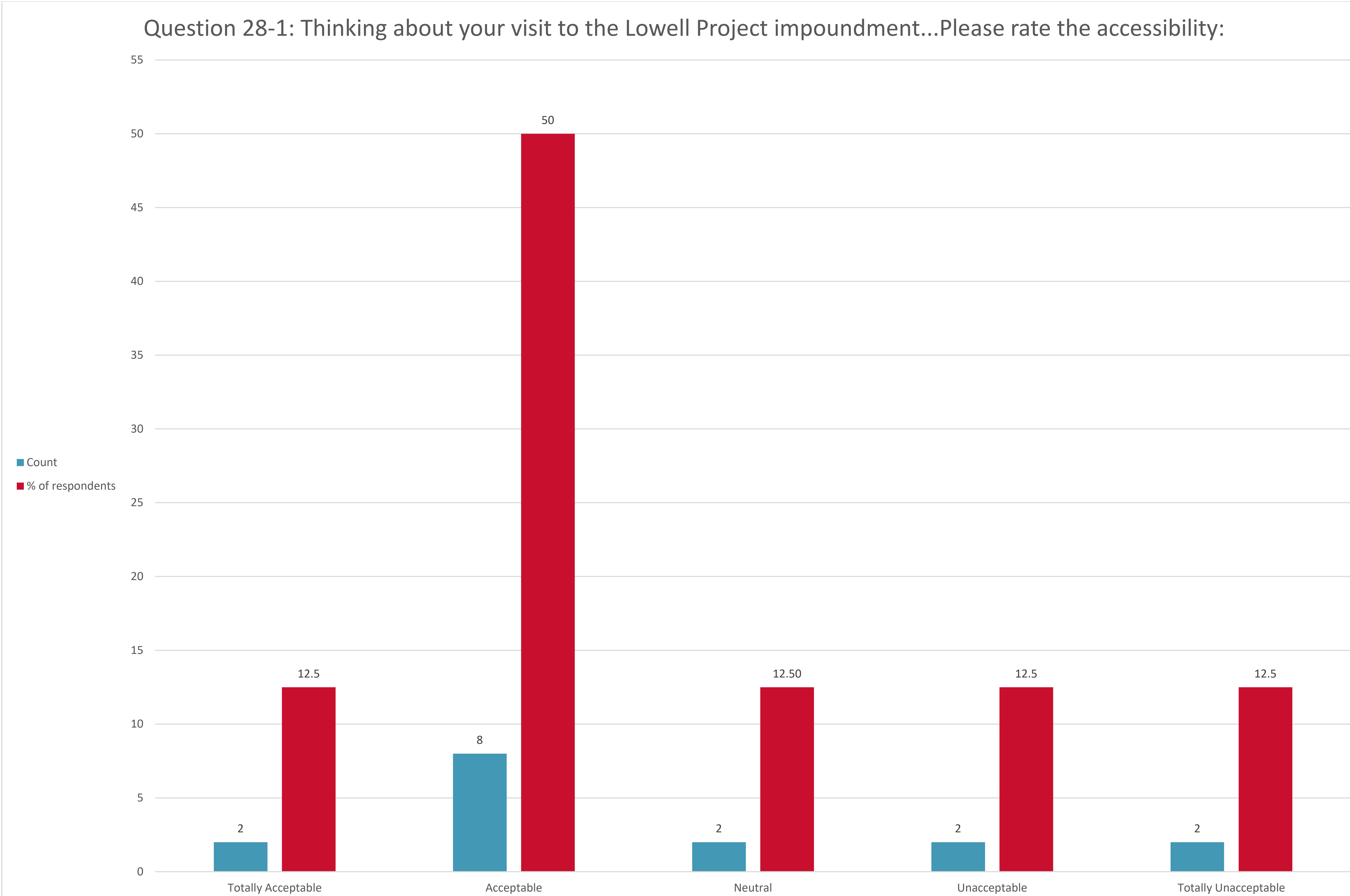
Question 27-5: Thinking about your visit to the Redevelopment Rove...Please rate the condition of recreation facilities:
3
2
1
0
Count
1
0
1
1
2
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

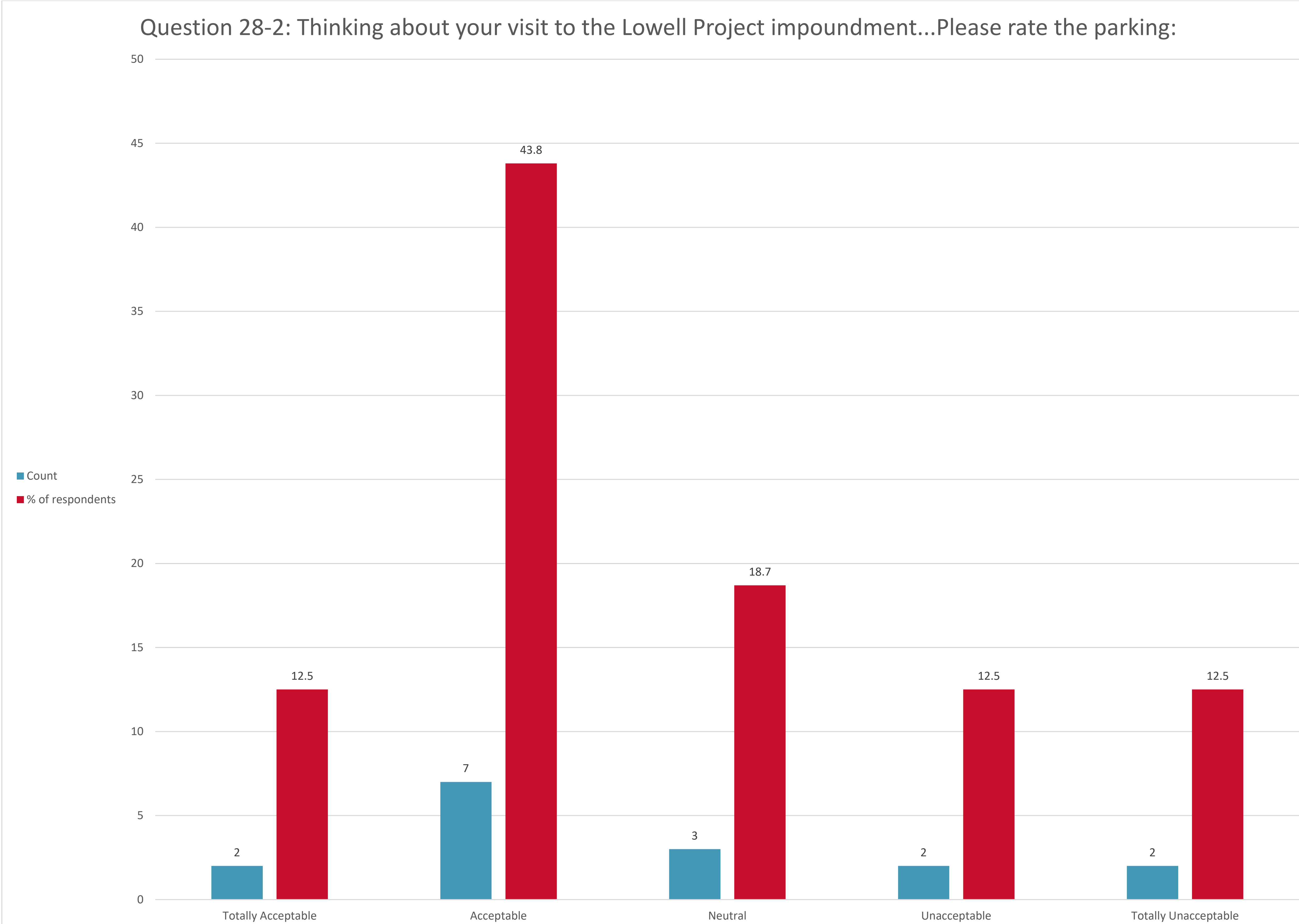

Question 27-6: Thinking about your visit to the Redevelopment Rove...Please rate the available amenities:
3
2
1
0
Count
1
1
1
0
2
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

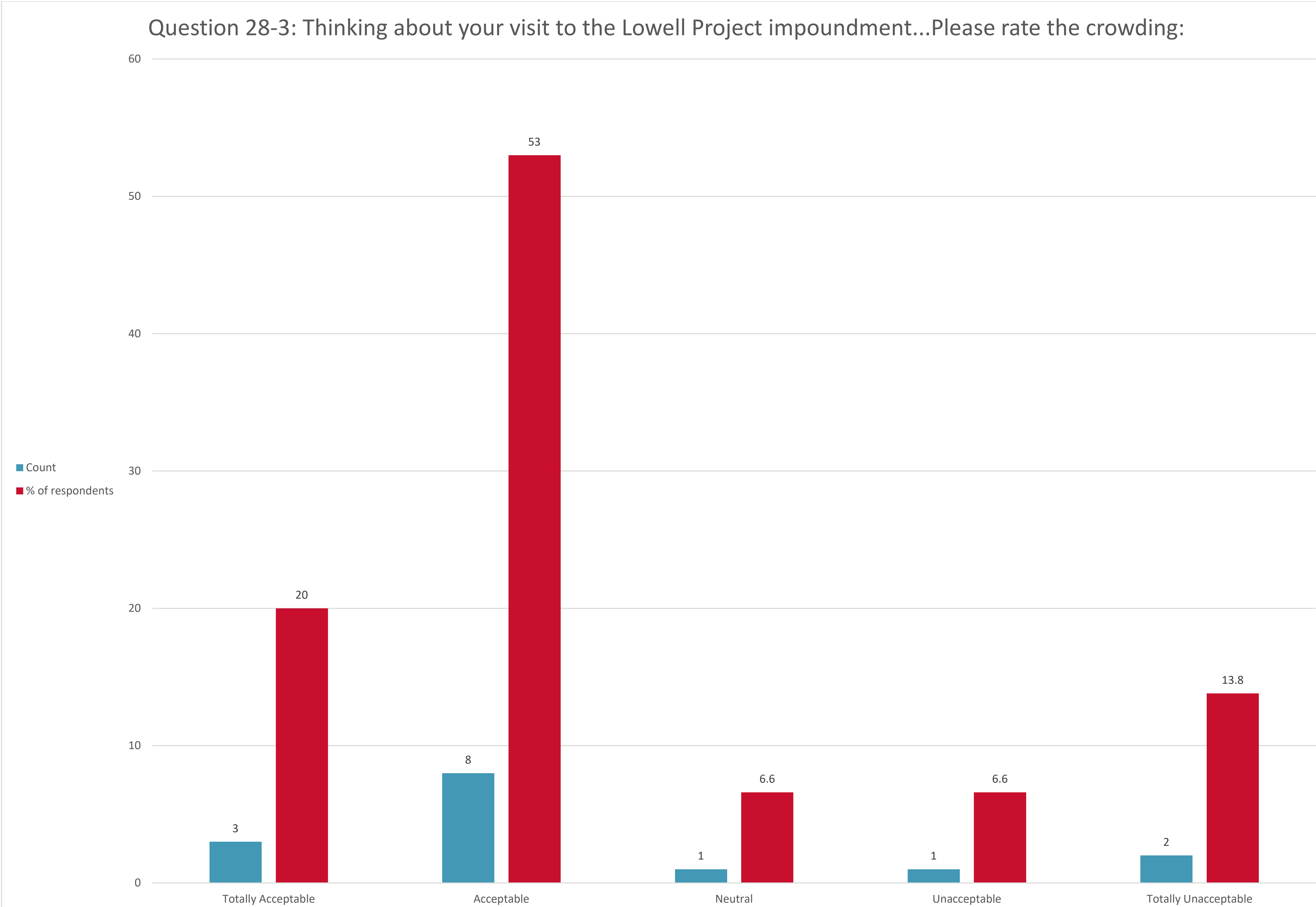


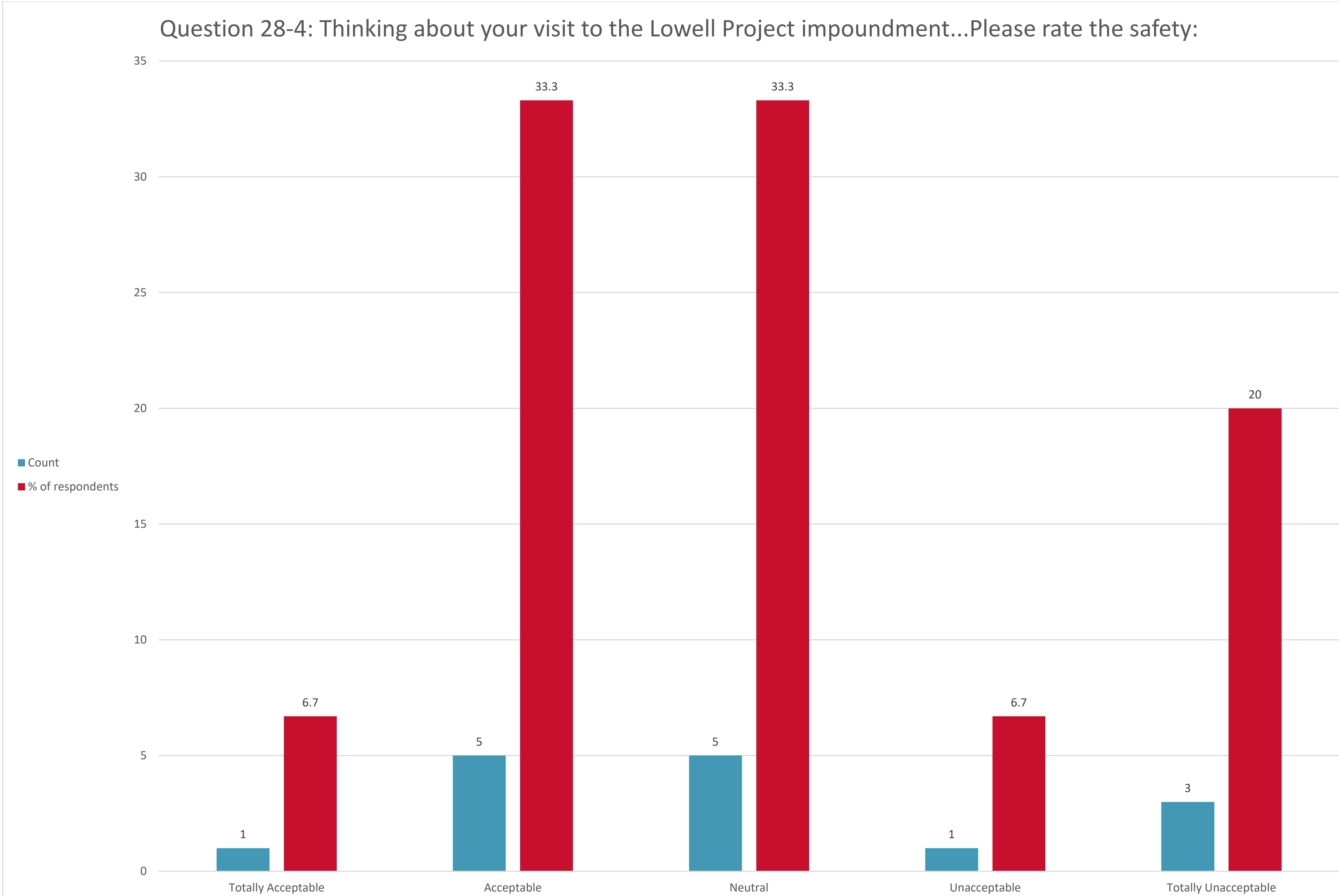
Question 27-7: Thinking about your visit to the Redevelopment Rove...Please rate the river/canal flow:
3
2
1
0
Count
0
0
1
2
2
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 27-8: Thinking about your visit to the Redevelopment Rove...
Please rate your overall experience:
3
2
1
0
Count
0
1
2
1
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

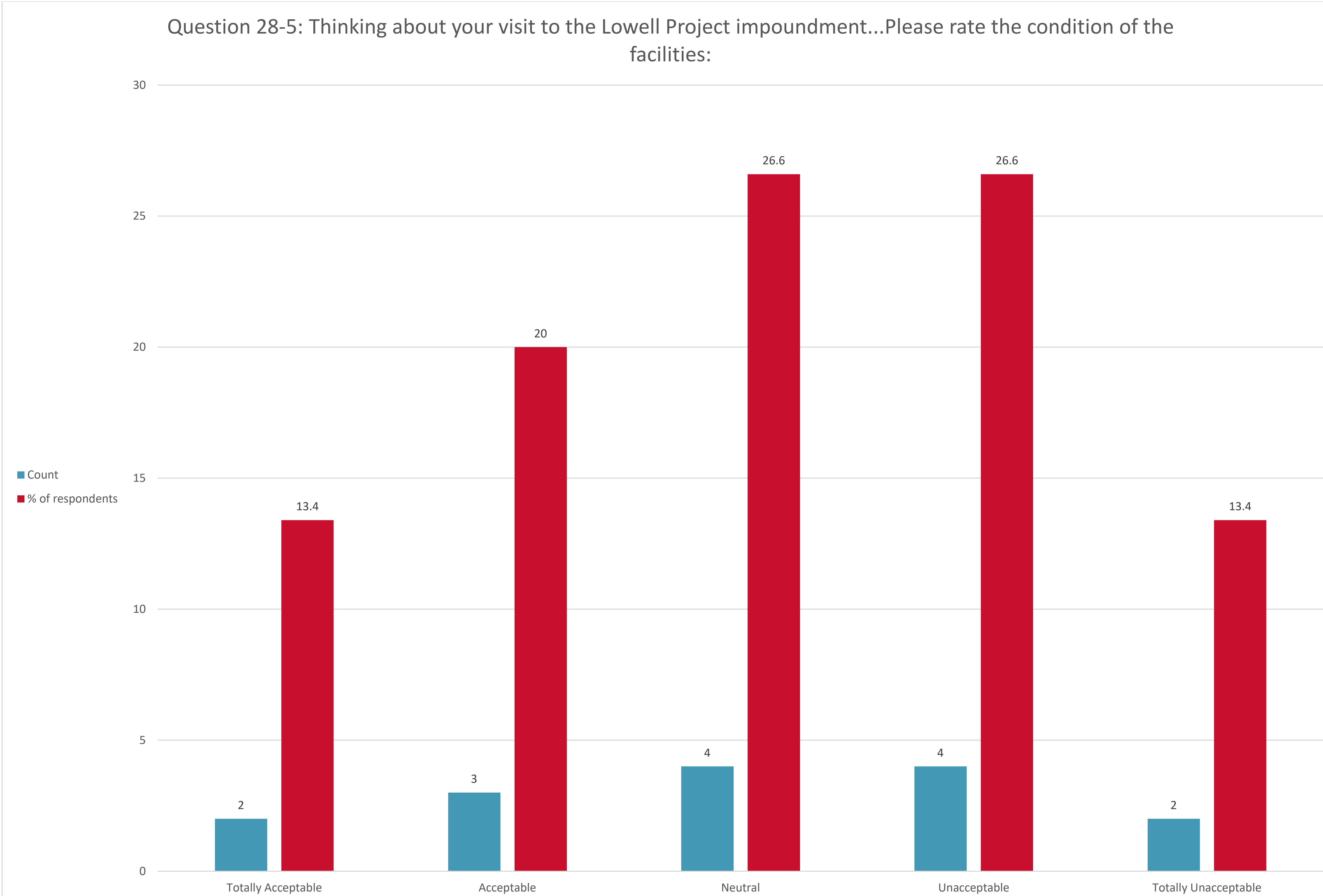

Question 28-1: Thinking about your visit to the Lowell Project impoundment...Please rate the accessibility:
55
50
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
2
12.5
8
50
2
12.50
2
12.5
2
12.5
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

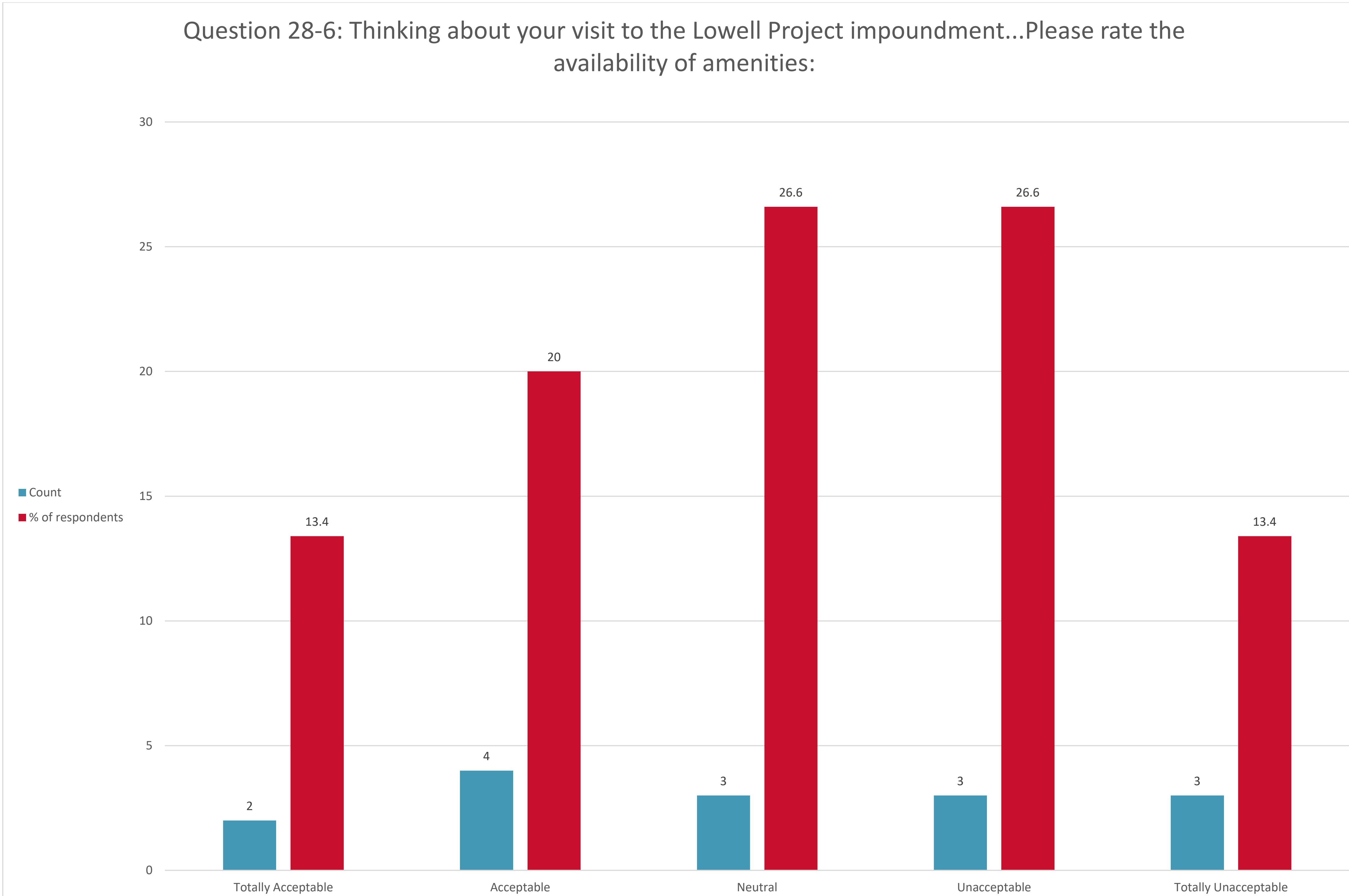

Question 28-2: Thinking about your visit to the Lowell Project impoundment...Please rate the parking:
50
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
2
12.5
7
43.8
3
18.7
2
12.5
2
12.5
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

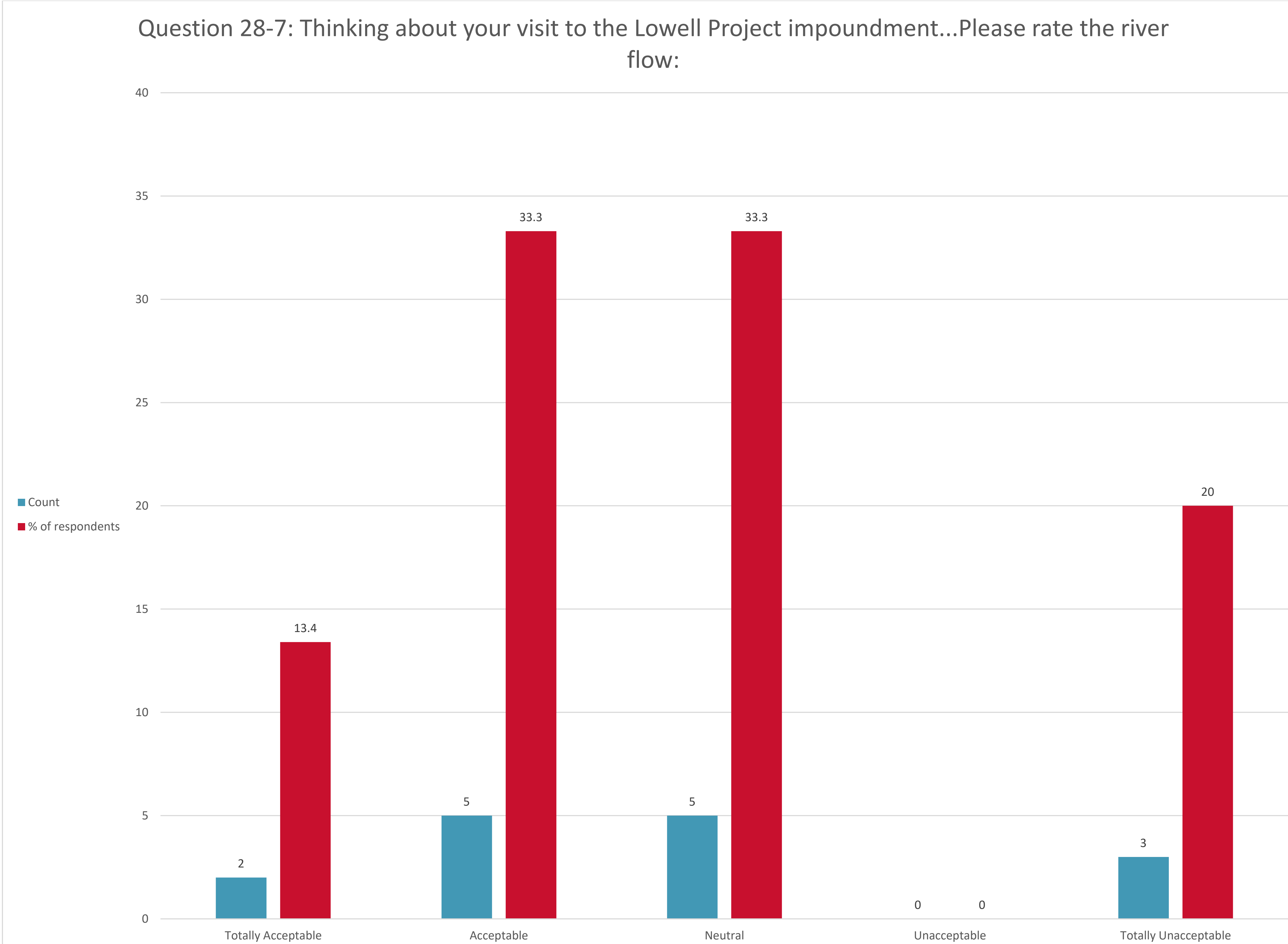

Question 28-3: Thinking about your visit to the Lowell Project impoundment...Please rate the crowding:
60
50
40
30
20
10
0
Count
% of respondents
53
20
3
8
1
6.6
1
6.6
2
13.8
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

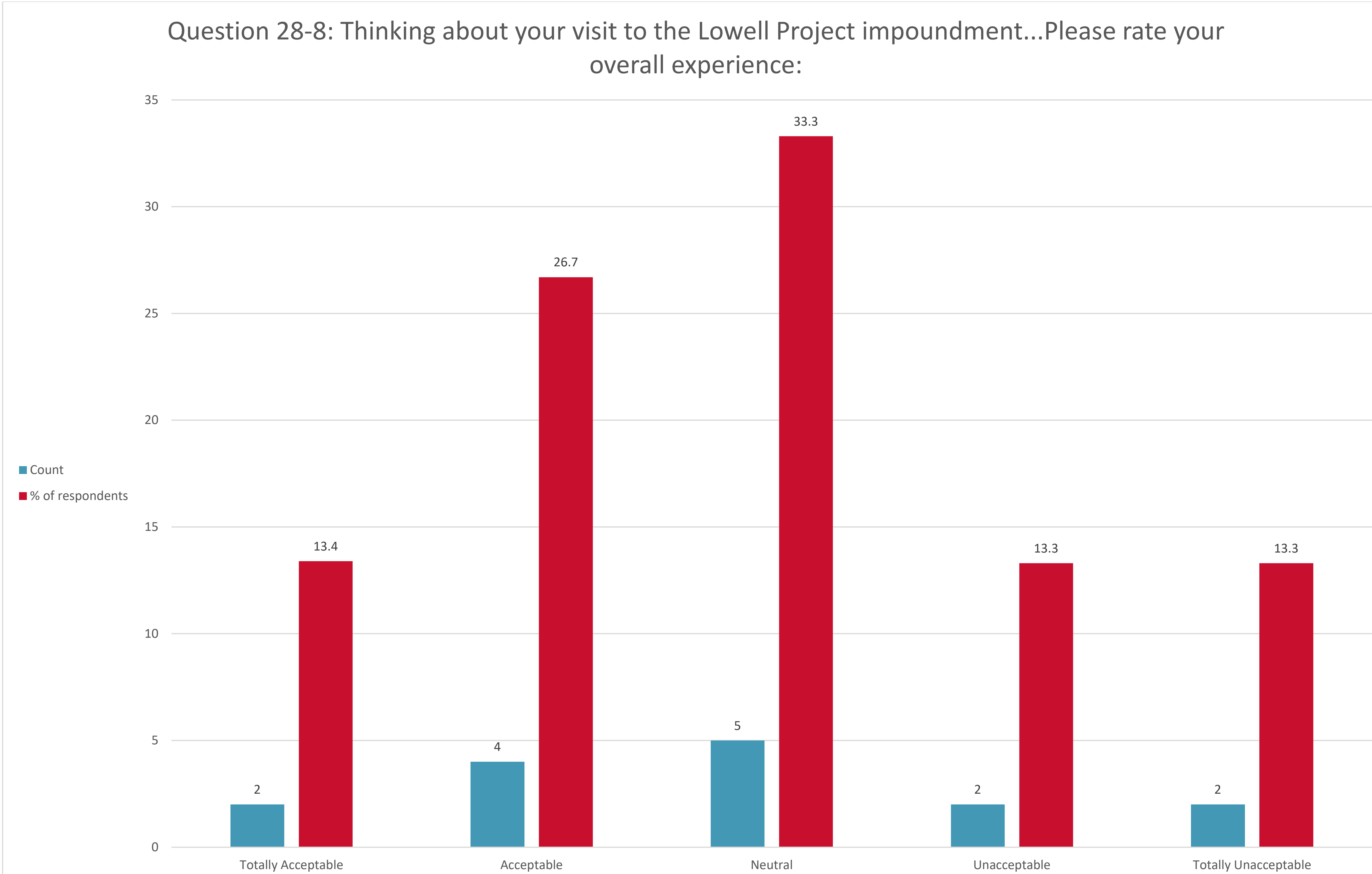


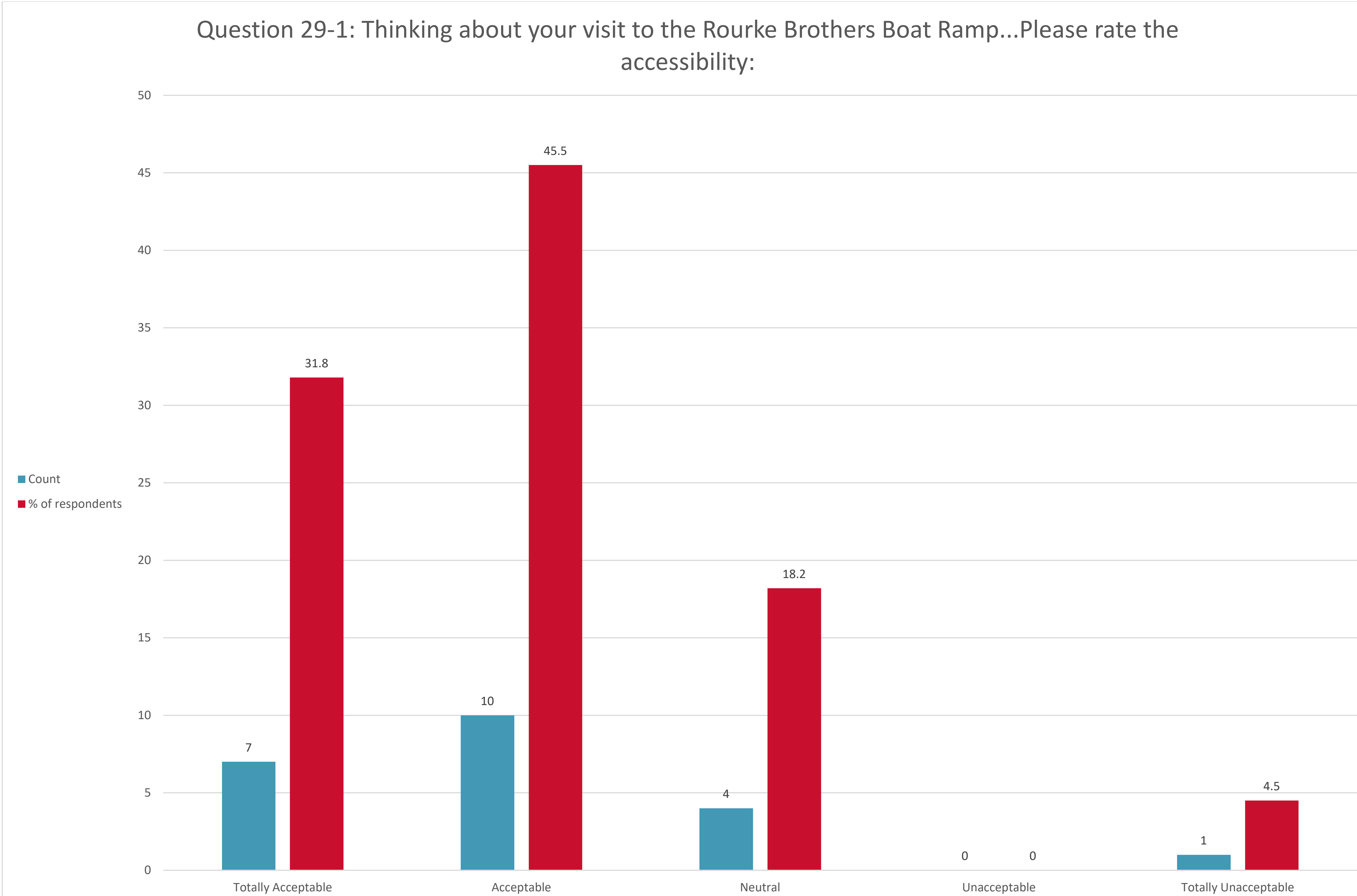
Question 28-4: Thinking about your visit to the Lowell Project impoundment...Please rate the safety:
35
30
25
20
15
10
5
0
Count
% of respondents
1
6.7
5
33.3
5
33.3
1
6.7
3
20
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

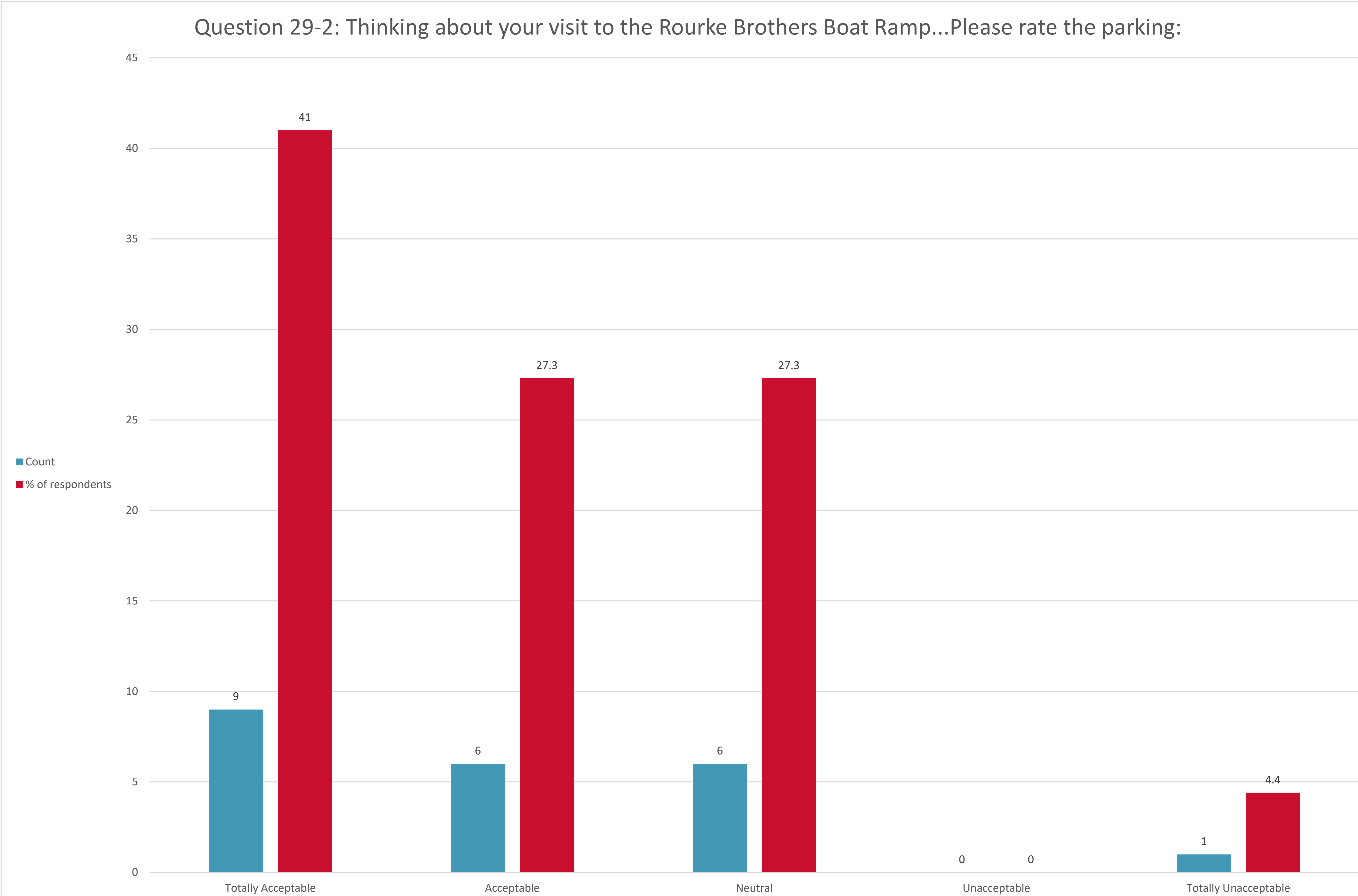

Question 28-5: Thinking about your visit to the Lowell Project impoundment...Please rate the condition of the facilities:
Count
% of respondents
30
25
20
15
10
5
0
2
13.4
3
20
4
26.6
4
26.6
2
13.4
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

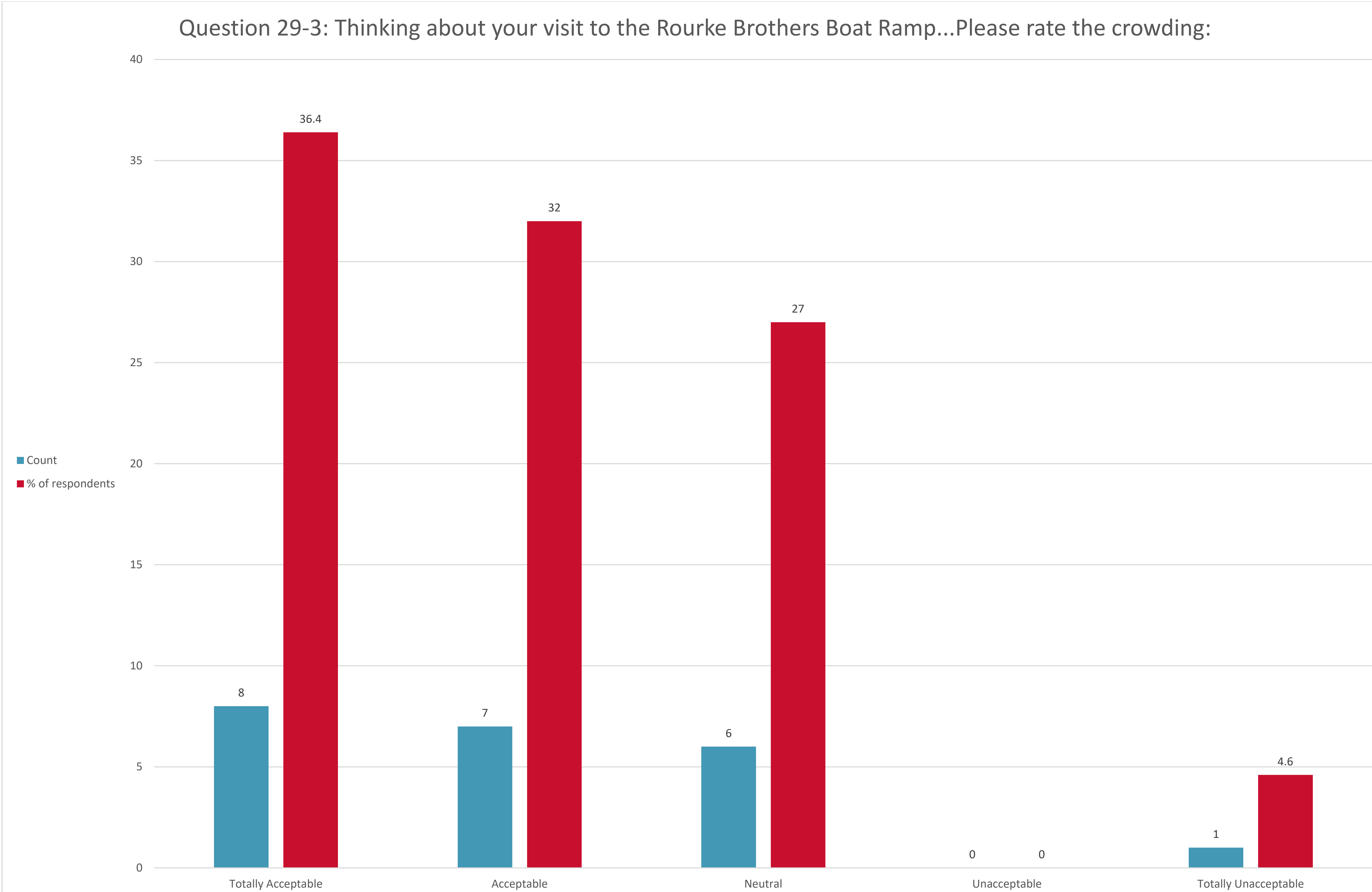

Question 28-6: Thinking about your visit to the Lowell Project impoundment...Please rate the availability of amenities:
Count
% of respondents
30
25
20
15
10
5
0
2
13.4
4
20
3
26.6
3
26.6
3
13.4
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

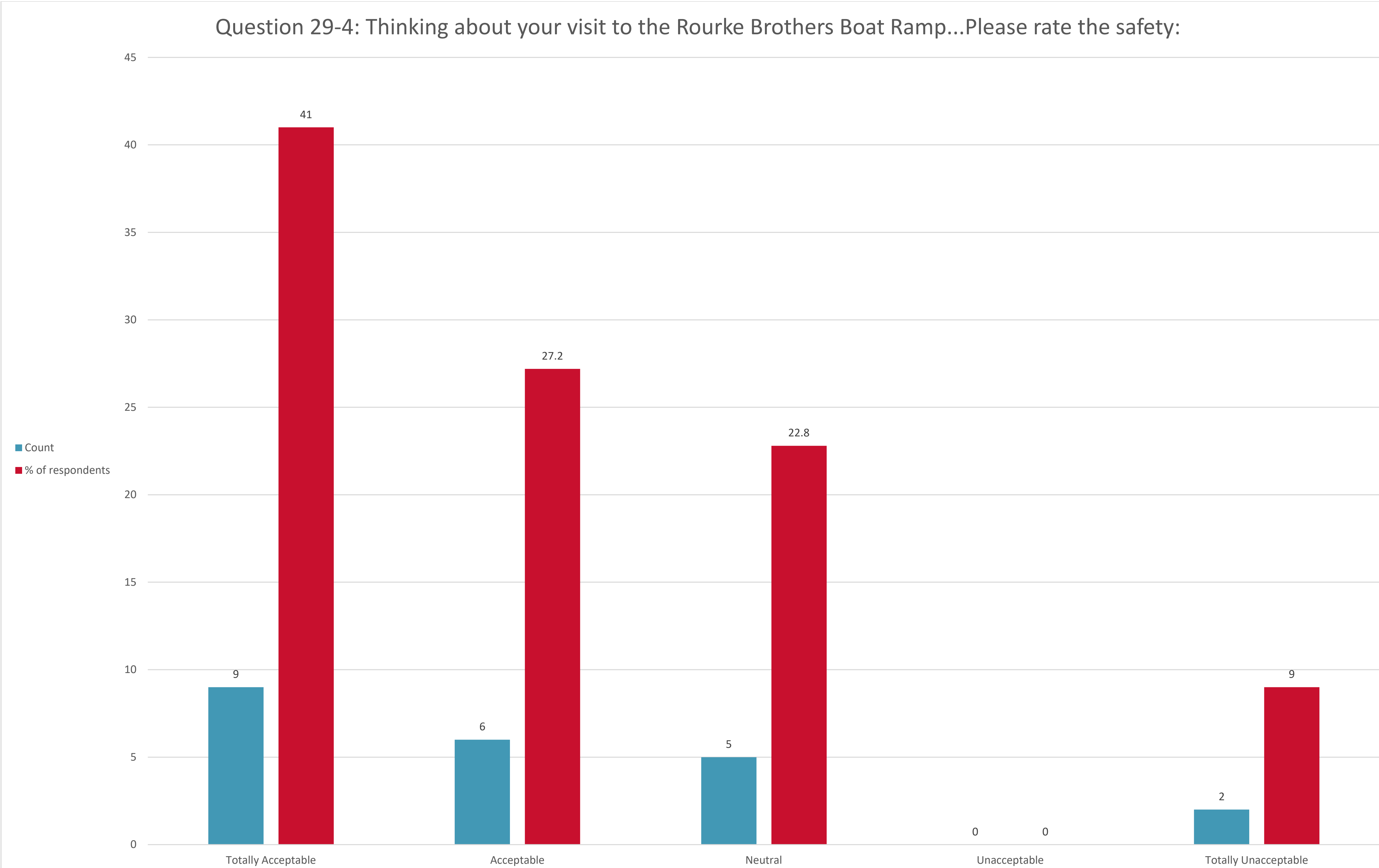

Question 28-7: Thinking about your visit to the Lowell Project impoundment...Please rate the river flow:
40
35
30
25
20
15
10
5
0
Count
% of respondents
2
13.4
5
33.3
5
33.3
0
0
3
20
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

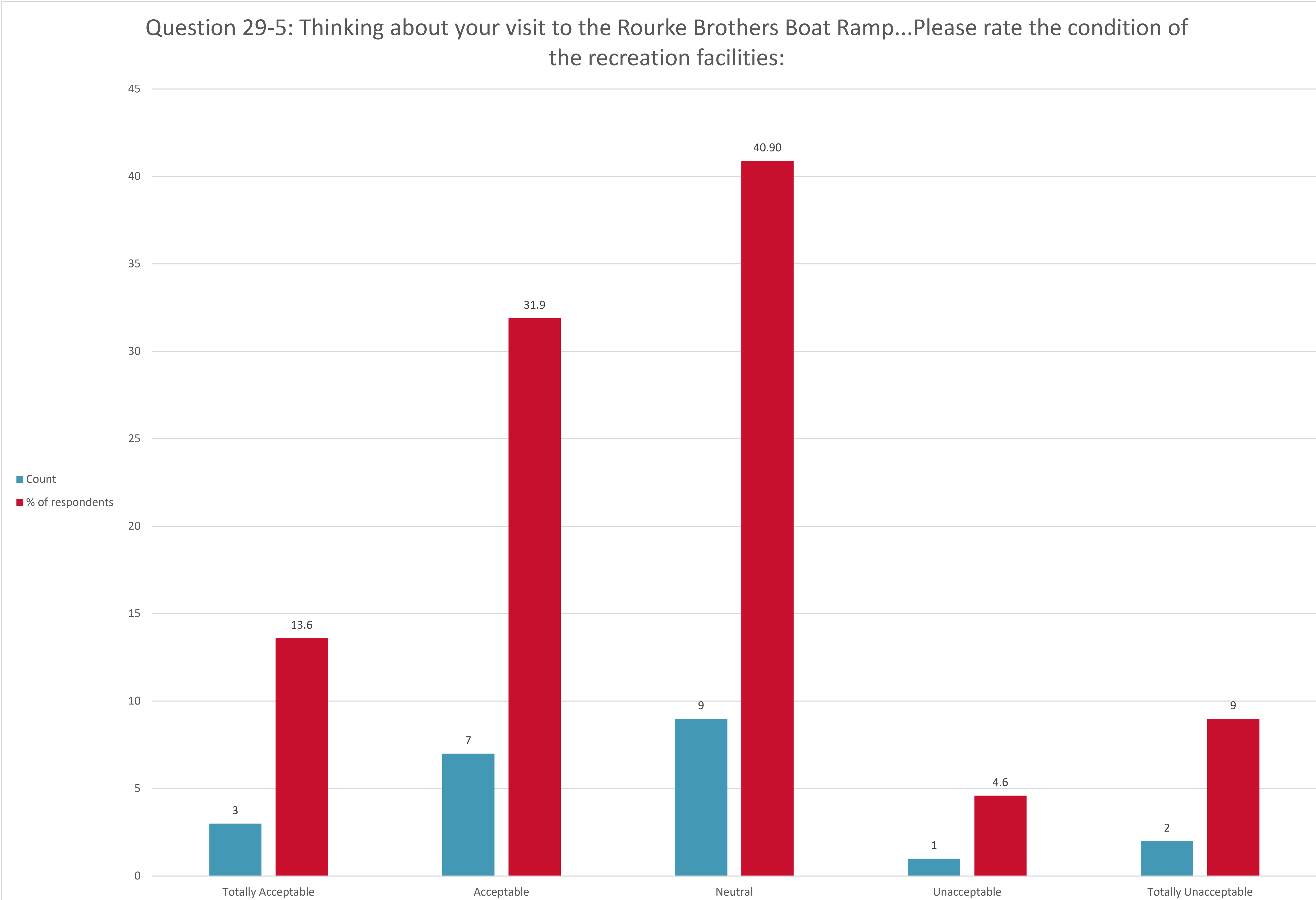

Question 28-8: Thinking about your visit to the Lowell Project impoundment...Please rate your overall experience:
35
30
25
20
15
10
5
0
Count
% of respondents
13.4
26.7
33.3
13.3
13.3
2
4
5
2
2
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

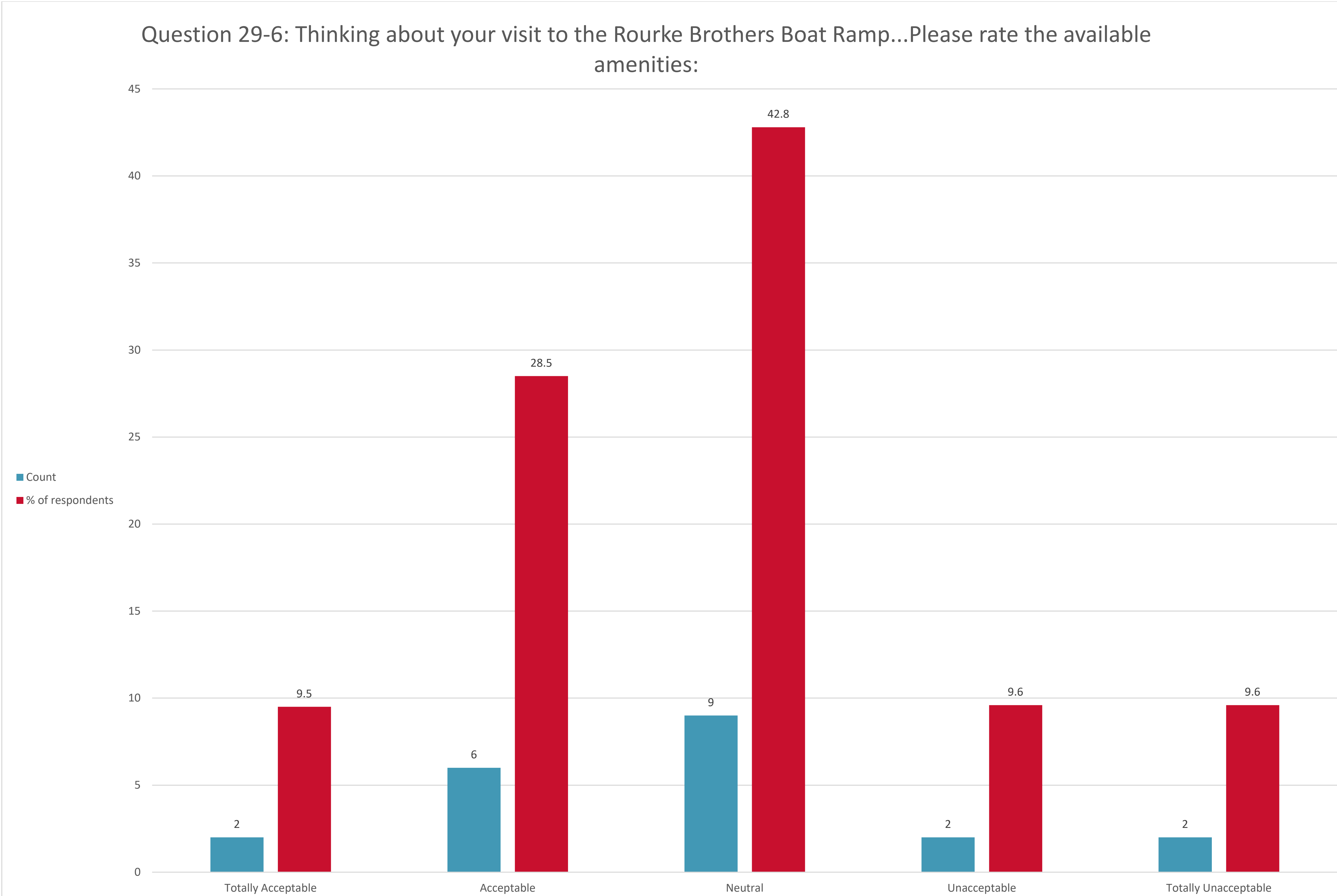

Question 29-1: Thinking about your visit to the Rourke Brothers Boat Ramp...Please rate the accessibility:
Count
% of respondents
0
5
10
15
20
25
30
35
40
45
50
7
31.8
10
45.5
4
18.2
0
0
1
4.5
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 29-2: Thinking about your visit to the Rourke Brothers Boat Ramp...Please rate the parking:
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
41
9
27.3
6
27.3
6
0
0
4.4
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

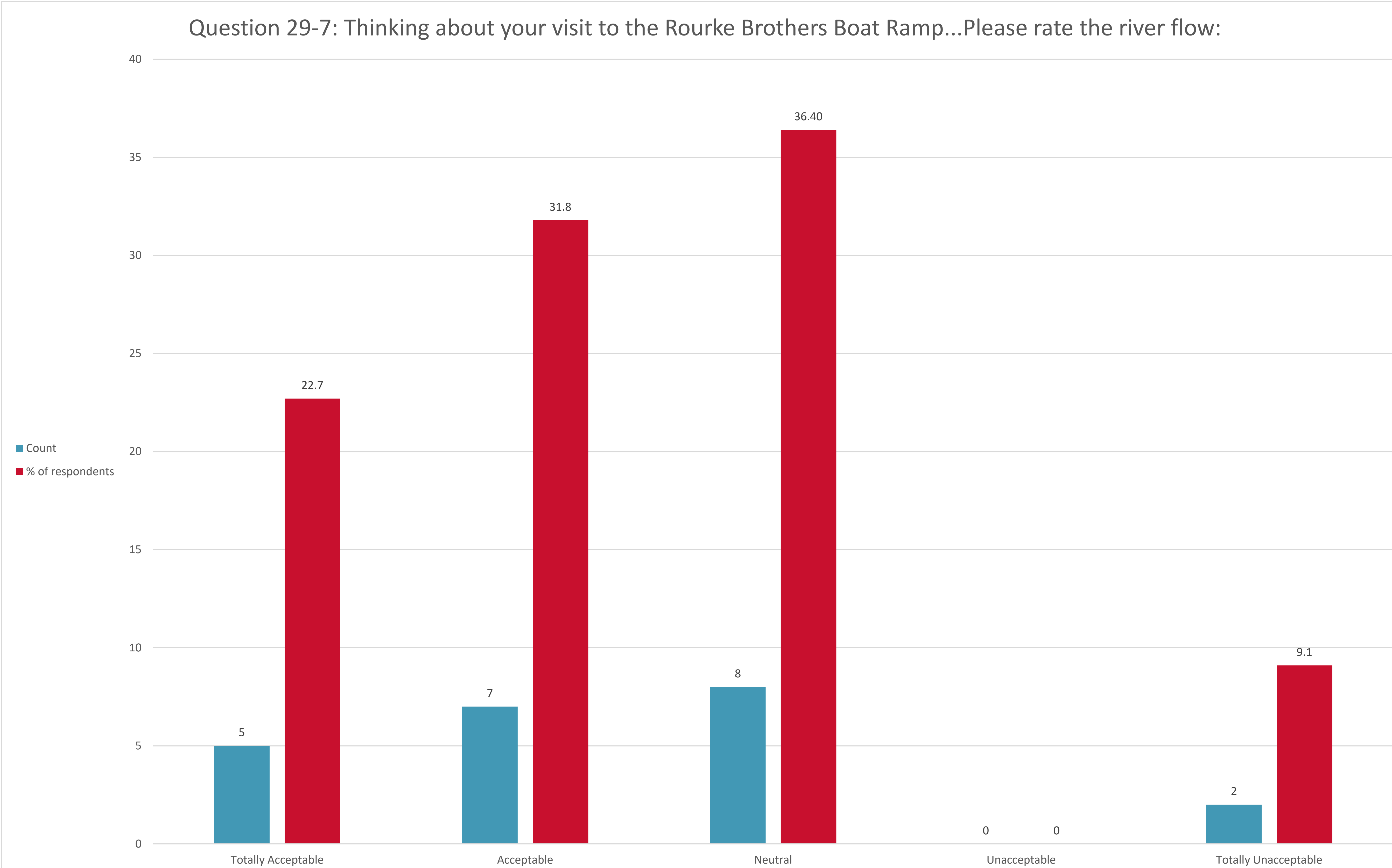

Question 29-3: Thinking about your visit to the Rourke Brothers Boat Ramp...Please rate the crowding:
40
35
30
25
20
15
10
5
0
Count
% of respondents
36.4
32
27
8
7
6
0
0
1
4.6
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

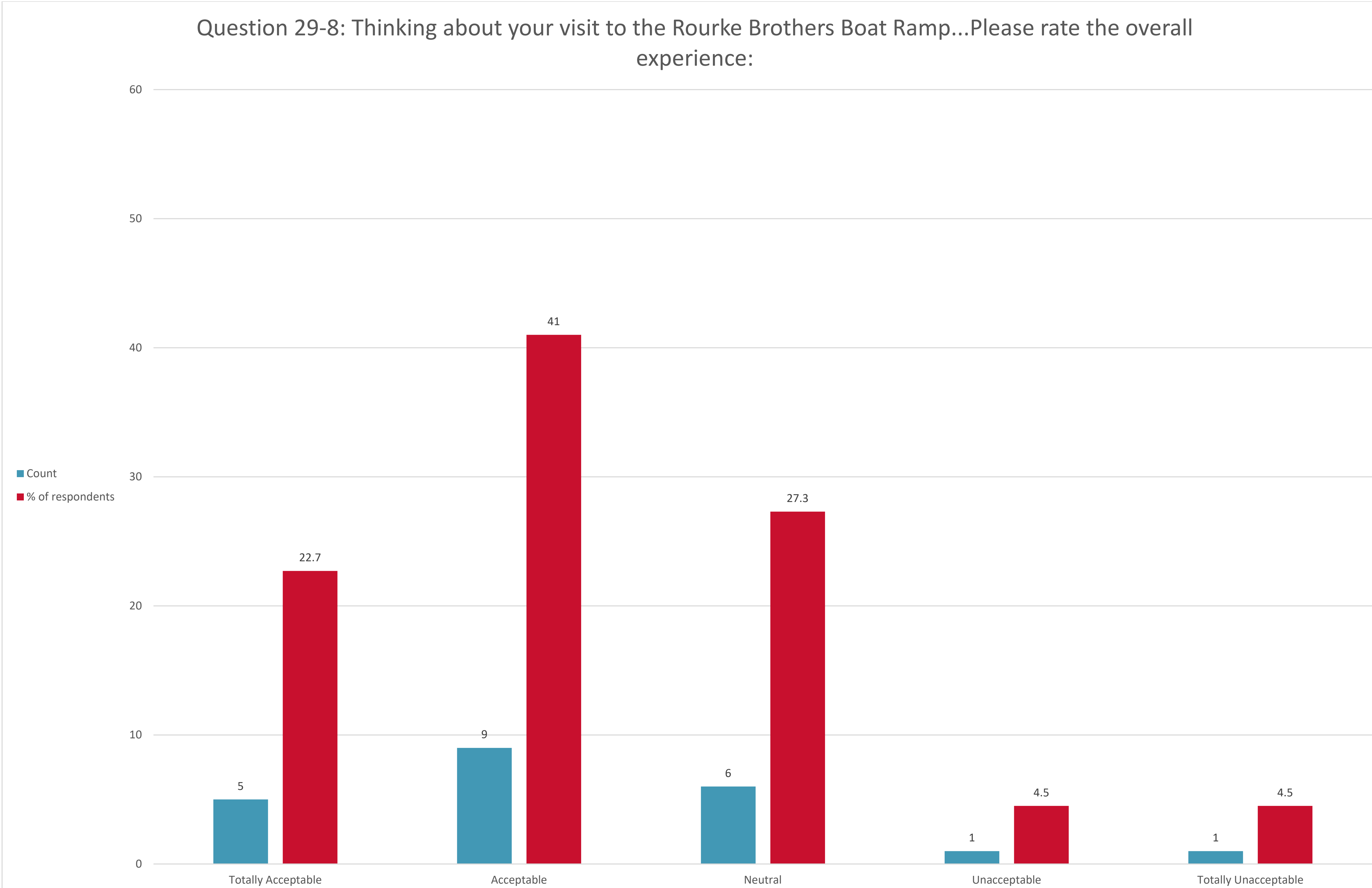

Question 29-4: Thinking about your visit to the Rourke Brothers Boat Ramp...Please rate the safety:
Count
% of respondents
45
40
35
30
25
20
15
10
5
0
41
27.2
22.8
9
6
5
0
0
2
9
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

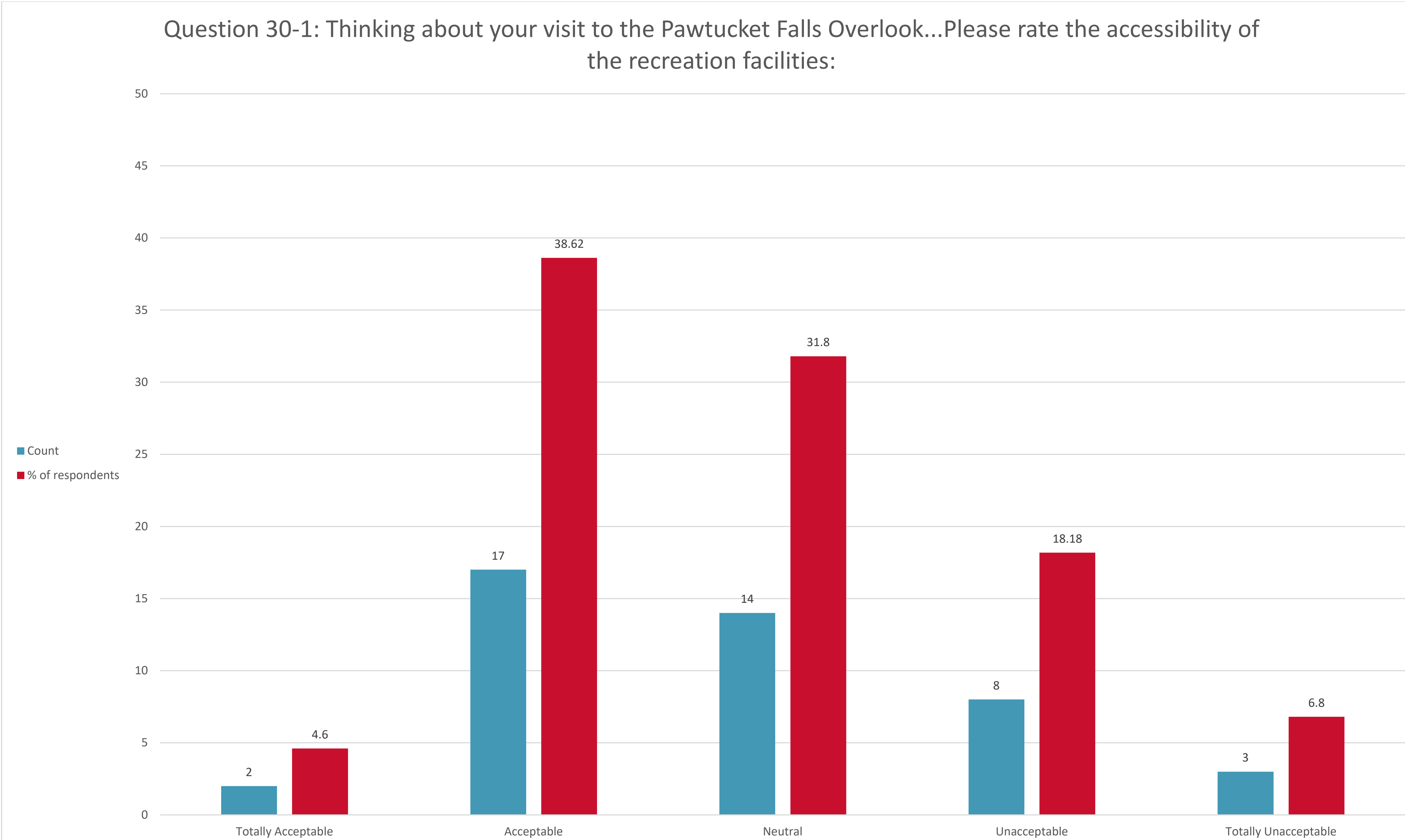

Question 29-5: Thinking about your visit to the Rourke Brothers Boat Ramp...Please rate the condition of the recreation facilities:
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
3
13.6
7
31.9
9
40.90
1
4.6
2
9
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

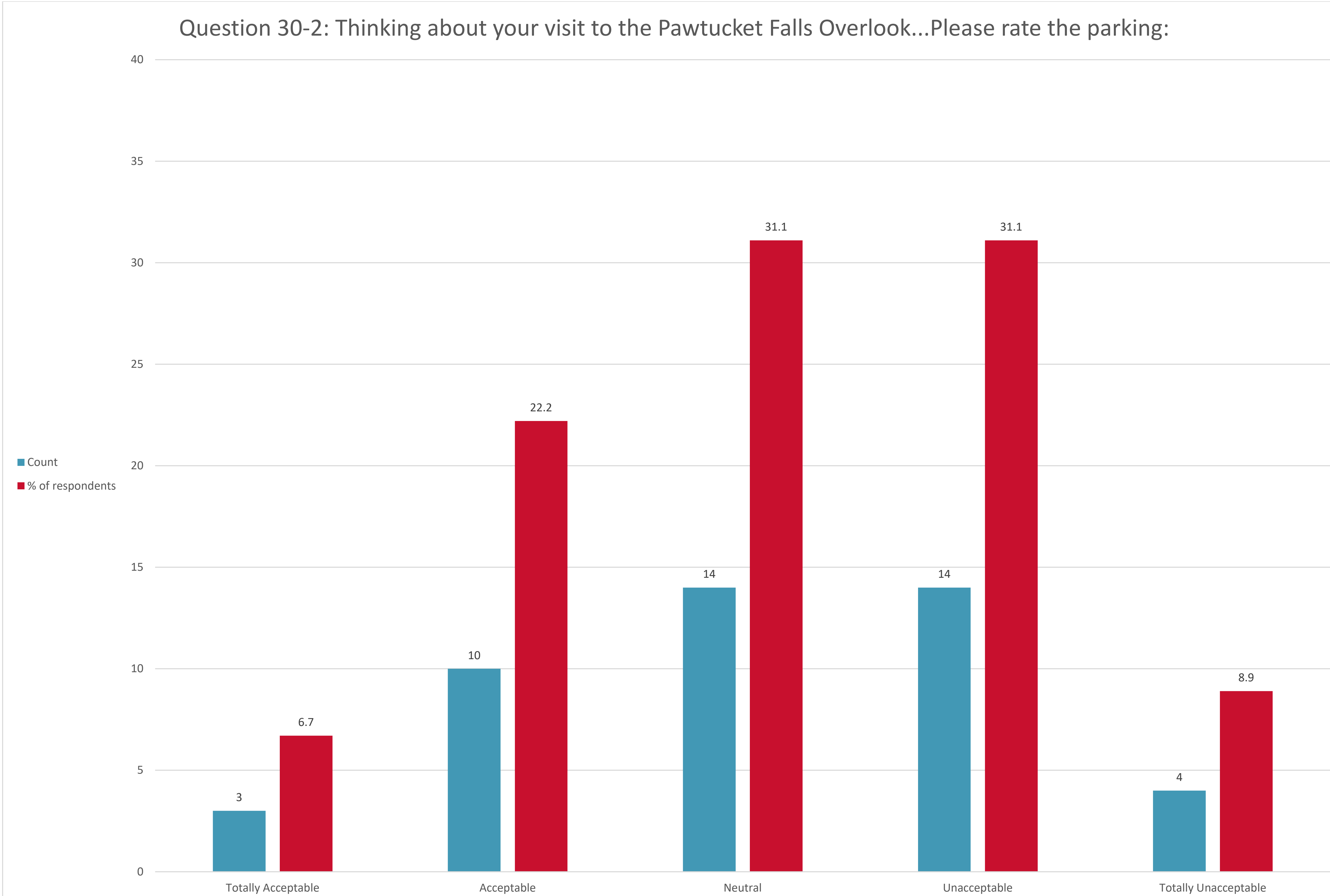


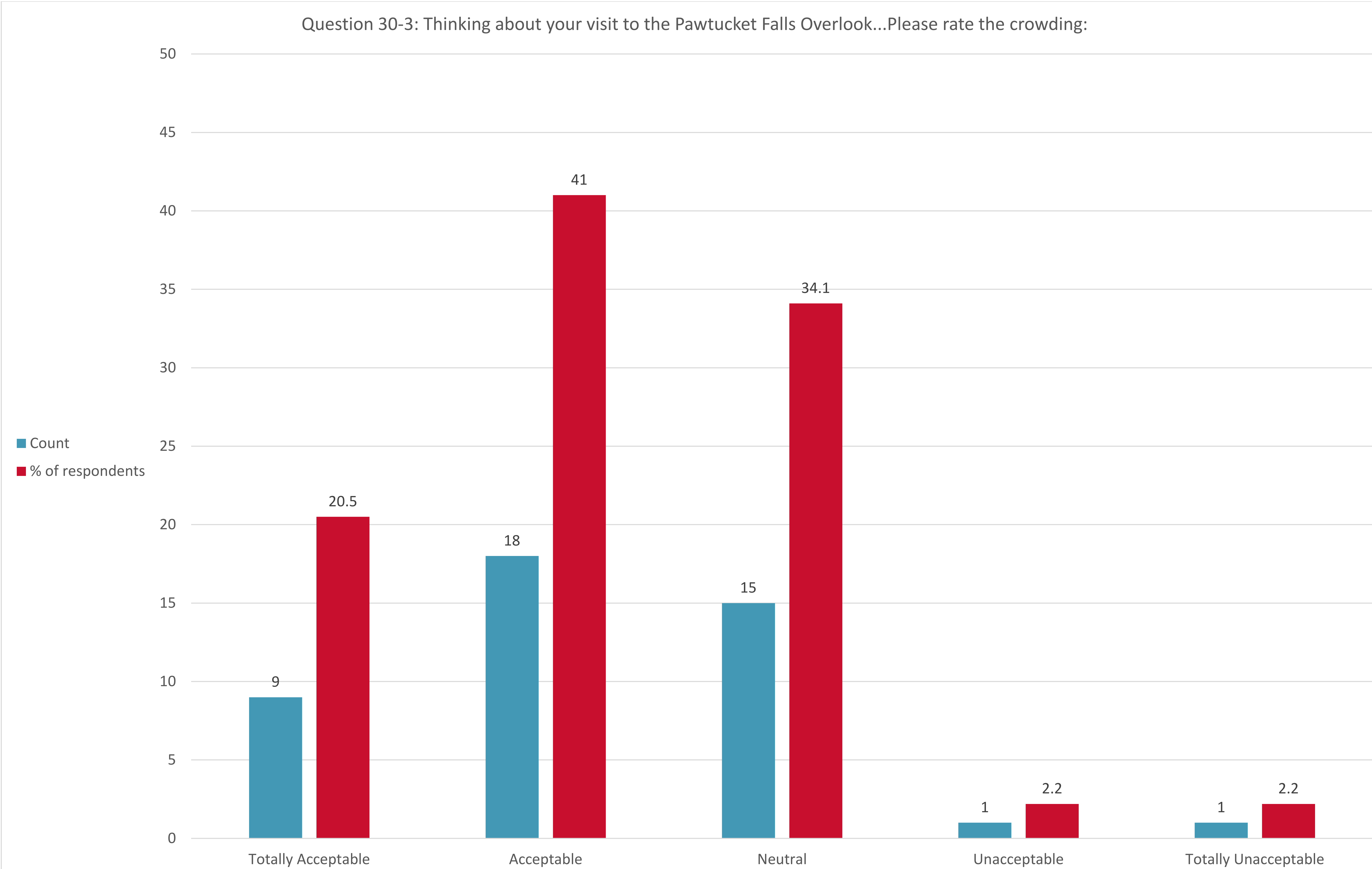
Question 29-6: Thinking about your visit to the Rourke Brothers Boat Ramp...Please rate the available amenities:
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
2
9.5
6
28.5
9
42.8
2
9.6
2
9.6
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

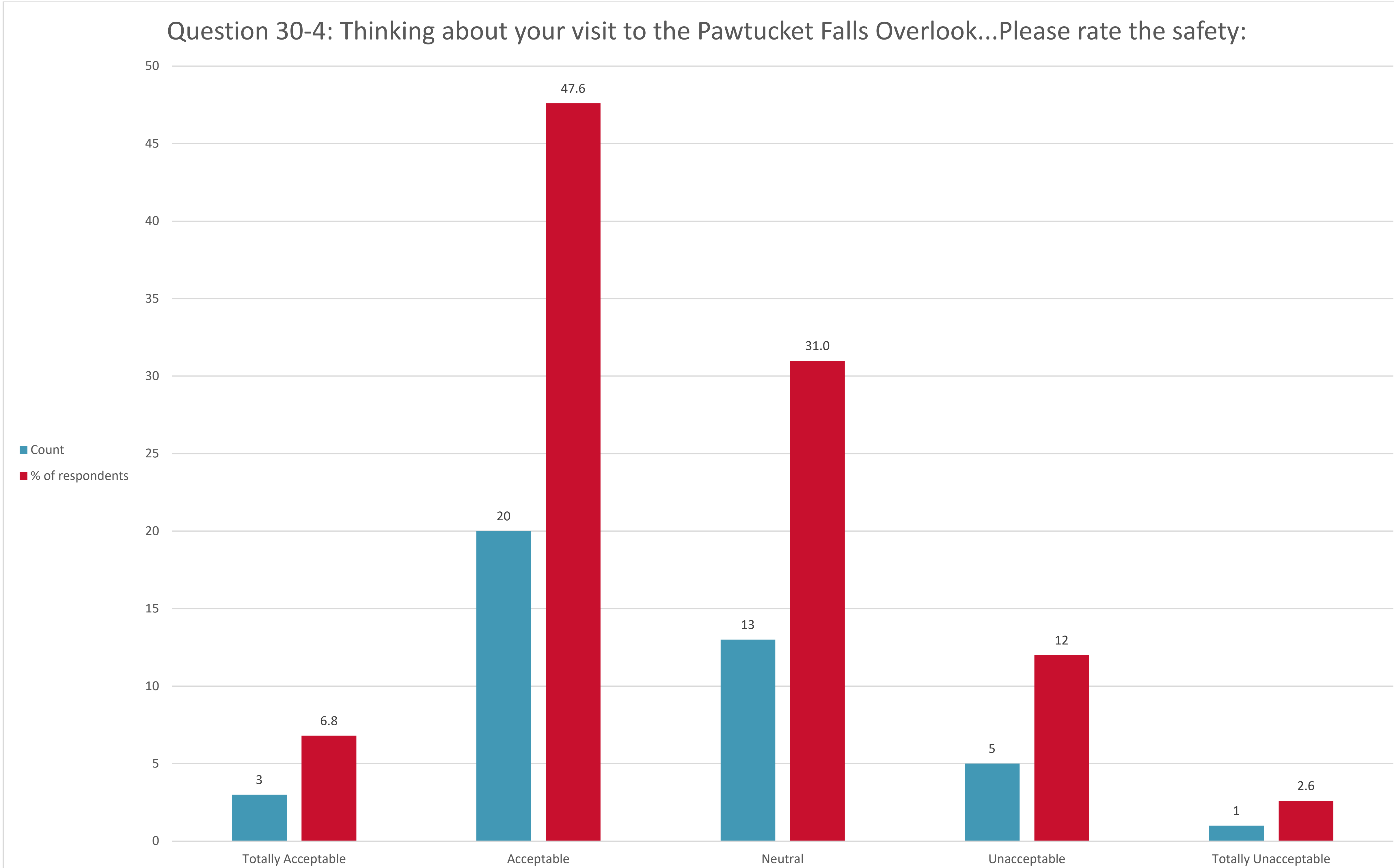

Question 29-7: Thinking about your visit to the Rourke Brothers Boat Ramp...Please rate the river flow:
40
35
30
25
20
15
10
5
0
Count
% of respondents
5
22.7
7
31.8
8
36.40
0
0
2
9.1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

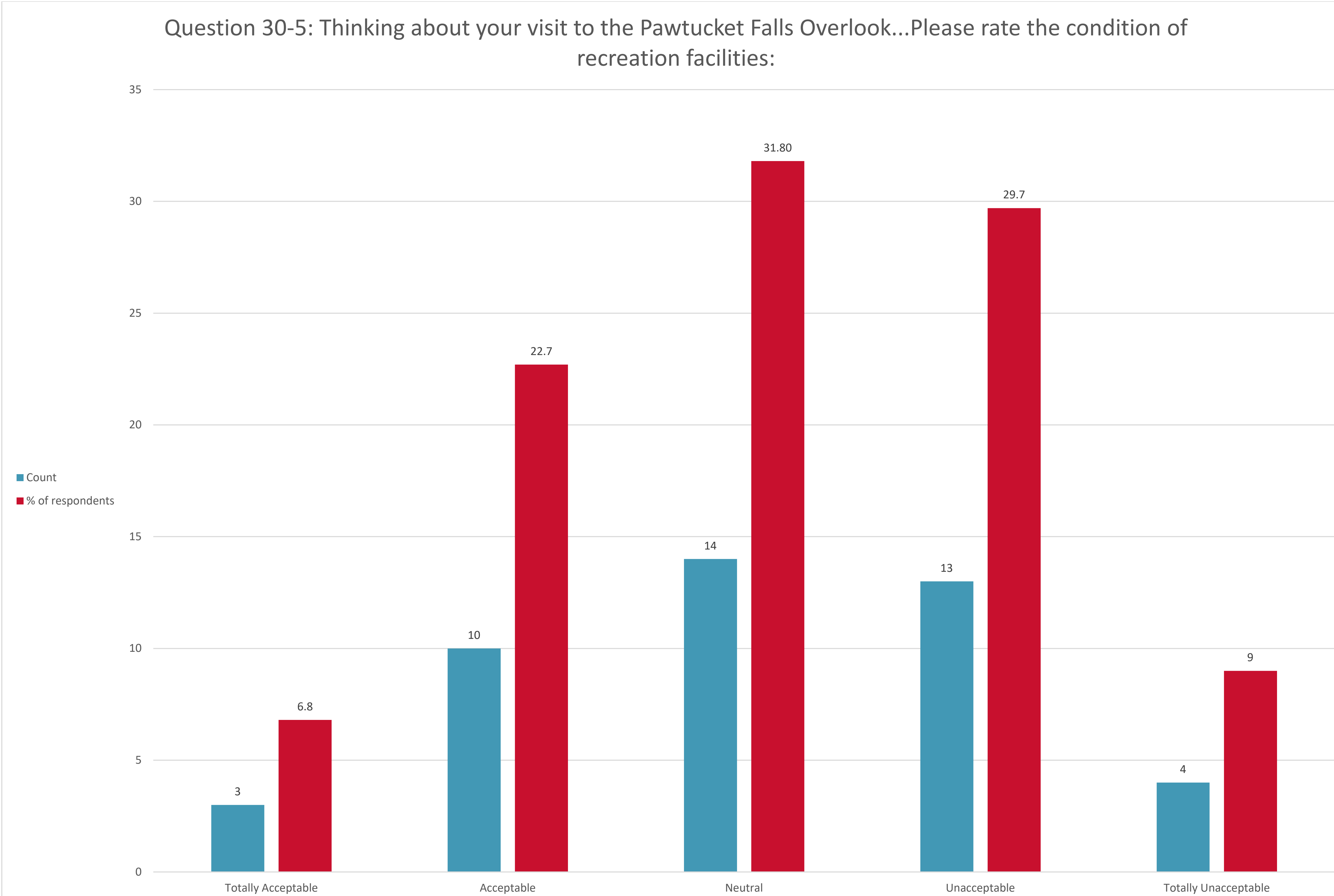

Question 29-8: Thinking about your visit to the Rourke Brothers Boat Ramp...Please rate the overall experience:
60
50
40
30
20
10
0
Count
% of respondents
22.7
41
27.3
5
9
6
1
4.5
1
4.5
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 30-1: Thinking about your visit to the Pawtucket Falls Overlook...Please rate the accessibility of the recreation facilities:
50
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
2
4.6
17
38.62
14
31.8
8
18.18
3
6.8
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

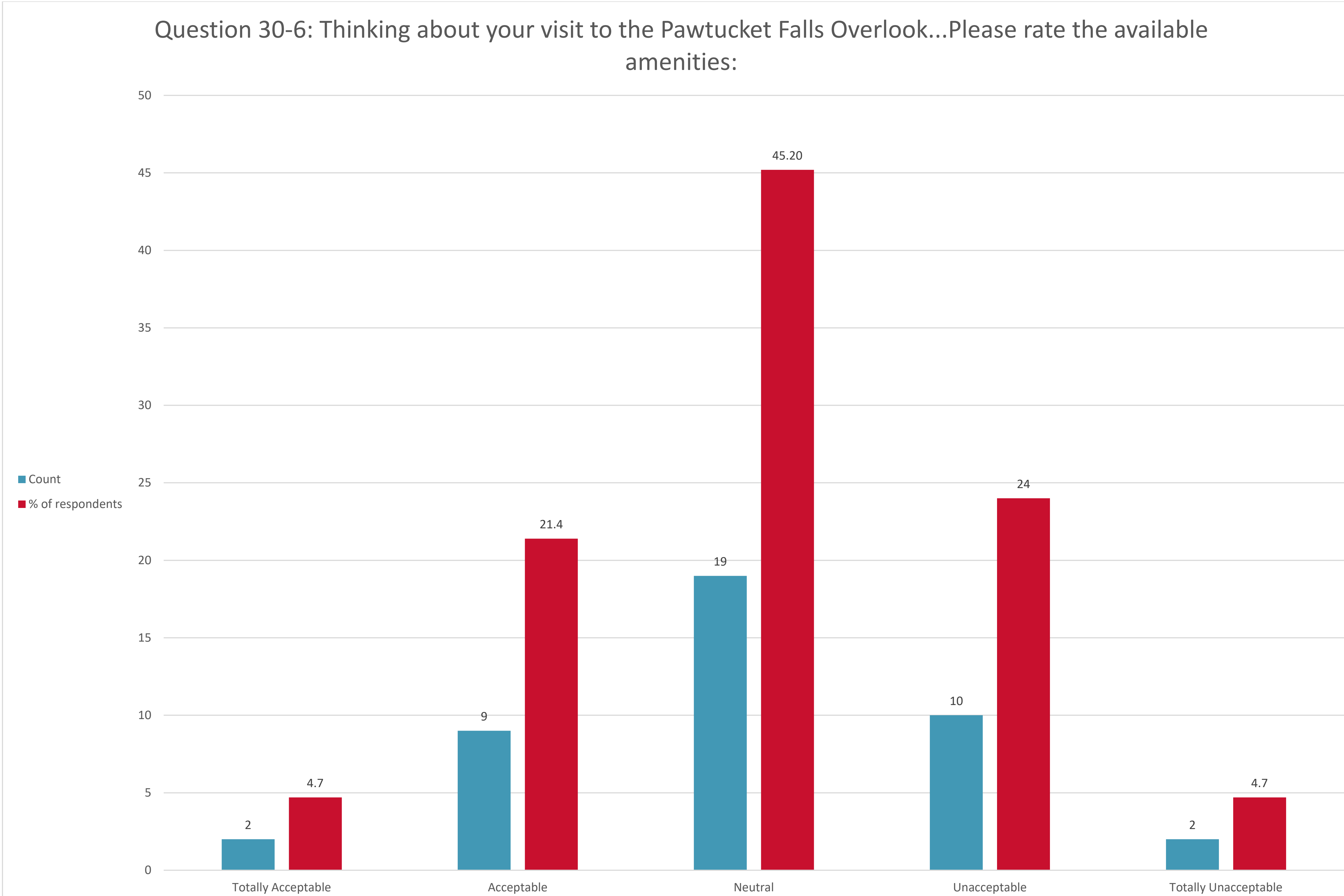

Question 30-2: Thinking about your visit to the Pawtucket Falls Overlook...Please rate the parking:
Count
% of respondents
40
35
30
25
20
15
10
5
0
3
6.7
10
22.2
14
31.1
14
31.1
4
8.9
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

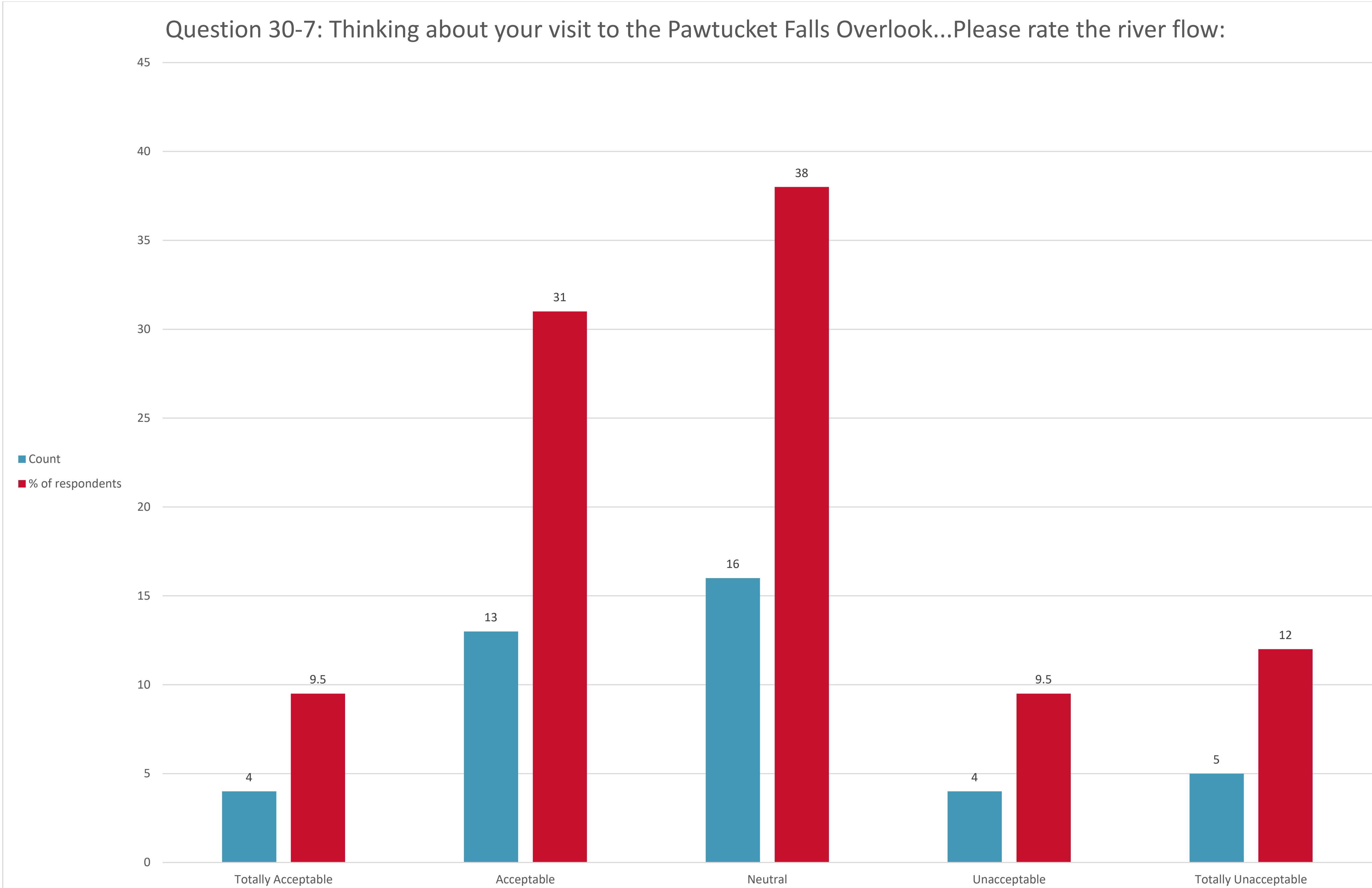

Question 30-3: Thinking about your visit to the Pawtucket Falls Overlook...Please rate the crowding:
Count
% of respondents
50
45
40
35
30
25
20
15
10
5
0
9
20.5
18
41
15
34.1
1
2.2
1
2.2
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

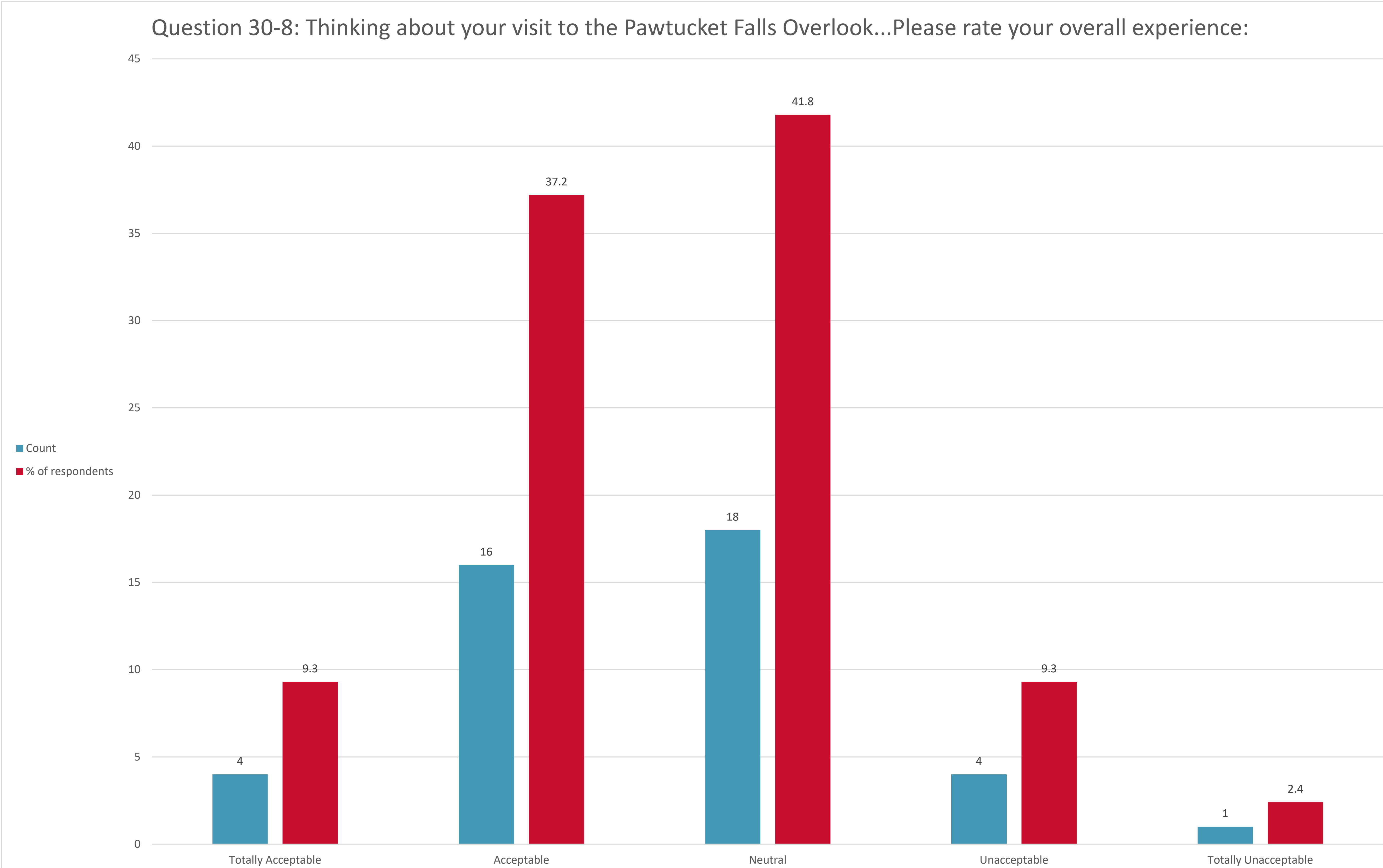

Question 30-4: Thinking about your visit to the Pawtucket Falls Overlook...Please rate the safety:
Count
% of respondents
50
45
40
35
30
25
20
15
10
5
0
3
6.8
20
47.6
13
31.0
5
12
1
2.6
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

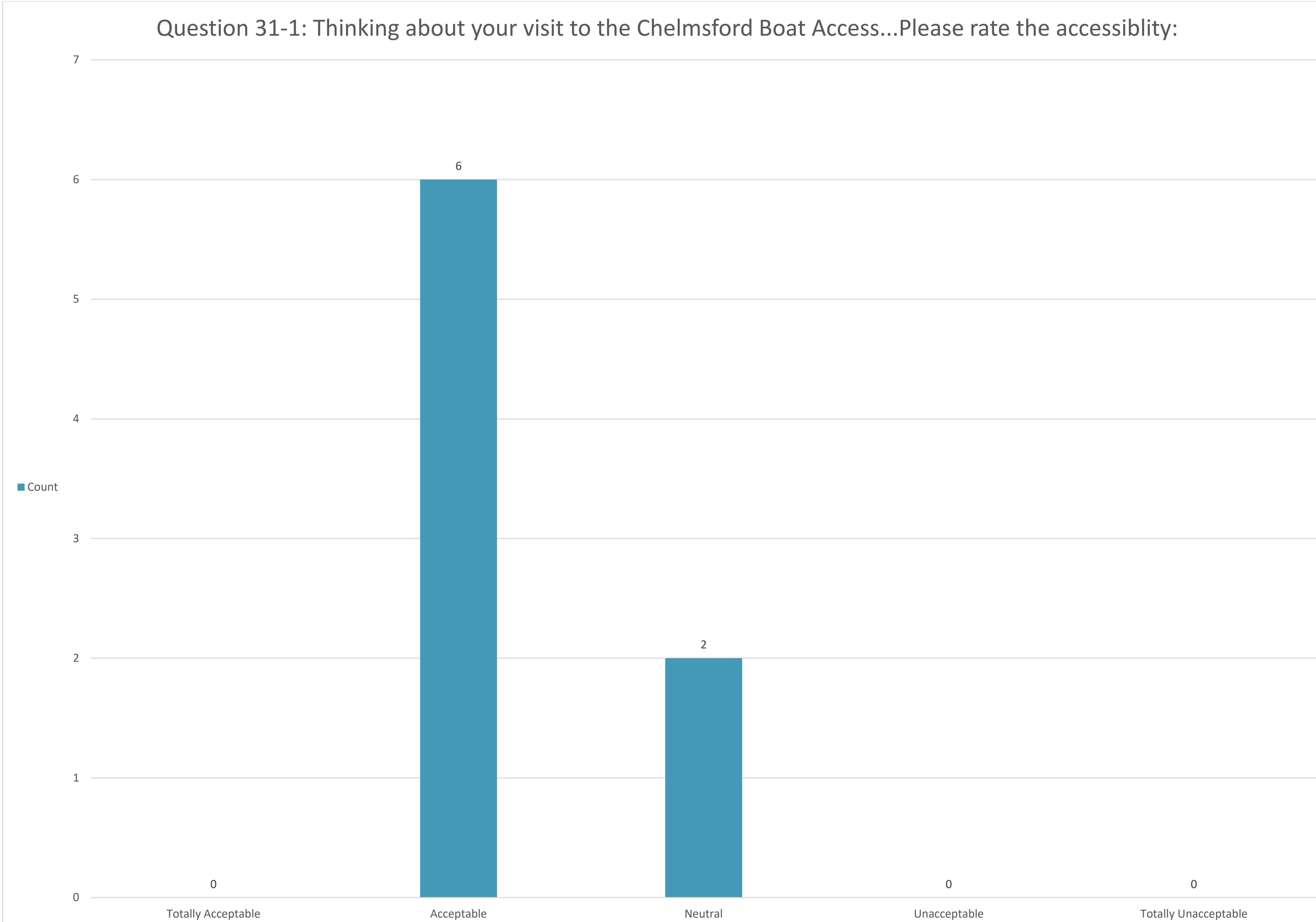


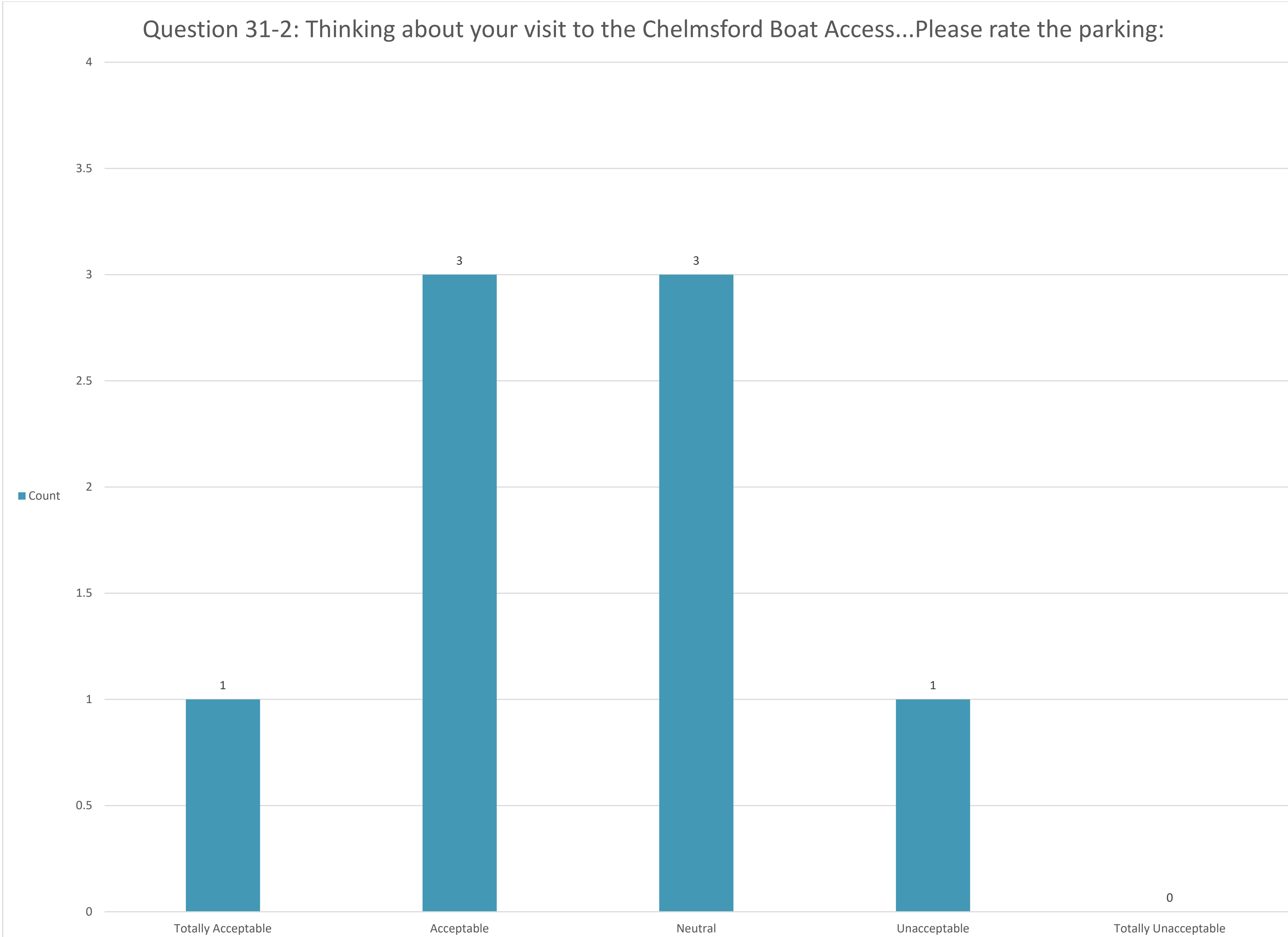
Question 30-5: Thinking about your visit to the Pawtucket Falls Overlook...Please rate the condition of recreation facilities:
35
30
25
20
15
10
5
0
Count
% of respondents
3
6.8
10
22.7
14
31.80
13
29.7
4
9
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

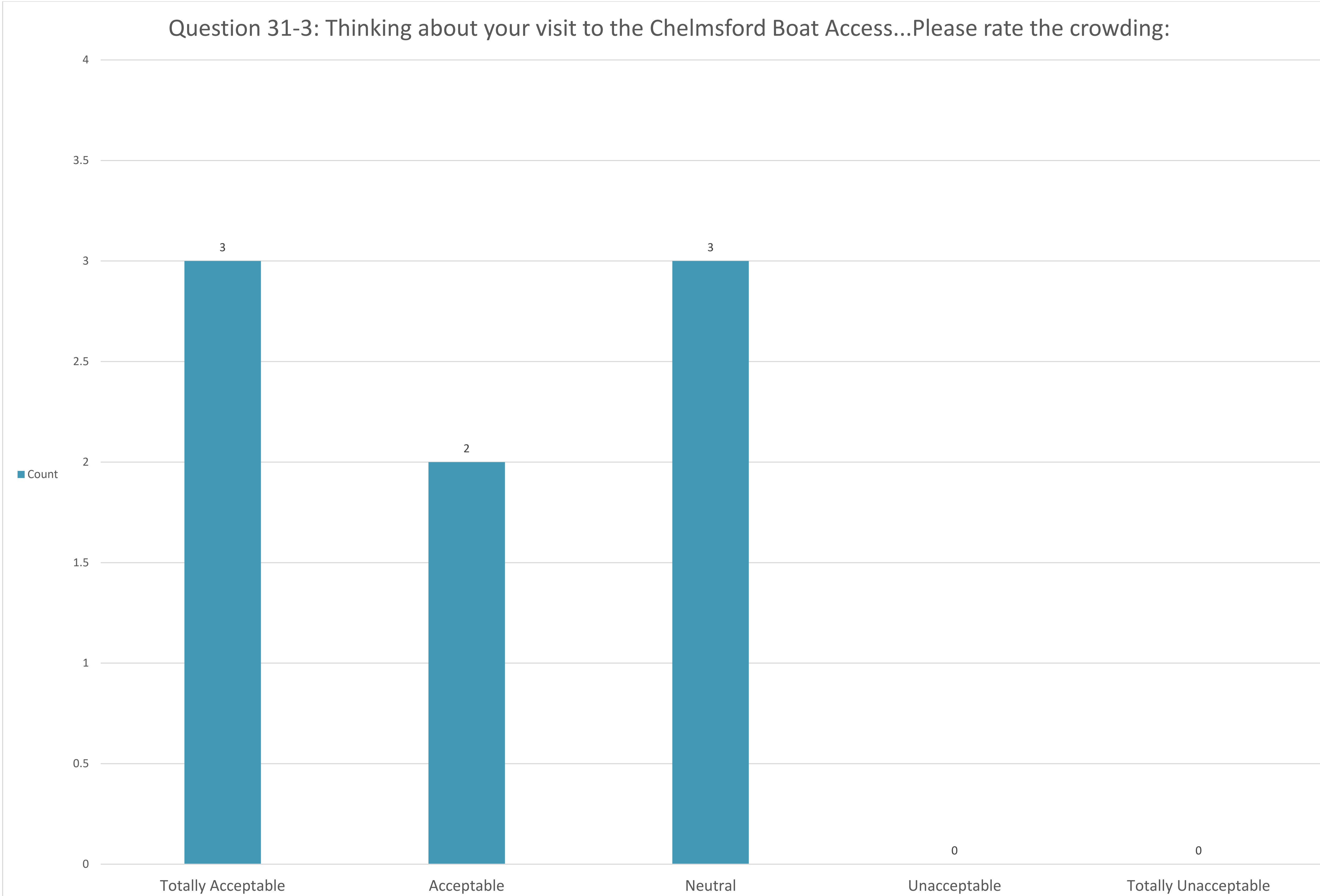

Question 30-6: Thinking about your visit to the Pawtucket Falls Overlook...Please rate the available amenities:
50
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
2
4.7
9
21.4
19
45.20
10
24
2
4.7
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

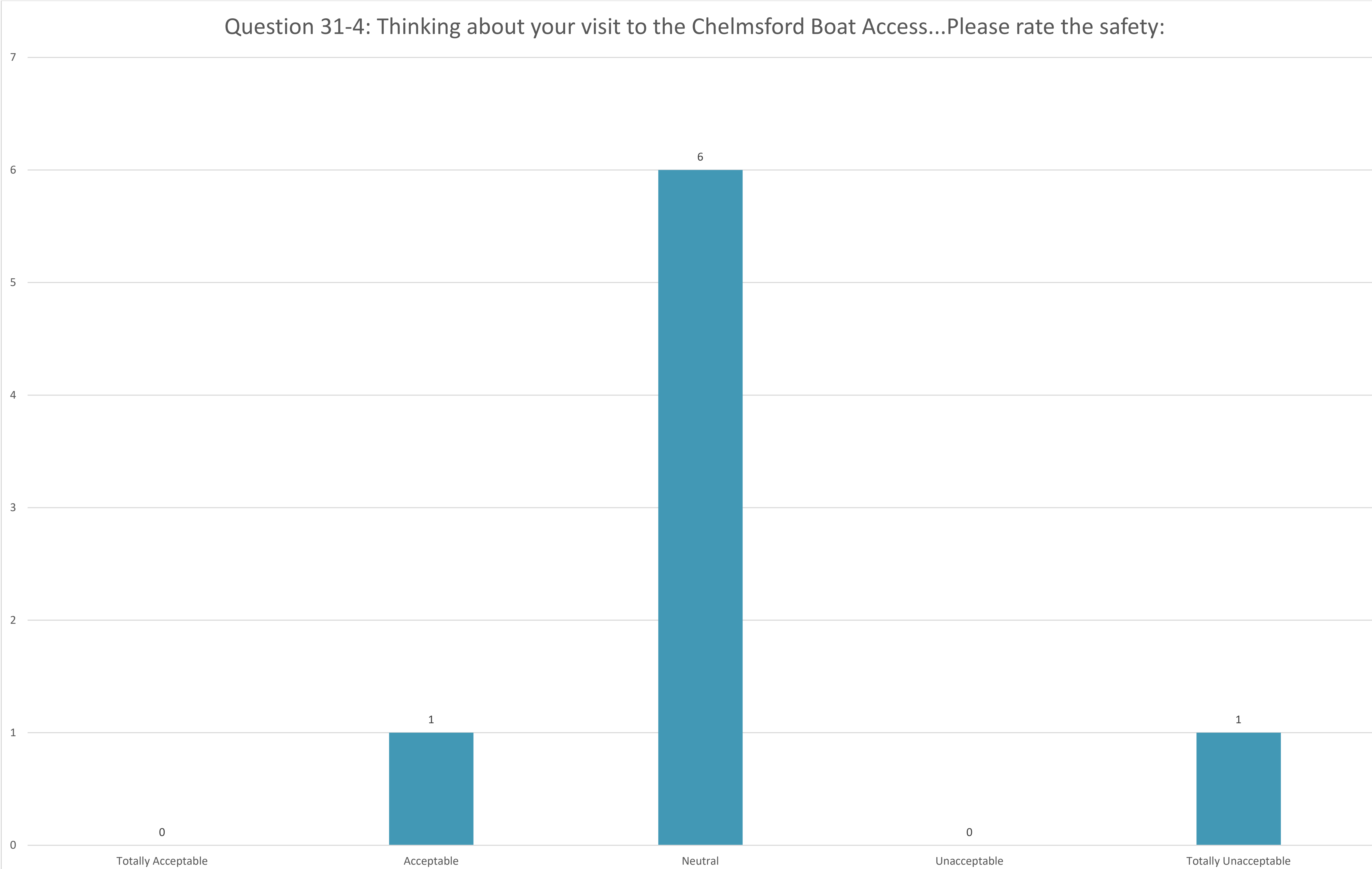

Question 30-7: Thinking about your visit to the Pawtucket Falls Overlook...Please rate the river flow:
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
4
9.5
13
31
16
38
4
9.5
5
12
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

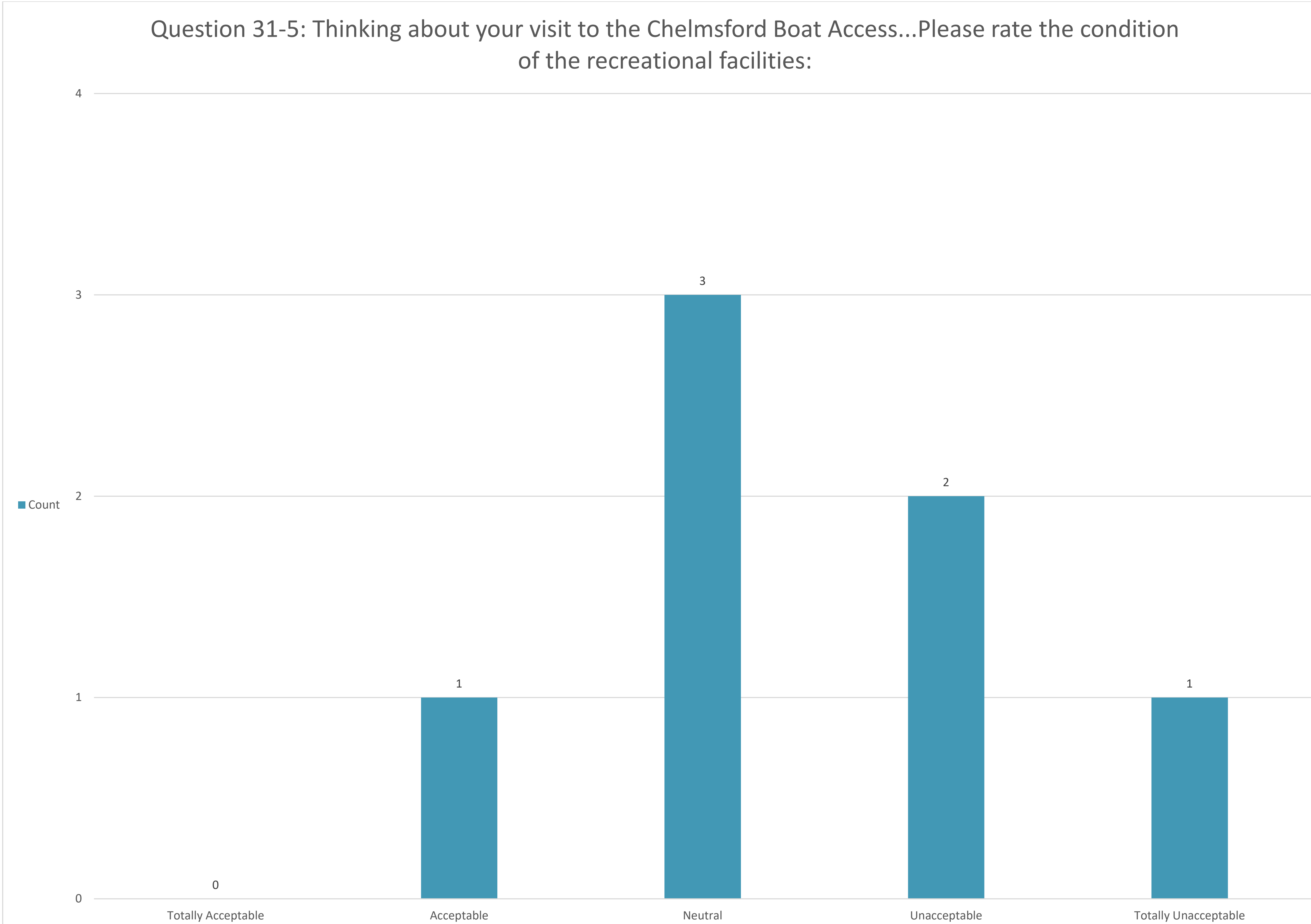

Question 30-8: Thinking about your visit to the Pawtucket Falls Overlook...Please rate your overall experience:
45
40
35
30
25
20
15
10
5
0
Count
% of respondents
4
9.3
16
37.2
18
41.8
4
9.3
1
2.4
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 31-1: Thinking about your visit to the Chelmsford Boat Access...Please rate the accessiblity:
Count
0
1
2
3
4
5
6
7
0
6
2
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

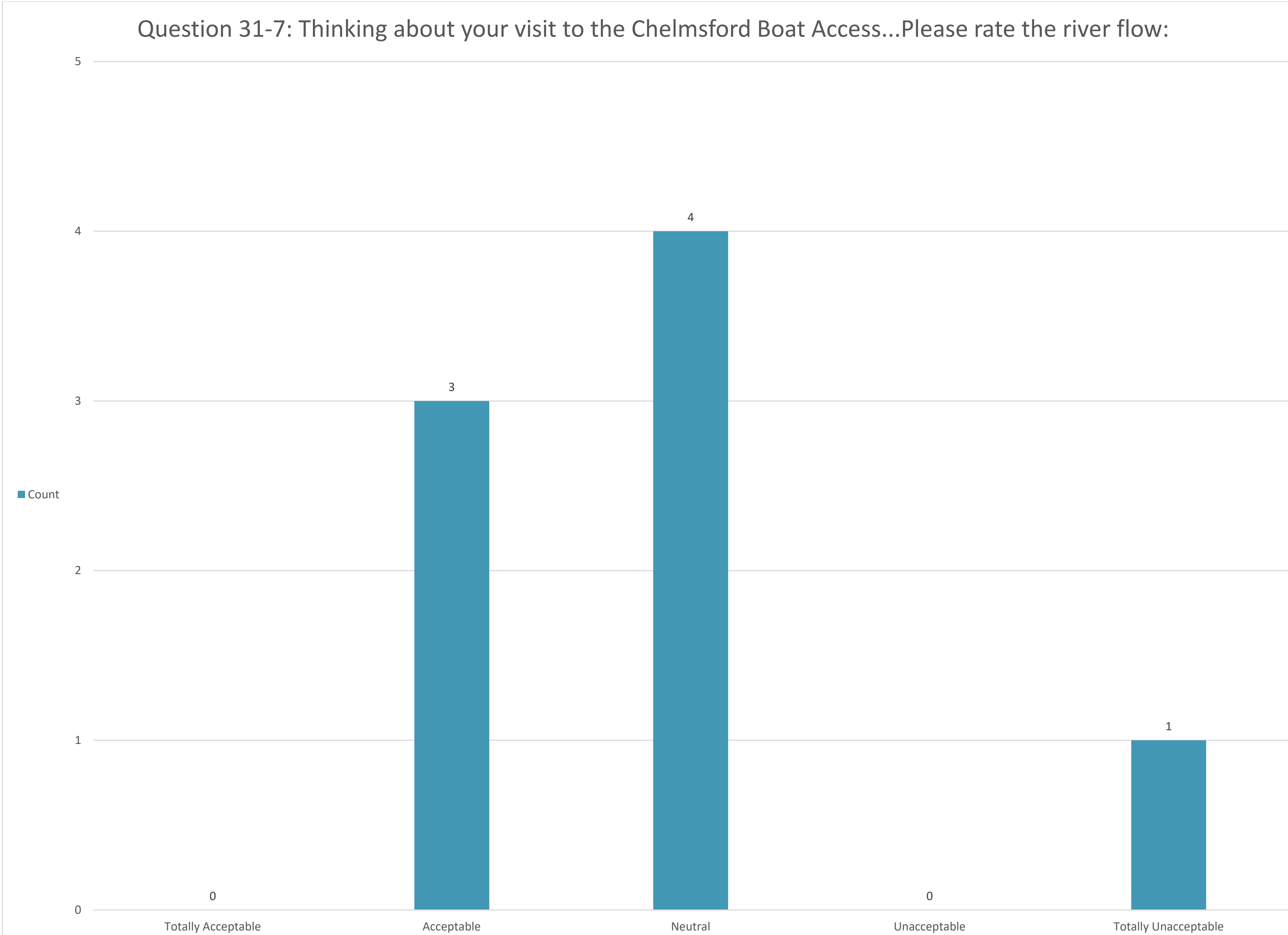

Question 31-2: Thinking about your visit to the Chelmsford Boat Access...Please rate the parking:
4
3.5
3
2.5
2
1.5
1
0.5
0
Count
1
3
3
1
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 31-3: Thinking about your visit to the Chelmsford Boat Access...Please rate the crowding:
4
3.5
3
2.5
2
1.5
1
0.5
0
Count
3
2
3
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

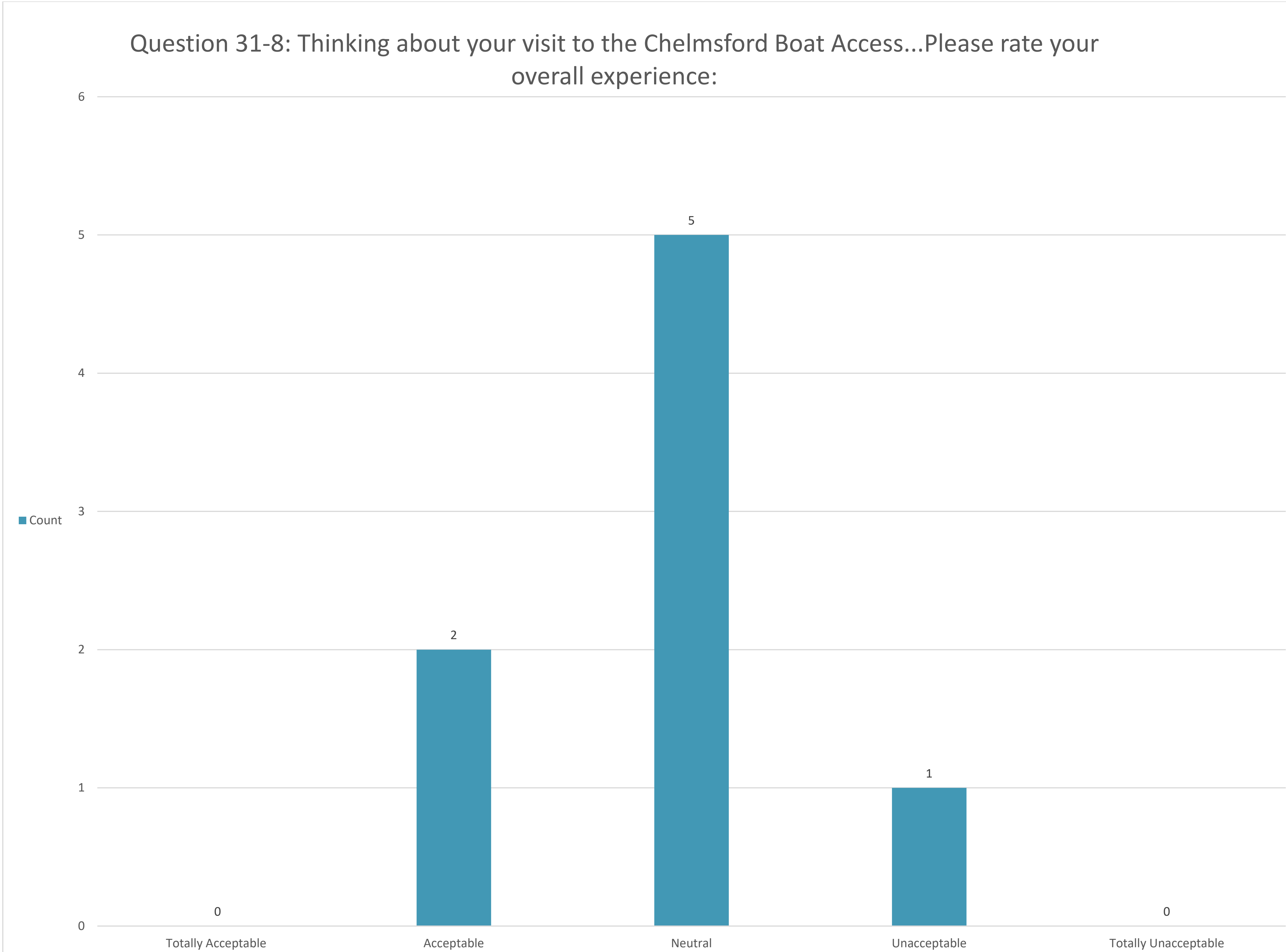

Question 31-4: Thinking about your visit to the Chelmsford Boat Access...Please rate the safety:
7
6
5
4
3
2
1
0
0
1
6
0
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

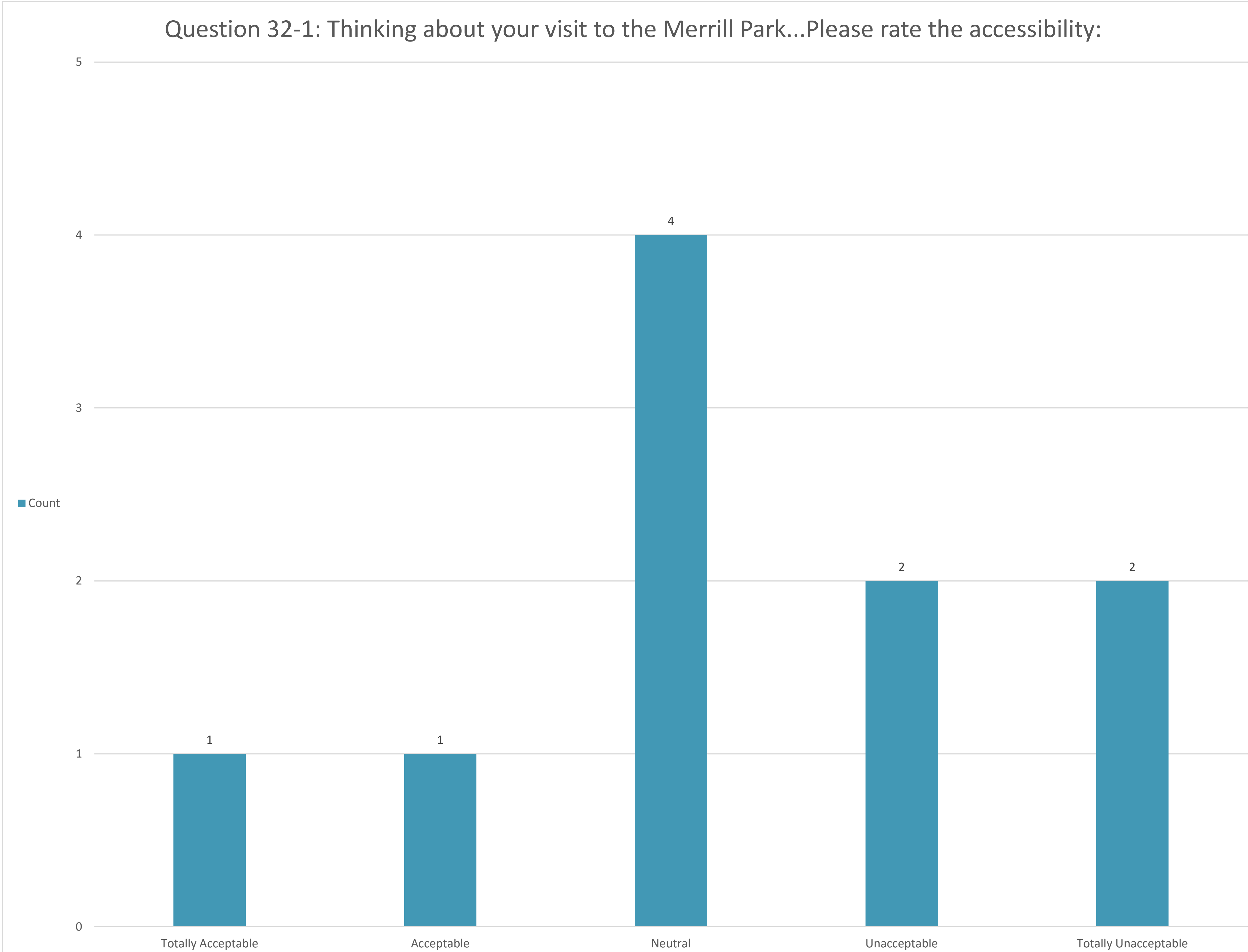

Question 31-5: Thinking about your visit to the Chelmsford Boat Access...Please rate the condition of the recreational facilities:
Count
4
3
2
1
0
0
1
3
2
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 31-6: Thinking about your visit to the Chelmsford Boat Access...Please rate the available amenities:
4
3
2
1
0
Count
0
0
3
3
2
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

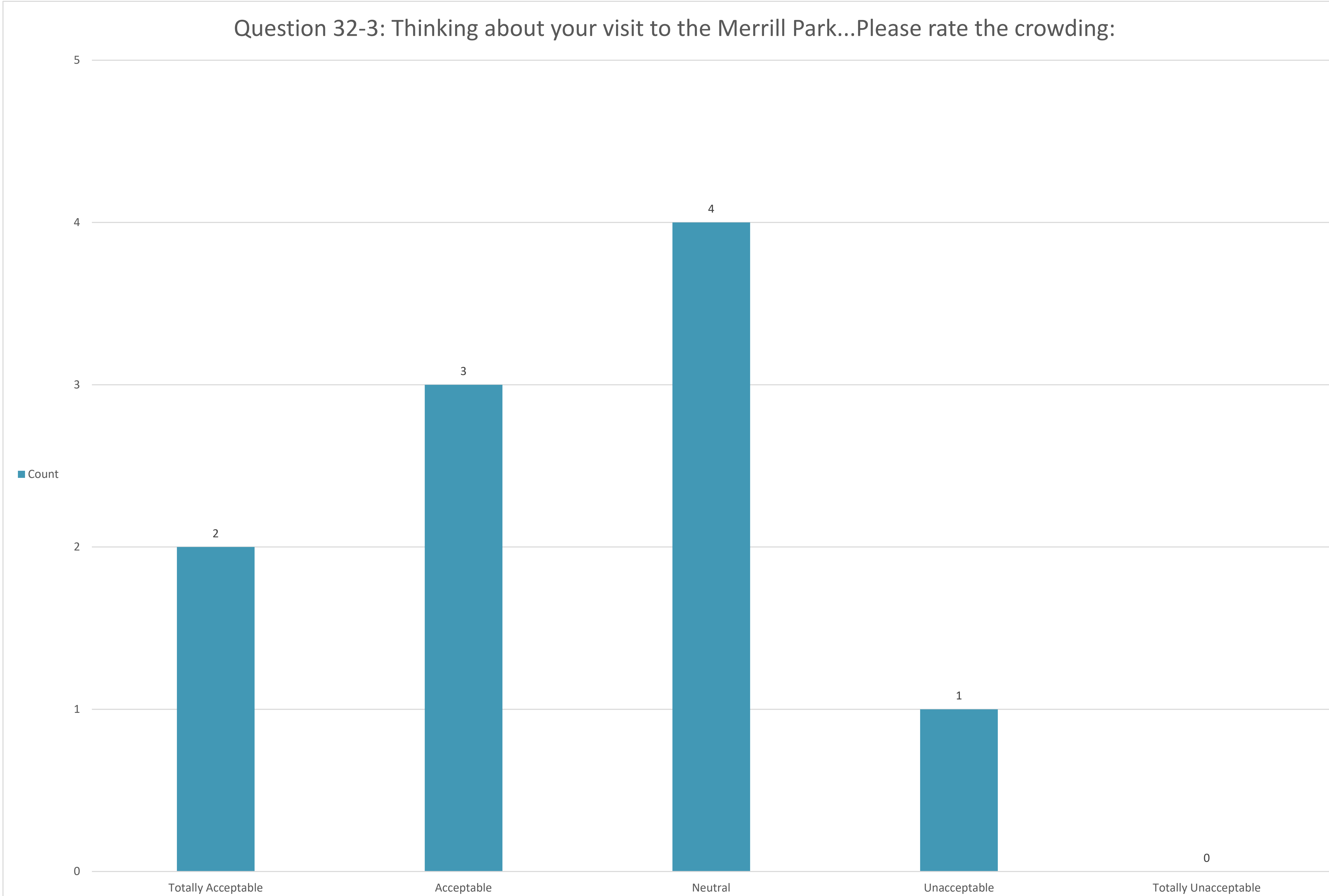


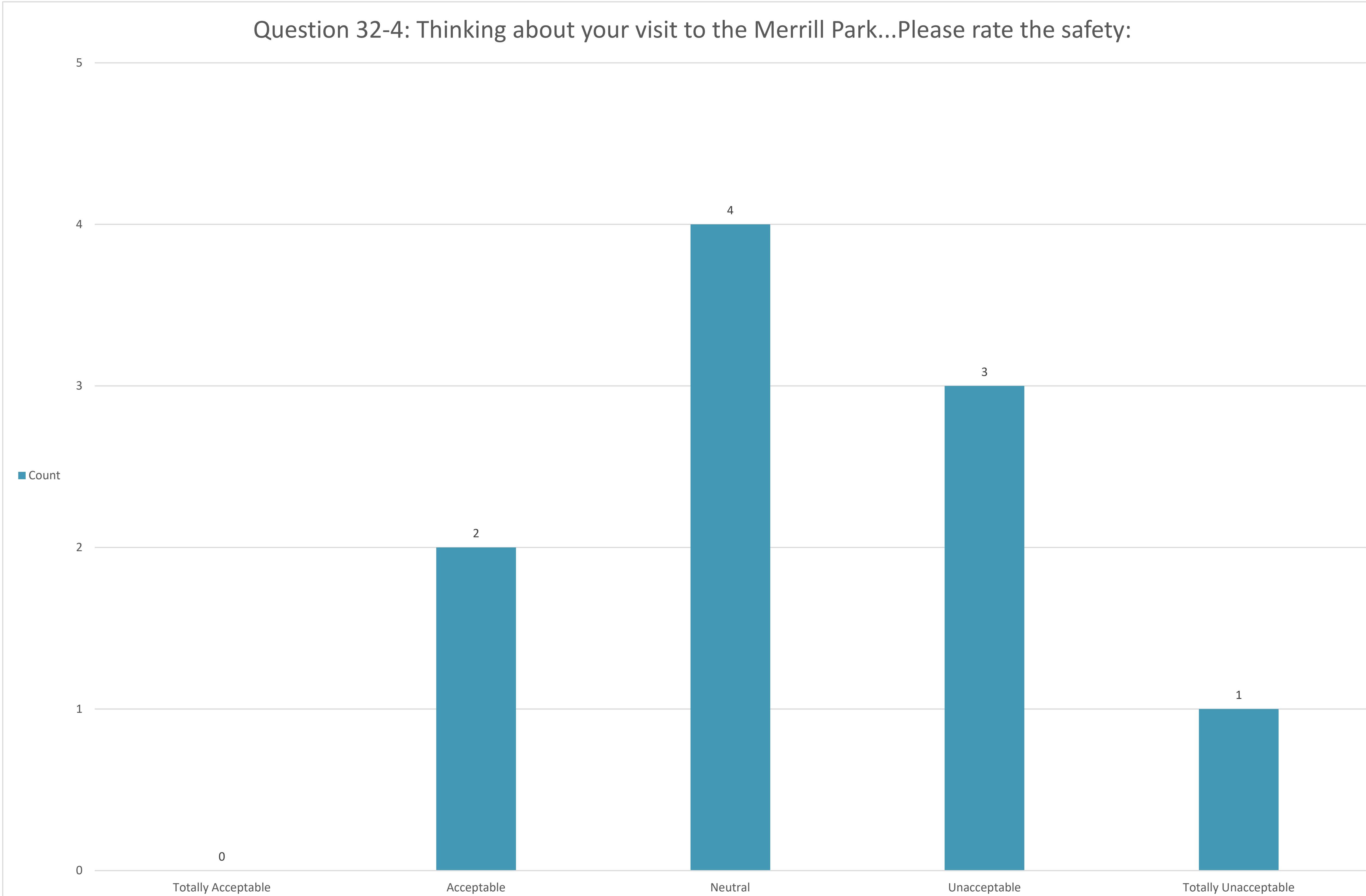
Question 31-7: Thinking about your visit to the Chelmsford Boat Access...Please rate the river flow:
5
4
3
2
1
0
Count
0
3
4
0
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

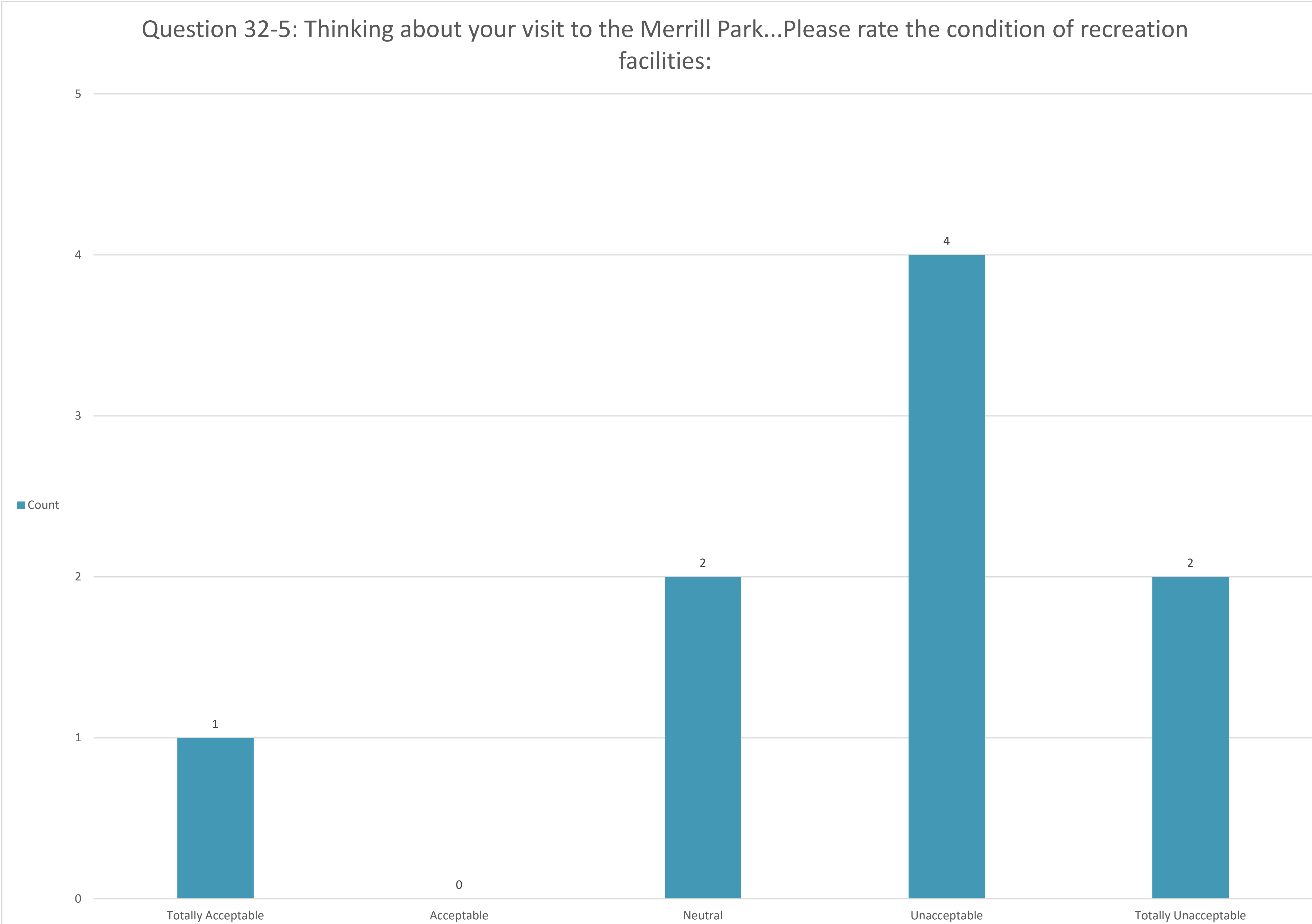

Question 31-8: Thinking about your visit to the Chelmsford Boat Access...Please rate your overall experience:
Count
6
5
4
3
2
1
0
0
2
5
1
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

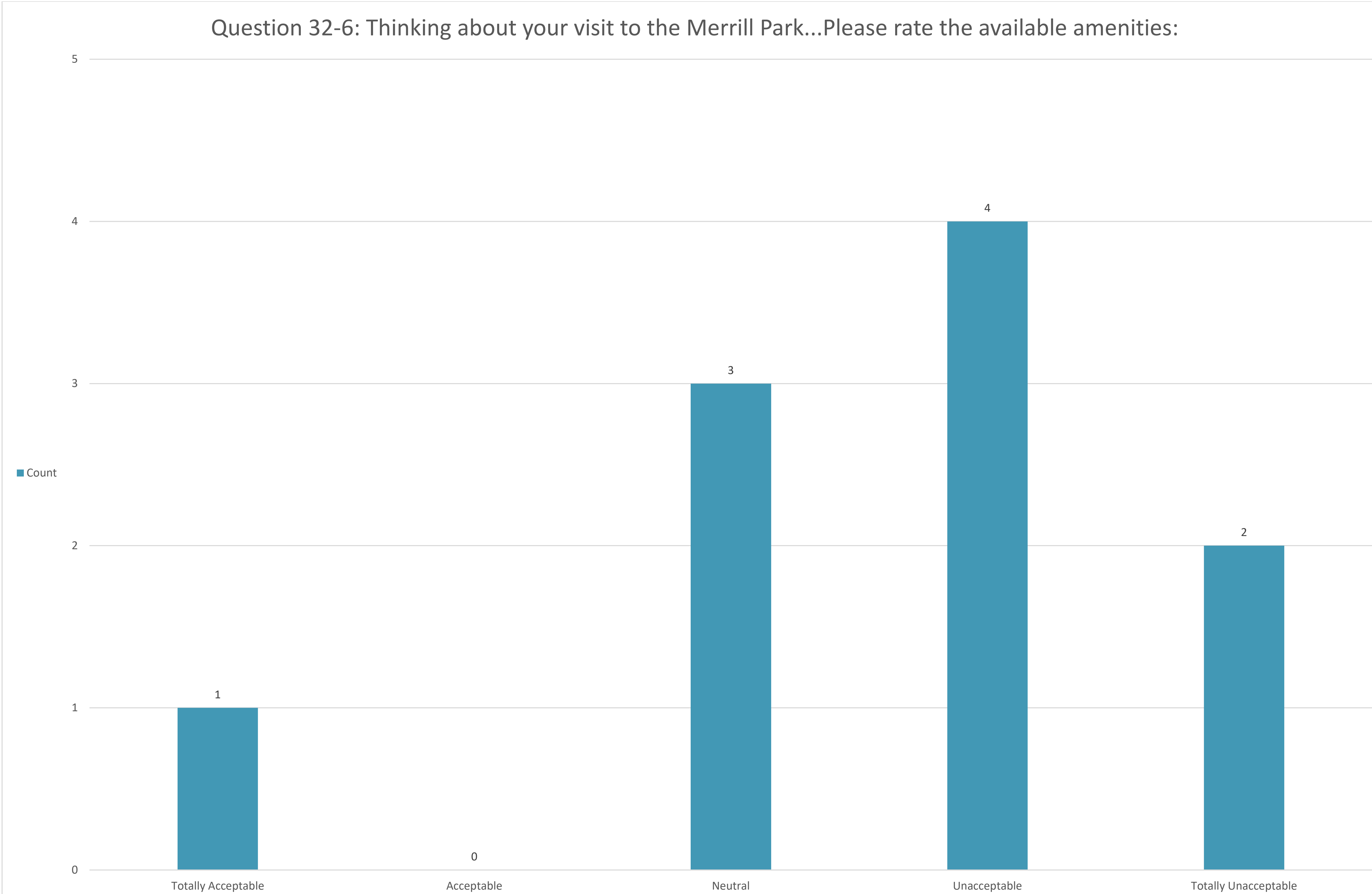

Question 32-1: Thinking about your visit to the Merrill Park...Please rate the accessibility:
Count
0
1
2
3
4
5
1
1
4
2
2
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

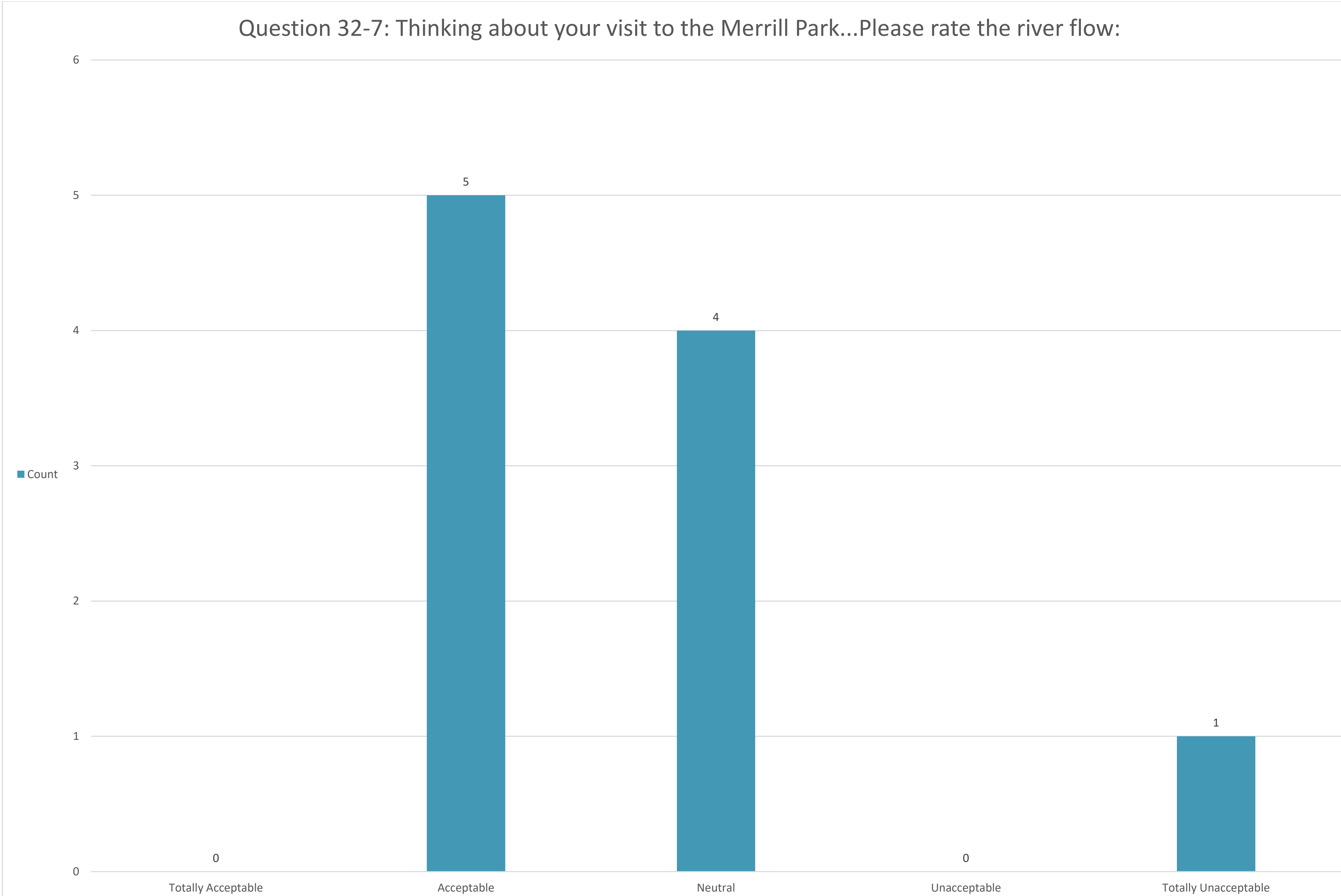

Question 32-2: Thinking about your visit to the Merrill Park...Please rate the parking:
5
4
3
2
1
0
Count
1
3
4
1
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

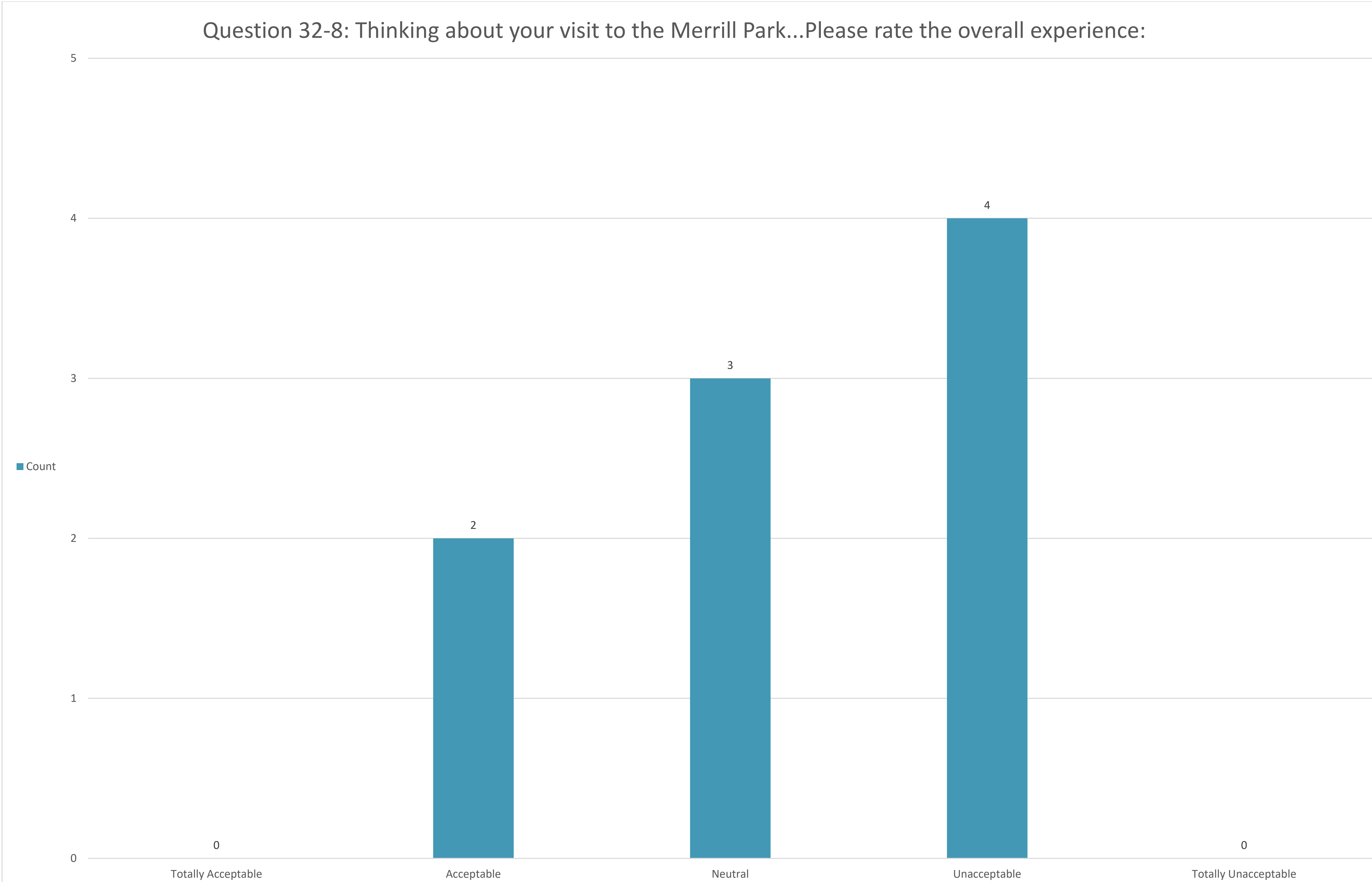

Question 32-3: Thinking about your visit to the Merrill Park...Please rate the crowding:
Count
5
4
3
2
1
0
2
3
4
1
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

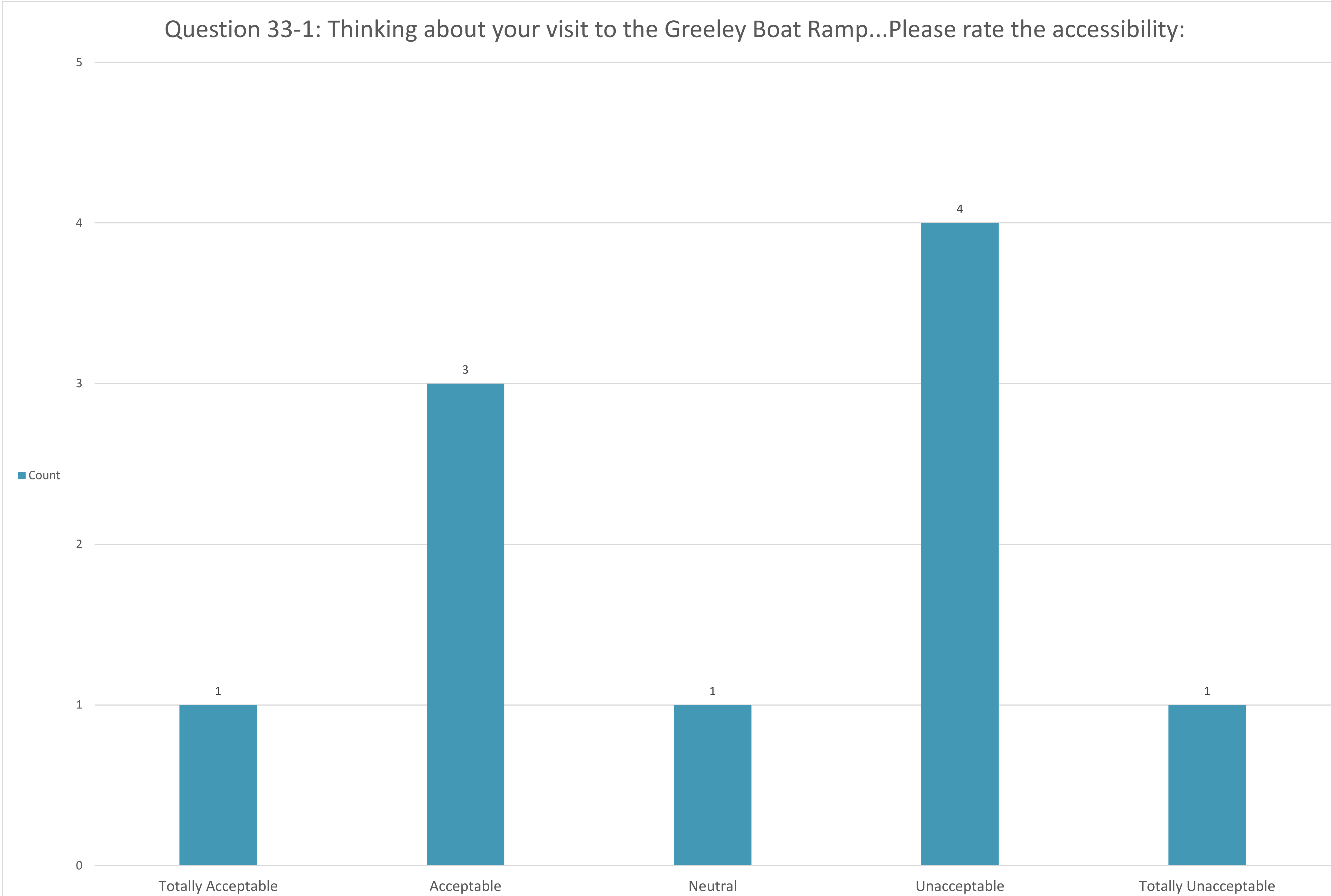

Question 32-4: Thinking about your visit to the Merrill Park...Please rate the safety:
5
4
3
2
1
0
Count
0
2
4
3
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 32-5: Thinking about your visit to the Merrill Park...Please rate the condition of recreation facilities:
Count
5
4
3
2
1
0
1
0
2
4
2
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

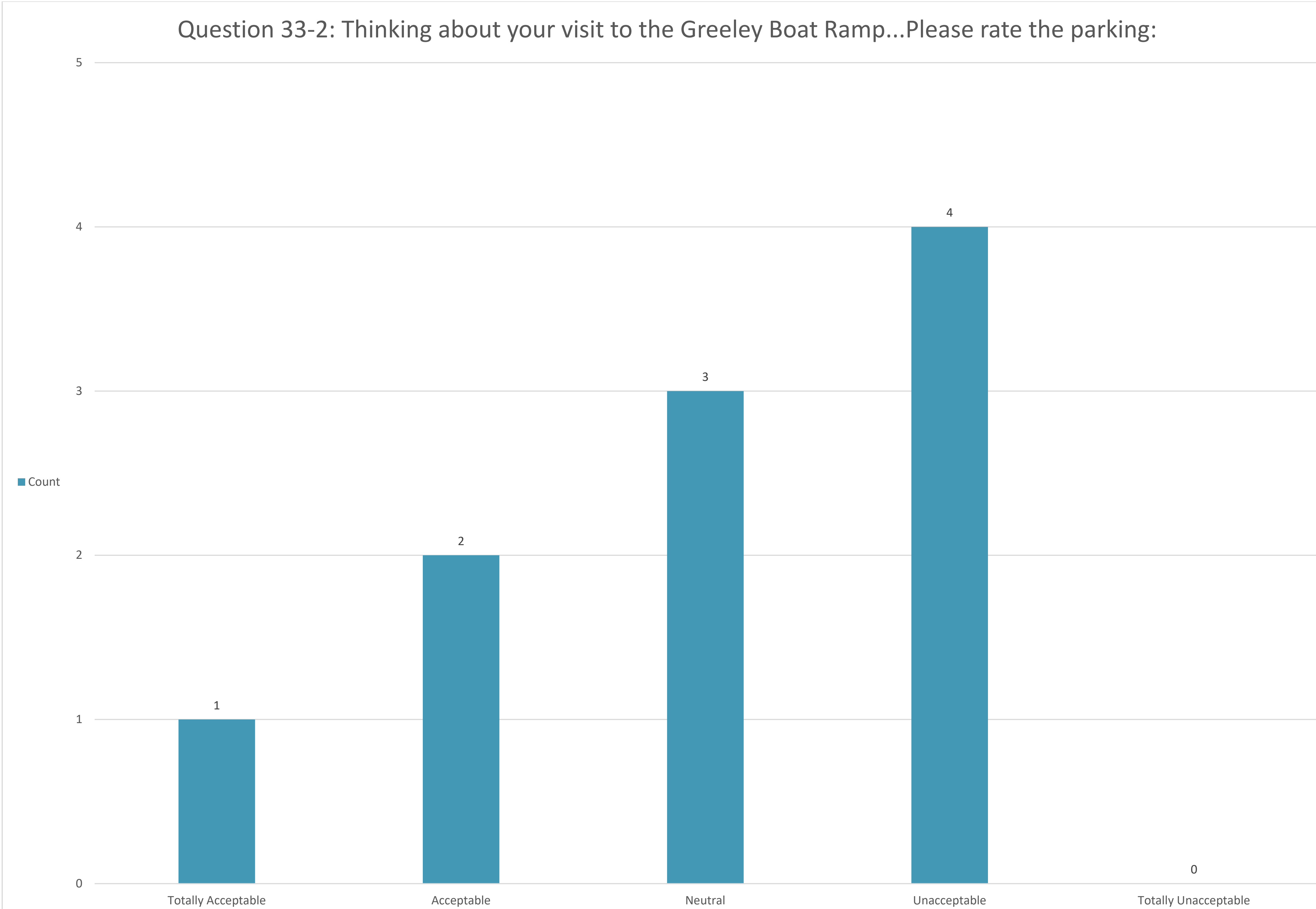

Question 32-6: Thinking about your visit to the Merrill Park...Please rate the available amenities:
Count
5
4
3
2
1
0
1
0
3
4
2
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 32-7: Thinking about your visit to the Merrill Park...Please rate the river flow:
6
5
4
3
2
1
0
Count
5
4
0
0
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

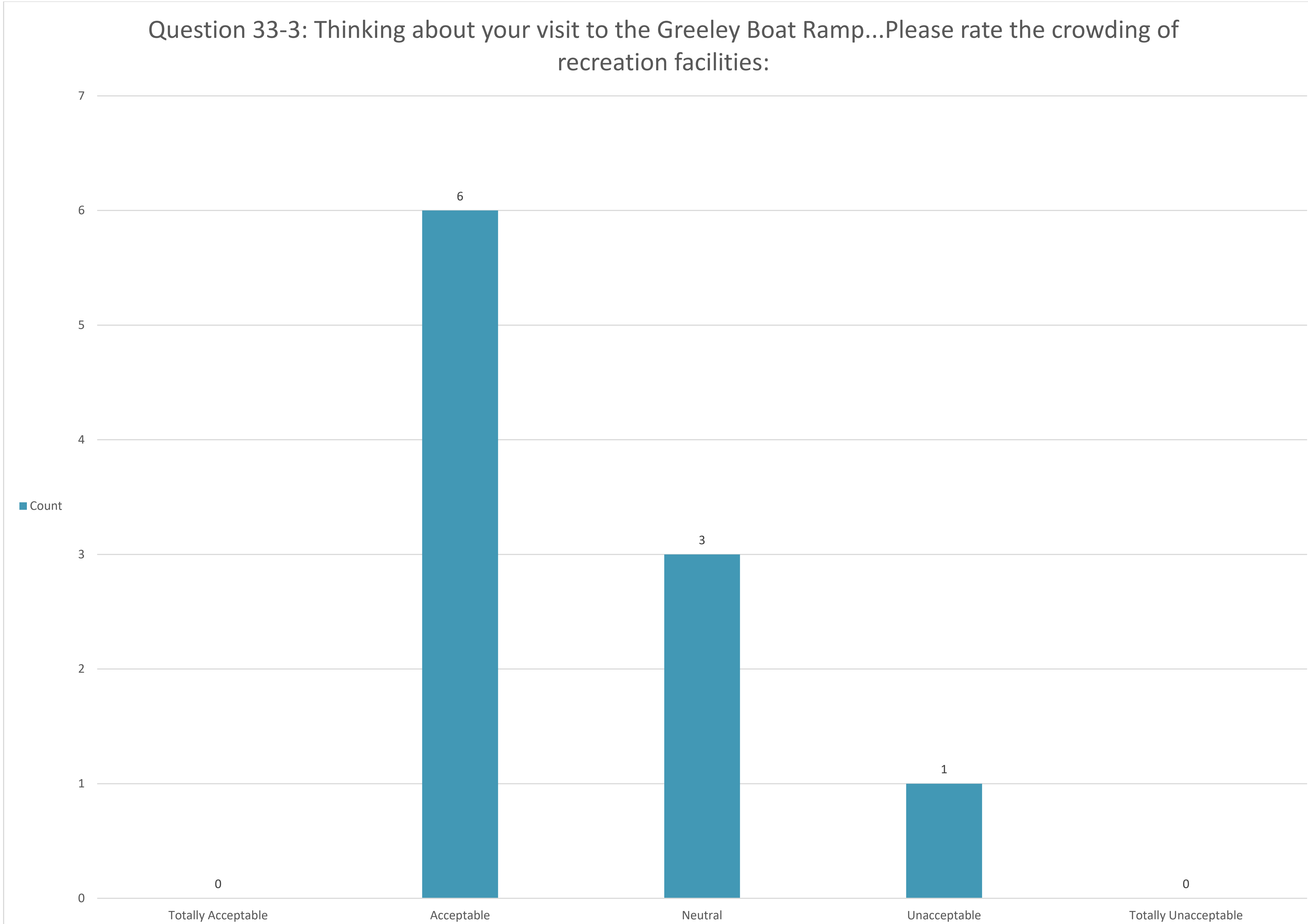

Question 32-8: Thinking about your visit to the Merrill Park...Please rate the overall experience:
Count
5
4
3
2
1
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable
0
2
3
4
0



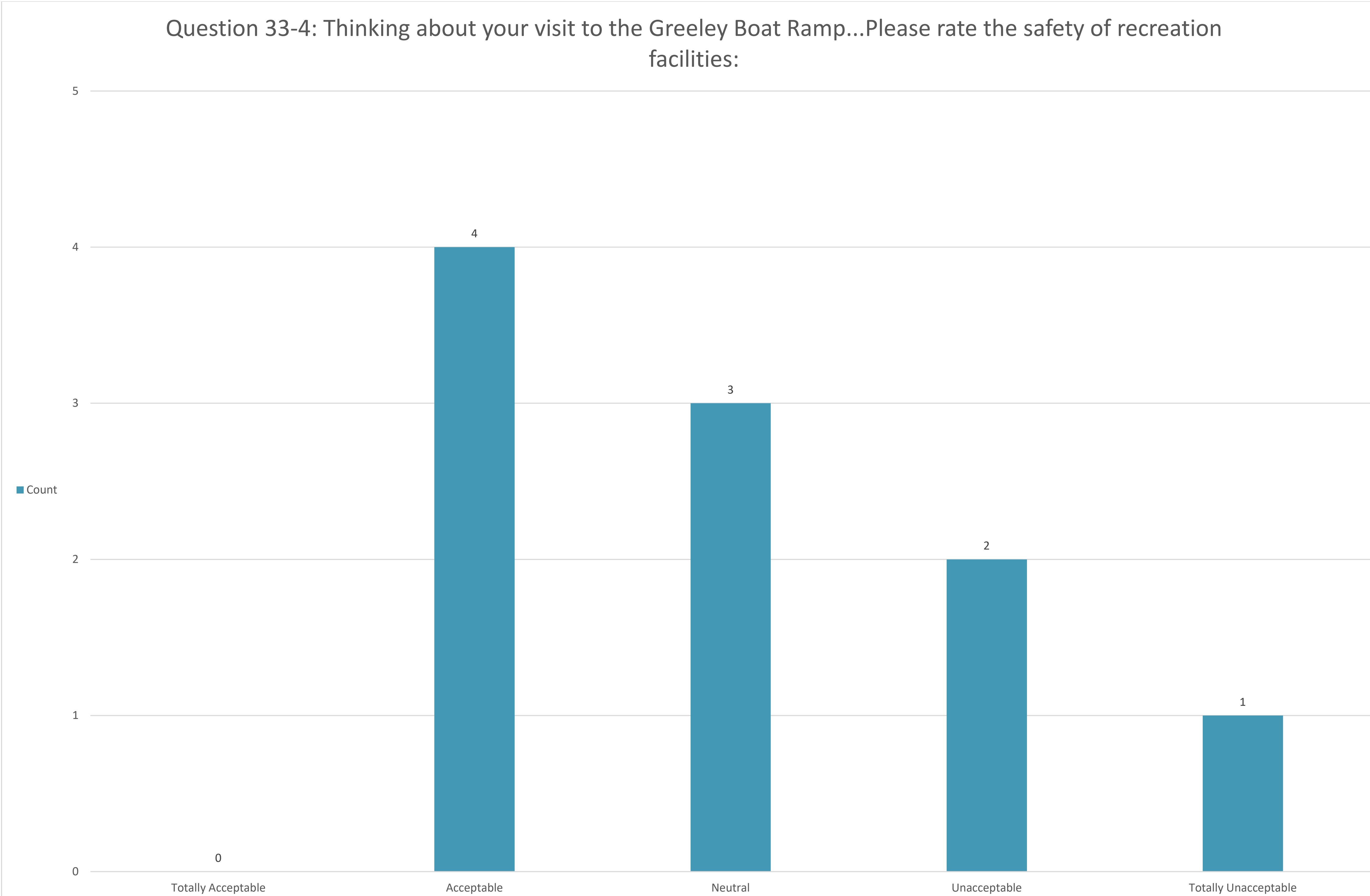
Question 33-1: Thinking about your visit to the Greeley Boat Ramp...Please rate the accessibility:
5
4
3
2
1
0
Count
1
3
1
4
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

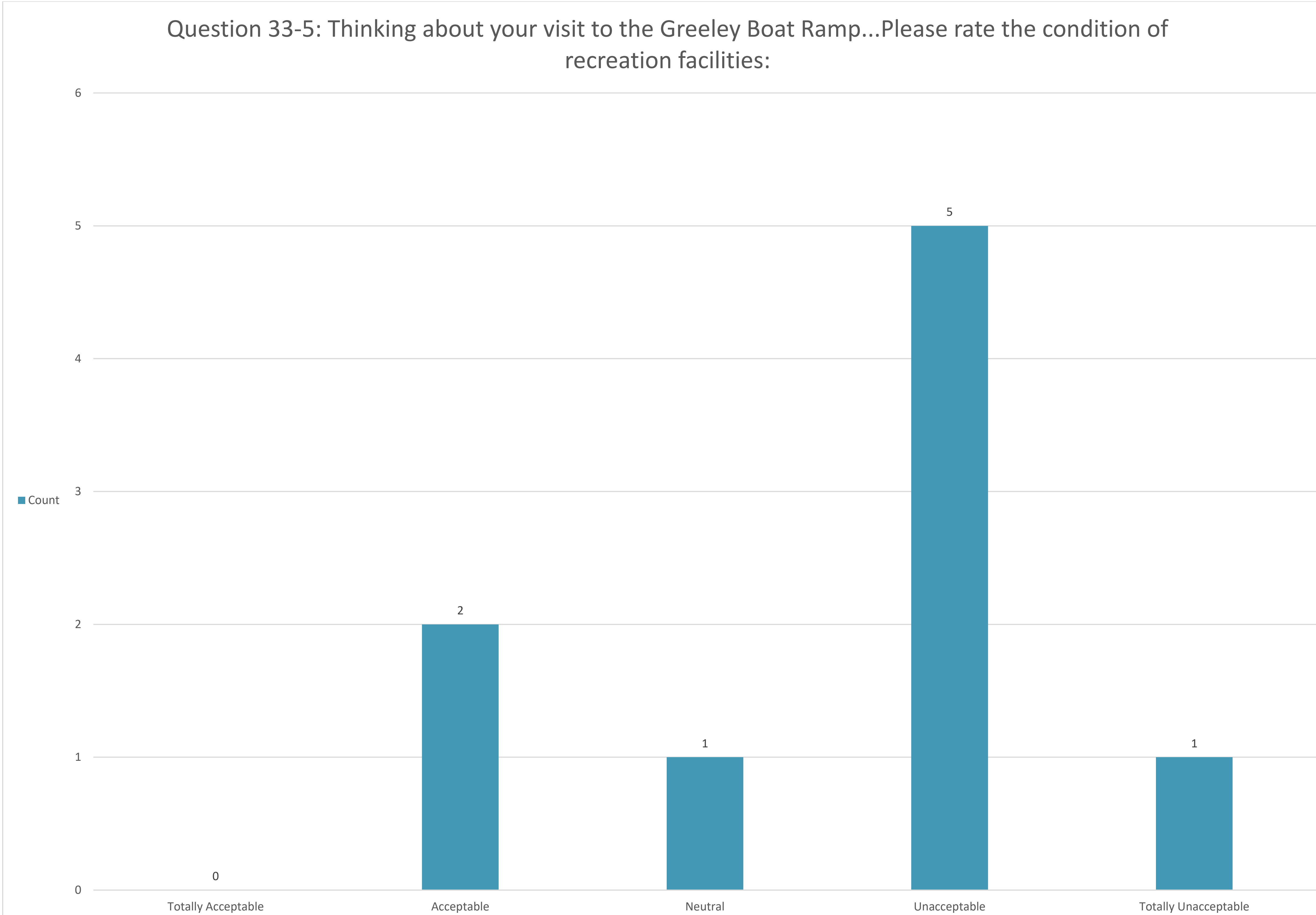


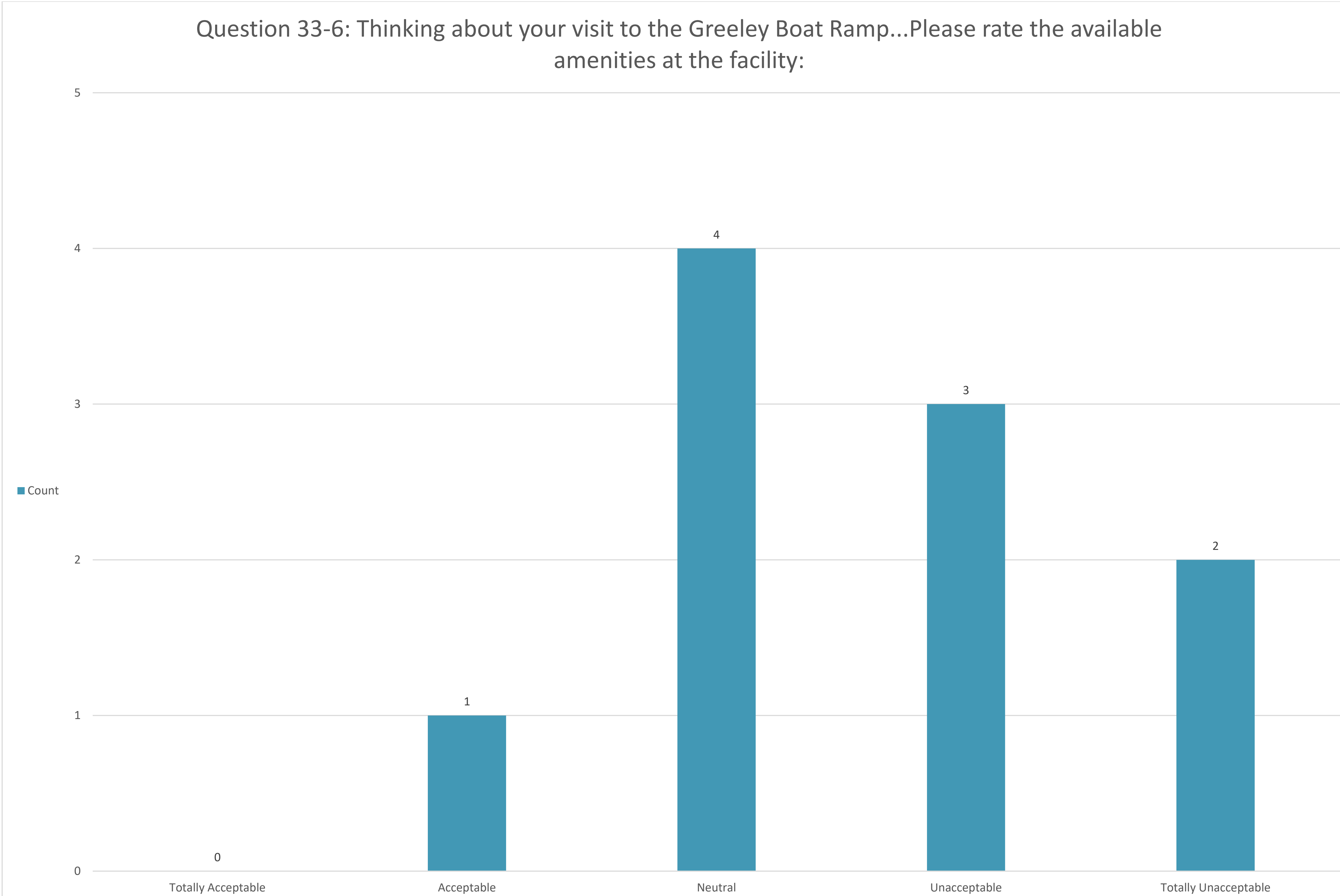
Question 33-2: Thinking about your visit to the Greeley Boat Ramp...Please rate the parking:
5
4
3
2
1
0
Count
1
2
3
4
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

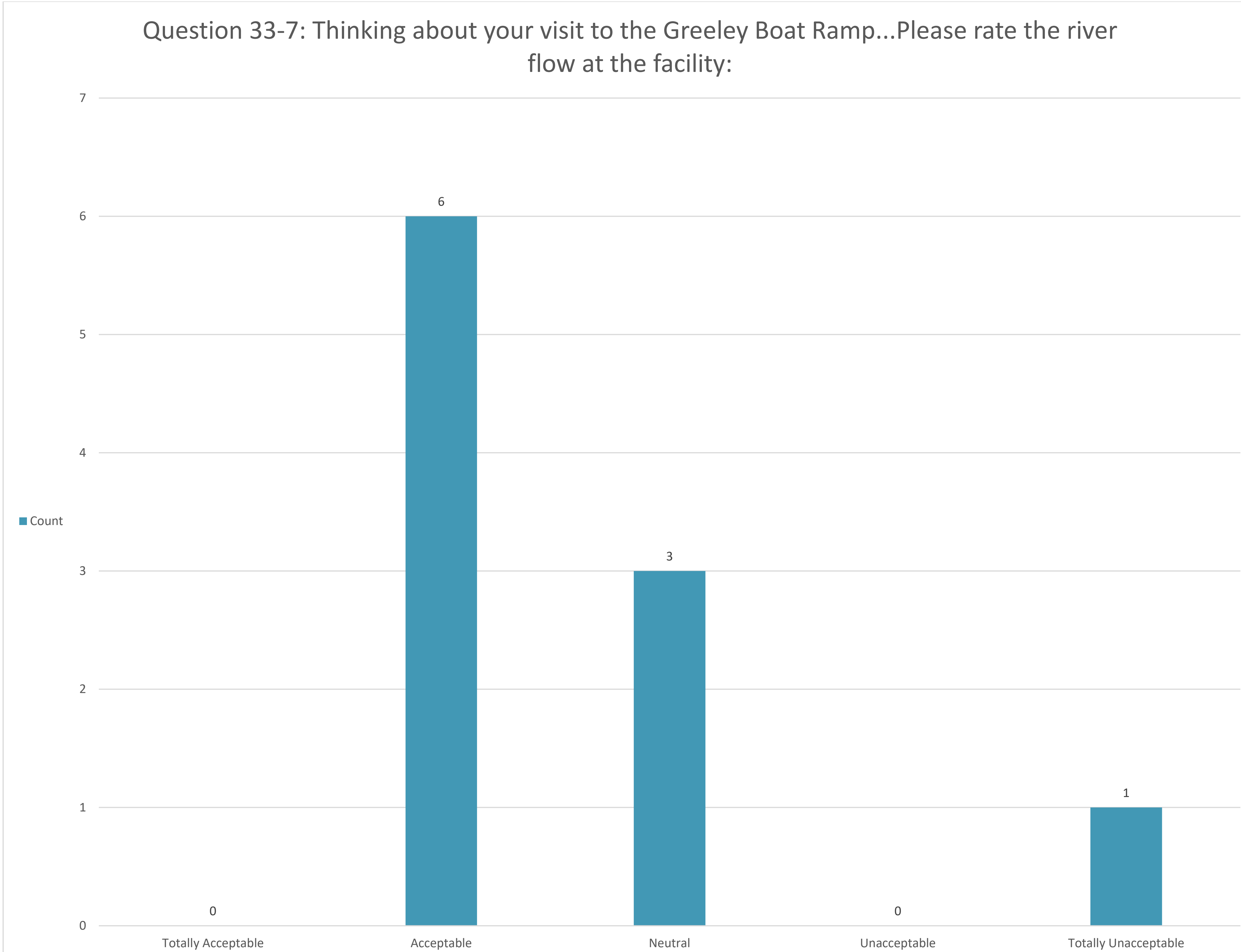


Question 33-3: Thinking about your visit to the Greeley Boat Ramp...Please rate the crowding of recreation facilities:
7
6
5
4
3
2
1
0
Count
6
3
1
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

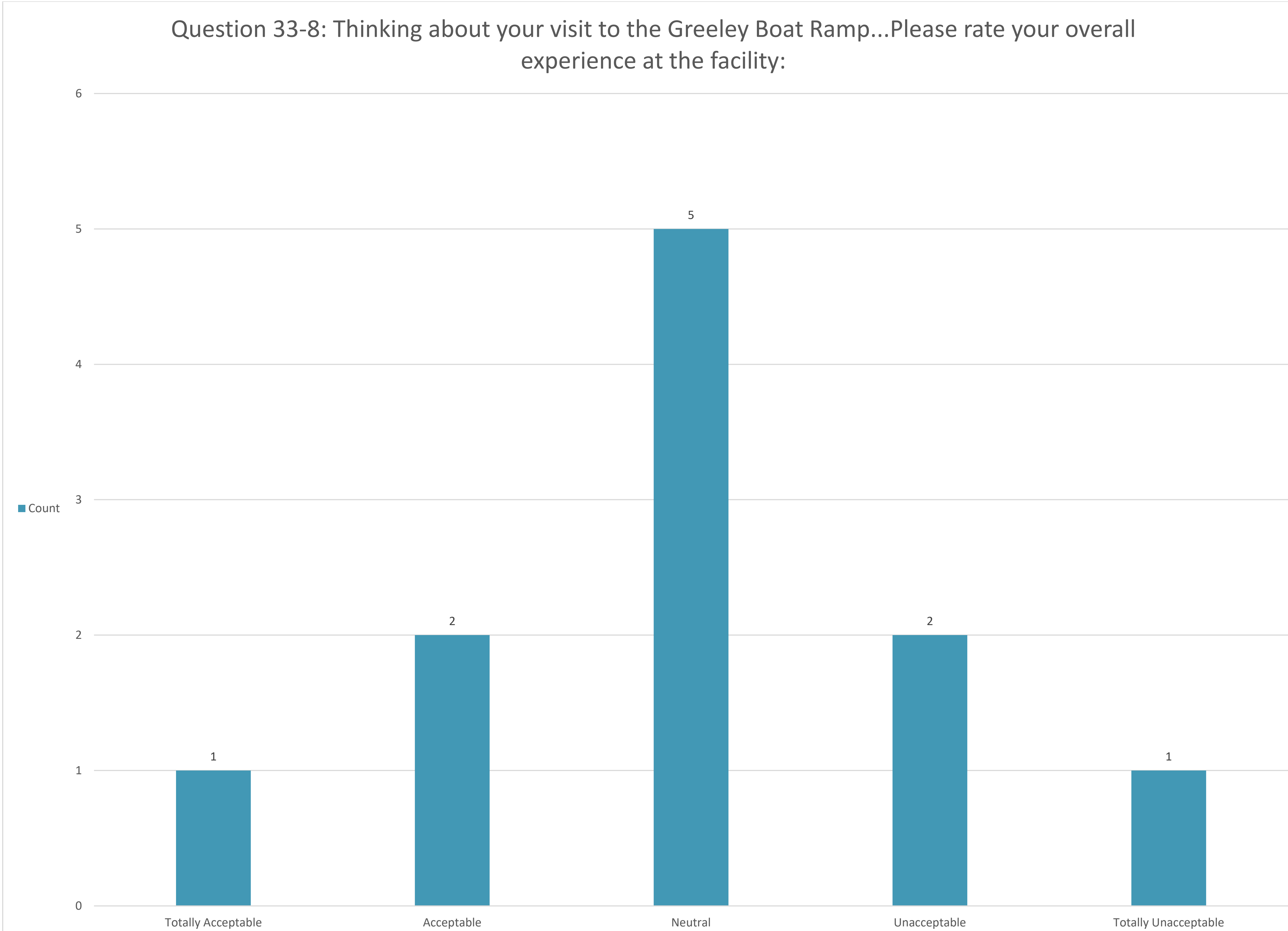

Question 33-4: Thinking about your visit to the Greeley Boat Ramp...Please rate the safety of recreation facilities:
5
4
3
2
1
0
Count
4
3
2
1
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

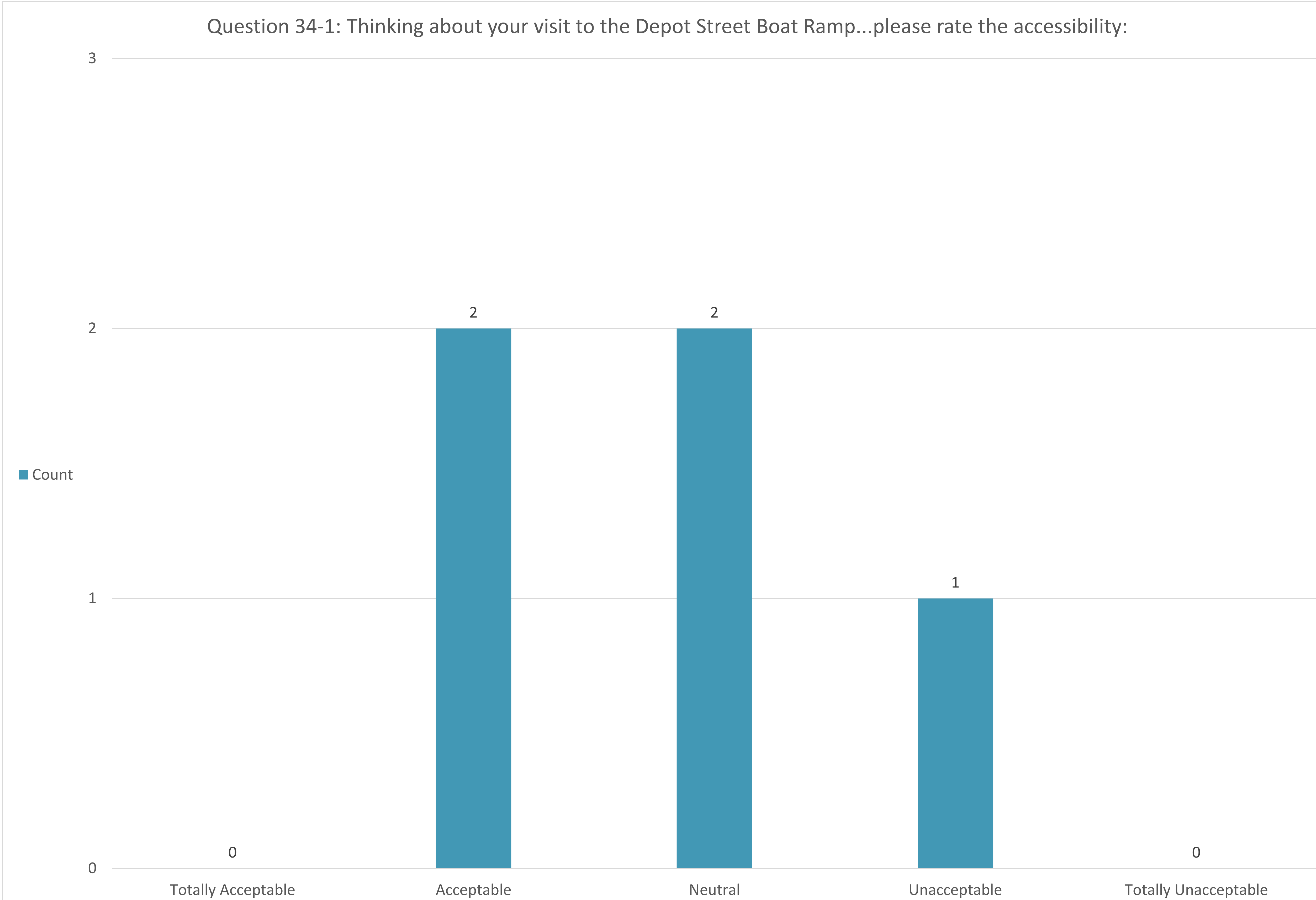

Question 33-5: Thinking about your visit to the Greeley Boat Ramp...Please rate the condition of recreation facilities:
Count
0
1
2
3
4
5
6
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable
0
2
1
5
1


Question 33-6: Thinking about your visit to the Greeley Boat Ramp...Please rate the available amenities at the facility:
5
4
3
2
1
0
Count
0
1
4
3
2
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

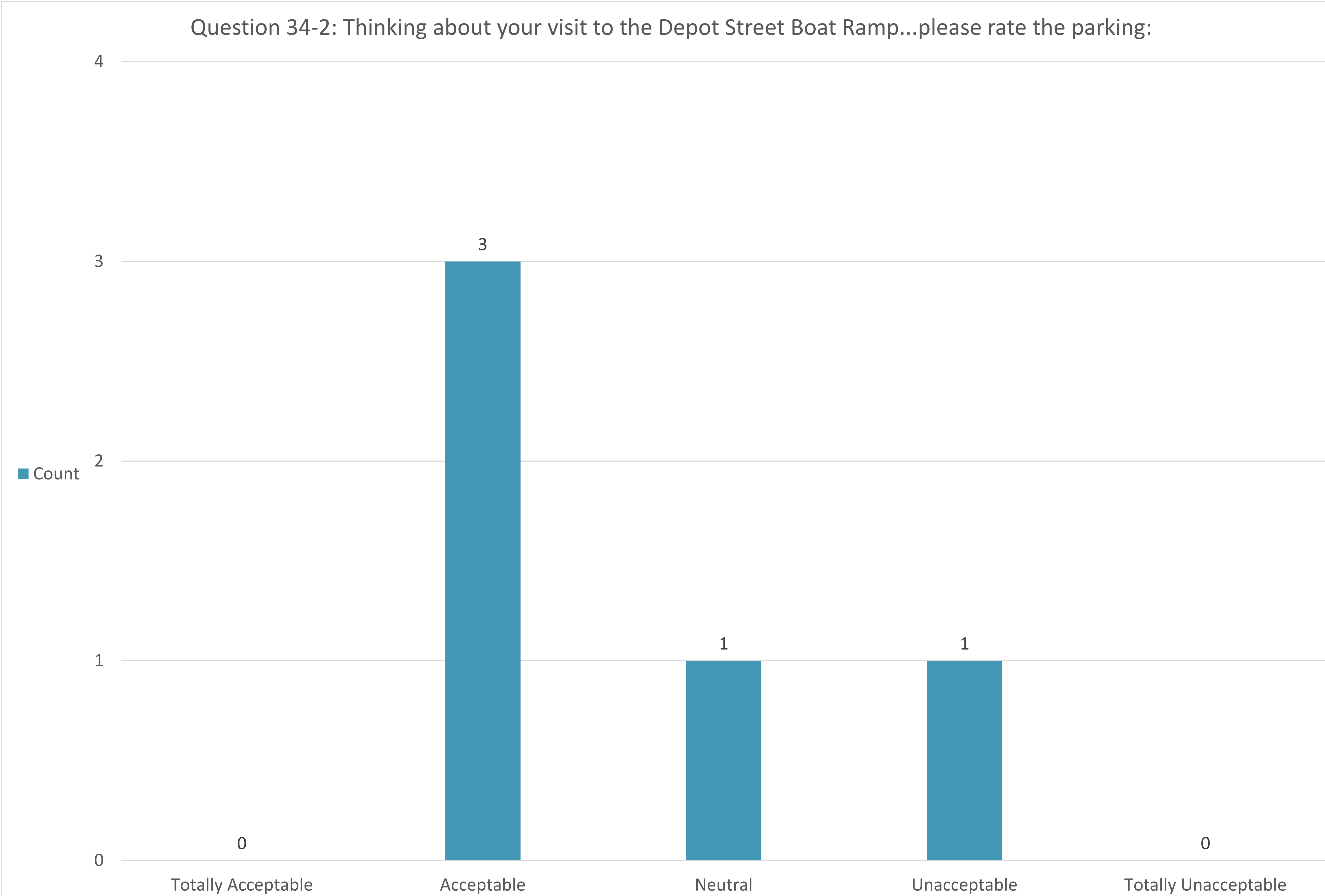


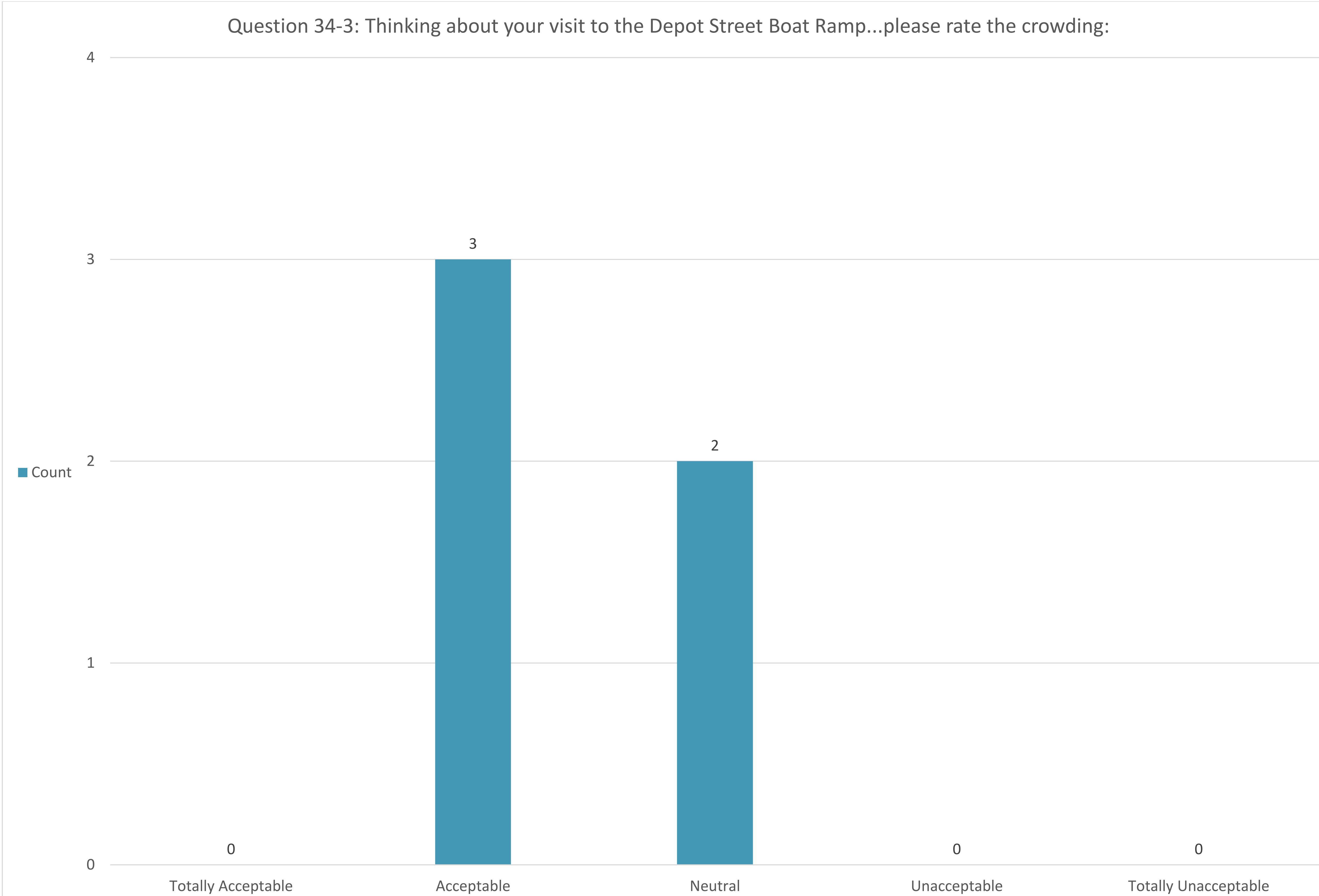
Question 33-7: Thinking about your visit to the Greeley Boat Ramp...Please rate the river flow at the facility:
7
6
5
4
3
2
1
0
Count
6
3
1
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 33-8: Thinking about your visit to the Greeley Boat Ramp...Please rate your overall experience at the facility:
Count
0
1
2
3
4
5
6
1
2
5
2
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

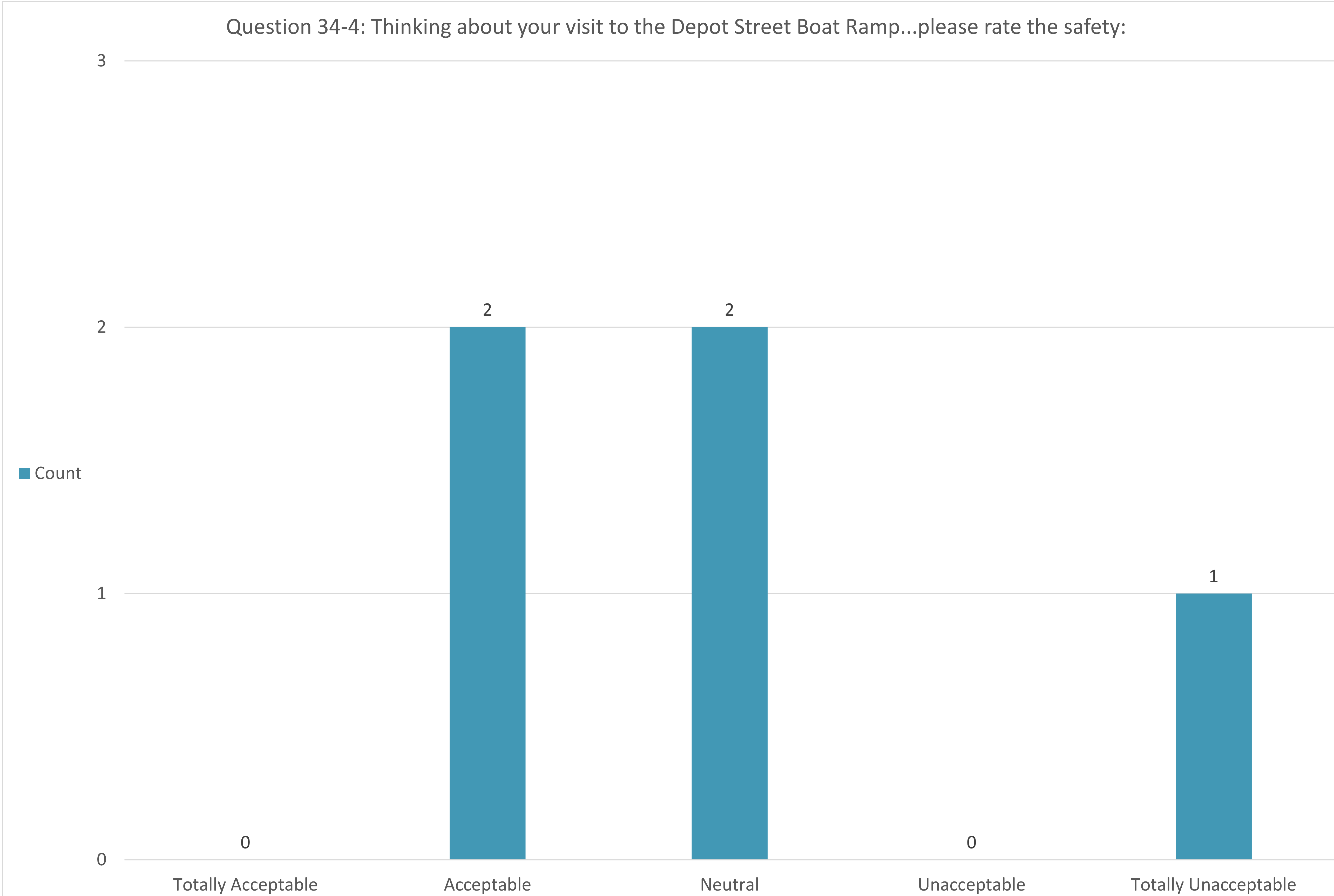


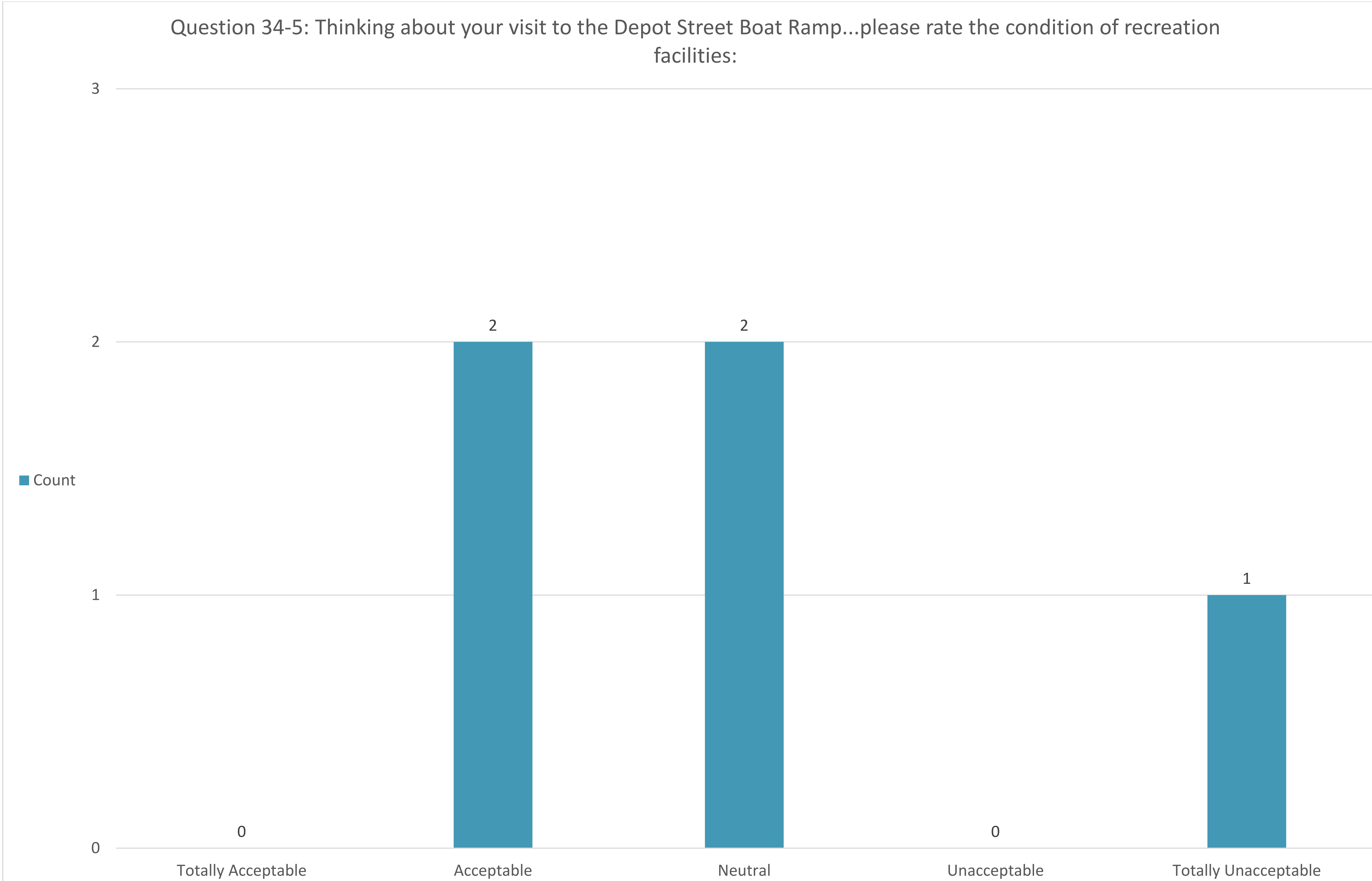
Question 34-1: Thinking about your visit to the Depot Street Boat Ramp...please rate the accessibility:
3
2
1
0
Count
0
2
2
1
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

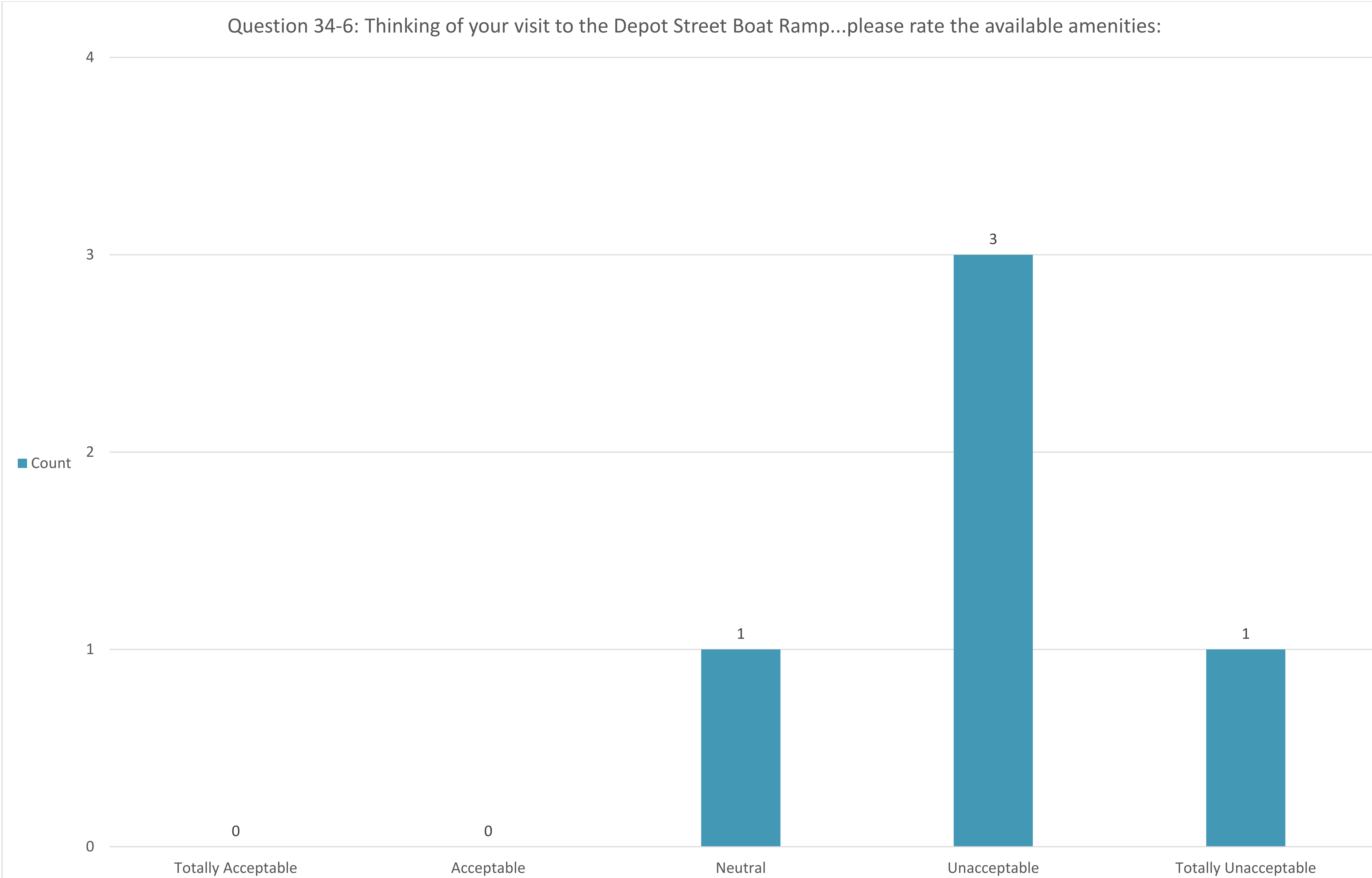

Question 34-2: Thinking about your visit to the Depot Street Boat Ramp...please rate the parking:
4
3
2
1
0
Count
3
1
1
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

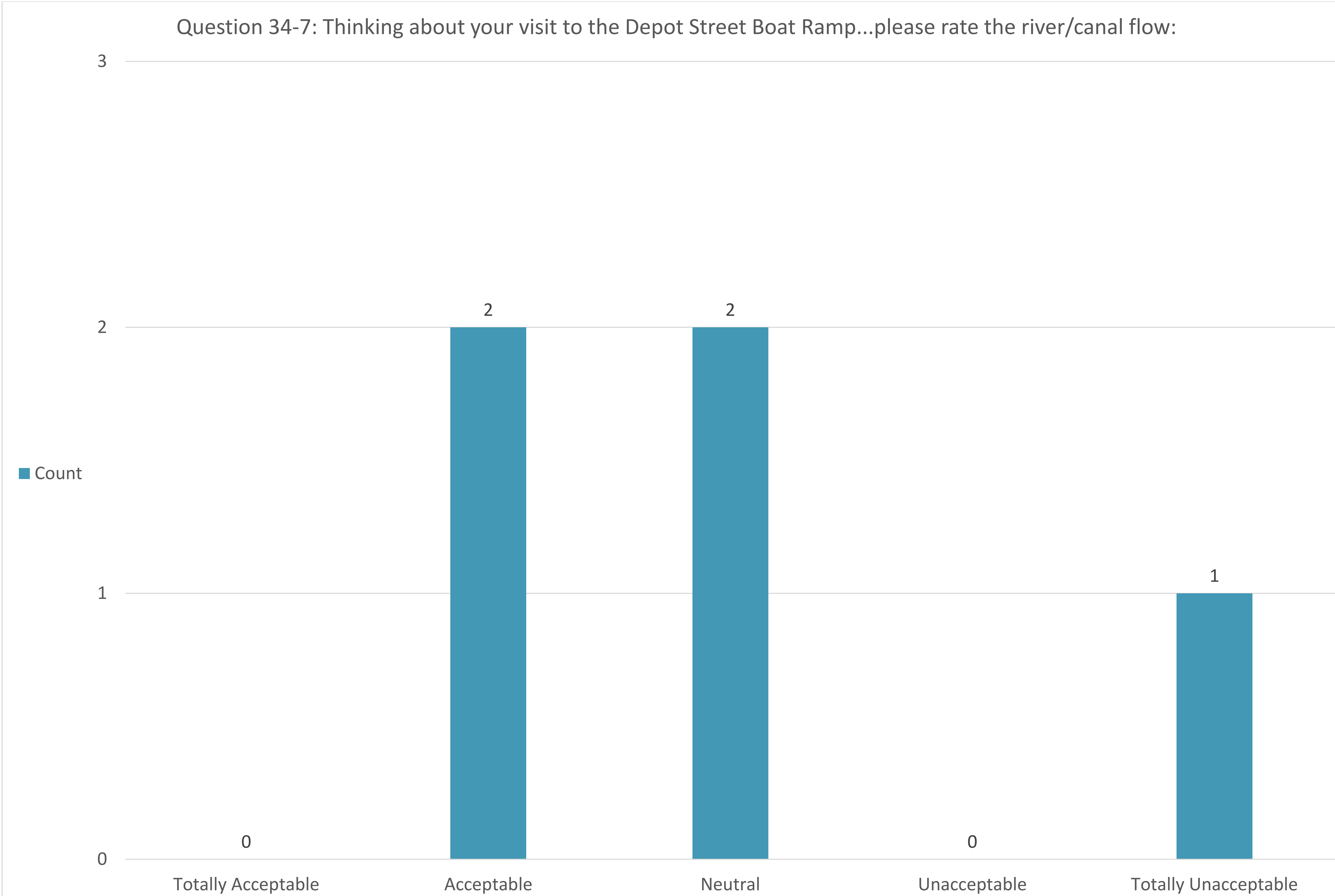


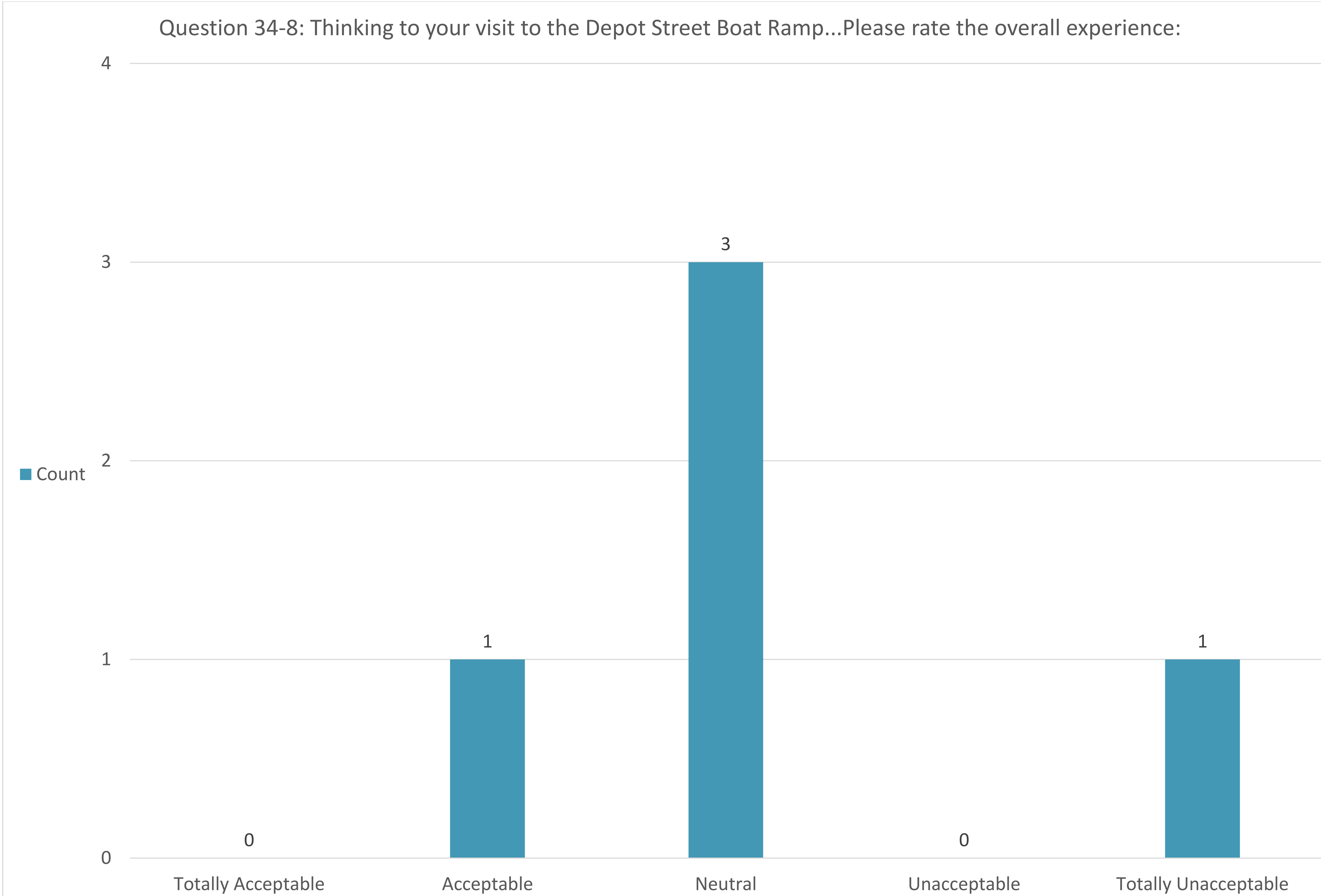
Question 34-3: Thinking about your visit to the Depot Street Boat Ramp...please rate the crowding:
Count
4
3
2
1
0
3
2
0
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

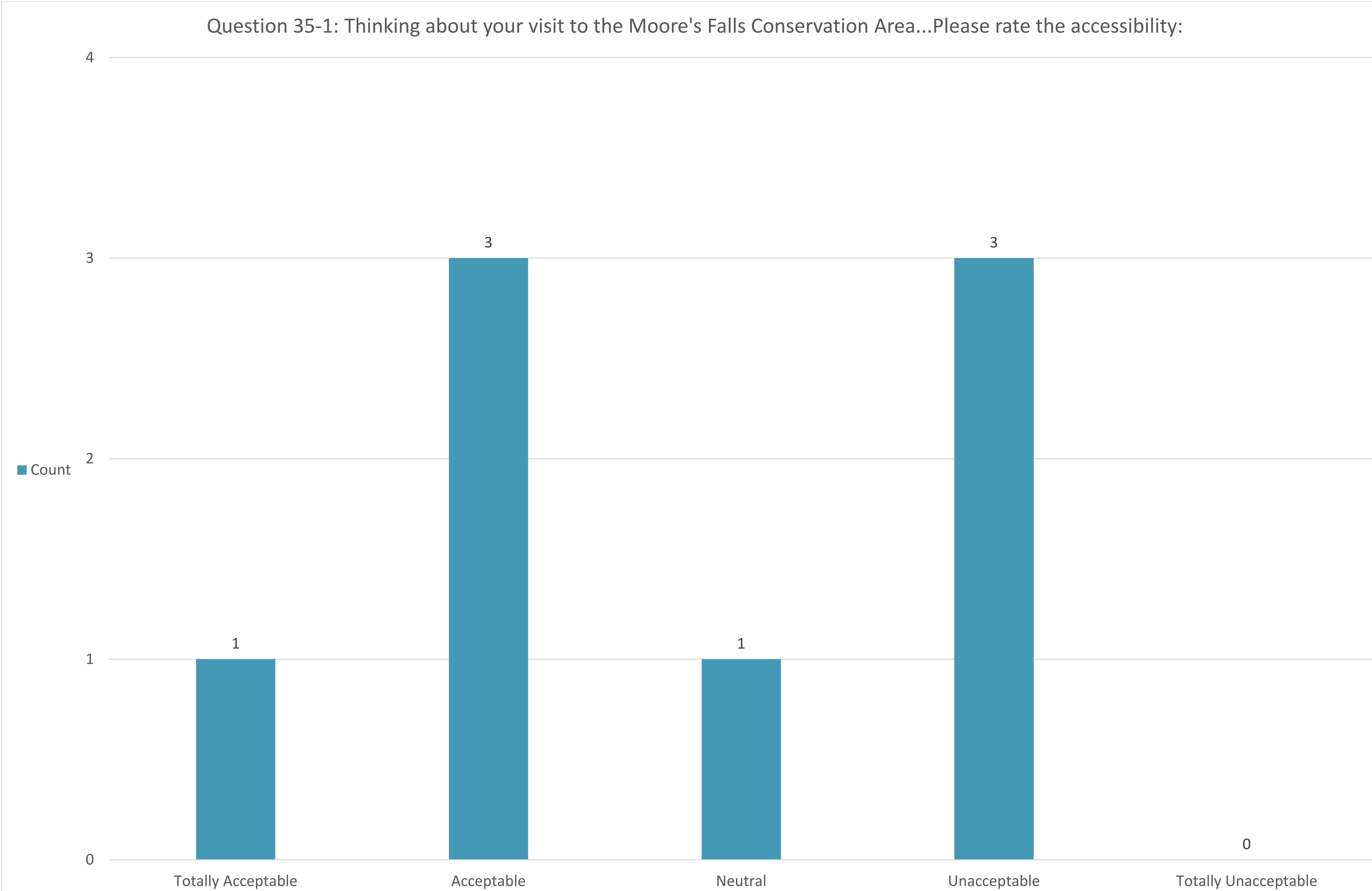

Question 34-4: Thinking about your visit to the Depot Street Boat Ramp...please rate the safety:
3
2
1
0
Count
0
2
2
0
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 34-5: Thinking about your visit to the Depot Street Boat Ramp...please rate the condition of recreation facilities:
Count
3
2
1
0
0
2
2
0
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

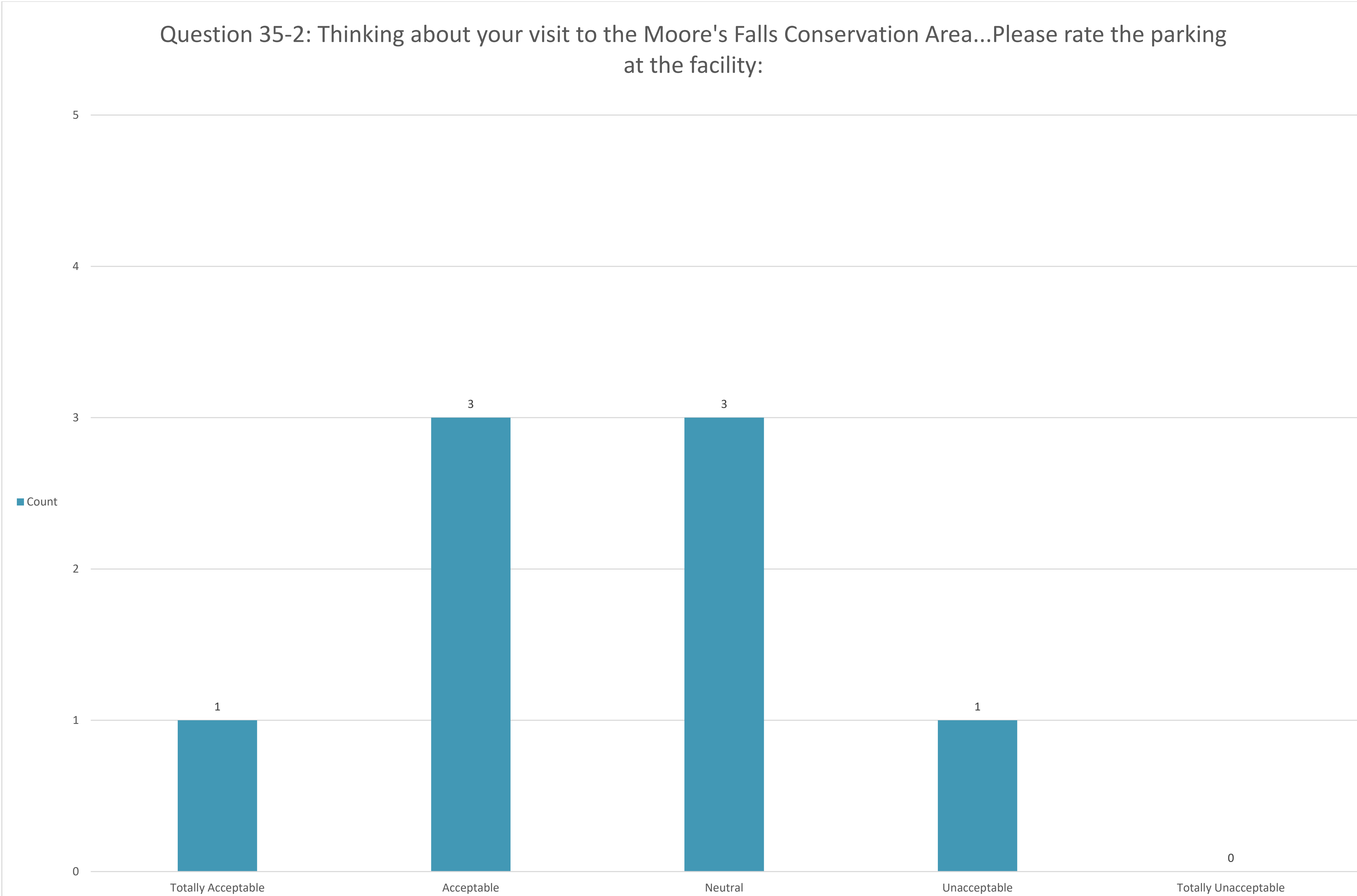

Question 34-6: Thinking of your visit to the Depot Street Boat Ramp...please rate the available amenities:
4
3
2
1
0
Count
3
1
1
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 34-7: Thinking about your visit to the Depot Street Boat Ramp...please rate the river/canal flow:
3
2
1
0
Count
0
2
2
0
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

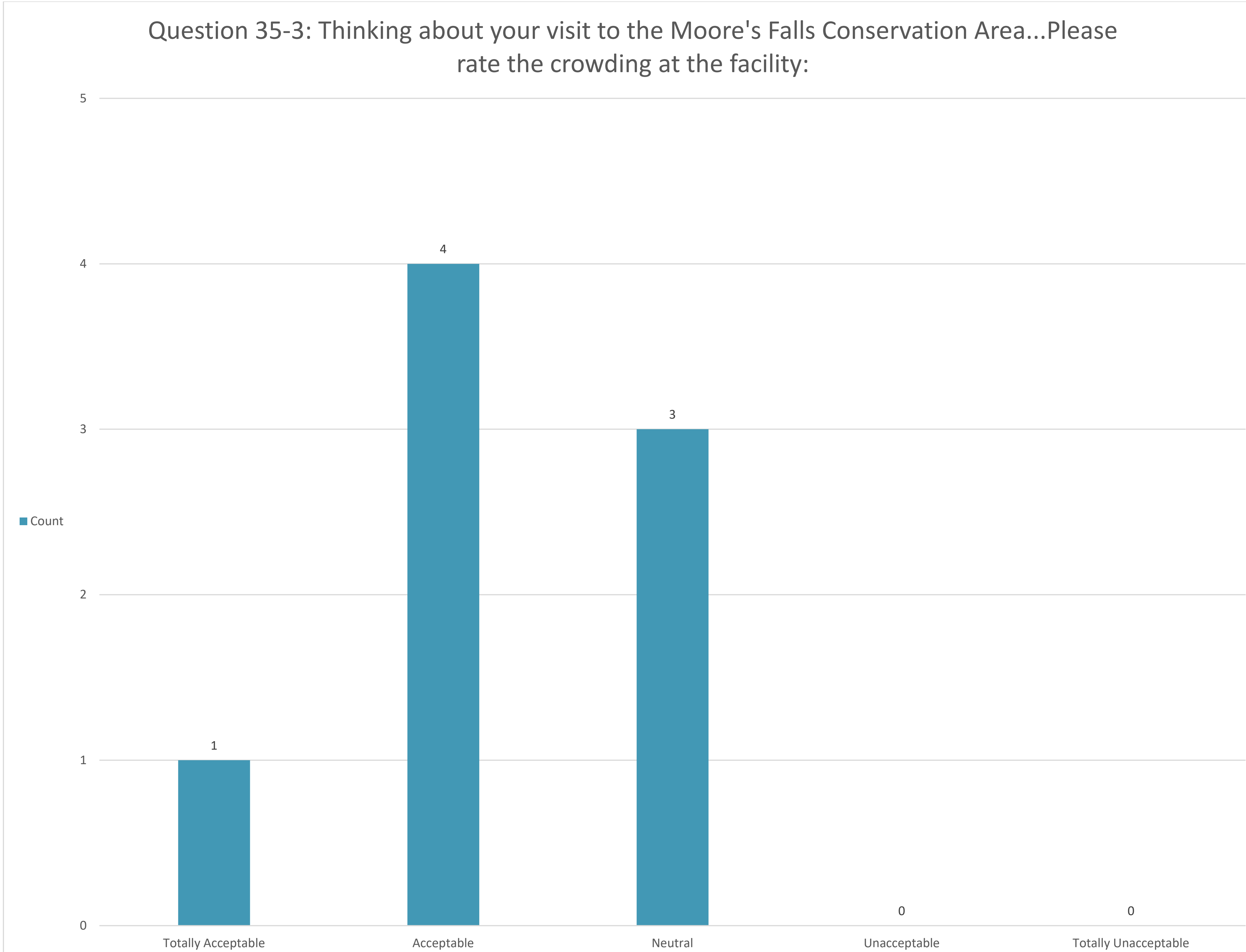

Question 34-8: Thinking to your visit to the Depot Street Boat Ramp...Please rate the overall experience:
Count
4
3
2
1
0
0
1
3
0
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

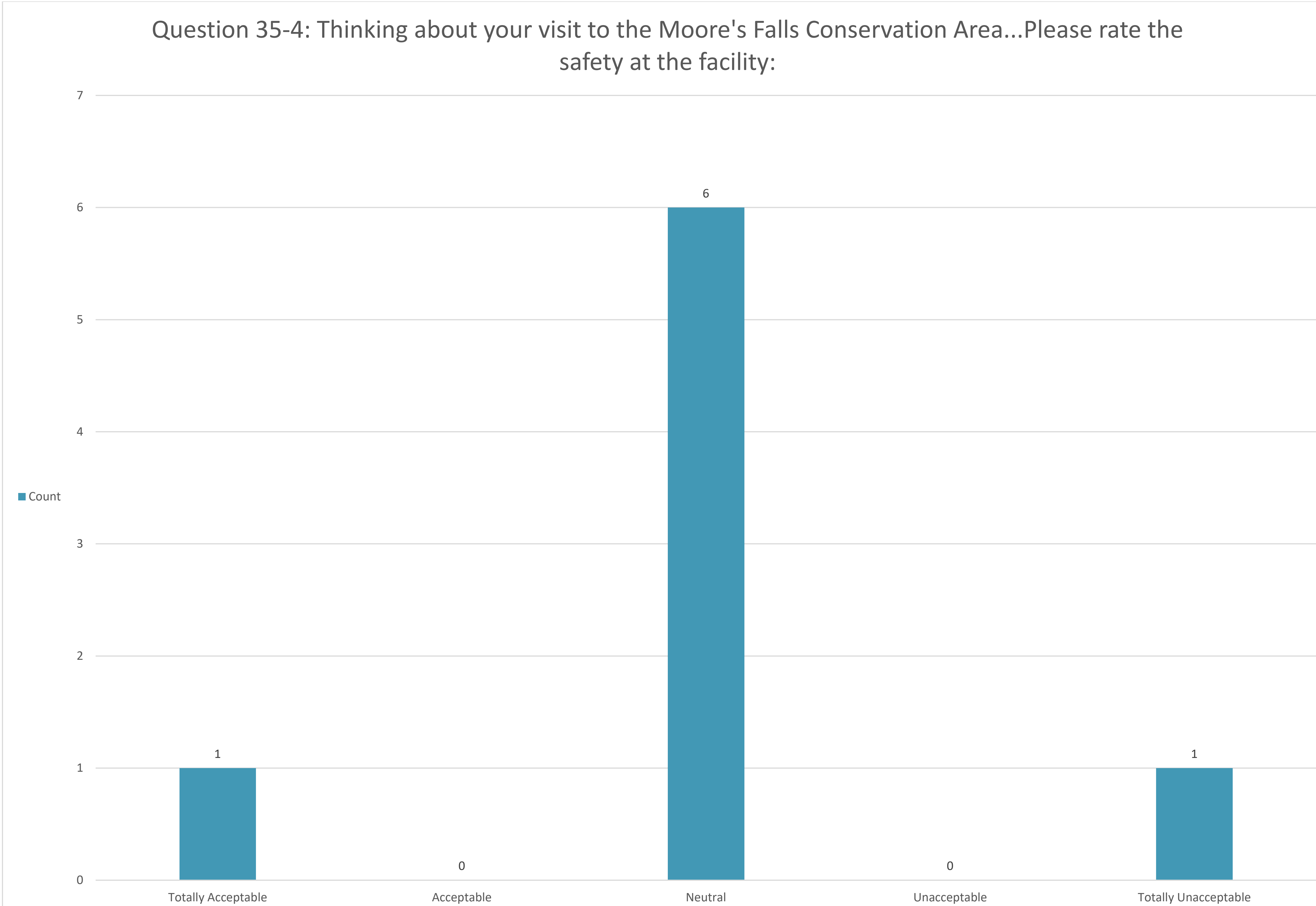


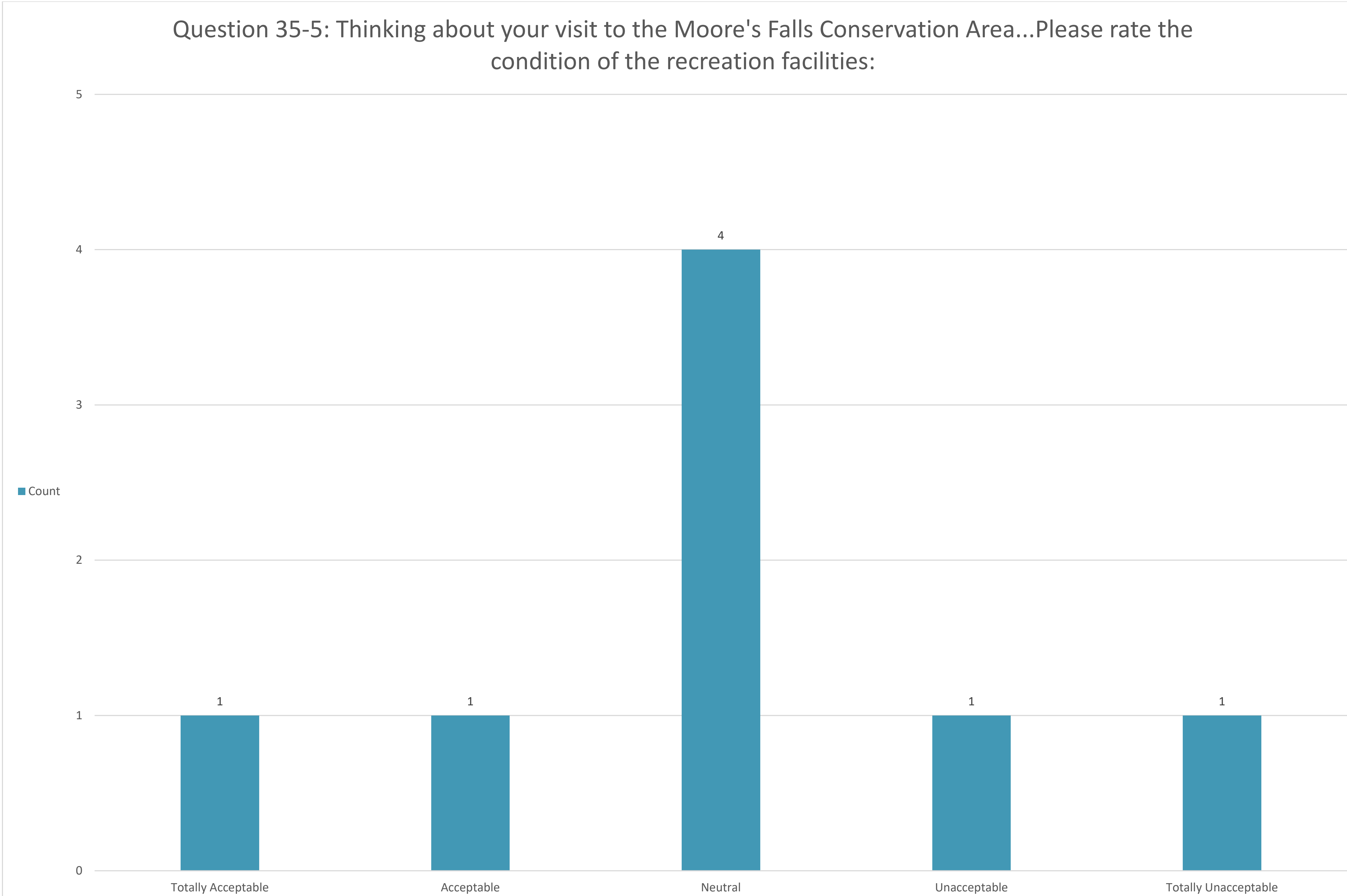
Question 35-1: Thinking about your visit to the Moore's Falls Conservation Area...Please rate the accessibility:
4
3
2
1
0
Count
1
3
1
3
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

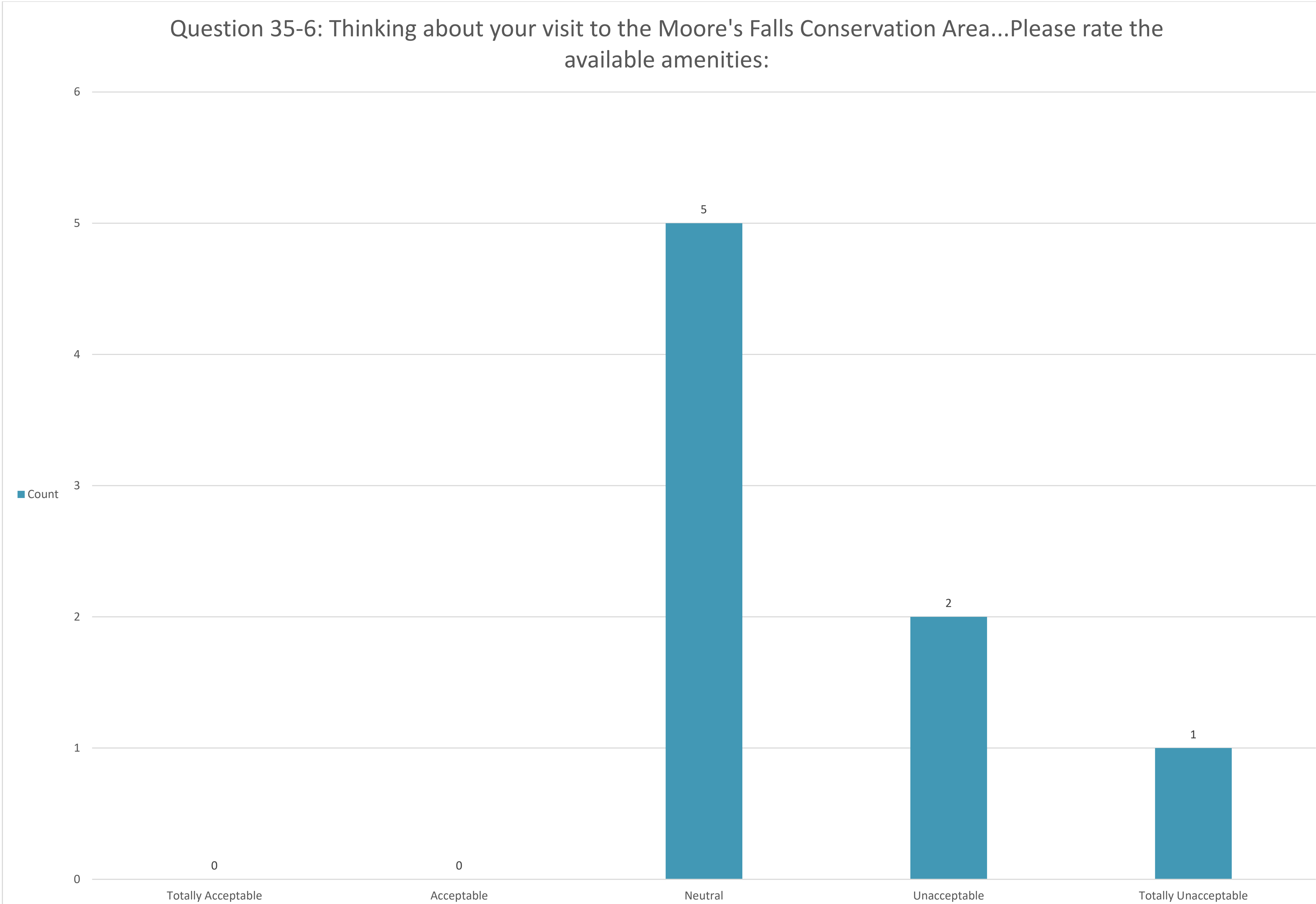


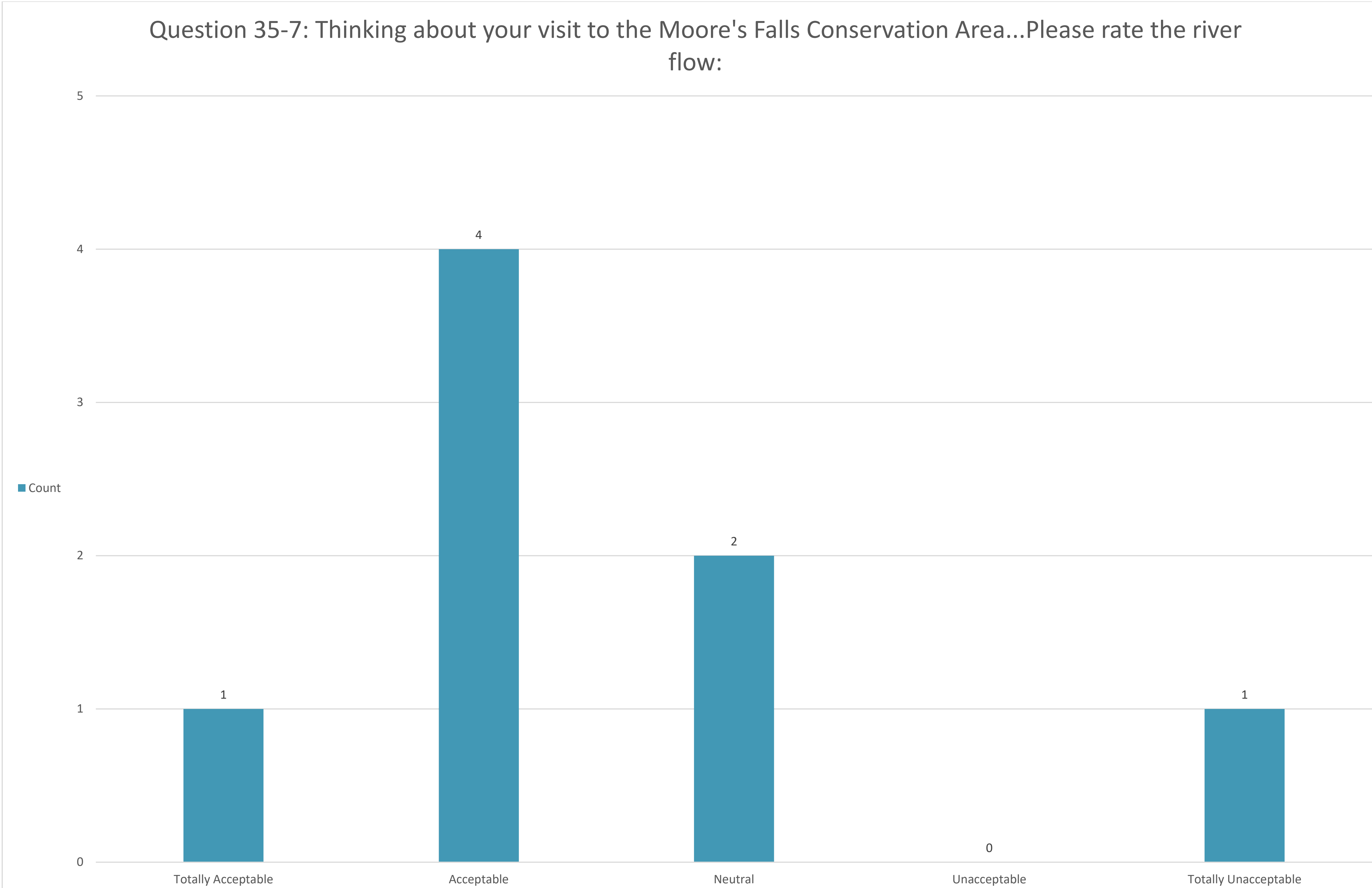
Question 35-2: Thinking about your visit to the Moore's Falls Conservation Area...Please rate the parking at the facility:
5
4
3
2
1
0
Count
3
3
1
1
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

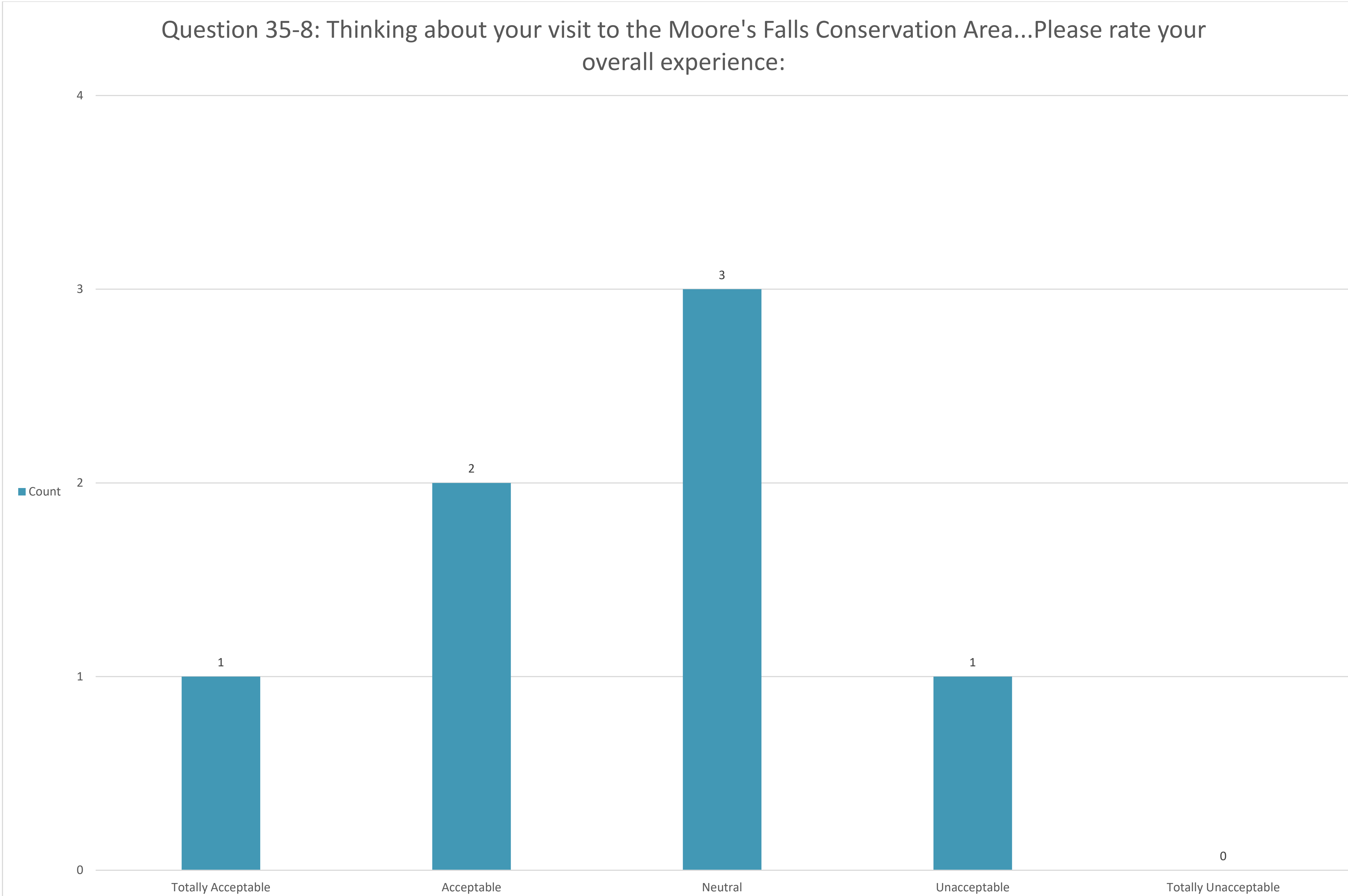

Question 35-3: Thinking about your visit to the Moore's Falls Conservation Area...Please rate the crowding at the facility:
Count
5
4
3
2
1
0
1
4
3
0
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 35-4: Thinking about your visit to the Moore's Falls Conservation Area...Please rate the safety at the facility:
7
6
5
4
3
2
1
0
Count
6
1
0
0
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 35-5: Thinking about your visit to the Moore's Falls Conservation Area...Please rate the condition of the recreation facilities:
Count
0
1
2
3
4
5
1
1
4
1
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 35-6: Thinking about your visit to the Moore's Falls Conservation Area...Please rate the available amenities:
Count
6
5
4
3
2
1
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 35-7: Thinking about your visit to the Moore's Falls Conservation Area...Please rate the river flow:
5
4
3
2
1
0
Count
1
4
2
0
1
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable


Question 35-8: Thinking about your visit to the Moore's Falls Conservation Area...Please rate your overall experience:
Count
0
1
2
3
4
1
2
3
1
0
Totally Acceptable
Acceptable
Neutral
Unacceptable
Totally Unacceptable

	Question 36-1: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Question 36-2: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Question 36-3: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Q37. Please share any other comments that you have regarding recreation near the Lowell Project:
Recorded Date	**Q36-1. Type of Recreation Enhancement:**	**Q. 36-1. Location(s)**	**Q36-2. Type of Recreation Enhancement:**	**Q. 36-2. Location(s)**	**Q36-3. Type of Recreation Enhancement:**	**Q. 36-3. Location(s)**	
5/8/2019 7:25	fishing access	Pawtucket falls area	whitewater recreational releases with improved access and adequate flow information	Pawtucket falls	Improved access and trails	Pawtucket falls area	Lowell's world class whitewater and long season, is a resource that is greatly overlooked and underutilized due to the current condition. Whitewater boating is a popular sport in New England with tens of thousands of participants. Many live in the greater Boston area, myself just a few miles. Many Boaters enjoy the rapids on neighboring Concord River. Lowell has potential here to create another unique thriving attraction. Not only to the private boaters but to commercial companies as well. Commercial rafting proceeds on the Concord, currently help fund much of the greenway project. A longer greater season for them means more financial assistance from their proceeds. Lowell should be and has all the potential to be, a Richmond VA of the North.
5/8/2019 8:08	improvements for whitewater paddlers						
5/8/2019 8:53	River access to whitewater sections	Anywhere there is whitewater, in particular just below the dam.					
5/8/2019 9:03	Improved public access to the canals	all canals	better public access for unguided canoeing / kayaking	all canals	public access ramps, parking areas	near canals	It would be fantastic for economic development, waterfront pubs, non-motorized boat rental, to allow public access to Lowell canals - at least from dawn till dusk.
5/8/2019 9:10	Whitewater Access	Pawtucket Falls	Recreational releases	Pawtucket Falls	Proper Flow Gauge for Pawtucket Falls	Pawtucket Falls	I have traveled the country paddling challenging whitewater. Lowell has some of the highest quality whitewater given the correct conditions. However its inaccessibility, lack of flow, and debris problem. Has allowed it

	Question 36-1: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Question 36-2: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Question 36-3: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Q37. Please share any other comments that you have regarding recreation near the Lowell Project:
Recorded Date	**Q36-1. Type of Recreation Enhancement:**	**Q. 36-1. Location(s)**	**Q36-2. Type of Recreation Enhancement:**	**Q. 36-2. Location(s)**	**Q36-3. Type of Recreation Enhancement:**	**Q. 36-3. Location(s)**	
							to be severely compromised, seldom visited and avoided commercially. Limited shoreline access has also created conditions of underutilized wooded areas, that largely harbor many homeless camps, dumping sites. Further adding to river and shoreline debris. Addressing these recreational potentials will greatly benefit the health of the river and the city as well as help developing Lowells growing recreational attractions.
5/8/2019 9:17							
5/8/2019 9:48							
5/8/2019 9:59	Keep rivers clear of debris and trash including trees	Concord					Good improvements to river putin and takeout locations.
5/8/2019 10:06	Boat ramps	Canals	Kayak and canoe access	Canals			
5/8/2019 10:12	Canoeing	Canals	Kayaking	Canals	Boat kayak access	Canals	
5/8/2019 10:12	Clean up trash	Everywhere					I stopped going because of the garbage, needles, etc
5/8/2019 10:22							
5/8/2019 10:57							

	Question 36-1: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Question 36-2: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Question 36-3: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Q37. Please share any other comments that you have regarding recreation near the Lowell Project:
Recorded Date	**Q36-1. Type of Recreation Enhancement:**	**Q. 36-1. Location(s)**	**Q36-2. Type of Recreation Enhancement:**	**Q. 36-2. Location(s)**	**Q36-3. Type of Recreation Enhancement:**	**Q. 36-3. Location(s)**	
5/8/2019 11:07	River side boating put in	Wamesit Falls Overlook area	River side boating take out	Eastern Canal Park			
5/8/2019 11:27							
5/8/2019 12:55	artificial whitewater park	Pawtucket Canal and/or Northern Canal	whitewater rafting and whitewater kayaking				If one hasn't occurred, a city sponsored business study on the economic cost/benefits of constructing an artificial whitewater park would identify the feasibility of such a project. The proximity to such a large population would drastically promote tourism and should be considered within the city's development and economic plan.
5/8/2019 16:01							Entire project needs to be promoted and spruced up. If more activities were offered on a regular basis, more people would enjoy them. Compare attendance and usage with LOWELL WALKS!
5/8/2019 16:20	Shoreline access	Concord River					It's a valuable whitewater resource for kayaking, canoeing and rafting in Eastern Mass
5/8/2019 19:19							
5/8/2019 20:25	better parking	near greenway					
5/9/2019 4:22							
5/9/2019 6:37	Better kayak access		More releases of water		Less trash, especially needles		Yes please improve access flows and cleanliness for whitewater boaters like myself. Many boaters in the Boston area have to drive all the way to mid New Hampshire tonget decent paddling.

	Question 36-1: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Question 36-2: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Question 36-3: Please tell us what type(s) of recreation enhancements you believe are needed and at what specific location(s) at the Lowell Project:		Q37. Please share any other comments that you have regarding recreation near the Lowell Project:
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5/9/2019 23:53	Clean up the hypodermic needles	All locations					clean up the hypodermic needles at all locations
5/10/2019 3:58							Used Hypodermic needles are the immediate safety concern that needs to be addressed
5/11/2019 9:55							
5/13/2019 11:14	River clean-up efforts	Concord River	Old dam clean-up/removal	Concord River			Broad boating access around the city of Lowell would result in my using the area for whitewater recreation significantly more frequently. Currently, there's no reasonable access for rafts to the Merrimack River sections with whitewater that I'm generally aware of.
5/16/2019 8:43	Improving flows to the dewatered section of river	Pawtucket falls.	Access trails along river	Along dewatered section of pawtucket falls	Canoe and kayak access point.	Below Pawtucket falls.	Lowell has been over looked and underutilized when it comes to its recreational resource potentials. This facility has lacked any real recreational efforts in its past license. Its current condition, has limited the window of world class whitewater conditions, to a very few days a year. This has limited the amount of participation from the community of enthusiasts of this region. Improving flows, access, pollution from canals and homeless camps along the facility, would greatly improve these conditions. This license is 47 years in that time Lowell could grow into a Richmond VA like city in that timeframe. If the right choices are made for the residents of Lowell and surrounding communities.
5/16/2019 16:15	Improved flow	Pawtucket falls	Gauge to measure flow	Pawtucket falls	Improved access	Pawtucket falls	Large homeless population needs to be addressed. Not saying they need to be evicted but it is need that should be addressed
5/16/2019 20:28	boat trips						

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6/27/2019 12:30	Kayaking	Somewhere safe on canal system	canoeing	Somewhere safe on canal system			More people would like to use the canal system as a form of recreation. Where can this happen? You are the experts to tell us.
6/27/2019 15:24	More trash cans that are emptied frequently	River walk/canal walk	Beautification of the river walk/ canal walk	All			There's sooo much trash in the canals and around the canal walks /river walk. It's really gross.
6/28/2019 19:57	Damage repair/restoration post operations	North canal gate house/gatekeepers house					My comments are not about recreation. They constantly fail to repair damage that is cause from their crane operations at the northern gate house. I have continously tried to establish a working relationship with them, but to no avail. I live in a house via Massachusetts DCR, historic curatorship program, and i promise they continue to fail on the rules of their permit. I deal with these operations on a yearly basis, for almost 5 years. Not once have they followed their permit and repaired damages.
7/4/2019 7:58	Accessibility	Merrill park	Trail maintenance	Merrill Park	Trash removal	Merrill Park	I go to Merrill Park daily. The park does not seem to be maintained at all. There are no amenities. I collect a bag of trash every day on my visit. This park could be a jewel with a little help.
7/4/2019 8:18	Boat launch	Tyngsboro					Boat ramps are crowded on weekends with jet skiers
7/4/2019 8:31	clearing brush and fixing the walking path down to the river bank	toilets					

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7/4/2019 8:50	Trail maintenace	Merrill park	Signage and mapping	Merrill park	Additional ameneties	Merrill park	Riverfront Park needs to be included in the survey area as this is a highly used access point for fishing and paddling and swimming and great for picnics
7/4/2019 9:09	Leave park as is. Donâ€™t encourage use.	Merrill Park					
7/4/2019 9:19	More access to the Northern Canal	Northern Canal					
7/4/2019 9:21							
7/4/2019 9:23	increase access conditions and accessibility to Northern Canal Walkway	Northern Canal Walkway					
7/4/2019 9:28							
7/4/2019 10:37							
7/4/2019 10:38	Protected bicycle lane (or multi-use path parallel to road)	Pawtucket Boulevard - especially, the sidewalk by the Pawtucket Falls Bridge has	Pedestrian signal controls	Crossing by Rourke Bros. Boat Ramp - in the MIDDLE	Protected Bicycle Lane	All bridges across Merrimack River. Yes,	The biggest impediment to cycling in or near the described recreational areas, is safe access by bicycle. The river, itself, is one of the biggest obstacles for cyclists. Within the City of Lowell, only one bridge - at University Ave - is even remotely "bike-friendly", and the intersections at either foot of ALL the bridges are abysmal to cycle through.

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		STAIRS, and is neither bike-friendly, nor even ADA compliant!		section, for access by road cyclists on Pawtucket Boulevard seeking to turn left (to Rourke Bros/ Boat Ramp) or right (to Heritage Ice Cream)		ALL of them!	
7/4/2019 11:20	More accessible walkways / pathways, eliminate stairs	Northern canal walkway					
7/4/2019 11:26							I live in the Boott Mills. The canals have been dry and are dirty and unsightly with litter and trash. Do better
7/4/2019 11:34							
7/4/2019 11:42	bike racks	various					Not every place needs a restroom and a parking lot, it's an urban park and walking should be expected. I'd like to see the Lowell riverwalk connected and extended.

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7/4/2019 12:24	Consider opening some of the canals to recreational boating						So far the river has been consistent in depth since the Crest gate system was installed on the dam.
7/4/2019 12:49							
7/4/2019 12:57							Enel needs to do more to clean up the canals.
7/4/2019 13:10	More Lighting	Riverwalk	More trash removal	All canals	Homeless	All Lowell parks	Let's tidy up. Let's raise taxes! Let's get the community involved!
7/4/2019 13:24	More paths along M river	Hudson	More paths along Nashua River	Nashua, Greeley Park	Safe Road cycling	All, connecting locations	General access to outdoor bike paths & areas to sit in the shade & sun. Connecting bike paths between locations would be good. Availability of coffee and sandwich shops for refreshment would be nice.
7/4/2019 13:53	Improvements	All	Cycling, hiking, fishing, running, walking, swimming	All			
7/4/2019 14:20	More public restrooms	Generally	Signage	Generally			
7/4/2019 15:33	Walkways leveled for better accessibility in certain areas	Canal walks	Canal trash clean up	Merrimack and Eastern canals			Can we have more easily available information about canal draw downs? connect the project area to the rail trails.

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7/4/2019 15:59	Canoe/kayak on the canal	Pawtucket Hamilton canals	Ice skating on canals	Pawtucket	Canal side dining	Pawtucket canal	Need to make the Lowell canals a destination for people to visit. Lighting and activities would be a great start.
7/4/2019 18:01							
7/4/2019 18:36	better and longer parking	Sheehy Memorial	Adult fixed exercise equipment	Merrimack Trail	Dog park	some place other than wher it is	Trash out of the canal. Less flooding in Lowell, due to high river levels. Better water quality in Merrimack.
7/4/2019 22:23							More parks, bocce, bike infrastructure, signage
7/5/2019 7:43	Casual canal boating	Merrimack, Western Canals	Cycling, walking	Merrimack River, Northern Bank	Water Taxi/Drinking/Shopping	Pawtucket Canal	The Canals are difficult for Lowell, as they limit road crossings. But they are also such an amenity unique in Massachusetts. Let's reclaim our title of Venice of America. We could also put up interpretive signage about how the canals still create renewable energy for the area and about how they contribute to the ecology, e.g., fish.
7/5/2019 12:15							
7/5/2019 13:30	Water fountain	All	Public bathroom		Bike and walking trails		The canals always has trash in them
7/5/2019 19:34							
7/7/2019 5:47							
7/7/2019 15:53	Off leash dog park	Anywhere shady by the river					

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7/7/2019 19:13							
7/7/2019 20:43	Boat ramp	Greeley park ramp	Widen access road, more parking fix ramp	Nashua			
7/16/2019 10:45	Better parking (current parking lots aren't enough, VFW highway semi-legal)	Heritage Park	Safety and beautification improvements between Sampas and the School St Bridge, by falls overlook				
7/16/2019 14:05							
7/16/2019 14:30	Seating	Along canal walkways	Parking	Near access points			
7/16/2019 15:09	more lighting						
7/16/2019 16:10	More trees, shade, greenery less pavement	all locations		all locations			

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7/16/2019 18:13	More public restroom access	throughout the area	More native plants to attract birds and mammals	throughout the area			I believe developing this aspect of our city can only make the area more attractive to visitors and better for residents who need access to nature
7/16/2019 18:19	Always concerned with access for non-motorized watercraft.	Through-paddlers					
7/16/2019 18:30							
7/17/2019 8:05	Pedestrian walkway improvement	All	Connecting trails	All	Clear, concise signage for areas and trails	All	Deteriorating sidewalks, excessive weedy brush along all trails. Unacceptable trash accumulation in all waterways detracts from top-notch opportunities for active and passive recreation. Desire paths connecting sites along Merrimack River are not suitable for anyone but the very sure-footed. Trash removal should be regular event not occasional event. More cooperation between private industry and local National Park/City and Conservation partners. The fish ladder is both an eyesore and poor function. Brush and weeds obscure walking vistas. Poison ivy. Chain link fences are not inviting or welcoming. Many walks are not in compliance with ADA regs
7/17/2019 18:53							
7/18/2019 12:07	Bathrooms available year-round	Lowell Heriatge State Park	More parking, less trash in waterWhole	Pawtucket Falls overlook			Whole area is an urban jewel which needs to be preserved and appreciated.

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			area is an urban jewel				
7/18/2019 14:32							
7/19/2019 10:00	better connected walking facilities	from the overlook to the heritage park					collection of trash in the canals and behind the dam.
7/27/2019 21:23	extra dock for boats						at the Rourke Brothers Boat Ramp the dock is only on the left side so most times you have to wait to load or unload. An extra dock on the right side would be very helpful.
7/29/2019 8:15	trash barrels	Rourke Brothers boat ramp					
8/4/2019 9:43	More boat docks	Rourke boat ramp	River hazard removal and or marking	Merrimack river to NH state line			
8/4/2019 14:35	Clean the canals, can't do anything with them being clean	Canals					You can't improve anything if the canals are full of trash.
8/29/2019 20:47	Whitewater boating	Pawtucket Falls	Fishing	Pawtucket Falls	River Surfing	Pawtucket Falls	Improved flow, access and gauging in the dewatered section of Pawtucket Falls, could greatly enhance recreational opportunity, through both whitewater boating and fishing. Creating better shoreline access, will also rid of the unsightly homeless camps, that are in these fenced off areas. Creating much of the water born trash in the dewatered section.

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8/29/2019 21:06	More fishing access	Canals near tsongas center	Free parking	Suffolk st	Cleaner water	Everywhere	There is a thriving aquatic ecosystem in those canals please help keep it clean for future generations to enjoy.
8/29/2019 21:26	river/bank cleanup and improved access from university ave bridge to beaver brook		trash cleanup at pawtucket falls, parking area, open throughout the year				overall reduction in the amount of trash buildup at dams/canals. Improved access for fishing/sightseeing along the river, especially in the area of umass lowell (university avenue bridge to beaver brook and at pawtucket falls.
8/30/2019 6:03	More shore fishing access from the boat rental ramp past the Rourke Bridge	Rourke Brothers Boat Ramp	Clean up the vegetation as you get closer to the bridge	Rourke Brothers Boat Ramp			
9/3/2019 17:04	None						
9/9/2019 7:24							
9/24/2019 16:02	Boat dock	Greely					The the boat ramp at Greeley is in serious Decline and is a tremendous safety hazard
10/9/2019 13:29							
11/14/2019 18:31	restrooms		interpretive panels		map panels to guide you to other features nearby		opening up the area for walking along the river with lights and benches and trash cans will really make the area, around the college and along the

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							canal, closer to what other cities have successfully done in developing their waterfront areas. great to see this project underway- Lowell is a real gem!
11/15/2019 14:50	Mapiing of navigation hazards	impoundment from Chelmsford to Cromwells Falls					Access in NH is way below contemporary standards
11/26/2019 19:08							
1/20/2020 8:29	Public notification of CSO events	Nashua, Manchester	whitewater recreational releases with improved access and adequate flow information	Pawtucket falls			Public has a right to receive automatic notification of upstream CSO events that would interfere with the use of the Impoundment

Appendix F - Respondents Zip Codes and Representative Map

Personal Interview Respondent Zip Codes

Zip code/location	Miles from Project
01440/Gardner, Massachusetts	42.1
01701/Framingham, Massachusetts	34.3
01810/Andover, Massachusetts	11.6
01821/Billerica, Massachusetts	8.7
01821/Billerica, Massachusetts	8.7
01824/Chelmsford, Massachusetts	6.0
01824/Chelmsford, Massachusetts	6.0
01824/Chelmsford, Massachusetts	6.0
01824/Chelmsford, Massachusetts	6.0
01826/Dracut, Massachusetts	2.4
01826/Dracut, Massachusetts	2.4
01826/Dracut, Massachusetts	2.4
01845/North Andover, Massachusetts	11.9
01850/Lowell, Massachusetts	1.5
01850/Lowell, Massachusetts	1.5
01851/Lowell, Massachusetts	1.5
01851/Lowell, Massachusetts	1.5
01851/Lowell, Massachusetts	1.5
01851/Lowell, Massachusetts	1.5
01852/Lowell, Massachusetts	1.5
01852/Lowell, Massachusetts	1.5
01852/Lowell, Massachusetts	1.5
01852/Lowell, Massachusetts	1.5
01852/Lowell, Massachusetts	1.5
01852/Lowell, Massachusetts	1.5
01853/Lowell, Massachusetts	0.5
01853/Lowell, Massachusetts	0.5
01854/Lowell, Massachusetts	0.5

Zip code/location	Miles from Project
01854/Lowell, Massachusetts	0.5
01854/Lowell, Massachusetts	0.5
01854/Lowell, Massachusetts	0.5
01854/Lowell, Massachusetts	0.5
01854/Lowell, Massachusetts	0.5
01854/Lowell, Massachusetts	0.5
01863/North Chelmsford, Massachusetts	7.5
01863/North Chelmsford, Massachusetts	7.5
01863/North Chelmsford, Massachusetts	7.5
01863/North Chelmsford, Massachusetts	7.5
01876/Tewksbury, Massachusetts	5.8
01876/Tewksbury, Massachusetts	5.8
01879/Tyngsboro, Massachusetts	11.2
01879/Tyngsboro, Massachusetts	11.2
01886/Graniteville, Massachusetts	12.8
01970/Salem, Massachusetts	33.1
02067/Sharon, Massachusetts	44.4
02461/Newton, Massachusetts	28.5
03051/Hudson, New Hampshire	11.5
03051/Hudson, New Hampshire	11.5
03051/Hudson, New Hampshire	11.5
03051/Hudson, New Hampshire	11.5
03110/Bedford, New Hampshire	31.3
21009/Abingdon, Maryland	383.0
98040/Mercer Island, Washington	3045.0

Online Survey Zip Codes

Zip Code	Miles from project
01340/Colrain, Massachusetts	88.9
01450/Groton, Massachusetts	19.1
01453/Leominster, Massachusetts	27.9
01463/Pepperell Massachusetts	20.2
01503/Berlin, Massachusetts	26.8
01516/Douglas, Massachusetts	58.9
01604/Worcester, Massachusetts	41.6
01719/Boxborough, Massachusetts	19.5
01748/Hopkinton, Massachusetts	40.0
01757/Milford, Massachusetts	44.5
01760/Natick, Massachusetts	31.8
01821/Billerica, Massachusetts	8.7
01821/Billerica, Massachusetts	8.7
01824/Chelmsford, Massachusetts	6.0
01824/Chelmsford, Massachusetts	6.0
01824/Chelmsford, Massachusetts	6.0
01826/Dracut, Massachusetts	2.4
01826/Dracut, Massachusetts	2.4
01844/Methuen, Massachusetts	9.8
01844/Methuen, Massachusetts	9.8
01850/Lowell, Massachusetts	1.5
01850/Lowell, Massachusetts	1.5
01850/Lowell, Massachusetts	1.5
01850/Lowell, Massachusetts	1.5
01851/Lowell, Massachusetts	1.5
01851/Lowell, Massachusetts	1.5
01851/Lowell, Massachusetts	1.5
01851/Lowell, Massachusetts	1.5

Zip Code	Miles from project
01851/Lowell, Massachusetts	1.5
01851/Lowell, Massachusetts	1.5
01852/Lowell, Massachusetts	1.5
01852/Lowell, Massachusetts	1.5
01852/Lowell, Massachusetts	1.5
01852/Lowell, Massachusetts	1.5
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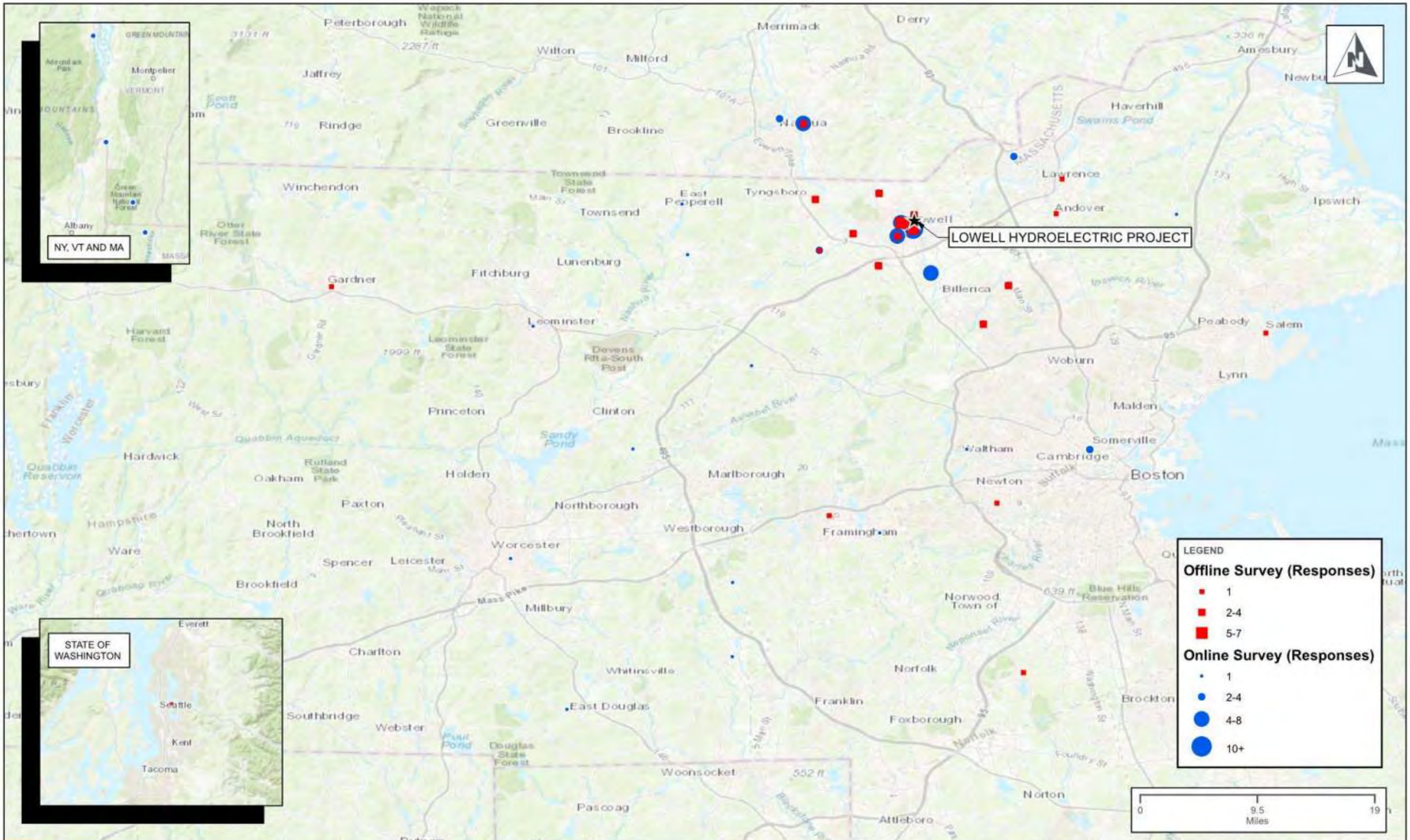
01852/Lowell, Massachusetts	1.5
01854/Lowell, Massachusetts	0.5
01854/Lowell, Massachusetts	0.5
01854/Lowell, Massachusetts	0.5
01854/Lowell, Massachusetts	0.5

Zip Code	Miles from project
01854/Lowell, Massachusetts	0.5
01854/Lowell, Massachusetts	0.5
01854/Lowell, Massachusetts	0.5
01854/Lowell, Massachusetts	0.5
01862/North Billerica, Massachusetts	5.1
01862/North Billerica, Massachusetts	5.1
01862/North Billerica, Massachusetts	5.1
01862/North Billerica, Massachusetts	5.1
01862/North Billerica, Massachusetts	5.1
01862/North Billerica, Massachusetts	5.1
01863/North Chelmsford, Massachusetts	7.5
01876/Tewksbury, Massachusetts	5.8
01876/Tewksbury, Massachusetts	5.8
01876/Tewksbury, Massachusetts	5.8
01879/Tyngsboro, Massachusetts	11.2
01886/Westford, Massachusetts	11.2
01886/Westford, Massachusetts	11.2
01921/Boxford, Massachusetts	19.6
02143/Somerville, Massachusetts	26.4
02143/Somerville, Massachusetts	26.4
02451/Waltham, Massachusetts	22.7
3051/Hudson, New Hampshire	11.5
03051/Hudson, New Hampshire	11.5
03051/Hudson, New Hampshire	11.5
03051/Hudson, New Hampshire	11.5
03051/Hudson, New Hampshire	11.5
03051/Hudson, New Hampshire	11.5
03051/Hudson, New Hampshire	11.5

Zip Code	Miles from project
03051/Hudson, New Hampshire	11.5
03064/Nashua, New Hampshire	13.0
03064/Nashua, New Hampshire	13.0
03064/Nashua, New Hampshire	13.0
05356/West Dover, Vermont	115.0
05743/Fair Haven, Vermont	175.0
10003/New York City, New York	218.0
12901/Plattsburgh, New York	231.0

*Not all respondents to the online survey provided a home zip code.

Representative Map



RECREATION AND AESTHETICS STUDY - RESIDENTIAL LOCATIONS OF SURVEY RESPONDENTS

FDR BOOTT HYDRO, LLC.

LOWELL HYDROELECTRIC PROJECT

FERC NO. 2790

AUGUST 2020

Appendix G - Visual Survey for Vegetation Growth Mapbook

Legend

- Canal System
- Project Facilities
- Photo Location*

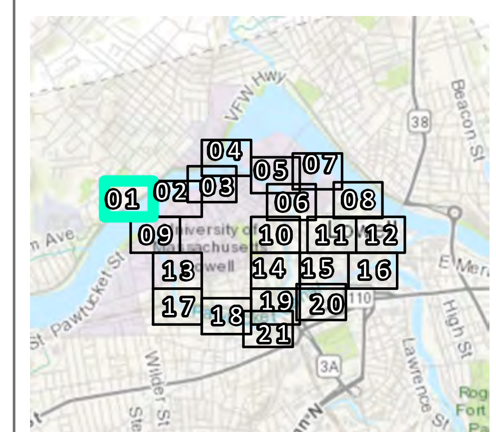
Dominant Vegetation Point

- Herbaceous
- Mixed
- Scrub-Shrub
- Trees

Dominant Vegetation Polygon

- Forested
- Herbaceous
- Mixed
- Scrub-Shrub
- Trees

*NOTE: PHOTO LOCATION IS IDENTIFIED IF IT IS NOT ASSOCIATED WITH A DOMINANT VEGETATION POINT OR DOMINANT VEGETATION POLYGON



Page 1 of 21

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LOWELL HYDROELECTRIC PROJECT
FERC NO. 2790

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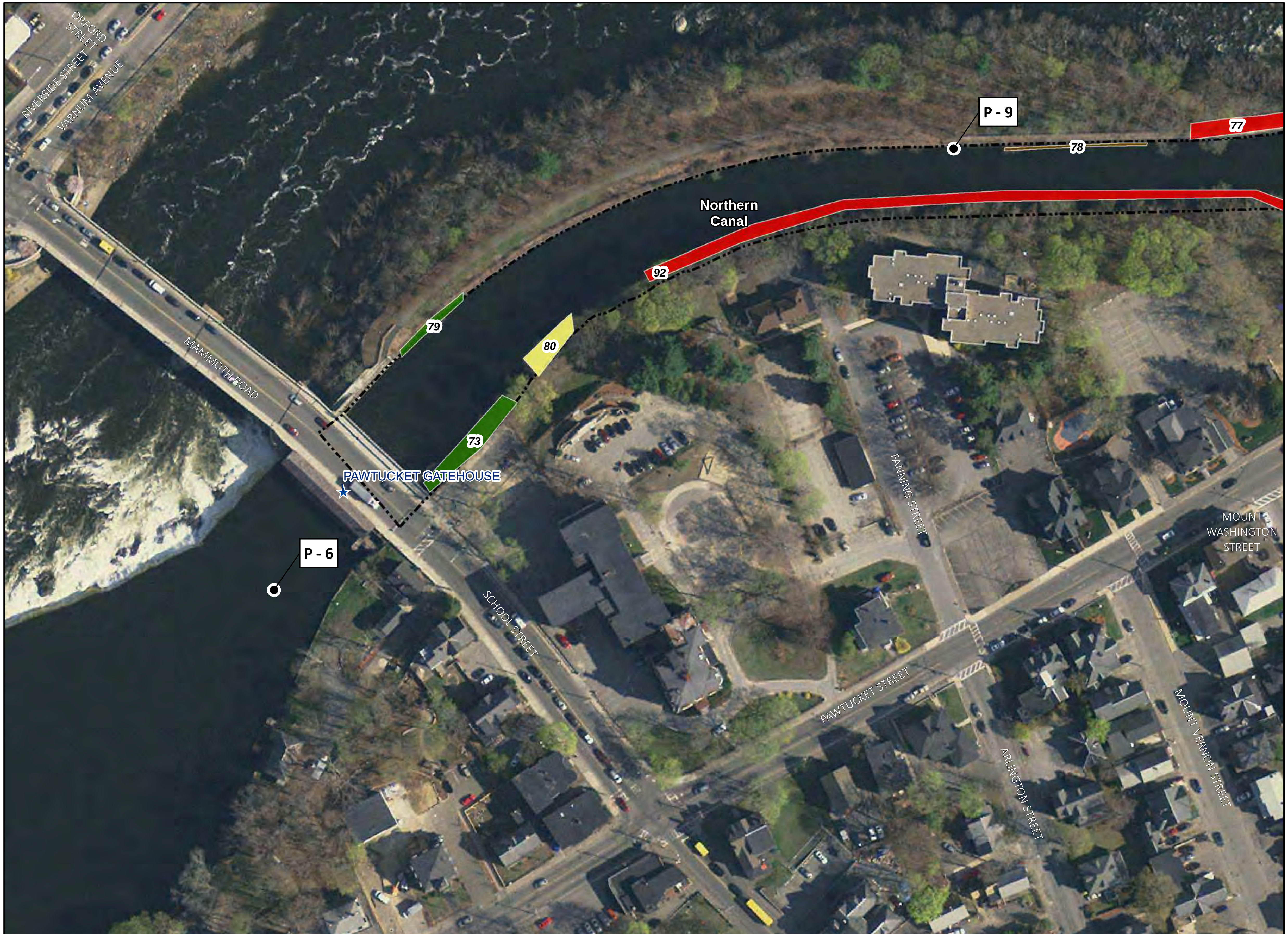

Legend

- Canal System
- ★ Project Facilities
- ● Photo Location*

Dominant Vegetation Point

- Herbaceous
- Mixed
- Scrub-Shrub
- Trees

Dominant Vegetation Polygon

- Forested
- Herbaceous
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- Scrub-Shrub
- Trees

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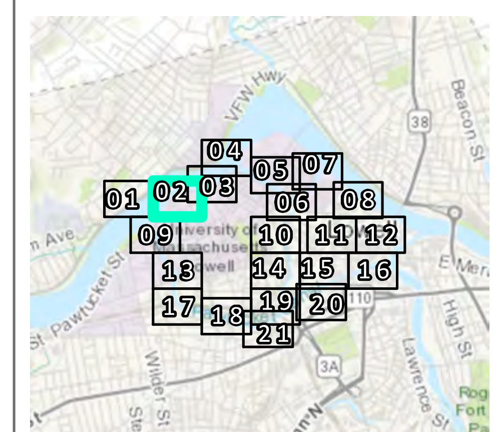

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MATCH TO SHEET 02

Legend

- Canal System
- Project Facilities
- Photo Location*

Dominant Vegetation Point

- Herbaceous
- Mixed
- Scrub-Shrub
- Trees

Dominant Vegetation Polygon

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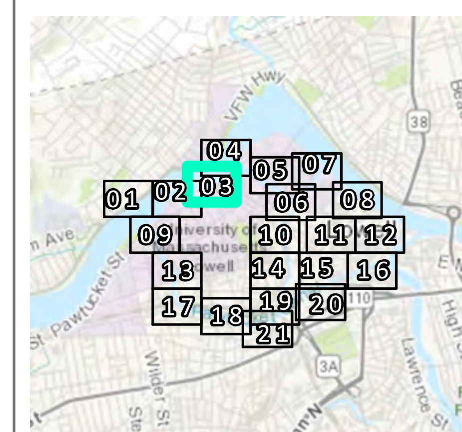

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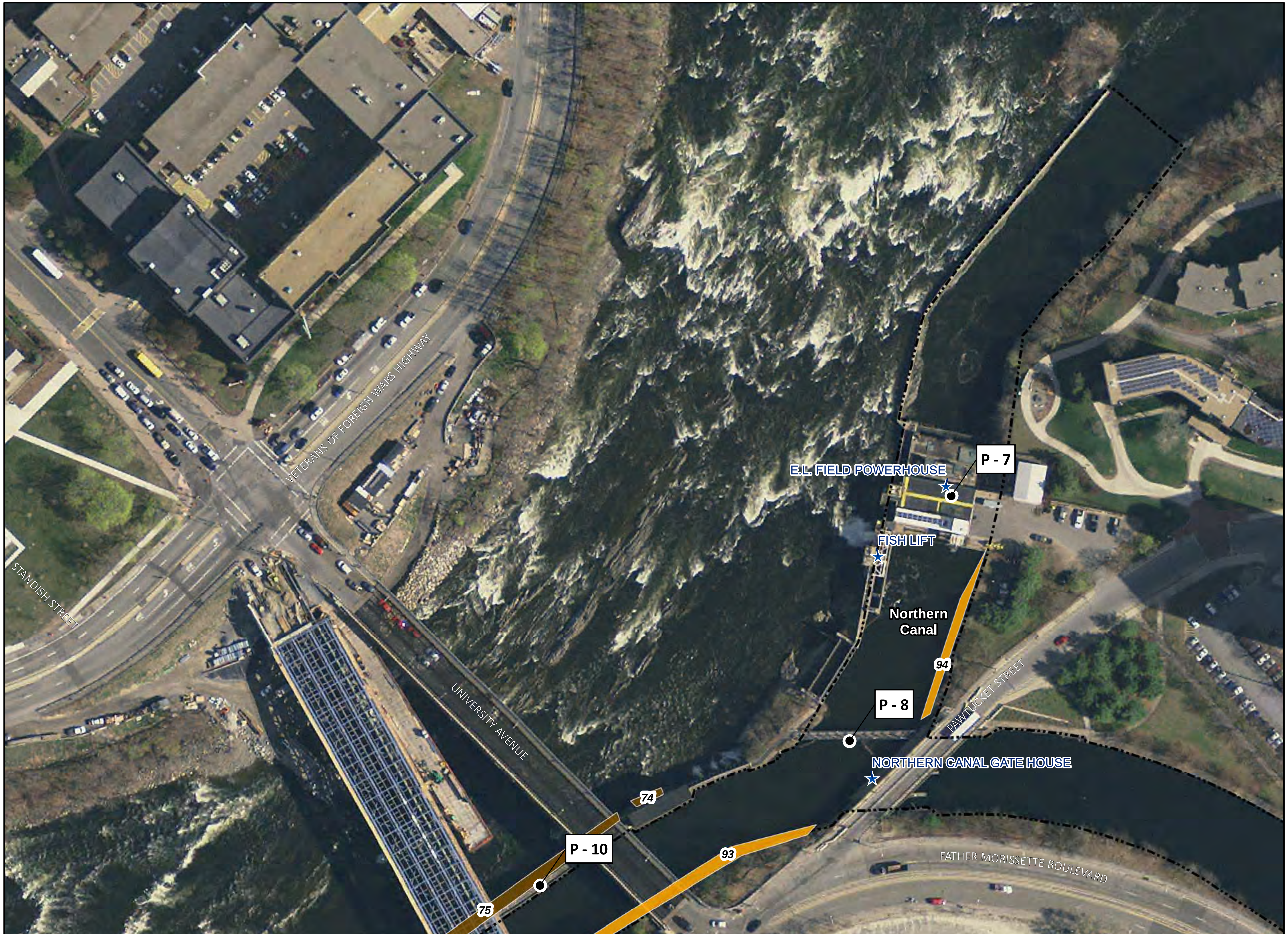

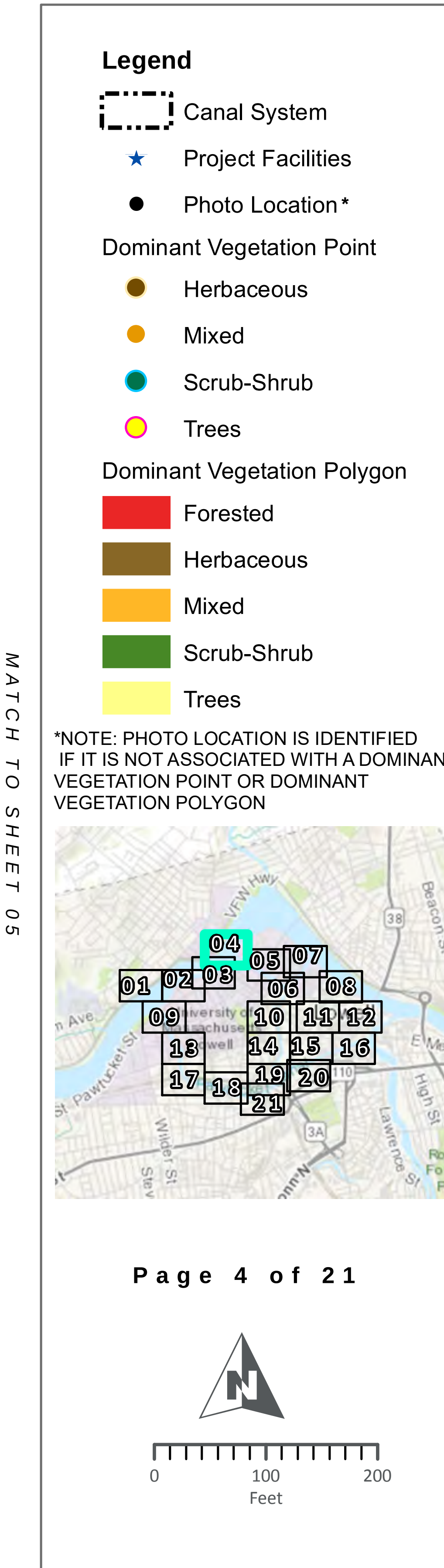

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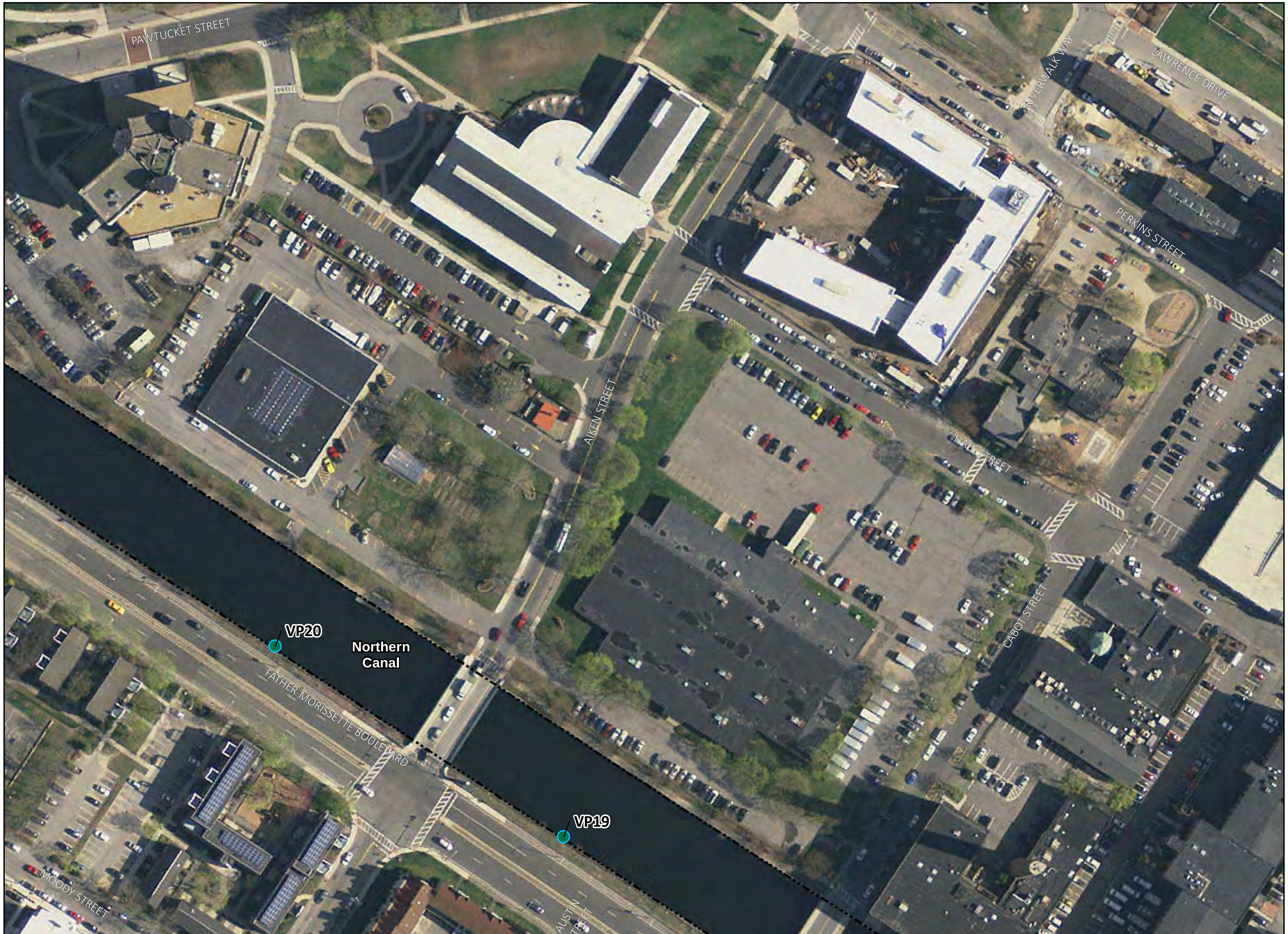
MATCH TO SHEET 04



MATCH TO SHEET 04

MATCH TO SHEET 07

Legend

- Canal System
- Project Facilities
- Photo Location*

Dominant Vegetation Point

- Herbaceous
- Mixed
- Scrub-Shrub
- Trees

Dominant Vegetation Polygon

- Forested
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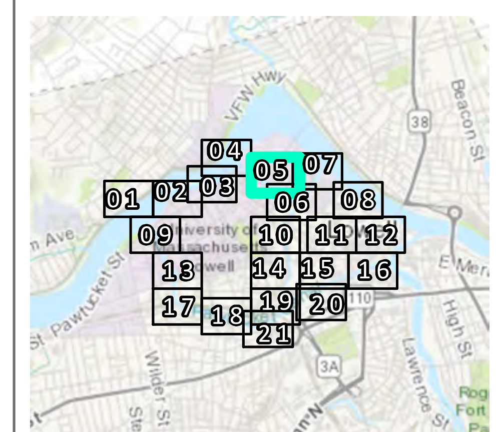

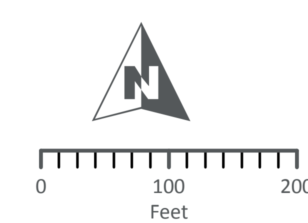

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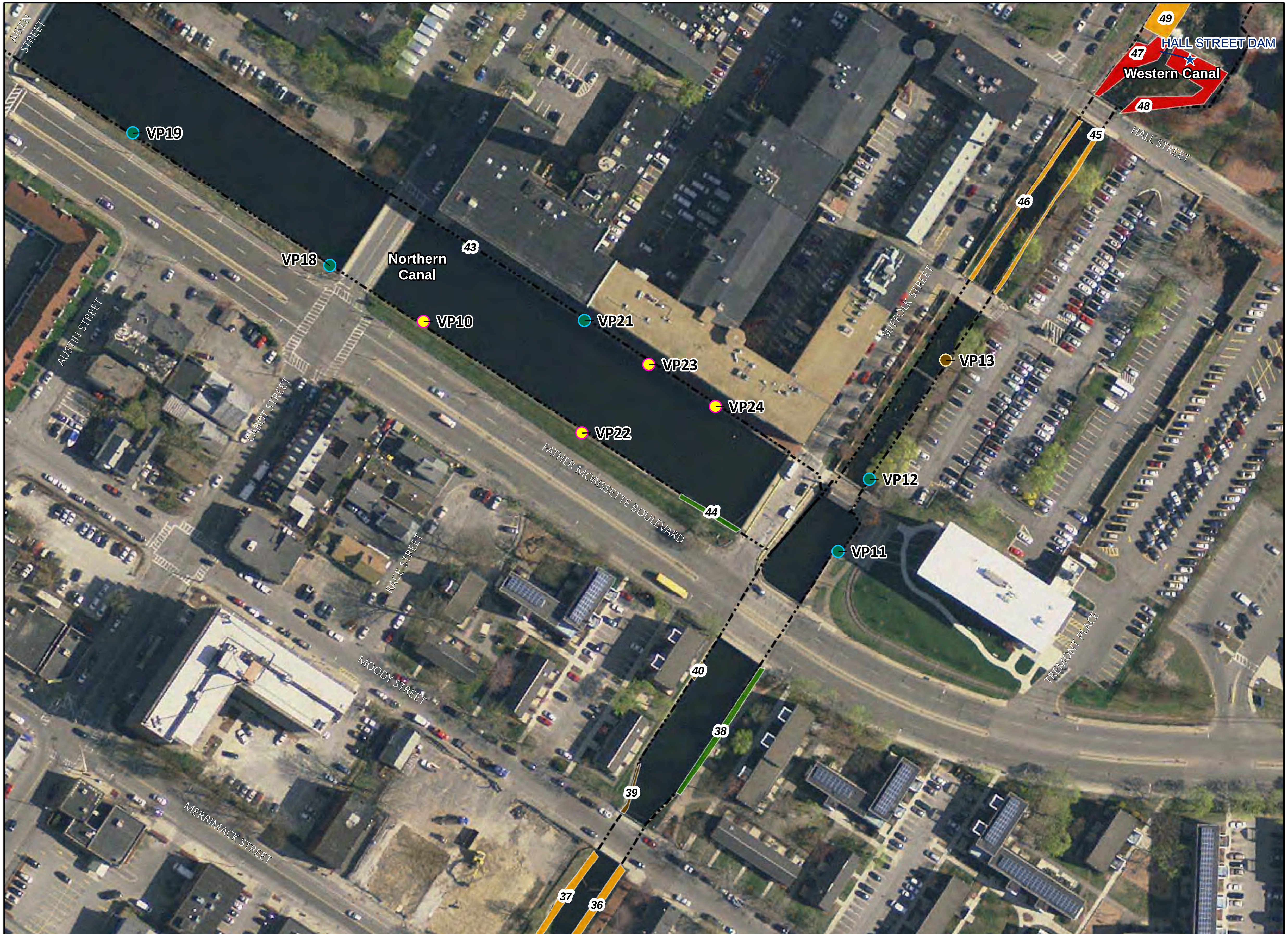

Legend

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- Project Facilities
- Photo Location*

Dominant Vegetation Point

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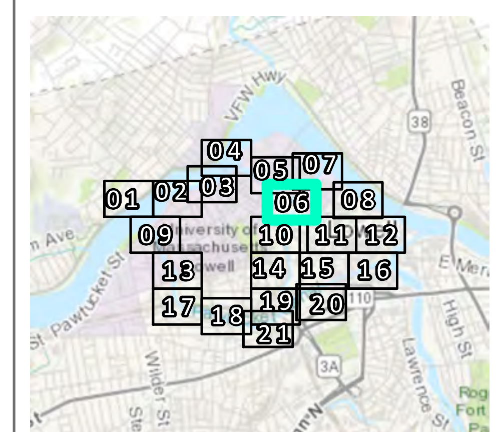

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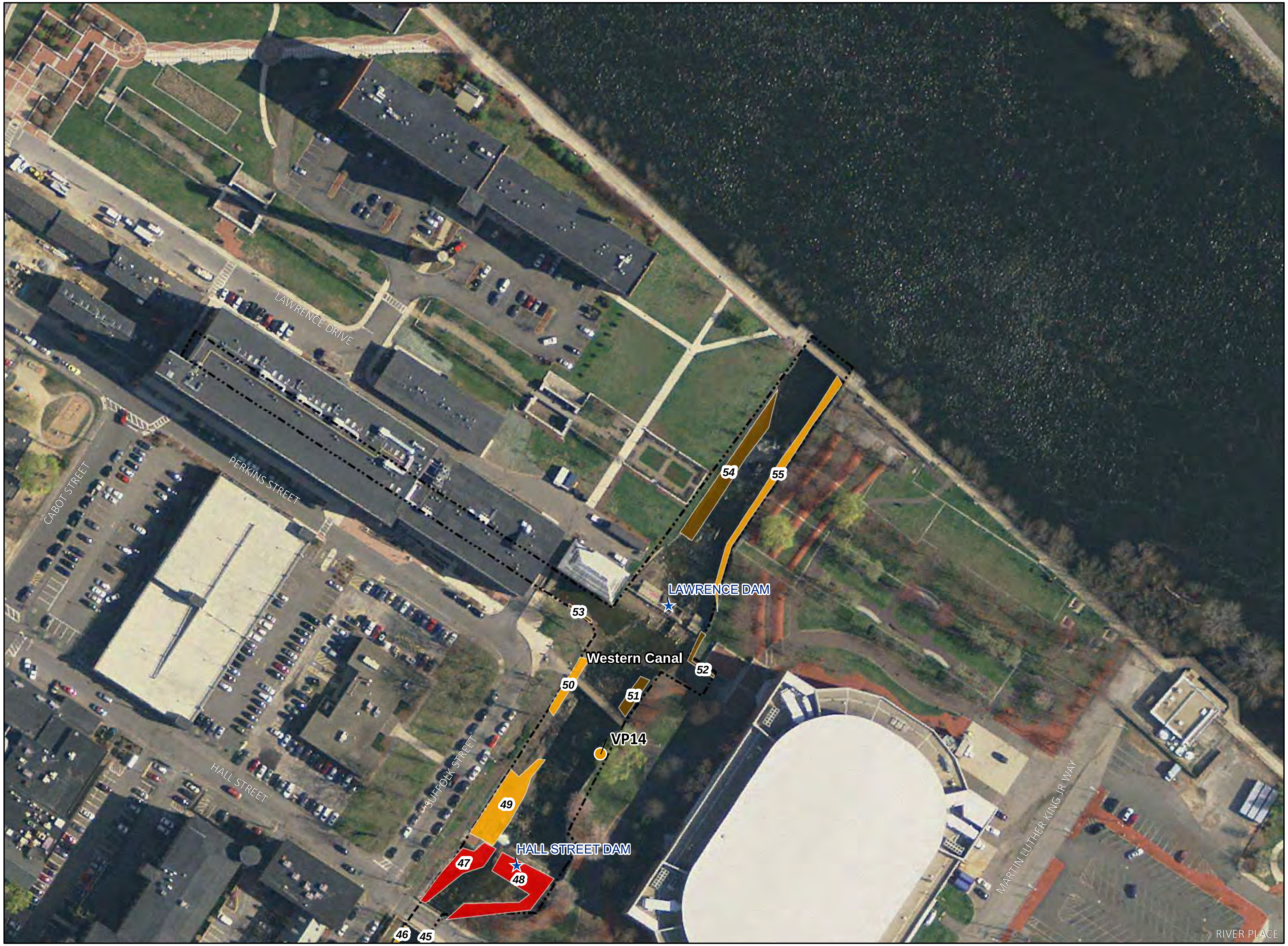

Legend

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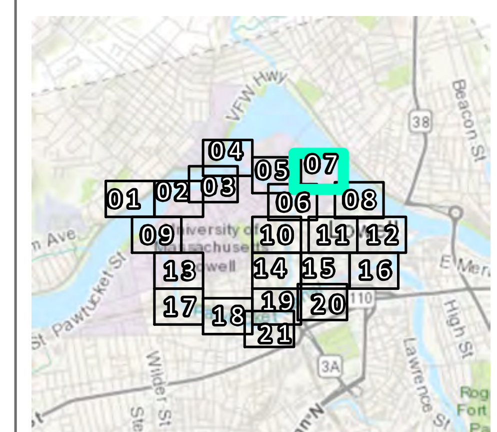

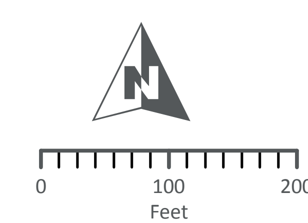

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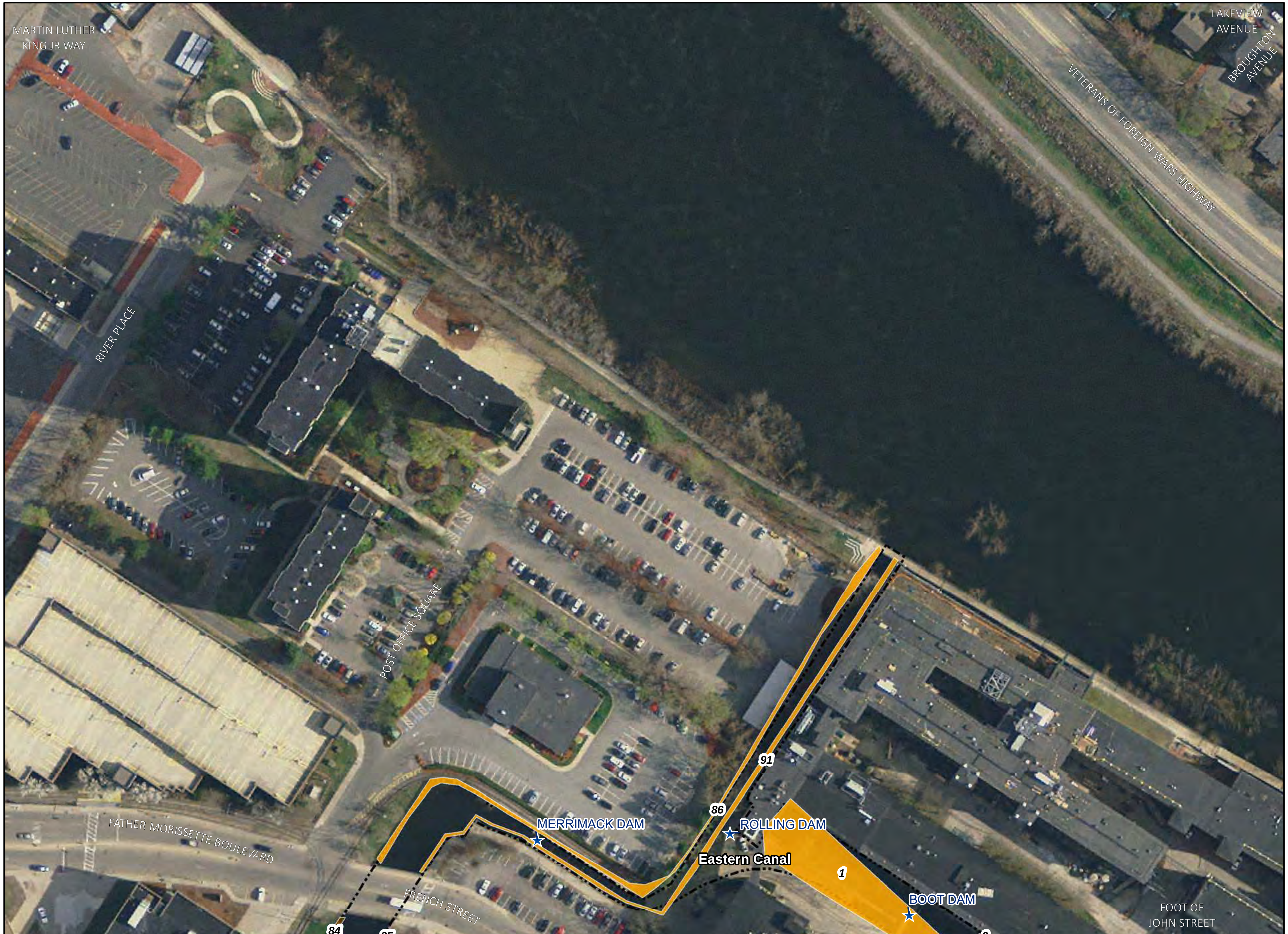

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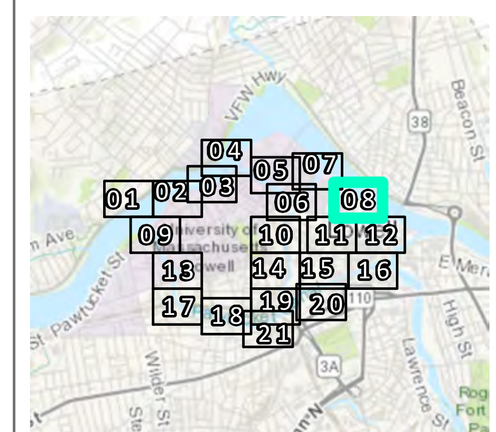

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LOWELL HYDROELECTRIC PROJECT
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AUGUST 2020

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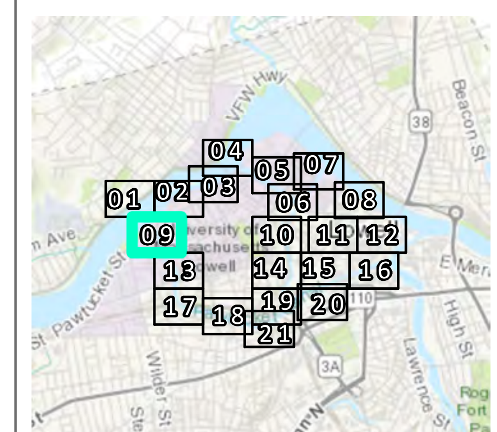

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RECREATION AND AESTHETICS STUDY
LOWELL HYDROELECTRIC PROJECT
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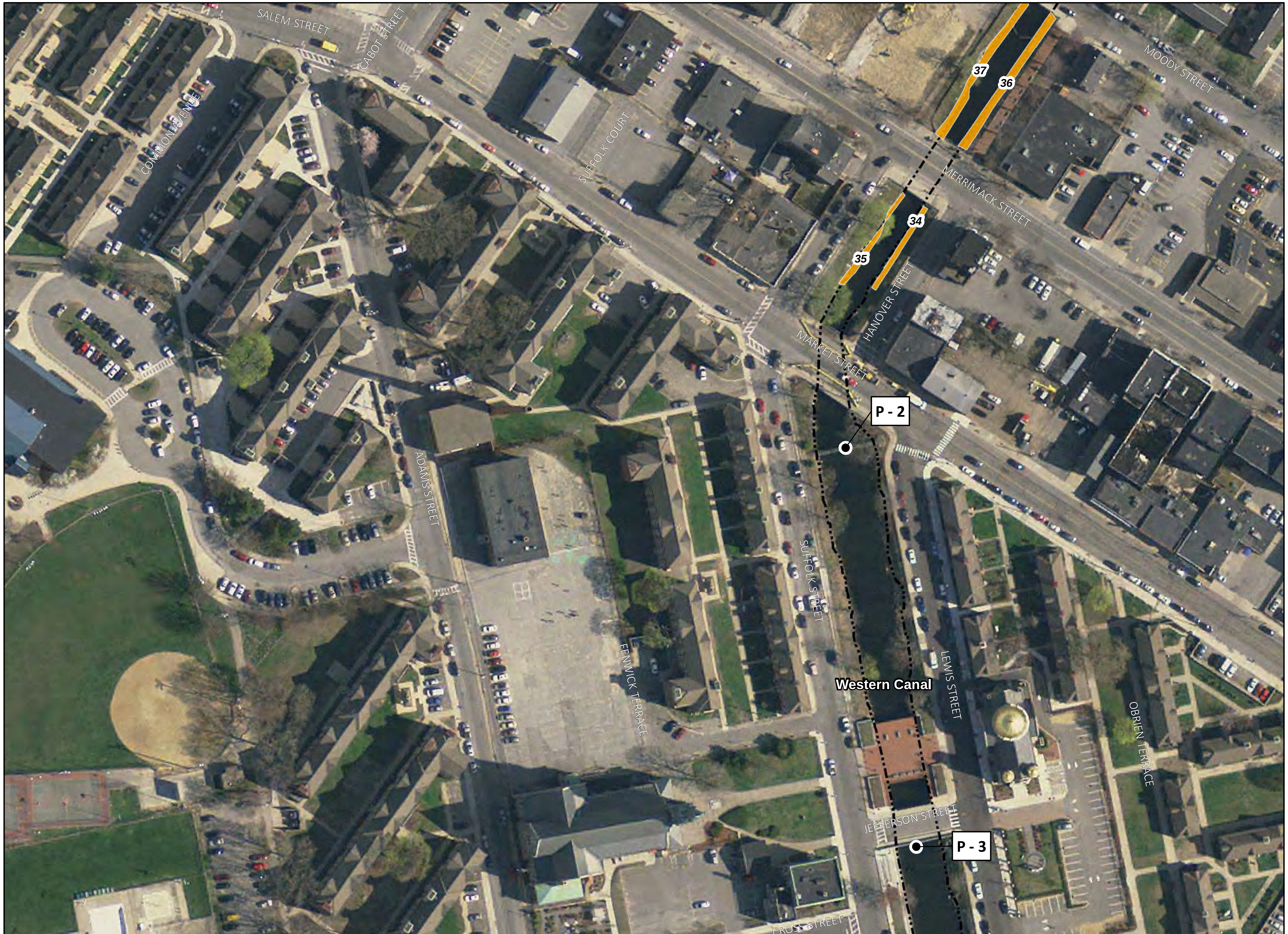

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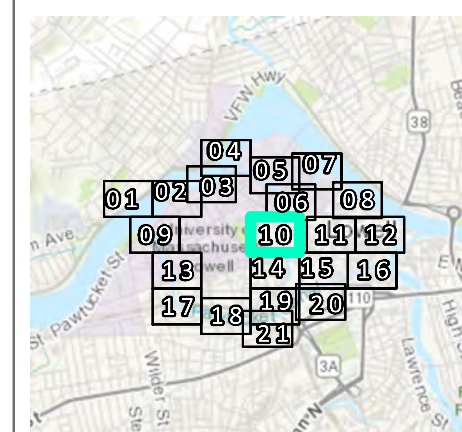

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LOWELL HYDROELECTRIC PROJECT
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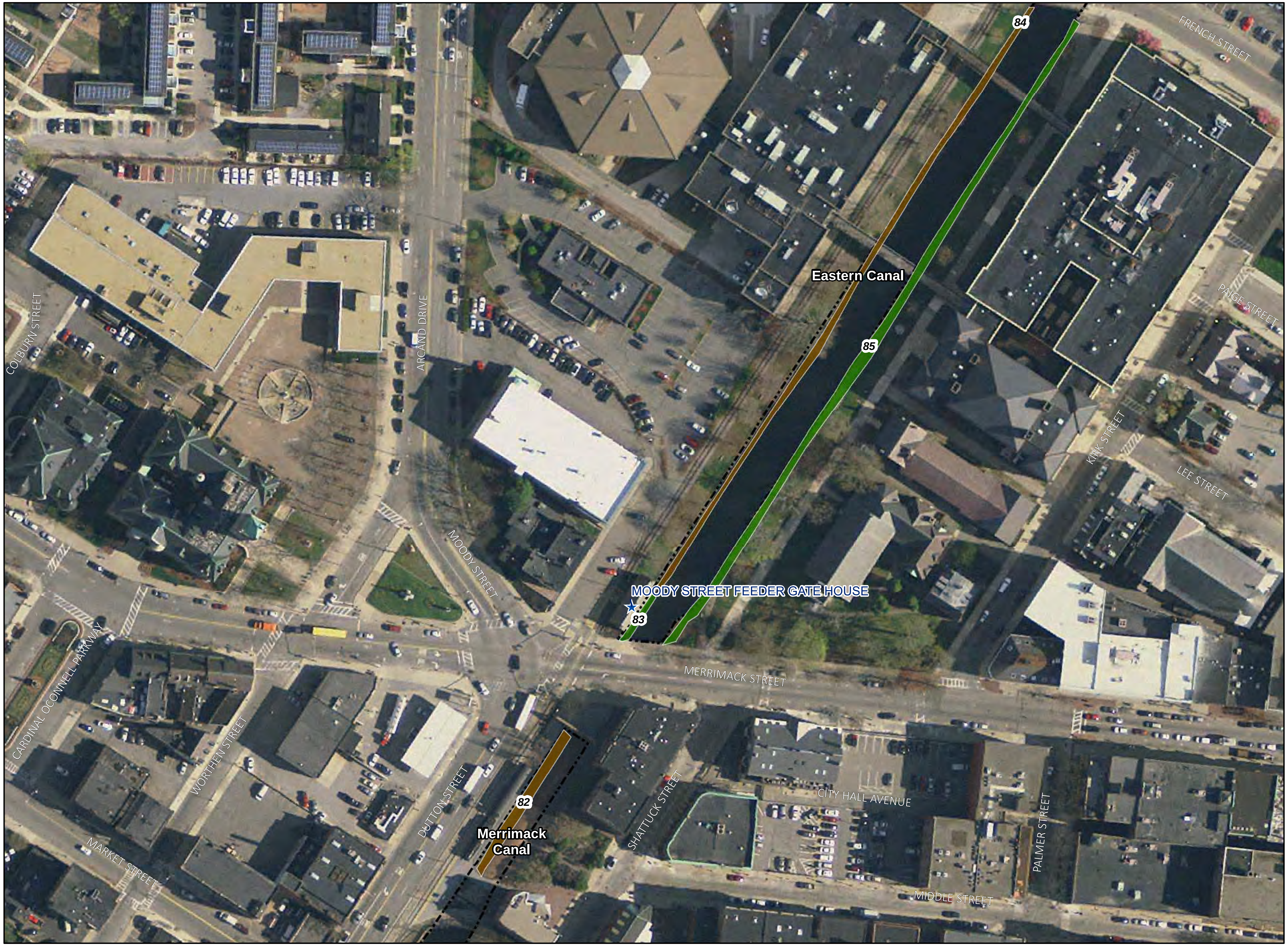

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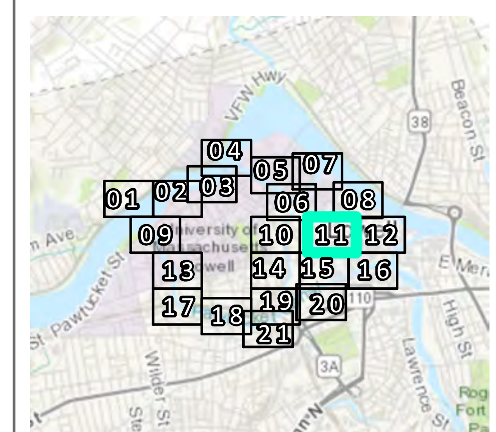

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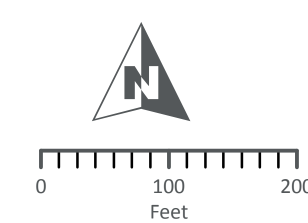

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RECREATION AND AESTHETICS STUDY
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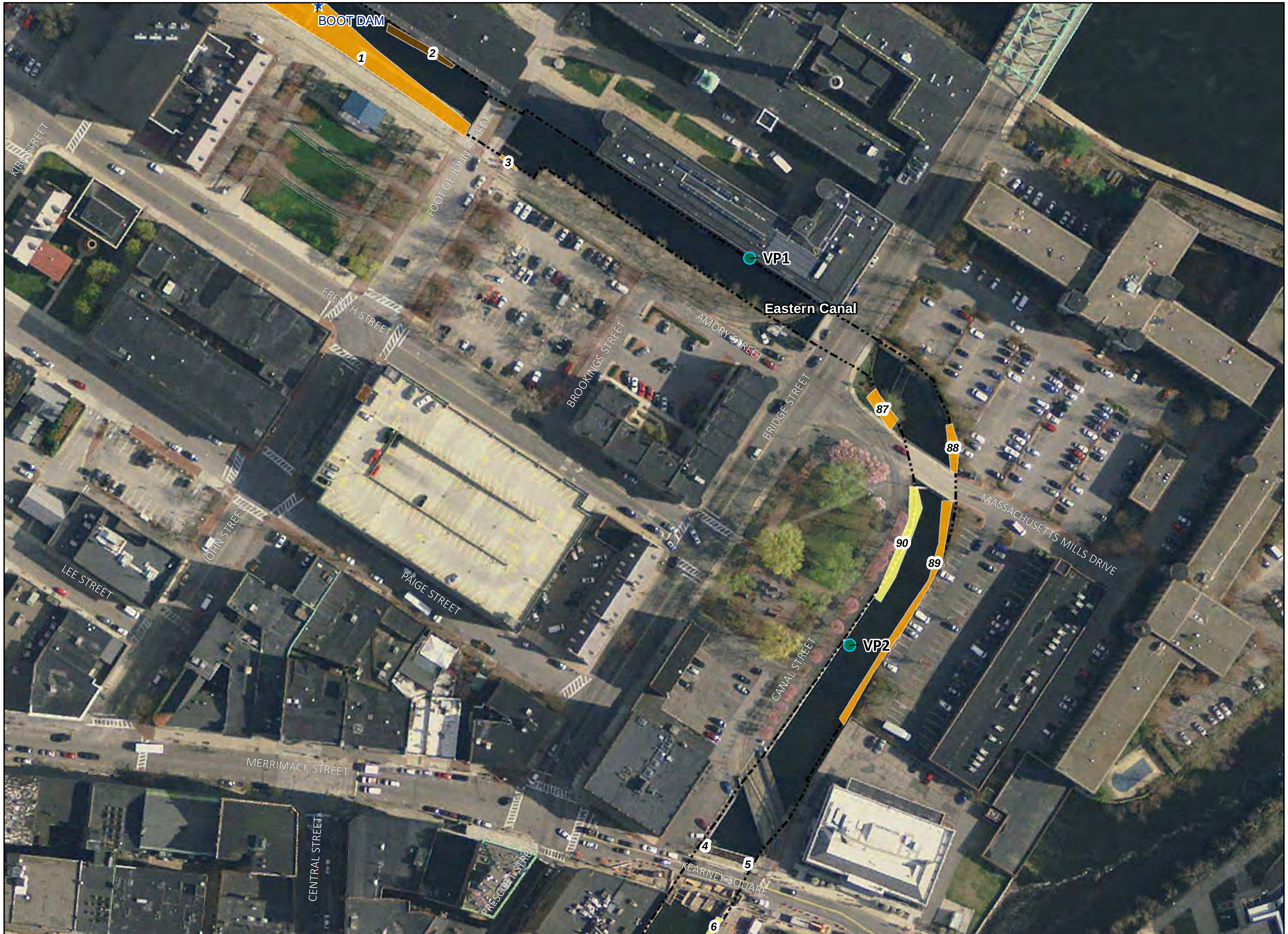
FERC NO. 2790

MATCH TO SHEET 11



Legend

Canal System

Project Facilities

Photo Location*

Dominant Vegetation Point

- Herbaceous
- Mixed
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- Trees

Dominant Vegetation Polygon

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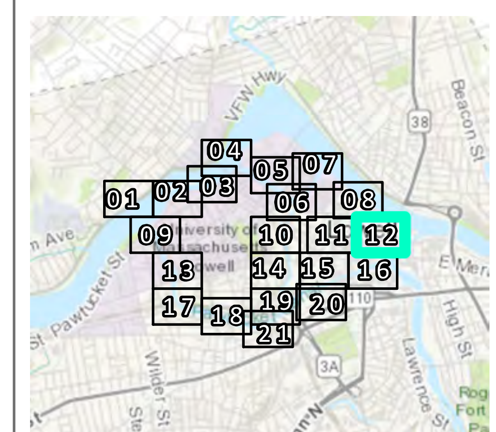

Page 12 of 21

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Feet

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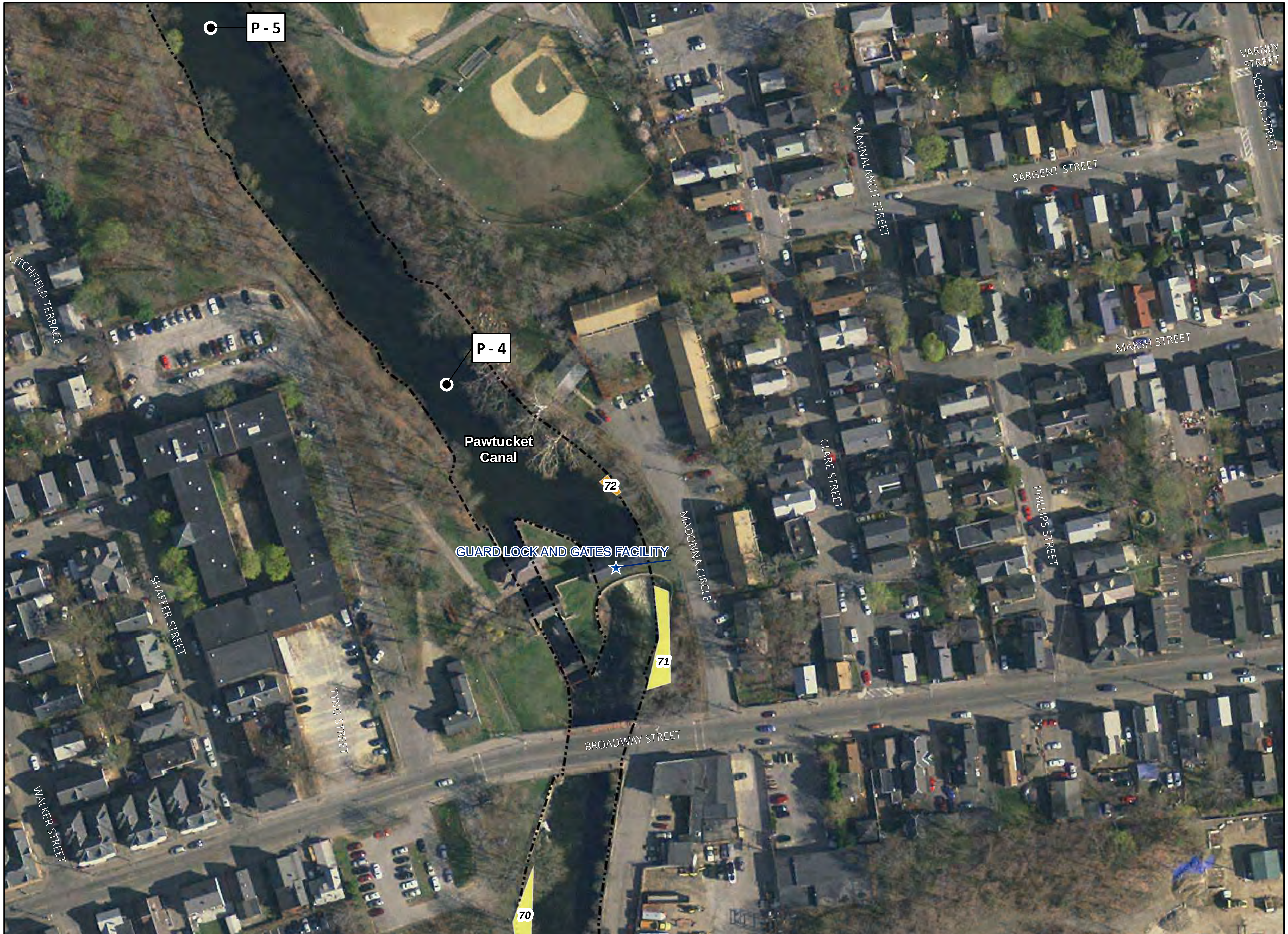

Legend

Canal System

Project Facilities

Photo Location*

Dominant Vegetation Point

Herbaceous

Mixed

Scrub-Shrub

Trees

Dominant Vegetation Polygon

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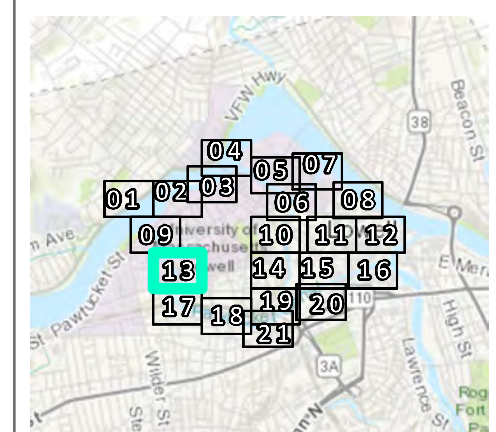

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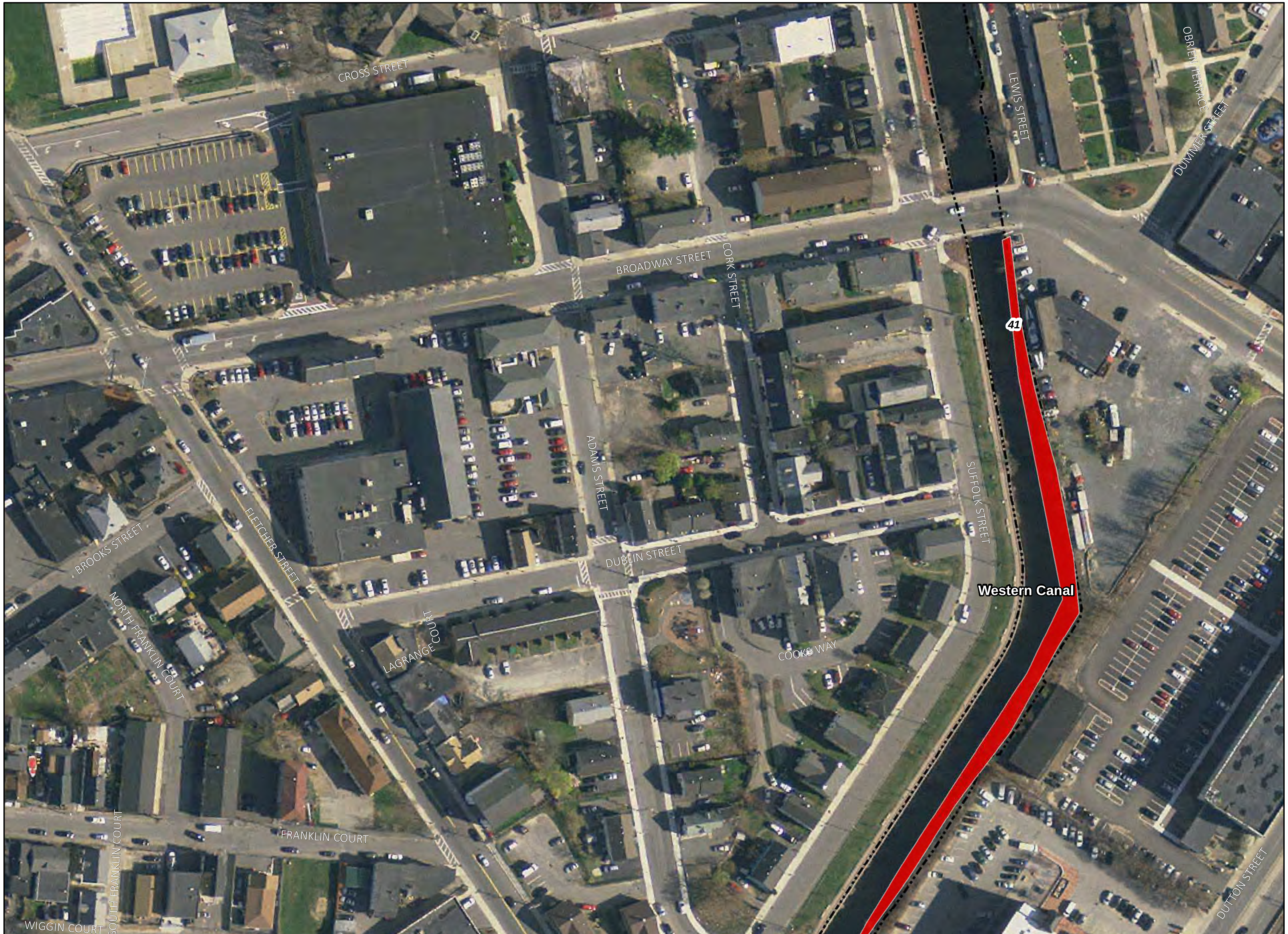

MATCH TO SHEET 15

Legend

- Canal System
- Project Facilities
- Photo Location*

Dominant Vegetation Point

- Herbaceous
- Mixed
- Scrub-Shrub
- Trees

Dominant Vegetation Polygon

- Forested
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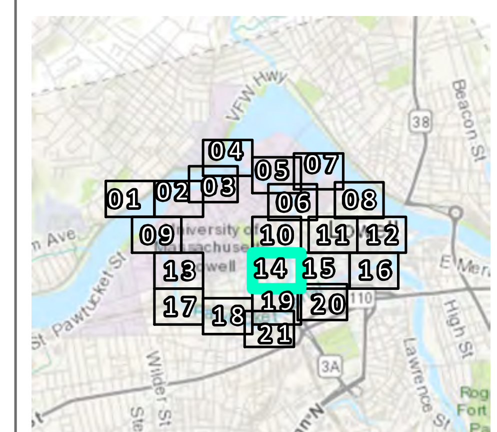

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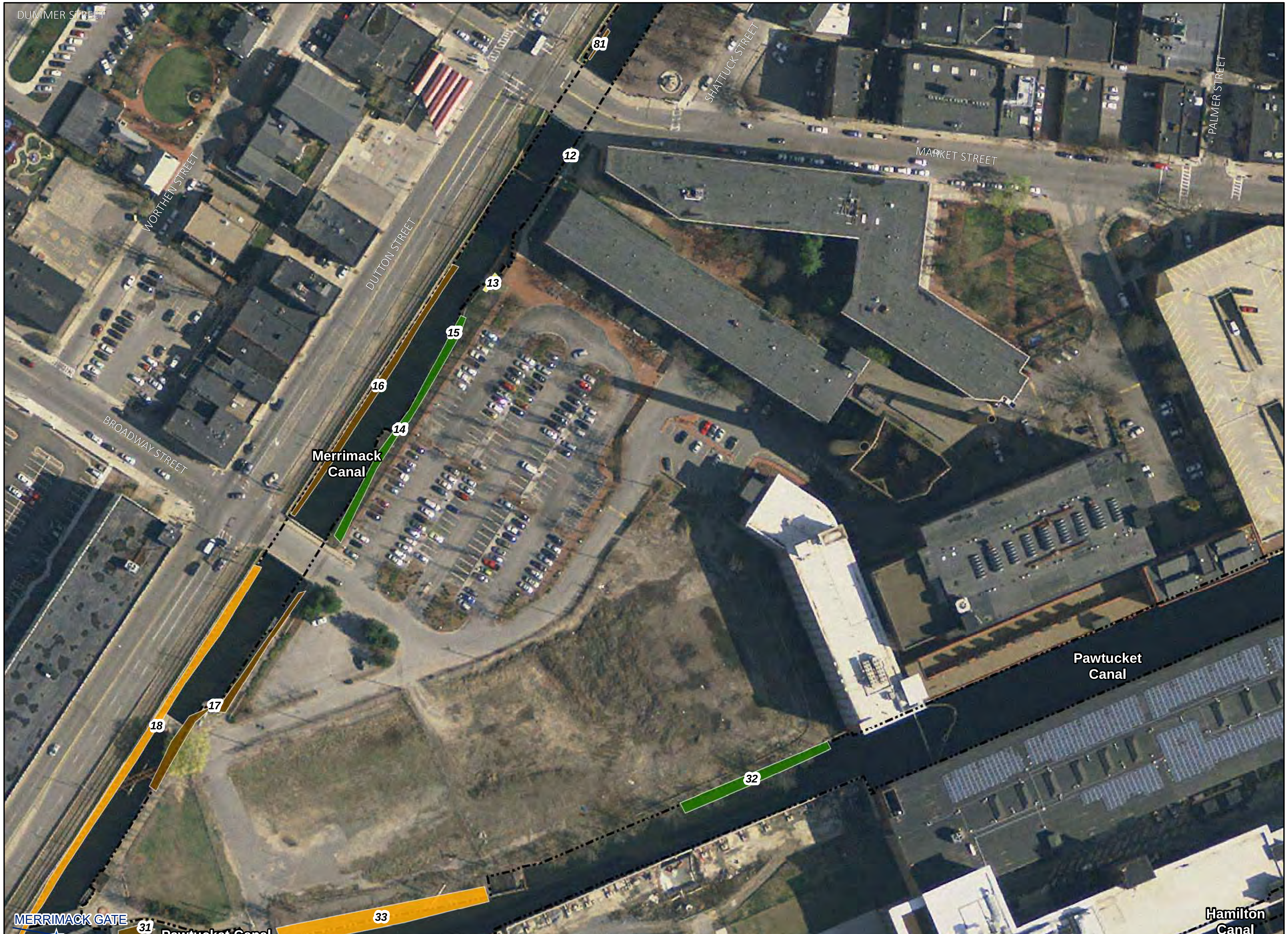

Legend

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- Project Facilities
- Photo Location*

Dominant Vegetation Point

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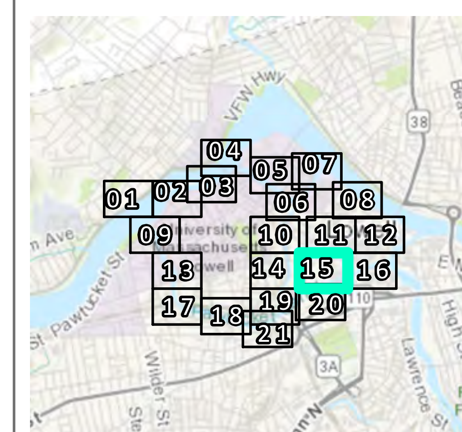

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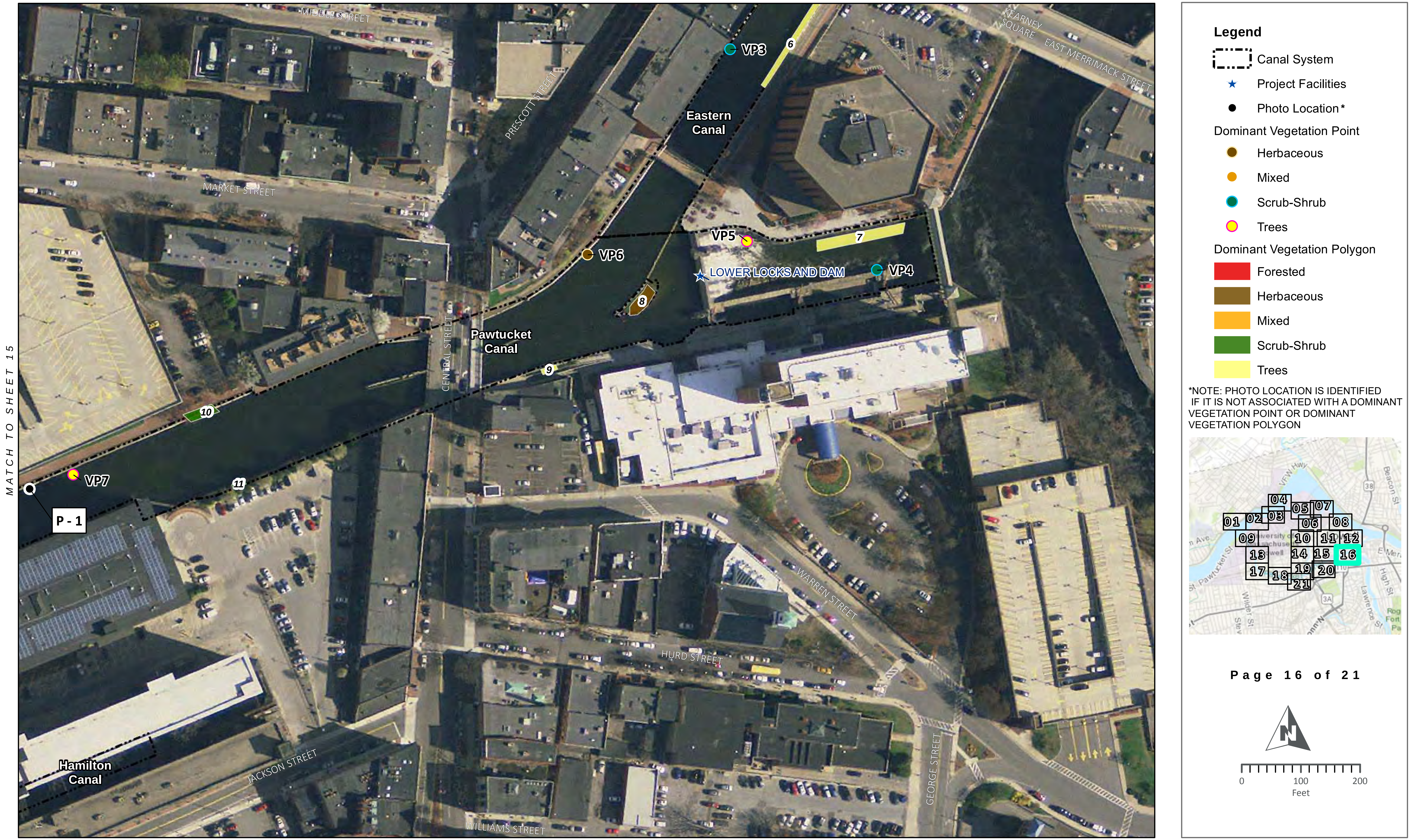

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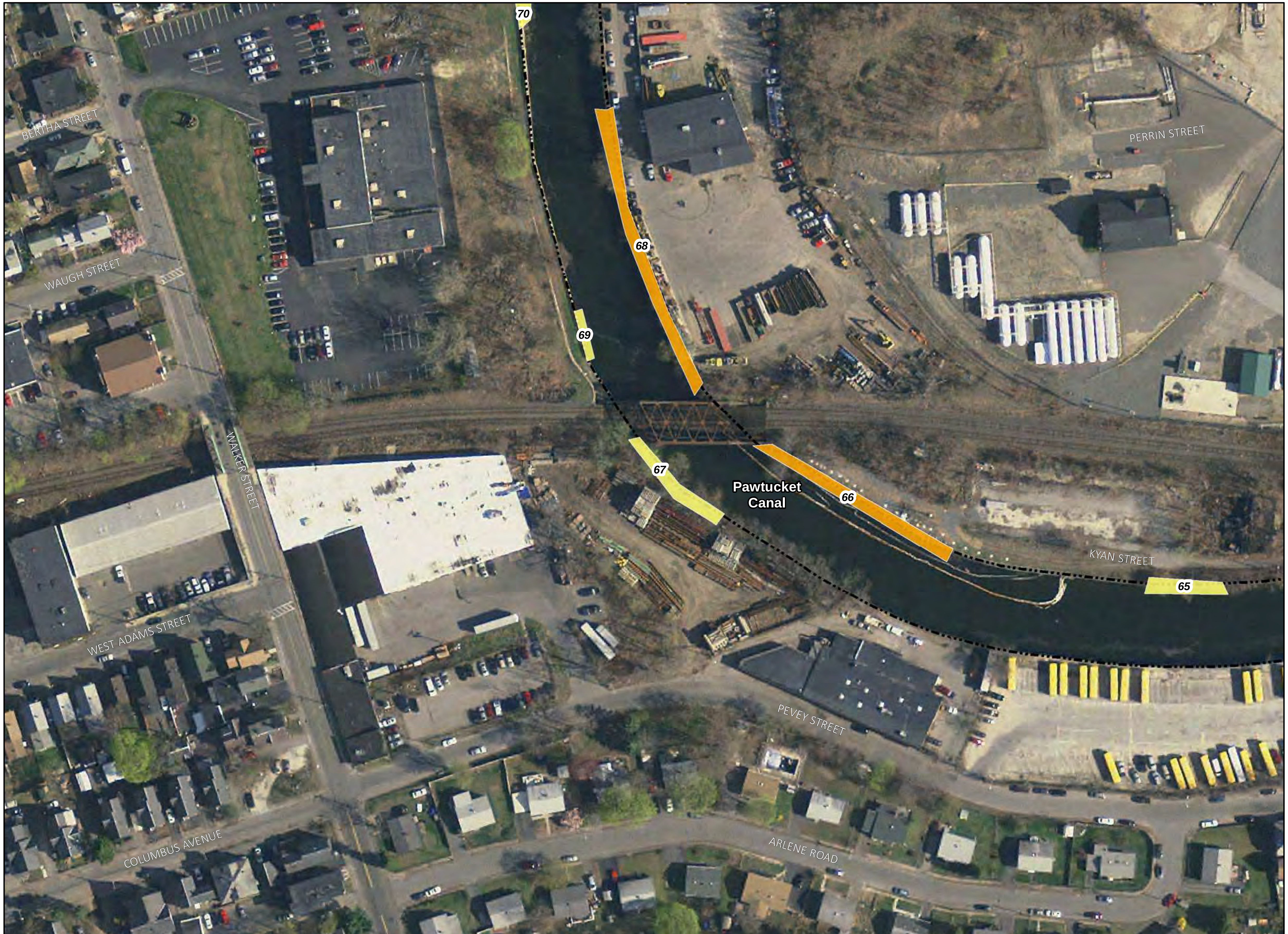

MATCH TO SHEET 18

Legend

- Canal System
- Project Facilities
- Photo Location*

Dominant Vegetation Point

- Herbaceous
- Mixed
- Scrub-Shrub
- Trees

Dominant Vegetation Polygon

- Forested
- Herbaceous
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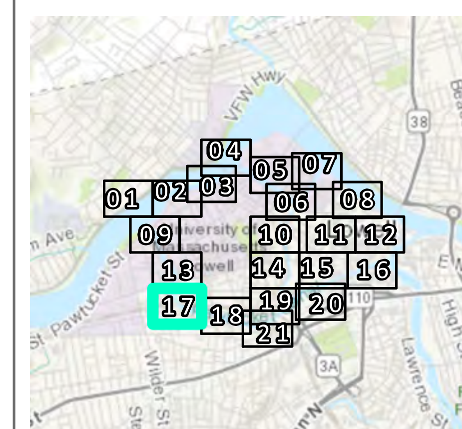

Page 17 of 21

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Feet

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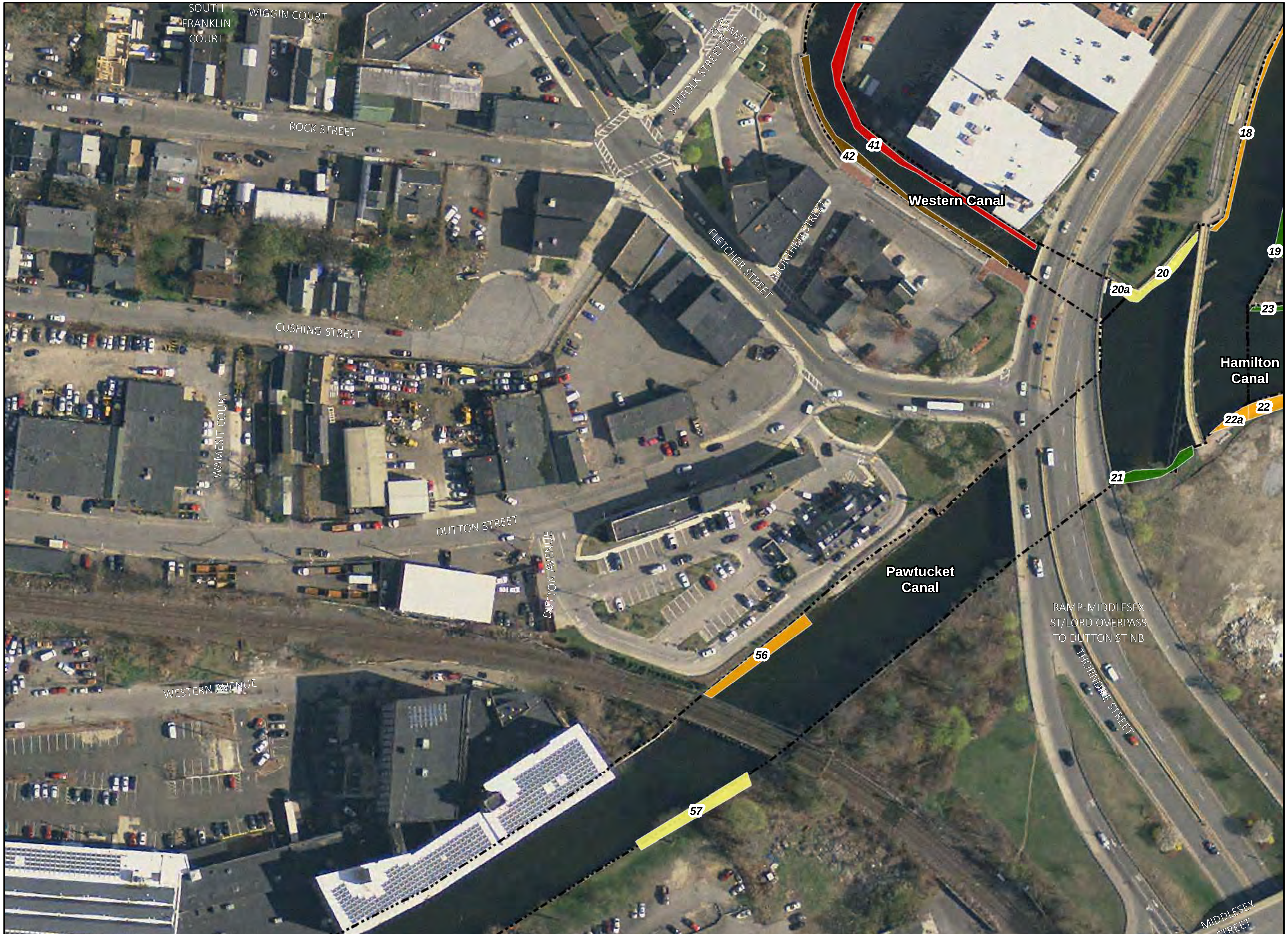
MATCH TO SHEET 18



MATCH TO SHEET 20

Legend

- Canal System
- Project Facilities
- Photo Location*

Dominant Vegetation Point

- Herbaceous
- Mixed
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- Trees

Dominant Vegetation Polygon

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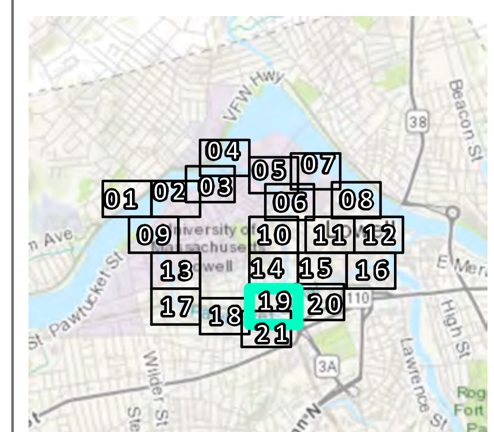

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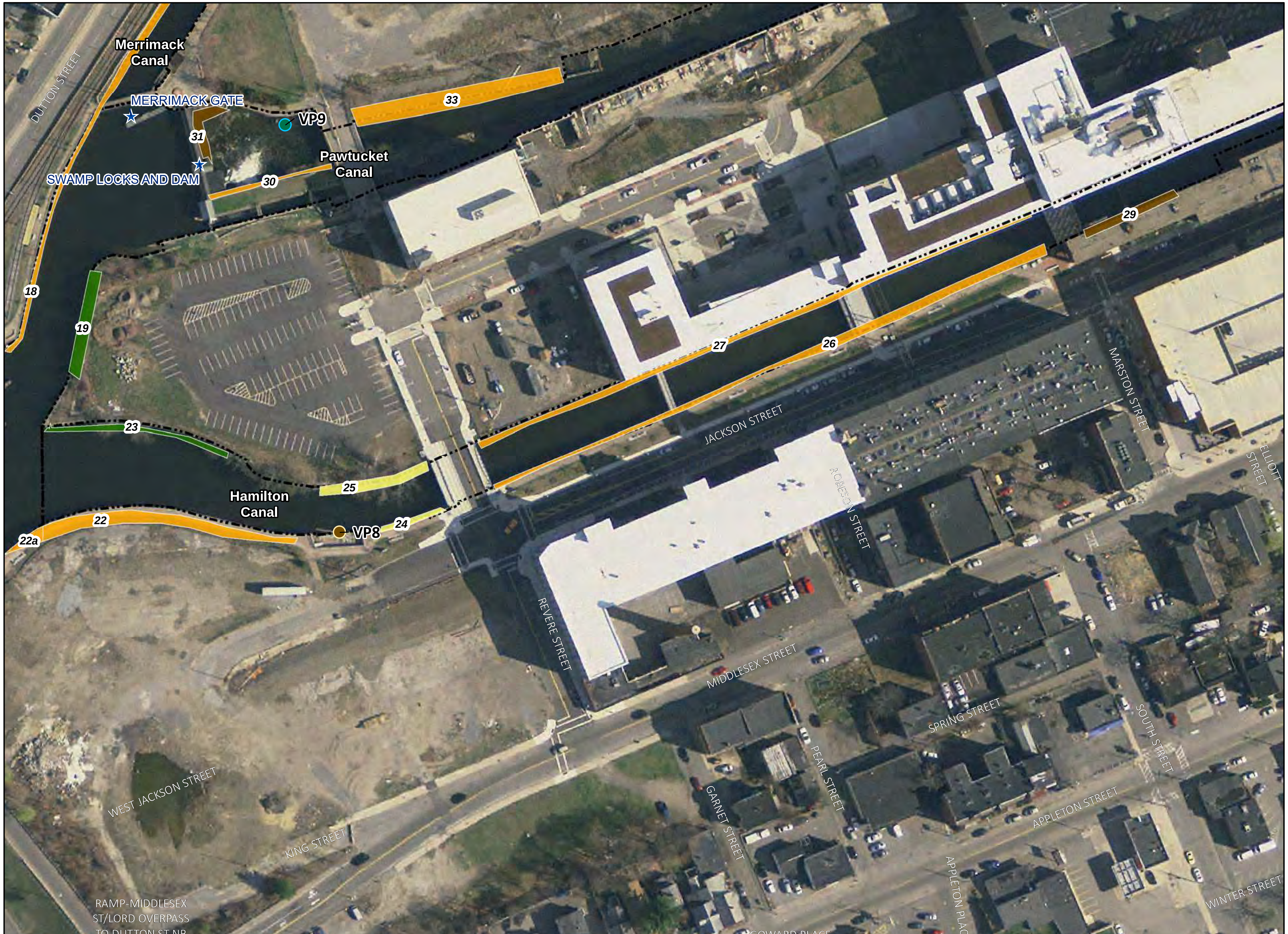
RECREATION AND AESTHETICS STUDY
LOWELL HYDROELECTRIC PROJECT
FERC NO. 2790

PATH: \\SYR-SRV01\GIS\PROJECTS\ENEL\LOWELL_RELICENSE\10104574_ENEL_LOWELL_STUDIES\MAP_DOCS\DRAFT\MAP_VEGETATION_COVERTYPESTUDY11X17_0304.MXD - USER: KAUSTIN - DATE: 8/18/2020

AUGUST 2020



MATCH TO SHEET 19

Legend

- Canal System
- Project Facilities
- Photo Location*

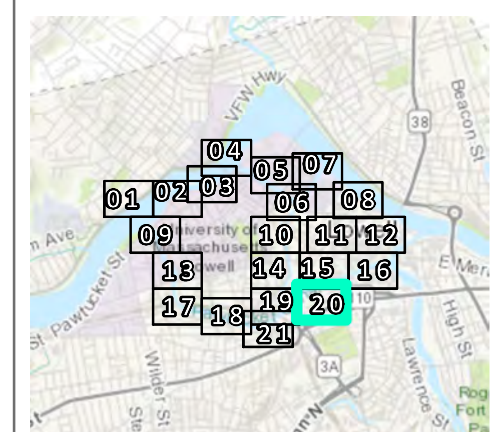
Dominant Vegetation Point

- Herbaceous
- Mixed
- Scrub-Shrub
- Trees

Dominant Vegetation Polygon

- Forested
- Herbaceous
- Mixed
- Scrub-Shrub
- Trees

*NOTE: PHOTO LOCATION IS IDENTIFIED IF IT IS NOT ASSOCIATED WITH A DOMINANT VEGETATION POINT OR DOMINANT VEGETATION POLYGON



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Feet

BOOTT HYDRO, LLC.

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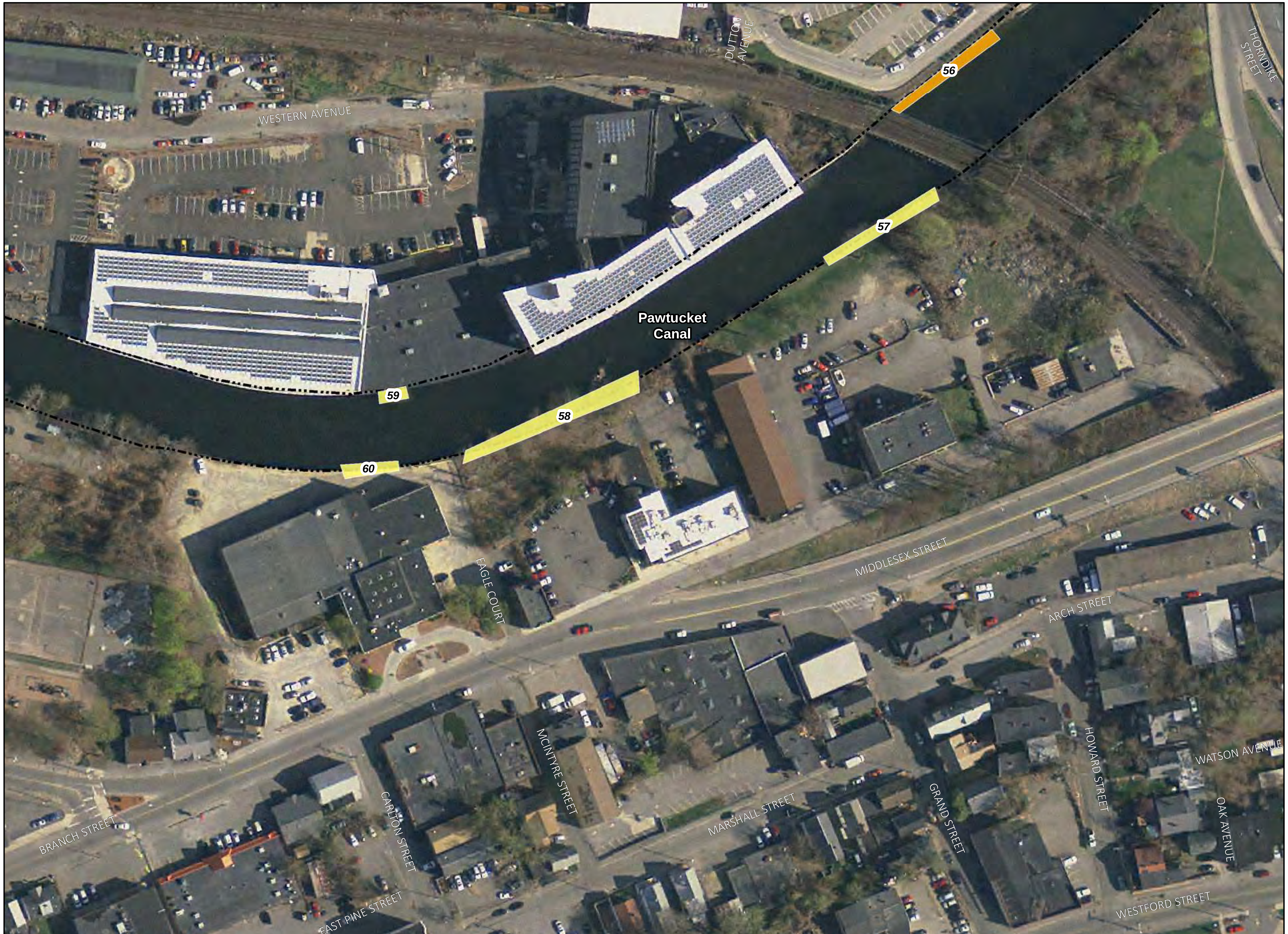
AUGUST 2020

MATCH TO SHEET 18



Legend

- Canal System
- Project Facilities
- Photo Location*

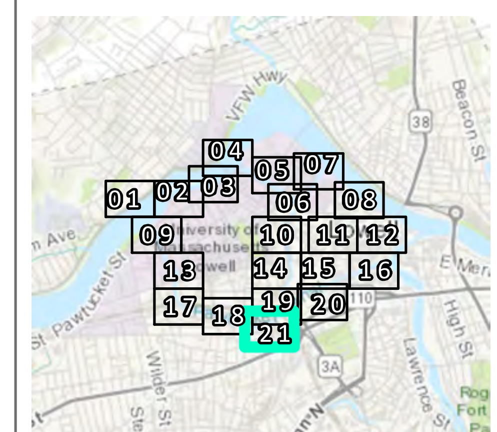
Dominant Vegetation Point

- Herbaceous
- Mixed
- Scrub-Shrub
- Trees

Dominant Vegetation Polygon

- Forested
- Herbaceous
- Mixed
- Scrub-Shrub
- Trees

*NOTE: PHOTO LOCATION IS IDENTIFIED IF IT IS NOT ASSOCIATED WITH A DOMINANT VEGETATION POINT OR DOMINANT VEGETATION POLYGON



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AUGUST 2020

Appendix H -
Visual Survey for Vegetation Growth Data

Vegetation Polygon/ Point Identifier	Dominant Vegetation Type[1]	Dominant Shoreline Type[2]	Canal[3]	Mapbook Sheet(s)	Polygon Acreage	Canal Acreage	% of Polygon	Field Notes Summary/Comments
1[4]	Mixed	Block Wall	Eastern	12	0.337	4.026	8.371	Several large woody trees are located at the northwestern end of the canal, while herbaceous plants dominate the western side of the canal
2	Herbaceous	Block Wall	Eastern	12	0.015	4.026	0.373	Small black locust scattered among purple loosestrife and other herbaceous weeds at base of building
3[4]	Mixed	Block Wall	Eastern	12	0.002	4.026	0.050	One elm tree, Boston ivy, ragweed; bottom of canal contains scattered aquatic vegetation
4[4]	Trees	Block Wall/Concrete/Stone Wall Mix	Eastern	12	0.002	4.026	0.050	One multi-trunked tree of heaven, 4 to 6 inches DBH
5	Trees	Block Wall/Concrete/Stone Wall Mix	Eastern	12	0.001	4.026	0.025	One multi-trunked birch, 1 inch DBH
6	Trees	Block Wall	Eastern	12, 16	0.024	4.026	0.596	Multiple tree of heaven and elm trees rooted and growing between stones of canal wall
7	Trees	Stone Wall	Pawtucket	16	0.034	19.630	0.173	Several large woody trees including river birch, tree of heaven, and silver maple, all 2 to 5 inches DBH
8	Herbaceous	Block Wall	Pawtucket	16	0.013	19.630	0.066	Canal contains what appears to be sediment deposited against the canal wall, sediment is topped with a layer of herbaceous plants
9	Trees	Concrete	Pawtucket	16	0.003	19.630	0.015	One tree of heaven and one unidentified hardwood growing on top of canal wall
10	Scrub-Shrub	Block Wall/Concrete/Stone Wall Mix	Pawtucket	16	0.010	19.630	0.051	Four tree of heaven, all 1 inch DBH growing on/out of canal wall
11	Scrub-Shrub	Block Wall	Pawtucket	16	0.003	19.630	0.015	Multiple tree of heaven growing out of canal wall
12	Trees	Block Wall/Concrete/Stone Wall Mix	Merrimack	15	0.002	1.402	0.143	Three multi-trunked elm trees, all with 1 inch DBH growing out of canal wall
13	Trees	Concrete	Merrimack	15	0.003	1.402	0.214	One elm tree and one mulberry growing out of concrete portion of canal wall
14	Herbaceous	Block Wall/Concrete/Stone Wall Mix	Merrimack	15	0.054	1.402	3.852	Approximately 20% of the canal wall has woody trees (i.e. elms, locust, and mulberry) or herbaceous plants growing on it

Vegetation Polygon/ Point Identifier	Dominant Vegetation Type[1]	Dominant Shoreline Type[2]	Canal[3]	Mapbook Sheet(s)	Polygon Acreage	Canal Acreage	% of Polygon	Field Notes Summary/Comments
15	Scrub-Shrub	Block Wall/Concrete/Stone Wall Mix	Merrimack	15	0.054	1.402	3.852	Approximately 20% of the canal wall has woody trees or herbaceous plants growing on it; woody trees include elms, locust, and mulberry
16	Herbaceous	Block Wall	Merrimack	15	0.053	1.402	3.780	Approximately 20% of the canal wall has woody trees (i.e. elms, locust, and mulberry) or herbaceous plants growing on it
17	Herbaceous	Block Wall/Concrete/Stone Wall Mix	Merrimack	15	0.049	1.402	3.495	Approximately 20% of the canal wall has woody trees (i.e. mulberry and tree of heaven) or herbaceous plants growing on it
18	Mixed	Block Wall	Pawtucket	15, 19, 20	0.121	19.630	0.616	Tree of heaven, ragweed, maple, common mullein, Japanese knotweed, estimated at 20 % cover; Japanese knotweed density increased at NPS boat dock
18a*	Mixed	Block Wall	Merrimack	15, 19, 20	0.121	1.402	8.631	Approximately 20% of the canal wall has woody trees, shrubs, and/or herbaceous plants growing on it; vegetation includes tree of heaven, maple, common mullein, Japanese knot weed and ragweed. Japanese knot weed coverage increases with closer proximity to the NPS boat dock
19	Scrub-Shrub	Block Wall	Pawtucket	19, 20	0.037	19.630	0.188	Vegetation on canal wall includes elms, birches, and scattered ferns
20	Trees	Block Wall	Pawtucket	19	0.023	19.630	0.117	Catalpa tree is growing out of the top of the canal wall and several tree of heaven and birch, some with 5 to 10 inches DBH
20a*	Trees	Block Wall	Pawtucket	19	0.005	19.630	0.025	Catalpa growing out of wall, several trees of heaven, and birch, some with DBH of 5 to 10 inches
21	Scrub-Shrub	Block Wall/Concrete/Stone Wall Mix	Pawtucket	19	0.020	19.630	0.102	Vegetation on canal wall includes glossy buckthorn, boxelder, and tree of heaven, some with 3 to 5 inches DBH
22	Mixed	Block Wall/Concrete/Stone Wall Mix	Hamilton	19, 20	0.076	2.005	3.791	Vegetation on canal wall includes woody trees such as tree of heaven and elms, scattered herbaceous plants such as ragweed and mullein, and Virginia creeper vine
22a*	Mixed	Block Wall/Concrete/Stone Wall Mix	Pawtucket	19, 20	0.010	19.630	0.051	Tree of heaven, elms, ragweed, mullein, and Virginia creeper

Vegetation Polygon/ Point Identifier	Dominant Vegetation Type[1]	Dominant Shoreline Type[2]	Canal[3]	Mapbook Sheet(s)	Polygon Acreage	Canal Acreage	% of Polygon	Field Notes Summary/Comments
23[4]	Scrub-Shrub	Block Wall	Hamilton	19, 20	0.027	2.005	1.347	Vegetation on canal wall is primarily tree of heaven and ragweed, with lesser density of mullein
24	Trees	Block Wall/Concrete/Stone Wall Mix	Hamilton	20	0.010	2.005	0.499	Vegetation on canal wall is primarily box elder and ragweed, with sporadic coverage of elm trees
25[4]	Trees	Block Wall	Hamilton	20	0.032	2.005	1.596	Vegetation growing out of canal wall includes one sycamore, several tree of heaven, glossy buckhorn, and ragweed
26[4]	Mixed	Block Wall/Concrete/Stone Wall Mix	Hamilton	20	0.105	2.005	5.237	The canal wall, west of walking bridge, consists of portions of concrete and is primarily covered in ragweed. The canal wall, east of walking bridge, contains trees, such as tree of heaven and elm
27[4]	Mixed	Block Wall/Concrete/Stone Wall Mix	Hamilton	20	0.076	2.005	3.791	Vegetation on canal wall consists primarily of trees with approximately 10 percent cover. Trees are smaller and less dense on canal wall east of the walking bridge. The canal wall west of the walking bridge consists of portions of concrete
29[5]	Herbaceous	Block Wall/Concrete/Stone Wall Mix	Hamilton	20	0.024	2.005	1.197	Vegetation growing out of canal wall at the eastern end is hard to distinguish because of lack of access; however, vegetation coverage was approximately 15-20 percent and likely consists of ragweed, ivy, and elms
30	Mixed	Block Wall/Concrete/Stone Wall Mix	Pawtucket	20	0.013	19.630	0.066	Vegetation is located at the toe of the canal wall and includes elm, tree of heaven, ragweed, and jewelweed
31	Herbaceous	Block Wall/Concrete/Stone Wall Mix	Pawtucket	15, 20	0.019	19.630	0.097	Vegetation growing out of canal wall is primarily herbaceous species, including purple loosestrife, Japanese knotweed, jewelweed, and buckthorn shrubs
32	Scrub-Shrub	Block Wall	Pawtucket	15	0.046	19.630	0.234	Shrubs are growing along the top of the canal wall, but cannot distinguish species because of lack of access; cannot tell if shrubs are growing out of the canal wall
33	Mixed	Block Wall	Pawtucket	15, 20	0.111	19.630	0.565	Vegetation growing on top of canal wall include several tree species and herbaceous species

Vegetation Polygon/ Point Identifier	Dominant Vegetation Type[1]	Dominant Shoreline Type[2]	Canal[3]	Mapbook Sheet(s)	Polygon Acreage	Canal Acreage	% of Polygon	Field Notes Summary/Comments
34[4]	Mixed	Block Wall/Concrete/Stone Wall Mix	Western	10	0.014	5.510	0.254	Vegetation growing on the canal wall is sparse and consists primarily of vines. Vegetation growing on top of and approximately 3 feet back from canal wall is primarily herbaceous
35[4]	Mixed	Block Wall/Concrete/Stone Wall Mix	Western	10	0.014	5.510	0.254	Vegetation growing out of the canal wall is sparse and there are a few trees growing on top of and approximately 3 feet back from the canal wall
36[4]	Mixed	Block Wall/Concrete/Stone Wall Mix	Western	6, 10	0.036	5.510	0.653	Vegetation growing out of canal wall consists of mostly vines with a few tree of heaven are growing on top of and approximately 5 feet back from canal wall
37	Mixed	Block Wall/Concrete/Stone Wall Mix	Western	6, 10	0.034	5.510	0.617	Vegetation growing out of canal wall consists of mostly vines and a few tree of heaven are growing on top of and approximately 3 feet back from canal wall
38[4]	Scrub-Shrub	Block Wall	Western	6	0.025	5.510	0.454	Vegetation growing out of the canal wall, near the top, consists of shrubs,
39[4]	Herbaceous	Block Wall	Western	6	0.004	5.510	0.073	A few, small tree of heaven trees are growing out of the canal wall, near the top of wall
40	Herbaceous	Block Wall	Western	6	0.002	5.510	0.036	Small clump of shrubs growing out of the canal wall
41[4]	Forested	Block Wall/Concrete/Stone Wall Mix	Western	14, 19	0.377	5.510	6.842	Portions of the canal wall at bridge crossings on each side of the canal are concrete and brick; the highest density of vegetation in the polygon consists of locust, tree of heaven, box elder, maples and scattered shrubs, some with 6 to 14 inches DBH
42	Herbaceous	Block Wall/Concrete/Stone Wall Mix	Western	19	0.051	5.510	0.926	Vegetation on canal wall consists of scattered herbaceous species that include Japanese knotweed, and scattered shrubs
43	Scrub-Shrub	Block Wall	Northern	6	0.001	11.670	0.009	Small clump of maple and elms growing on the canal wall
44	Scrub-Shrub	Block Wall	Northern	6	0.009	11.670	0.077	A clump of five small trees, including ash and elm with 1 to 2 inches DBH, growing on the canal wall

Vegetation Polygon/ Point Identifier	Dominant Vegetation Type[1]	Dominant Shoreline Type[2]	Canal[3]	Mapbook Sheet(s)	Polygon Acreage	Canal Acreage	% of Polygon	Field Notes Summary/Comments
45[4]	Mixed	Block Wall	Western	6, 7	0.019	5.510	0.345	Vegetation growing on the eastern side of the canal wall includes several trees (i.e. mulberry, buckthorn, tree of heaven) and dense vines, including Boston and poison ivy
46[4]	Mixed	Block Wall	Western	6, 7	0.020	5.510	0.363	Vegetation growing on western side of the canal wall includes less trees than the eastern side of the canal wall (see Polygon 46) and similar vine species, such as Boston ivy and poison ivy
47[4]	Forested	Block Wall/Concrete/Stone Wall Mix	Western	6, 7	0.037	5.510	0.672	Vegetation growing on the canal wall includes large locust trees and ragweed
48	Forested	Block Wall/Concrete/Stone Wall Mix	Western	6, 7	0.065	5.510	1.180	Vegetation growing on the canal wall includes dense clumps of large buckhorn, elm, and birch
49	Mixed	Block Wall/Concrete/Stone Wall Mix	Western	6, 7	0.060	5.510	1.089	Tree of heaven, elms, vines and dense herbaceous species growing on canal wall
50	Mixed	Block Wall	Western	7	0.015	5.510	0.272	Tree of heaven, elms, and ragweed growing on canal wall
51[4]	Herbaceous	Block Wall	Western	7	0.012	5.510	0.218	Vegetation growing on canal wall include trees, such as mulberry and elms, and herbaceous ragweed
52	Herbaceous	Block Wall	Western	7	0.006	5.510	0.109	Vegetation growing on canal wall include trees, such as sycamore, and herbaceous species, such as purple loosestrife and Japanese knotweed
53	Herbaceous	Block Wall	Western	7	0.002	5.510	0.036	Small shrubs are growing out of canal wall
54[4]	Herbaceous	Block Wall	Western	7	0.060	5.510	1.089	Vegetation growing on canal wall consists primarily of vines; a few tree of heaven trees are growing at the toe of the canal wall, likely on deposited sediment
55[4]	Mixed	Block Wall	Western	7	0.045	5.510	0.817	Vegetation growing on canal wall consists primarily of herbaceous vegetation, such as ragweed, and vines; a few tree of heaven also growing on canal wall, but mostly at the toe of the canal wall

Vegetation Polygon/ Point Identifier	Dominant Vegetation Type[1]	Dominant Shoreline Type[2]	Canal[3]	Mapbook Sheet(s)	Polygon Acreage	Canal Acreage	% of Polygon	Field Notes Summary/Comments
56[4]	Mixed	Concrete	Pawtucket	19, 21	0.037	19.630	0.188	Most of the canal wall is made of concrete with riprap placed at the toe of the wall; vegetation growing on wall consists of tree of heaven, box elder, and vines, such as Boston ivy
57	Trees	Block Wall	Pawtucket	19, 21	0.043	19.630	0.219	Vegetation growing out of the canal wall includes ash trees with 6 to 8 inches DBH
58[4]	Trees	Block Wall	Pawtucket	21	0.086	19.630	0.438	Vegetation growing out of the canal wall includes locust trees, tree of heaven, wild grape, and oriental bittersweet
59	Trees	Block Wall/Concrete/Stone Wall Mix	Pawtucket	21	0.010	19.630	0.051	Clump of trees currently growing out of the canal wall was being removed at time of survey
60	Trees	Block Wall	Pawtucket	21	0.019	19.630	0.097	Vegetation growing out of canal wall includes five small shrubs and ash and elm trees
61	Trees	Block Wall	Pawtucket	18	0.144	19.630	0.734	Vegetation growing out of canal wall consists primarily of oriental bittersweet; trees, such as birch and box elder, are growing primarily on top of the canal wall at the edge
62	Trees	Block Wall	Pawtucket	18	0.008	19.630	0.041	4 small birches are growing out of the canal wall
63	Trees	Block Wall	Pawtucket	18	0.091	19.630	0.464	Several tree species are growing out of the canal wall
64	Trees	Block Wall	Pawtucket	18	0.078	19.630	0.397	Black locust and box elder with 2 to 4 inches DBH are growing out of canal wall
65	Trees	Block Wall	Pawtucket	17	0.033	19.630	0.168	Tree species growing out of canal wall include tree of heaven, locust, and birch
66[4]	Mixed	Block Wall	Pawtucket	17	0.078	19.630	0.397	Vegetation growing out of canal wall at top of the wall include trees such as tree of heaven and birch, and vines, such as Boston ivy
67[4]	Trees	Block Wall	Pawtucket	17	0.044	19.630	0.224	Large locust and birch trees growing on top of canal wall
68	Mixed	Block Wall	Pawtucket	17	0.103	19.630	0.525	Sporadic trees, including elms and birch, and ragweed are growing on top edge of canal wall; vines, such as Boston ivy growing down canal wall

Vegetation Polygon/ Point Identifier	Dominant Vegetation Type[1]	Dominant Shoreline Type[2]	Canal[3]	Mapbook Sheet(s)	Polygon Acreage	Canal Acreage	% of Polygon	Field Notes Summary/Comments
69[4]	Trees	Block Wall/Concrete/Stone Wall Mix	Pawtucket	17	0.012	19.630	0.061	Trees growing out of canal wall include tree of heaven and elms, approximately 10 feet tall
70[4]	Trees	Concrete	Pawtucket	13, 17	0.033	19.630	0.168	Canal wall is primarily concrete with trees, such as locust and elm, growing at the toe of the wall
71	Trees	Block Wall	Pawtucket	13	0.039	19.630	0.199	Tree of heaven and elm trees are primarily growing on top of the canal wall
72	Mixed	Block Wall	Pawtucket	13	0.005	19.630	0.025	Vegetation growing out of canal wall includes tree of heaven and vines
73	Scrub-Shrub	Block Wall	Northern	2	0.056	11.670	0.480	Tree of heaven, catalpa, and ash trees are growing on top of the canal wall
74[4]	Herbaceous	Block Wall/Concrete/Stone Wall Mix	Northern	3,4	0.007	11.670	0.060	Ragweed is growing out of the canal wall located beneath the building
75[4]	Herbaceous	Block Wall/Concrete/Stone Wall Mix	Northern	3,4	0.236	11.670	2.022	Vegetation is growing from small sill under the first block down on the canal wall and is dominated by herbaceous plants, such as ragweed, purple loosestrife, aster, scattered ferns, golden rod spp., scattered mulberry, elms, and buckthorn.
76	Mixed	Block Wall	Northern	3	0.157	11.670	1.345	Scattered trees and shrubs are growing out of the canal wall and along the toe of the wall
77[4]	Forested	Block Wall/Concrete/Stone Wall Mix	Northern	2, 3	0.048	11.670	0.411	At the western edge of polygon, the canal broadens and is forested with riparian species; topography extends to bypass reach; species include elms, mulberry, and honeysuckle; some stumps have been cut along the wall on the same side as the bypass reach
78[4]	Herbaceous	Block Wall	Northern	2, 3	0.011	11.670	0.094	Vegetation growing out of the canal walls include tree of heaven and mulberry and herbaceous species such as purple loosestrife and mullein
79[4]	Scrub-Shrub	Block Wall	Northern	2	0.017	11.670	0.146	Tree of heaven trees and vines are growing on top of the canal wall and within approximately 3 feet of the canal wall
80	Trees	Block Wall	Northern	2	0.033	11.670	0.283	Vegetation consists of few, large trees growing at the toe of the canal wall

Vegetation Polygon/ Point Identifier	Dominant Vegetation Type[1]	Dominant Shoreline Type[2]	Canal[3]	Mapbook Sheet(s)	Polygon Acreage	Canal Acreage	% of Polygon	Field Notes Summary/Comments
81	Herbaceous	Stone Wall	Merrimack	15	0.003	1.402	0.214	Scattered ferns and 1 small, 4 ft. maple with .5 inch DBH growing out of canal wall
82[4]	Herbaceous	Block Wall/Concrete/Stone Wall Mix	Merrimack	11	0.045	1.402	3.210	90% vegetative cover in this area; vegetation is mostly herbaceous, including ragweed, clover, *Aster* spp., and weeds; two small tree of heaven also present on canal wall
83	Scrub-Shrub	Block Wall	Eastern	11	0.010	4.026	0.248	Vegetation on the canal wall includes a dense clump of climbing vines, one small maple, and one small honeysuckle
84[4]	Herbaceous	Block Wall	Eastern	8, 11	0.109	4.026	2.707	Approximately 20% vegetative cover on the western side of the canal wall located primarily one block down from the top of the wall; vegetation includes a few maples, honeysuckle, and scattered herbaceous species.
85[4]	Scrub-Shrub	Block Wall	Eastern	8, 11	0.160	4.026	3.974	Approximately 40% vegetative cover on the east side of the canal wall; vegetation includes several 5 ft. elms, several birches, and a few red maples
86[4]	Mixed	Block Wall	Eastern	8	0.088	4.026	2.186	Mixed vegetation includes tree of heaven and some emergent wetland vegetation and cattail spp.; other herbaceous species are growing at the bottom of the canal
87	Mixed	Block Wall/Concrete/Stone Wall Mix	Eastern	12	0.014	4.026	0.348	Vegetation growing out of the canal wall includes and 8-trunked box elder at 5-10 inches DBH, glossy buckthorn, and two mulberry shrubs
88	Mixed	Block Wall/Concrete/Stone Wall Mix	Eastern	12	0.012	4.026	0.298	Vegetation growing out of the canal wall includes five tree of heaven at 1-2 inches DBH, one quaking aspen, and several multi-stemmed birches
89[4]	Mixed	Block Wall/Concrete/Stone Wall Mix	Eastern	12	0.046	4.026	1.143	Vegetation growing out of the canal wall includes an approximately 10-trunked tree of heaven tree at 6 inches DBH and poison ivy
90[4]	Trees	Block Wall/Concrete/Stone Wall Mix	Eastern	12	0.034	4.026	0.845	Vegetation growing out of canal wall is a 3-trunked tree of heaven tree at 4 inches DBH; also observed a recently cut birch tree tied with rope

Vegetation Polygon/ Point Identifier	Dominant Vegetation Type[1]	Dominant Shoreline Type[2]	Canal[3]	Mapbook Sheet(s)	Polygon Acreage	Canal Acreage	% of Polygon	Field Notes Summary/Comments
91[4]	Mixed	Block Wall/Concrete/Stone Wall Mix	Eastern	8	0.078	4.026	1.937	Vegetation growing on the canal wall is primarily herbaceous, however, one maple at approximately 5-10 inches DBH is within polygon
92[4]	Forested	Block Wall	Northern	2, 3	0.191	11.670	1.637	View toward south side of canal showing vegetation growing on top of single stone/block
93[4]	Mixed	Earthen/ Terrestrial Cultural	Northern	3,4	0.093	11.670	0.797	View looking toward E.L Field Powerhouse, vegetation growing on bedrock along the south side of the canal
94	Mixed	Earthen/ Terrestrial Cultural	Northern	4	0.034	11.670	0.291	View looking west toward the E.L. Field Powerhouse from the NPS walking trail; vegetation is growing on bedrock along the south side of the canal
VP-1[4]	Scrub-Shrub	Block Wall	Eastern	12	N/A	4.026	N/A	Vegetation includes a single shrub growing out of the canal wall below the brick building and sparse herbaceous species
VP-2	Scrub-Shrub	Block Wall/Concrete/Stone Wall Mix	Eastern	12	N/A	4.026	N/A	Two tree of heaven at 1 inch DBH are growing out of the canal wall
VP-3	Scrub-Shrub	Block Wall/Concrete/Stone Wall Mix	Eastern	16	N/A	4.026	N/A	A single maple tree and a single elm tree are growing out of the canal wall
VP-4[4]	Scrub-Shrub	Stone Wall	Pawtucket	16	N/A	19.630	N/A	A multi-trunked clump of trees, approximately 6 to 8 feet tall, are growing out of canal wall
VP-5	Trees	Stone Wall	Pawtucket	16	N/A	19.630	N/A	A single small hardwood tree, approximately 6 feet tall, is growing out of the canal wall at toe of wall
VP-6	Herbaceous	Block Wall/Concrete/Stone Wall Mix	Pawtucket	16	N/A	19.630	N/A	A single, small elm, approximately 4 feet tall, is growing out of canal wall/piping along wall
VP-7	Trees	Block Wall/Concrete/Stone Wall Mix	Pawtucket	16	N/A	19.630	N/A	One birch at 3 inches DBH is growing out of the canal wall
VP-8	Herbaceous	Block Wall/Concrete/Stone Wall Mix	Hamilton	20	N/A	2.005	N/A	One tree of heaven, approximately 4 feet tall, is growing at the edge of the lock platform

Vegetation Polygon/ Point Identifier	Dominant Vegetation Type[1]	Dominant Shoreline Type[2]	Canal[3]	Mapbook Sheet(s)	Polygon Acreage	Canal Acreage	% of Polygon	Field Notes Summary/Comments
VP-9	Scrub-Shrub	Concrete	Pawtucket	20	N/A	19.630	N/A	One tree of heaven growing out of a concrete portion of the canal wall, at top of the wall along sidewalk
VP-10[4]	Trees	Block Wall	Northern	6	N/A	11.670	N/A	Small maple growing out of the canal wall, near top of wall
VP-11[4]	Scrub-Shrub	Block Wall	Western	6	N/A	5.510	N/A	A small clump of silver maples are growing out of canal wall
VP-12	Scrub-Shrub	Concrete	Western	6	N/A	5.510	N/A	A small clump of mulberry growing out of canal wall
VP-13[4]	Herbaceous	Block Wall	Western	6	N/A	5.510	N/A	One tree of heaven growing out of canal wall
VP-14[4]	Mixed	Block Wall	Western	7	N/A	5.510	N/A	A small clump of shrubs growing out of canal wall
VP-15	Trees	Block Wall	Pawtucket	18	N/A	19.630	N/A	A single ash tree growing out of the canal wall
VP-16[4]	Trees	Block Wall	Pawtucket	18	N/A	19.630	N/A	Large tree growing out of canal wall
VP-17	Trees	Block Wall	Pawtucket	18	N/A	19.630	N/A	Small tree growing out of canal wall near outfall
VP-18	Scrub-Shrub	Block Wall	Northern	6	N/A	11.670	N/A	Two small shrubs growing on top of the canal wall
VP-19	Scrub-Shrub	Block Wall	Northern	5,6	N/A	11.670	N/A	One tree, likely dead, growing out of canal wall
VP-20	Scrub-Shrub	Block Wall	Northern	5	N/A	11.670	N/A	A single shrub (next to smaller shrubs) growing out of the canal wall
VP-21	Scrub-Shrub	Block Wall	Northern	6	N/A	11.670	N/A	Tree of heaven and oriental bittersweet growing out canal wall
VP-22	Trees	Block Wall	Northern	6	N/A	11.670	N/A	One small maple growing out of the canal wall
VP-23	Trees	Block Wall	Northern	6	N/A	11.670	N/A	Small clump of birch trees growing out of canal wall
VP-24	Trees	Block Wall	Northern	6	N/A	11.670	N/A	One small birch tree growing out of canal wall

Notes:
***** In instances where a polygon was recorded in more than one canal, for reporting purposes, it was separated into two distinct polygons that were each given a unique polygon identifier (e.g., 18 and 18a).

N/A = Not Applicable. Vegetation Points (VPs) were used to identify areas along canal walls where a single vegetation type point was recorded. VPs were not included in vegetation category percentage calculations because they represent a single point on the canal wall and were not assigned area estimates**.**

[1] Dominant Vegetation Types:
Herbaceous - Characterized by primarily herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and woody plants less than 3 feet tall.
Scrub-Shrub - Consists of woody plants less than 3 inches diameter at breast height (DBH) and greater than or equal to 3 feet tall.
Trees - Consists of woody plants 3 inches or more in DBH, regardless of height. This vegetation type description was generally used to describe areas along canal walls where only a few trees were growing in a clump.
Forested - Characterized as a relatively large area that consists of primarily trees and underbrush.
Mixed - Characterized by a mosaic of herbaceous, scrub-shrub, and/or trees.

[2] Dominant Shoreline Types:
Block Wall - Canal walls primarily dominated by placed, generally uniformly-sized blocks with concrete caps or block alone.
Concrete - Canal walls primarily dominated by concrete, with various types of cements and aggregate.
Earthen/Terrestrial Cultural - Canal walls generally dominated by earthen embankments (forested and unforested) and areas of exposed bedrock. Some of these areas (e.g., riprapped areas) have been created and/or maintained by human activities.
Stone Wall - Canal walls primarily dominated by placed, generally non-uniformly-sized blocks with concrete caps or blocks alone.
Block Wall/Concrete/Stone Wall Mix - Areas of canal walls predominantly composed of a conglomeration of block wall, concrete, or stone wall at varying quantities.

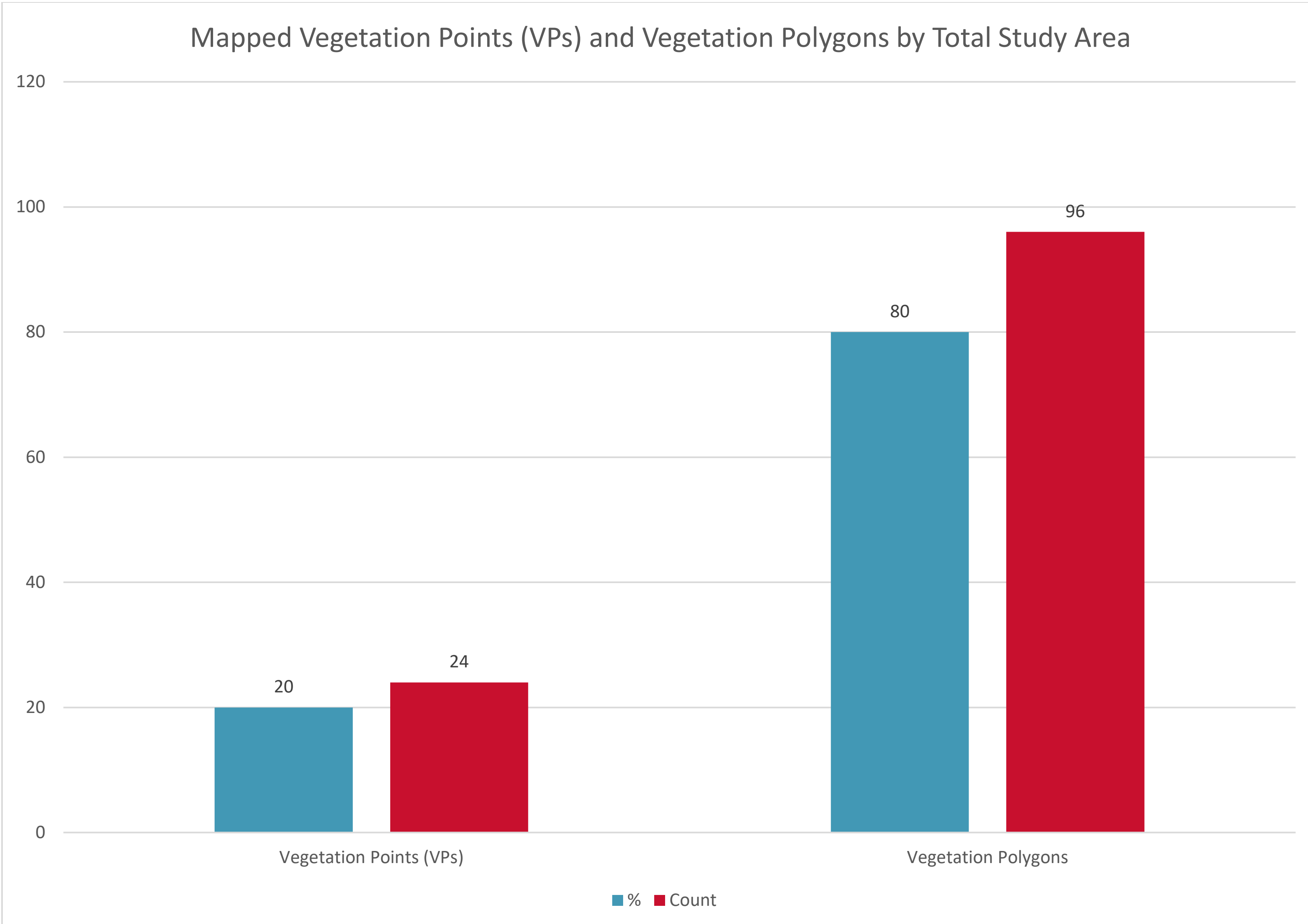
[3] The vegetation survey was conducted between September 25 and 27, 2019. For the purposes of examining vegetation type distribution, the study area was divided into the six canals associated with the Lowell Project canal system including: 1) Pawtucket Canal; 2) Northern Canal; 3) Western Canal; 4) Merrimack Canal; 5) Eastern Canal; and 6) Hamilton Canal.

[4]This Vegetation Polygon/Point Identifier has a photograph(s) included in Appendix J.

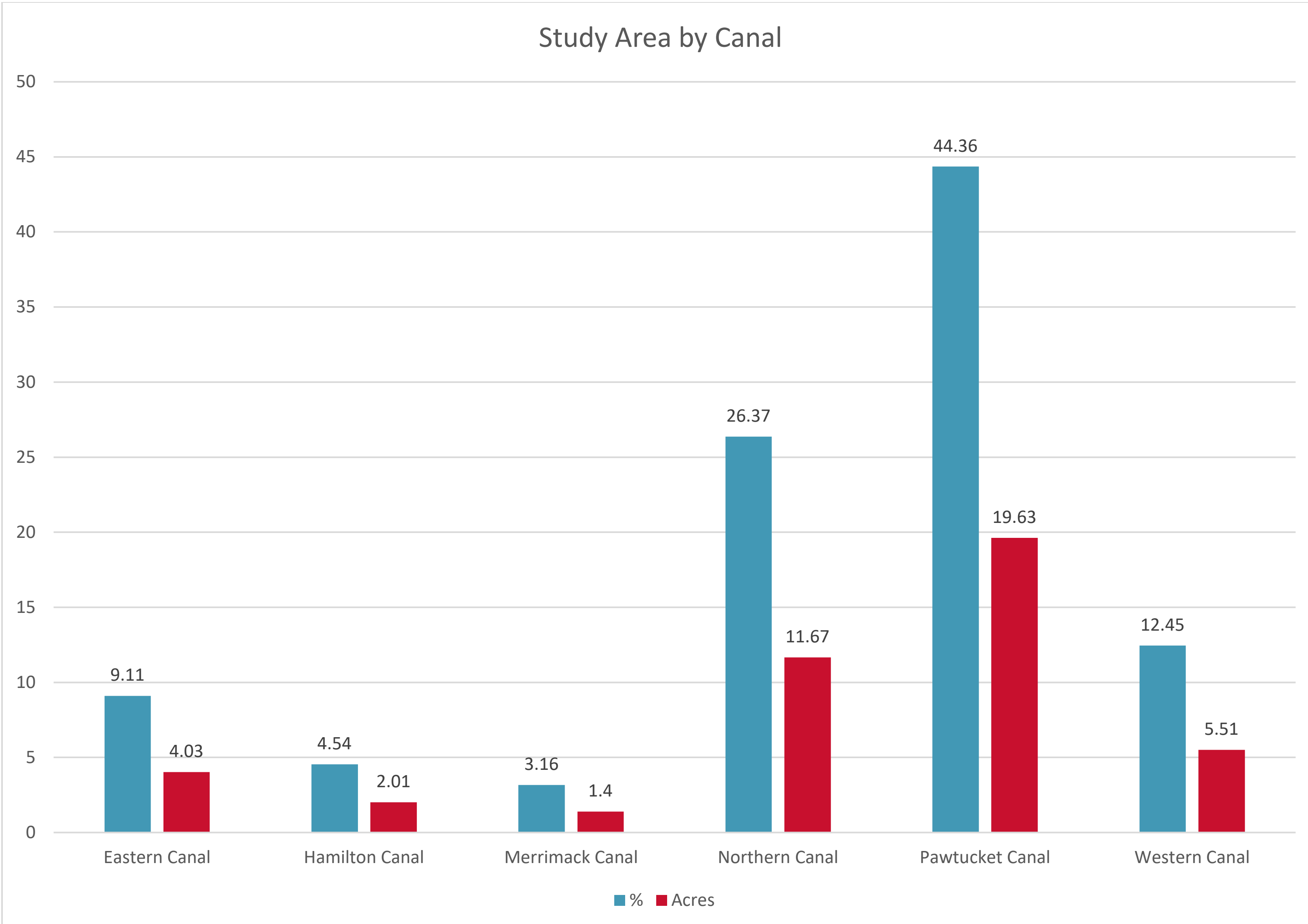
[5] Vegetation Polygon/Point Identifier 28 was not included in final results.

Appendix I - Visual Survey for Vegetation Growth Data Summary

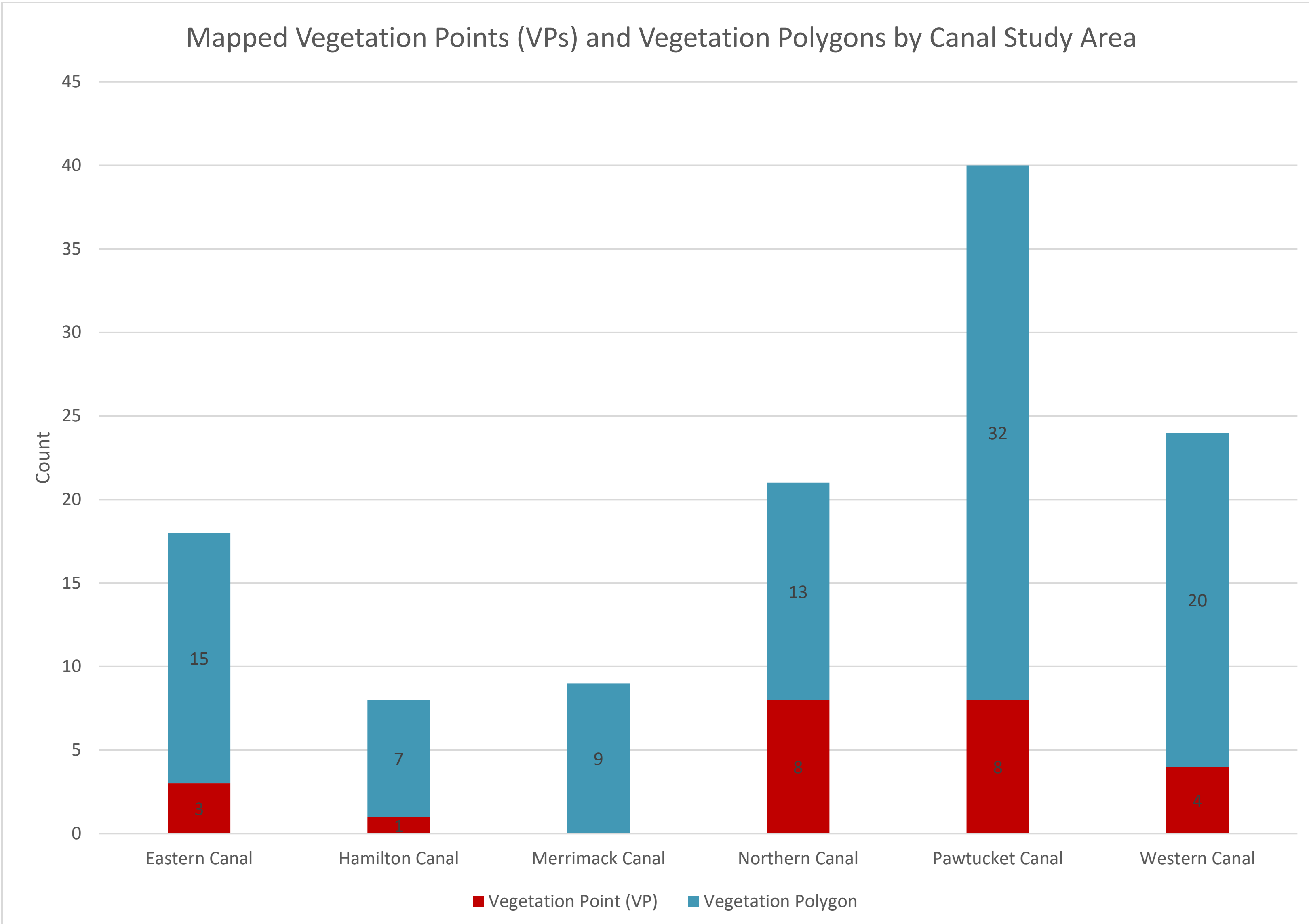
Summary of Visual Survey for Vegetation Growth Data

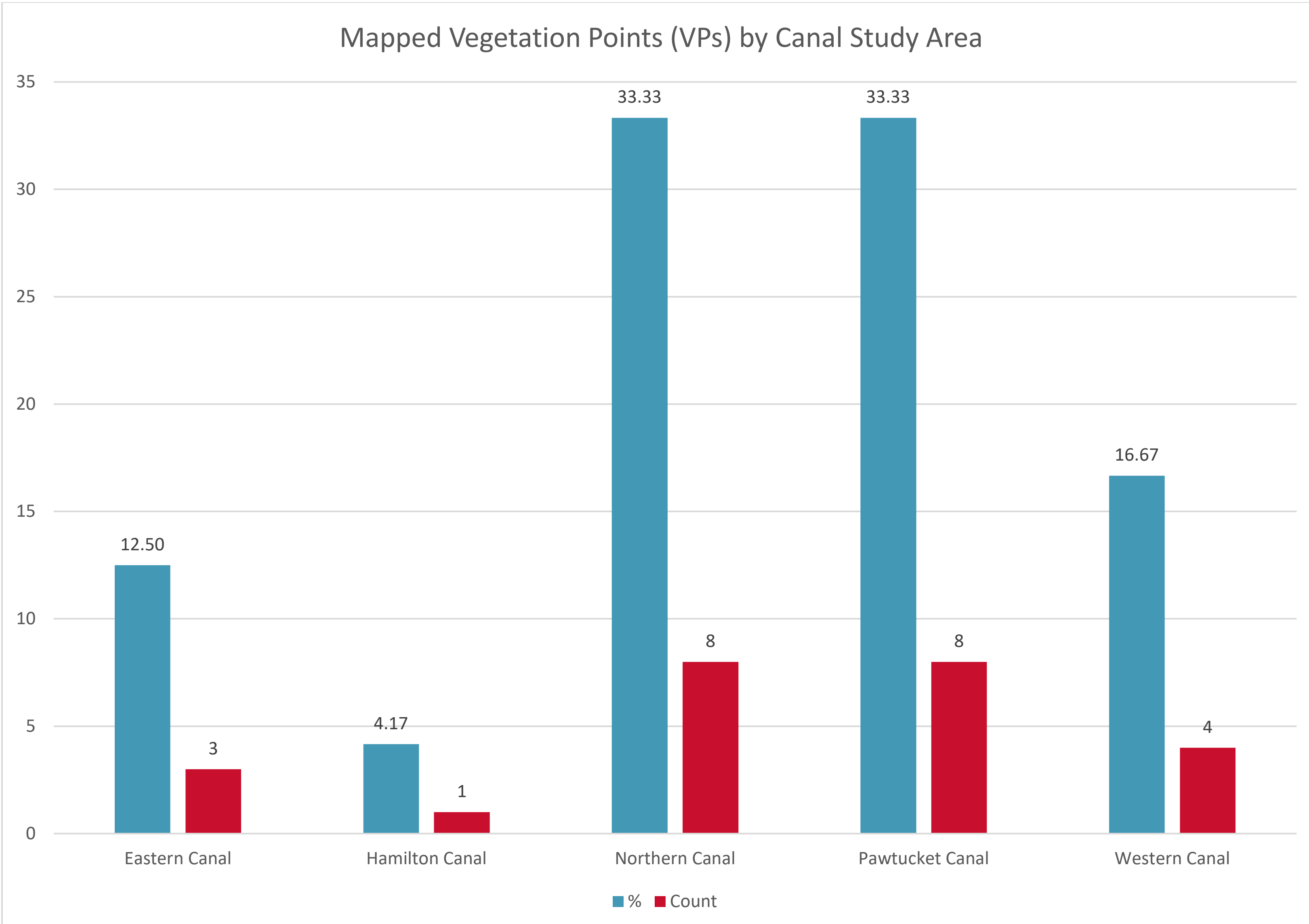


Mapped Vegetation Points (VPs) and Vegetation Polygons by Total Study Area
120
100
80
60
40
20
0
20
24
80
96
Vegetation Points (VPs)
Vegetation Polygons
%
Count

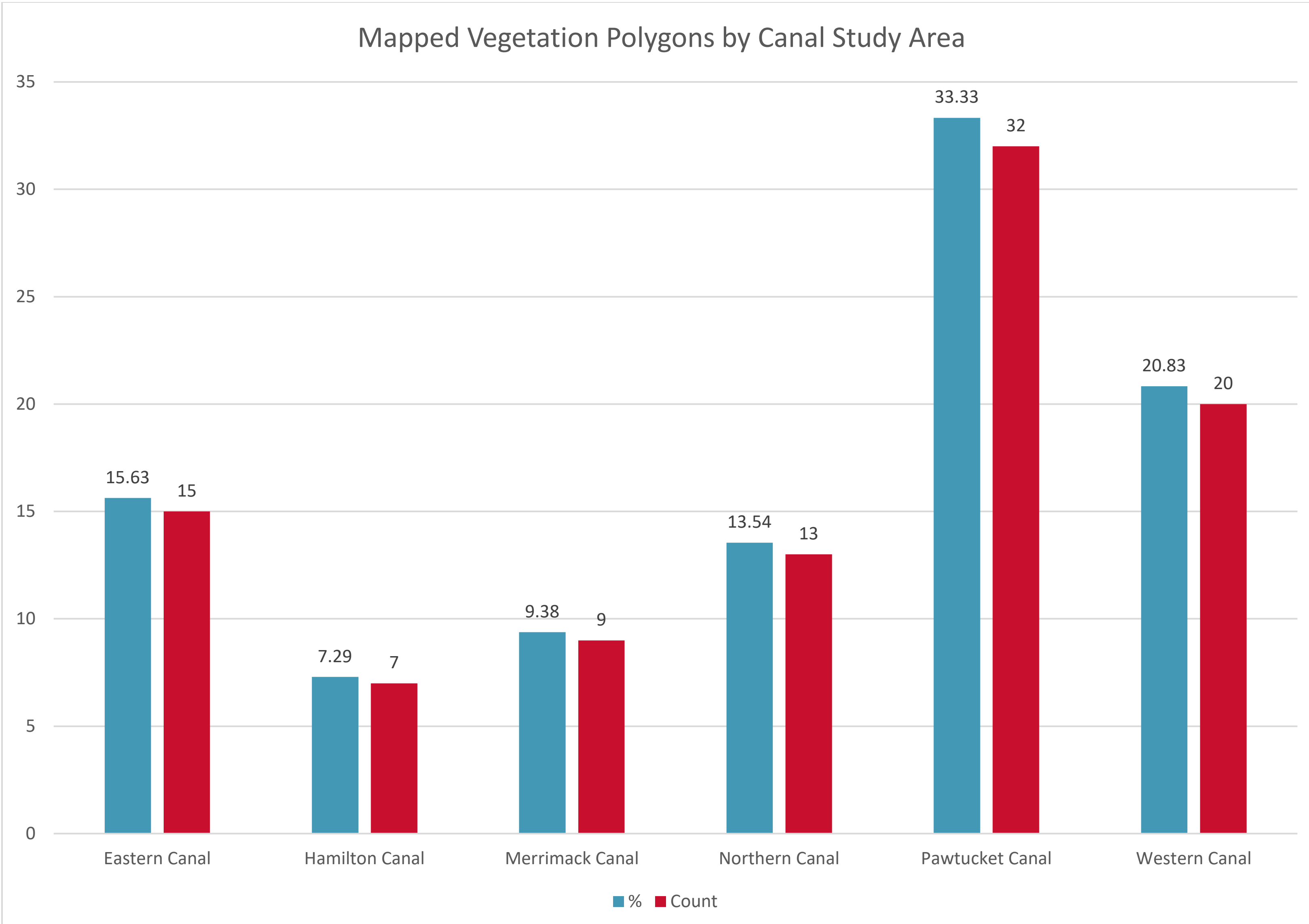


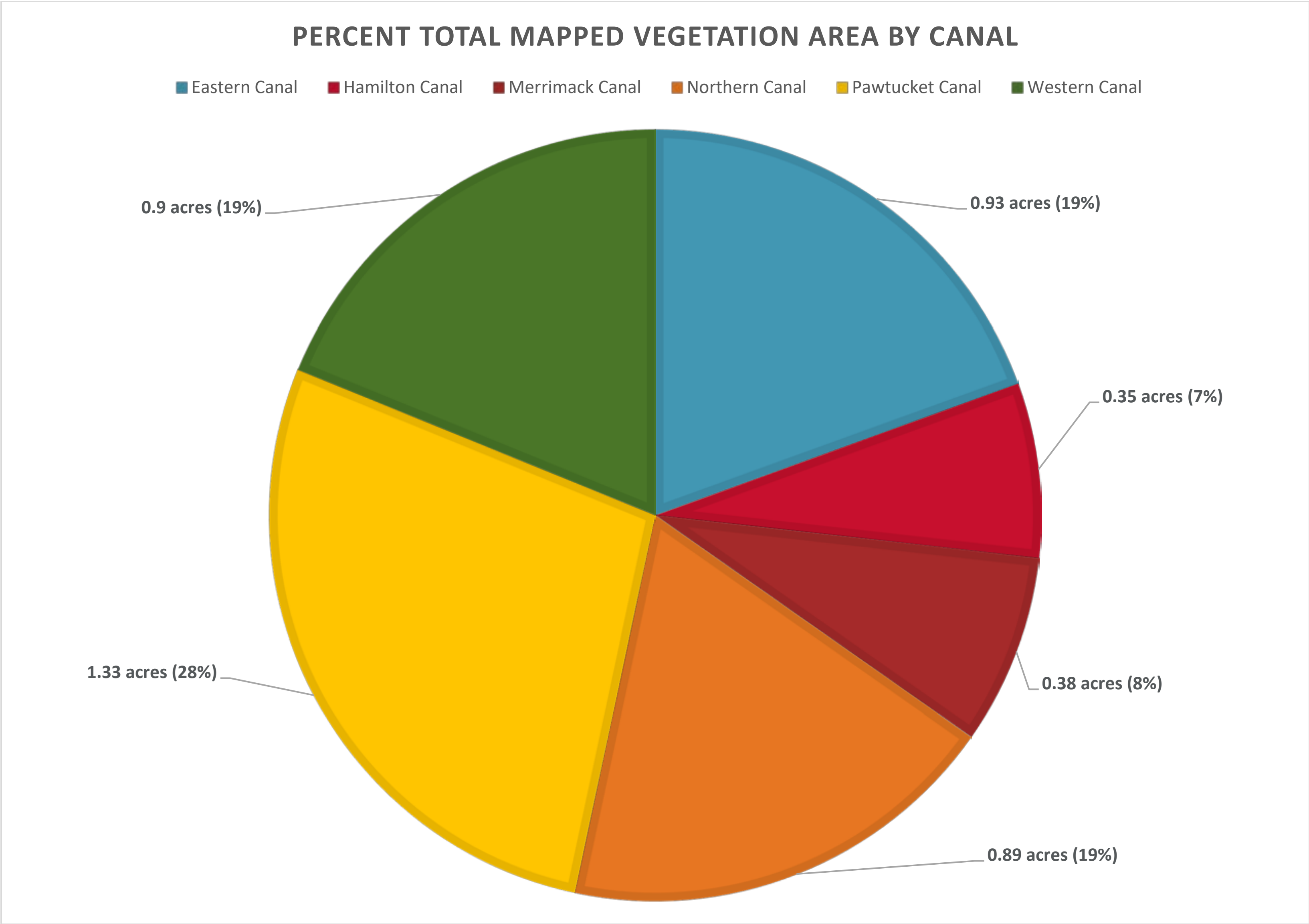
Study Area by Canal
50
45
40
35
30
25
20
15
10
5
0
9.11
4.03
4.54
2.01
3.16
1.4
26.37
11.67
44.36
19.63
12.45
5.51
Eastern Canal
Hamilton Canal
Merrimack Canal
Northern Canal
Pawtucket Canal
Western Canal
%
Acres


Mapped Vegetation Points (VPs) and Vegetation Polygons by Canal Study Area
Count
45
40
35
30
25
20
15
10
5
0
15
3
7
1
9
13
8
32
8
20
4
Eastern Canal
Hamilton Canal
Merrimack Canal
Northern Canal
Pawtucket Canal
Western Canal
Vegetation Point (VP)
Vegetation Polygon

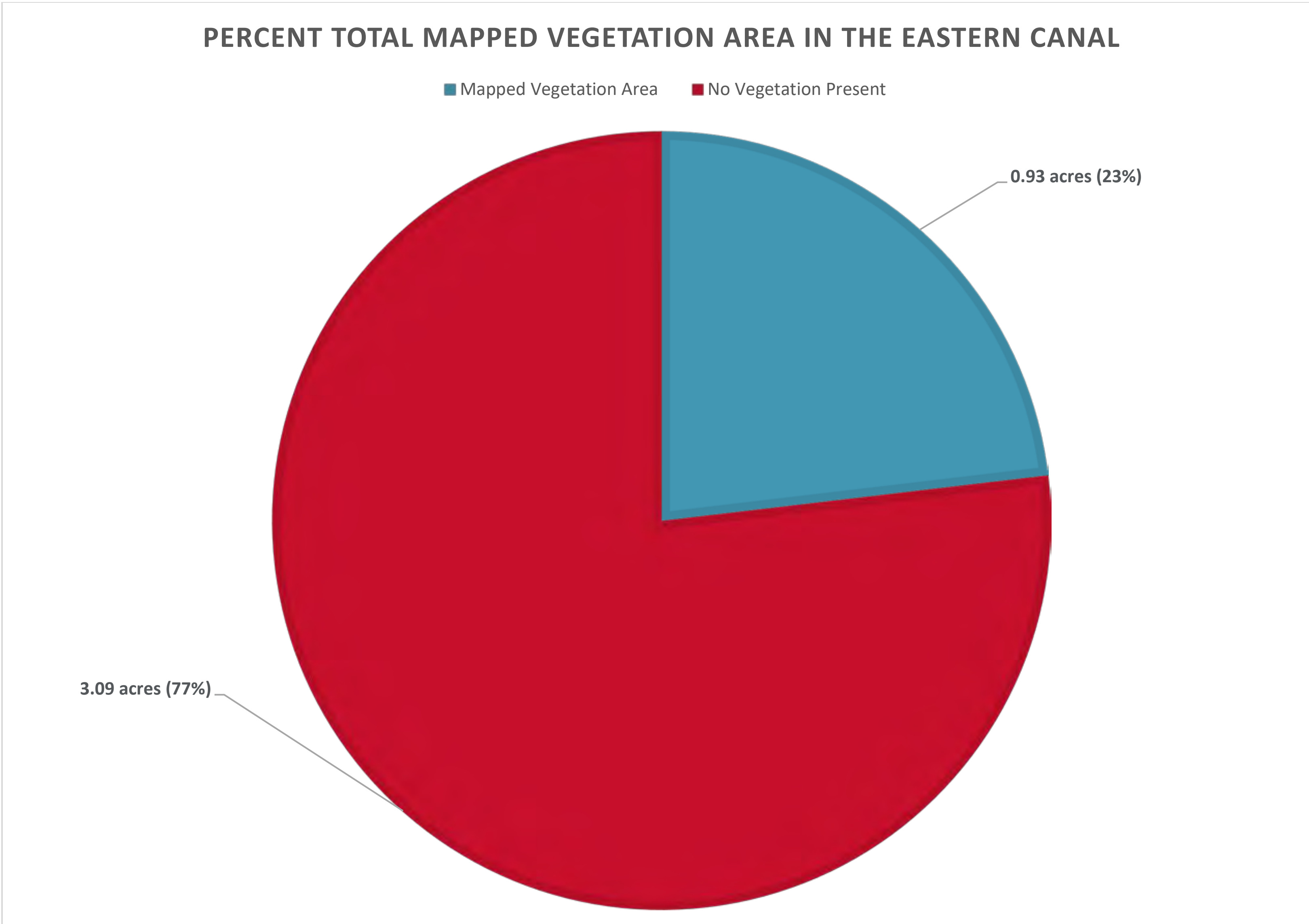


Mapped Vegetation Points (VPs) by Canal Study Area
35
30
25
20
15
10
5
0
33.33
33.33
16.67
12.50
4.17
8
8
4
3
1
Eastern Canal
Hamilton Canal
Northern Canal
Pawtucket Canal
Western Canal
%
Count

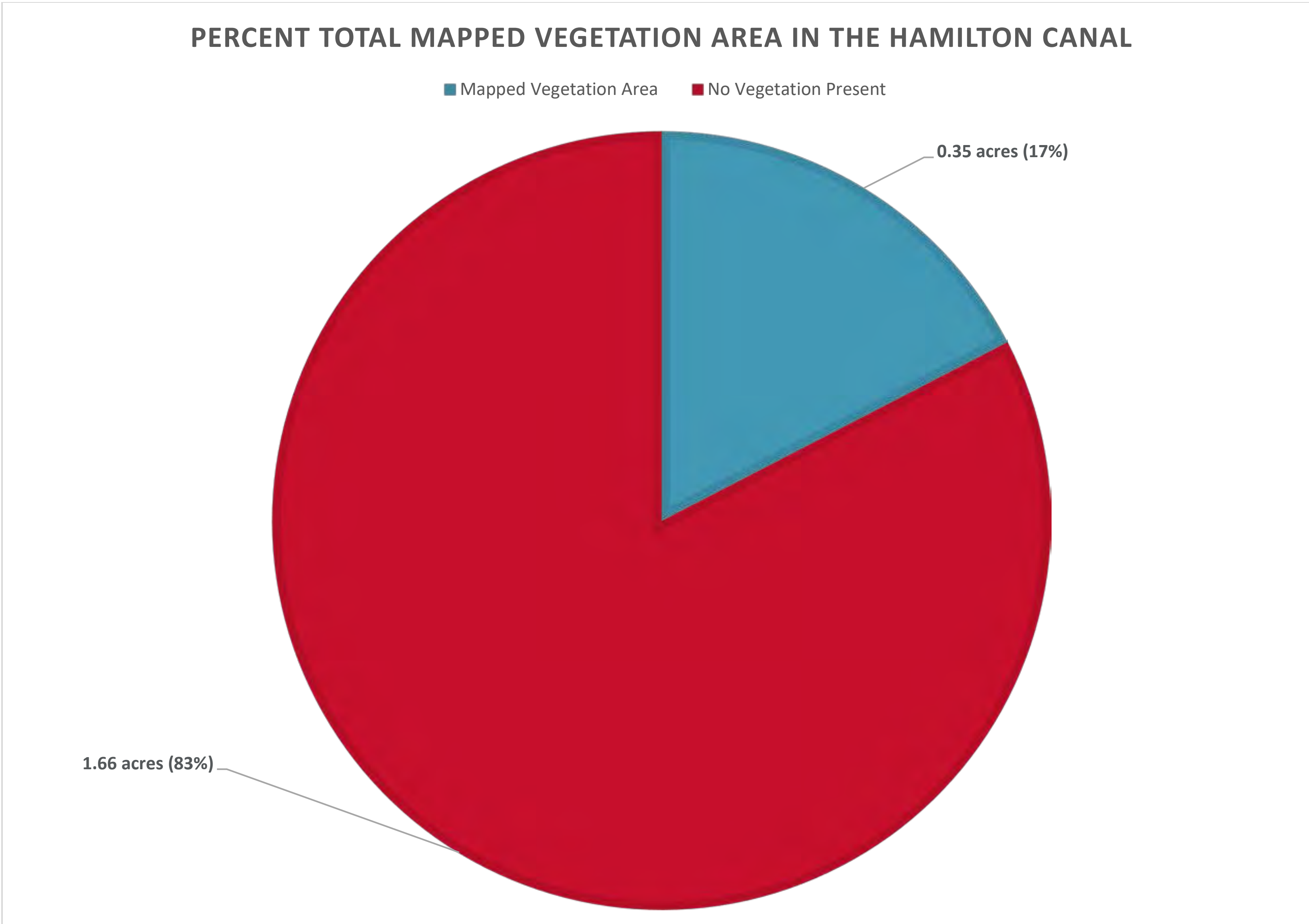

Mapped Vegetation Polygons by Canal Study Area
35
30
25
20
15
10
5
0
15.63
15
7.29
7
9.38
9
13.54
13
33.33
32
20.83
20
Eastern Canal
Hamilton Canal
Merrimack Canal
Northern Canal
Pawtucket Canal
Western Canal
%
Count



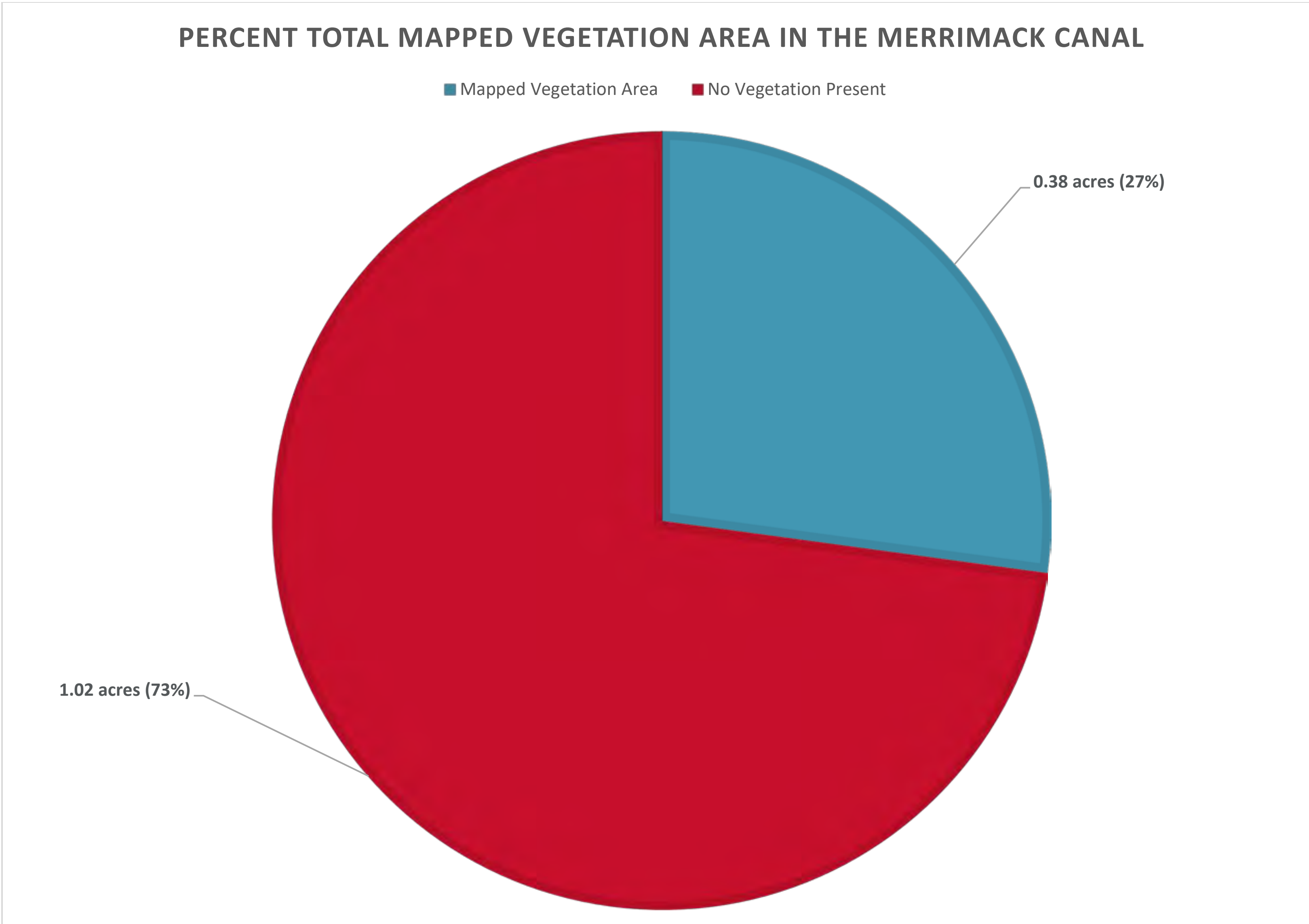
Note: Vegetation Points (VPs) are not included in mapped vegetation acreage calculations



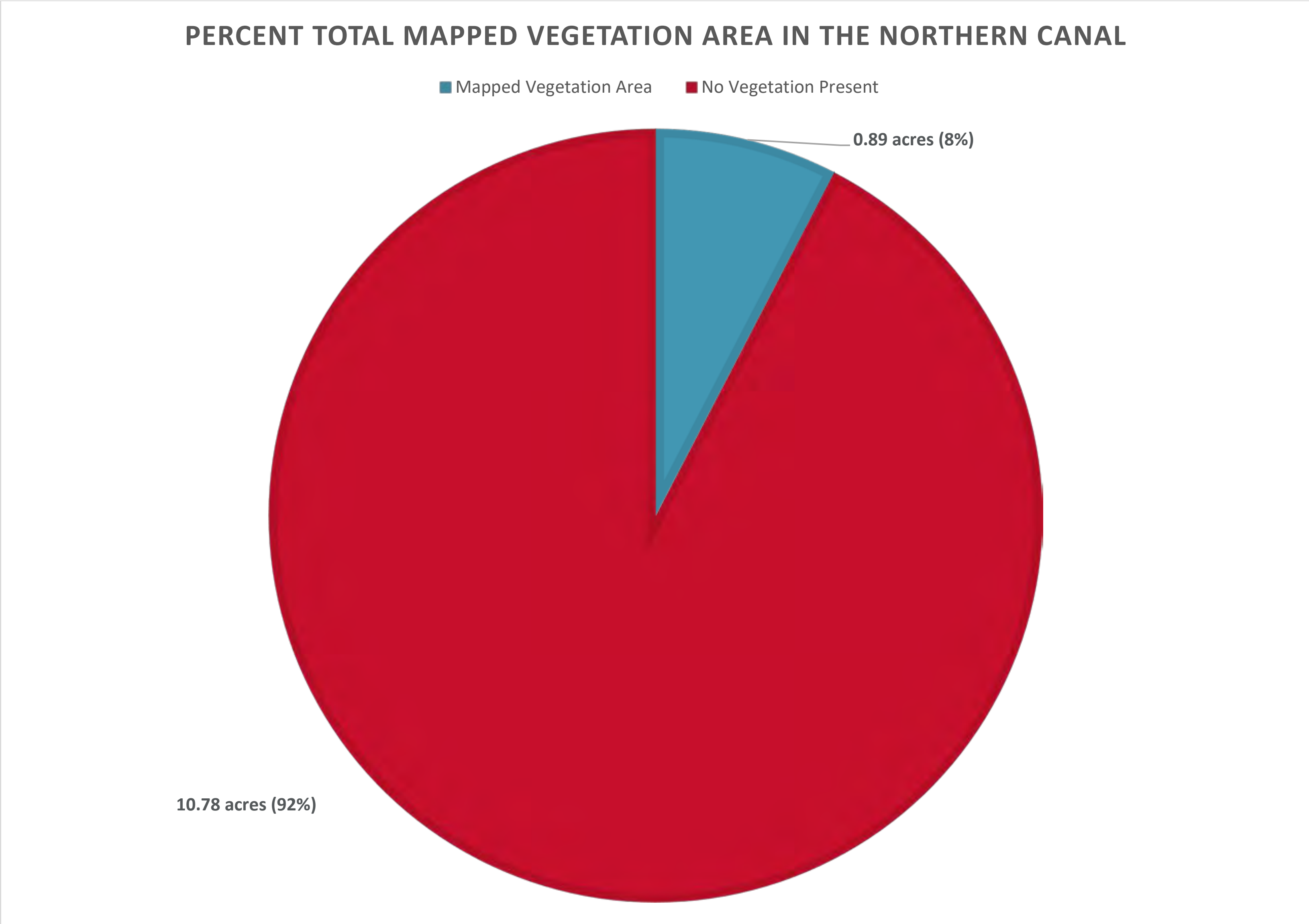
Note: Vegetation Points (VPs) are not included in mapped vegetation acreage calculations



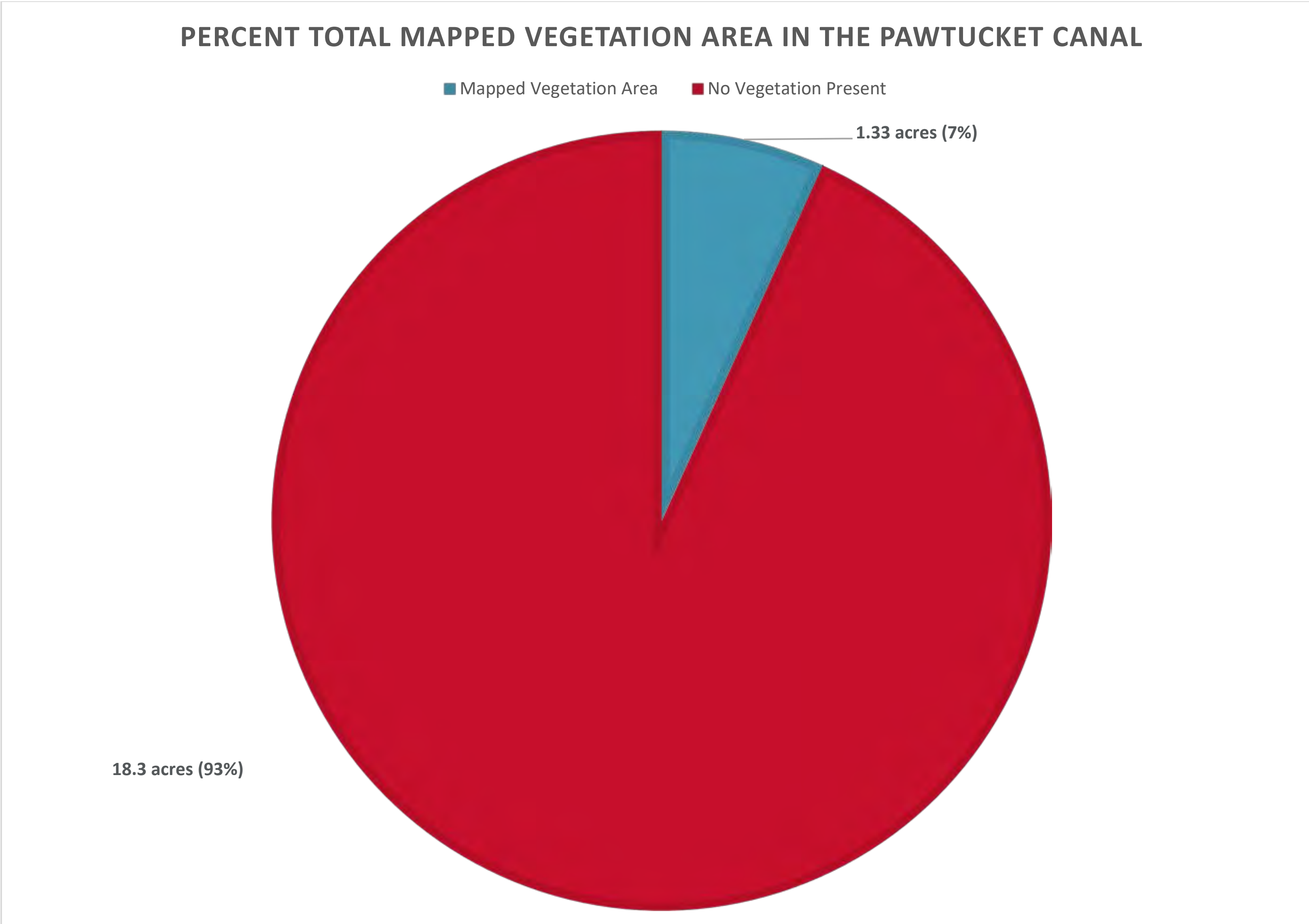
Note: Vegetation Points (VPs) are not included in mapped vegetation acreage calculations



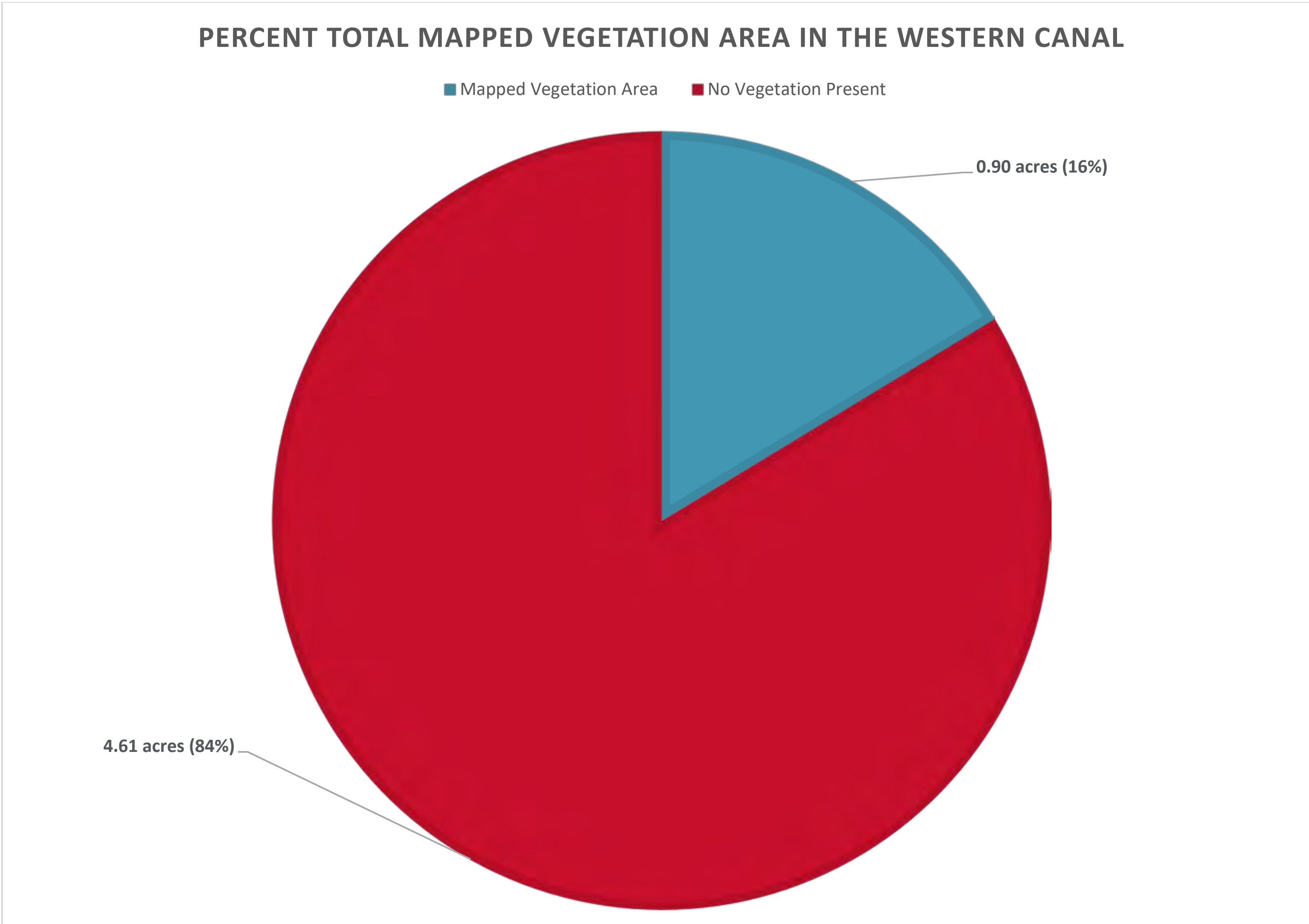
Note: Vegetation Points (VPs) are not included in mapped vegetation acreage calculations



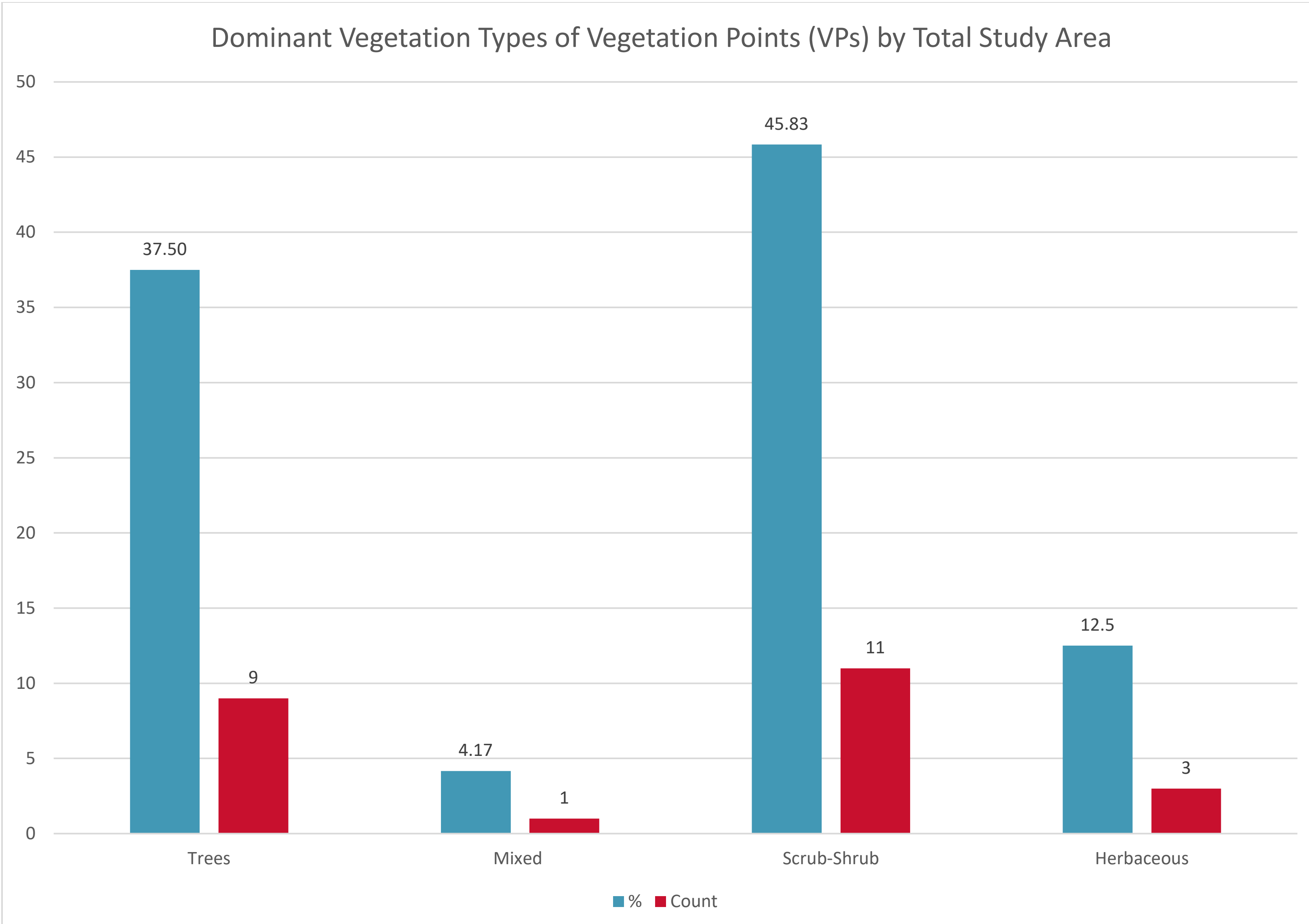
Note: Vegetation Points (VPs) are not included in mapped vegetation acreage calculations



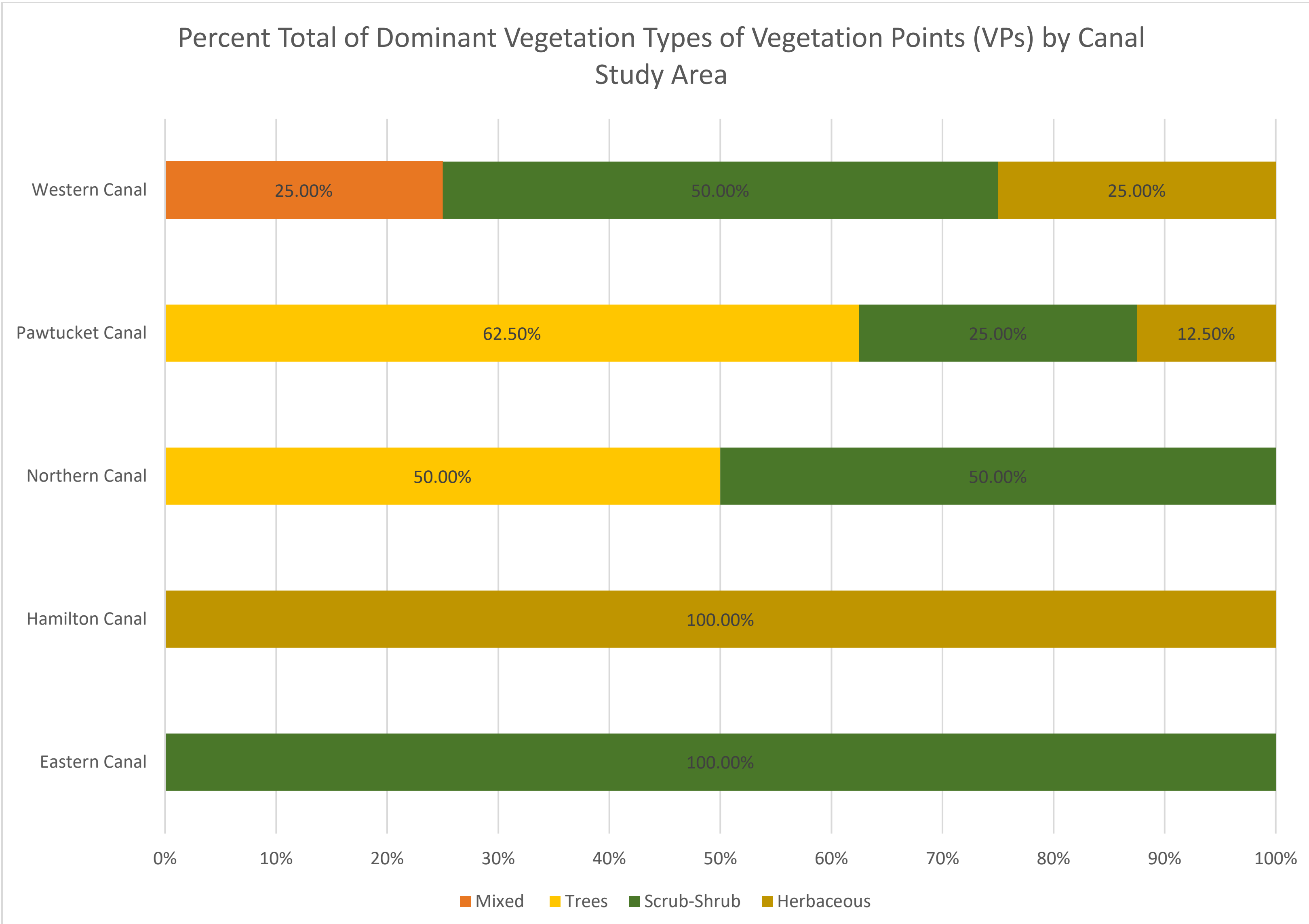
Note: Vegetation Points (VPs) are not included in mapped vegetation acreage calculations



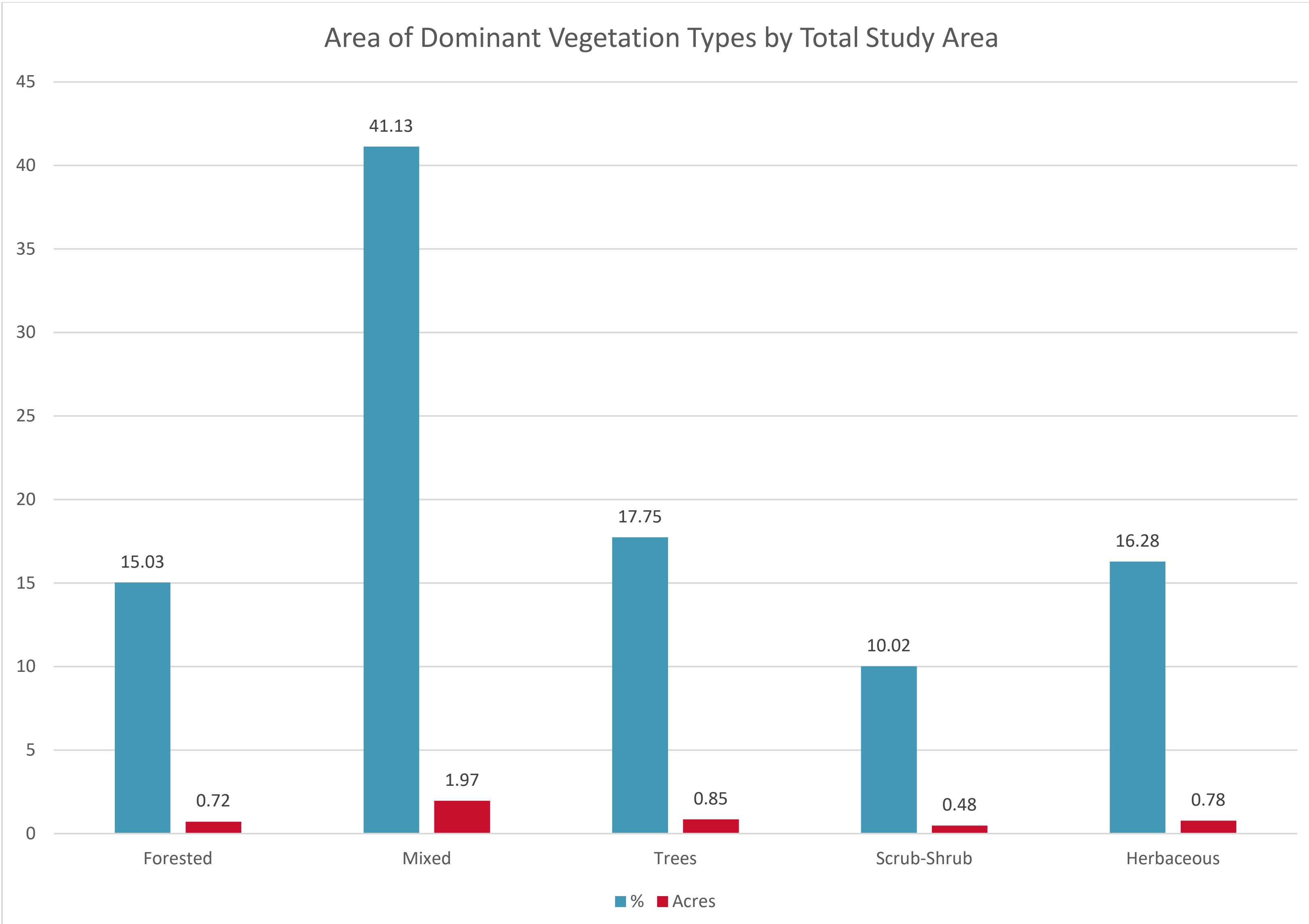
Note: Vegetation Points (VPs) are not included in mapped vegetation acreage calculations



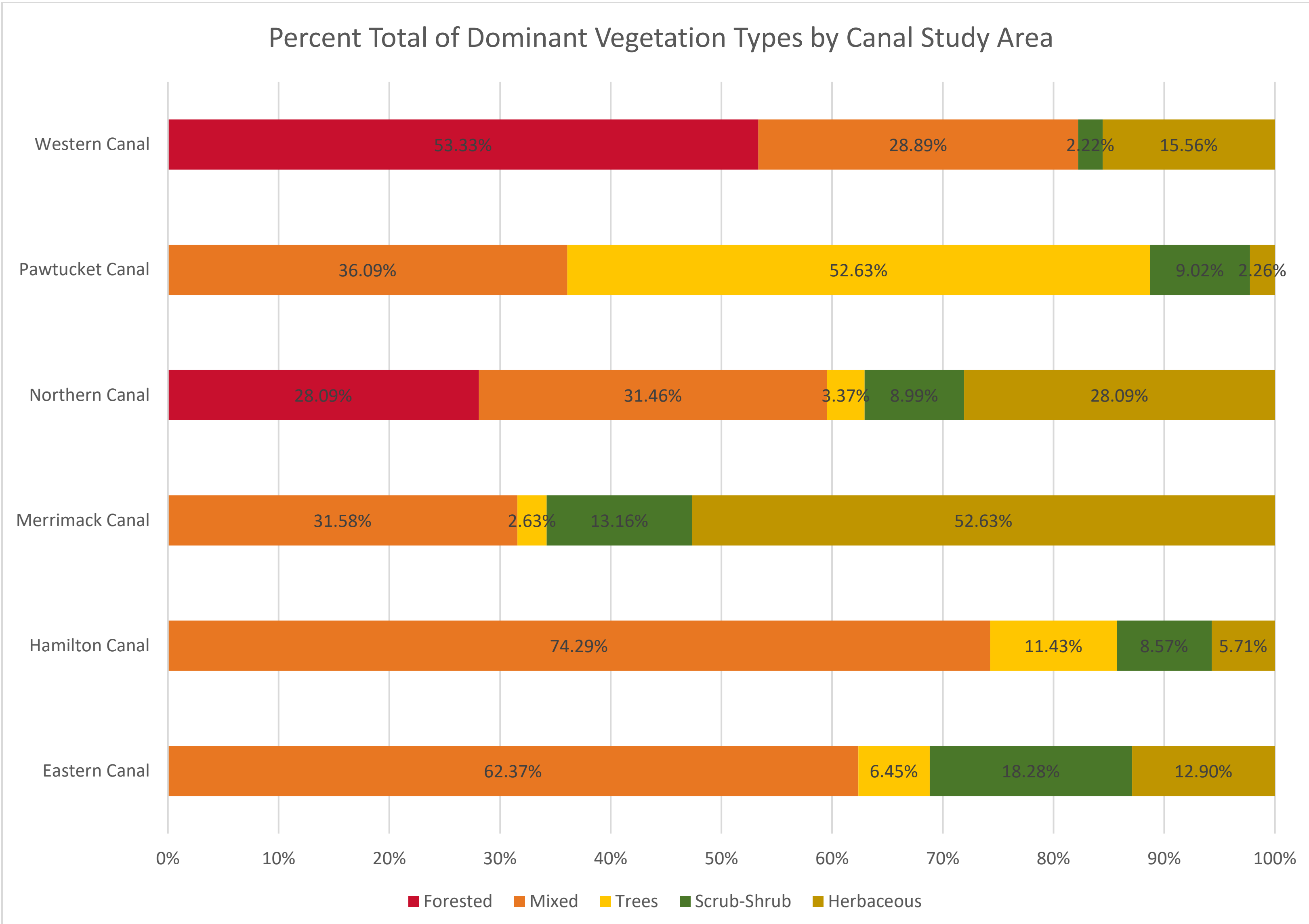
Dominant Vegetation Types of Vegetation Points (VPs) by Total Study Area
50
45
40
35
30
25
20
15
10
5
0
37.50
9
4.17
1
45.83
11
12.5
3
Trees
Mixed
Scrub-Shrub
Herbaceous
%
Count



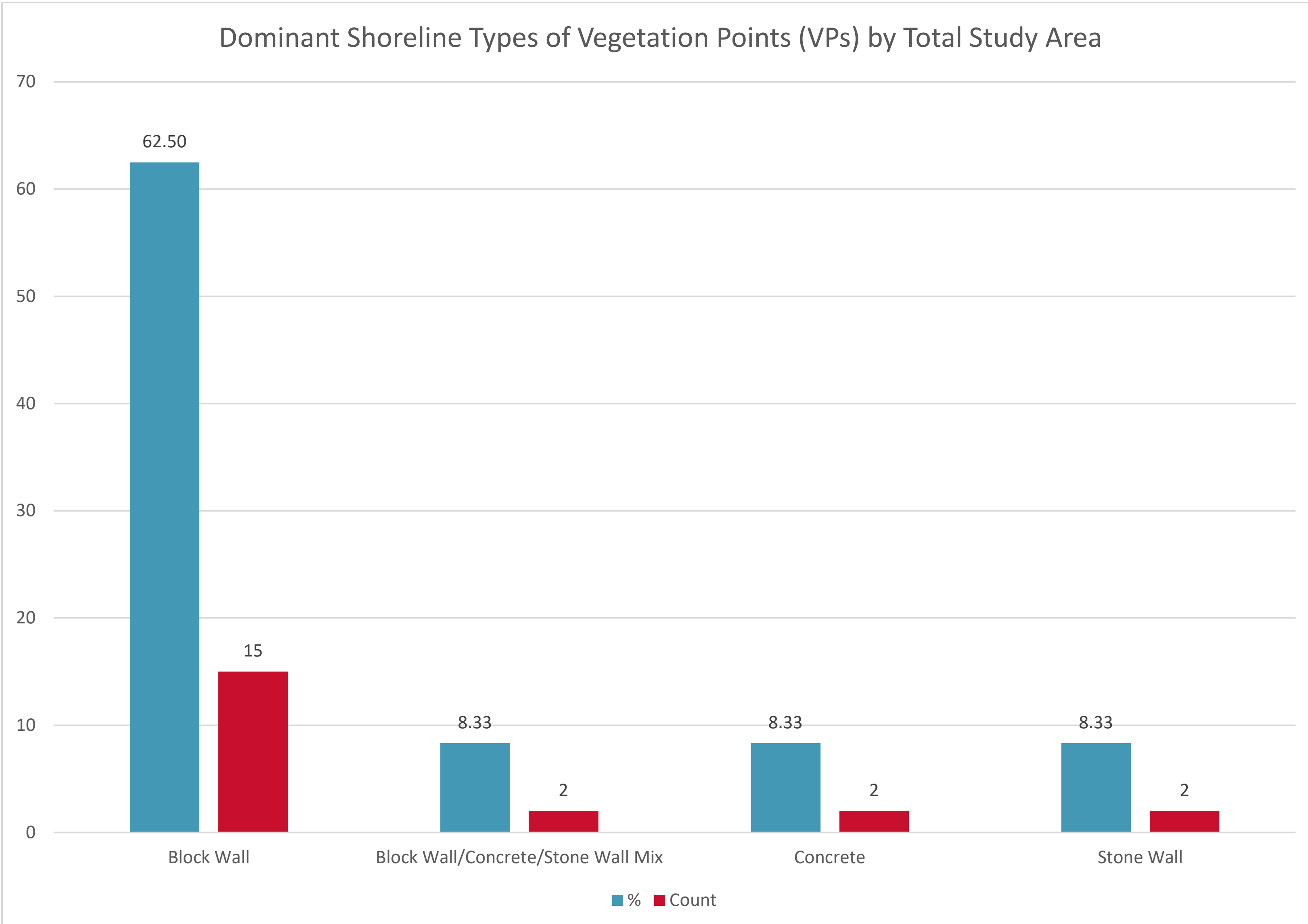
Percent Total of Dominant Vegetation Types of Vegetation Points (VPs) by Canal Study Area
Western Canal
Pawtucket Canal
Northern Canal
Hamilton Canal
Eastern Canal
25.00%
50.00%
25.00%
62.50%
25.00%
12.50%
50.00%
50.00%
100.00%
100.00%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Mixed
Trees
Scrub-Shrub
Herbaceous



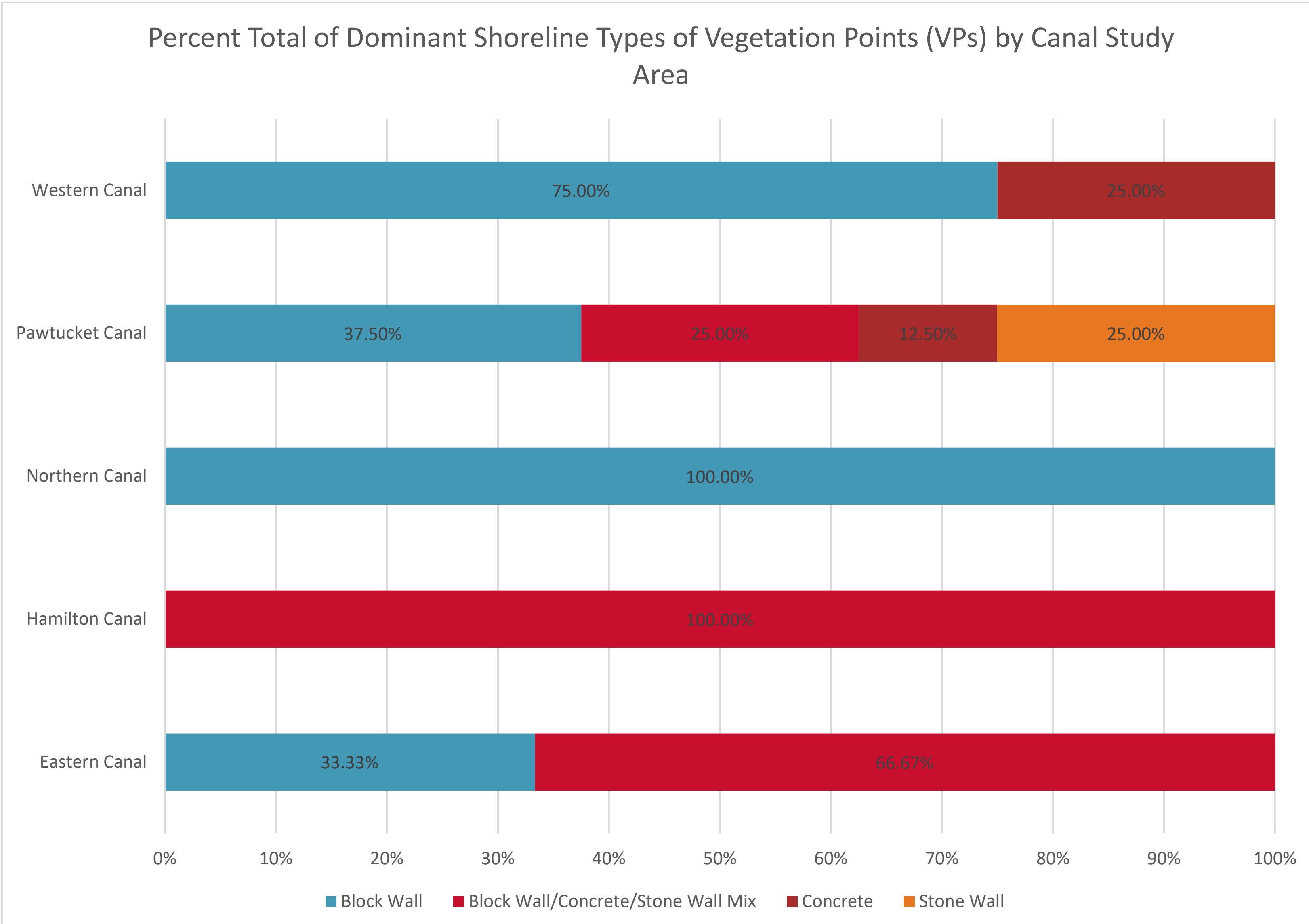
Note: Vegetation Points (VPs) are not included in mapped vegetation acreage calculations



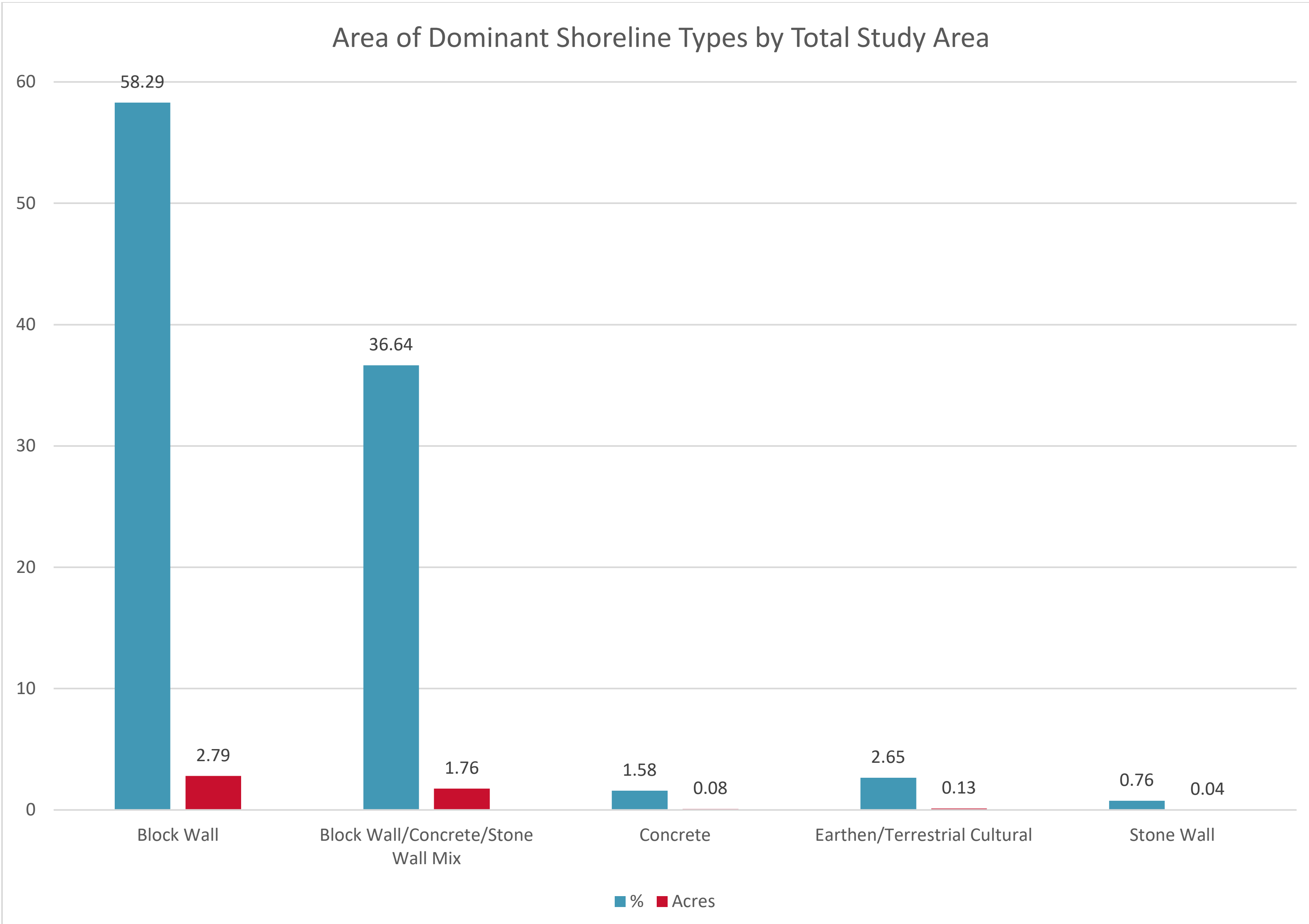
Note: Percent totals are based on mapped vegetation acreages from Vegetation Polygons; Vegetation Points (VPs) are not included in mapped vegetation acreage calculations



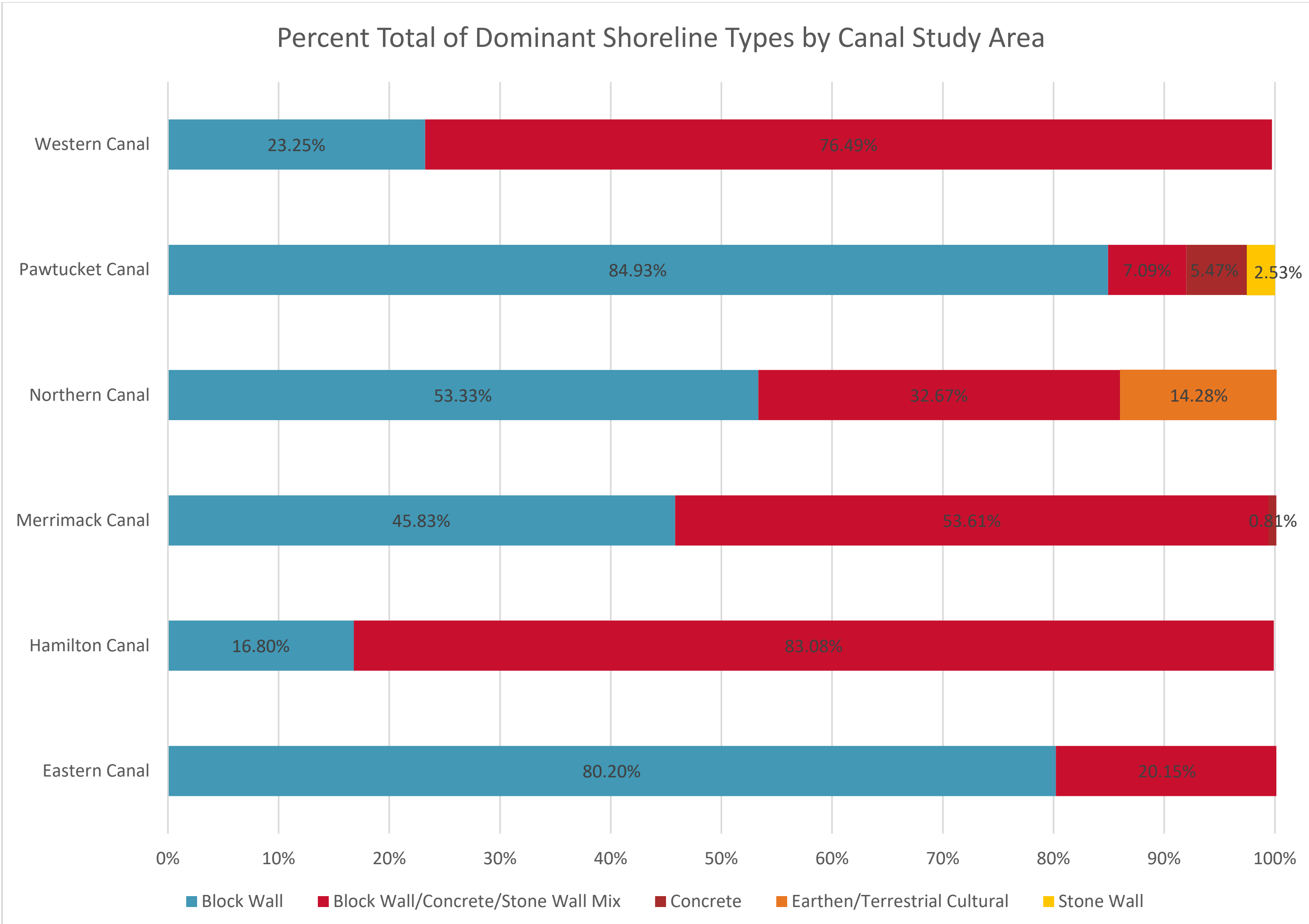
Dominant Shoreline Types of Vegetation Points (VPs) by Total Study Area
70
60
50
40
30
20
10
0
62.50
15
8.33
2
8.33
2
8.33
2
Block Wall
Block Wall/Concrete/Stone Wall Mix
Concrete
Stone Wall
%
Count



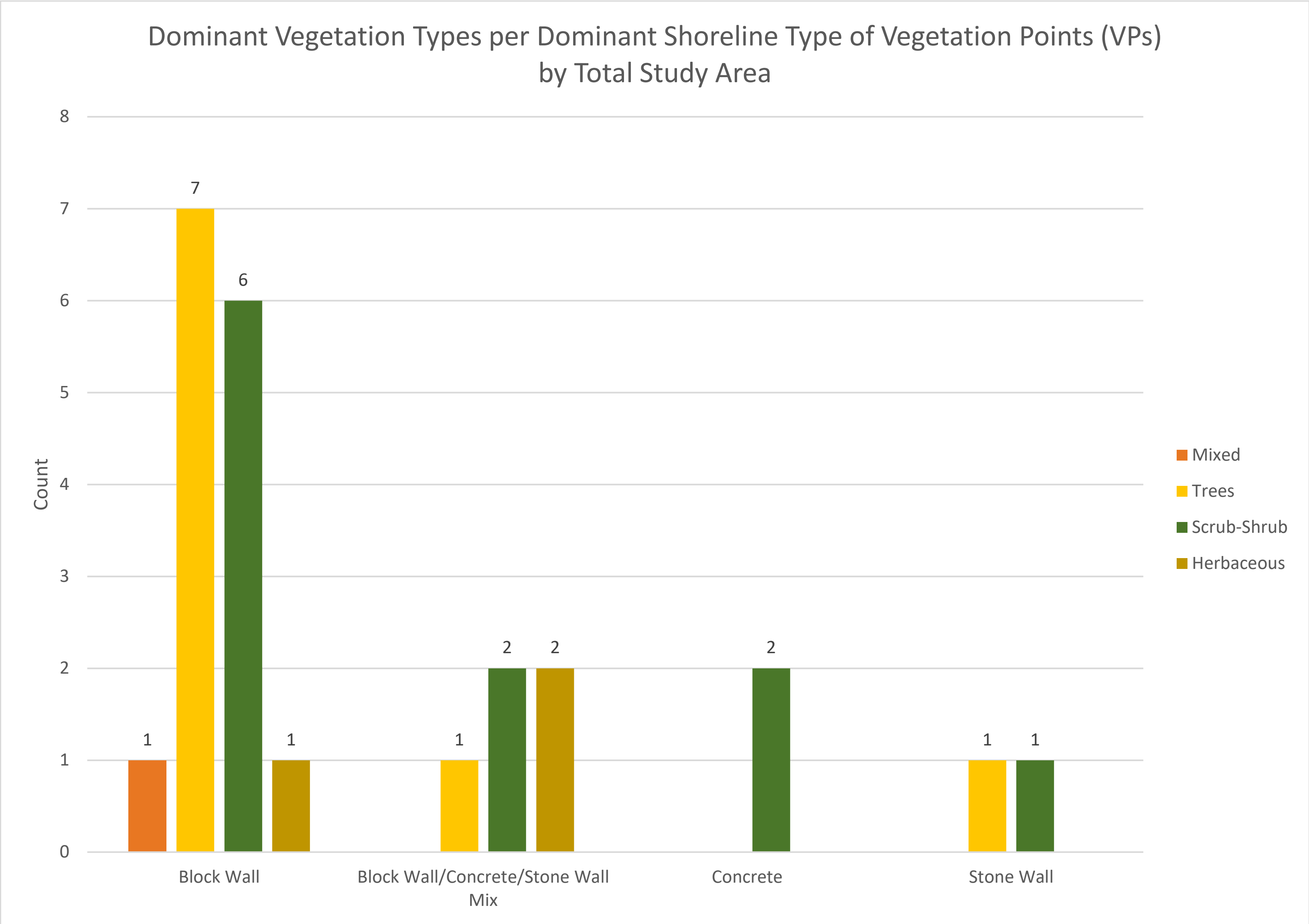
Percent Total of Dominant Shoreline Types of Vegetation Points (VPs) by Canal Study Area
Western Canal
Pawtucket Canal
Northern Canal
Hamilton Canal
Eastern Canal
75.00%
25.00%
37.50%
25.00%
12.50%
25.00%
100.00%
100.00%
33.33%
66.67%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Block Wall
Block Wall/Concrete/Stone Wall Mix
Concrete
Stone Wall

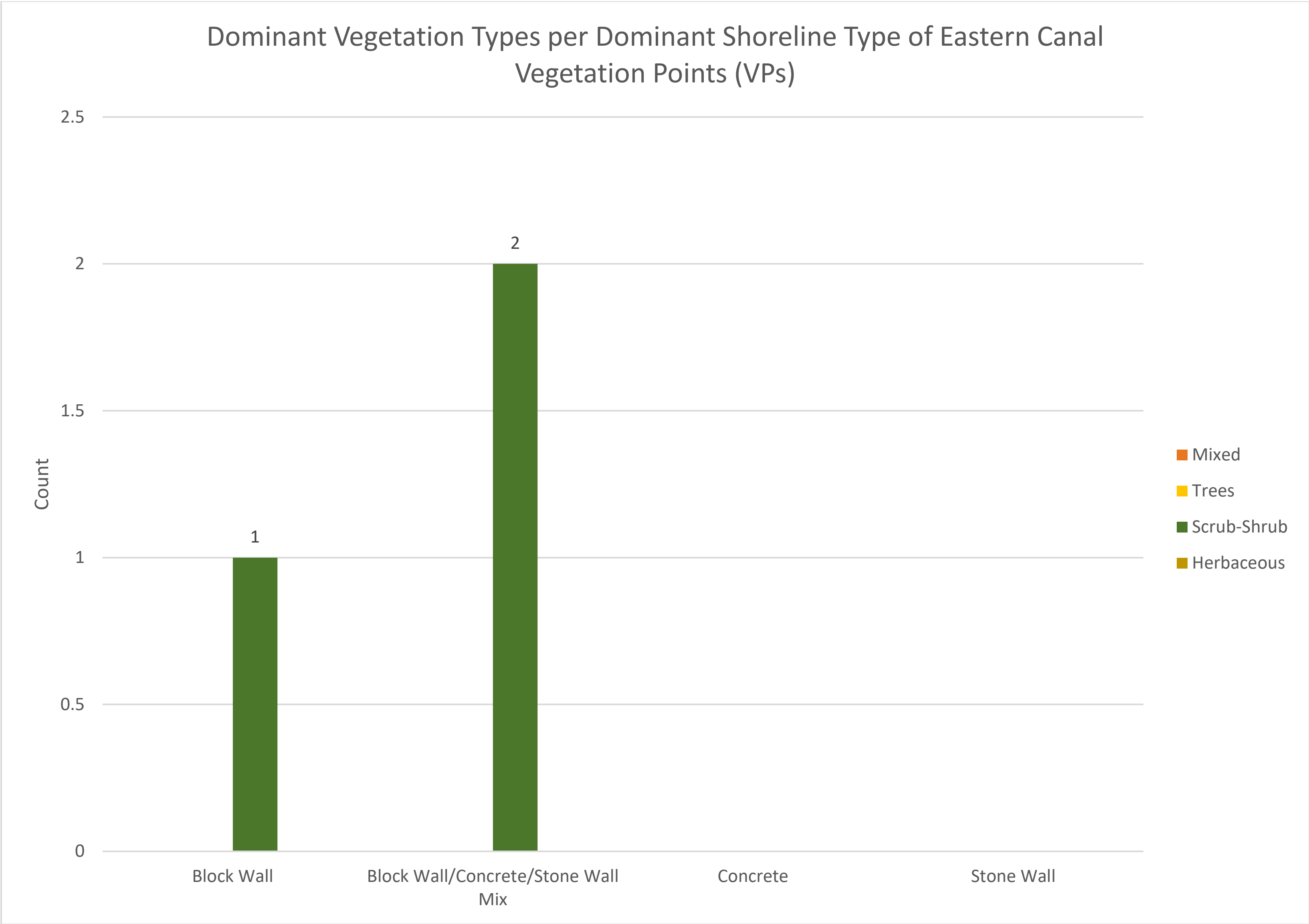


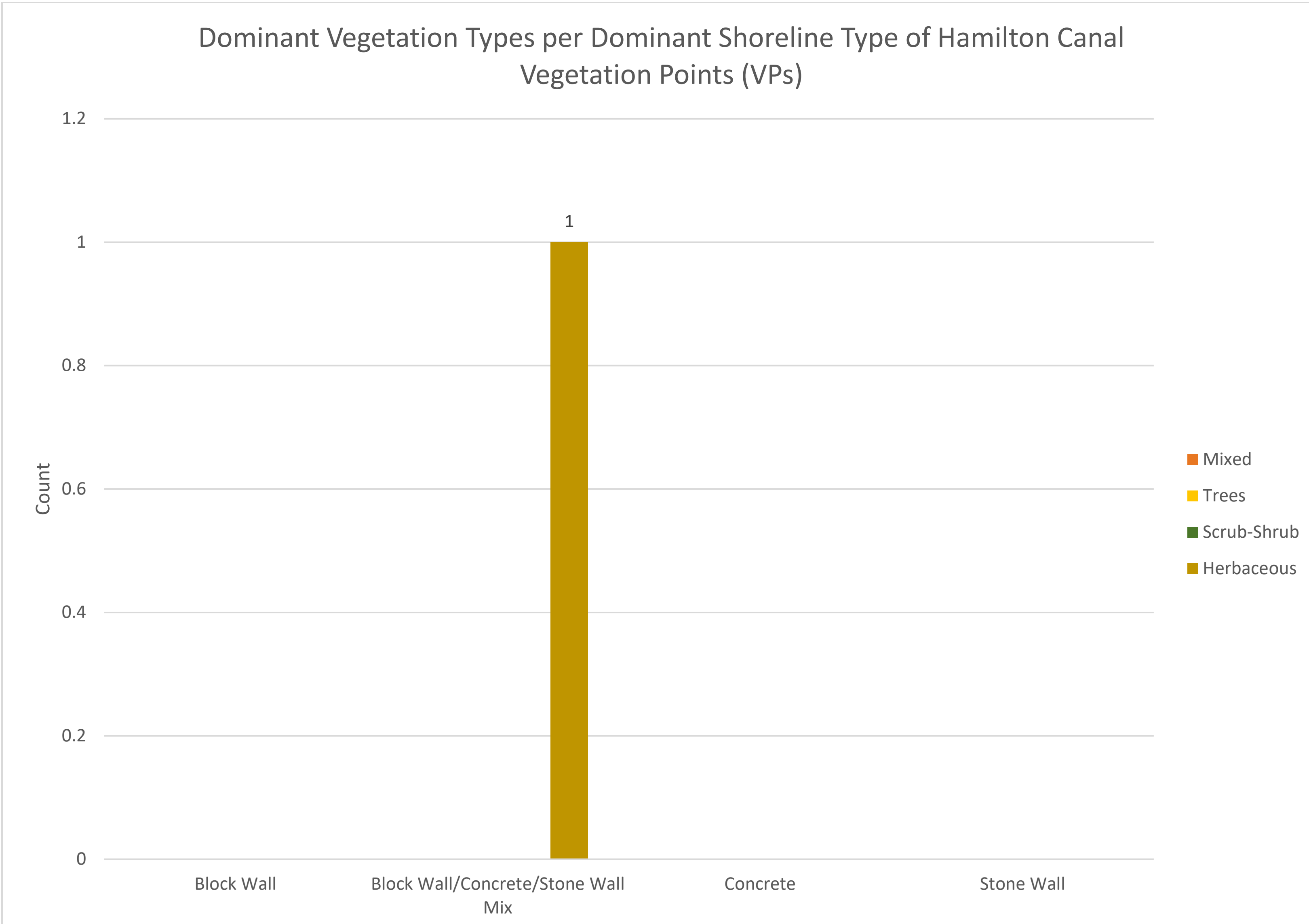
Note: Vegetation Points (VPs) are not included in mapped vegetation acreage calculations

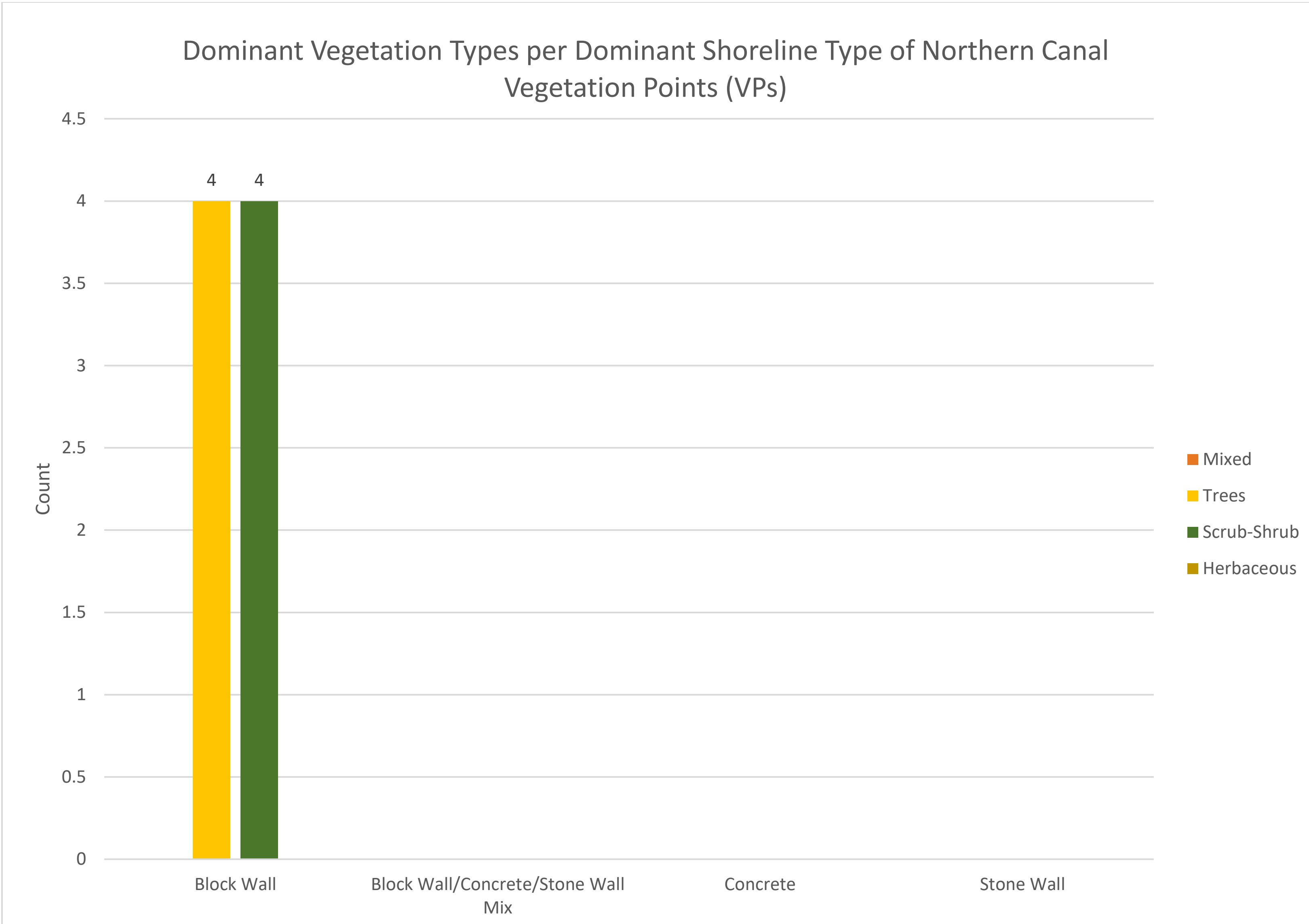


Note: Percent totals based on mapped vegetation acreages from Vegetation Polygons; Vegetation Points (VPs) are not included in mapped vegetation acreage calculations

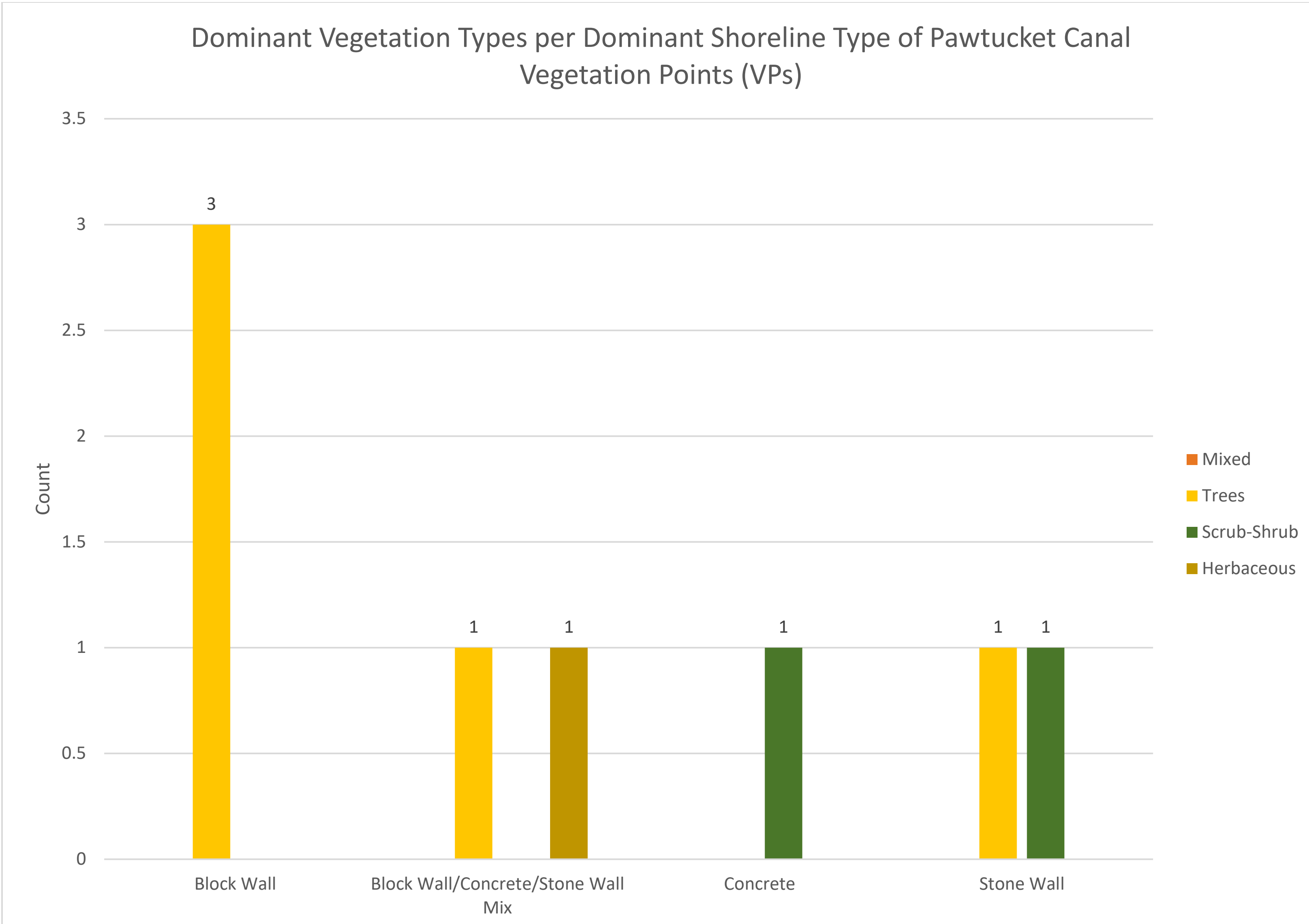

Dominant Vegetation Types per Dominant Shoreline Type of Vegetation Points (VPs) by Total Study Area
Count
8
7
6
5
4
3
2
1
0
7
6
1
1
1
2
2
2
1
1
Block Wall
Block Wall/Concrete/Stone Wall Mix
Concrete
Stone Wall
Mixed
Trees
Scrub-Shrub
Herbaceous


Dominant Vegetation Types per Dominant Shoreline Type of Eastern Canal Vegetation Points (VPs)
2.5
2
1.5
1
0.5
0
Count
1
2
Block Wall
Block Wall/Concrete/Stone Wall Mix
Concrete
Stone Wall
Mixed
Trees
Scrub-Shrub
Herbaceous

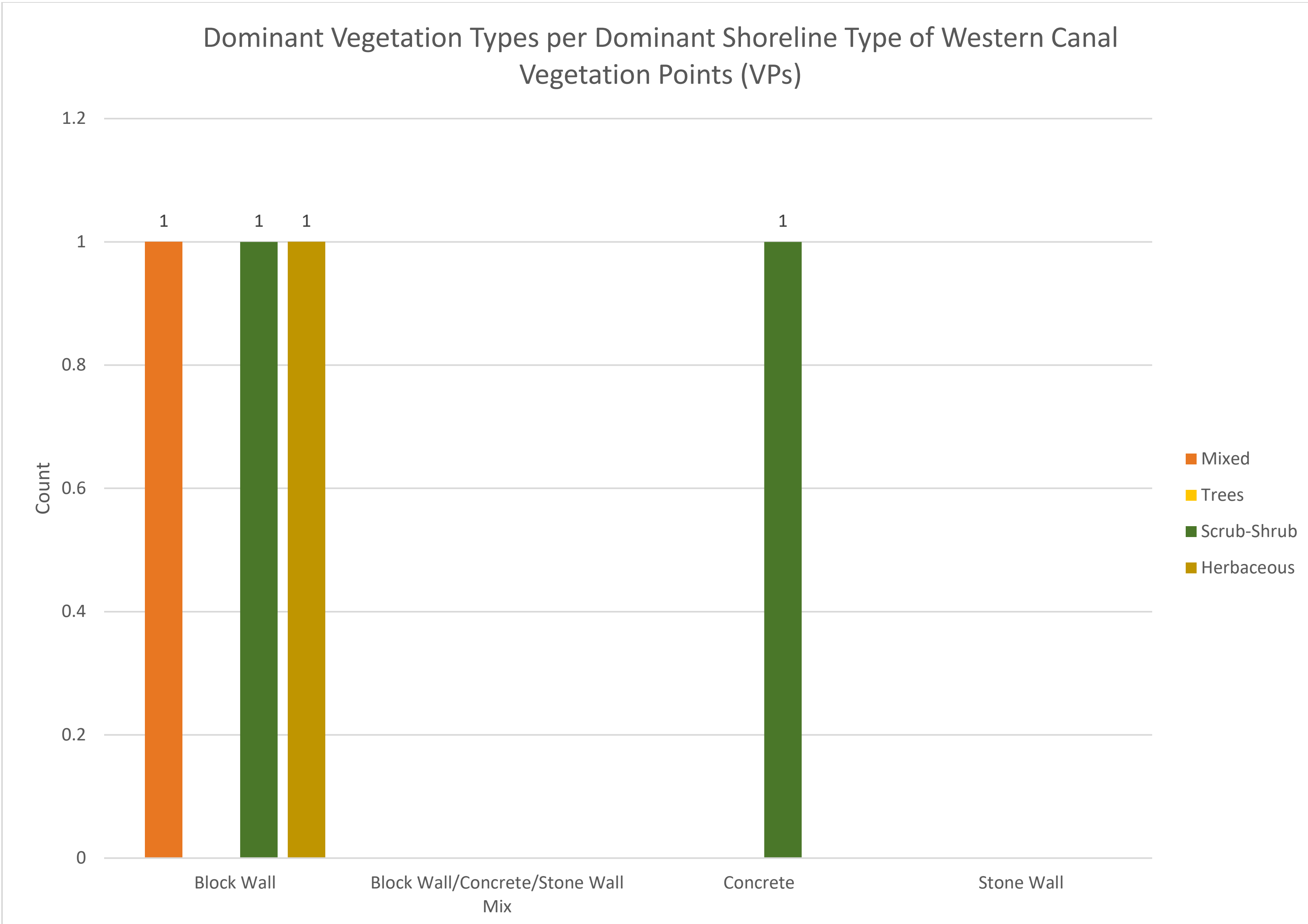

Dominant Vegetation Types per Dominant Shoreline Type of Hamilton Canal Vegetation Points (VPs)
Count
1.2
1
0.8
0.6
0.4
0.2
0
1
Block Wall
Block Wall/Concrete/Stone Wall Mix
Concrete
Stone Wall
Mixed
Trees
Scrub-Shrub
Herbaceous

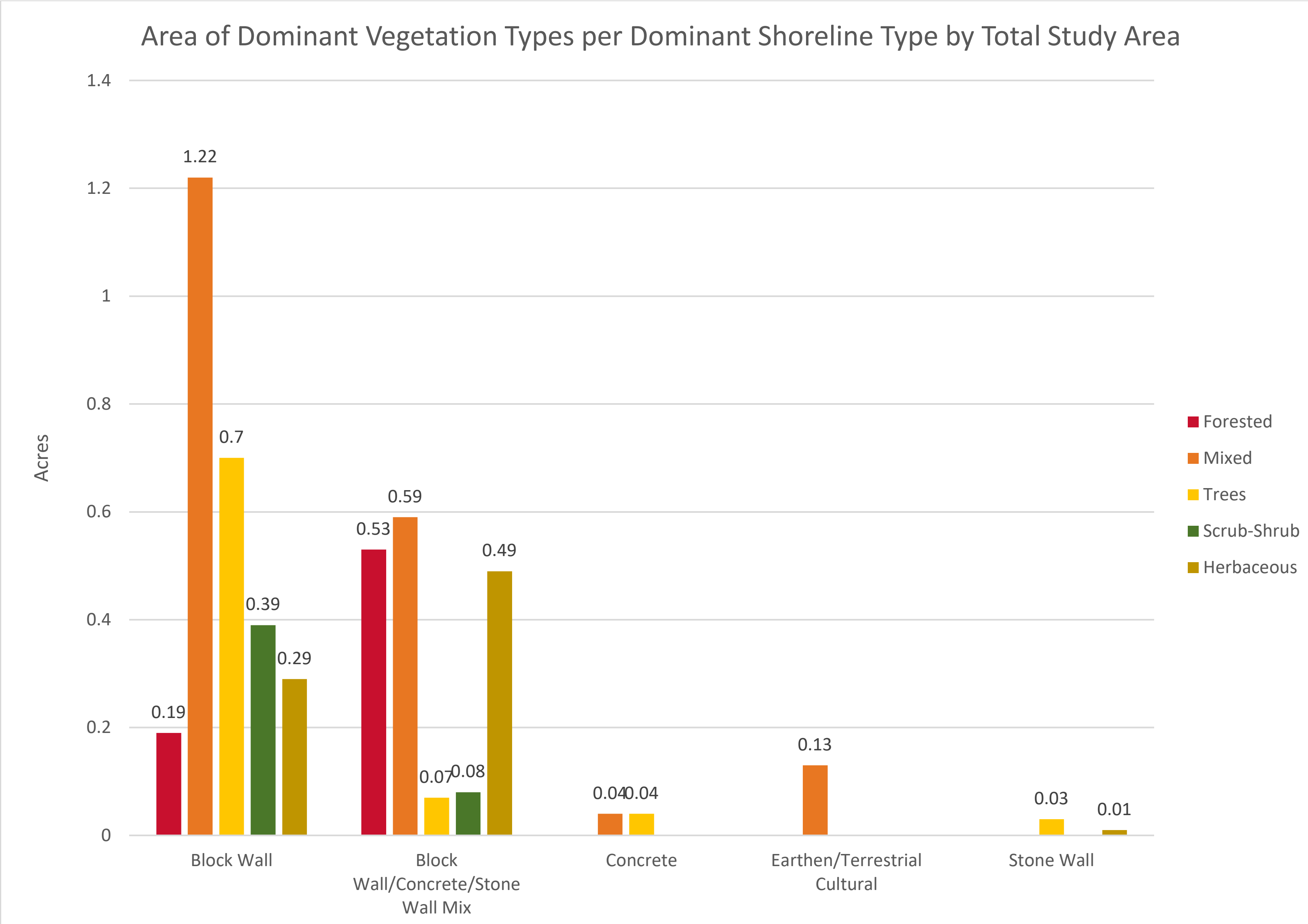


Dominant Vegetation Types per Dominant Shoreline Type of Northern Canal Vegetation Points (VPs)
Count
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
4
4
Block Wall
Block Wall/Concrete/Stone Wall Mix
Concrete
Stone Wall
Mixed
Trees
Scrub-Shrub
Herbaceous

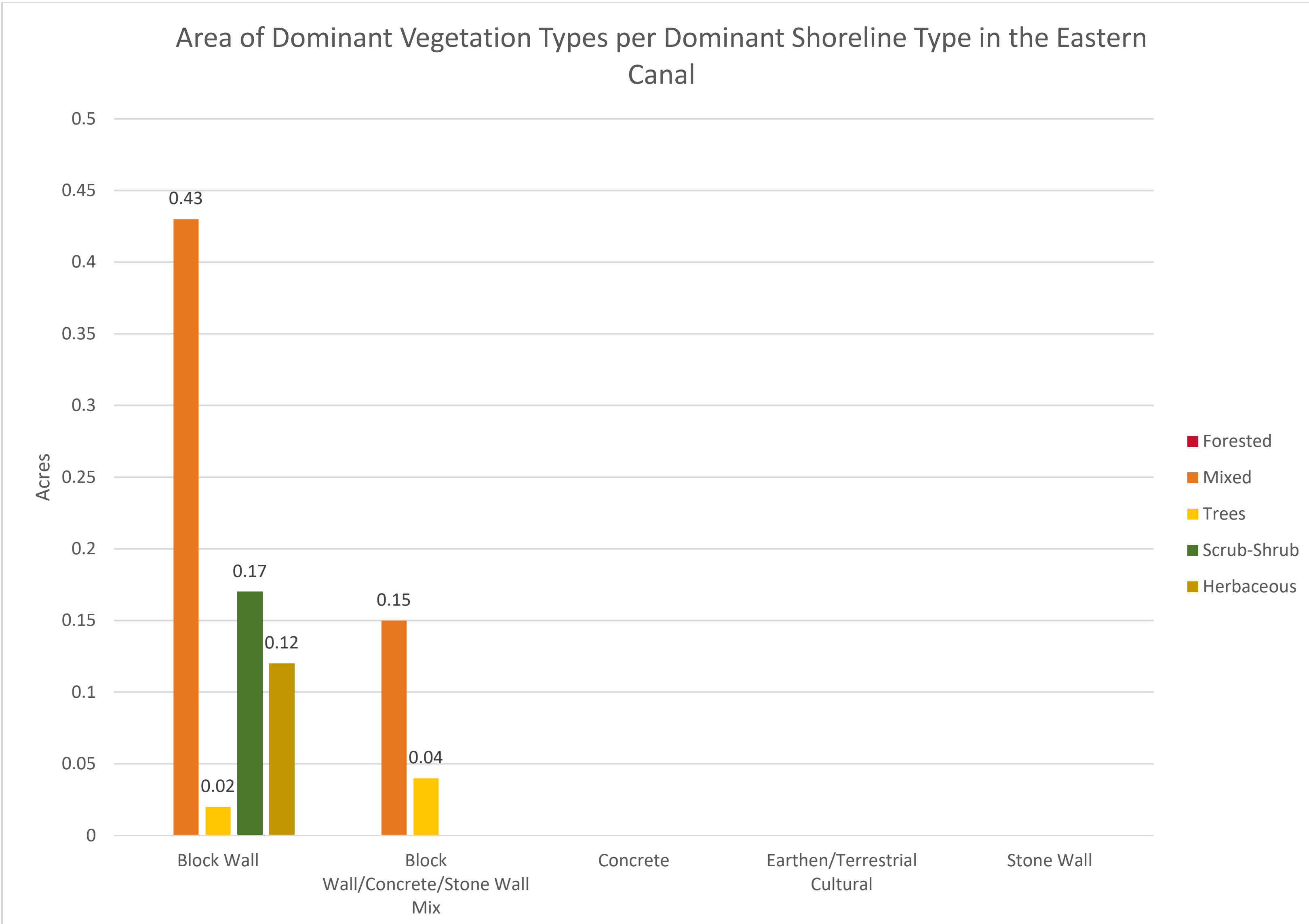


Dominant Vegetation Types per Dominant Shoreline Type of Pawtucket Canal Vegetation Points (VPs)
Count
3.5
3
2.5
2
1.5
1
0.5
0
3
1
1
1
1
1
Block Wall
Block Wall/Concrete/Stone Wall Mix
Concrete
Stone Wall
Mixed
Trees
Scrub-Shrub
Herbaceous

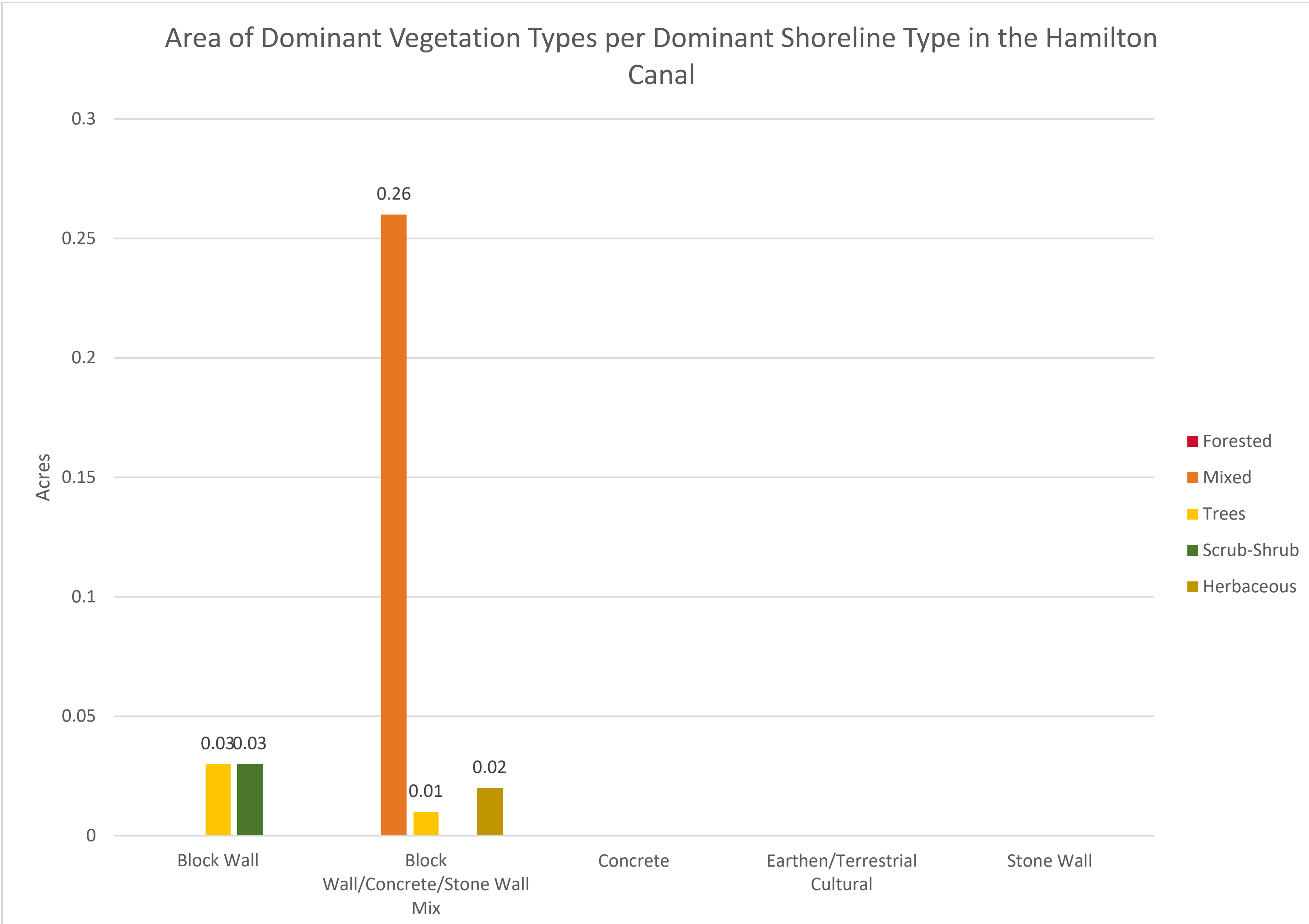

Dominant Vegetation Types per Dominant Shoreline Type of Western Canal Vegetation Points (VPs)
Count
1.2
1
0.8
0.6
0.4
0.2
0
1
1
1
1
Block Wall
Block Wall/Concrete/Stone Wall Mix
Concrete
Stone Wall
Mixed
Trees
Scrub-Shrub
Herbaceous



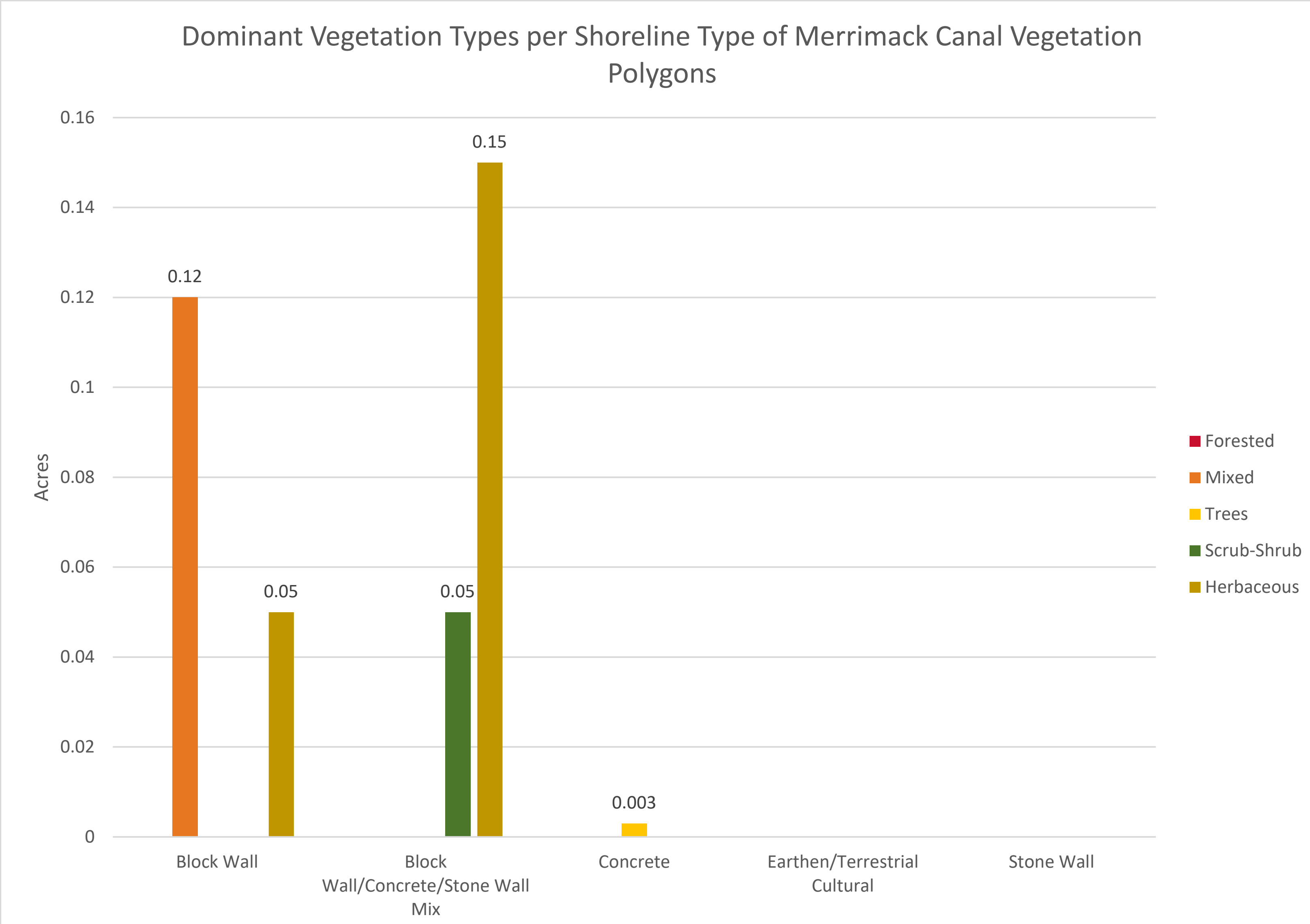
Note: Vegetation Points (VPs) are not included in mapped vegetation acreage calculations



Note: Vegetation Points (VPs) are not included in mapped vegetation acreage calculations

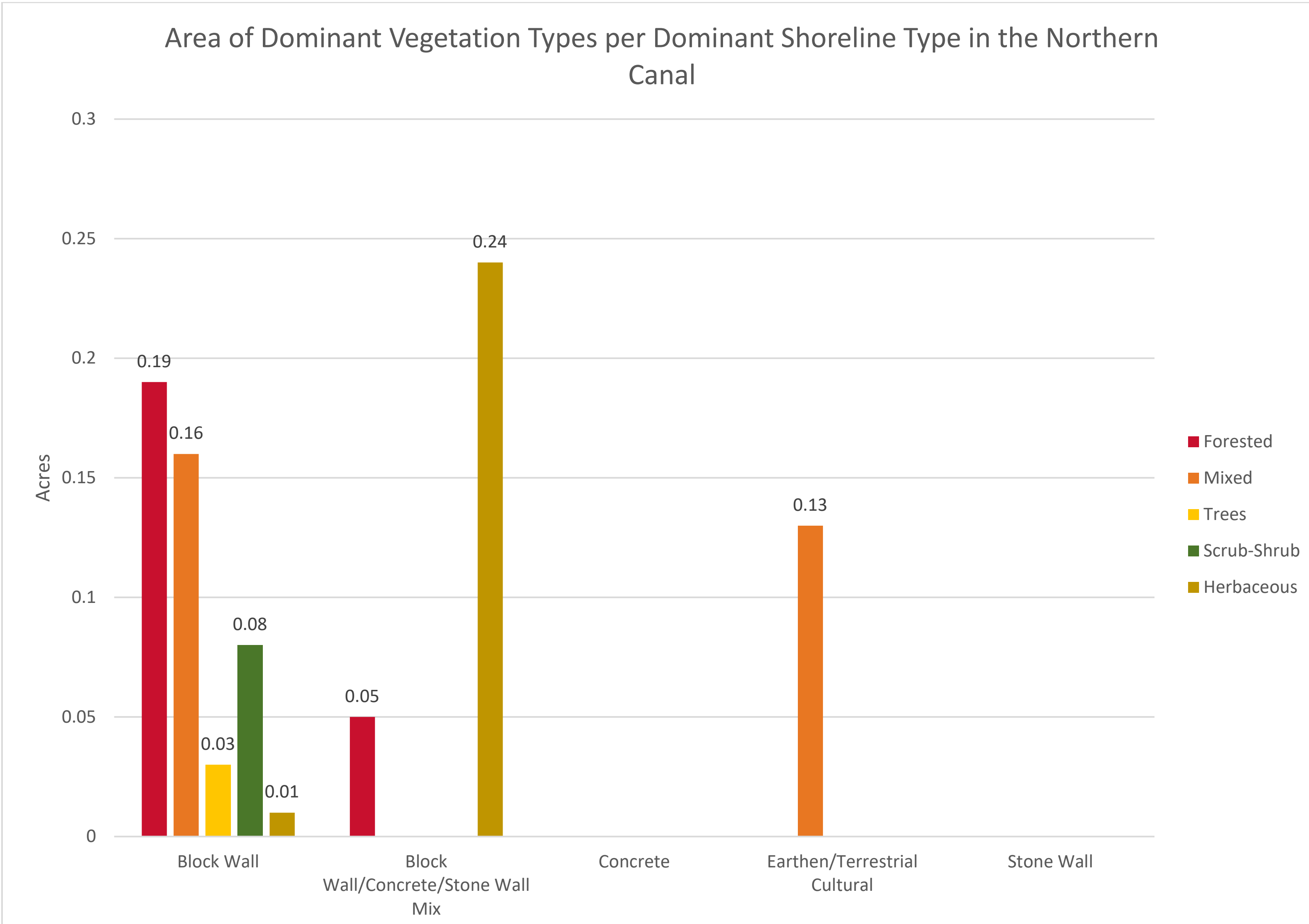


Note: Vegetation Points (VPs) are not included in mapped vegetation acreage calculations

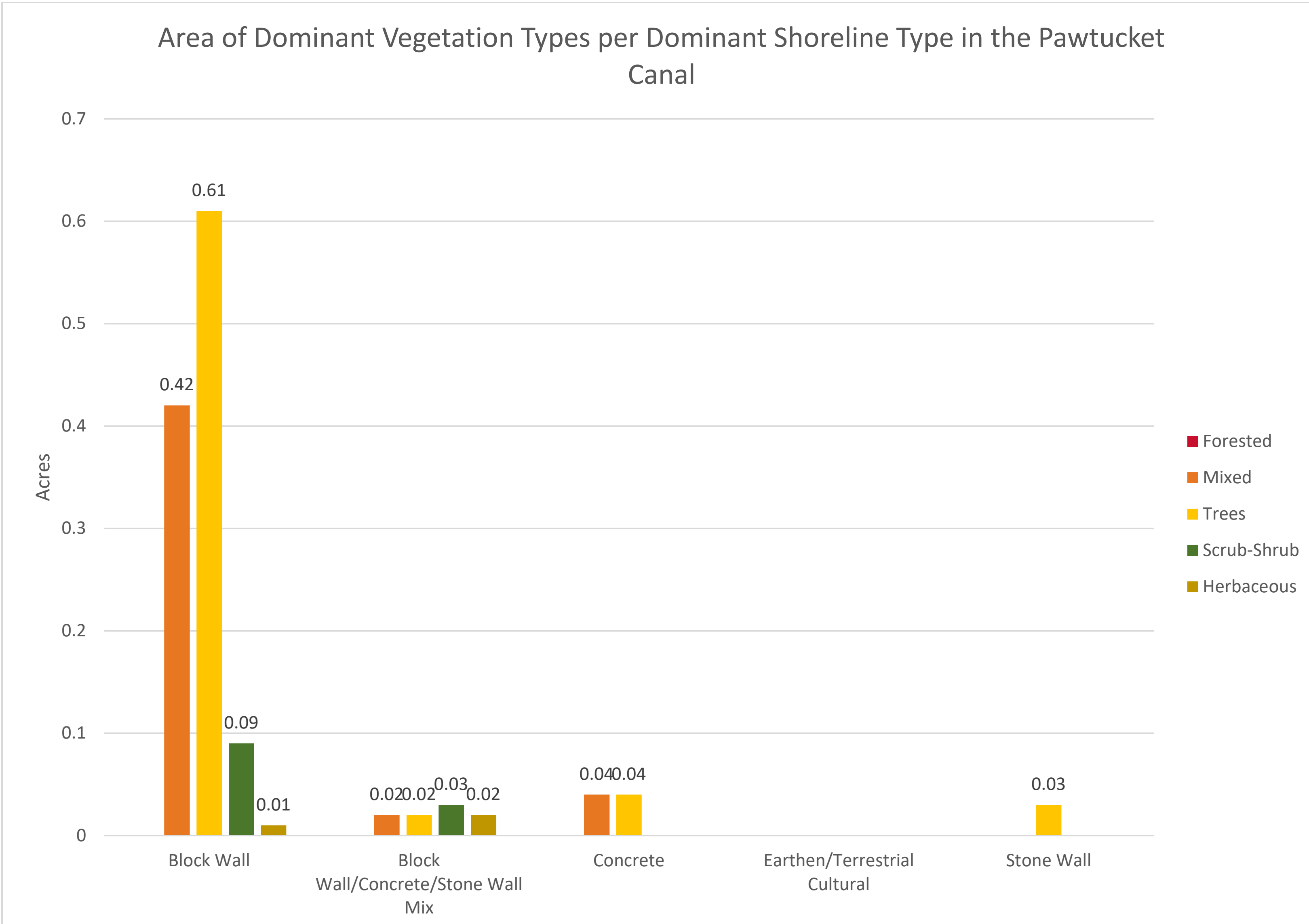


Dominant Vegetation Types per Shoreline Type of Merrimack Canal Vegetation Polygons
Acres
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.12
0.05
0.15
0.05
0.003
Block Wall
Block Wall/Concrete/Stone Wall Mix
Concrete
Earthen/Terrestrial Cultural
Stone Wall
Forested
Mixed
Trees
Scrub-Shrub
Herbaceous

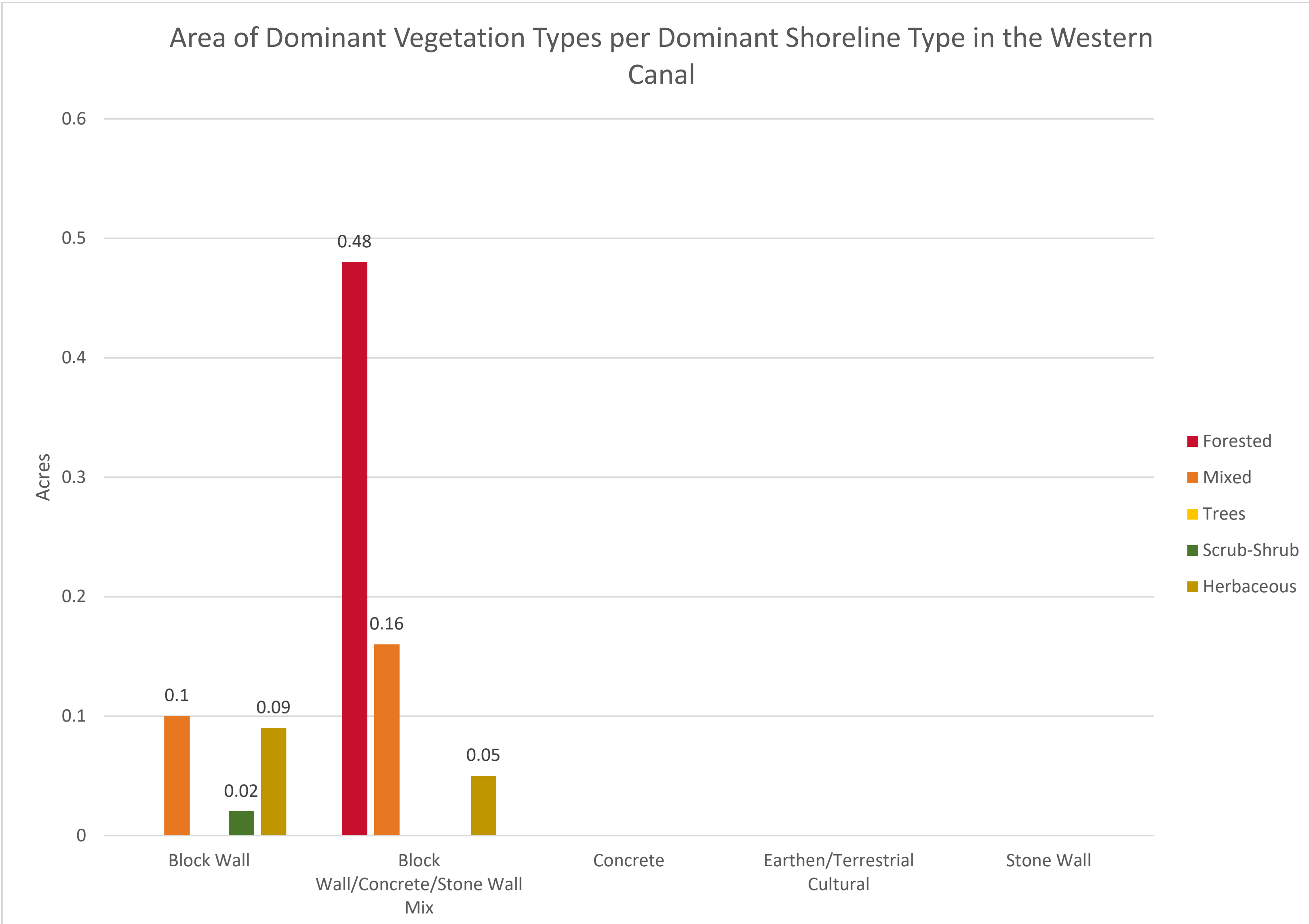
Note: Vegetation Points (VPs) are not included in mapped vegetation acreage calculations



Note: Vegetation Points (VPs) are not included in mapped vegetation acreage calculations



Note: Vegetation Points (VPs) are not included in mapped vegetation acreage calculations



Note: Vegetation Points (VPs) are not included in mapped vegetation acreage calculations

Appendix J - Visual Survey for Vegetation Growth Representative Photographic Log

Canal Wall Vegetation Mapping Photo Log

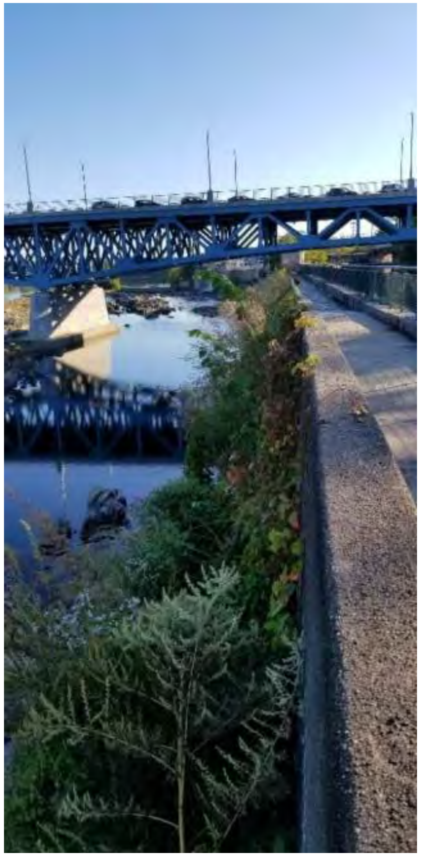
Polygon No.: 79
Photo No.: 79
Date: 9/27/2019
Direction Photo Taken: Northeasterly
Description: Tree of heaven trees and vines are growing on top of the canal wall and within approximately 3 feet of the canal wall.

Polygon No.: 78
Photo No.: 78
Date: 9/27/2019
Direction of Photo Taken: Westerly
Description: Vegetation growing out of the canal walls include tree of heaven and mulberry and herbaceous species such as purple loosestrife and mullein.

Polygon No.: 92
Photo No.: P-9
Date: 9/27/2019
Direction Photo Taken: Southerly
Description: Vegetation growing on top of single stone/block wall on south side of the canal is forested habitat.

Polygon No.: 77
Photo No.: 77a
Date: 9/27/2019
Direction Photo Taken: Westerly
Description: At the western edge of the polygon, the canal broadens and is forested with riparian species. The topography extends to the bypass reach. Species include elms, mulberry, and honeysuckle. Some stumps have been cut along the canal wall on the same side as the bypass reach.

Photo Location No.: P-6
Date: 9/26/2019
Direction Photo Taken: Easterly
Description: View of Pawtucket Gatehouse. Vegetation is growing on debris deposited against the gatehouse.



Polygon No.: 75
Photo No.: 75a
Date: 9/27/2019
Direction: Northeasterly
Description: Vegetation is growing from small sill under the first block down on the canal wall and is dominated by herbaceous plants such as ragweed, purple loosestrife, aster, scattered ferns, golden rod spp., scattered mulberry, elms, and buckthorn.

Canal Wall Vegetation Mapping Photo Log

Polygon No.: 74
Photo No.: 74
Date: 9/27/2019
Direction: Northeasterly
Description: Ragweed is growing out of the canal wall located beneath the building.

Polygon No.: 93
Photo Location No.: P-10
Date: 9/27/2019
Direction Photo Taken: Southerly
Description: Vegetation is growing on bedrock along south side of the canal.

Photo Location No.: P-7
Date: 9/26/2019
Direction Photo Taken: Northeasterly
Description: View from E.L. Field Powerhouse deck.

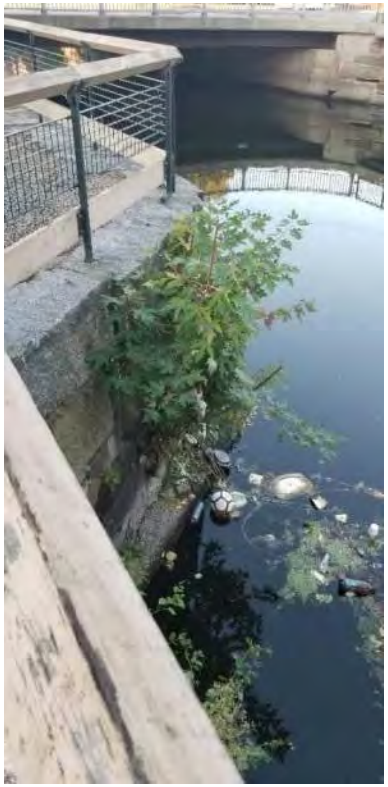
Polygon No.: 94
Photo Location No.: P-8
Date: 9/26/2019
Direction Photo Taken: Northerly
Description: View looking west toward E.L. Field Powerhouse from the NPS walking trail. Vegetation is growing on bedrock along south side of the canal.

Recreation and Aesthetics Study Report

Lowell Hydroelectric Project (FERC No. 2790)

Canal Wall Vegetation Mapping Photo Log

Vegetation Point No.: VP-10
Photo No.: VP-13
Date: 9/26/2019
Direction Photo Taken: Southerly
Description: A small maple is growing out of the canal wall, near the top of the wall.



Vegetation Point No.: VP-11
Photo No.: VP-14
Date: 9/26/2019
Direction Photo Taken: Southwesterly
Description: A small clump of silver maples are growing out of the canal wall.

Recreation and Aesthetics Study Report

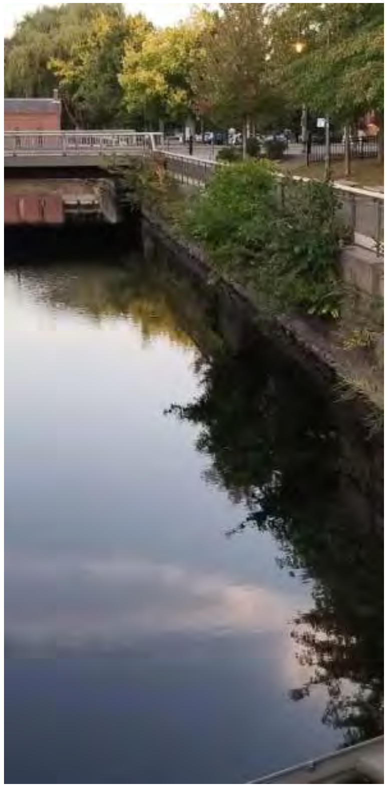
Lowell Hydroelectric Project (FERC No. 2790)

Canal Wall Vegetation Mapping Photo Log

Polygon No.: 45 and 46
Photo No.: 45
Date: 9/26/2019
Direction Photo Taken: Northeasterly
Description: Vegetation growing on the eastern side of the canal wall (left side of the photograph) includes several tree species (i.e. mulberry, buckthorn, tree of heaven, etc.) and dense vines, including Boston ivy and poison ivy. Vegetation growing on the western side of the canal wall (right side of the photograph) includes less trees than the eastern side of the canal and similar vine species.

Polygon No.: 47
Photo No.: 47
Date: 9/26/2019
Direction Photo Taken: Northeasterly
Description: The vegetation growing on the canal wall includes large locust trees and ragweed.

Polygon No.: 39
Photo No.: 39
Date: 9/25/2019
Direction Photo Taken: Northerly
Description: A few small tree of heaven trees are growing out of the canal wall, near the top of the wall.



Polygon No.: 38
Photo No.: 38
Date: 9/25/2019
Direction Photo Taken: Northeasterly
Description: Vegetation growing out of the canal wall, near the top of the wall consists of shrubs.

Canal Wall Vegetation Mapping Photo Log

Vegetation Point No.: VP-14
Photo No.: VP-17
Date: 9/26/2019
Direction Photo Taken: Southwesterly
Description: A small clump of shrubs growing out of the canal wall.

Polygon No.: 51
Photo No.: 51
Date: 9/26/2019
Direction Photo Taken: Northeasterly
Description: Vegetation growing on the canal wall include trees, such as mulberry and elms, and herbaceous ragweed.

Canal Wall Vegetation Mapping Photo Log

Polygon No.: 54 and 55
Photo No.: 54
Date: 9/26/2019
Direction Photo Taken: Northerly
Description: Vegetation growing on the northern side of the canal wall (left side of the photograph) consists of primarily vines. Vegetation growing on the southern side of the canal wall (right side of the photograph) consists primarily of herbaceous vegetation, such as ragweed, and vines. A few tree of heaven trees are growing primarily at the toe of the canal wall on both sides of the canal; likely on deposited sediment, especially along the northern canal wall.

Polygon No.: 86
Photo No.: CV_Poly6
Date: 9/25/2019
Direction Photo Taken: Northerly
Description: Vegetation growing on canal wall at the southwestern end of Polygon 86 is primarily herbaceous.

Canal Wall Vegetation Mapping Photo Log

Polygon No.: 86
Photo No.: CV_Poly6b
Date: 9/25/2019
Direction Photo Taken: Easterly
Description: The vegetation growing out of the canal includes tree of heaven and potentially milfoil and *Typha* spp.; other herbaceous species are growing at the bottom of the canal.

Polygon No.: 91
Photo No.: CV_Poly6a
Date: 9/25/2019
Direction Photo Taken: Northerly
Description: The vegetation growing on the canal is primarily herbaceous; however, one maple at approximately 5-10 inches diameter at breast height is located approximately 2 feet back from the wall.

Recreation and Aesthetics Study Report

Lowell Hydroelectric Project (FERC No. 2790)

Canal Wall Vegetation Mapping Photo Log

Polygon No.: 1
Photo No.: 1
Date: 9/25/2019
Direction Photo Taken: Northwesterly
Description: Several large woody trees are located at the northwestern end of the canal, including river birch growing on top of the canal wall. Herbaceous plants including ragweed and Boston ivy dominate the western side of the canal wall (left side of the photograph).

Polygon No.: 1
Photo No.: 1a
Date: 9/25/2019
Direction Photo Taken: Easterly
Description: Herbaceous plants including ragweed and Boston ivy dominate the western side of the canal wall (right side of the photograph).

Recreation and Aesthetics Study Report

Lowell Hydroelectric Project (FERC No. 2790)

Canal Wall Vegetation Mapping Photo Log

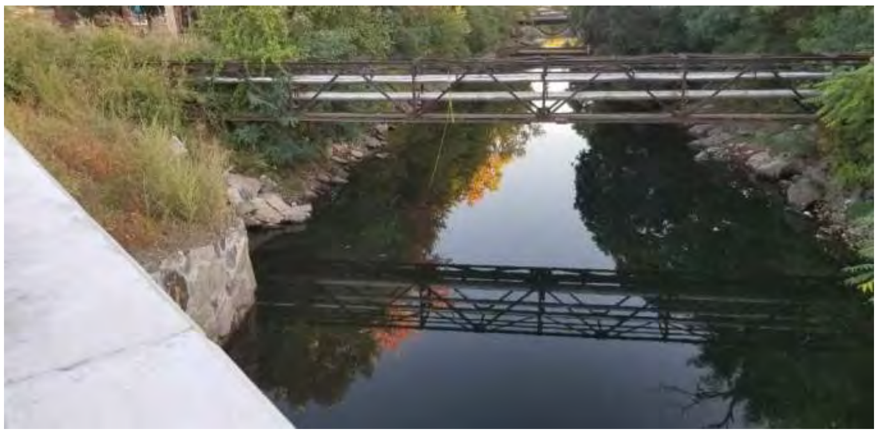


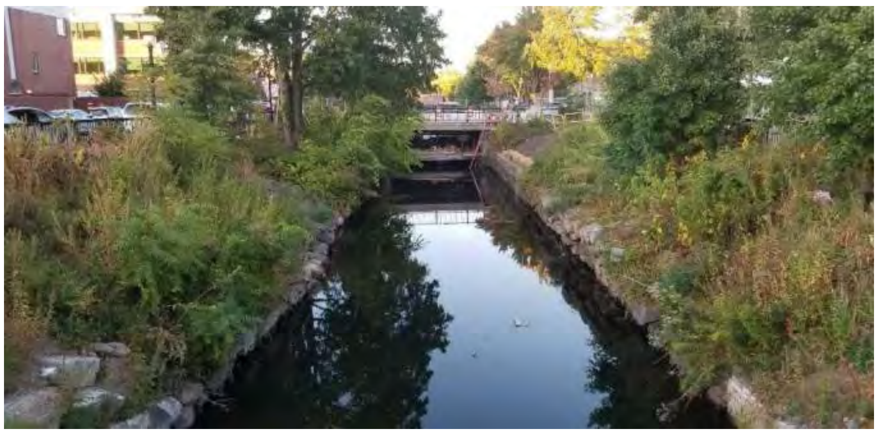
Photo Location No.: P-2
Date: 9/25/2019
Direction Photo Taken: Southwesterly
Description: Vegetation is growing on the riprap shoreline along both sides of the canal.

Photo Location No.: P-3
Date: 9/25/2019
Direction Photo Taken: Southwesterly
Description: Vegetation is growing on the riprap shoreline located on the eastern side of the canal (left side of the photograph). The western side of the canal wall (right side of the photograph) is concrete with little to no vegetation present.

Recreation and Aesthetics Study Report

Lowell Hydroelectric Project (FERC No. 2790)

Canal Wall Vegetation Mapping Photo Log



Polygon No.: 34, 35, and 36
Photo No.: 34
Date: 9/25/2019
Direction Photo Taken: Northeasterly
Description: The vegetation growing out of the eastern side of the canal wall (right side of the photograph) is sparse and consists primarily of vines. The vegetation growing on top of and approximately 3 feet back from the western side of the canal wall (left side of the photograph) is primarily herbaceous.

Polygon No.: 82
Photo No.: CV_Poly2
Date: 9/25/2019
Direction Photo Taken: Northeasterly
Description: There is approximately 90 percent vegetative cover in this area; vegetation is mostly herbaceous, including ragweed, clover, *Aster* spp., and other common weeds. Two small tree of heaven trees are also present on the canal wall.

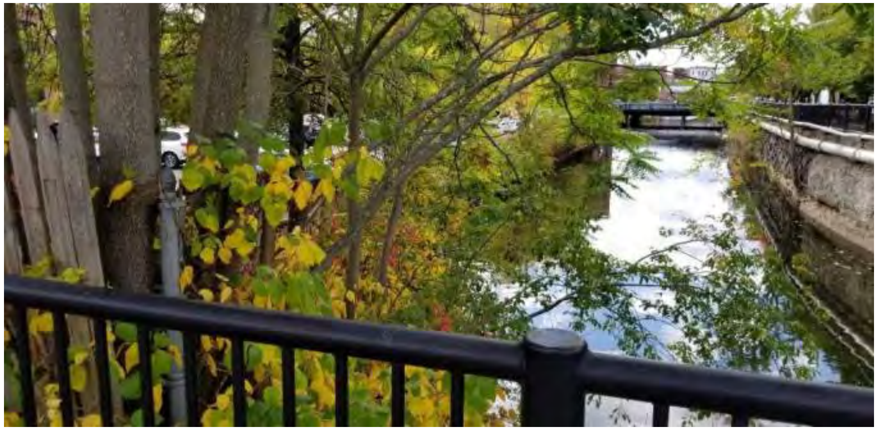
Canal Wall Vegetation Mapping Photo Log

Polygon No.: 84 and 85
Photo No.: CV_Poly4c
Date: 9/25/2019
Direction Photo Taken: Northeasterly
Description: There is approximately 20 percent vegetative cover on the western side of the canal wall (right side of the photograph) located primarily one block down from the top of the wall; vegetation includes a few maples, honeysuckle, and scattered herbaceous species. There is approximately 40 percent vegetative cover on the eastern side of the canal wall (left side of the photograph); vegetation includes several elms, approximately 5 feet tall, several birches, and a few red maples.

Polygon No.: 3
Photo No.: 3
Date: 9/25/2019
Direction Photo Taken: Northwesterly
Description: The vegetation growing on the canal wall includes one elm tree, Boston ivy, and ragweed. Scattered submerged aquatic vegetation is growing in the canal.

Canal Wall Vegetation Mapping Photo Log

Vegetation Point No.: VP-1
Photo No.: VP-4
Date: 9/25/2019
Direction Photo Taken: Northeasterly
Description: Vegetation includes a single shrub growing out of the canal wall below the brick building and sparse herbaceous species.



Polygon No.: 89
Photo No.: CV_Poly9
Date: 9/25/2019
Direction Photo Taken: Southeasterly
Description: The vegetation growing out of the canal wall includes an approximately 10-trunked tree of heaven tree at approximately 6 inches diameter at breast height and poison ivy.

Canal Wall Vegetation Mapping Photo Log

Polygon No.: 90
Photo No.: CV_Poly10a
Date: 9/25/2019
Direction Photo Taken: Southwesterly
Description: The vegetation growing out of canal wall is a 3-trunked tree of heaven tree at approximately 4 inches diameter at breast height. A recently cut birch tree tied with rope was also observed along the canal wall.

Polygon No.: 4
Photo No.: 4
Date: 9/25/2019
Direction Photo Taken: Southerly
Description: There is one, multi-trunked tree of heaven tree at approximately 4 to 6 inches diameter at breast height growing out of the canal wall.

Polygon No.: 70
Photo No.: 70
Date: 9/26/2019
Direction Photo Taken: Northwesterly
Description: The canal wall is primarily concrete with trees, such as locust and elm, growing at the toe of the wall.

Photo Location No.: P-4
Photo No.: P-15
Date: 9/26/2019
Direction Photo Taken: Easterly
Description: Dense vegetation is growing on earthen banks along the canal.

Photo Location No.: P-5
Photo No.: P-16
Date: 9/26/2019
Direction Photo Taken: Northwesterly
Description: Upstream view of dense vegetation growing on earthen banks along both sides of the canal.

Polygon No.: 41
Photo No.: 41b
Date: 9/25/2019
Direction Photo Taken: Southeasterly
Description: Portions of the canal wall at bridge crossings on each side of the canal are concrete and brick. The highest density of vegetation in the polygon consists of locust, tree of heaven, box elder, maples and scattered shrubs, some with approximately 6 to 14 inches diameter at breast height.

Recreation and Aesthetics Study Report

Lowell Hydroelectric Project (FERC No. 2790)

Canal Wall Vegetation Mapping Photo Log

Polygon No.: 13
Photo No.: 13
Date: 9/25/2019
Direction Photo Taken: Southerly
Description: There is one elm tree and one mulberry growing out of concrete portion of the canal wall.

Polygon No.: 16
Photo No.: 16
Date: 9/25/2019
Direction Photo Taken: Northerly
Description: Approximately 20 percent of the canal wall has woody trees (i.e. elms, locust, and mulberry) or herbaceous plants growing on it.

Canal Wall Vegetation Mapping Photo Log

Polygon No.: 18
Photo No.: 18
Date: 9/25/2019
Direction Photo Taken: Southwesterly
Description: Approximately 20 percent of the canal wall has woody trees, shrubs, and/or herbaceous plants growing on it. The vegetation includes tree of heaven, maple, common mullein, Japanese knot weed, and ragweed. Japanese knot weed coverage increases with closer proximity to the National Park Service boat dock.

Polygon No.: 7
Photo No.: 7a
Date: 9/25/2019
Direction Photo Taken: Easterly
Description: Several large woody trees including river birch, tree of heaven, and silver maple, all approximately 2 to 5 inches diameter at breast height are growing out of the canal wall.

Canal Wall Vegetation Mapping Photo Log

Polygon No.: 8
Photo No.: 8
Date: 9/25/2019
Direction Photo Taken: Easterly
Description: The canal contains potential sediment deposited against the canal wall; the sediment is topped with a layer of herbaceous plants.

Vegetation Point No.: VP-4
Photo No.: VP-7
Date: 9/25/2019
Direction Photo Taken: Southeasterly
Description: A multi-trunked clump of trees, approximately 6 to 8 feet tall, are growing out of canal wall .

Canal Wall Vegetation Mapping Photo Log

Polygon No.: 69
Photo No.: 69
Date: 9/26/2019
Direction Photo Taken: Northwesterly
Description: The trees growing out of canal wall include tree of heaven and elms at approximately 10 feet tall.

Polygon No.: 67
Photo No.: 67
Date: 9/26/2019
Direction Photo Taken: Northwesterly
Description: Large locust and birch trees are growing on top of the canal wall.

Canal Wall Vegetation Mapping Photo Log

Polygon No.: 66
Photo No.: 66a
Date: 9/26/2019
Direction Photo Taken: Northerly
Description: The vegetation growing out of the eastern side of the canal wall (right side of the photograph), at the top of the wall, includes trees, such as tree of heaven and birch, and vines, such as Boston ivy.

Vegetation Point No.: VP-16
Photo No.: VP-19
Date: 9/26/2019
Direction Photo Taken: Northerly
Description: A small clump of mulberry are growing out of the canal wall.

Canal Wall Vegetation Mapping Photo Log

Polygon No.: 56
Photo No.: 56
Date: 9/26/2019
Direction Photo Taken: Southwesterly
Description: Most of the canal wall is made of concrete with riprap placed at the toe of the wall. The vegetation growing on the canal wall consists of tree of heaven, box elder, and vines, such as Boston ivy.

Polygon No.: 57
Photo No.: 57
Date: 9/26/2019
Direction Photo Taken: Easterly
Description: Vegetation growing out of the canal wall includes ash trees at approximately 6 to 8 inches diameter at breast height.

Canal Wall Vegetation Mapping Photo Log

Polygon No.: 23
Photo No.: 23
Date: 9/25/2019
Direction Photo Taken: Northerly
Description: The vegetation on the canal wall is primarily tree of heaven and ragweed, with lesser density of mullein.

Polygon No.: 25
Photo No.: 25
Date: 9/25/2019
Direction Photo Taken: Northerly
Description: The vegetation growing out of the canal wall includes one sycamore, several tree of heaven, glossy buckhorn, and ragweed.

Canal Wall Vegetation Mapping Photo Log

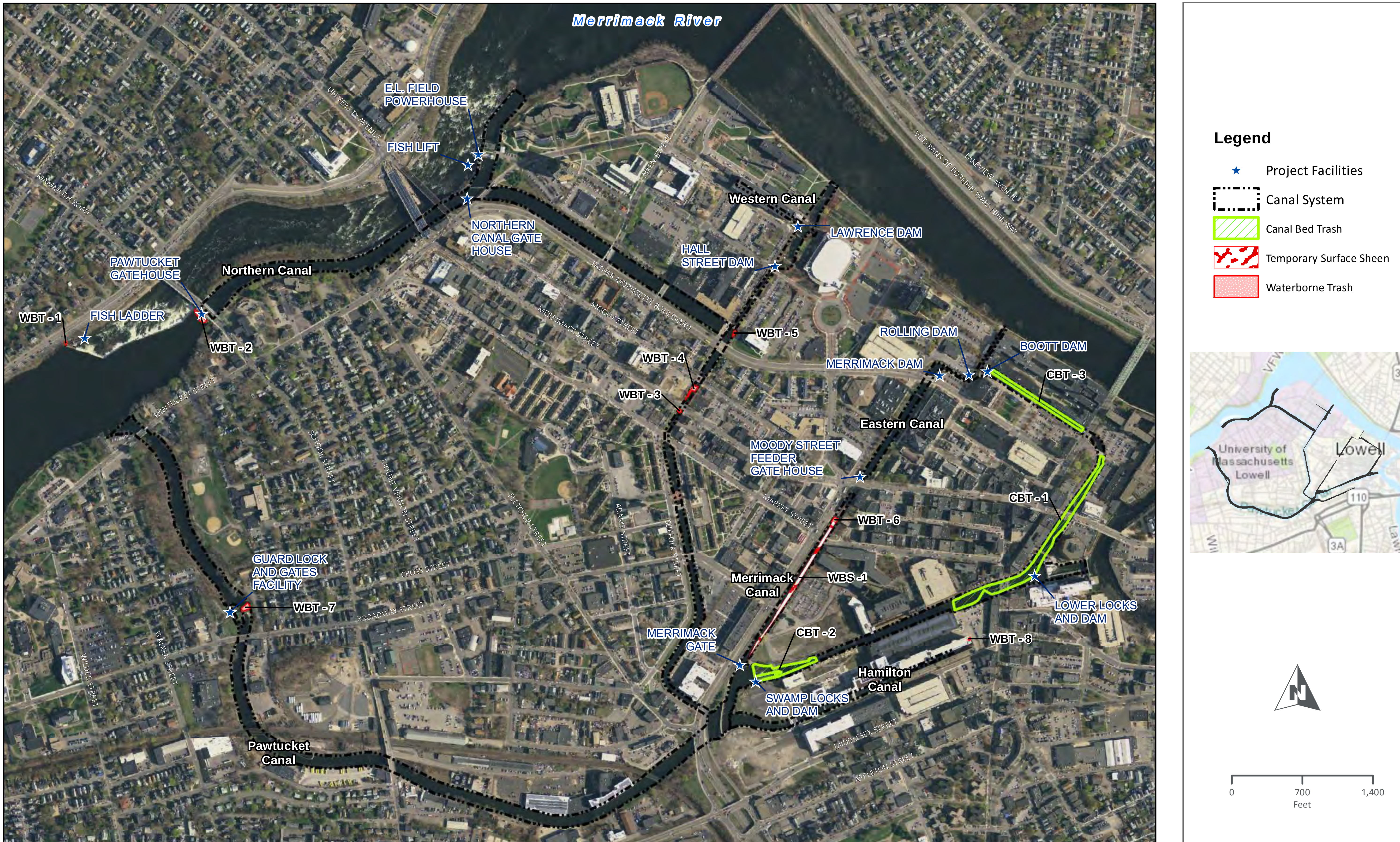
Polygon No.: 26 and 27
Photo No.: 26
Date: 9/25/2019
Direction Photo Taken: Northeasterly
Description: The southern side of the canal wall (right side of the photograph), west of the walking bridge, consists of portions of concrete and is primarily covered in ragweed. Vegetation on the northern side of the canal wall (left side of the photograph) consists primarily of trees with approximately 10 percent cover. The northern side of the canal wall, west of the walking bridge, consists of portions of concrete.

Polygon No.: 26 and 27
Photo No.: 26a
Date: 9/25/2019
Direction Photo Taken: Southwesterly
Description: The southern side of the canal wall (left side of the photograph), east of the walking bridge, contains trees, such as tree of heaven and elm. Trees on the northern side of the canal wall (right side of the photograph), east of the walking bridge, are smaller and less dense than west of the walking bridge.

Canal Wall Vegetation Mapping Photo Log

Polygon No.: 58
Photo No.: 58b
Date: 9/26/2019
Direction Photo Taken: Southerly
Description: The vegetation growing out of the canal wall includes locust trees, tree of heaven trees, wild grape, and oriental bittersweet.

Appendix K - Visual Survey for Waterborne Trash Mapbook



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TRASH ASSESSMENT AND MAPPING STUDY
LOWELL HYDROELECTRIC PROJECT
FERC NO. 2790

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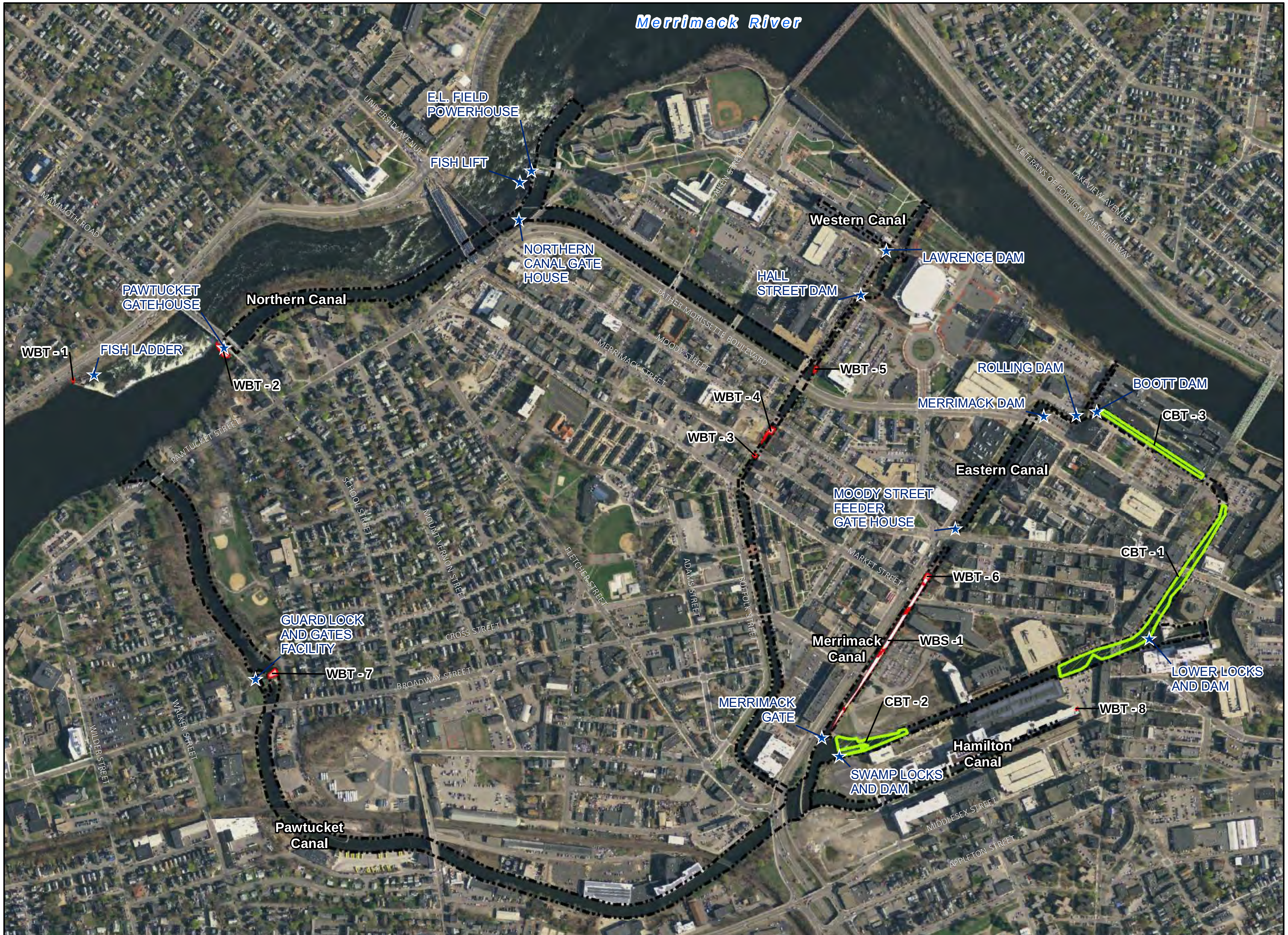

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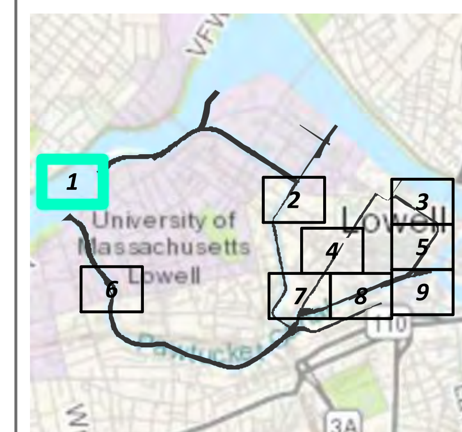
Legend

- ★ Project Facilities
- Canal System
- Canal Bed Trash
- Temporary Surface Sheen
- Waterborne Trash



Page 1 of 9

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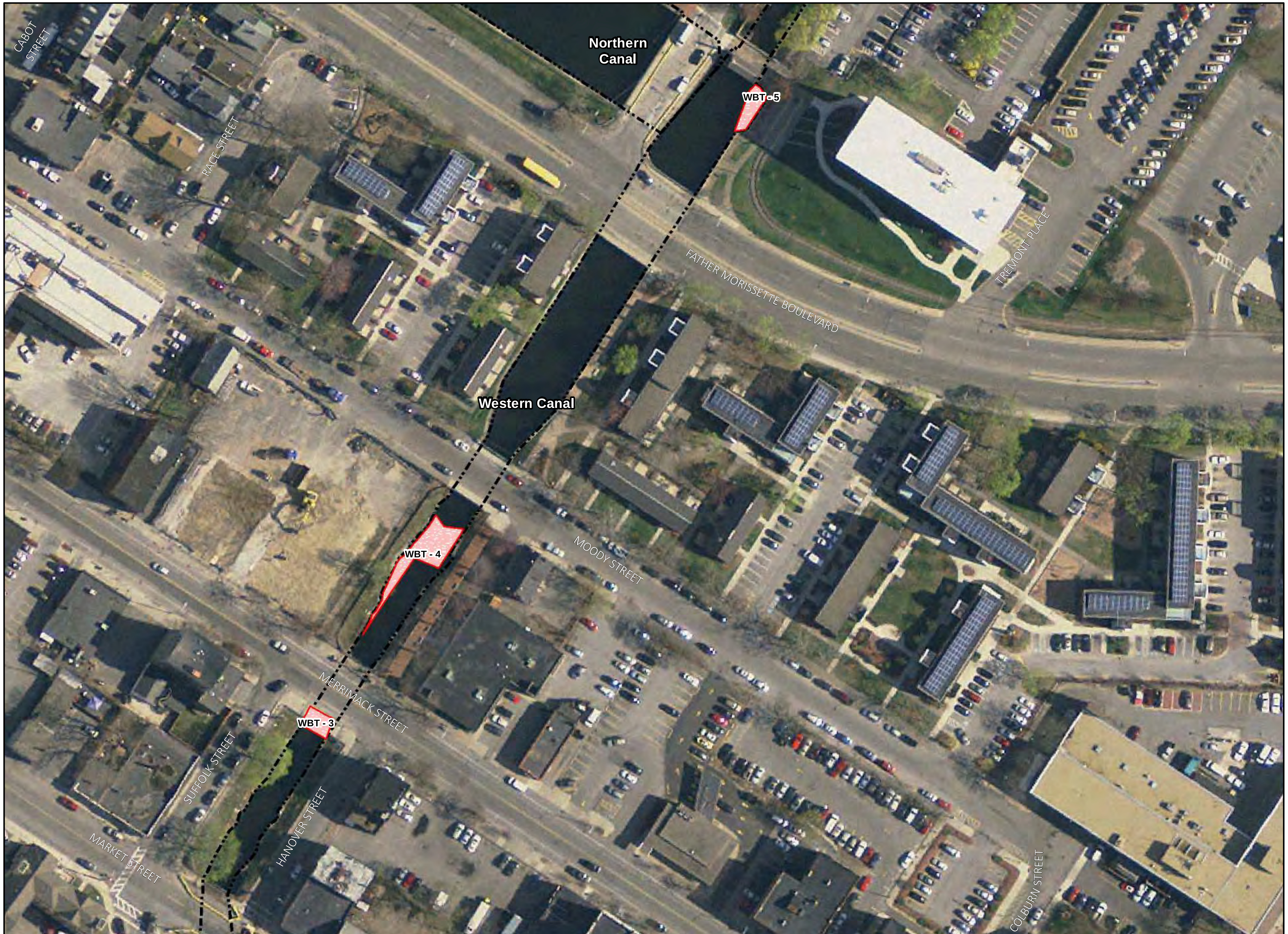

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- Canal System
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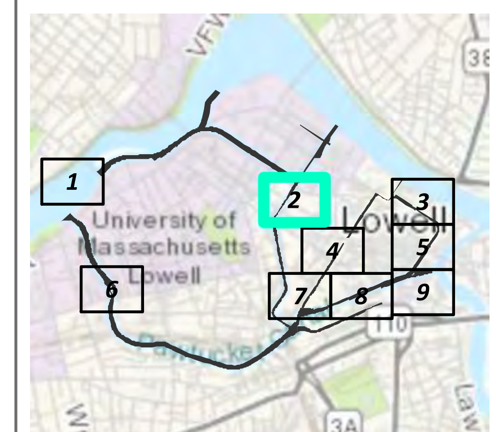
- Waterborne Trash



Page 2 of 9

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FERC NO. 2790

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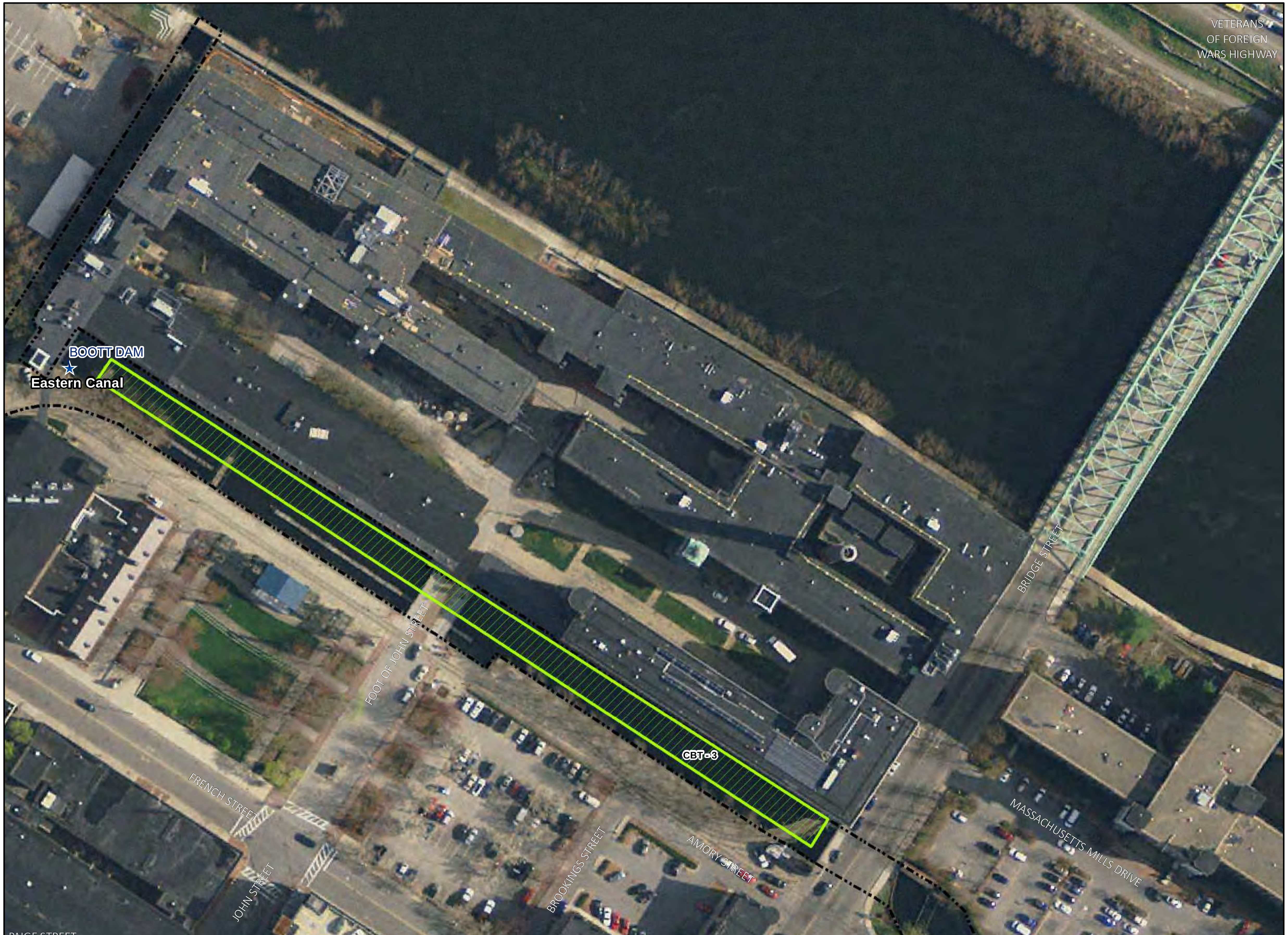
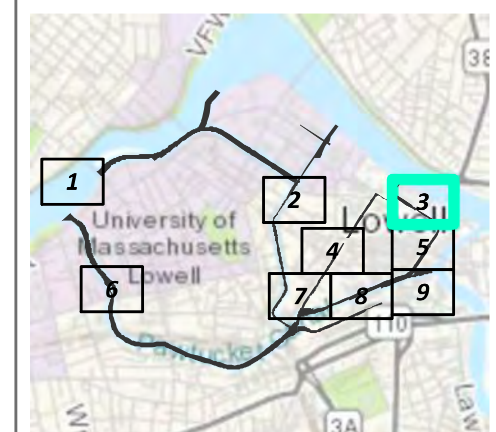
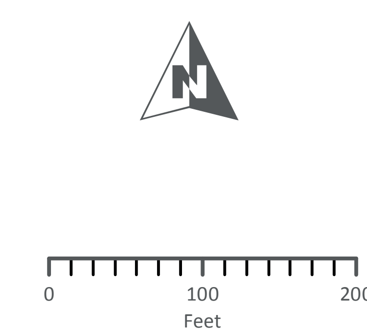


Legend

- ★ Project Facilities
- Canal System
- Canal Bed Trash
- Temporary Surface Sheen
- Waterborne Trash



Page 3 of 9



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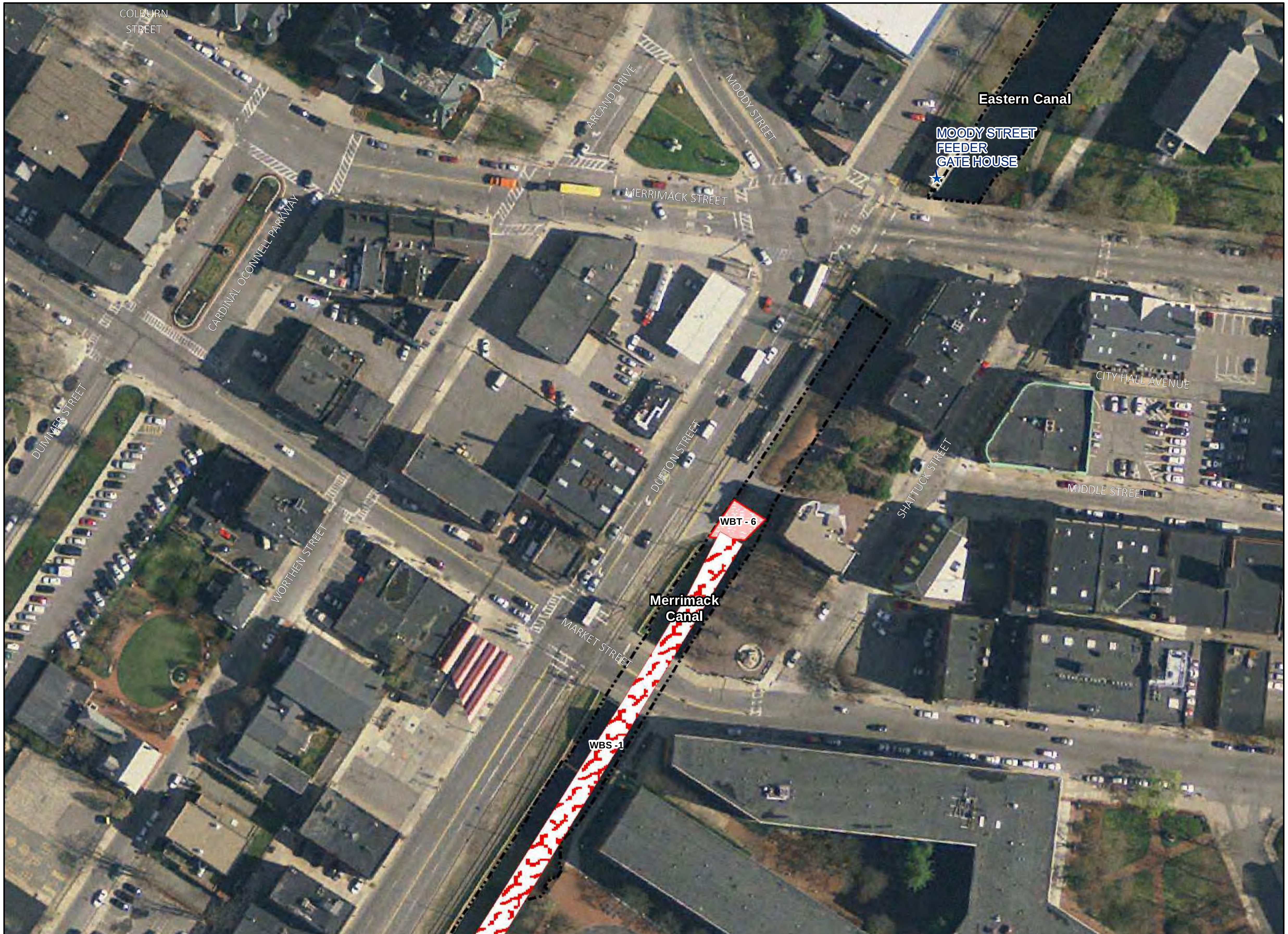

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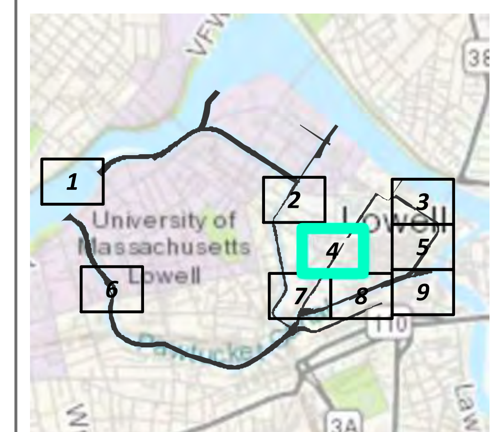

Page 4 of 9

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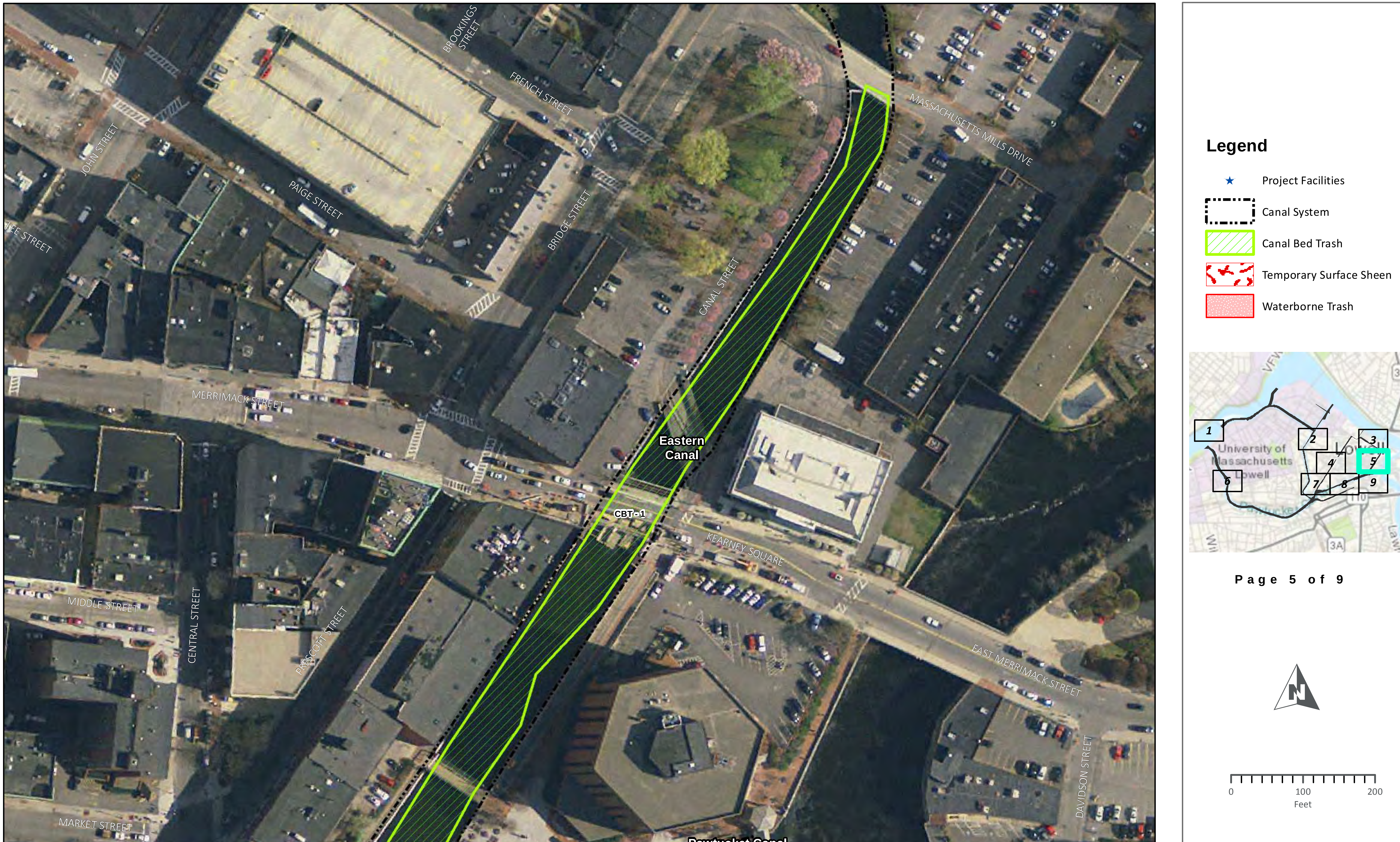

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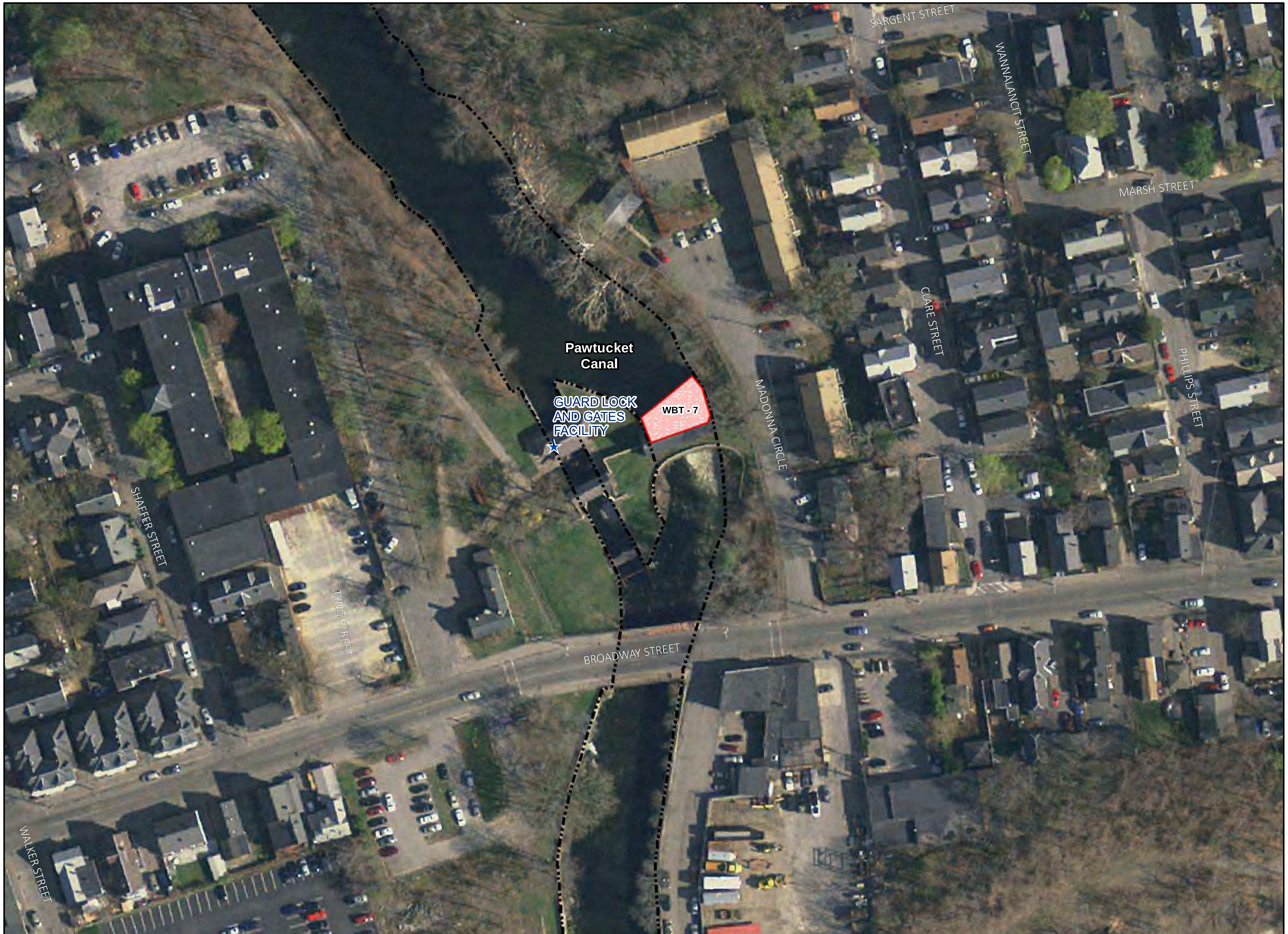

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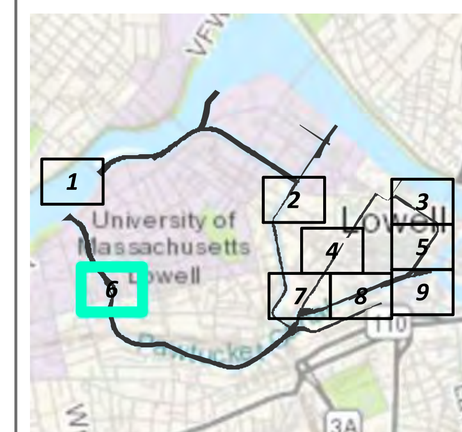

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LOWELL HYDROELECTRIC PROJECT
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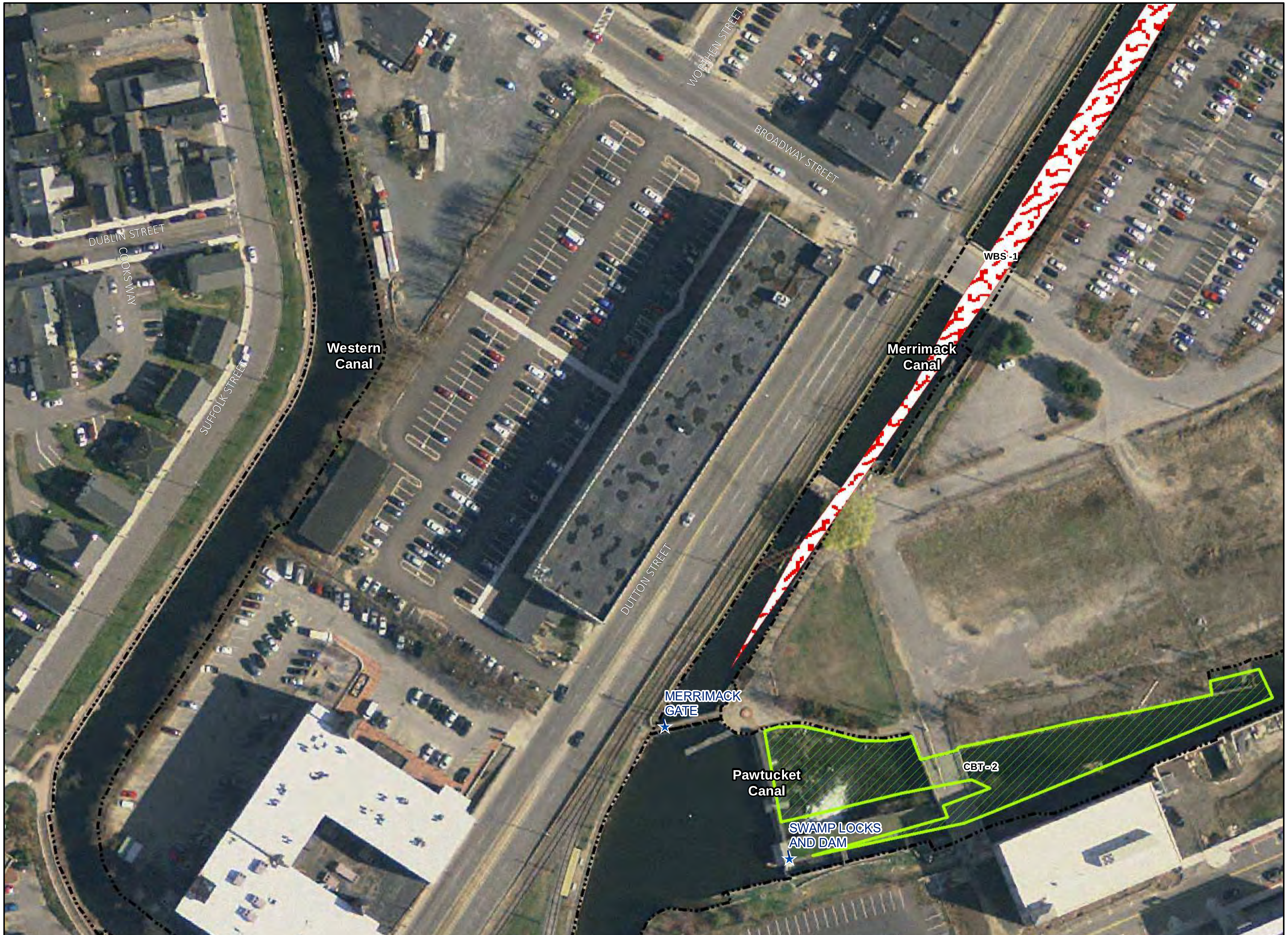

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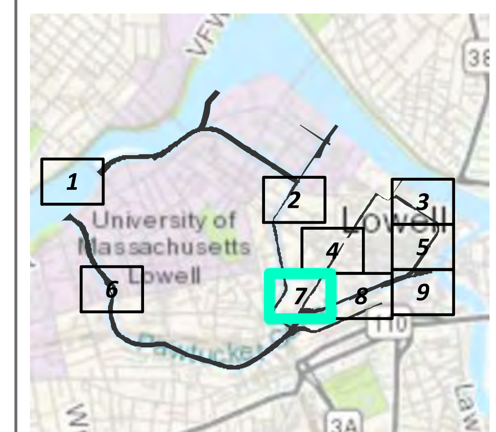

Page 7 of 9

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TRASH ASSESSMENT AND MAPPING STUDY
LOWELL HYDROELECTRIC PROJECT
FERC NO. 2790

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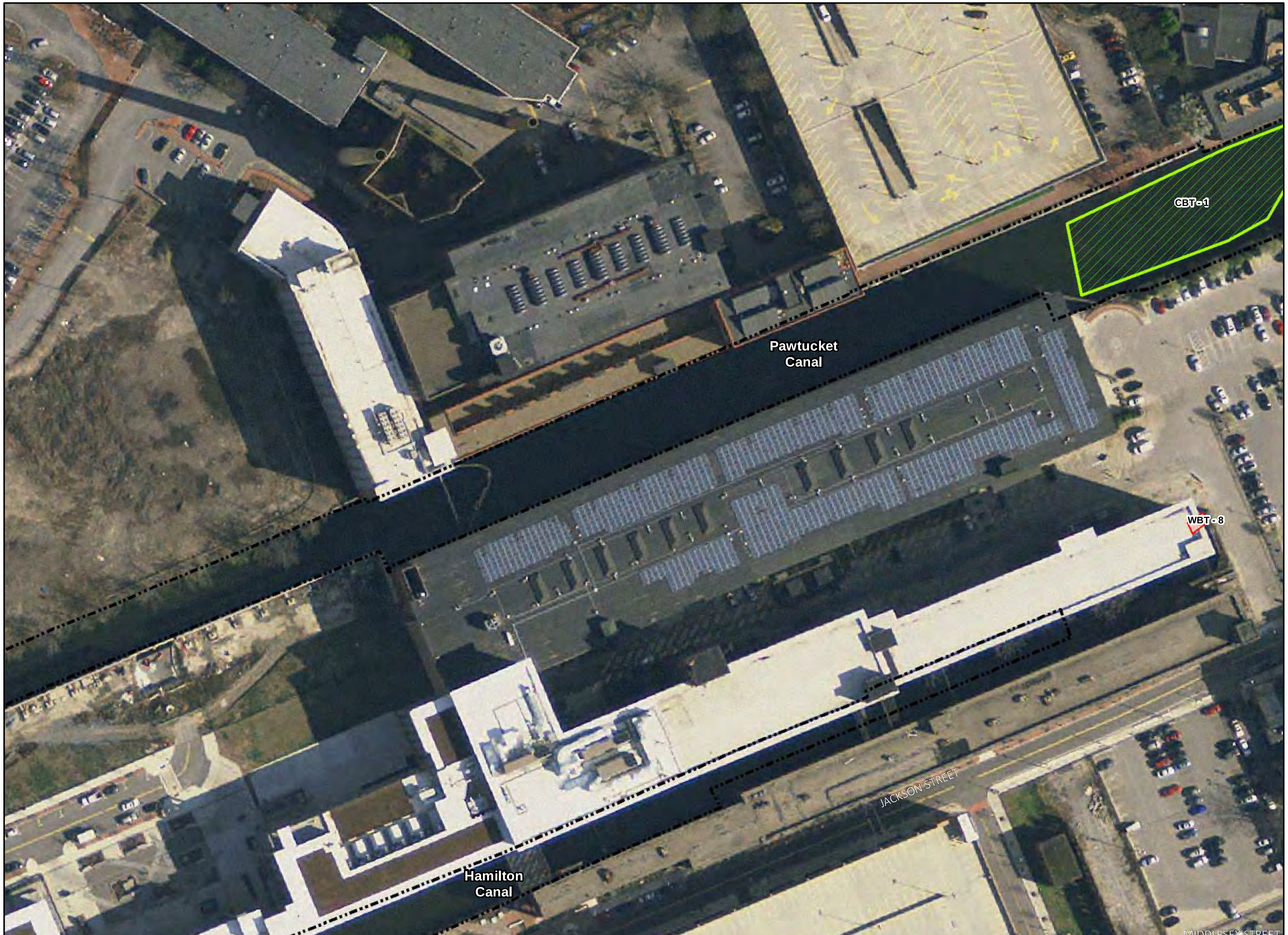

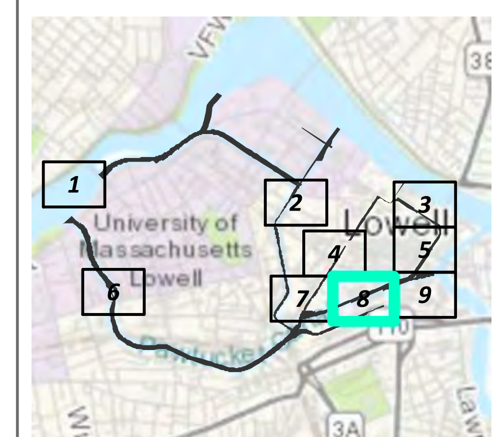

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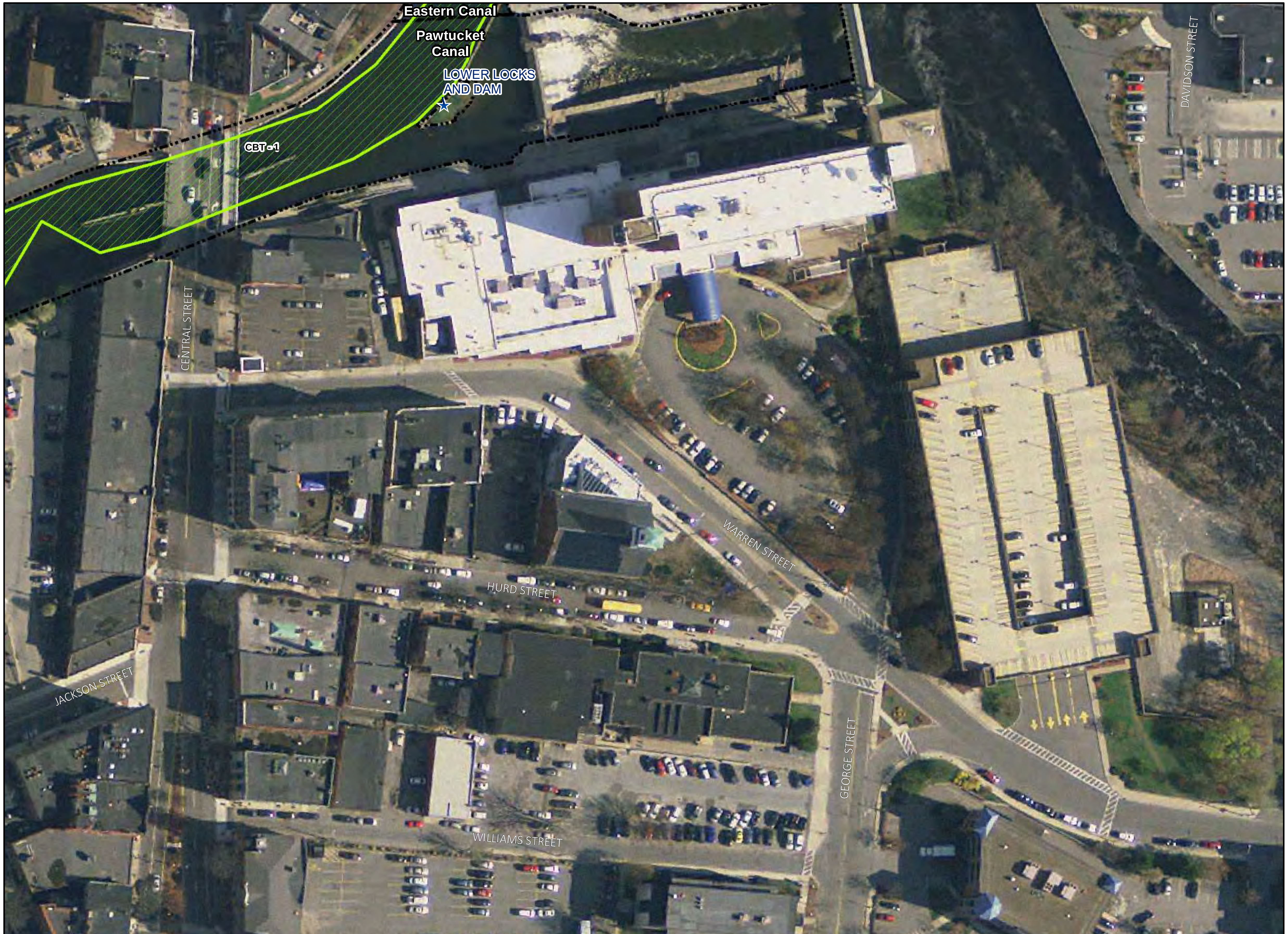

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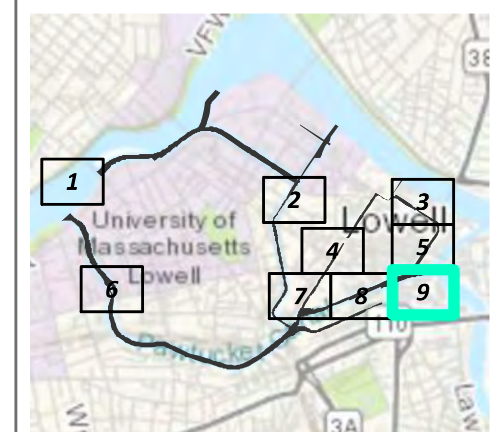
- ★ Project Facilities
- Canal System
- Canal Bed Trash
- Temporary Surface Sheen
- Waterborne Trash



Page 9 of 9

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BOOTT HYDRO, LLC.

TRASH ASSESSMENT AND MAPPING STUDY
LOWELL HYDROELECTRIC PROJECT
FERC NO. 2790

Appendix L - Correspondence and Consultation Log

Scott, Kelsey

From:	Quiggle, Robert
Sent:	Tuesday, May 7, 2019 2:08 PM
To:	celeste_bernardo@nps.gov; Bob Nasdor (bob@americanwhitewater.org); Kevin.hollenbeck@state.ma.us
Cc:	Kevin_mendik@nps.gov; 'Kevin.Webb@enel.com'; Anderson, Elise (EGP North America); Gibson, Jim; MacVane, Kelly; Scott, Kelsey
Subject:	Lowell Hydroelectric Project (FERC No. 2790-072) -- Consultation Regarding the Recreation and Aesthetics Study
Attachments:	20190507 Lowell Hydro Project Recreation Study Consultation.pdf

Ms. Bernardo, Mr. Nasdor, and Mr. Hollenbeck:

On behalf of Boott Hydropower, LLC (Boott), I am distributing the attached consultation request in support of the Federal Energy Regulatory Commission (FERC) relicensing of the Lowell Hydroelectric Project (Project). As described in the attached correspondence, Boott is consulting with the National Park Service, American Whitewater, and the Massachusetts Department of Conservation and Recreation to identify locations in the Project's vicinity to conduct visitor intercept surveys of recreationists for the approved Recreation and Aesthetics Study.

Should you have any questions regarding the attached correspondence, please contact Kevin Webb with Boott at 978-935-6039 or Kevin.Webb@enel.com.

Thank you,

Robert Quiggle, RPA
Regulatory and Environmental Section Manager

HDR
1304 Buckley Road, Suite 202
Syracuse, New York 13212-4311
D 315.414.2216 **M** 724.989.1579
Robert.Quiggle@hdrinc.com

hdrinc.com/follow-us

Boott Hydropower, LLC
A Subsidiary of Enel Green Power North America, Inc.

100 Brickstone Square, Suite 300 – Andover, MA 01810 – USA
T +1 978 681 1900 – F +1 978 681 7727

Via Electronic Distribution May 7, 2019

Celeste Bernardo
Superintendent of Lowell National Historical Park
National Park Service
67 Kirk Street
Lowell, MA 01852

Robert Nasdor
NE Stewardship Director
American Whitewater
65 Blueberry Hill Lane
Sudbury, MA 01776

Kevin Hollenbeck
Metrowest District Manager
DCR Great Brook Farm State Park
984 Lowell Street
Carlisle, MA 01741

Re: Lowell Hydroelectric Project (FERC No. 2790-072);
Consultation Regarding the Recreation and Aesthetics Study

Dear Stakeholders:

Boott Hydropower, LLC (Boott), a subsidiary of Enel Green Power North America, Inc. (Enel), is the Licensee and operator of the 22.4 megawatt (MW) Lowell Hydroelectric Project (Project or Lowell Project). The Lowell Project is located on the Merrimack River in Middlesex County, Massachusetts, and in Hillsborough County, New Hampshire. The existing license for the Project was issued by the Federal Energy Regulatory Commission (FERC or Commission) with an effective date of May 1, 1973. The existing license expires on April 30, 2023. Accordingly, Boott is pursuing a new license for the Project pursuant to the Commission's Integrated Licensing Process (ILP), as described at 18 Code of Federal Regulations (CFR) Part 5.

In accordance with the Commission's Study Plan Determination issued on March 13, 2019, Boott is initiating consultation with the National Park Service (NPS), American Whitewater, and the Massachusetts Department of Conservation and Recreation (MADCR) to identify specific locations for field reconnaissance and visitor-intercept surveys. As part of the Recreation and Aesthetics Study, Boott will conduct field reconnaissance and visitor-intercept interviews at specific recreational facilities during the prime recreational season from May 2019 through October 2019. Boott will interview recreationists visiting these locations to collect data relevant to visitors' recreational experience in the Project area, including but not limited to, data regarding demographics, types of recreational activities participated in or may participate in during their visit, and their reasons for choosing the site or area. As a separate component of the Recreation and Aesthetics Study, Boott is hosting an online version of the visitor-intercept survey to capture additional recreationists that would like to participate (the online version of the visitor survey is available at: https://hdrinc.co1.qualtrics.com/jfe/form/SV_0AnPxTboxMRT8nX). Boott will install signage informing recreationists of the online survey at various locations determined in consultation with NPS.
As shown in Figure 1 provided as Attachment A, Boott is proposing the following nine locations to conduct the reconnaissance and visitor-intercept surveys:

- Lowell Heritage State Park
- Merrimack Trail System

- Pawtucket Falls Overlook
- NPS Canal Walkways
- Lowell National Historic Park
- Lowell National Historic Park Visitor Center
- Chelmsford Boat Access
- Rourke Brothers Boat Ramp
- Merrill Park

Boott is also proposing ten locations[1] (as shown in Figure 1) to install the temporary signs informing recreationists of the online survey opportunity. Boott respectfully requests any comments regarding the proposed reconnaissance and visitor-intercept locations or the signage locations within 15 days of this letter (i.e., by May 22, 2019). Following consultation with stakeholders, Boott will develop the final list of reconnaissance and visitor-intercept locations and will file the final list with the Commission and distribute to American Whitewater, NPS, and the MADCR. If we do not receive a response from your office, Boott will move forward with the study to include the visitor-intercept survey locations as shown in the attached figure.

On behalf of Boott, I appreciate the opportunity to consult with your offices regarding this study. Please do not hesitate to contact me at (978) 935-6039 if you have any questions concerning this matter.

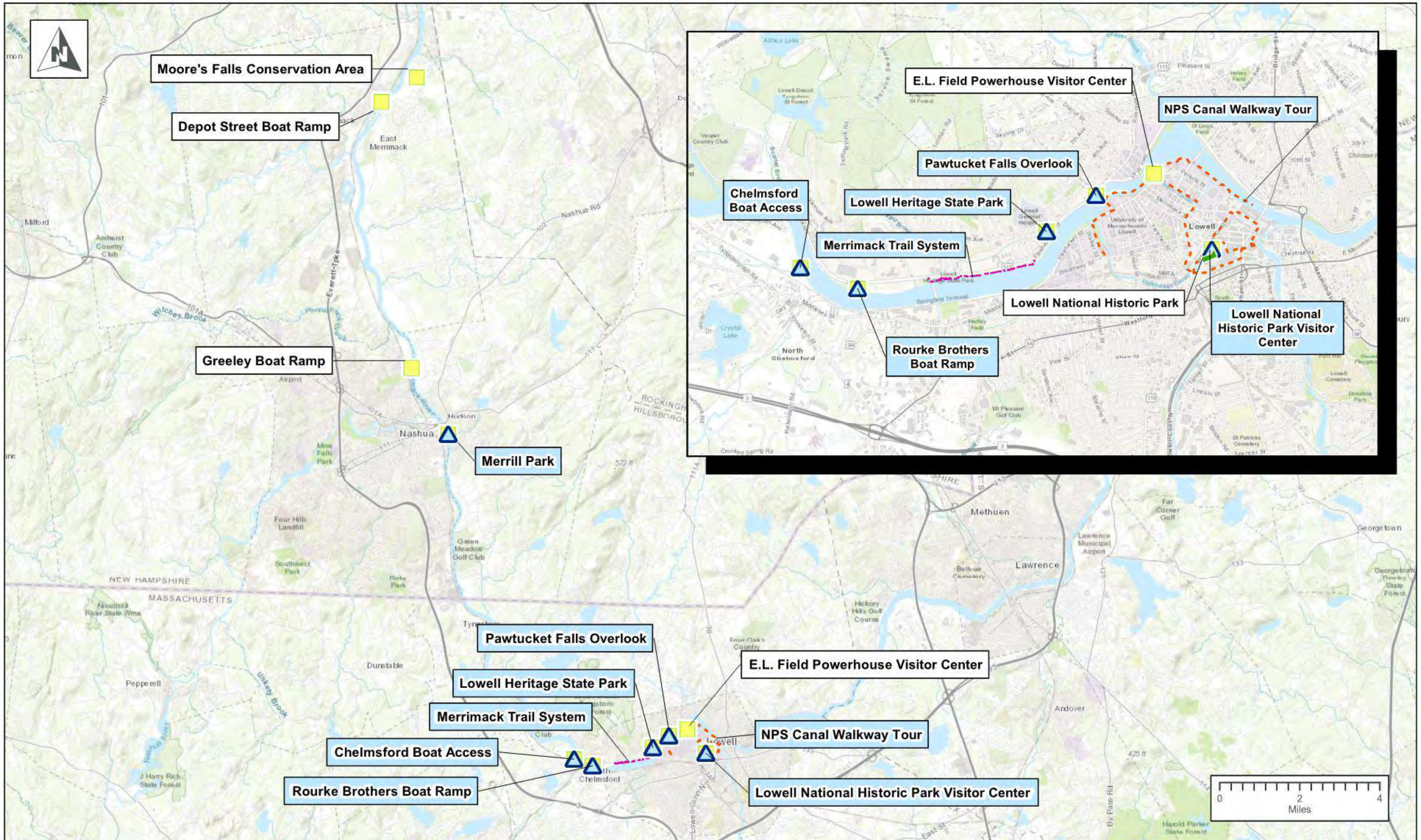
Sincerely,
Boott Hydropower, LLC

Kevin M. Webb
Hydro Licensing Manager

cc: K. Bose, FERC
K. Mendik, NPS

Attachment A – Figure 1

[1]Boott will install temporary signs that will be removed at the completion of the study season. Boott will not affix signage to any historic structures or cultural resources without additional prior consultation with NPS and NPS partners.



HDR BOOTT HYDRO, LLC.

Recreation Survey Location | Proposed Signage Location | Merrimack River Trail | NPS Canal Walkway Tour

RECREATION SURVEY

LOWELL HYDROELECTRIC PROJECT

FERC NO. 2790

MAY 2019

AMERICAN WHITEWATER
www.americanwhitewater.org

Robert A. Nasdor
Northeast Stewardship & Legal Director
365 Boston Post Road, Suite 250
Sudbury, MA 01776
617-584-4566
bob@americanwhitewater.org

May 17, 2019

Kevin Webb
Enel Green Power
100 Brickstone Square, Suite 300
Andover, MA 01810

Dear Kevin,

I write in response to your letter of May 7, 2019 regarding the proposed locations for field reconnaissance user intercept surveys for the Lowell Hydroelectic Project Recreation and Aesthetics Study. Thank you for reaching out to us to solicit our feedback in accordance with the requirements of the Study Plan Determination.

While the proposed locations will provide useful information to better understand aspects of current and future recreational use in the project area, these proposed locations will not collect information that will enable the Licensee and FERC to evaluate recreational demand for flows, access, and facilities that would support whitewater boating opportunity in the bypassed reach or in other areas that are impacted by project operations. There is well established history of whitewater boating on the Concord River during the spring freshet, demonstrating that there is strong interest in whitewater boating opportunity in the project area. Given the current lack of flows, access and information that would provide for whitewater boating opportunity in the bypassed reach, we do not believe that the survey locations will adequately collect information that will be useful for determining future whitewater boating use.

We recommend that the Licensee utilize the online survey instrument to collect information from whitewater boaters to evaluate the demand for whitewater boating opportunity at the project. In addition, the Licensee should incorporate into this study the results of the planned whitewater boating study that will evaluate the suitability of the bypassed reach for whitewater boating. We also recommend that the licensee collect user intercept surveys at the whitewater takeout on the Merrimack River below the confluence with the Concord River during weekends during the spring freshet in 2020 in order to include information from whitewater boaters in this study.

Thank you for considering this information in the development of the survey plan.

We look forward to working with you throughout the relicensing process.

Very truly yours,

Bob Nasdor
Northeast & Legal Stewardship Director
365 Boston Post Road, Suite 250
Sudbury, MA 01776
617-584-4566
bob@americanwhitewater.org

Scott, Kelsey

To: Jones, Scott
Subject: RE: [EXTERNAL] Lowell Project Recreation and Aesthetics Study

From: Bruins, Christine [mailto:christine_bruins@nps.gov]
Sent: Friday, June 14, 2019 10:15 AM
To: Jones, Scott <Scott.Jones@hdrinc.com>
Cc: Quiggle, Robert <Robert.Quiggle@hdrinc.com>; Webb, Kevin (EGP North America) <Kevin.Webb@enel.com>
Subject: Re: [EXTERNAL] Lowell Project Recreation and Aesthetics Study

Scott,

The City of Lowell is carrying out a number of bridge construction project this year and the crew is experiencing issues controlling water. There is a moderate probability the entire canal system will be drained down next week to diagnose and resolve the problem. City is being fined thousands of dollars daily while work cannot not resume and the water control issue cannot be delayed. Is there any chance you could rework your schedule for the following week?

Christine Bruins | Community Planner
Lowell National Historical Park
978.275.1726 (office) | 978.954.1011 (cell)

On Fri, Jun 14, 2019 at 7:52 AM Jones, Scott <Scott.Jones@hdrinc.com> wrote:

> Christine,
>
> Right now we are scheduled for Tuesday (6/18) as I am also scheduled to be on another project on Wednesday and Thursday of that week. This other work is flow and weather dependent so if anything changes I will certainly let you know. Thanks for the update.
>
> Regards,
>
> **Scott A. Jones, B.S., PWS**
> Senior Environmental Scientist/Project Manager
> **D** 315.414.2205 **M** 315.317.6680
> scott.jones@hdrinc.com
> hdrinc.com/follow-us

From: Bruins, Christine [mailto:christine_bruins@nps.gov]
Sent: Thursday, June 13, 2019 11:54 AM
To: Jones, Scott <Scott.Jones@hdrinc.com>
Cc: Quiggle, Robert <Robert.Quiggle@hdrinc.com>; Webb, Kevin (EGP North America) <Kevin.Webb@enel.com>
Subject: Re: [EXTERNAL] Lowell Project Recreation and Aesthetics Study

Scott,

Now that the Eastern Canal is drained for bridge work, there is a lot of trash visible on the canal bottom. This includes electronics and other hazardous items. Our staff are in a required 2-day occupational hazard training Tuesday and Wednesday next week. Would it at all be possible to meet in the field with you Thursday instead?

Christine Bruins | Community Planner

Lowell National Historical Park

978.275.1726 (office) | 978.954.1011 (cell)

On Wed, Jun 12, 2019 at 2:47 PM Bruins, Christine <christine_bruins@nps.gov> wrote:

> We can arrange to take you by trolley/boat to efficiently get you to and around most of the canal areas.
>
> **Christine Bruins | Community Planner**
>
> Lowell National Historical Park
>
> 978.275.1726 (office) | 978.954.1011 (cell)
>
> On Wed, Jun 12, 2019 at 2:44 PM Jones, Scott <Scott.Jones@hdrinc.com> wrote:

Christine,

Thank you for following up with us. I received your message but have been tied up this afternoon. I am still solidifying my plans for next week, but we envision either Tuesday or Wednesday and can certainly meet you/staff/partners during one of those afternoons. I should know for sure by the end of this week. Thank you also for the detailed map, it will certainly make our visit more efficient. I will let you know as soon as I confirm my schedule. Thanks again,

Scott A. Jones, B.S., PWS

Senior Environmental Scientist/Project Manager

D 315.414.2205 **M** 315.317.6680

scott.jones@hdrinc.com

hdrinc.com/follow-us

From: Bruins, Christine [mailto:christine_bruins@nps.gov]
Sent: Wednesday, June 12, 2019 2:34 PM
To: Webb, Kevin (EGP North America) <Kevin.Webb@enel.com>
Cc: Jones, Scott <Scott.Jones@hdrinc.com>; Quiggle, Robert <Robert.Quiggle@hdrinc.com>
Subject: Re: [EXTERNAL] Lowell Project Recreation and Aesthetics Study

Scott,

Celeste asked me to coordinate your trash survey next week with our staff and partners. I have gathered information from our staff on the areas where trash collects (see attached map). I am very interested in meeting with you to discuss the issues and problem areas. I'd also be interested in accompanying you and others for part of your field work. I'm collecting the availability of other staff and partners that would like to be involved in the study. Have you narrowed your field work within next week? My availability next week is as follows, will update you when I hear back from a couple of others.

Mon 6/17 - After 2 pm

Tue 6/18 - after 12 pm

Wed 6/19 before 2 pm

Thurs - anytime

Fri - anytime

Christine Bruins | Community Planner

Lowell National Historical Park

978.275.1726 (office) | 978.954.1011 (cell)

On Tue, Jun 4, 2019 at 10:35 AM Bernardo, Celeste <celeste_bernardo@nps.gov> wrote:

Christine, in my absence, are you okay with coordinating with ENEL on this? I am fine with them attending a management team or biweekly meeting, although biweekly would be better since there are more supervisors. Or else you can set up a separate meeting. Can you check with Paul and Kevin and see who on their staffs should participate?

Celeste

Celeste Bernardo

Superintendent

Lowell National Historical Park

978 275-1703

celeste_bernardo@nps.gov

Like us on Facebook

---------- Forwarded message ---------
From: **Jones, Scott** <Scott.Jones@hdrinc.com>
Date: Mon, Jun 3, 2019 at 2:50 PM

Subject: [EXTERNAL] Lowell Project Recreation and Aesthetics Study
To: Bernardo, Celeste <celeste_bernardo@nps.gov>
Cc: Kevin.Webb@enel.com <Kevin.Webb@enel.com>, Quiggle, Robert <Robert.Quiggle@hdrinc.com>

Celeste,

As part of the Lowell Recreation and Aesthetics Study, HDR is planning on visiting the Project the week of June 17-21, 2019 to survey and document waterborne trash as outlined in the study plan approved by the Federal Energy Regulatory Commission. In accordance with the approved plan, HDR is conducting this work in the spring of 2019 when higher flows typically push trash and debris downstream. Based on our meeting last week, HDR understands that NPS staff is very familiar with locations within the canal system where waterborne trash accumulates. In anticipation of our visit, HDR would like to coordinate with your office to identify these areas so that we can accurately document and record these locations.

Accordingly, we are hoping to meet with you or your staff to briefly review project maps prior to the start of fieldwork. If you could let me know a good time during the week of June 17 to meet with you or appropriate NPS staff, it would be greatly appreciated. Please note that NPS staff is also welcome to accompany us as we conduct this fieldwork (we expect the work to take about a day to complete).

Thank you,

Scott A. Jones, B.S., PWS

Senior Environmental Scientist/Project Manager

HDR

1304 Buckley Road, Suite 202
Syracuse, NY 13212
D 315.414.2205 **M** 315.317.6680
scott.jones@hdrinc.com

hdrinc.com/follow-us

Scott, Kelsey

From: Bernardo, Celeste <celeste_bernardo@nps.gov>
Sent: Wednesday, July 3, 2019 8:25 AM
To: Jones, Scott
Cc: Kevin.Webb@enel.com; Quiggle, Robert
Subject: Re: [EXTERNAL] Lowell Project Recreation and Aesthetics Study

That's great Scott. Thank you for the clarification. Look forward to assisting where we can.

Celeste

Celeste Bernardo
Superintendent
Lowell National Historical Park
978 275-1703
celeste_bernardo@nps.gov
Like us on Facebook

On Tue, Jul 2, 2019 at 7:48 PM Jones, Scott <Scott.Jones@hdrinc.com> wrote:

> Celeste,
> As the RSP and the FERC SPD indicates we will be surveying for water-borne trash after spring freshet, so with the unusual conditions this year we will be performing this component in 2020. Tomorrow we will be downloading the level loggers and installing recreational survey signs. Call or email me if you or Christine have any questions.
>
> Sent via the Samsung Galaxy S9+, an AT&T 5G Evolution capable smartphone

Scott, Kelsey

From:	Scott, Kelsey
Sent:	Friday, November 1, 2019 2:24 PM
To:	celeste_bernardo@nps.gov; christine_bruins@nps.gov; Paul_Fontaine@nps.gov; kevin_coffee@nps.gov; laurel_racine@nps.gov; peter_reitchel@nps.gov; kevin_mendik@nps.gov; duncan_hay@nps.gov; Emily.Byrne@mail.house.gov; darryl.forgione@mass.gov; patrice.kish@mass.gov; thomas.m.walsh@mass.gov; william.cooksey@mass.gov; peter.hoffmann@mass.gov; dtradd@lowellma.gov; KKeefeMullin@lowellma.gov; cthomas@lowellma.gov; cclancy@lowellma.gov; jwinward@lowellma.gov; CRicker@lowellma.gov; chayes@lowellma.gov; CMcCall@lowellma.gov; scerand@hotmail.com; greenesh@comcast.net; jcalvin@lowelllandtrust.org; ffaust@edgegroupinc.com
Cc:	Quiggle, Robert; Webb, Kevin (EGP North America); elise.anderson@enel.com
Subject:	Lowell Hydroelectric Project (FERC No. 2790) Study Workshop
Attachments:	November 2019_Lowell Hydro Project Workshop Agenda.pdf

Dear Stakeholders:

Boott Hydropower, LLC (Boott) is pursuing a new license from the Federal Energy Regulatory Commission (FERC) for the continued operation of the Lowell Hydroelectric Project (FERC No. 2790)(Project) located along the Merrimack River. In support of Project relicensing, Boott is conducting a Recreation and Aesthetics Study, a Historically Significant Waterpower Equipment Study, and a Water Level and Flow Effects on Historic Resources Study, as approved in FERC's March 13, 2019 Study Plan Determination for the Project. Boott intends to hold a two-day Lowell Hydroelectric Project Study Workshop (Workshop) with interested stakeholders to address data needs and conduct a Project site visit related to the above studies.

The Workshop will be held in Lowell, MA over two days in November 2019. The first day will focus on stakeholder consultation, information gathering, and data needs for the three studies mentioned above. Boott anticipates this first day will take place from 9am-4pm in Lowell, MA. Additional details regarding the meeting space to follow. The second day will consist of a site visit to target specific Project facilities associated with the studies.

Boott is proposing the following dates for the two-day Workshop:

November 12-13, 2019
November 13-14, 2019
November 14-15, 2019
November 19-20, 2019

Please notify Boott of the dates you can attend the Workshop by completing the poll here: https://www.surveymonkey.com/r/YQFX7LD . Boott has developed the attached Lowell Hydroelectric Project Study Workshop Agenda. In order to facilitate the scheduling of the Workshop, Boott is asking that all interested stakeholders complete the poll by November 6, 2019. If you have questions or need additional information, please contact Kevin Webb, Boott Hydro Licensing Manager, at (978) 935-6039 or via email at Kevin.Webb@enel.com.

Thank You –

Kelsey Scott, MS
Assistant Regulatory Specialist

HDR

1304 Buckley Road, Suite 202
Syracuse, NY 13212
D 315.414.2206 **M** 315.706.5176
kelsey.scott@hdrinc.com
hdrinc.com/follow-us

Agenda

Project:	Lowell Hydroelectric Project (FERC No. 2790)
Date/Time:	TBD
Location:	Lowell National Historic Park, Lowell MA
Subject:	**Lowell Hydroelectric Project Study Workshop**

Boott Hydropower, LLC (Boott), a subsidiary of Enel Green Power North America, Inc., is the Licensee and owner of the 20.2 megawatt Lowell Hydroelectric Project (FERC No. 2790) (Project). The Project is located on the Merrimack River in Middlesex County, Massachusetts, and in Hillsborough County, New Hampshire. The existing license for the Project was issued by the Federal Energy Regulatory Commission (FERC or Commission) with an effective date of May 1, 1973. The existing license expires on April 30, 2023. Accordingly, Boott is pursuing a new license for the Project pursuant to the Commission's Integrated Licensing Process, as described at 18 Code of Federal Regulations Part 5.

In support of Project relicensing, Boott is proposing to hold a two-day study workshop in Lowell, MA to consult with the National Park Service (NPS), Massachusetts Department of Conservation and Recreation (MADCR), City of Lowell (City), and other partners regarding certain studies approved in the Commission's March 13, 2019 Study Plan Determination for the Project. As described in the approved study plan, Boott is seeking information from the NPS, MADCR, and other partners regarding the Recreation and Aesthetics Study, the Historically Significant Waterpower Equipment Study, and the Water Level and Flow Effects on Historical Resources Study. The proposed two-day workshop will be an opportunity for consulting parties to share information and to identify the specific focus for field activities.

Day One: Data Needs and Information Gathering

The first day of the proposed workshop is intended to allow Boott, the NPS, MADCR, City, and other participating parties to discuss data needs and review available documentation. A proposed agenda for this day one of the workshop is presented below.

1. Introduction

- Welcome and introduction
- Overview and status of FERC relicensing process

2. Recreation and Aesthetics Study

Study-specific Data Needs and Information Gathering

- Recreation opportunities and access along the canal system;
- Future use or planning documents that address anticipated or desired changes to the Lowell National Historic Park and Lowell Heritage State Park (e.g., The Foundation Report, or 5-year and 10-year plans);
- Documentation of any reoccurring public safety issues or incidents within the parks associated with the canal infrastructure related to public recreation;
- Annual maintenance schedules for the canal system;
- Management or operations plans for the parks; and
- Annual use records.

3. Historically Significant Waterpower Equipment Study

Study-specific Data Needs and Information Gathering

- Historically significant waterpower equipment owned and operated by Boott Hydropower of interest to the NPS for potential future interpretation, exhibition, or as scrap equipment to maintain and operate other historic machinery;
- Engineering reports, drawings, and/or photographs related to historically significant waterpower equipment owned and operated by Boott Hydropower of interest to the NPS; and
- Components of historically significant waterpower equipment owned and operated by Boott Hydropower that will require photography and documentation.

4. Water Level and Flow Effects on Historic Resources Study

Study-specific Data Needs and Information Gathering

- Engineering reports or evaluations of historic canal structures, including documentation of previous maintenance and/or repairs related to canal water levels;
- Descriptions and/or photographs of properties that have been previously affected by canal operations; and
- Engineering and architectural drawings, maintenance records, and structural modifications of the Great River Wall.

5. Action Items and Next Steps

<u>Day Two: Site Visit</u>

Day two of the proposed workshop is focused on a site visit at the Project. The purpose of the site visit is to view locations identified during day one of the workshop, including:

- Areas of potential recreation enhancements and potential recreational access areas;
- Historically significant waterpower equipment selected by the NPS for documentation, including specific equipment to be photographed;
- Canal features that have been previously impacted by flows and water levels; and
- Areas along the canal system where waterborne trash collects.

Scott, Kelsey

To: Racine, Laurel
Subject: RE: [EXTERNAL] Lowell Hydroelectric Project (FERC No. 2790) Study Workshop

From: Racine, Laurel [mailto:laurel_racine@nps.gov]
Sent: Monday, November 4, 2019 8:09 AM
To: Scott, Kelsey <Kelsey.Scott@hdrinc.com>
Subject: Re: [EXTERNAL] Lowell Hydroelectric Project (FERC No. 2790) Study Workshop

Kelsey,
I'm writing because the NPS blocked my access to your poll. My participation would be most useful for the first day, not the site visits. Days I'm available for the day 1 workshop are November 12 or November 13, so either of the first two options are good for me. Thanks.
Laurel

Laurel A. Racine, Chief of Cultural Resources
Lowell National Historical Park
67 Kirk Street
Lowell, MA 01852

Desk: 978-970-5055
Cell: (978) 423-3081

FIND YOUR PARK

On Fri, Nov 1, 2019 at 2:24 PM Scott, Kelsey <Kelsey.Scott@hdrinc.com> wrote:

> Dear Stakeholders:
>
> Boott Hydropower, LLC (Boott) is pursuing a new license from the Federal Energy Regulatory Commission (FERC) for the continued operation of the Lowell Hydroelectric Project (FERC No. 2790)(Project) located along the Merrimack River. In support of Project relicensing, Boott is conducting a Recreation and Aesthetics Study, a Historically Significant Waterpower Equipment Study, and a Water Level and Flow Effects on Historic Resources Study, as approved in FERC's March 13, 2019 Study Plan Determination for the Project. Boott intends to hold a two-day Lowell Hydroelectric Project Study Workshop (Workshop) with interested stakeholders to address data needs and conduct a Project site visit related to the above studies.

The Workshop will be held in Lowell, MA over two days in November 2019. The first day will focus on stakeholder consultation, information gathering, and data needs for the three studies mentioned above. Boott anticipates this first day will take place from 9am-4pm in Lowell, MA. Additional details regarding the meeting space to follow. The second day will consist of a site visit to target specific Project facilities associated with the studies.

Boott is proposing the following dates for the two-day Workshop:

November 12-13, 2019

November 13-14, 2019

November 14-15, 2019

November 19-20, 2019

Please notify Boott of the dates you can attend the Workshop by completing the poll here: https://www.surveymonkey.com/r/YQFX7LD . Boott has developed the attached Lowell Hydroelectric Project Study Workshop Agenda. In order to facilitate the scheduling of the Workshop, Boott is asking that all interested stakeholders complete the poll by November 6, 2019. If you have questions or need additional information, please contact Kevin Webb, Boott Hydro Licensing Manager, at (978) 935-6039 or via email at Kevin.Webb@enel.com.

Thank You –

Kelsey Scott, MS

Assistant Regulatory Specialist

HDR

1304 Buckley Road, Suite 202
Syracuse, NY 13212

D 315.414.2206 **M** 315.706.5176
kelsey.scott@hdrinc.com

hdrinc.com/follow-us

Scott, Kelsey

From: Hayes, Christopher <chayes@lowellma.gov>
Sent: Monday, November 4, 2019 9:59 AM
To: Scott, Kelsey
Cc: Ricker, Claire V.; McCall, Christine
Subject: RE: Lowell Hydroelectric Project (FERC No. 2790) Study Workshop

Follow Up Flag: Follow up
Flag Status: Flagged

Hi, Kelsey,

Should I forward this to other potential interested stakeholders, or is the invitation limited to this list?

Thanks so much,
-Chris

Christopher Glenn Hayes | *Neighborhood Planner*
The City of Lowell | Department of Planning and Development
50 Arcand Drive | Lowell, MA 01852
t: 978.674.1405 | f: 978.970.4262
http://www.lowellma.gov

LOWELL ***Alive. Unique. Inspiring.***

From: Scott, Kelsey [mailto:Kelsey.Scott@hdrinc.com]
Sent: Friday, November 01, 2019 2:24 PM
To: celeste_bernardo@nps.gov; christine_bruins@nps.gov; Paul_Fontaine@nps.gov; kevin_coffee@nps.gov; laurel_racine@nps.gov; peter_reitchel@nps.gov; kevin_mendik@nps.gov; duncan_hay@nps.gov; Emily.Byrne@mail.house.gov; darryl.forgione@mass.gov; patrice.kish@mass.gov; thomas.m.walsh@mass.gov; william.cooksey@mass.gov; peter.hoffmann@mass.gov; Tradd, Diane; Keefe Mullin, Kara; Thomas, Craig; Clancy, Christine; jwinward@lowellma.gov; Ricker, Claire V.; Hayes, Christopher; McCall, Christine; scerand@hotmail.com; greenesh@comcast.net; jcalvin@lowelllandtrust.org; ffaust@edgegroupinc.com
Cc: Quiggle, Robert; Webb, Kevin (EGP North America); elise.anderson@enel.com
Subject: Lowell Hydroelectric Project (FERC No. 2790) Study Workshop

Dear Stakeholders:

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Thank You –

Kelsey Scott, MS
Assistant Regulatory Specialist

HDR
1304 Buckley Road, Suite 202
Syracuse, NY 13212
D 315.414.2206 **M** 315.706.5176
kelsey.scott@hdrinc.com
hdrinc.com/follow-us

Scott, Kelsey

To: Scott, Kelsey
Subject: RE: Update - Lowell Hydroelectric Project (FERC No. 2790) Study Workshop

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From: Scott, Kelsey
Sent: Thursday, November 21, 2019 4:42 PM
To: 'celeste_bernardo@nps.gov' <celeste_bernardo@nps.gov>; 'christine_bruins@nps.gov' <christine_bruins@nps.gov>; 'Paul_Fontaine@nps.gov' <Paul_Fontaine@nps.gov>; 'kevin_coffee@nps.gov' <kevin_coffee@nps.gov>; 'laurel_racine@nps.gov' <laurel_racine@nps.gov>; 'peter_reitchel@nps.gov' <peter_reitchel@nps.gov>; 'kevin_mendik@nps.gov' <kevin_mendik@nps.gov>; 'duncan_hay@nps.gov' <duncan_hay@nps.gov>; 'Emily.Byrne@mail.house.gov' <Emily.Byrne@mail.house.gov>; 'darryl.forgione@mass.gov' <darryl.forgione@mass.gov>; 'patrice.kish@mass.gov' <patrice.kish@mass.gov>; 'thomas.m.walsh@mass.gov' <thomas.m.walsh@mass.gov>; 'william.cooksey@mass.gov' <william.cooksey@mass.gov>; 'peter.hoffmann@mass.gov' <peter.hoffmann@mass.gov>; 'dtradd@lowellma.gov' <dtradd@lowellma.gov>; 'KKeefeMullin@lowellma.gov' <KKeefeMullin@lowellma.gov>; 'cthomas@lowellma.gov' <cthomas@lowellma.gov>; 'cclancy@lowellma.gov' <cclancy@lowellma.gov>; 'jwinward@lowellma.gov' <jwinward@lowellma.gov>; 'CRicker@lowellma.gov' <CRicker@lowellma.gov>; 'chayes@lowellma.gov' <chayes@lowellma.gov>; 'CMcCall@lowellma.gov' <CMcCall@lowellma.gov>; 'scerand@hotmail.com' <scerand@hotmail.com>; 'greenesh@comcast.net' <greenesh@comcast.net>; 'jcalvin@lowelllandtrust.org' <jcalvin@lowelllandtrust.org>; 'ffaust@edgegroupinc.com' <ffaust@edgegroupinc.com>; 'Euris Gonzalez (DCR) (Euris.Gonzalez@mass.gov)' <Euris.Gonzalez@mass.gov>
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Cc: 'Anderson, Elise (EGP North America)' <elise.anderson@enel.com>; Webb, Kevin (EGP North America) <Kevin.Webb@enel.com>; Quiggle, Robert <Robert.Quiggle@hdrinc.com>
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https://doodle.com/poll/dp2qb9232aq66awg

In order to facilitate the scheduling of the Workshop, Boott is asking that all interested stakeholders complete the poll by November 13, 2019. If you have questions or need additional information, please contact Kevin Webb, Boott Hydro Licensing Manager, at (978) 935-6039 or via email at Kevin.Webb@enel.com.

Thank You –

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Scott, Kelsey

From:	Scott, Kelsey
Sent:	Monday, December 9, 2019 3:55 PM
To:	'celeste_bernardo@nps.gov'; 'christine_bruins@nps.gov'; 'Paul_Fontaine@nps.gov'; 'kevin_coffee@nps.gov'; 'laurel_racine@nps.gov'; 'peter_reitchel@nps.gov'; 'kevin_mendik@nps.gov'; 'duncan_hay@nps.gov'; 'Emily.Byrne@mail.house.gov'; 'darryl.forgione@mass.gov'; 'patrice.kish@mass.gov'; 'thomas.m.walsh@mass.gov'; 'william.cooksey@mass.gov'; 'peter.hoffmann@mass.gov'; 'dtradd@lowellma.gov'; 'KKeefeMullin@lowellma.gov'; 'cthomas@lowellma.gov'; 'cclancy@lowellma.gov'; 'jwinward@lowellma.gov'; 'CRicker@lowellma.gov'; 'chayes@lowellma.gov'; 'CMcCall@lowellma.gov'; 'scerand@hotmail.com'; 'greenesh@comcast.net'; 'jcalvin@lowelllandtrust.org'; 'ffaust@edgegroupinc.com'; 'Euris Gonzalez (DCR) (Euris.Gonzalez@mass.gov)'
Cc:	'Anderson, Elise (EGP North America)'; 'Webb, Kevin (EGP North America)'; Quiggle, Robert
Subject:	RE: Update - Lowell Hydroelectric Project (FERC No. 2790) Study Workshop
Attachments:	December 2019 Lowell Study Workshop Agenda.pdf

Dear Stakeholders:

The agenda is attached for the upcoming December 18 – 19, 2019 Study Workshop & Site Visit for the Lowell Hydroelectric Project. Boott appreciates the opportunity to consult with stakeholders and we look forward to seeing you next week.

Should you have any questions about the Study Workshop, please contact me at the phone number or email address below, or contact Mr. Kevin Webb, Enel Hydro Licensing Manager, at 978-935-6039 or via email at Kevin.Webb@enel.com.

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Agenda

Project:	Lowell Hydroelectric Project (FERC No. 2790)
Subject:	Lowell Project Study Workshop & Site Visit
Date:	December 18 – 19, 2019
Location:	Lowell National Historical Park Visitor Center (246 Market Street), Lowell, MA.

Pursuant to the Federal Energy Regulatory Commission's (FERC or Commission) Study Plan Determination (SPD) for the relicensing of the Lowell Hydroelectric Project (FERC No. 2790) (Project), Boott Hydropower, LLC (Boott) will conduct a Recreation and Aesthetics Study, a Water Level and Flow Effects on Historic Resources Study, and a Historically Significant Waterpower Equipment Study (collectively Studies). This Study Workshop to consult with stakeholders regarding these Studies will be held from 9:00 AM until 4:00 PM at the Lowell National Historical Park Visitor Center (246 Market Street) in Lowell, MA. The adjacent parking at 304 Dutton Street is free. On the following day after the Study Workshop, stakeholders are invited to participate in a site visit of the Project to consult on the field portion of the Studies, which is expected to end at noon. The proposed agenda for the Study Workshop is as follows:

Welcome and Introductions.......... 9:00 AM – 9:30 AM

Discussion of FERC Relicensing and ILP Study Process.......... 9:30 AM – 10:00 AM

Break..........10:00 AM – 10:15 AM

Recreation and Aesthetics Study Needs.......... 10:15 AM – 11:15 AM

Water Level and Flow Effects on Historic Resources Study Needs.......... 11:15 AM – 12:00 PM

Lunch Break.......... 12:00 PM – 1:00 PM

Historically Significant Waterpower Equipment Study Needs.......... 1:00 PM – 2:00 PM

Open discussion/Break.......... 2:00 PM – 3:00 PM

Upcoming ILP Schedule (2020-2021).......... 3:00 PM – 3:30 PM

Action Items and Next Steps.......... 3:30 PM – 4:00 PM

Scott, Kelsey

From:	Bruins, Christine <christine_bruins@nps.gov>
Sent:	Thursday, December 19, 2019 9:22 AM
To:	Webb, Kevin (EGP North America); Scott, Kelsey; Quiggle, Robert
Cc:	Mendik, Kevin; Duncan Hay
Subject:	Lowell NHP Exotic Species Treatment Schedule - Vegetation Mgmt
Attachments:	2018.9.11 EXOTIC SPECIES TREATMENT LOWELL.docx

Hi folks,

Thank you so much for hosting a meeting with the canal stewardship partners. I'm attaching a document from our maintenance department which outlines the exotic species that exist along the canals and treatment schedules.

Christine Bruins | Community Planner
Lowell National Historical Park
978.275.1726 (office) | 978.954.1011 (cell)

EXOTIC SPECIES TREATMENT CALENDAR FOR LOWELL NATIONAL HISTORICAL PARK

Prepared by Lars Boyd, Sept 11, 2018.

OUTLINE

I. PURPOSE

This document provides a series of tables and exotic plant management information to aid in organizing of a 2019 treatment schedule for Lowell NHP.

This document will present an appropriate species to be focused on in a park for the given, and a potential control method. Often other species may be treated at the same time as the target species if the appropriate treatment method is able to be performed concurrently. For foliar spraying, a generic herbicide mixture can be used to treat a broad spectrum of species within the same day. A generic herbicide mixture can be applied to multiple species for basal bark and cut stem/stump treatments as well. Refer to the individual species treatment guides (Table 6-13) to determine if the application method is appropriate within the given time window before treating other species in the area with herbicide.

II. TARGET SPECIES FOR 2019 LOWELL NHP

Table 1: Reported Target Species W/ Locations for FY 2019

Species	NCW	BSS	FG	SW/JS	DSC&T	KP	VCC	TT	KSH	WCW
Ailanthus altissima (Tree of Heaven)	X		X		X					X
Alliaria petiolata (Garlic mustard)		X	X	X		X			X	
Celastrus orbiculatus (Asiatic Bittersweet)	X		X		X	X				X
Convolvulus arvensis (Bind Weed)										X
Cynanchum louiseae (Black Swallow-wort)	X			X	X	X	X	X		X
Fallopia japonica (Japanese Knotweed)		X		X	X					
Lythrum salicaria (Purple Loosestrife)	X			X						X
Rosa multiflora (Multiflora Rose)										X

NCW- Northern Canal Walkway
BSS- Black Smith Shop
FG- Francis Gate
SW/JS- Swamp Locks/Jackson St
DSC&T- Dutton St Canal & Tracks
KP- Kerouac Park
VCC- Visitor Center Courtyard
TT- Tremont St Tracks
KSH- Kirk St Headquarters
WCW- Western Canal Walkway

III. TENTATIVE CALENDAR FOR LOWELL NHP EXOTIC PLANT REMOVAL

Table 2: Foliar Spray Treatment Sequencing

Species	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
Rosa multiflora (Multiflora Rose)			X	X					
Ailanthus altissima (Tree of Heaven)				X	X	X			
Cynanchum louiseae (Black Swallow-wort)				X	X				
Convolvulus arvensis (Bindweed)					X	X	X		
Fallopia japonica (Japanese Knotweed)						X	X		
Lythrum salicaria (Purple Loosestrife)						X			
Alliaria petiolata (Garlic mustard)							X	X	
Celastrus orbiculatus (Asiatic Bittersweet)								X	X

IV. BEST MANAGEMENT PRACTICES (ADOPTED FROM THE EXOTIC SPECIES TREATMENT CALENDAR FOR BOSTON METROPOLITAN PARKS by Lyndon Langthorne)

Non-chemical Treatment

Non-chemical treatment, when appropriate for the target species, should be attempted before chemical treatment. In most situations, chemical treatment can be made more effective when applied in conjunction with non-chemical management strategies. Non-chemical management strategies are generally labor intensive, but can be performed in most areas, including areas where chemical treatment would not be advisable.

Table 3. Non-chemical Treatment Methods

Hand pulling	Manual removal of top growth of plant, and as much of the root system as possible. Extensive, deep, and large root systems are not removable by hand. Hand pulling will prevent the formation of seed pods if consistently implemented throughout the growing season. This method is often not effective in managing regenerative species. Rhizomatous species are not generally manageable through this strategy alone.
Digging	Manual or mechanical removal of root system when hand pulling alone is not sufficient in removing the root system. Species that re-

	sprout from roots must have the root system removed. Digging is labor intensive. This method is not viable when managing regenerative plants with extensive, deep, or large roots. Digging disturbs the soil, encouraging colonization by other exotic species.
Cutting	Manual removal of the entire top growth of the plant by cutting the stem close to the ground. Plant matter removed by cutting may, depending on the species and desired conditions, be allowed to compost (either where it is cut or moved to another location), or destroyed to prevent reshooting of roots. Cutting can be effective on annuals or biennials if done before seeding, but in most perennial species, cutting alone is not capable of achieving control. Stump grinding of larger, woody stumps can prevent reshooting (e.g. *F. alnus*, *R. cathartica*, *A. altissima*). Herbicide can be applied to the cut surface to destroy the roots and prevent reshooting.
Flower clipping / Seed-heading	Manual removal of flowers or seed heads to prevent seeding or seed spread, but not removal of the plant top growth; seeds collected are destroyed. This method will limit the ability of the plant to spread through seeding, but will not prevent vegetative spread by the root system. Some plants do not rely on seeds as the primary vector of spread (e.g. *F. japonica*).
Mulching / Mats / ”Buckthorn Bags”	Covering of a disturbed or treated area to limit the ability of exotic species to grow and recolonize an area. Mulch can be layered over soil, and possible supplemented with a permeable material, like cloth or paper, to limit the ability of exotics to reshoot while also providing an area that can be used for planting. Reshooting may still occur with mulch, and monitoring is advisable. Mats of rubber or black plastic can be layered on the soil as an impervious surface. This surface cannot be used for planting, but is more likely to prevent any regrowth. If the mats are in an area of direct or partial sunlight, the heat collected will kill covered roots. “Buckthorn bags” can be placed over stumps of *F. alnus* and *R. cathartica* that are over two inches in diameter. Left in place for two years, these bags will prevent regeneration and destroy the root system of the plant.
Mowing	Mechanical removal of top growth of plants. Able to be applied quickly to large areas. Mowing is less precise than most manual methods, and is most viable on land that is already managed land. Will not destroy the root system of most plants, but often stresses the plant and prevents seed production if done consistently. Herbicide applied after mowing will often be more effective, either applying immediately after mowing as cut stem/stump treatment, or upon regrowth as a foliar spray.

Stump grinding	Perennial shrubs and trees can have their stumps ground to prevent reshooting.

Seeds forming on exotic plants should always be removed when observed. Removal of seeds can be a valuable management strategy in areas of lower priority, or where other management strategies are inadvisable. Seed removal will not disrupt existing plants, but will limit growth and spread of these populations. Seed removal also prevents exotics from further contributing to the soil seed bank, all the viable seeds existing within the soil of an area. Seeds of exotics should be burned or bagged and disposed of in a landfill to prevent further contamination.

Bare patches of soil, particularly those remaining after soil is disturbed by digging or hand pulling, is vulnerable to colonization by new exotic species. To mitigate this threat, new plants and grasses should be added to bare areas whenever possible. If a bare patch was the site of chemical treatment that will be repeated the following year, seed of an inexpensive annual ryegrass can be planted to limit the cost of further chemical treatments.

Chemical Treatment

Use pesticides at rates recommended by the label, and never exceed labeled rates. Mitigate damage to other plants and ecosystems by taking care for herbicide drift. Only apply herbicides on calm, dry days, and never any closer to standing water than is specified on the label. Herbicide applicators should always be properly fitted with Personal Protective Equipment (PPE) required by label, which represents the **minimum** PPE required for use. When applying chemicals, it is advisable to add a dye to the mix, unless otherwise stipulated, to better mark which plants have been treated. Dyes also allow contaminated gear to be easily identified for safety reasons.

Table 4. Chemical Treatment Method Overview

Foliar Spray	Broadcast or spot application of herbicide with a sprayer targeting foliage of species, wetting the leaves with herbicide to be absorbed into the root system. Apply to intact, green leaves. This is often the most efficient herbicide application method. Lower concentrations are used with foliar spray than other application methods. Foliar spray has the greatest potential to unintentionally damage surrounding plants, and may not be preferred for this reason. Foliar application is best for treating large, dense stands of invasive plants where risk of damaging surrounding plants can be minimized. When spraying, herbicide should wet leaves without dripping, as excessive spraying can harm non-target species. The extent of the application depends on the size of the area being treated. Spot spraying is application of herbicide in one location,

	generally to one plant. This type of application minimizes damage to surrounding plants. Broadcast application is more extensive than spot spraying for heavier infestations. Foliar spraying should not be performed on wet weather days as any herbicide may not be absorbed into plants, instead being washed away as runoff. Foliar spraying should not be performed on days when wind speeds are greater than 5 mph to prevent pesticide drift. Foliar spraying should also not be performed in areas where damage to non-target species is a concern. Large trees should not be treated by foliar spray.
Cut Stem/Stump	Application of herbicide either by brush or spray bottle to a cut surface to be absorbed into the root system. After cut, herbicide should be applied to the cut surface immediately for best effect, and not more than 15 minutes later; this time limit is particularly important for the best absorption of water-based herbicides, and oil based herbicides can be applied longer after cutting. Cut stump applications are more effective than basal bark on woody stems greater than 5” diameter, and thick barked species.
Basal Bark	Application of herbicide to the bark with a sprayer, from surface to 12-18 inches above the root collar, to be absorbed into root system. Useful in precisely controlling woody species. Treatment can be performed while herbaceous species are dormant. Uses oil-based herbicides that penetrate bark, mixed with a carrier (basal oil). The entire surface area of the trunk should be coated within the 12-18 inch range, and rough bark requires more spray. Application should be stopped short of runoff.
Stem Injection	Application of herbicide into the stems of hollow plants via specialized injection equipment. This method ensures absorption of the herbicide into the roots of the plant, and limits exposure to and contamination by pesticides.
Hand Wicking (“Glove of death”)	Application of herbicide to the leaf surface with an absorbent cotton glove coated in herbicide layered over a chemical resistant glove. Small spray bottles are used to wet the fingertips and palm of the glove, which is then wiped directly on the plant, coating the leaves. This method is precise, faster than cut stem/stump treatment, and limits exposure of herbicide to other plants. Cuff the ends of the glove to prevent dripping. Gloves used for this method will becomes saturated with herbicide and should not be stored with other equipment.

Herbicides

Use with caution.
Be aware of local regulations before use.
Always read the label thoroughly before use, and follow all requirements (including PPE, site location, concentration, etc.).

Chemicals should be chosen based on a variety of factors, including: effectiveness on target species, environmental impact (toxicity to animals, persistence in soil, activity in water), and safety. The correct herbicide should be chosen for the site, and herbicide labelling will list use sites.

Table 5. General Overview of Commonly Used Herbicides

Glyphosate	(*Rodeo®*)	Glyphosate is a non-selective systemic post-emergent herbicide, damaging to most plants, including broadleaf plants and grasses. Pure glyphosate is generally environmentally safe, essentially non-toxic to mammals and fish, and mildly toxic to birds. Glyphosate is quickly absorbed into soil, and has negligible lasting environmental effects, and leaching to other areas is not expected to occur. Glyphosate has a short half-life in soil and water. Glyphosate may or may not be metabolized by plants, and potentially persists in plants where it was applied, including in the roots. Be aware that not all glyphosate herbicides are registered for aquatic use, and some formulations are contain adjuvants that make them highly toxic to aquatic life. If using in an aquatic area, be sure to use a product that omits these toxic ingredients (eg. *Rodeo®*). Pure glyphosate has low human toxicity, but is often made more hazardous to humans with adjuvants that disseminate the chemical into plants. Causes significant eye irritation.
Triclopyr amine	(*Garlon® 3A*)	Triclopyr is a selective systemic post-emergent herbicide. It is relatively non-toxic to humans and terrestrial mammals, and some formulations are registered for aquatic use. Triclopyr should generally be used in areas where it is desired to protect surrounding grasses and sedges. Triclopyr amine is preferred for foliar applications over triclopyr ester.

Triclopyr ester	(*Garlon® 4 Ultra)*	Triclopyr is a selective systemic post-emergent herbicide. It is relatively non-toxic to humans and terrestrial mammals. It is not registered for aquatic use. Triclopyr ester is only recommended as a foliar spray prior to full leaf-out of the target plant. After leaf out, other herbicides would be preferred. Good for basal barking when mixed with a basal oil. Cannot be used within 35 ft. of wetland.
Imazapyr	(*Plateau®, Habitat®*)	Imazapyr is a non-selective, systemic, pre- and post-emergent herbicide. Imazapyr formulations can be registered for aquatic use. Imazapyr has a low human toxicity in skin contact or if ingested. Harmful if inhaled and may cause irreversible eye damage.

A good strategy for foliar application efficiency is to mix a general formulation of triclopyr amine and glyphosate. This mixture can be applied on a wide spectrum of species, and allow more treatment to occur during a single application session.

V. BRIEF DESCRIPTION OF EACH TARGET SPECIES (ADOPTED FROM THE EXOTIC SPECIES TREATMENT CALENDAR FOR BOSTON METROPOLITAN PARKS by Lyndon Langthorne)

Ailanthus altissima (Tree of Heaven)

Description

https://www.extension.iastate.edu/forestry/iowa_trees/trees/tree_of_heaven.html

A. altissima is a large non-native short-lived deciduous perennial tree. The trunk grows up to eighty feet tall, and is straight and gray, with smooth to bumpy bark that fissures with age. Leaves are silvery-green and pinnately compound, with alternate leaflets on one to four foot leaf veins. Leaves produce a foul smell if crushed. Five-petaled flowers are small, yellow-green, and grow in dense clusters. Reddish-brown seed pods are produced in late summer, and are twisted like helicopters, each containing one seed

The tree is resilient, and will grow in a wide range of environments, including urban where the root system can disrupt hardscaping and cause damage to structures. *A. altissima* crowds out native trees quickly with its ability to spread quickly to new areas. The roots are toxic and may limit growth potential for native plants.

Non-chemical Treatment

Seedlings and root suckers should be dug consistently to control spread. Any remaining stumps and roots will continue to generate new shoots. Cutting and mowing alone are not an effective form of management, and may increase density and spread potential. Mechanical measures that remove top growth are most effective when followed up by chemical treatment.

Chemical Treatment

Foliar spraying is the most common form of treatment for *A. altissima*] Foliar treatment best applied between full canopy and fall color. Foliar application cannot be applied to larger trees, and is most effective in treating dense stands of saplings.

Cut stump treatment is a more labor intensive method, but may be necessary in treating larger trees. After cutting tree, immediately apply herbicide to cut surface. Cutting alone will lead to increased suckering, and should be mitigated with herbicide application

Basal bark used for follow up treatments or small infestations. Root injury is maximized when used after full canopy to fall color. Following basal bark treatment, the tree is left in place to be cut at a later time. *A. altissima* may require multiple applications.

To maximize root damage, any chemical treatment should be performed within the time window where the tree has developed its full canopy and before the leaves have turned to fall colors.

Table 6: *A. altissima* Treatment Guide

Application Method	Herbicide	Brand	Selectivity	Concentration	Time	Notes
Non-chemical Treatment						
Hand pulling					Apr - Jun	Seedlings and saplings
Chemical Treatment						
Foliar	Glyphosate	*Rodeo®*	Non-selective	2%	Late Jun - Aug	Surfactant
	Triclopyr	*Garlon® 3A*	Selective	2%		
		Garlon® 4 Ultra		1.5%		
	Imazapyr	*Habitat®*	Non-selective	1%		
Cut stem/stump	Triclopyr	*Garlon® 3A, Garlon® 4 Ultra*	Selective	50%	Late Jun - Aug	
Basal bark	Triclopyr ester	*Garlon® 4 Ultra*	Selective	20-25%[1]	Mar - Oct[1]	Basal oil

Notes:
1. Contributed by BM

***Alliaria petiolata* (Garlic Mustard)**

Description

https://www.michigan.gov/invasives/0,5664,7-324-68002_71240_73853-379483--,00.html

A. petiolata is a non-native biennial herb. First year plants are immature and resemble many native plants, such as *Viola*. In its first year leaves stay green all year long. *A. petiolata* is much easier to identify in the second year after bolting. In the second year, the leaves take on a garlicky odor and the stem forms up to three feet in height. Leaves are alternate, sharply toothed, and triangular. Flowers bloom early in the season and are white with four petals. Seed pods develop atop the stem and burst to project seeds up to five feet from the plants, leading to rapid expansion of patches. *A. petiolata* produces more seeds in wet environments.

A. petiolata populations can grow rapidly when unchecked. Roots of *A. petiolata* have an allelopathic effect on native plants, limiting growth potential in areas of infestation. The plant provides no benefits as a food source for native animal species.

Non-chemical Treatment

Stems are attached to a single root, and plants can be removed entirely by pulling, particularly in moist and loose soil. Plants can also be dug. These methods can be an effective for control, but disturbs soil and leaves bare patches, which can be recolonized. Roots must be removed completely to prevent resprouting and are easily broken.

Mowing or cutting of *A. petiolata* in its second year after bolting can also be an effective management strategy, destroying plants, especially those already under stress, and preventing seed development.

Clipping and removing of flowers will prevent the formation of new seeds, and will reduce population growth rates.

These methods must be repeated over many years until seed bank is depleted. Size of the seed bank depends on the age of the population. When utilizing these methods, it is important to clean any equipment used or worn in order to prevent seed spread.

Chemical Treatment

Foliar spray is the recommended method for chemical treatment of A. petiolata, if chemical treatment is deemed necessary. Leaves should be cleaned of debris prior to application to ensure absorption into the plant. Glyphosate and triclopyr amine application to rosettes is most effective in late fall, and is best used only on dense stands where non-chemical treatment would be prohibitively laborious. Triclopyr amine can be used to avoid damaging surrounding grasses.

Table 7. *A. petiolata* Treatment Guide

Method	Herbicide	Brand	Selectivity	Concentration	Time	Notes
Non-chemical Treatment						
Hand pulling					Apr - Oct	
Mowing					Aug - Oct	Most effective if plants are already under stress (drought, etc.)
Flower clipping					Apr - Jun	
Chemical Treatment						
Foliar spray	Glyphosate	*Rodeo®*	Non-selective	0.5-1%[1]	Sep - Oct	
	Triclopyr amine	*Garlon® 3A*	Selective	0.5-1%[1]		

Notes:
1. Contributed by BM

Celastrus orbiculatus (Asiatic Bittersweet)

Description

https://orleansconservationtrust.org/asiatic-bittersweet-celastrus-orbiculatus/

C. orbiculatus is a non-native deciduous woody perennial that grows as either a vine or a shrub. Stem is woody with smooth brown bark. Leaves are alternate, glossy, and round with a pointed tip and shallow toothed margins. The leaves grow from two to five inches in length. Small greenish-yellow flowers with five petals form at leaf axils in clusters. Fruits are distinctive, in round orange capsules that split open in fall revealing fleshy red fruits with one or two seeds each.

The fruits persist throughout winter, and are highly attractive to birds and other animals, and to humans who often use vines and fruits in decorative manners. *C. orbiculatus* can spread far as seed, and is also capable of root suckering.

C. orbiculatus looks very similar to *C. scandens* (American Bittersweet), particularly when young. As the plant matures, it distinguishes itself with the placement of the fruit: *C. scandens* develops fruit on the tips of its branches, whereas *C. orbiculatus* develops fruits on the leaf axils. *C. scandens* leaves are also less round. Hybridization makes identification difficult. *C. orbiculatus* may be sold as *C. scandens* due to the difficulty in identification.

C. orbiculatus displaces native species through competition, and also displaces *C. scandens* through hybridization, potentially threatening *C. scandens* genetic identity. *C. orbiculatus* grows rapidly and can quickly dominate areas it is introduced into. *C. orbiculatus* also twines around native trees, increasing the load on limbs and contributing to failure.

Non-chemical Treatment

Smaller plants can be hand pulled or dug out. The entire root should be removed to prevent resprouting.

Vines climbing into trees can be cut at a comfortable height to kill any of the vine in the canopy and relieve trees. The base of the vine will continue to grow, and will require continued treatment to manage. When cutting vines from trees, take care to limit damage done to the bark of the tree as much as possible, for the sake of continued tree health.

Chemical Treatment

Foliar spraying of triclopyr is recommended for large, dense patches. Foliar spray is best applied in autumn or early winter, after most other species are dormant. If the vine is fully leafed out at the time of spraying, it is recommended to use triclopyr amine over the ester form. Foliar spray should only be applied on calm days when ambient air temperature is above the required sixty-five degrees Fahrenheit.

Vines of the plant that grow up into the canopy cannot viably be treated with a foliar application. The cut stump method is preferable for *C. orbiculatus* vines that climb trees, as well as for vines that are in close proximity to desired plants. When cutting, cut the vine six inches above the ground, in case more cut stump applications are required. Immediately apply the herbicide with a brush or spray bottle. Cut stump treatment can be used at any time in the year as long as the ambient air temperature is above the necessary temperatures: forty degrees Fahrenheit for glyphosate application, and sixty-five degrees Fahrenheit for triclopyr application. The ground should not be frozen at the time of application.

Basal bark treatment with triclopyr ester can also be applied at any time in the year, if the ambient air temperature has been above the required sixty-five degrees Fahrenheit for several days. Basal bark treatment should also not be done if there is snow on the ground, or if any part of the application area is wet from rain or flooding. Before applying, cut any stems sprouting from the vine within the twelve to eighteen inch application range to reveal the bark, and apply the treatment to cover the entire of that area.

Systemic herbicides should destroy an entire *C. orbiculatus* plant in a week.

Table 8. *C. orbiculatus* Treatment Guide

Method	Herbicide	Brand	Selectivity	Concentration	Time	Notes
Non-chemical Treatment						
Hand pulling					Mar - Nov	Small plants
Cutting					Mar - Nov	Will kill any climbing vines in canopy to relieve tree, will not destroy roots
Chemical Treatment						
Foliar spray	Triclopyr	*Garlon® 3A*, *Garlon® 4 Ultra*	Selective	2%	Oct - Nov	Use late season so most native species are dormant; ambient temperature should still be above 65 degrees F
Cut stem/stump	Glyphosate	*Rodeo®*	Non-selective	25%	Year round	Ambient air temperature above 40°F
	Triclopyr	*Garlon® 3A*, *Garlon® 4 Ultra*	Selective			Ambient air temperature above 65°F, no frozen ground
Basal bark	Triclopyr ester	*Garlon® 4 Ultra*	Selective	20%	Year round	Should only be performed when ambient air temperature has been above 65°F for several days

Cynanchum louiseae (Black Swallow-wort)

Description

https://www.maine.gov/dacf/mnap/features/invasive_plants/cynanchum.htm

C. louiseae is a non-native rhizomatous perennial milkweed. Stems are yellowish-green, long and thin, vine-like and twining. The stems tend to climb and twist around other plant stems or themselves. Leaves are opposite, smooth, shiny, dark green, and elliptic or heart shaped with sharp tips. Flowers are small and dark purple, with five petals. *C. louiseae* has milkweed-like seed pods, with many small brown seeds attached to fluffy white hairs.

C. louiseae is spread long distances by its seeds, which float in wind, and many seeds will drop into already infested areas, increasing the density of *C. louiseae* in patches.

C. louiseae outcompetes native species and forms sprawling and dense mats of plant matter that completely cover areas, limiting the growth potential for native species. It will also twine around native species, stressing those plants and limiting ability to grow.

Non-chemical Treatment

Non-chemical treatment of C. louiseae has limited effects for control. Hand pulling or mowing the part of the plant above soil prevents the development of seed pods, limiting the ability of the plant to spread; this is not an effective method of long-term control.

Digging the roots of the plant is labor intensive, and any control established is limited as the plant will resprout from any remaining rhizomatous matter. The entire crown and root system must be removed in order to control by digging.

Any seed pods that do form should be pulled by hand and bagged or burned to prevent propagation.

Chemical Treatment

C. louiseae is a pervasive species and will require multiple years of treatment to achieve control. It is very important to not apply herbicide too early in the season when treating *C. louiseae*. While the shoots emerge in the early spring, herbicide should only be applied after the plants have begun to flower in June or July, and must be applied before the formation of seed pods. Foliar spraying before the formation of seed pods will greatly reduce seed viability in affected plants.

Foliar spray is optimal when treating large monotypic stands of *C. louiseae*. If the exotic plants are surrounded by desired grasses, then triclopyr can be used minimize damage to grasses. Plants will appear sick one to two weeks after herbicide treatment, exhibiting yellowed leaves, and dead spots. Do not reapply herbicide to plants that are sick, as sick plants cannot effectively absorb herbicides into roots.

For particularly sensitive areas, cut stem treatment of *C. louiseae* is a viable control method. Stems should be cut to about two inches from the ground, and non-selective herbicide should be applied immediately.

Table 9. *C. louiseae* Treatment Guide

Method	Herbicide	Brand	Selectivity	Concentration	Time	Notes
Non-chemical Treatment						
Hand-pulling					Aug - Nov	Target seedpods
Chemical Treatment						
Foliar spray	Glyphosate	*Rodeo®*	Non-selective	3-5%	June - July	Spray as plants begin to flower
	Triclopyr	*Garlon® 3A*, *Garlon® 4 Ultra*	Selective	1%		
	Imazapyr	*Habitat®*				
Cut stem/stump	Glyphosate	*Rodeo®*	Non-selective	50-100%	June - July	Cut stems to two inches from the

						ground before applicati on

Fallopia japonica (Japanese Knotweed)

Description

https://www.hortweek.com/network-rail-loses-japanese-knotweed-court-ruling/landscape/article/1486930

F. japonica is a non-native rhizomatous perennial that is a particularly difficult exotic species to manage. The stems emerge in early spring and grow tall, up to ten feet. The stems are reddish-brown and hollow, resembling bamboo. Heart-shaped leaves are large, growing four to seven inches in length. Clusters of small, greenish-yellow to white flowers are formed in July. Fruits mature in August or September, and are winged to increase seed dispersal.

The seeds rarely germinate, and North American knotweed is presumed to be a sterile male clone. It is still possible to produce viable seeds, usually through hybridization. F. japonica mainly spreads vegetatively, extending its massive woody rhizome system and sending up new shoots. Any piece of rhizome material moved to a new area can lead to new infestation. As such, it is generally contained in defined patches, and will not cross impervious surfaces like roads easily.

F. japonica offers no ecological benefits to native species other than dense cover. It can colonize a variety of ecosystems, swiftly converting them to monocultures, and degrading habitat value.

Non-chemical Treatment

Digging is an ineffective method of management, as *F. japonica* grows from a thick rhizome, forming large crowns that are extremely difficult to fully remove.

Mowing of *F. japonica* alone is not an effective means of control, and must be coupled with chemical treatment.

Small stands of *F. japonica* can be managed by mowing the area and covering it with impervious mats, thick enough that *F. japonica* is unable to grow through. Leaving the mats in place for several years will prevent the root system from sending up new shoots in the covered area, preventing photosynthesis. If in an area of full or partial sun, the heat will also damage the root system.

F. japonica is limited in its ability to spread across impervious surfaces, and will be more easily contained closer to roads.

Chemical Treatment

The most effective method of chemical treatment is first to mow *F. japonica* at the beginning of July, and follow with herbicide application. At least six weeks should pass between mowing and herbicide application, and when herbicide is applied the height of *F. japonica* is limited to its regrowth: three to four feet tall instead of six to ten feet tall.

Glyphosate can be applied as a foliar spray. Glyphosate is a non-selective herbicide, and patches with *F. japonica* are generally monocultures. Glyphosate should be applied twice in the first year of treatment, first in early August, and following up in September before the first frost.Grass can be seeded in the area if it is necessary for erosion control. As knotweed requires multiple years of treatment, an inexpensive annual rye grass would be optimal.

F. japonica can also be treated by stem injection, where herbicide is injected at the nodes, the location where the leaves meet the stem. Stem injection directs as much chemical as possible to the root system, but is labor intensive and requires specialized injection equipment.

F. japonica thrives in a range of soils, from sandy roadsides to moist wetlands. In wetland areas, use mechanical methods to the greatest extent feasible (such as thick mats). Work from the upstream seed source to downstream populations. If chemical treatment is used, care should be taken to use an herbicide that will not injure amphibian food sources and rare species such as Blanding’s turtle. The table below provides guidance on using *Rodeo®.*

Application should not exceed the regulated rate per acre, of particular concern when filling hollow stems or injecting herbicide.

Herbicide should not be applied after the first frost, as *F. japonica* is frost sensitive and will die back, leaving any herbicides applied after frost unabsorbed.

Table 10. *F. japonica* Treatment Guide

Method	Herbicide	Brand	Selectivity	Concentration	Time	Notes
Non-chemical Treatment						
Mowing					Aug; Sep	
Chemical Treatment						
Foliar spray	Glyphosate	*Rodeo®*	Non-selective	2-4%[1]	Early Aug - Late Sep	Surfactant; first application: Add surfactant, must wait 6 weeks after early July mowing, second application: add surfactant, must be applied before first frost
Stem injection	Glyphosate	*Rodeo®*	Non-selective	100%	August	Injected at the stem nodes
Notes: 1. Contributed by BM						

Convolvulus arvensis (Bindweed)

Description

https://www.swcoloradowildflowers.com/White%20Enlarged%20Photo%20Pages/convolvulus%20arvensis.htm

"Deep rooted perennial vine that grows along the ground until it comes in contact with other plants or structures; then climbs aggressively. Smooth, arrowhead-shaped leaves. Slender, twining stems that can grow to 6 feet long. Trumpet-shaped flowers, light pink to white. Two small leaf bracts about one inch below the flower. Fleshy pale roots that travel deeply and widely" https://www.nwcb.wa.gov

"Reproduces vegetatively from roots, rhizomes,stem fragments and by seeds that can lie dormant in the soil for up to 20 or more years. Roots spread widely underground, both vertically and horizontally, forming dense mats. Flowering is indeterminate, so flowers continue to develop along stems until the first frost" https://www.nwcb.wa.gov

Non-chemical Treatment

"Avoid digging or tilling the soil around mature field bindweed roots; roots or rhizome fragments left behind may resprout. Repeated hand pulling works eventually, but is highly labor intensive. It is best to limit hand pulling and tilling to seedlings; do in early spring when the ground is wet. Smothering plants with mulch, black plastic or plastic-fiber mats (geotextiles) is another option, but the covering must be kept in place for several years. Success may be somewhat limited as field bindweed can persist without light, sending its underground roots beyond the edge of the covering to start a new infestation. If using coverings, check often for cracks or openings; pull or spot spray any new growth coming up through the covering. Cutting alone will not control this plant and is not recommended." https://www.nwcb.wa.gov

Chemical Treatment

"Herbicides can be painted or brushed on leaves to avoid drift onto desirable plants. Products containing glyphosate are effective when applied in the summer and fall before the leaves die back. However, glyphosate is “non-selective” and will injure any foliage that it comes in contact with including grass. Selective broadleaf herbicides with the active ingredients triclopyr and 2,4-D work well for lawn areas as they won’t harm most grasses. Repeat on regrowth as needed. All these herbicides are absorbed by foliage and moved throughout the plant to kill the roots and shoots. If retreating with glyphosate in the same season, allow plants to grow and produce flowers before each application.” https://www.nwcb.wa.gov

Table 11. *C. arvensis* Herbicide Treatment Guide

Method	Herbicide	Brand	Selectivity	Concentration	Time	Notes
Non-chemical Treatment						
Hand-pulling					Mar - Sept	
Digging					Mar - Sept	
Mowing					Mar - Sept	
Chemical Treatment						
Foliar spray	Glyphosate	*Rodeo®*	Non-selective	2%	July - Sept	
	Triclopyr	*Garlon® 3A*	Selective	3-5%		
	Imazapyr	*Habitat®*	Non-selective	2%		

***Lythrum salicaria* (Purple Loosestrife)**

Description

L. salicaria is a non-native herbaceous perennial forb that is an aggressive invader of wetlands. Several four-sided square erect stems grow from a single plant, two to six feet in height. Leaves are opposite on the stem or in whorls around the base, and are smooth, elongated, and heart-shaped. Flower spikes are showy and magenta, made up of many small, five-petaled individual flowers, blooming late in the growing season. The fruit is a capsule developed in autumn containing small seeds.

https://www.minnesotawildflowers.info/flower/purple-loosestrife

L. salicaria is spread by seed, which are viable for many years, and remain dormant in the soil until conditions are right for growth.

L. salicaria can dominate areas where it is introduced, displacing native species and reduces biodiversity. *L. salicaria* also degrades wetlands, catching sediment that fills in wetlands, leading to reduced water flow, and decreased flood retention.

Non-chemical Treatment

L. salicaria populations can be partially managed by pulling and digging as long as the entire taproot is removed. This is time consuming and labor intensive, and should only be implemented on small pioneer populations that can be removed efficiently.

Biological control is the best method for long term large scale. Insect species can be introduced to feed on the plants, preventing *L. salicaria* from seeding and weakening, eventually destroying the plant.

Chemical Treatment

L. salicaria most commonly is found in sensitive wetland areas. The two most effective herbicides are glyphosate and triclopyr. Glyphosate and triclopyr amine, both registered for aquatic use, are commonly applied when managing *L. salicaria*. Treatment should occur prior to seed set to prevent future spread of the species.

Glyphosate can damage surrounding grasses and sedges, leaving new opportunities for colonization by *L. salicaria*. Pesticide should be selected based on density of the stands being treated, and whether or not surrounding plants are desirable. If surrounding plants are desirable grasses and sedges, triclopyr amine should be selected. If there are many exotic plants, glyphosate should be used, or a mixture of glyphosate and triclopyr. Follow up treatments will be required for years until the seedbank is depleted.

Table 12. *L. salicaria* Herbicide Treatment Guide

Application Method	Herbicide	Brand	Selectivity	Concentration	Time	Notes
Non-chemical Treatment						
Hand pulling					Apr - Sep	
Digging					Apr - Sep	
Cutting					Apr - Sep	
Biological					Apr - Jun	Introduced insect species to feed on plant
Chemical Treatment						
Foliar spray	Glyphosate	*Rodeo®*	Non-selective	1-2%	Late Aug	Apply after peak bloom; cut and dispose of flower heads prior to application
	Triclopyr amine	*Garlon® 3A*	Selective	1%		
Hand wicking					Late Aug	

***Rosa multiflora* (Multiflora Rose)**

Description

R. multiflora is a thorny non-native perennial shrub. The plants is tolerant of many conditions and can grow ten feet tall and ten feet wide. Stems are long, green to brown, with hooked thorns that make hand removal hazardous. Leaves are opposite with five to eleven leaflets, and leaflets are one to two inches in length. White to pinkish five petal flowers form in clusters in the summer. The plant produces bright red fleshy fruits (hips).

https://production.wordpress.uconn.edu/cipwg/wp-content/uploads/sites/244/2014/04/RobRoutledgeSaultCollegeBugwood.jpg

R. multiflora can generate new stems to spread, but it is predominantly spread by seed.

R. multiflora is easily distinguished from native *Rosa* species. In R. multiflora the base of leaf where it is attached to the thorny stem is fringed, and the plant's white to pinkish five petalled flowers occur in branched structures.

Benefits of the plant include the food and cover it provides to native animals. However, the overall effect this shrub has on habitat value is negative. *R. multiflora* crowds out native species and creates dense, impenetrable stands. *R. multiflora* can also act almost as a vine, and choke out native trees.

Non-chemical Treatment

Controlling small populations is much easier than attempting control dense stands. Hand pulling can be effective if the entire root of the plant is removed.

Cutting or mowing alone will not control *R. multiflora*, but are useful in preparation for herbicide treatment. Cut stem application would be impossible on dense stands, so mowing leads to better control.

Chemical Treatment

Foliar applications are made in summer when *R. multiflora* is flowering, with peak bloom being in early June. Spray should thoroughly cover the foliage of the plant, wetting as many leaves as possible without dripping. Glyphosate is less effective on multiflora rose than other herbicides but may be desirable if soil activity is a concern, or to avoid damaging surrounding grasses. Triclopyr can be applied as a foliar spray, and will eliminate top growth; future applications may be necessary to destroy the root system.

Triclopyr can also be applied to cut stems or as basal bark, and is most effective when applied in the dormant season. Cut stem use when mowing or cutting is practical; remove the top growth of the shrub and wet the stubble. This method can be applied year round. Basal bark is only feasible when the base of the plant can be accessed. It is best applied from January to autumn color. Wet the lower twelve inches of plant stem without causing runoff.

Table 13. *R. multiflora* Treatment Guide

Method	Herbicide	Brand	Selectivity	Concentration	Time	Notes
Non-chemical Treatment						
Hand pulling					Mar - Nov	Remove entire root
Cutting/Mowing					Mar - Nov	Effective when followed immediately by chemical treatment
Chemical Treatment						
Foliar spray	Glyphosate	*Rodeo®*	Non-selective	2%	May - Jun	
	Triclopyr	*Garlon® 3A*, *Garlon® 4 Ultra*	Selective	1%		
Cut stump/stem	Triclopyr	*Garlon® 3A*, *Garlon®*	Selective	50%	Year round	

		4 Ultra				
Basal bark	Triclopyr ester	*Garlon®* *4 Ultra*	Selective	20-25%	Jan - Aug	Basal oil

Important Note: *Mention of specific products in this document does not constitute endorsement. Specific product names are mentioned in the resources used to create this document. This document is meant to serve as a guideline for exotic plant management, and is not a legal authority. By law, pesticides must be applied according to their labeling.*

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Scott, Kelsey

To: Quiggle, Robert
Subject: RE: Lowell Heritage State Park information

From: Quiggle, Robert
Sent: Friday, December 20, 2019 3:28 PM
To: Harris, Jeffrey (DCR) <jeffrey.harris@state.ma.us>
Cc: Scott, Kelsey <Kelsey.Scott@hdrinc.com>
Subject: RE: Lowell Heritage State Park information

Jeffrey:

It was good to meet you this week, and thanks for providing this information so quickly. We'll look through this and let you know if we have additional questions, etc.

Have a great holiday,

Robert Quiggle, RPA
Regulatory and Environmental Section Manager

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Robert.Quiggle@hdrinc.com

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From: Harris, Jeffrey (DCR) [mailto:jeffrey.harris@state.ma.us]
Sent: Friday, December 20, 2019 12:33 PM
To: Quiggle, Robert <Robert.Quiggle@hdrinc.com>
Subject: Lowell Heritage State Park information

Rob-

Thank you for your presentation on the Boott Hydro relicensing project on Wednesday. As a follow-up, I wanted to provide you with some additional information that may be helpful in the various studies that are planned.

The first is a 2014 Resource Management Plan for the broader complex that includes Lowell Heritage State Park. This addresses DCR ownership, recreation, and other issues within the park. The document is available here: https://www.mass.gov/service-details/lowell-great-brook-planning-unit

Secondly, our GIS team undertook a major effort a number of years ago to clarify DCR ownership of parcels within the City of Lowell. This data is currently available through Mass GIS: https://docs.digital.mass.gov/dataset/massgis-data-protected-and-recreational-openspace

Let me know if you have any questions!

Jeffrey

Jeffrey Harris, Preservation Planner

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DCR's Office of Cultural Resources
Protecting the legacy and experience of history in Massachusetts state parks.

Scott, Kelsey

From:	Bruins, Christine A <Christine_Bruins@nps.gov>
Sent:	Friday, March 13, 2020 2:13 PM
To:	Quiggle, Robert
Cc:	Scott, Kelsey; Jones, Scott
Subject:	Re: [EXTERNAL] Lowell Hydro Relicensing Waterborne Trash Mapping

The COVID 19 situation is evolving rapidly. I don't think we can realistically schedule something this month. Let's set a tentative date 30+ days out? Week of 4/20? Monday, Thursday, Friday are free.

Christine Bruins | Community Planner
Lowell National Historical Park
978.275.1726 (office) | 978.954.1011 (cell)

From: Quiggle, Robert
Sent: Friday, March 13, 2020 12:03 PM
To: Bruins, Christine A
Cc: Scott, Kelsey ; Jones, Scott
Subject: [EXTERNAL] Lowell Hydro Relicensing Waterborne Trash Mapping

Christine: We are looking to schedule our waterborne trash survey and mapping, and I wanted to check in with you to see if there were any specific dates that we should target or avoid. We'd like to get the fieldwork completed before mid-April, and we'd like to meet briefly with NPS staff that may have relevant information on waterborne trash issues while we're at the project.

We can be pretty flexible in terms of scheduling the fieldwork, but just let us know what makes sense on your end.

Thanks,

Robert Quiggle, RPA
Regulatory and Environmental Section Manager

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