Lowell Hydroelectric Project (FERC No. 2790)

Second Revised Initial Study Report Meeting

Agenda for Revised ISR Meeting

- 9:00 - 9:15 AM: Introductions
- 9:15 - 10:00 AM: Three-Dimensional Computational Fluid Dynamics Modeling Study
- 10:00 - 10:30 AM: Fish Passage Survival Study
- 10:30 - 11:30 AM: Instream Flow Habitat Assessment and Zone of Passage Study
- *11:30 -12:30 PM Break for Lunch*
- 12:30 - 1:30 PM: Resources, Ownership, Boundaries, and Land Rights Study
- 1:30 - 2:30 PM: Water Level and Flow Effects on Historic Resources Study
- 2:30 - 3:00 PM: Historically Significant Waterpower Equipment Study
- 3:00 - 3:30 PM: Operation Analysis of the Lowell Canal Study
- 3:30 – 4:00 PM: Recreation and Aesthetics Study

Revised Initial Study Report Meeting Objectives

- Pursuant to the ILP, Boott filed the second Revised Initial Study Report (ISR) on February 25, 2021 with FERC.
  - The second Revised ISR presents results of the following studies:
    - Three-Dimensional Computational Fluid Dynamics Modeling Study (3D CFD);
    - Fish Passage Survival Study;
    - Instream Flow Habitat Assessment and Zone of Passage Study in the Bypassed Reach;
    - Resources, Ownership, Boundaries, and Land Rights Study;
    - Operation Analysis of the Lowell Canal Study;
    - Historically Significant Waterpower Equipment Study;
  - The Commission's regulations at 18 C.F.R. § 5.15(c) requires Boott to hold today's Revised ISR Meeting within 15 days of filing the ISR.

Revised Initial Study Report Meeting Objectives

- Included in the Revised ISR filing is the updated Recreation and Aesthetics Study Report and the additional information regarding the upstream fish ladder requested by FERC on February 2, 2021.

- Boott filed the Water Level and Flow Effects on Historic Resources Study on March 5, 2021 with FERC, and this will be presented as well today.

- Boott intends to file additional results on the 3D CFD model by March 30, 2021.

Process Plan and Schedule

Major Milestones	Responsible Party	Dates
File PAD and NOI (18 CFR §5.5(d))	Boott	April 30, 2018
File Proposed Study Plan (PSP) (18 CFR §5.11)	Boott	September 28, 2018
File Revised Study Plan (RSP) (18 CFR §5.13(a))	Boott	January 26, 2019
Issuance of Study Plan Determination (18 CFR §5.13(c))	FERC Director	March 13, 2019
Initial Study Report (18 CFR §5.15(c))	Boott	February 25, 2020
Issuance of Revised Process Plan and Schedule	FERC	June 12, 2020
File Revised ISR	Boott	September 30, 2020
File Draft License Application (18 CFR §5.16(a))	Boott	December 2, 2020
Issuance of Determination on Requests for Study Modifications	FERC	February 2, 2021
File second Revised ISR (18 CFR §5.15(f))	Boott	February 25, 2021
Revised Initial Study Report Meeting	All stakeholders	March 11, 2021
Revised Initial Study Report Meeting Summary	Boott	March 27, 2021
File Final License Application (18 CFR §5.17)	Boott	April 30, 2021

Upcoming ILP Milestones

- Based on FERC's June 12, 2020 *Revised Process Plan and Schedule and Determination on Requests for Study Modifications for the Lowell Hydroelectric Project*

Milestone	Responsible Party	Date
Revised Initial Study Report Meeting	All stakeholders	March 11, 2021
Revised Initial Study Report Meeting Summary	Boott	March 26, 2021
Any Disputes/Requests to Amend Study Plan Due	All stakeholders	April 25 (Sunday)/April 26, 2021
File Final License Application	Boott	April 30, 2021
Responses to Disputes/Amendment Requests Due	All stakeholders	May 25, 2021
Director's Determination on Disputes/Amendments	FERC	June 24, 2021

Any Disputes/Requests to Amend Study (18 C.F.R. § 5.15(d))

- *Criteria for modification of approved study.* Any proposal to modify an ongoing study must be accompanied by a showing of good cause why the proposal should be approved, and must include, as appropriate to the facts of the case, a demonstration that:
  - (1) Approved studies were not conducted as provided for in the approved study plan; or
  - (2) The study was conducted under anomalous environmental conditions or that environmental conditions have changed in a material way.

- If requesting new studies, stakeholders must consider FERC's Criteria (18 C.F.R. § 5.15(e)).

- www.LowellProjectRelicensing.com
- FERC eLibrary Docket Number (P-2790)

Three-Dimensional Computational Fluid Dynamics (CFD) Modeling

March 11, 2021

CFD Model Study

Goals and Objectives

- The goal of this study is to determine the flow field conditions that exist in and around the Lowell Project's fish passage facilities, including around the fishway entrances, within fishway structures, and in the E.L. Field Powerhouse forebay.
- The specific objectives of this study are to:
  - Develop and calibrate three-dimensional models of areas pertinent to fish passage structure;
  - Simulate various operational conditions using each model; and
  - Produce a series of color contour maps depicting flow fields relating to fishway attraction, fishway hydraulics, and forebay and bypass approach.

CFD Model Study

Study Methods

- Bathymetry Data
  - Surveys were conducted to collect bathymetry, depth, and three-dimensional flow data under low and high design flow conditions in the bypass reach in the vicinity of the Pawtucket Dam fish ladder.

- Model construction and Calibration
  - Three-dimensional models for three areas pertinent to fish passage:
    - The E.L. Field Powerhouse forebay;
    - The E.L. Field Powerhouse AWS and tailrace; and
    - The Pawtucket Dam fish ladder and approach and entrance area in the bypass reach

Three-Dimensional Computational Fluid Dynamics Modeling: **Study Methods**

Study Methods: Pawtucket Dam Fish Ladder

Simulation #1:

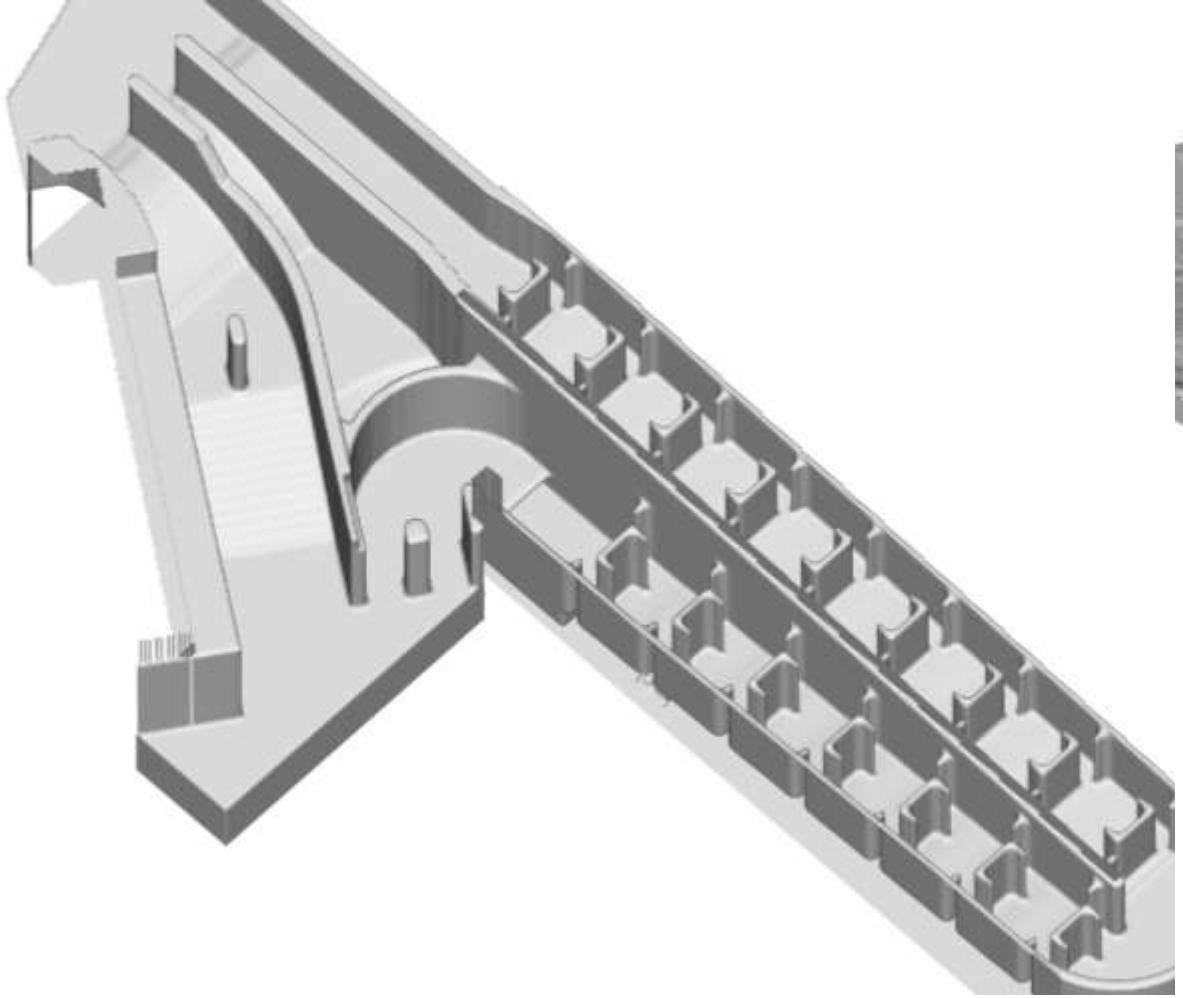
- Auxiliary water supply (30 cfs via ladder/90 cfs via diffuser)
- 300 cfs minimum flow provided via the adjacent crest gate
- Total ladder attraction flow and spill of 420 cfs

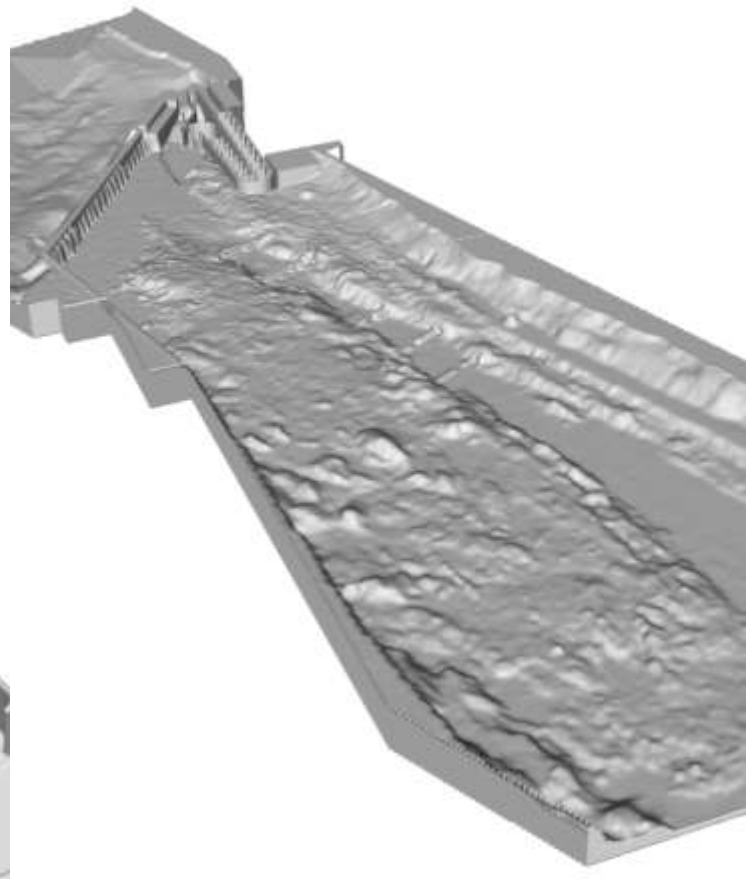
Simulation #2:

- Auxiliary water supply (30 cfs via ladder/90 cfs via diffuser)
- 360 cfs minimum flow provided via the sluice gate
- Total ladder attraction flow and sluice gate of 480 cfs, per the fish ladder design drawings.

Simulation #3:

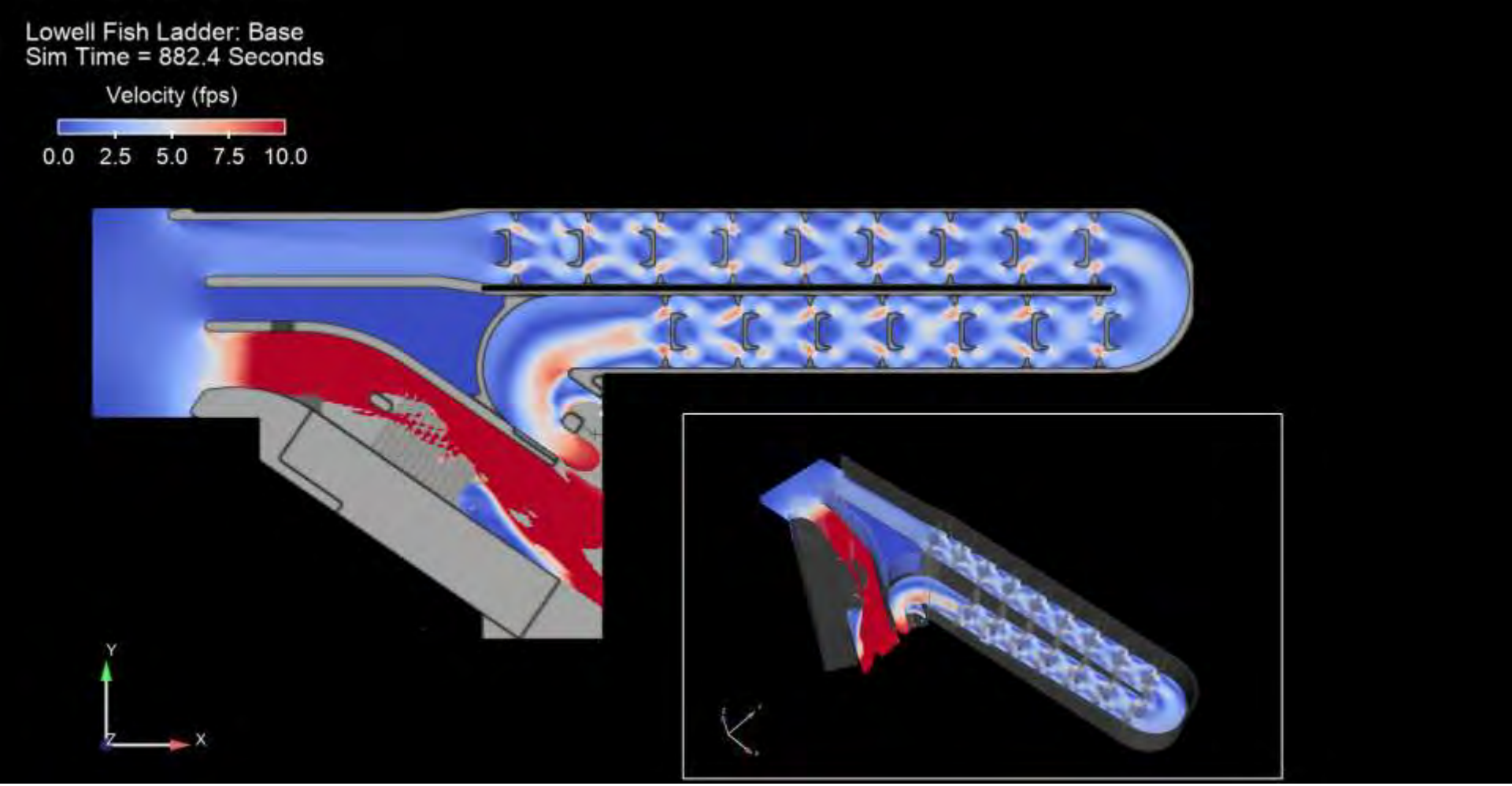
- *Auxiliary water supply (30 cfs via ladder/90 cfs via diffuser)*
- *Merrimack River at 5% exceedance level for migratory period of record (~26,000 cfs) (location and magnitude of crest gate spill to be determined through continued consultation with working group)*
- *E.L. Field at full capacity (6,600 cfs)*





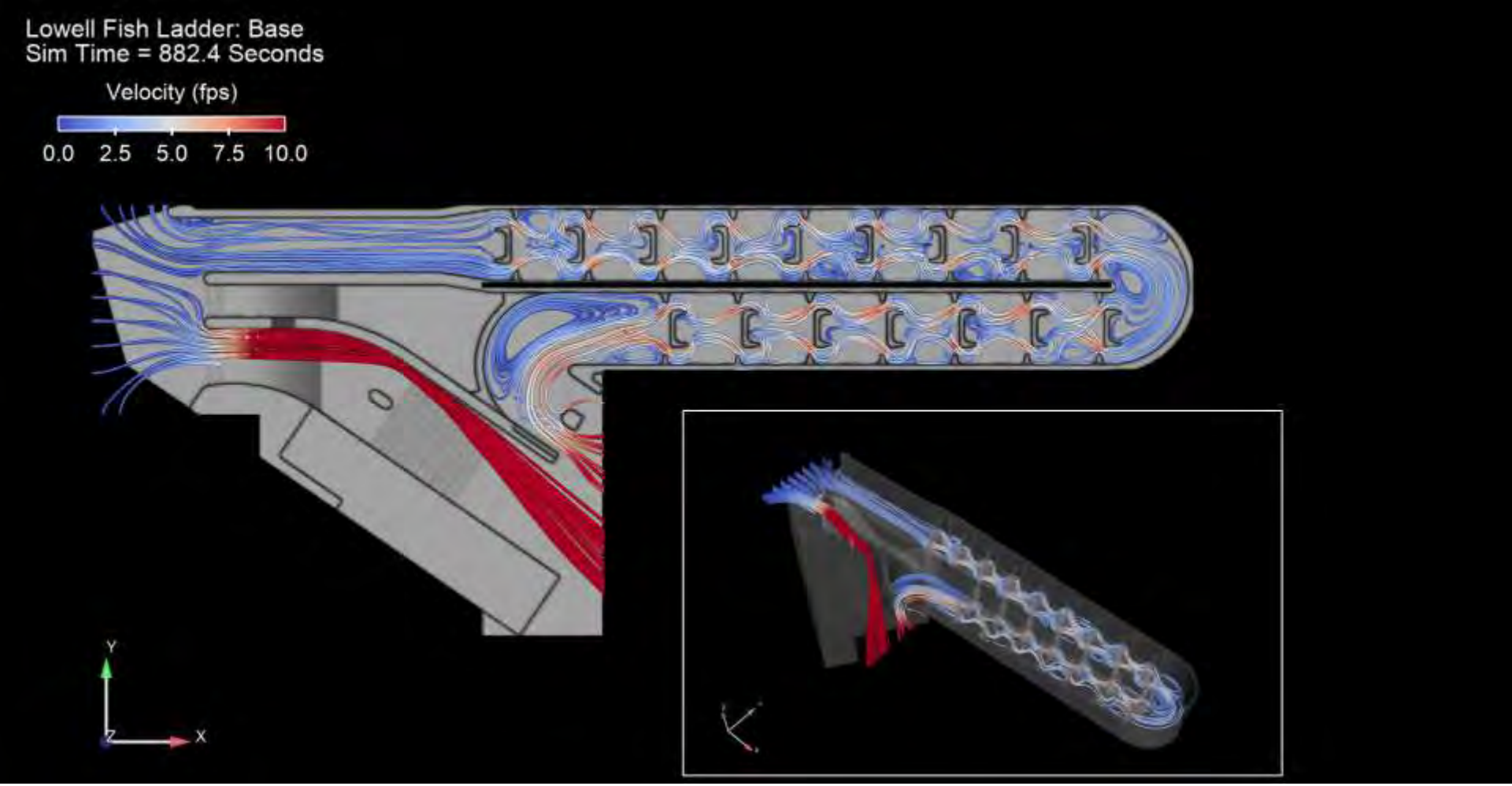
Three-Dimensional Computational Fluid Dynamics Modeling:

Results Summary – Pawtucket Fish Ladder



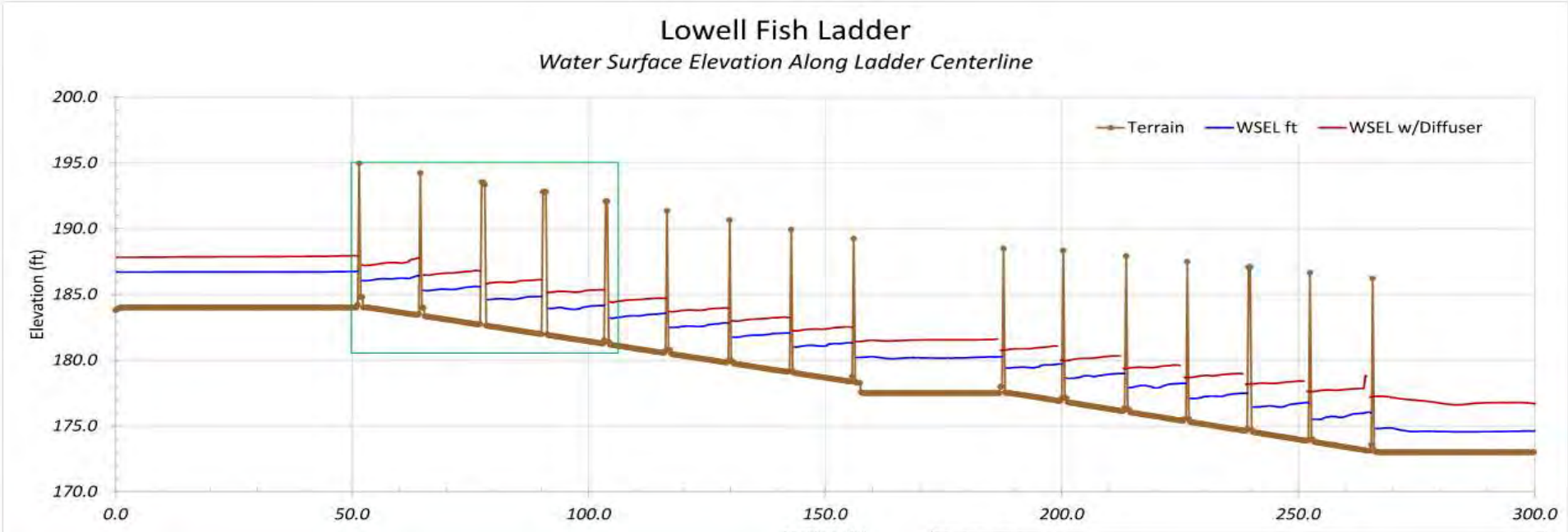
Three-Dimensional Computational Fluid Dynamics Modeling:

Results Summary – Pawtucket Fish Ladder



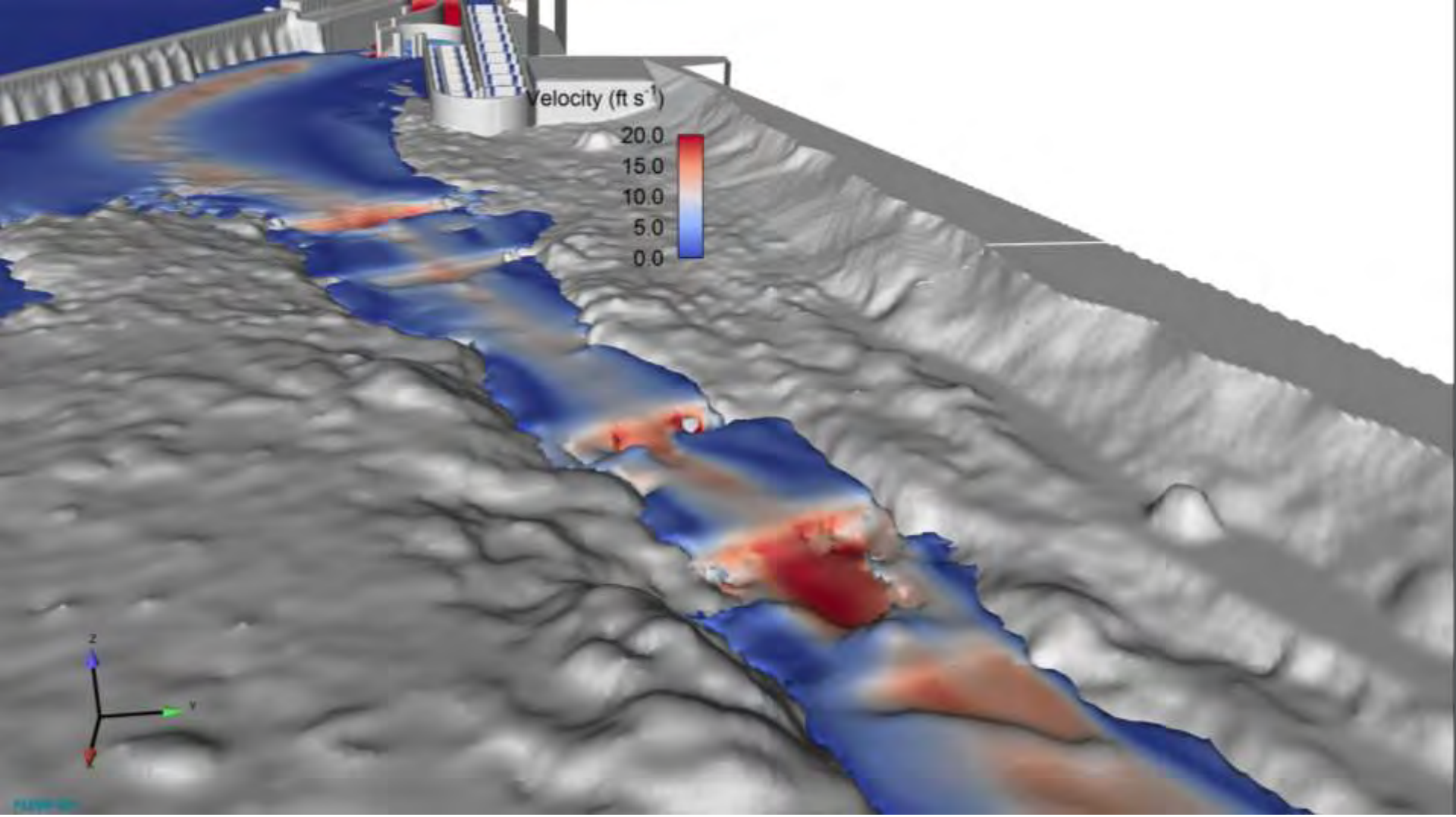
Three-Dimensional Computational Fluid Dynamics Modeling:

Results Summary – Pawtucket Fish Ladder



Three-Dimensional Computational Fluid Dynamics Modeling:

Results Summary – Pawtucket Fish Ladder



Three-Dimensional Computational Fluid Dynamics Modeling:

Results Summary – Pawtucket Fish Ladder

CFD Model Study:

Study Methods: E.L. Field Powerhouse Forebay Model

Simulation #1:

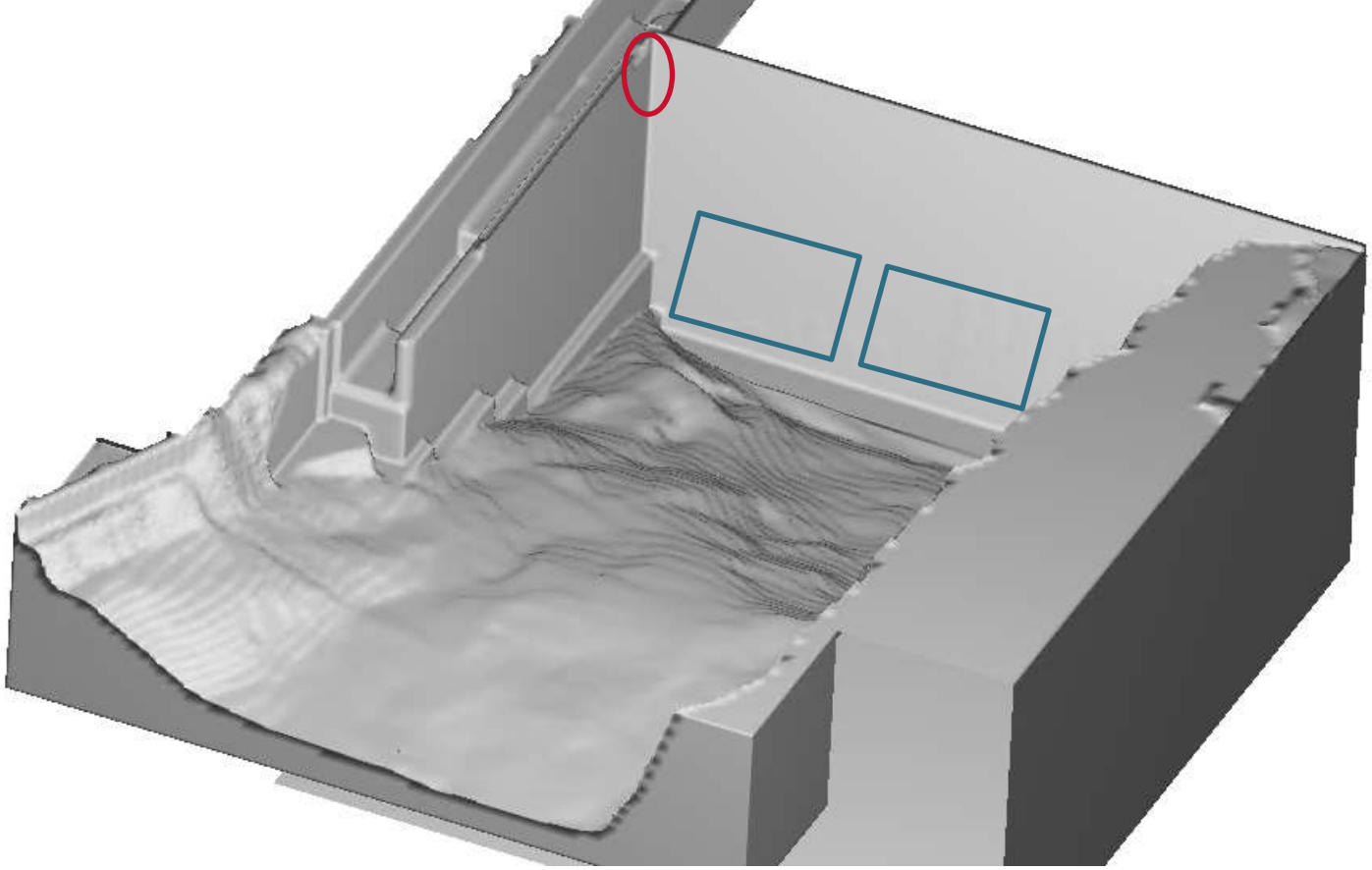
- E.L. Field at full capacity (6,600 cfs)
- Fish bypass discharge (130 cfs)

Simulation #2:

- E.L. Field – Unit 1 or 2 at minimum flow (600 cfs split/1,200 cfs total)
- Fish bypass discharge (130 cfs)

Simulation #3:

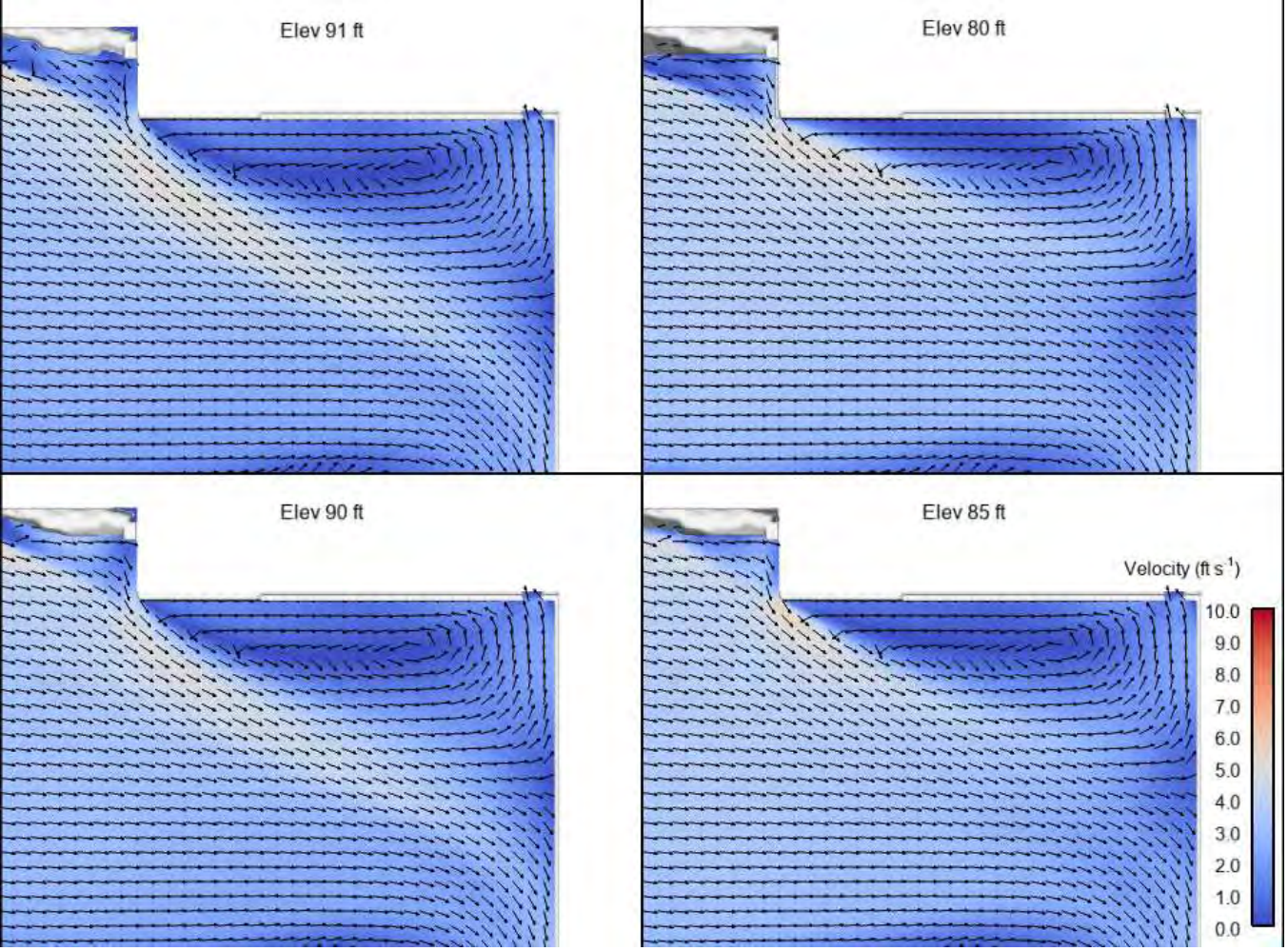
- Merrimack River at 75% exceedance level for migratory period of record (2,750 cfs)
- E.L. Field at typical unit settings for flow condition (6,600 cfs)
- Fish bypass discharge (130 cfs)



CFD Model Study: **Results Summary – ELF Forebay**

Model Setup

- 175 ft of river upstream
- 2-Powerhouse inlets (blue) [~31-ft x 32-ft]
- Bypass Inlet (red) [4-ft wide]

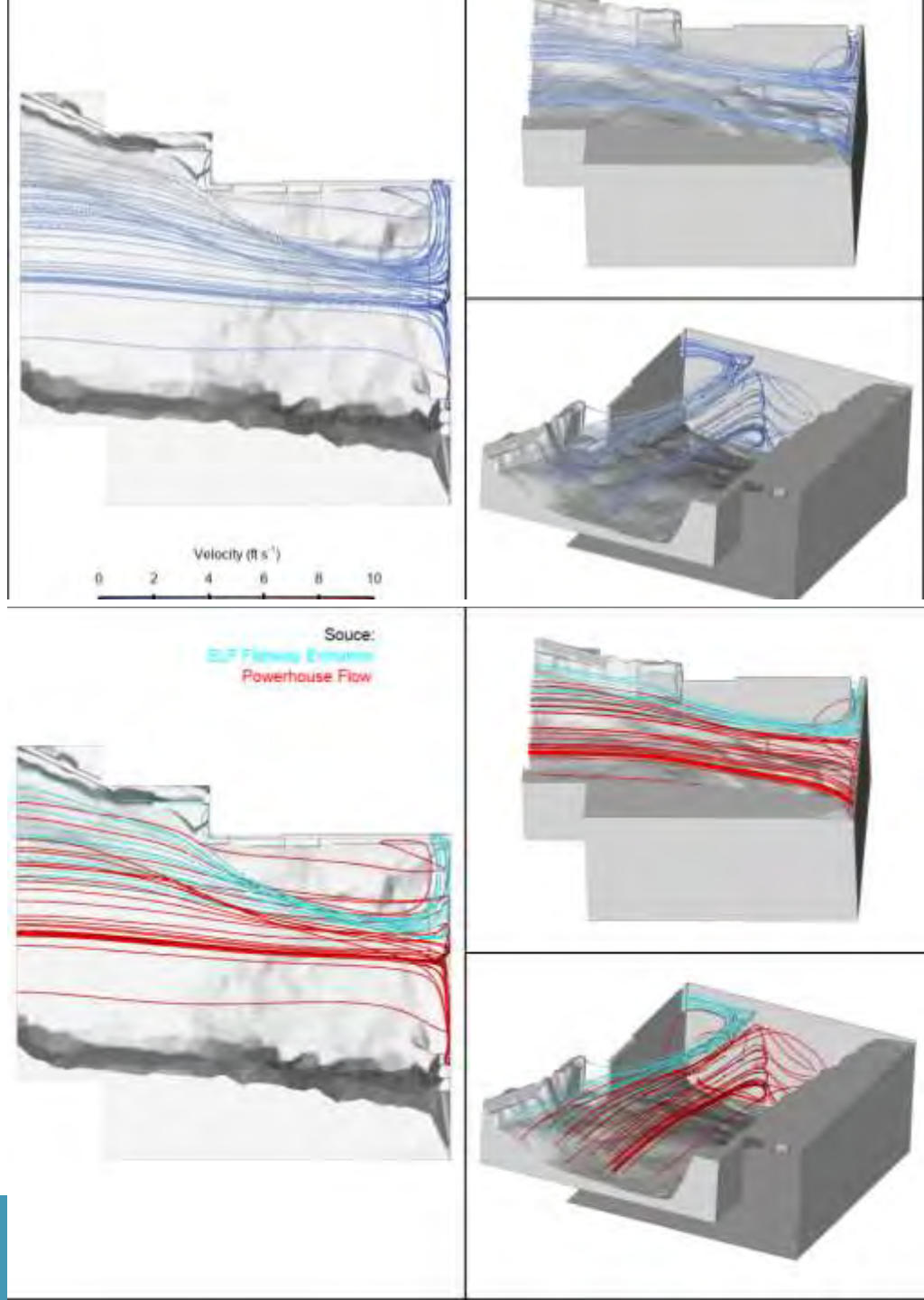


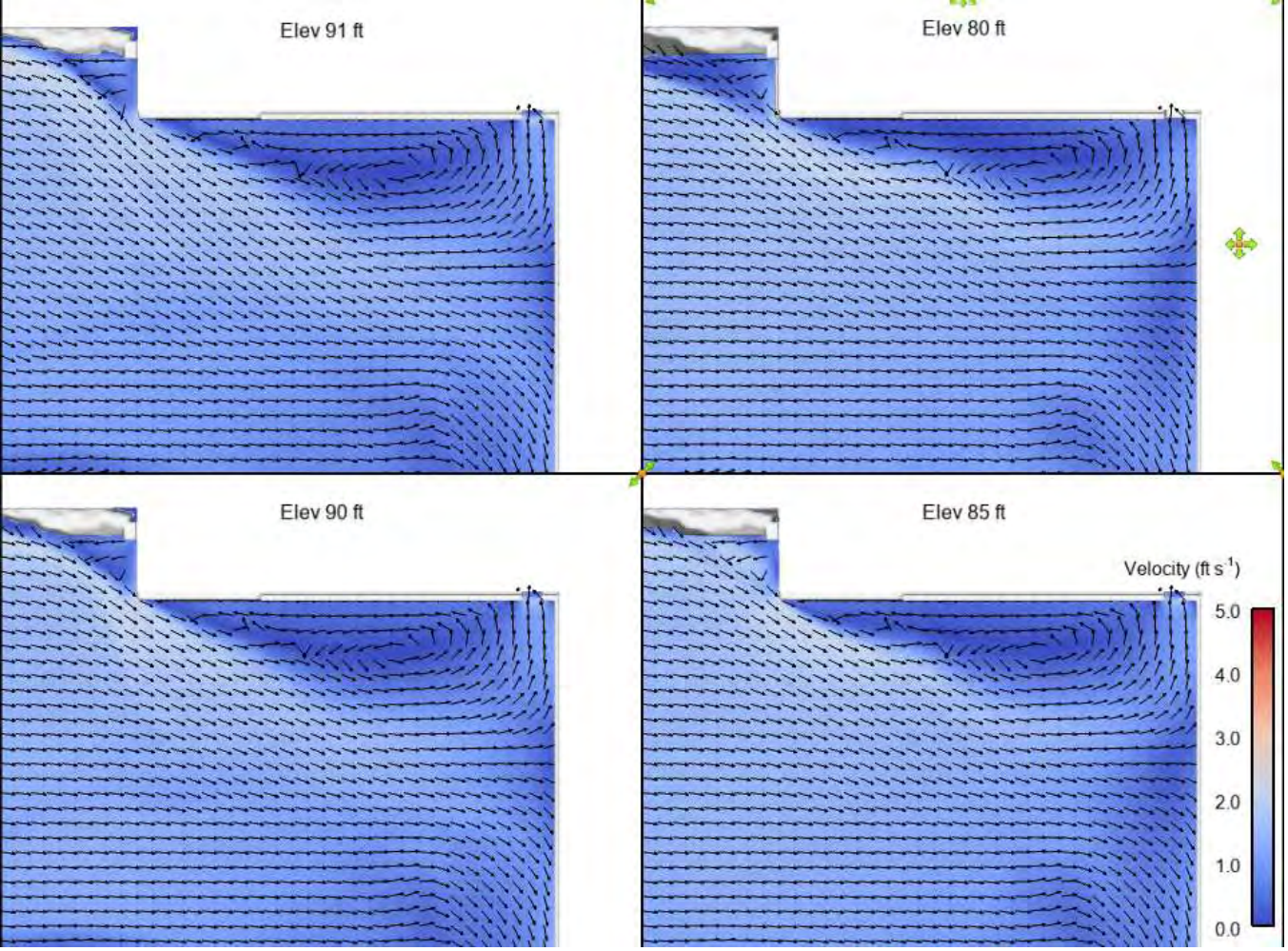
CFD Model Study:

Results Summary – ELF Forebay – High Flow (6,730 cfs)

CFD Model Study:

Results Summary – ELF Forebay – High Flow (6,730 cfs)



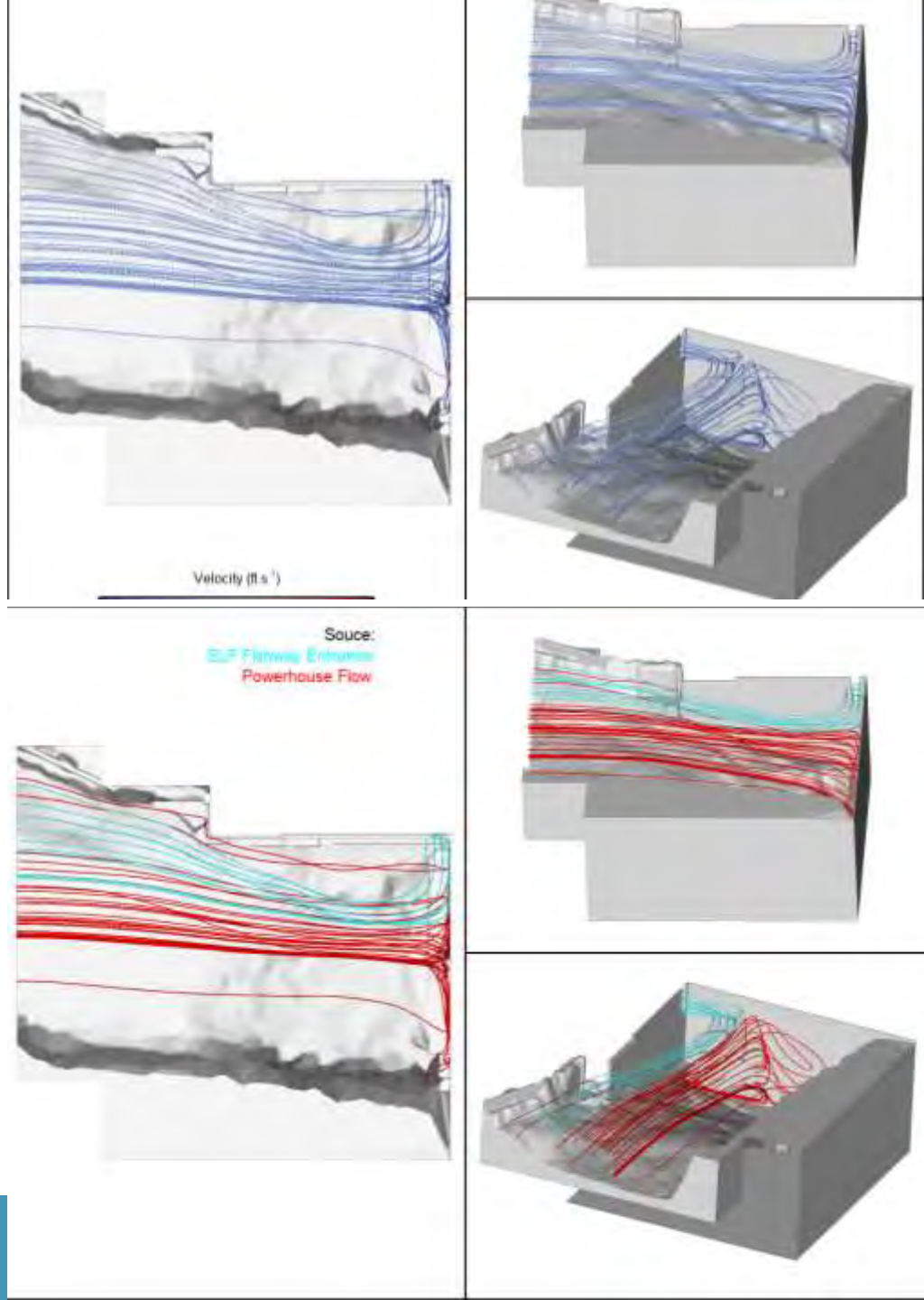


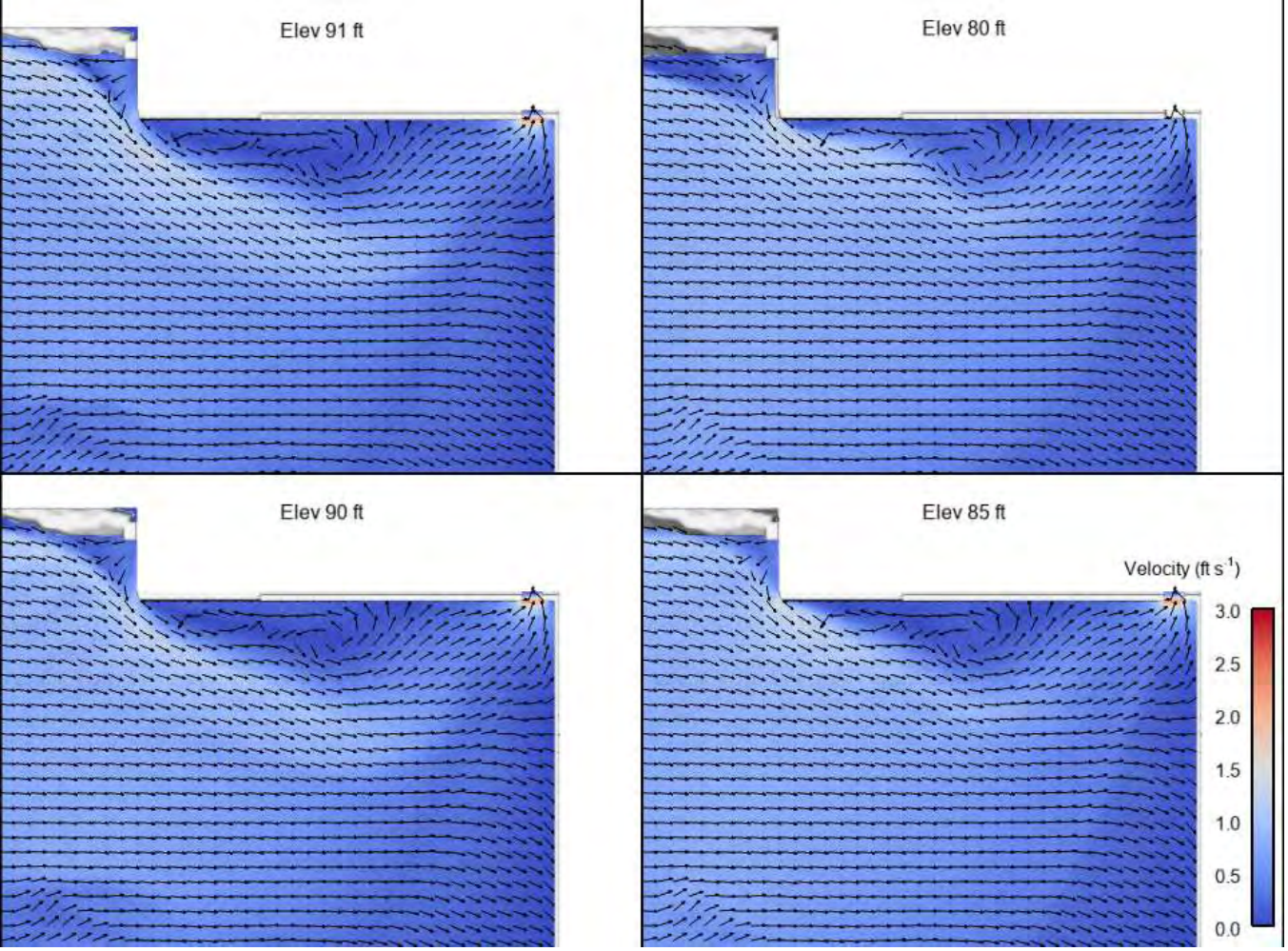
CFD Model Study:

Results Summary – ELF Forebay – Mid Flow (2,750 cfs)

CFD Model Study:

Results Summary – ELF Forebay – Mid Flow (2,750 cfs)



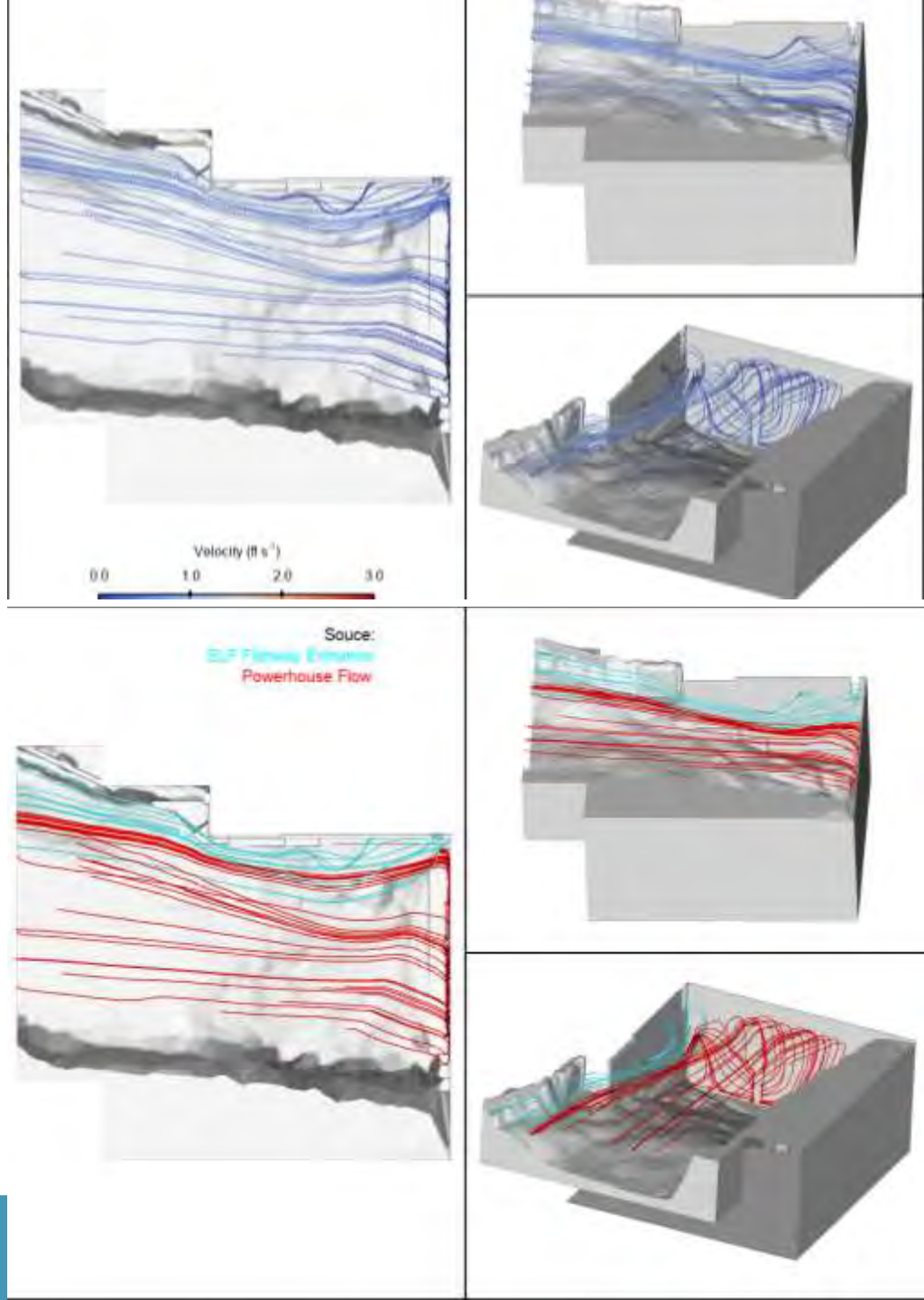


CFD Model Study:

Results Summary – ELF Forebay – Low Flow (1,330 cfs)

CFD Model Study:

Results Summary – ELF Forebay – Low Flow (1,330 cfs)



CFD Model Study:

Study Methods: E.L. Field Powerhouse Tailrace Model

Simulation #1:

- Fish lift in operation under recommended settings (120 cfs)
- E.L Field at full capacity (6,600 cfs)
- High tailrace condition (5% exceedance level [26,000 cfs], 57.7 ft)

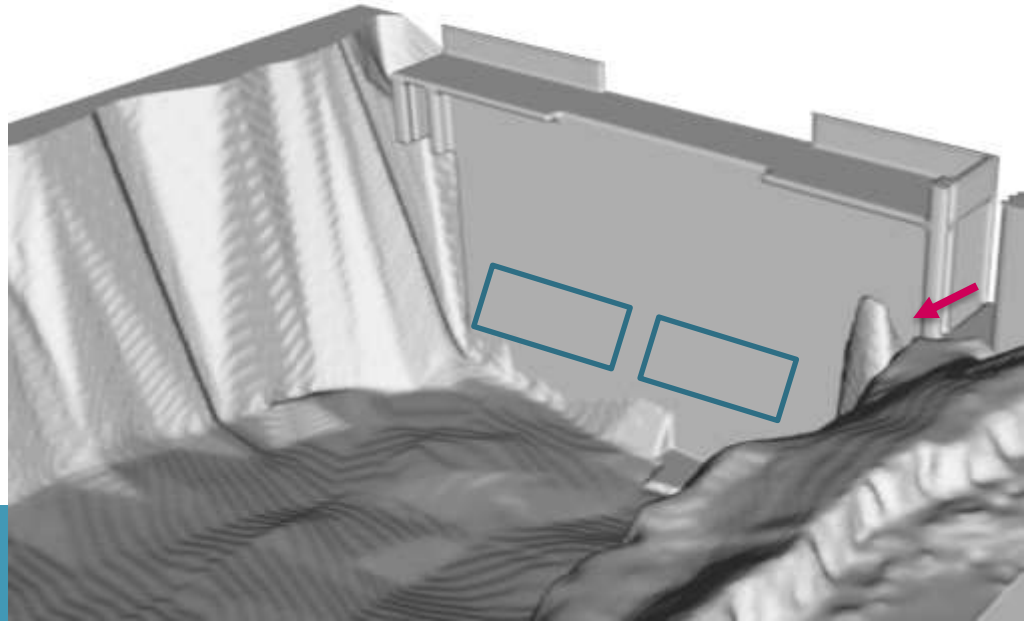
Simulation #2:

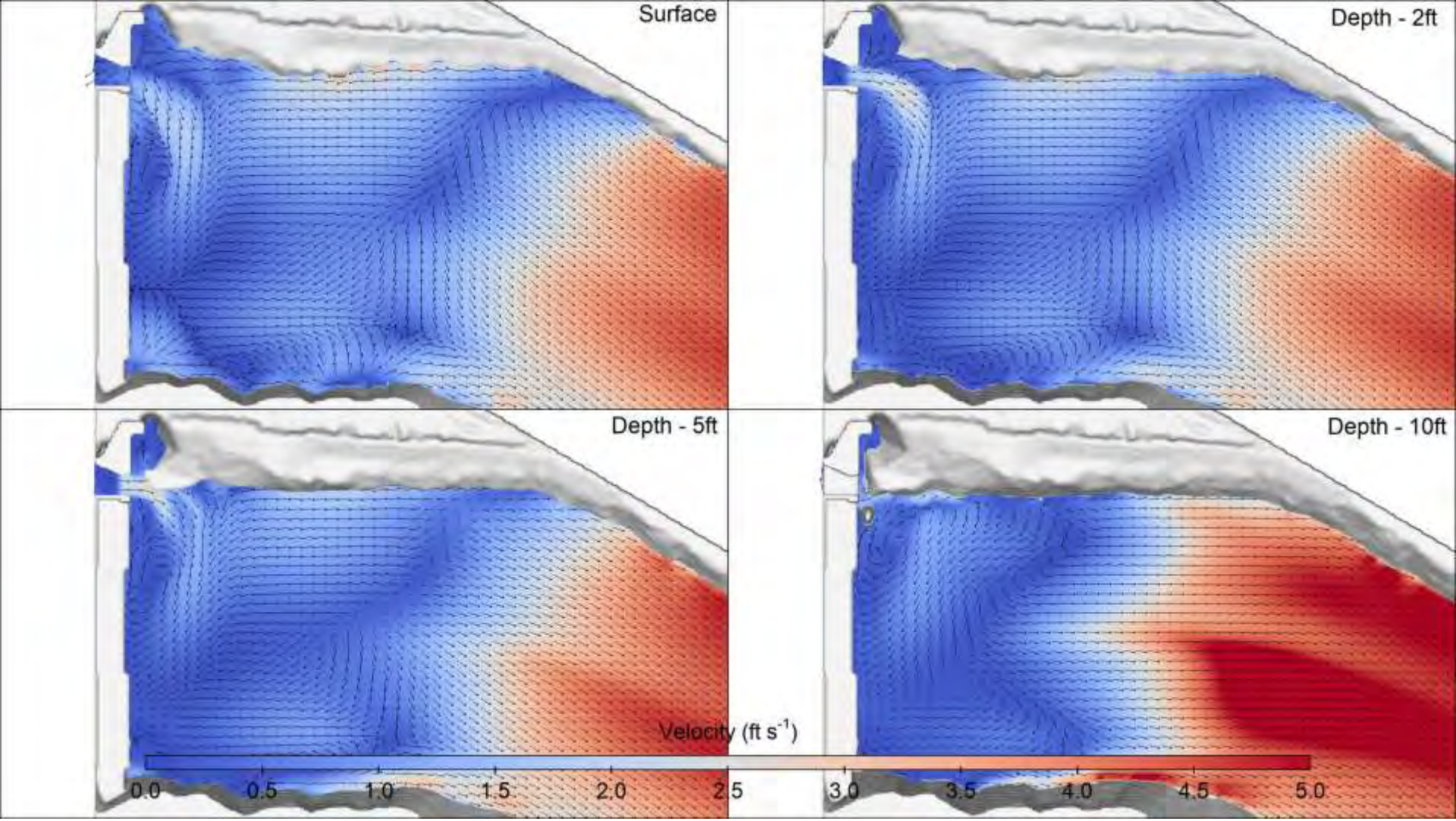
- Fish lift in operation under recommended settings (120 cfs)
- E.L. Field at full capacity (6,600 cfs)
- Low tailrace condition (50% exceedance level [6,770 cfs], 52.4 ft)

CFD Model Study:

Results Summary – E.L. Field Powerhouse Tailrace

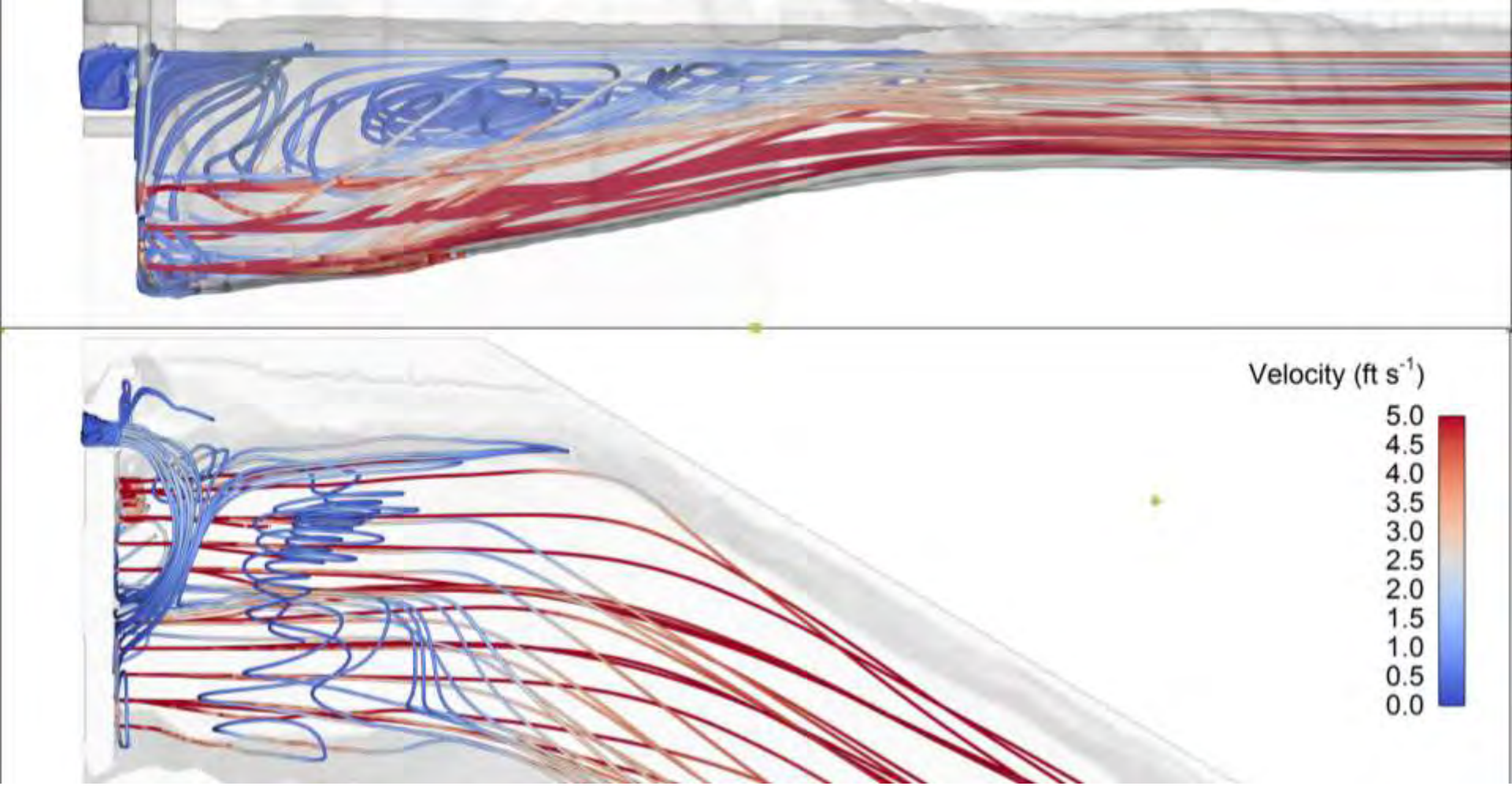
- 2 Powerhouse Outflows (blue)
- AWS Riverside Flow (red)





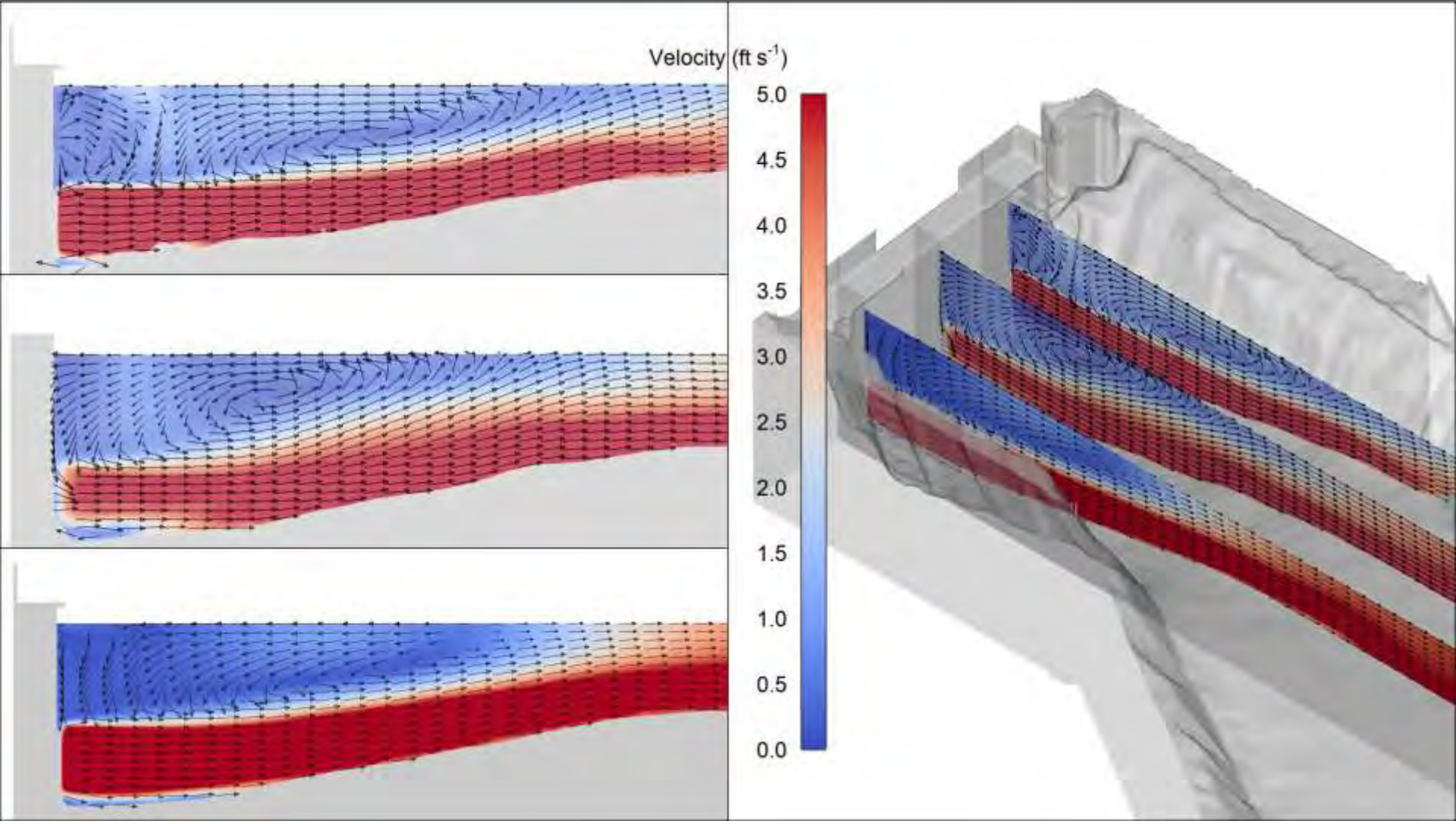
CFD Model Study

E.L. Field Powerhouse Tailrace – 5% Exceedance



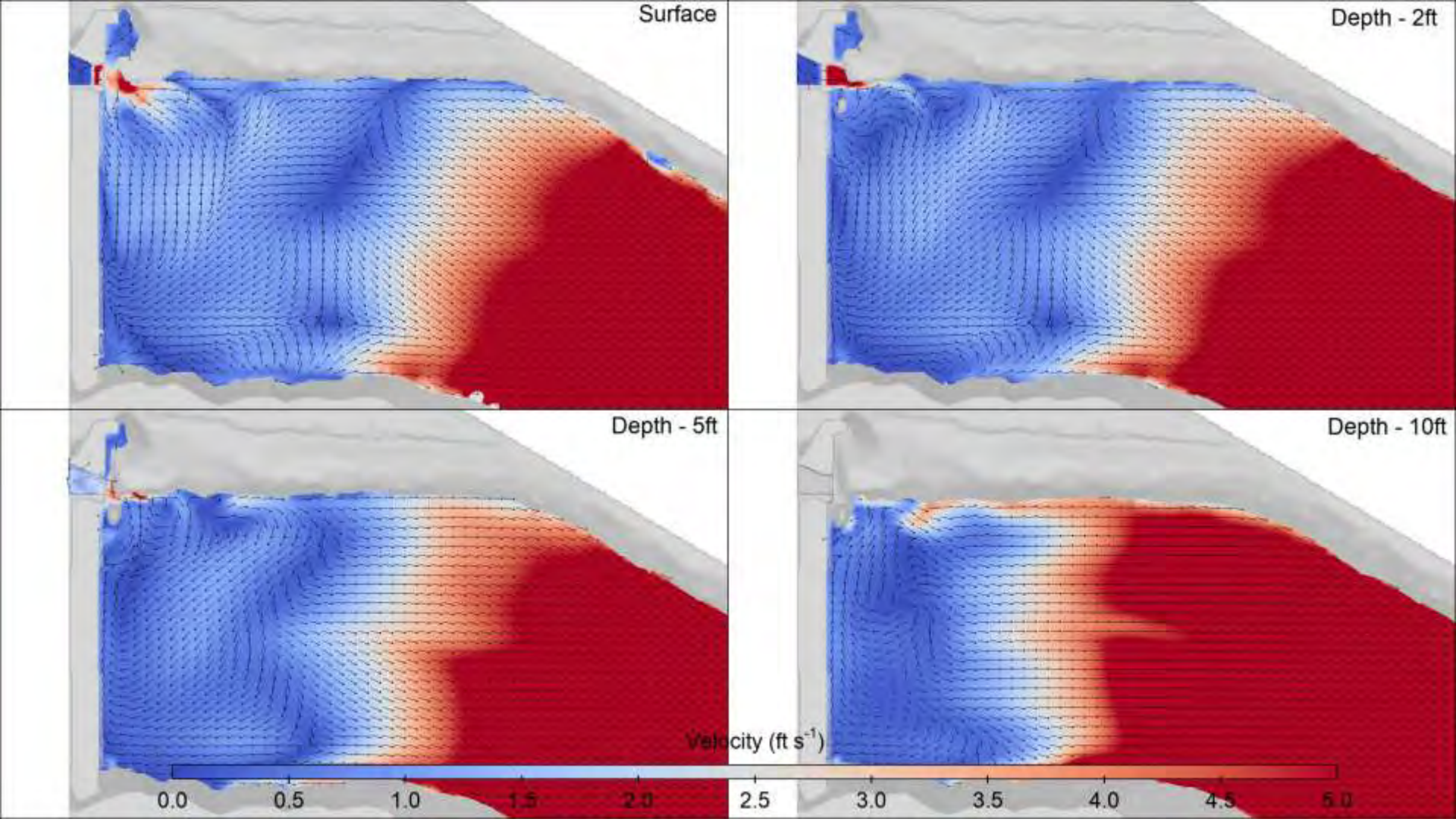
CFD Model Study

E.L. Field Powerhouse Tailrace – 5% Exceedance



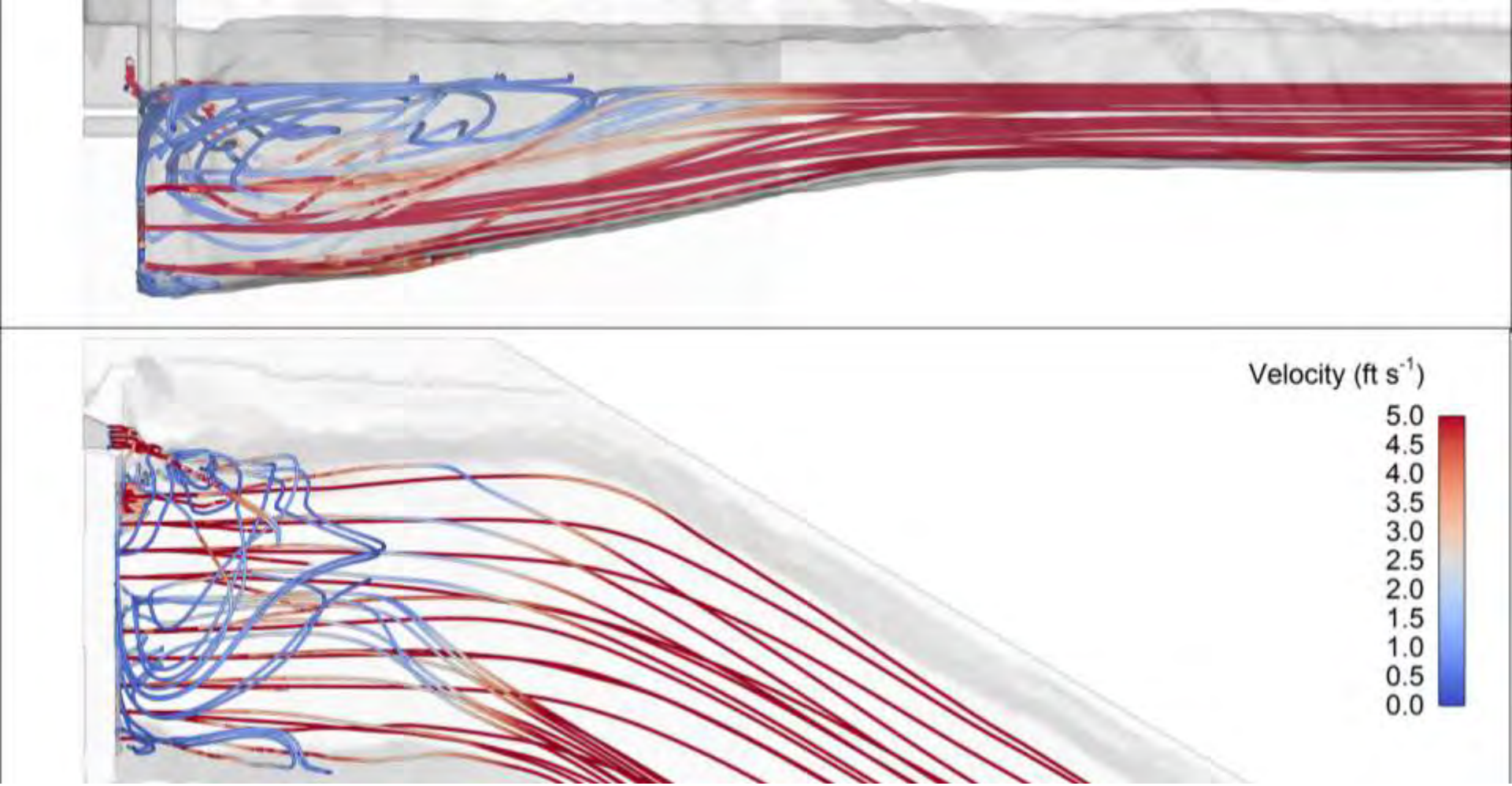
CFD Model Study

E.L. Field Powerhouse Tailrace – 5% Exceedance



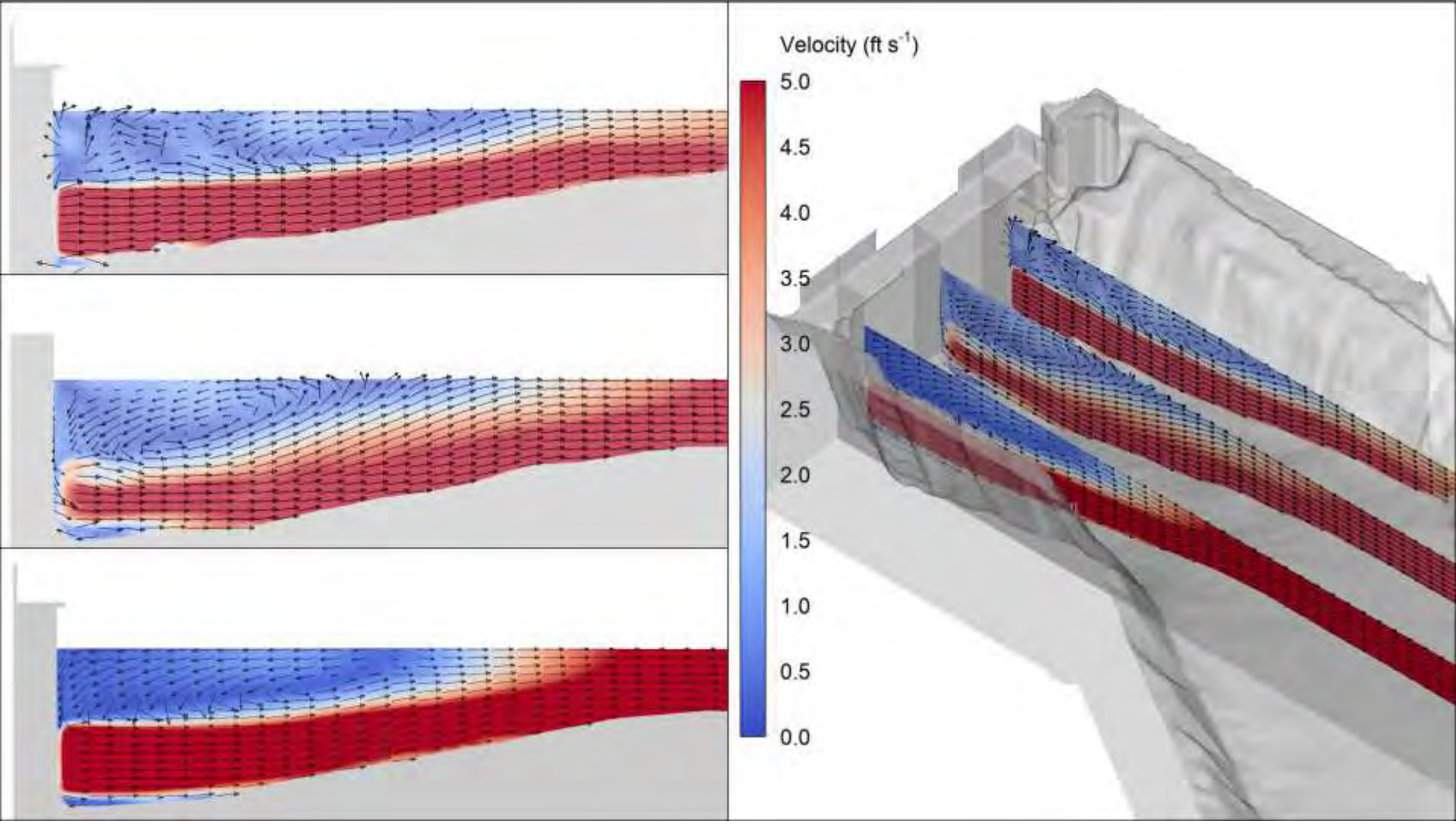
CFD Model Study

E.L. Field Powerhouse Tailrace – 50% Exceedance



CFD Model Study

E.L. Field Powerhouse Tailrace – 50% Exceedance



CFD Model Study

E.L. Field Powerhouse Tailrace – 50% Exceedance

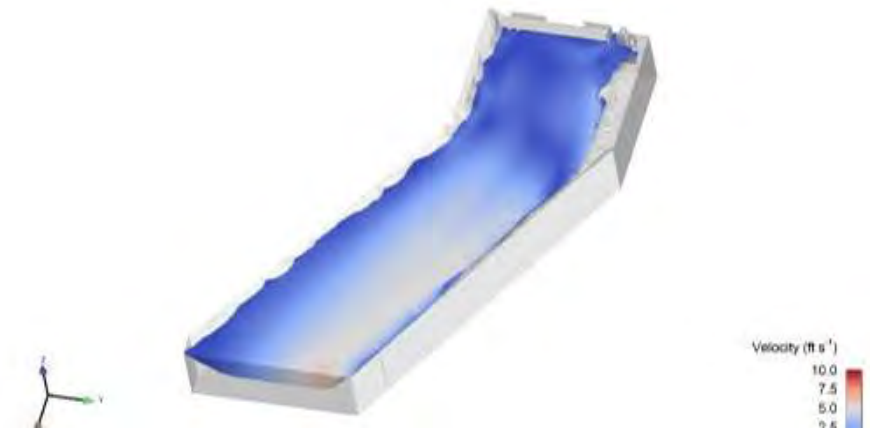
CFD Model Study
Next Steps

E.L. Field Powerhouse Tailrace

- Finalize simulations
  - Post-process

E.L. Field Powerhouse Forebay

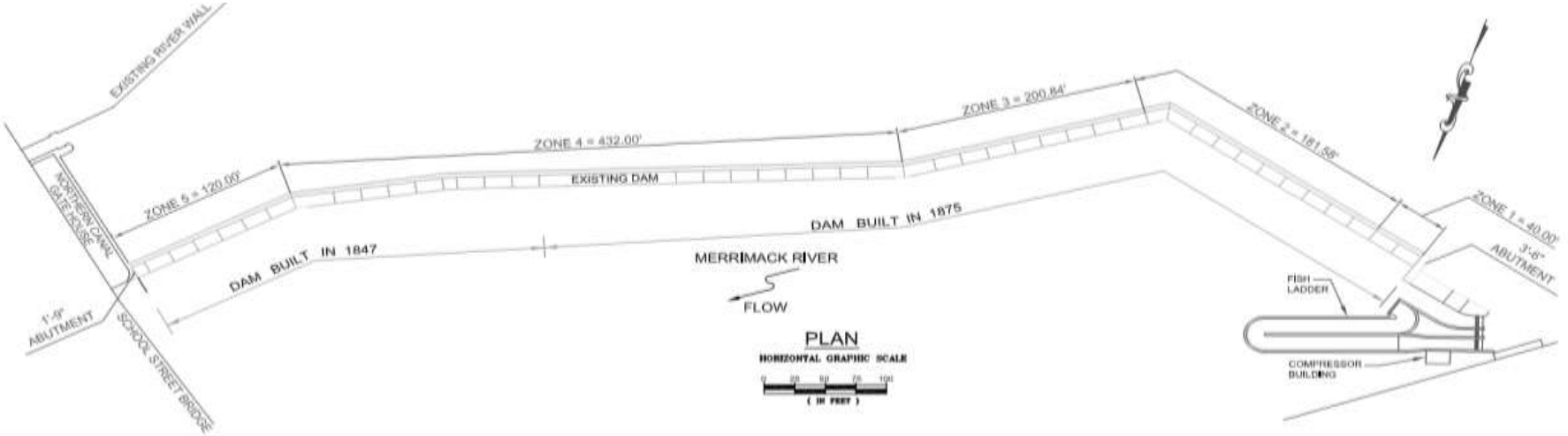
- Update boundary conditions
- Finalize simulations



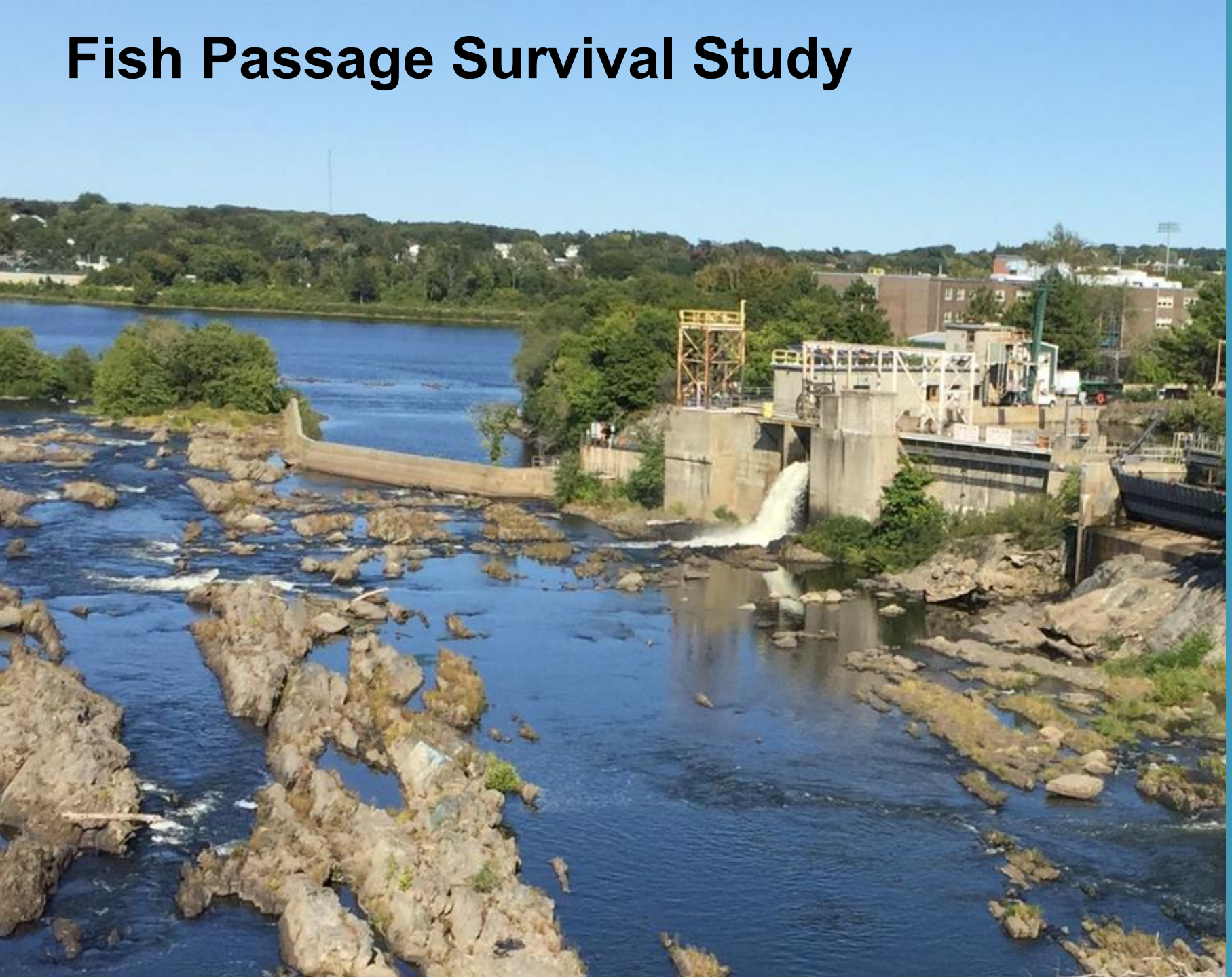
CFD Model Study
Next Steps

Pawtucket Dam Fish Ladder

- Finalize Geometry
- Crest Flow Location
  - 300 cfs
  - 5% Exceedance Flow
    - 26,000 total
    - 6,600 cfs powerhouse
    - 120 cfs AWS
    - Crest Gate Operations



Fish Passage Survival Study



Fish Passage Survival Study: Goals and Objectives

- Study Goal: assess the potential survival of fish passing downstream through the E.L. Field* turbines and to inform estimates of Project passage survival for emigrating diadromous fish species (adult and juvenile American shad, river herring, and American eel)
- Specific Objectives:
  - Assess the potential for impingement for the target species and life stages;
  - Assess the potential for entrainment for target species and life stages;
  - Conduct a desktop survival analysis to estimate passage survival of target species and life stages for each active turbine type; and
  - Assess total Project survival for the target species and life stages.

*Focus of the February 25, 2021 Fish Passage Survival Study on E.L. Field turbines due to Boott decision to eliminate Bridge Street, Hamilton, and John Street turbines from future Project license.

Fish Passage Survival Study: Desktop Review

Project Description:

Lowell Project:

- Run-of-river operation
- 23 mile impoundment
- Normal full pond elevation = 92.2’
- E.L. Field Powerhouse sits at DS end of power canal
- Intake rack upper/lower elevations = 72.5’ & 40.5’
- Total rack area = 1,034 ft^2
- Calculated intake velocity at max generation = 3.2 fps

E.L. Field Powerhouse:

- 2 Kaplan style turbines
  - 5 blade
  - 12.7’ runner diameter
  - 120 rpm
  - 3,300 maximum capacity
  - Efficiency ~92%
- 7.25” intake rack spacing

Fish Passage Survival Study: Desktop Review

Fish Community:

- Resident Species – described in detail in the Fish Assemblage Study
  - Documented 22 fish species in the Lowell impoundment – primarily centrachid and cyprinid spp.
- Diadromous Species –
  - Focus of three empirical studies during 2019 and 2020 as well as this review

Target Species	Periods of Greatest Likelihood of Exposure
American Shad	June-July: Following spawning at upstream locations, adult American shad migrate downstream to return to marine habitat
	September-October: Following time spent in upstream rearing habitat, juveniles migrate downstream to enter marine habitat
River Herring (Alewife and Blueback Herring)	May-June: Following spawning at upstream locations, adult river herring migrate downstream to return to marine habitat
	September-October: Following time spent in upstream rearing habitat, juveniles migrate downstream to enter marine habitat
American Eel	September-November: Adult “silver” eels migrate downstream to begin spawning migration to the Sargasso Sea

Fish Passage Survival Study: Desktop Review

Consideration of Existing Rack Spacing:

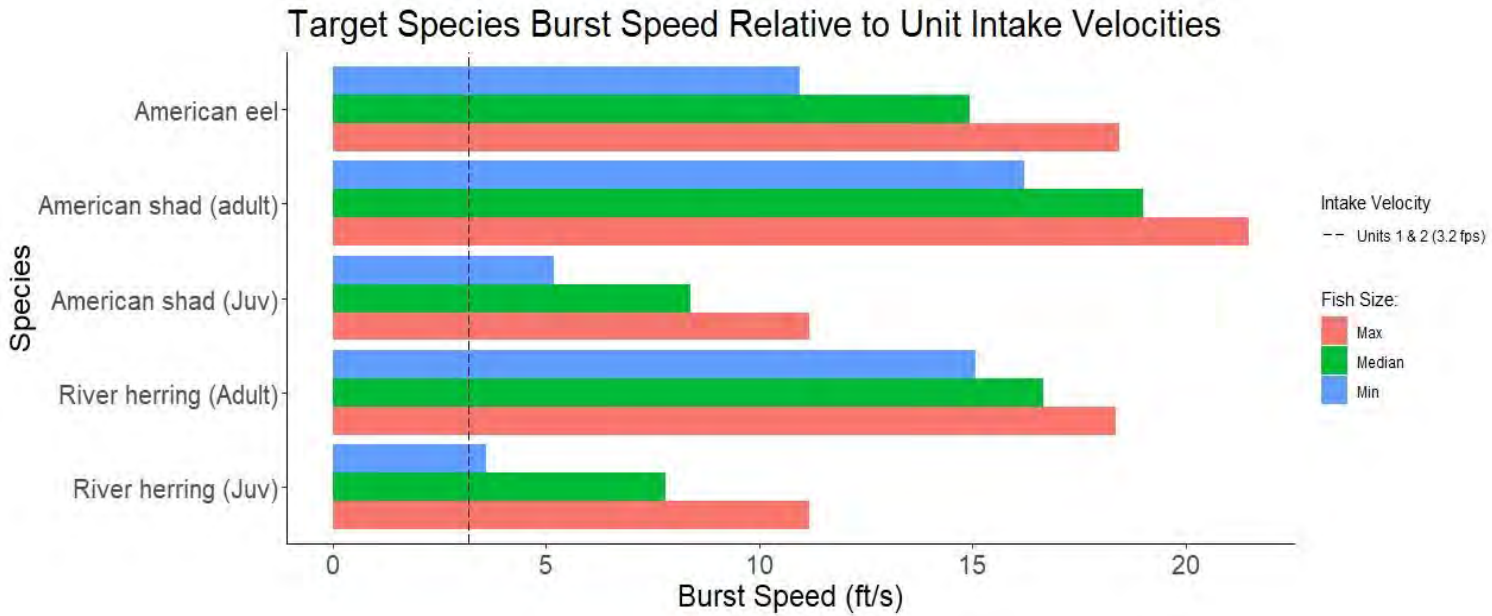
- What is the relation between the existing rack spacing and body size for fish species of concern?

Common Name	Scaling Factor for Body Width[1]	Typical Length (inches) for target species juveniles and adults potentially encountered at the Project		Calculated Minimum Exclusion Length (inches)
American shad	0.134	Juvenile	2-6	none
		Adult	15-23	
River herring	0.105	Juvenile	1.5-6	none
		Adult	9-13	
American eel	0.037	Adult	25-41	none

Fish Passage Survival Study: Desktop Review

Consideration of Approach Velocity:

- What is the relation between the approach velocity and swim capabilities for fish species of concern?
  - Utilized swim speed tool developed by Fisheries and Oceans Canada to evaluate burst capabilities of target species
  - Developed a range of burst speeds for each spp, life stage, body size
  - Considered median burst speeds predicted for min, mid and max body sizes expected for Project area



Fish Passage Survival Study: Desktop Review

Entrainment Passage:

- If entrained at E.L. Field, what is the calculated probability of turbine survival?
  - Modeled using USFWS TBSA Tool – predictor of blade strike probability for a "fish" of size X

Species/Life Stage	Size potentially encountered the region (in)	Body Length (Inches)							
		2 in	4 in	6 in	8 in	12 in	16	20	25
American shad (Juv)	2-6	98.6%	97.2%	95.9%					
American shad (Adult)	15-23						89.0%	86.4%	83.1%
River herring (Juv)	1.5-6	98.6%	97.2%	95.9%					
River herring (Adult)	9-13				94.8%	91.8%	89.0%		

Species/Life Stage	Size potentially encountered the region (in)	Body Length (Inches)						
		21	24	28	32	36	40	45
American eel (Adult)	25-41	71.2%	67.3%	61.8%	56.5%	51.7%	46.0%	39.1%

Fish Passage Survival Study: Desktop Review

Desktop Approach:

- How does need, rack spacing, body size, approach velocity, swim capability and strike probability come together?

Species and Life Stage	Entrainment Potential			Survival
	Behavior, Habitat and Life History	Trash rack Clear Spacing	Swim Speed compared to Lowell Units	
		7.25 inches	(3.2 fps)	Kaplan
American Shad				
Juvenile	H	H	L	H
Adult	H	H	L	M-L
River Herring				
Juvenile	H	H	M-L	H
Adult	H	H	L	M
American Eel				
Adult (silver)	H	H	L	L

Fish Passage Survival Study: Desktop Review

Total Project Survival:

- Empirical estimates for adult fish, TBSA estimate for juvenile alosines

Adult River Herring

- Total project survival: 80.1% (75% CI = 76.7%-83.6%)
  - Downstream bypass: 87.8% (75% CI = 81.8%-91.5%)
  - E.L. Field turbines: 73.9% (75% CI = 68.8%-79.1%)
- TBSA estimates 92% for a 12” fish

Adult American Shad

- Total project survival: 70.0% (75% CI = 64.5%-74.6%)
  - Downstream bypass: 82.6% (75% CI = 75.7%-90.9%)
  - Spill: 89.2% (75% CI = 82.6%-93.8%)
  - E.L. Field turbines: 35.5% (75% CI = 25.8%-45.2%)
- TBSA estimates 86% for a 20” fish

Adult American Eel

- Total project survival: 75.5% (75% CI = 71.4%-79.6%)
  - E.L. Field turbines: 75.0%; 75% CI = 70.6%-79.4%)
- TBSA estimates 67-46% for a 24-40” eel

Fish Passage Survival Study: Desktop Review

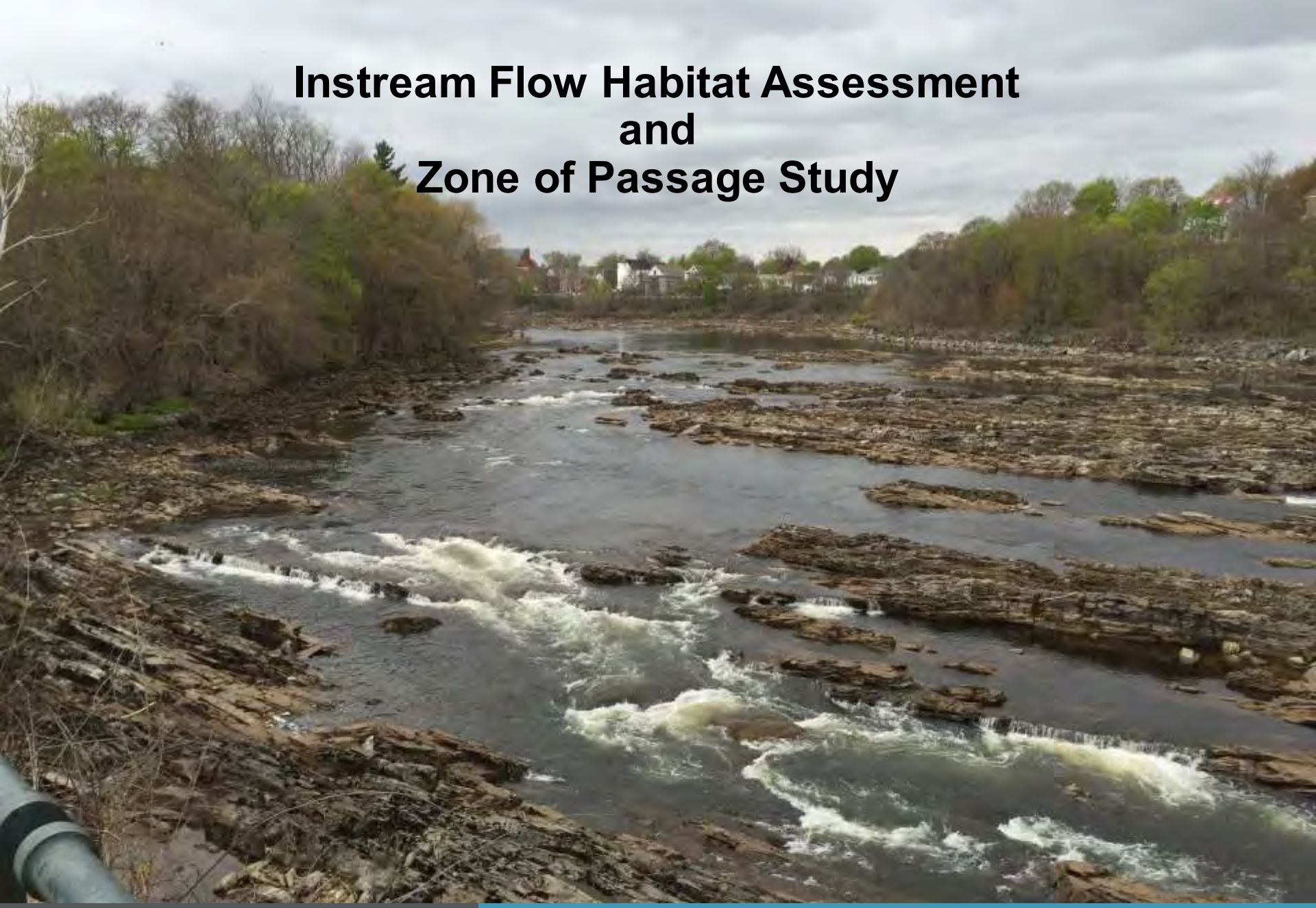
Total Project Survival:

- Empirical estimates for adult fish, TBSA estimate for juvenile alosines

Juvenile Alosines

- Constructed using USFWS TBSA Tool
  - Incorporated empirical estimates for passage route distribution collected during fall 2019 field study
    - 12% spill, 15% DS bypass, 73% turbine passage
  - Assumed a normally distributed population of juvenile alosines (mean TL = 3.5”, S.D. = 1.0”)
  - Assumed comparable mortality rates observed for adult alosines during 2020 study at bypass and spill (11-12%)
  - Allowed TBSA to predict blade strike using E.L. Field specific turbine parameter set
- Total project survival estimated at 94.8%
  - Passage failure attributed to blade strike (2.1%) and mortality during non-turbine passage (3.1%)

Instream Flow Habitat Assessment and Zone of Passage Study



Instream Flow Habitat Assessment and Zone of Passage Study: Goals and Objectives

- Study Goal: Determine Project impact on the rearing habitat of resident fish species and the upstream migration of anadromous fish species within the Bypass Reach.

- Specific Objectives:
  - Assess the relationship between bypass flows and the quantity, quality, and distribution of suitable spawning and rearing habitat for resident fish species (e.g., smallmouth bass, white suckers, fallfish, etc.).

  - Assess the relationship between bypass flows and the availability of potential migration routes for upstream passage by adult river herring and American shad.

Instream Flow Habitat Assessment and Zone of Passage Study: Bypass Study Reach

- ~4,000 ft Study Reach for 2D Habitat and Passage Modeling

Instream Flow Habitat Assessment and Zone of Passage Study: Bypass Study Reach

- Lower ~3,000 ft complex, exposed bedrock ledges and chutes

Instream Flow Habitat Assessment and Zone of Passage Study: Bypass Study Reach

- Upper ~1,000 ft (to School Street Bridge) deeper/slower with more diverse substrate

Instream Flow Habitat Assessment and Zone of Passage Study: Bypass Study Reach

- Reach above School Street Bridge not modeled due to transverse accretion over spillway at higher flows

Instream Flow Habitat Assessment and Zone of Passage Study: Field Survey Methods

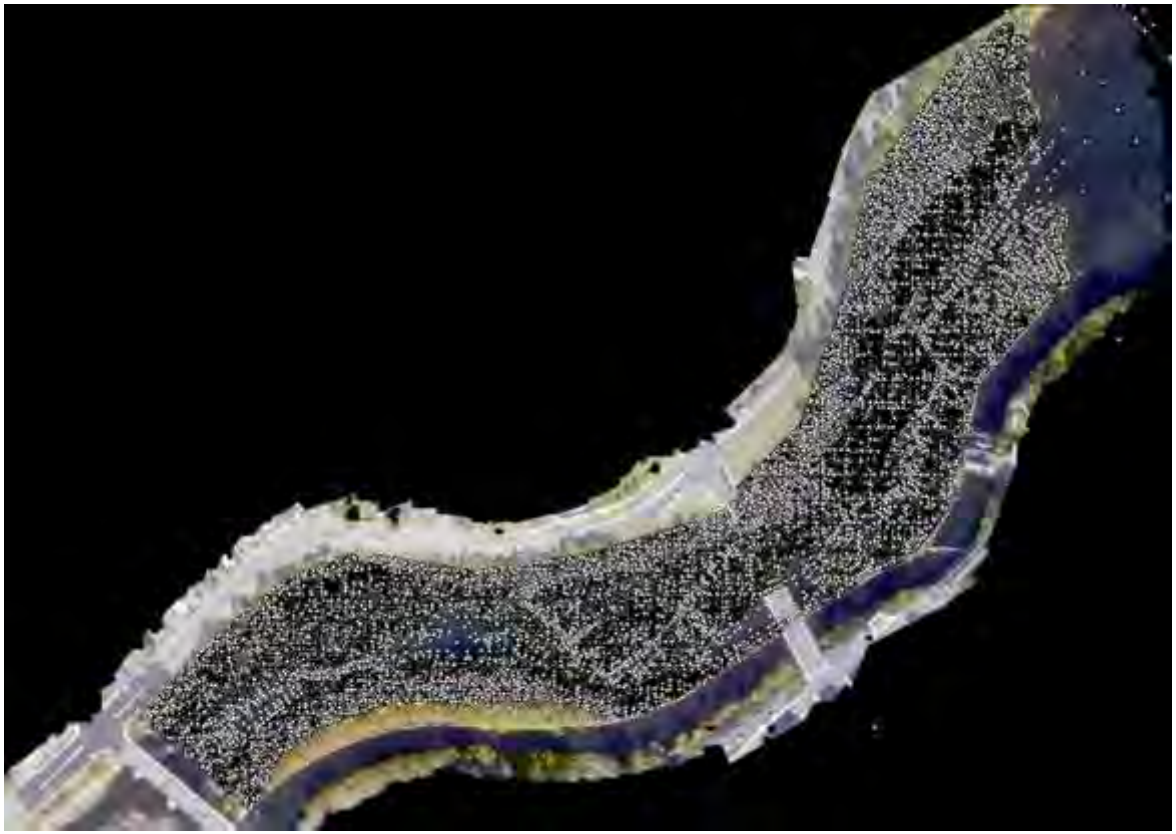
- A 2D model (River2D) was developed using a lidar-equipped drone to survey out-of-water habitat
- Boots on the ground used RTK to map elevations of accessible shallow-water habitat and to map substrate polygons

Instream Flow Habitat Assessment and Zone of Passage Study: Model Development

- A topographic bedfile was developed containing 18,223 nodes and 35,858 elements
- Calibration flows of 482 cfs, 4,345 cfs, and 7,011 cfs were measured to represent low, middle, and high flows, respectively

- Water surface elevation, depth, and mean column velocity was estimated for flows ranging from 250 cfs to 14,000 cfs

- The hydraulic model was combined with Habitat Suitability Criteria (HSC) to estimate spawning habitat, rearing habitat, and passage conditions

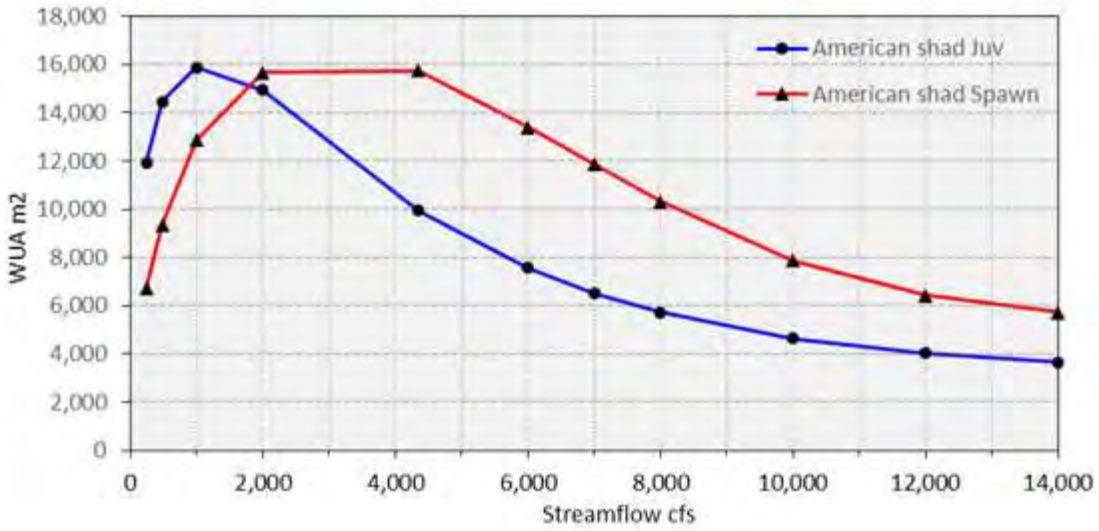


Instream Flow Habitat Assessment and Zone of Passage Study: Aquatic Habitat Assessment

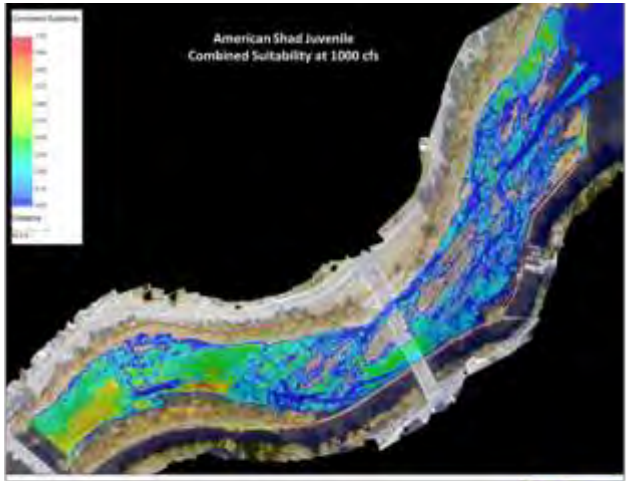
- HSC were selected for target resident and anadromous species:
  - American shad (juvenile, spawning)
  - River herring (spawning)
  - Smallmouth bass (fry, juvenile, adult, spawning)
  - Fallfish (juvenile, adult)
  - White sucker (fry, juvenile/adult, spawning)
  - Longnose dace (juvenile, adult)
  - Sea lamprey (spawning & incubation)
  - Freshwater mussels (rearing)
  - Benthic macroinvertebrates
- An index of suitable habitat was expressed as Weighted Usable Area (WUA) in m^2

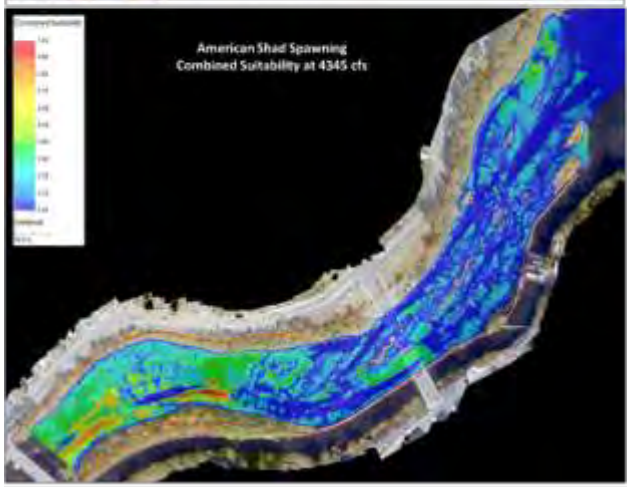
Instream Flow Habitat Assessment and Zone of Passage Study: Aquatic Habitat Assessment

- WUA maximized at relatively low flows (≤1,000 cfs) for some species (e.g., juvenile shad, juvenile and adult fallfish) and at relatively high flows (>2,000 cfs) for other species (e.g., lamprey spawning, shad spawning)

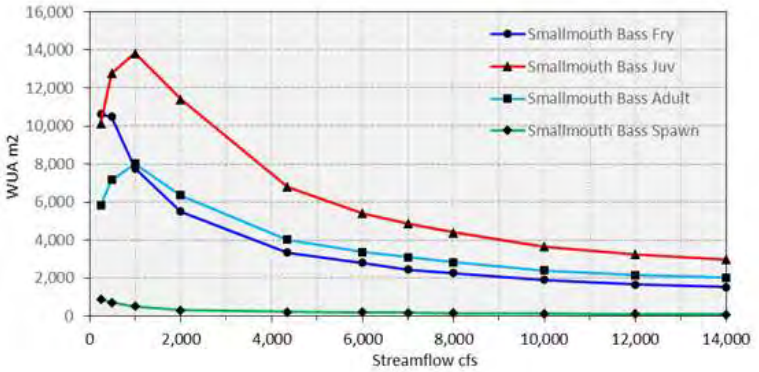


- For many species, little habitat occurred in the lower bedrock area; most suitable habitat was in the upper 1/3 of the modeled reach

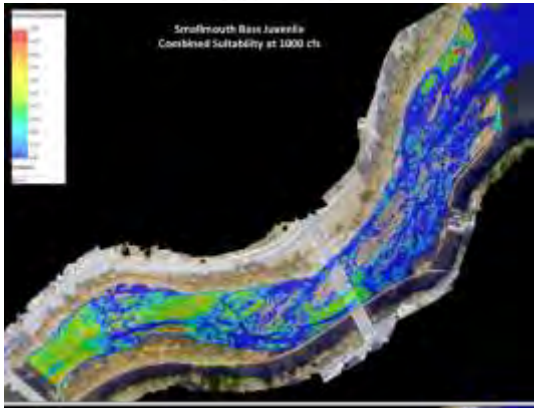


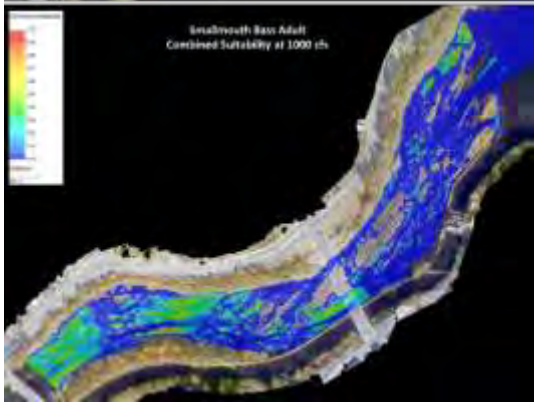


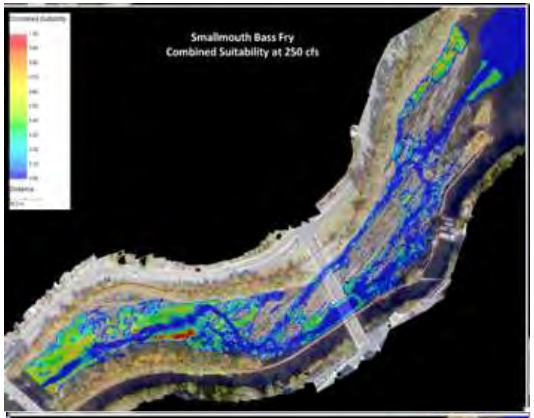
Instream Flow Habitat Assessment and Zone of Passage Study: Aquatic Habitat Assessment



- Little spawning habitat was present for species requiring gravel/cobble substrate (e.g., bass, suckers)
- available habitat was generally restricted to the upper 1/3

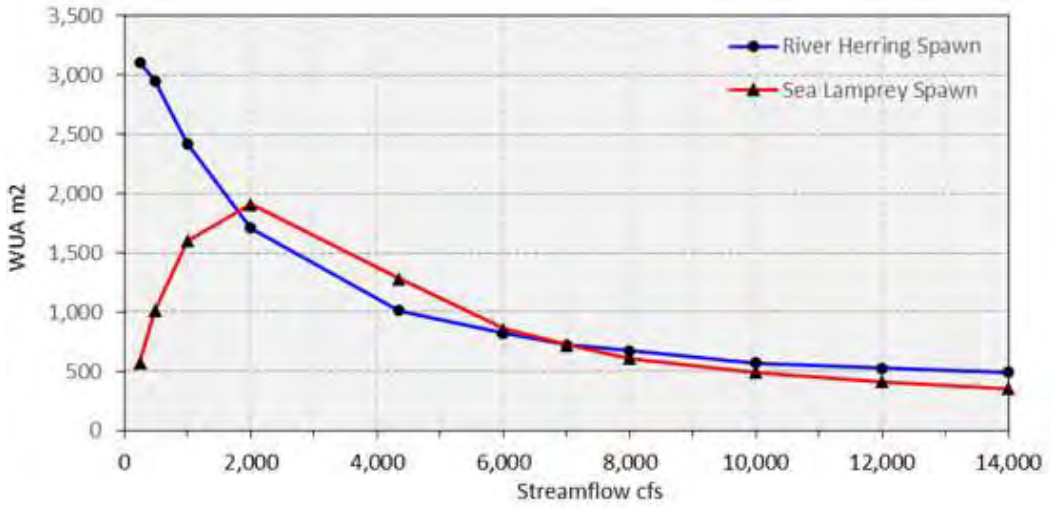




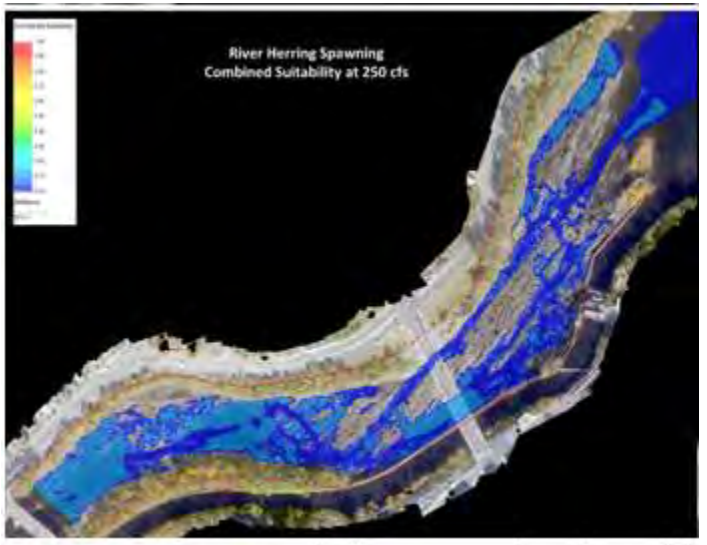


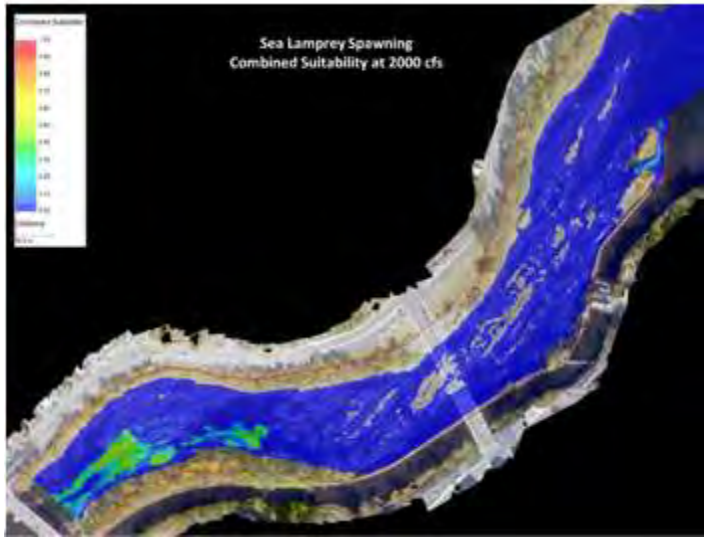
Instream Flow Habitat Assessment and Zone of Passage Study: Aquatic Habitat Assessment

- Low quality spawning habitat for river herring at the lowest modeled flow

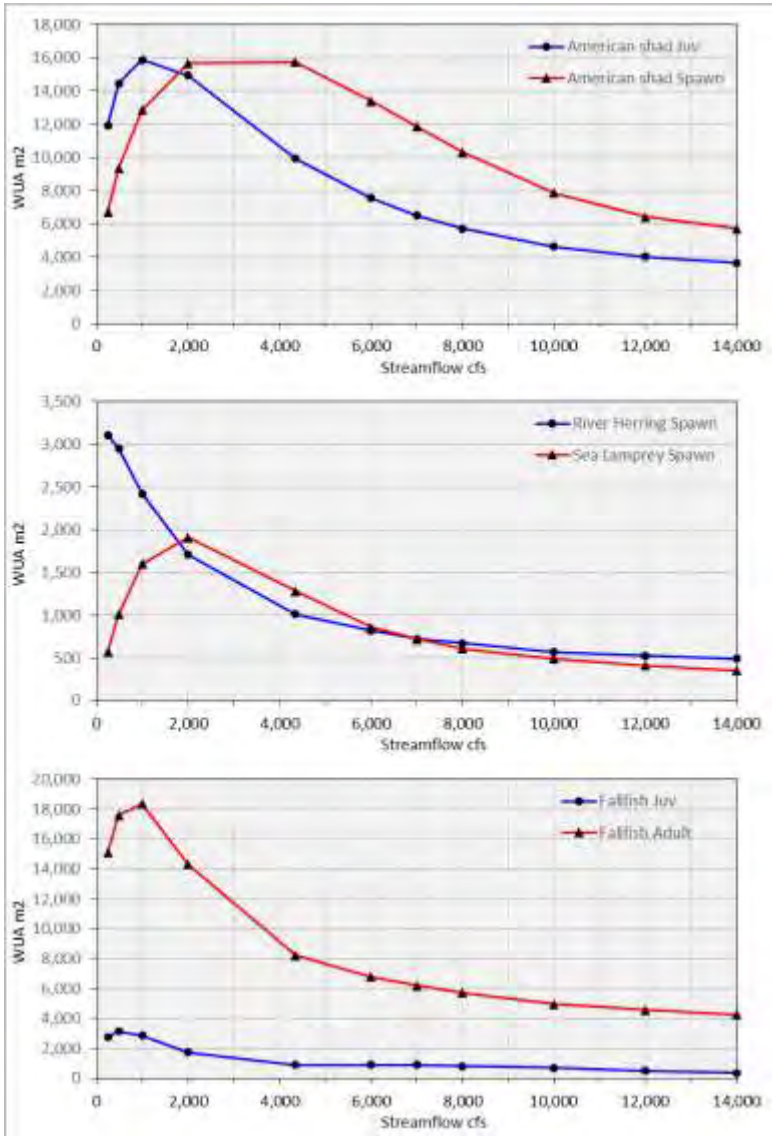


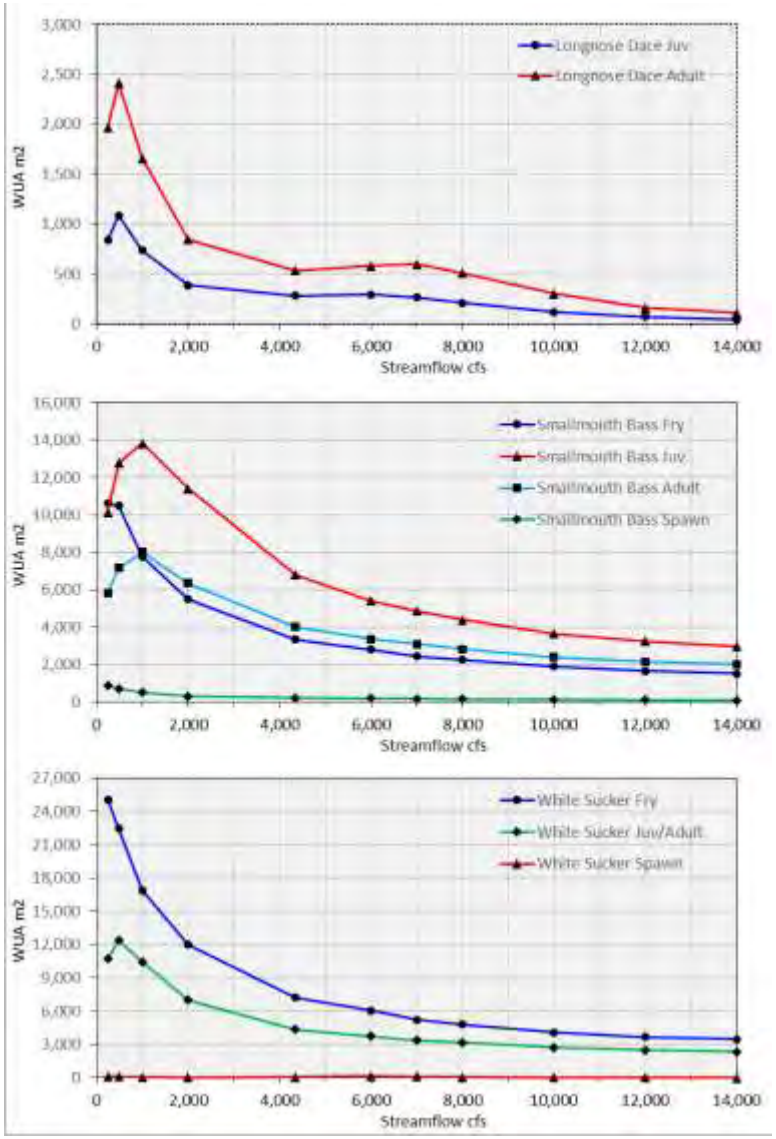
- Small amount of low to moderate quality spawning habitat for lamprey at a higher flow





Instream Flow Habitat Assessment and Zone of Passage Study: Aquatic Habitat Assessment





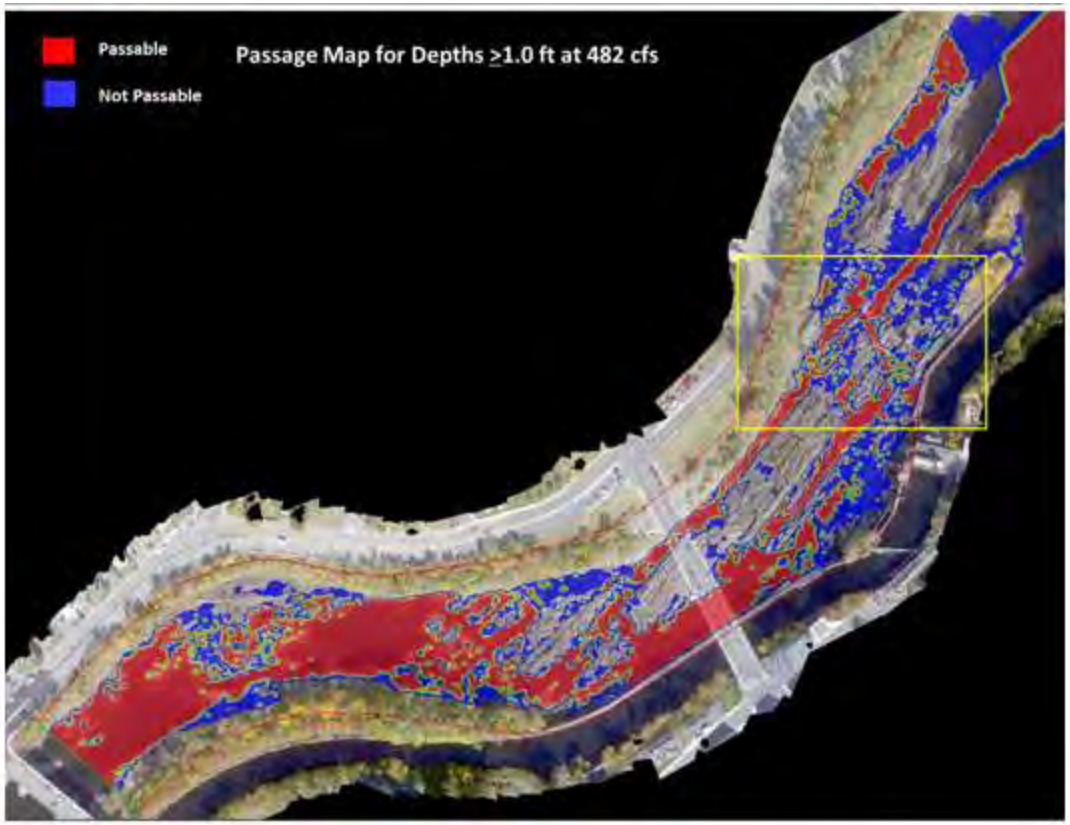
Instream Flow Habitat Assessment and Zone of Passage Study: Zone of Passage Assessment

- Zone of passage was assessed for upstream migrant American shad and river herring

- Herring passage criteria were:
  - Mean Column Velocity $\leq$6.0 fps
  - Depth $\geq$1.0 ft
- Shad passage criteria were:
  - Mean Column Velocity $\leq$ 8.25 fps
  - Depth $\geq$2.25 ft
  - Alternate Depth $\geq$1.0 ft
- Passage assessment primarily relied upon depth criteria due to higher confidence in actual elevation measurements and greater uncertainty in velocity estimates along margins or bottoms of bedrock channels

Instream Flow Habitat Assessment and Zone of Passage Study: Zone of Passage Assessment

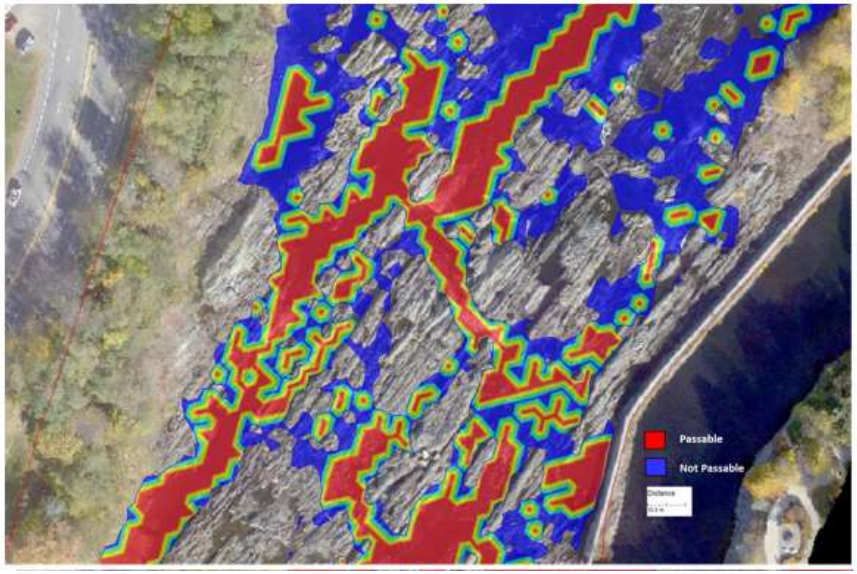
- Zone of passage was assessed for upstream migrant river herring and American shad

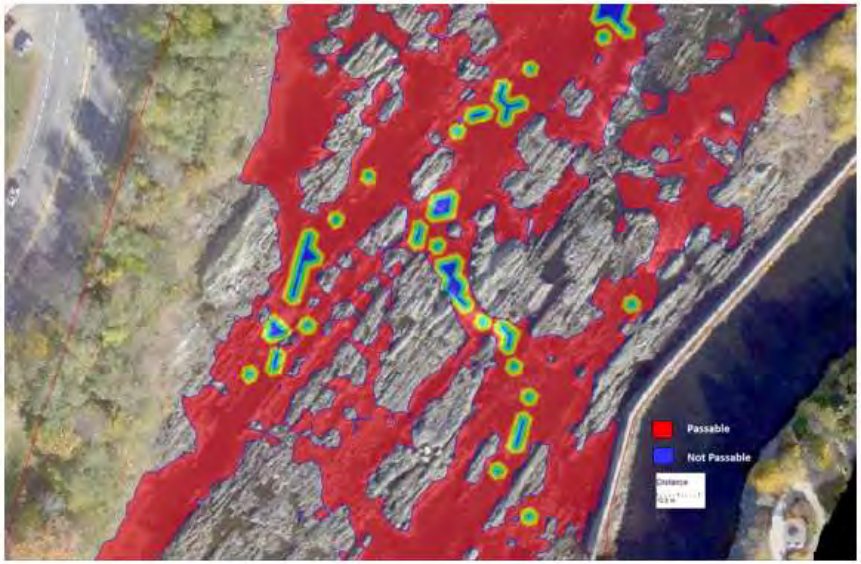


- Herring passage criteria were:
  - Mean Column Velocity ≤6.0 fps
  - Depth ≥1.0 ft
- Shad passage criteria were:
  - Mean Column Velocity ≤ 8.25 fps
  - Depth ≥2.25 ft
  - Alternate Depth ≥1.0 ft
- Passage assessment primarily relied upon depth criteria due to higher confidence in actual elevation measurements and greater uncertainty in velocity estimates along margins or bottoms of bedrock channels

Instream Flow Habitat Assessment and Zone of Passage Study: Zone of Passage Assessment

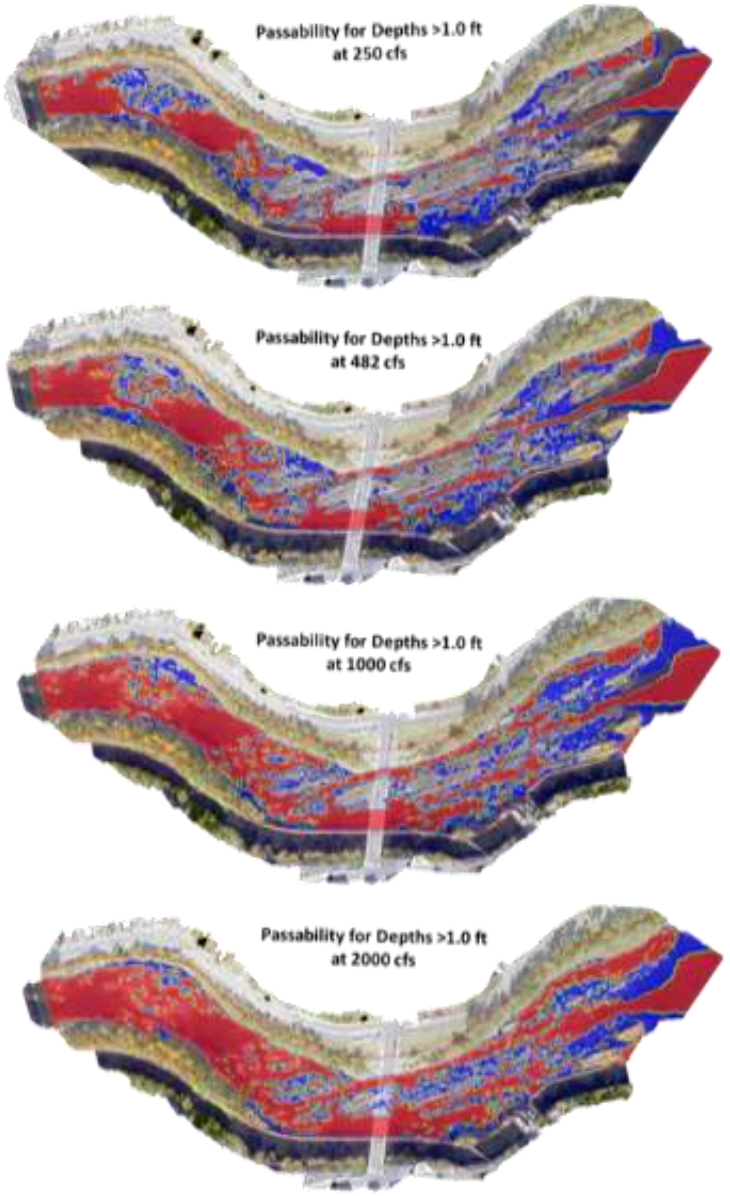
- Zoomed in section showing passage depths of ≥1 ft (left figure) and passage velocities ≤6.0 fps (right figure) at 482 cfs





Instream Flow Habitat Assessment and Zone of Passage Study: Zone of Passage Assessment

- Passage for depth increases with flow, with a relatively continuous channel ≥1.0 ft at 482 cfs
- Passage for velocity is greatest at the lowest flow but decreases as flows increase
- Passage for river herring appeared suitable at a flow of 482 cfs
- Passage for shad was never achieved using the 2.25 ft depth criteria
- Shad passage using a 1.0 ft depth criteria appeared suitable at 482 cfs (velocities well under 8.25 fps)



Instream Flow Habitat Assessment and Zone of Passage Study: Zone of Passage Assessment

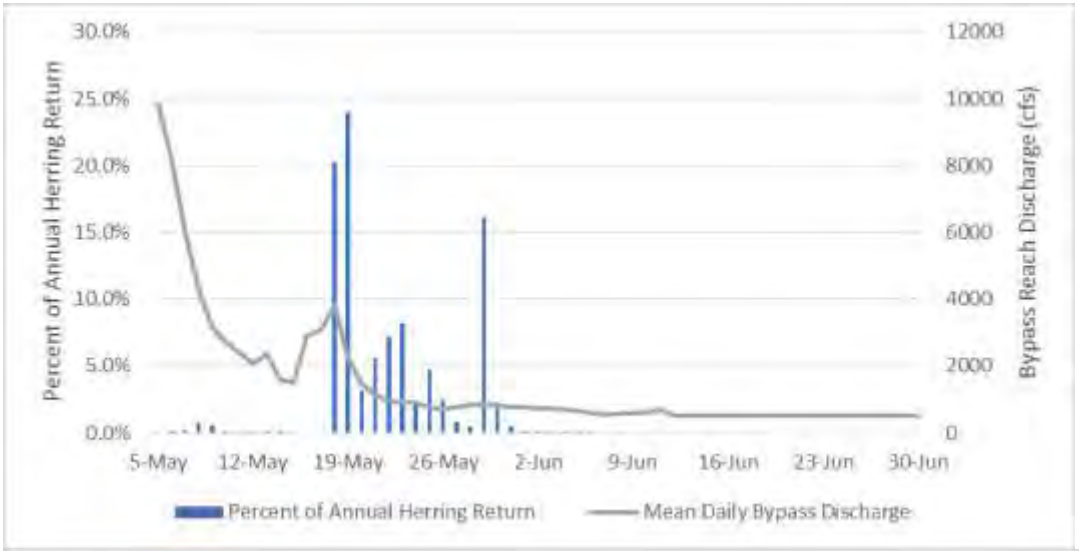
- Radio telemetry (2020 *Upstream and Downstream Adult Alosine Passage Assessment* Study) and SalmonSoft fish counts at the Pawtucket Dam fish ladder
- Results can be used to compare with predicted passage using the 2D passage model

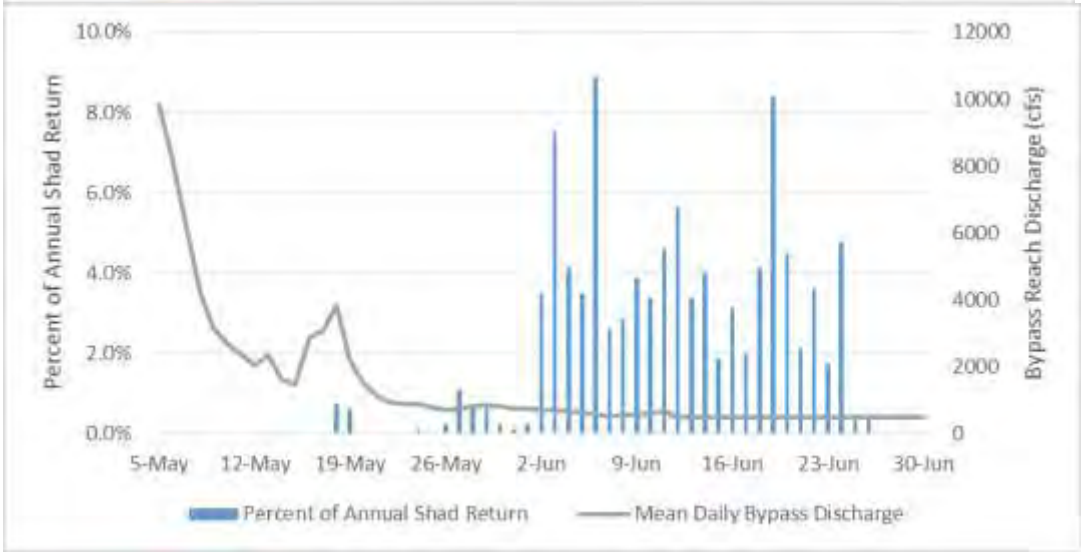
Instream Flow Habitat Assessment and Zone of Passage Study: Zone of Passage Assessment

- Ladder counts revealed that over 42,000 adult herring migrated through the Lowell Bypass and passed the Pawtucket Dam fish ladder at mean daily flows ranging from 546 cfs to 900 cfs (upper graph – May 24 to June 6)

- 799 adult American shad were counted at the fish ladder during steady flows of about 500 cfs (lower graph)

- Both species appear to successfully migrate through the Bypass Reach at flows of about 500 cfs





Lunch Break

Resources, Ownership, Boundaries, and Land Rights Study Report

Resources, Ownership, Boundaries, and Land Rights Study Report: **Goals and Objectives**

- The goal of this study is to determine current ownership of resources within the canal system and existing Project Boundary, and document maintenance responsibilities, access rights, and clarify FERC jurisdiction.

- The specific objectives of this study are as follows:
  - Determine the current ownership of resources within the canal system in a comprehensive manner;
  - Record maintenance responsibilities and obligations to resources within the canal system;
  - Clarify FERC jurisdiction;
  - Document recreational, educational, or other land access rights to resources within the canal system; and
  - Develop a GIS database of resources, ownership, boundaries, and land rights.




Resources, Ownership, Boundaries, and Land Rights Study Report: **Study Methods**

- Literature Review and Analysis
  - Boott compiled and reviewed available ownership and rights documentation. As appropriate and relevant, public guidance, conceptual planning, and management documentation was reviewed by Boott including the following:
    - 1980 *Details of the Preservation Plan*;
    - 1981 *Final General Management Plan*;
    - 1990 *Preservation Plan Amendment*; and
    - 1991 *Memorandum of Understanding*
  - Boott reviewed the three legal documents that establish most of the ownership and easement rights of the Lowell canal system: the 1984 *Great Deed*, 1986 *Order of Taking*, and the 1995 *Grant of Easement*. These were filed as appendices to the Study Report.
  - The GIS Database was developed using ESRI's ArcMap, ArcCatalog, and ArcGIS Online. Exports of the database were provided in the Study Report as an appendix.




Resources, Ownership, Boundaries, and Land Rights Study Report: **Results Summary**

Literature Review and Analysis

- The results of the literature review are presented in Section 5 of the Study Report.
  - Section 5.1 Conceptual Planning of the Lowell Canal System
  - Section 5.2 Ownership of the Lowell Canal System
  - Section 5.3 Easement Rights to the Lowell Canal System
  - Section 5.4 Resource Rights in the Lowell Canal System
  - Section 5.5 Historical Management Agreements
  - Section 5.6 FERC Jurisdiction

Resources, Ownership, Boundaries, and Land Rights Study Report: **Results Summary**

Literature Review and Analysis

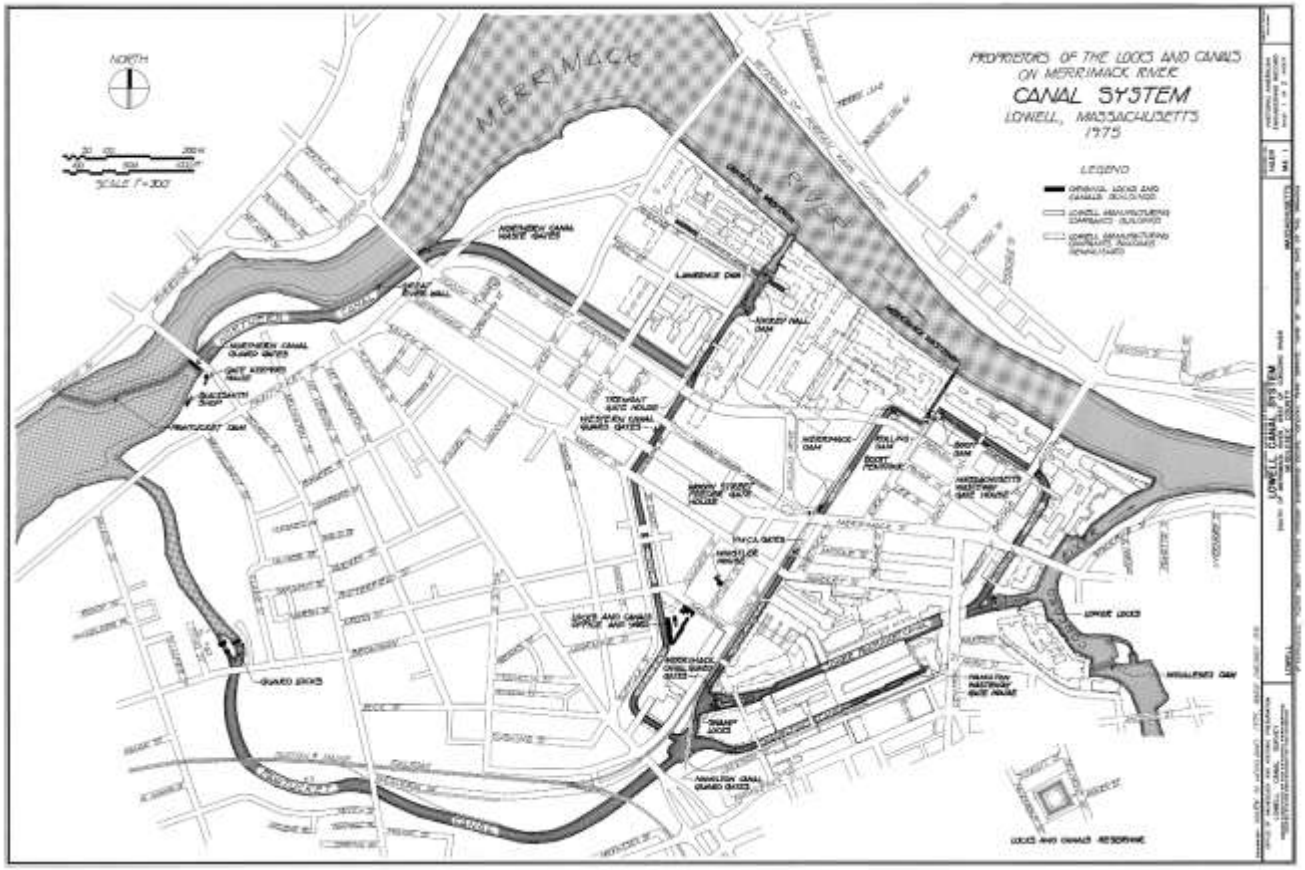
- Section 5.1 Conceptual Planning of the Lowell Canal System
  - The *1977 Report of the LHCDC* proposed cooperative undertaking of the NPS and the Commonwealth of Massachusetts, acting through what is today the Massachusetts Department of Conservation and Recreation (MADCR). It was understood that almost all the structures would remain in private ownership, but the structures would be developed and managed by NPS and MADCR. Privately owned but publicly managed.
  - 1980 *Details of the Preservation Plan* and the 1981 *Final General Management Plan* provided more context and details to the roles of NPS, the Commonwealth of Massachusetts (acting through MADCR), the City of Lowell, and private companies.
  - Ultimately, the conceptual framework for the rights and responsibilities for management of the Lowell canal system remain consistent within the conceptual public planning documents (1977-1990).

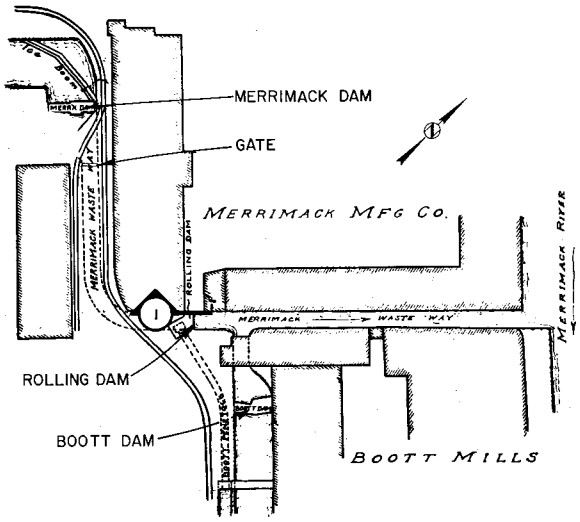



Resources, Ownership, Boundaries, and Land Rights Study Report: **Results Summary**

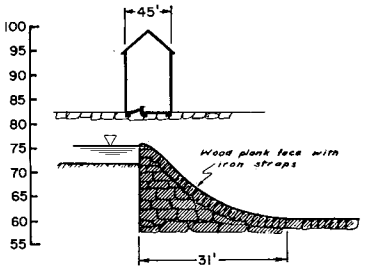
Literature Review and Analysis

- Section 5.2 Ownership of the Lowell Canal System
  - Ownership of the Lowell canal system is largely determined by the 1984 *Great Deed* and 1986 *Order of Taking*.
    - Proprietors owns much of the Pawtucket Canal and structures of the Pawtucket Canal.
    - Boott owns the other canals, and specific dams, lock structures, and hydroelectric equipment within those canals, often based on elevation.
    - MADCR owns most of the gatehouses and several other historical structures throughout the Lowell canal system, also often based on elevation.



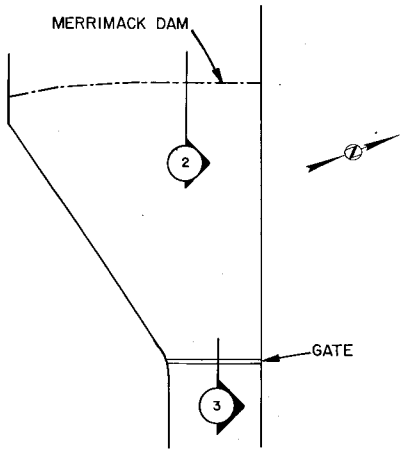


PLAN

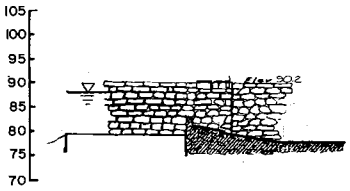


SECTION 1

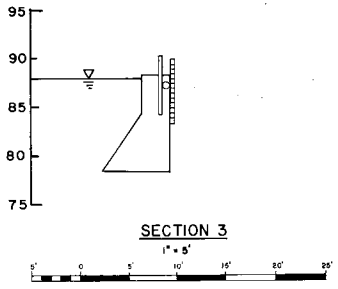
ROLLING DAM



DETAILED PLAN
1" = 10'

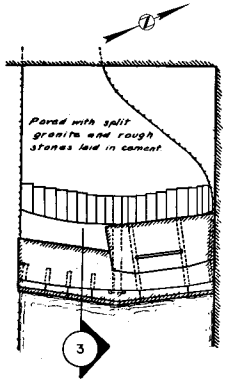


SECTION 2

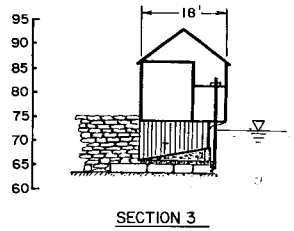


SECTION 3

MERRIMACK DAM AND GATE



DETAILED PLAN



SECTION 3

BOOTT DAM

THIS DRAWING IS PART OF THE APPLICATION FOR A LICENSE MADE BY THE UNDERSIGNED THIS 30th DAY OF MAY, 1980

BOOTT MILLS
PROPRIETORS OF THE LOCKS AND CANALS ON MERRIMACK RIVER

BY: Melvin G. Lazberg, President

EXHIBIT F-21

BOOTT MILLS
LOWELL HYDROELECTRIC PROJECT
ROLLING DAM, MERRIMACK DAM, AND BOOTT DAM
PLANS AND SECTIONS

1" = 10'
10' 0 10' 30' 50'

Resources, Ownership, Boundaries, and Land Rights Study Report: **Results Summary**

Literature Review and Analysis

- Section 5.3 Easement Rights
  - Easement rights to structures of the Lowell canal system are held by Proprietors, Boott, MADCR, and NPS.
    - Boott obtained easement rights, in common with Proprietors, to the Pawtucket Canal and structures of the Pawtucket Canal. These easement rights allow Boott to access, operate, maintain, repair, and replace the Pawtucket Canal and structures of the Pawtucket Canal.
    - In the 1986 *Order of Taking*, MADCR obtained a permanent and exclusive easement to structures of the canal system, including canal walls, beds, and bottoms, for purposes including conservation, preservation, construction of boat ramps, and docks, and other uses consistent with the use of the system as a park.
    - NPS obtained similar easement rights through the 1995 *Grant of Easement*.




Dec 15 86

157 69

Sheet 5 of 38 Sheets

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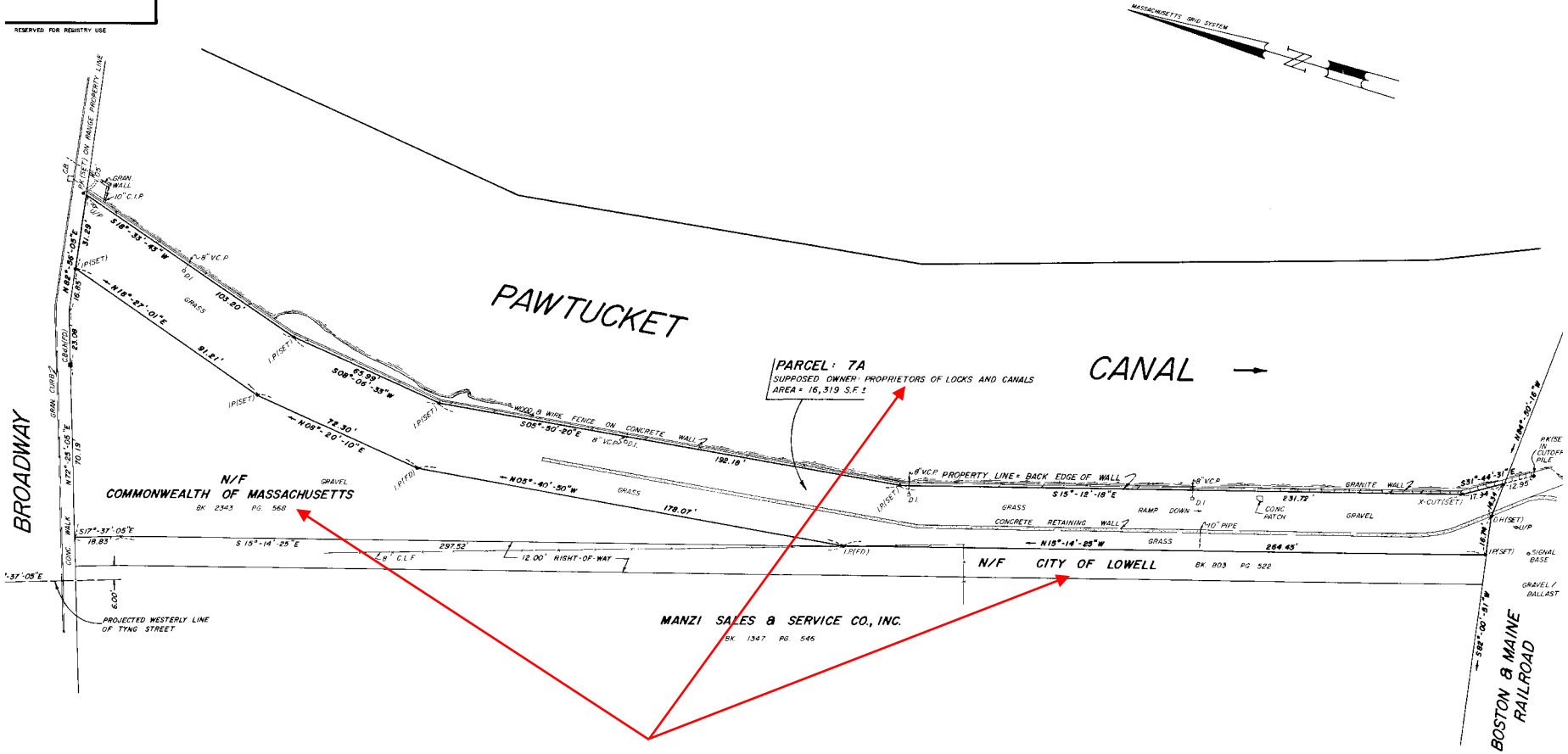


APPROVAL UNDER THE SUBDIVISION CONTROL LAW NOT REQUIRED.

Dec 5 1986

LOWELL PLANNING BOARD

NOTE

PLAN AND DEED REFERENCES RECITED HEREON REFER TO PLANS AND DEEDS RECORDED AT THE MIDDLESEX COUNTY REGISTRY OF DEEDS, NORTH DISTRICT, IN LOWELL.

PLAN BK.	114	PLAN	97
" "	133	"	86
" "	133	"	137

Frank W. Grady
CITY ENGINEER
12-5-86

I CERTIFY THAT THIS PLAN HAS BEEN PREPARED IN CONFORMANCE WITH THE RULES AND REGULATIONS OF THE REGISTERS OF DEEDS.

27 JUNE 1983
DATE

Nicholas Blinn
PREPARED BY

ATLANTIC ENGINEERING AND SURVEY ASSOCIATES
66 Rapid Street
Lynn, MA 01904

1 JULY 1983
DATE

COMMONWEALTH OF MASSACHUSETTS NICHOLAS W. BLINN No 19671 REGISTERED LAND SURVEYOR

Nicholas W. Blinn
REGISTERED LAND SURVEYOR

scale 20 0 20 40 feet

Commonwealth of Massachusetts
DEPARTMENT OF ENVIRONMENTAL MAN
Division of Forests and Parks

LOWELL HERITAGE STATE PARK
Lowell, Massachusetts
Project No. 97
Contract No. 97

TITLE: LOWELL CANAL SYSTEM

SCALE: 1" = 20'

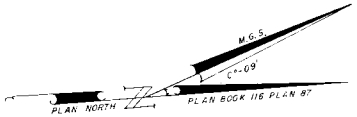
DATE: JUNE 27

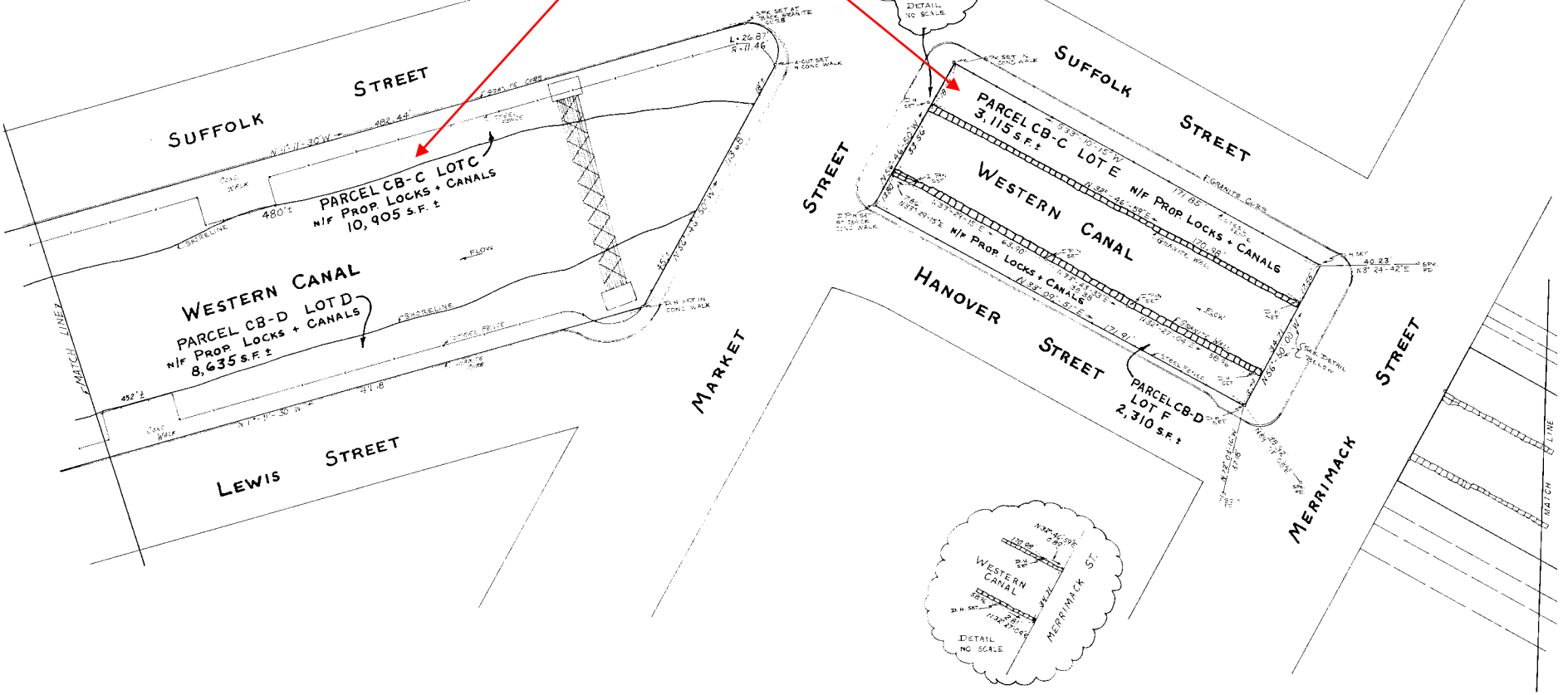
SHEET NO: 5 0

LWC 15 86
157 69

Sheet 27 of 38 sheets

RESERVED FOR REGISTRY USE





APPROVAL UNDER THE SUBDIVISION CONTROL LAW NOT REQUIRED.

Dec 3, 1986

LOWELL PLANNING BOARD

NOTE

PLAN AND DEED REFERENCES RECITED HEREON REFER TO PLANS AND DEEDS RECORDED AT THE MIDDLESEX COUNTY REGISTRY OF DEEDS, NORTH DISTRICT, IN LOWELL.

PLAN BOOK 116 PLAN 87

Frank W. Gearty
CITY ENGINEER
12-5-86

I CERTIFY THAT THIS PLAN HAS BEEN PREPARED IN CONFORMANCE WITH THE RULES AND REGULATIONS OF THE REGISTERS OF DEEDS.

30 JUNE 1983
DATE

PREPARED BY

56 Rand Street
Lynn, MA 01904

6 JULY 1993
DATE

REGISTERED LAND SURVEYOR

20 10 0 20 40
scale feet

SHEET 2 OF 3

Commonwealth of Massachusetts
DEPARTMENT OF ENVIRONMENTAL MAN
Division of Forests and Parks

LOWELL HERITAGE STATE PARK
Lowell, Massachusetts
Project No. 97
Contract No. 97

TITLE: LOWELL CANAL SYSTEM

SCALE: 1" = 20'

DATE: JUNE 30

SHEET NO: 27

Resources, Ownership, Boundaries, and Land Rights Study Report: **Results Summary**

Literature Review and Analysis

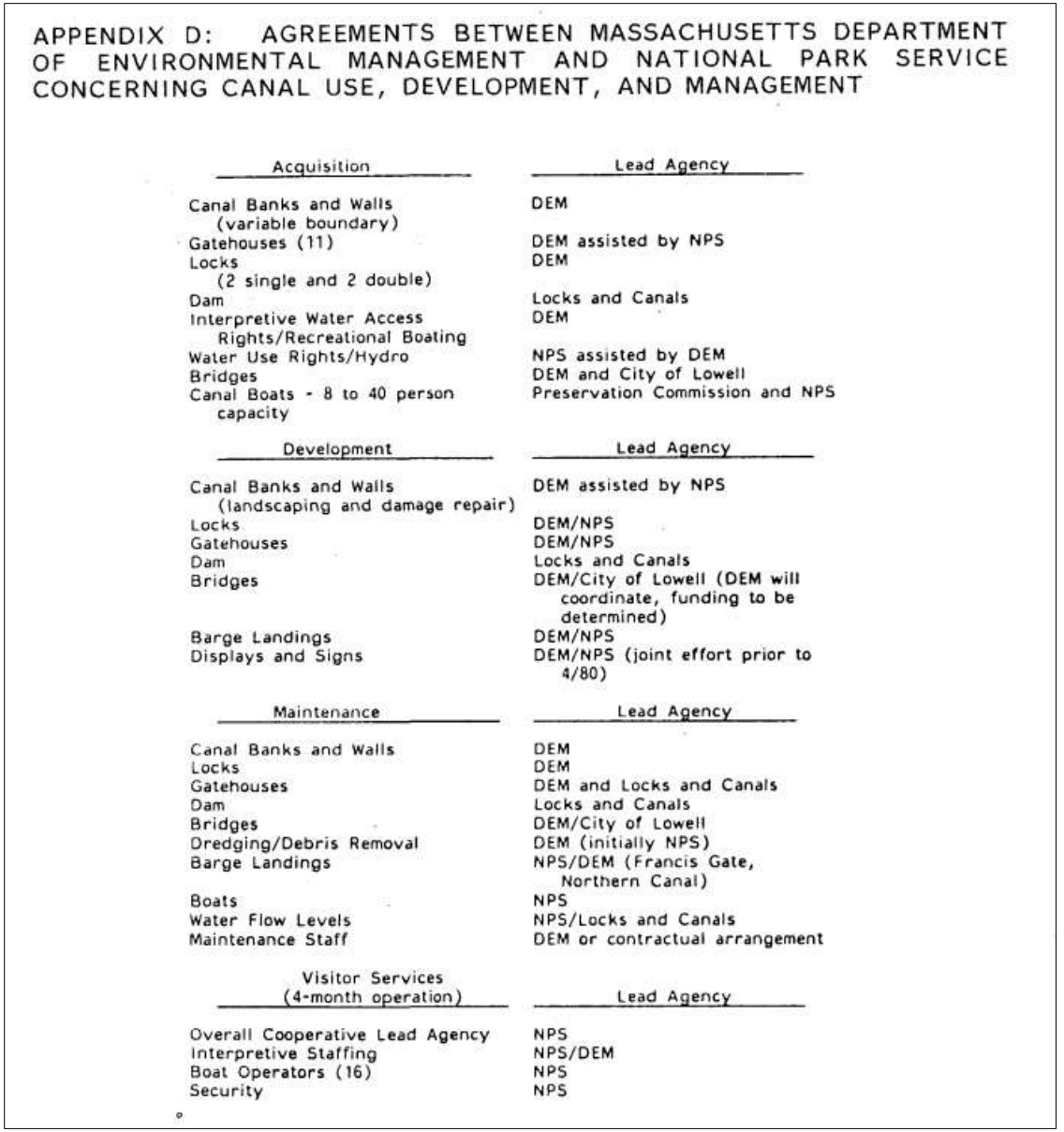
- Section 5.4 Resource Rights
  - Recreational resources: Conceptual planning documents and legal ownership and easement documents are all consistent regarding recreational resource rights. MADCR owns exclusive rights to use the entire canal system for "recreational, educational, and navigational purposes." MADCR holds an exclusive and permanent easement for placement and attachment of docks, wharves, walls, and boat ramps of a temporary or permanent nature.
  - Air resources: The 1986 *Order of Taking* transferred to MADCR "all air rights over the canals, including the canal walls and any dams thereon."
  - Boott and Proprietors retain certain rights to flow water through the downtown canal system.




Resources, Ownership, Boundaries, and Land Rights Study Report: **Results Summary**

Literature Review and Analysis

- Section 5.5 Historical Management Agreement
  - 1979 Agreement
  - 1991 Memorandum of Understanding
    - Ownership and "duty of care"
- These agreements are the "bookends" to the legal documents (1984 *Great Deed* and 1986 *Order of Taking*)



APPENDIX D: AGREEMENTS BETWEEN MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL MANAGEMENT AND NATIONAL PARK SERVICE CONCERNING CANAL USE, DEVELOPMENT, AND MANAGEMENT

Acquisition	Lead Agency
Canal Banks and Walls (variable boundary)	DEM
Gatehouses (11)	DEM assisted by NPS
Locks (2 single and 2 double)	DEM
Dam	Locks and Canals
Interpretive Water Access Rights/Recreational Boating	DEM
Water Use Rights/Hydro	NPS assisted by DEM
Bridges	DEM and City of Lowell
Canal Boats - 8 to 40 person capacity	Preservation Commission and NPS

Development	Lead Agency
Canal Banks and Walls (landscaping and damage repair)	DEM assisted by NPS
Locks	DEM/NPS
Gatehouses	DEM/NPS
Dam	Locks and Canals
Bridges	DEM/City of Lowell (DEM will coordinate, funding to be determined)
Barge Landings	DEM/NPS
Displays and Signs	DEM/NPS (joint effort prior to 4/80)

Maintenance	Lead Agency
Canal Banks and Walls	DEM
Locks	DEM
Gatehouses	DEM and Locks and Canals
Dam	Locks and Canals
Bridges	DEM/City of Lowell
Dredging/Debris Removal	DEM (initially NPS)
Barge Landings	NPS/DEM (Francis Gate, Northern Canal)
Boats	NPS
Water Flow Levels	NPS/Locks and Canals
Maintenance Staff	DEM or contractual arrangement

Visitor Services (4-month operation)	Lead Agency
Overall Cooperative Lead Agency	NPS
Interpretive Staffing	NPS/DEM
Boat Operators (16)	NPS
Security	NPS

Resources, Ownership, Boundaries, and Land Rights Study Report: **Results Summary**

Literature Review and Analysis

- Section 5.6 FERC Jurisdiction
  - Section 23(b)(1) of the Federal Power Act (FPA) requires that each non-federal hydroelectric project falls under FERC jurisdiction if it meets four requirements and does not have a pre-1920 federal permit.
  - The Project Boundary defines the geographical limits of FERC's jurisdiction and those are provided by Exhibit G.
  - The Licensee is required to manage operations within the Project Boundary in accordance with the conditions set forth in the FERC license.
  - Additionally, Section 10(c) of the FPA requires Licensees with to maintain the project works within the Project Boundary in a condition of repair adequate for the purposes of navigation and for the efficient operation of said works in the development and transmission of power, . . . To maintain and operate said works as not to impair navigation, and . . . conform to such rules and regulations as the Commission may from time to time prescribe for the protection of life, health, and property.

Resources, Ownership, Boundaries, and Land Rights Study Report: **Variances from FERC-approved Study Plan**

- The Resources, Ownership, Boundaries, and Land Rights Study Report was conducted in full accordance with the methods described in the FERC-approved study plan.




Water Level and Flow Effects on Historic Resources Study

Water Level and Flow Effects on Historic Resources Study: **Goals and Objectives**

- The goal of this study is to assess the potential effect of water level fluctuations within the headpond, Northern Canal, and the Pawtucket Canal on the historic structures.

- The specific objectives of this study are as follows:
  - Evaluate how Project operations, including manipulation of the new crest gate system, canal head gates, spillways, locks, fish passage structures, and generating units will change water levels in the Upper Pawtucket and Northern Canals;
  - Determine the extent to which water flows or elevations are having an effect on historic resources;
  - Conduct a structural assessment of the Great River Wall; and
  - Identify potential impacts of current Project operations on nationally significant historic resources, including a structural assessment of the Great River Wall.




Water Level and Flow Effects on Historic Resources Study: **Methods**

- Documentation Review of Existing Conditions: Documents reviewed are listed in Section 5 of the Study Report and include comments from stakeholders and documents received from NPS.

- Site Visit to Document Existing Conditions: Boott conducted a site visit to historic canal structures with input from NPS to identify issues previously noted by the NPS related to the flow and water levels on historic structures.

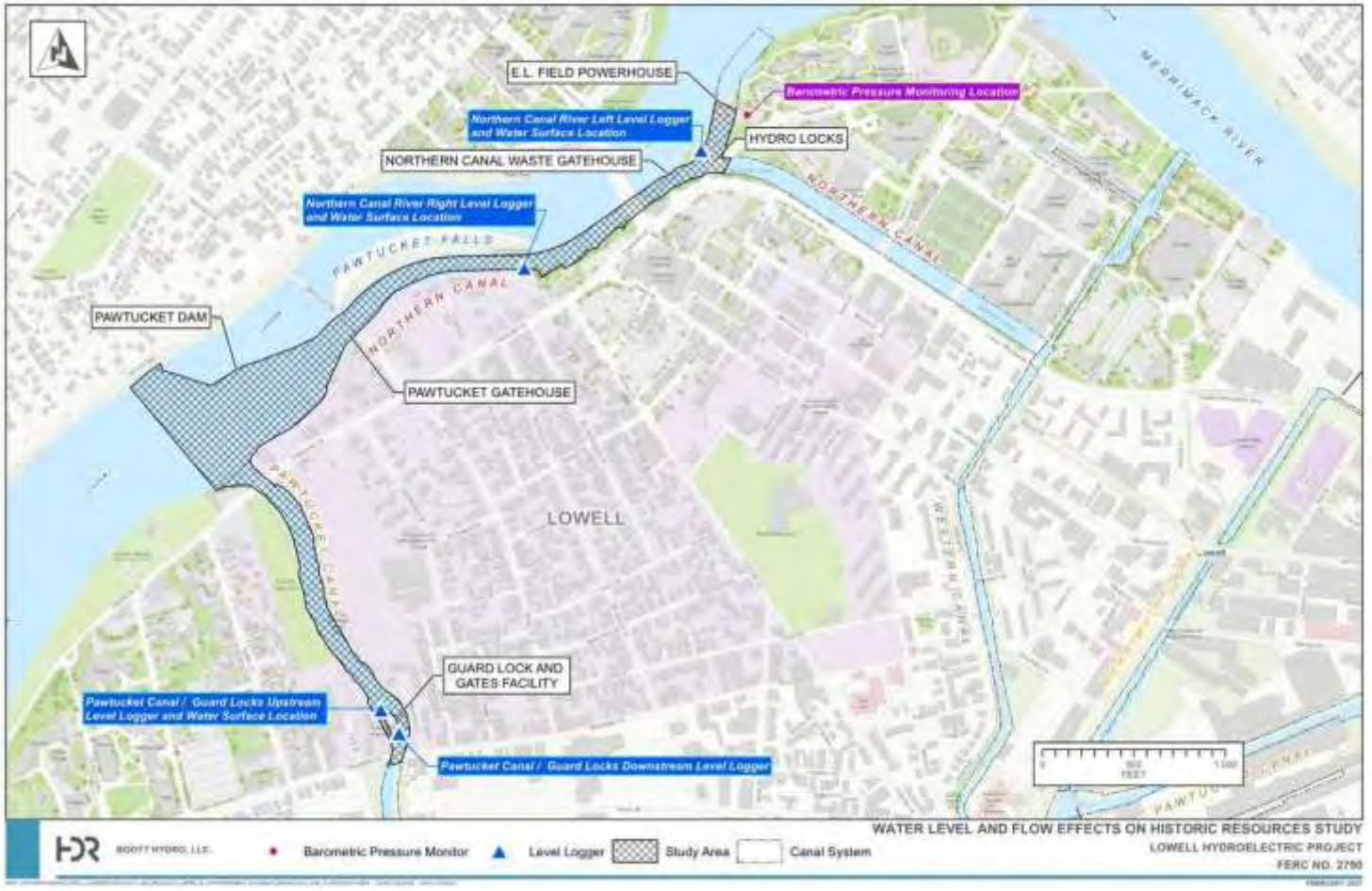
- Canal Water Level Monitoring: Boott installed level loggers at four locations within the canal system, which recorded relative water depths at 15-minute intervals over the study period (March 10 to September 23, 2020).

- Project Operations Review: Boott reviewed Project operational data including headpond elevation, forebay elevation, Project operations, and Merrimack River flows (January 1995 through December 2010).

- Analysis of Potential Project Related Effects: Using data gathered from the above methods to determine Project-specific damage to any historic infrastructure.

Water Level and Flow Effects on Historic Resources Study: **Results Summary**

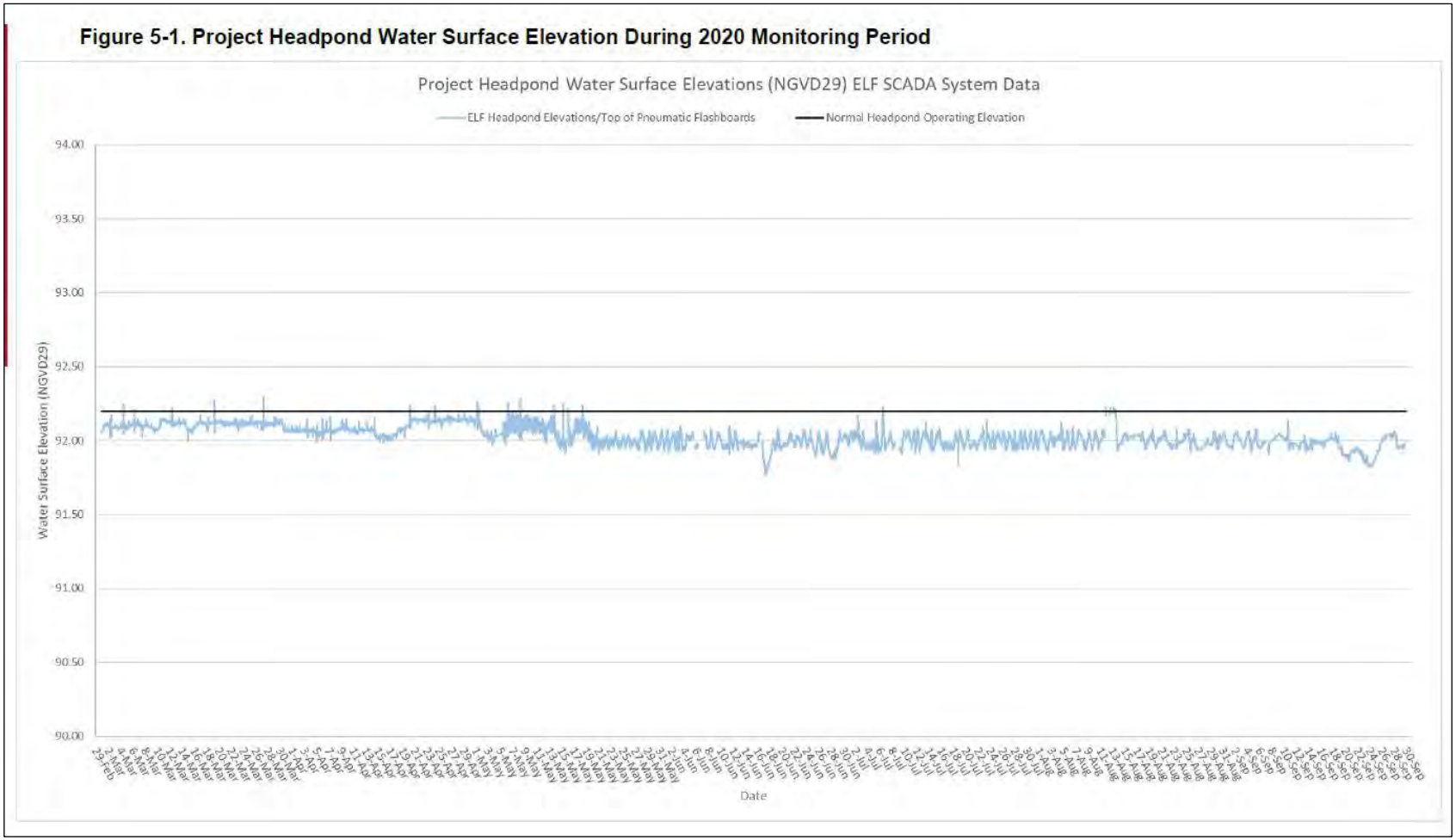
Canal Water Level Monitoring: Boott installed level loggers at four locations within the canal system, which recorded relative water depths at 15-minute intervals over the study period (March 10 to September 23, 2020).



Water Level and Flow Effects on Historic Resources Study: **Results Summary**

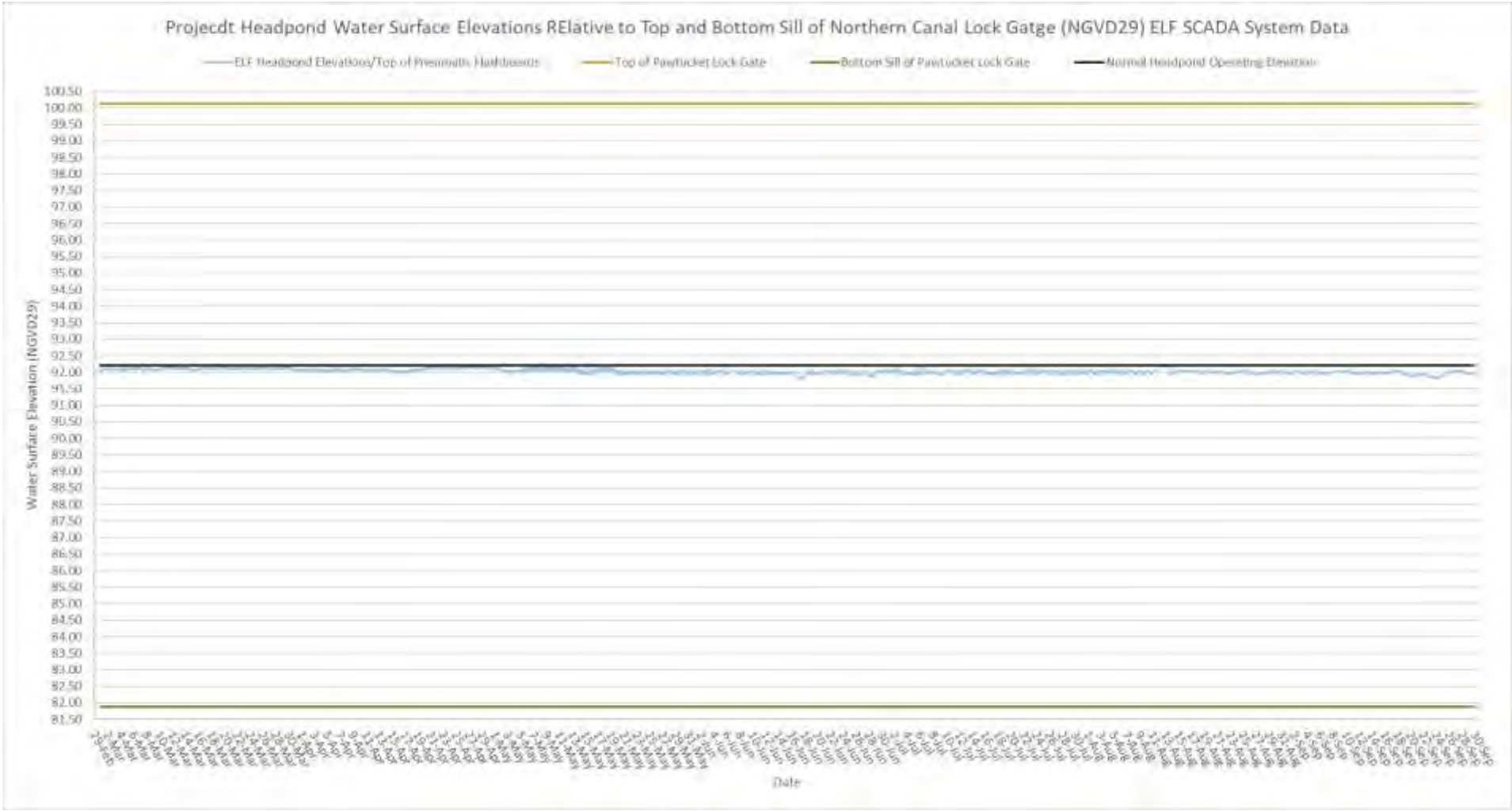
- Canal Water Level Monitoring: E.L. Field Headpond
  - Water surface elevations within the Project headpond during the study period (March 10 – September 29, 2020) range from a minimum of 91.76 ft to a maximum of 92.30 ft for a range of 0.54 ft.

Figure 5-1. Project Headpond Water Surface Elevation During 2020 Monitoring Period



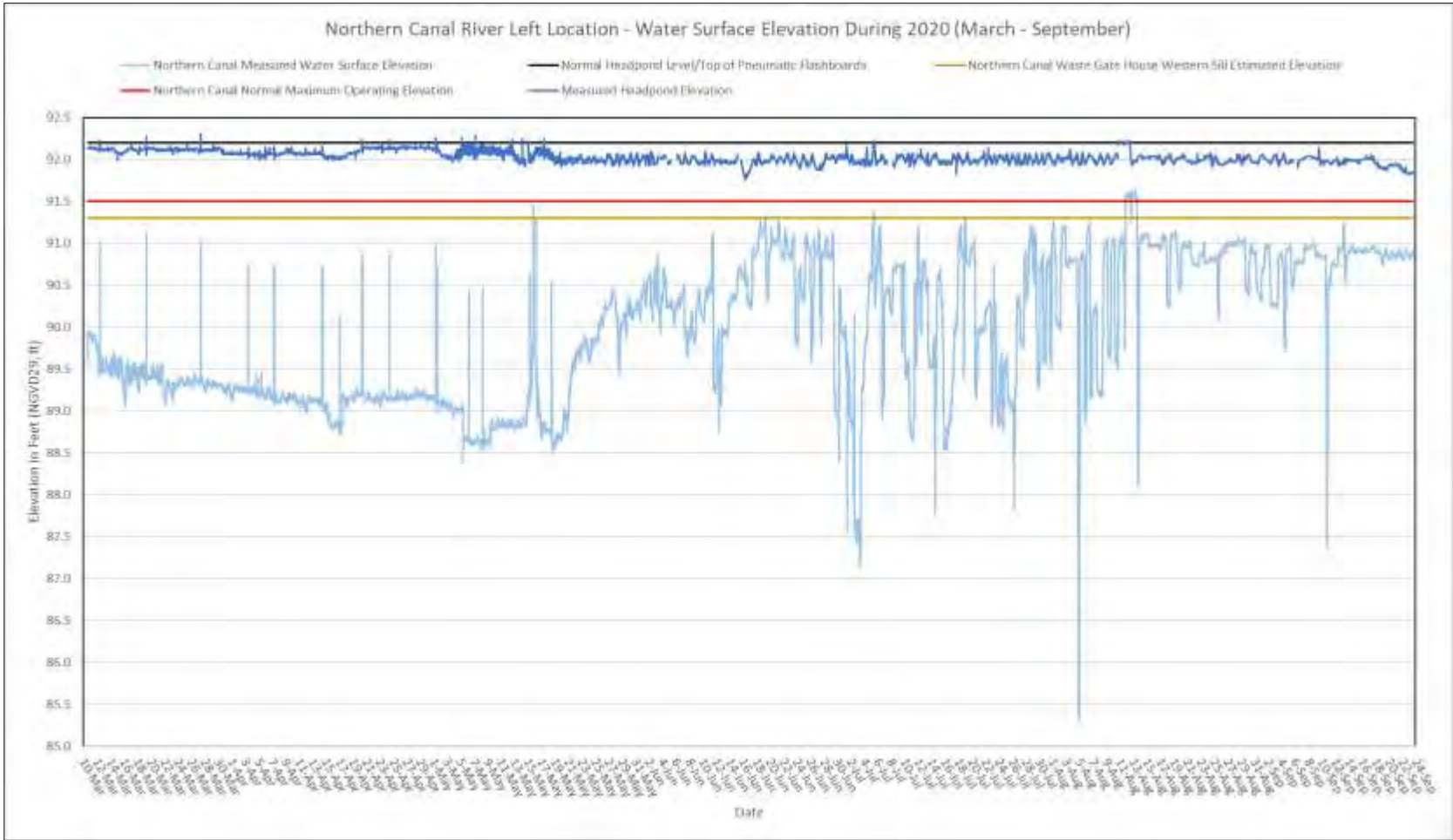
Water Level and Flow Effects on Historic Resources Study: **Results Summary**

- Canal Water Level Monitoring: E.L. Field Headpond and Pawtucket Gatehouse



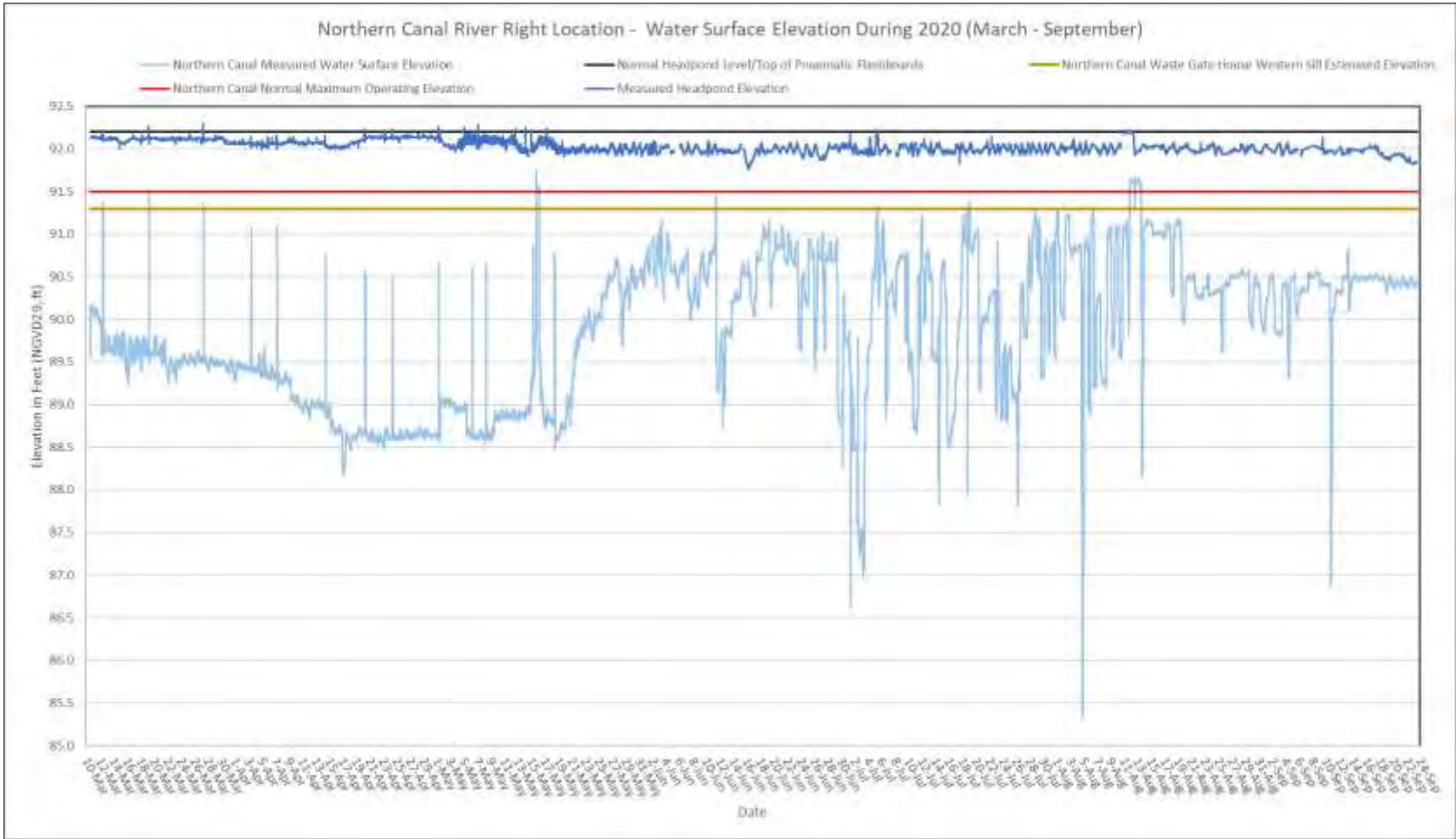
Water Level and Flow Effects on Historic Resources Study: **Results Summary**

- Canal Water Level Monitoring: Northern Canal
- Water surface elevations within the Northern Canal collected during the study period ranged from a minimum of 85.30 ft to a maximum of 91.64 ft with a range of 6.34 ft at the Northern Canal River Left (RL).



Water Level and Flow Effects on Historic Resources Study: **Study Methods**

- Canal Water Level Monitoring: Northern Canal
- Water surface elevations within the Northern Canal collected during the study period ranged from 85.71 ft to a maximum of 92.14 ft for a range of 6.43 ft at the Northern Canal River Right (RR) location.



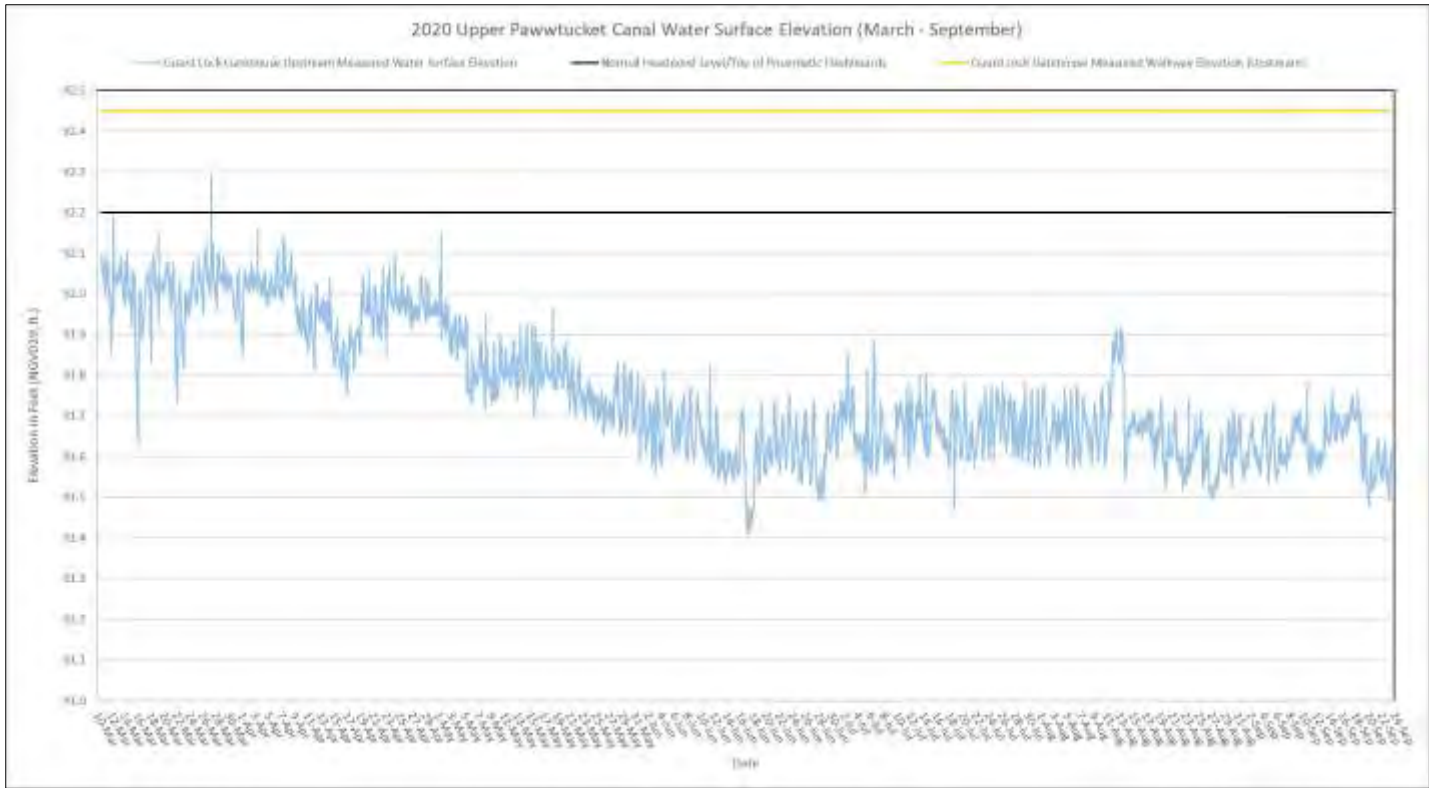
Water Level and Flow Effects on Historic Resources Study: **Results Summary**

- Based on RL location level logger data, water surface elevations within the Northern Canal reached elevations greater than 91.5 ft (the normal maximum operating elevation of the Northern Canal) on one occasion during the monitoring period.

- Based on the level logger data collected in the Northern Canal at the RR location, water surface elevations within the Northern Canal reached elevations greater than 91.5 ft on three occasions.

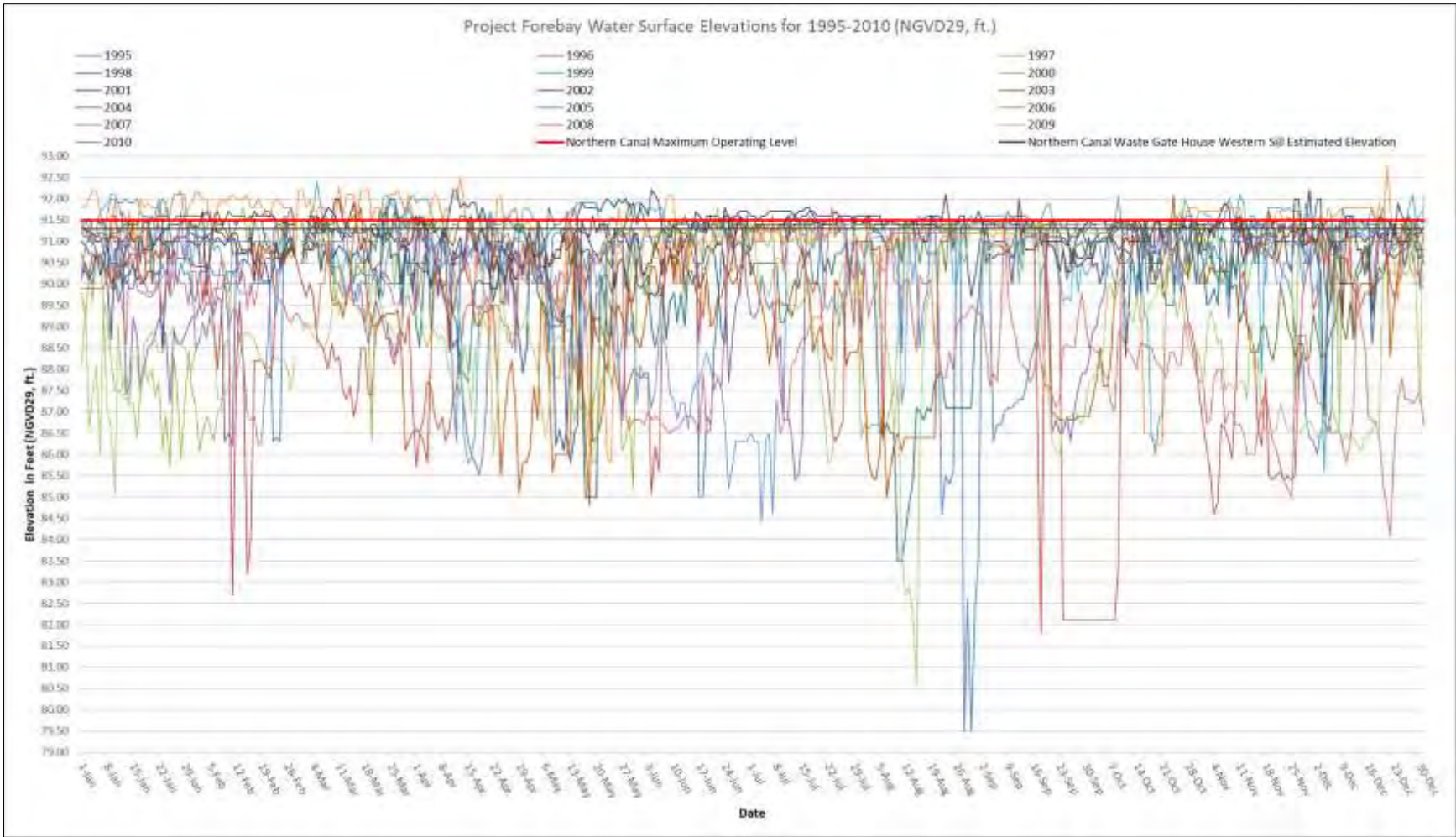
Water Level and Flow Effects on Historic Resources Study: **Results Summary**

- Canal Water Level Monitoring: Upper Pawtucket Canal
- Water surface elevations within the Upper Pawtucket Canal during the study period ranged from a minimum of 91.69 ft to a maximum of 92.35 ft for a maximum range of 0.66 ft, which is consistent with the impoundment level data.
- On one occasion during the study period, the water surface elevation within the Upper Pawtucket Canal reached an elevation greater than 92.2 ft (the normal operating elevation of the Project headpond).



Water Level and Flow Effects on Historic Resources Study: **Results Summary**

- Project Operations Review
  - Boott has reviewed the operational data for the E.L. Field Powerhouse forebay elevations for the available period of record (January 1995 through December 2010).



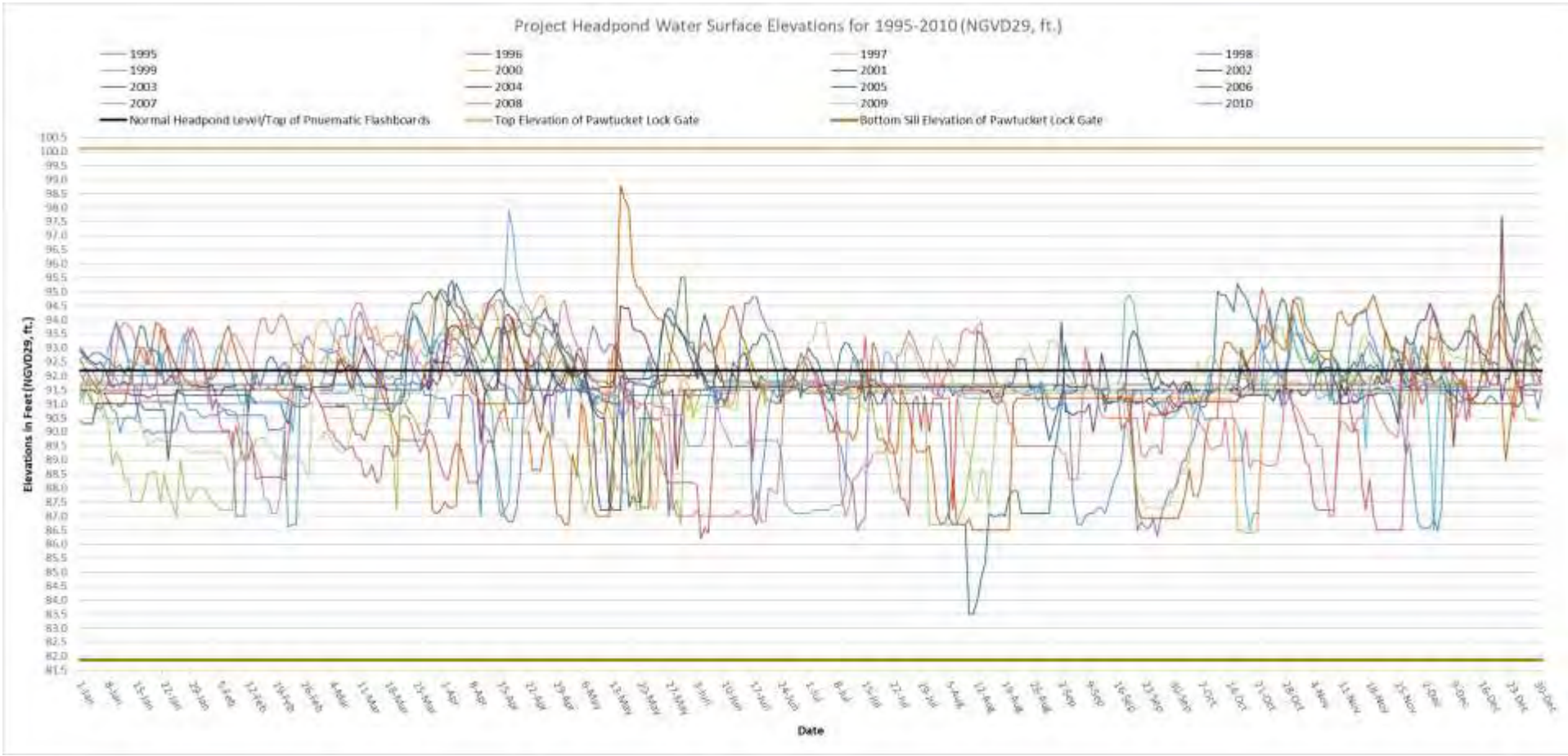
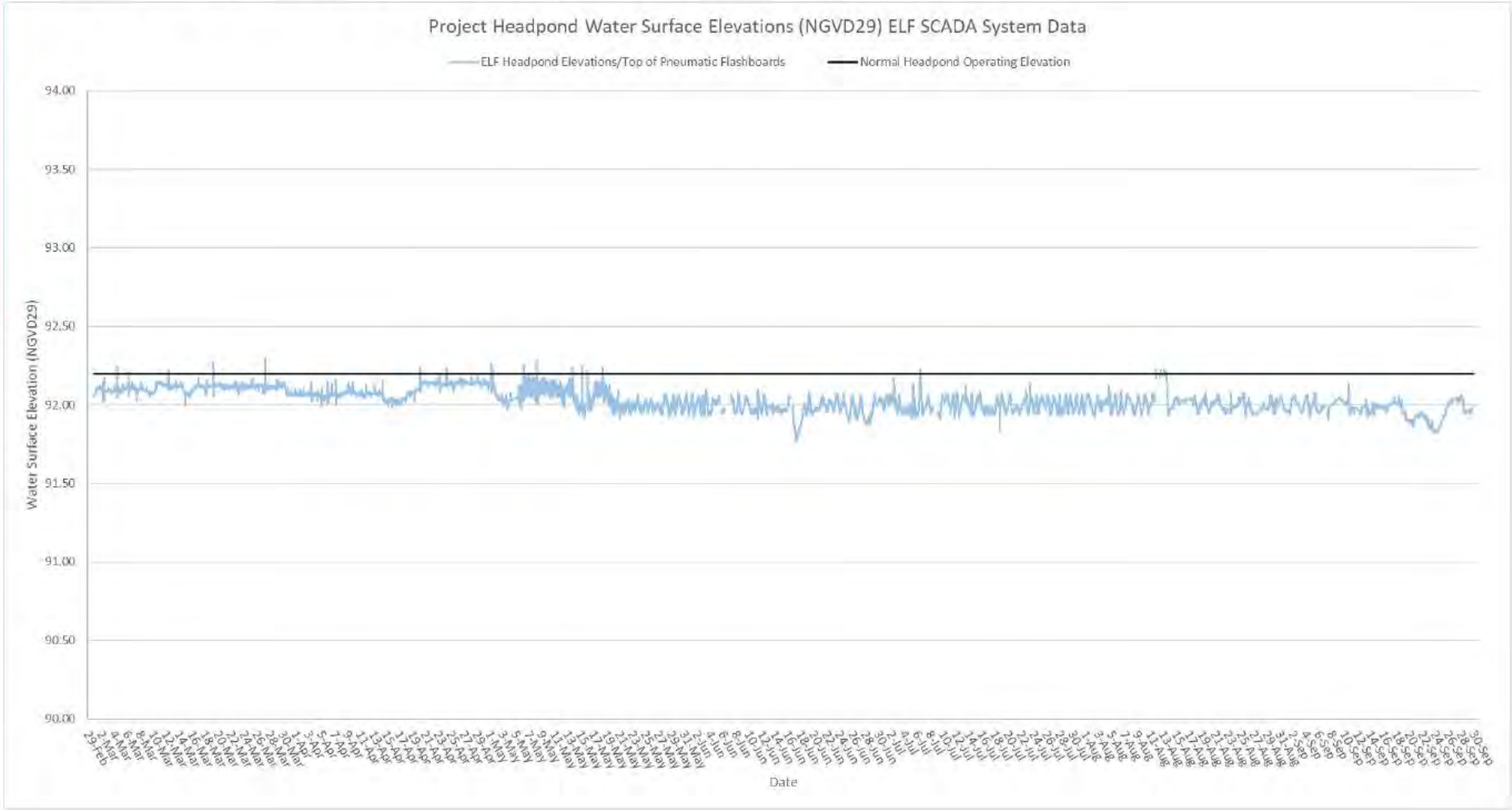

Project Headpond Water Surface Elevations for 1995-2010 (NGVD29, ft.)
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Normal Headpond Level/Top of Pneumatic Flashboards
Top Elevation of Pawtucket Lock Gate
Bottom Sill Elevation of Pawtucket Lock Gate
Elevations in Feet (NGVD29, ft.)
Date

Figure 5-1. Project Headpond Water Surface Elevation During 2020 Monitoring Period



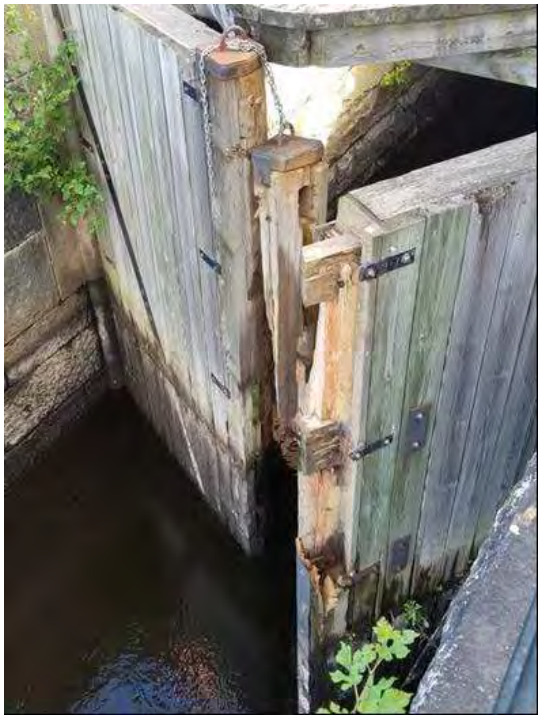
Water Level and Flow Effects on Historic Resources Study: **Results Summary**

- Project Operations Review:
  - The data demonstrate that with the wooden flashboards, headpond levels were highly variable, due in large part to the Licensee's inability to maintain normal pond level when the flashboards were partially damaged or failed.
  - Repair and replacement of the failed flashboards required a 5-foot drawdown of the project impoundment, typically for 2 days, to enable safe working conditions on the dam crest.
  - In contrast, the pneumatic crest gate system maintains a steady impoundment level by automatically adjusting the height of the crest gate panels in response to increasing flows, thereby eliminating any need for impoundment drawdowns for flashboard repairs.

Water Level and Flow Effects on Historic Resources Study: **Results Summary**

Analysis of Potential Project Related Effects

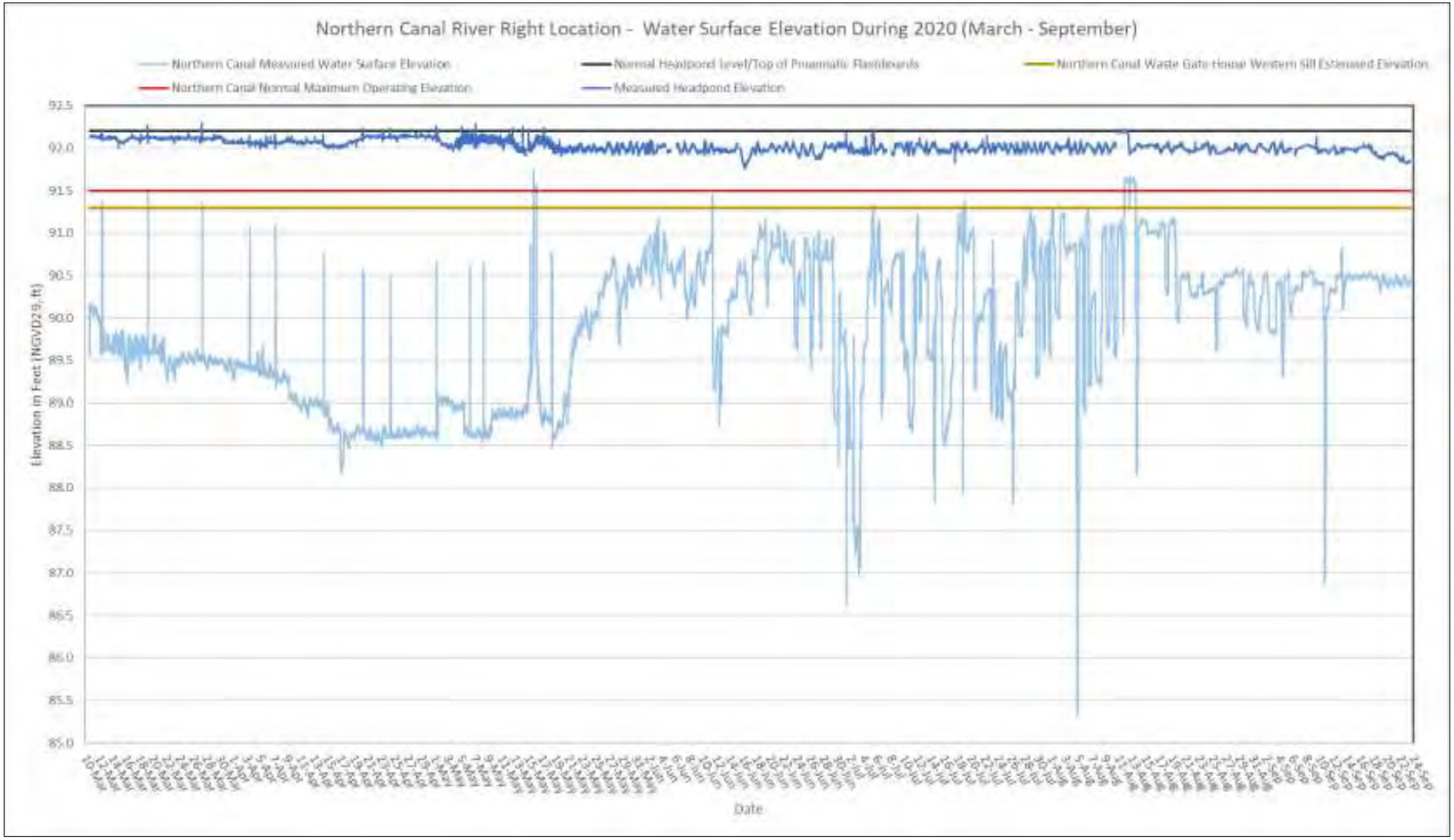
- Pawtucket Gatehouse: The gatehouse shows normal wear from exposure to the natural river conditions. Boott did not identify potential Project-related effects on the Pawtucket Gatehouse.
- Northern Canal lock structure: Potential Project-related effects have been documented at the Northern Canal lock structure adjacent to the Pawtucket Canal.



Water Level and Flow Effects on Historic Resources Study: **Results Summary**

Analysis of Potential Project Related Effects

- Northern Canal Waste Gatehouse (circa 1872)
  - Wooden sill which overhangs the Northern Canal, with a bottom elevation of approximately 91.3 ft NGVD 29.
  - The canal water surface elevations for the study period occasionally exceeded the bottom sill elevation, thereby inundating the heavy timber bottom sill on the south side of the structure.
  - Other factors, including the age of the wooden timbers, general maintenance, weathering, and atmospheric conditions are also likely to have contributed to the deterioration of the southern sill, and the eastern portion of the northern sill. The age of the sills is not known, i.e., it is not known if the existing sills are the original timbers from the 1872 construction of the gatehouse.


Northern Canal River Right Location - Water Surface Elevation During 2020 (March - September)
Northern Canal Measured Water Surface Elevation
Normal Headpond Level/Top of Pneumatic Flashboards
Northern Canal Waste Gate House Western Sill Estimated Elevation
Northern Canal Normal Maximum Operating Elevation
Measured Headpond Elevation
Elevation in Feet (NGVD29, ft)
92.5
92.0
91.5
91.0
90.5
90.0
89.5
89.0
88.5
88.0
87.5
87.0
86.5
86.0
85.5
85.0
Date

Water Level and Flow Effects on Historic Resources Study: **Results Summary**

Analysis of Potential Project Related Effects

- Guard Locks and Gates
  - Water levels in the Upper Pawtucket Canal (upstream of the Guard Locks complex) remained below the normal headpond level of 92.2 ft NGVD29 throughout the study period except for one occasion.
  - The elevation of the walkway (92.45 ft), the clapboard siding (92.45 ft), and the bottom of the mid-level windows (94.08 ft) are all above the normal water level of the Upper Pawtucket Canal. Under normal operating conditions, these features are rarely inundated.
  - The steps (104.87 ft) leading to the lower level door of the Guard Gatehouse and the bottom sill of the lower level door itself (100.34 ft) are significantly above the maximum recorded Project headpond elevation for the recent period of record.
  - River flows in excess of 35,000 cfs could cause the Upper Pawtucket Canal to inundate the wooden structural elements of the gatehouse; however, these conditions are outside of the ability of the project to control the impoundment water level and therefore not attributable to Project operations.

Water Level and Flow Effects on Historic Resources Study: **Variances from FERC-approved Study Plan**

- The Water Level and Flow Effects on Historic Resources Study Report was conducted in full accordance with the methods described in the FERC-approved study plan.
  - During meetings and consultation with the NPS after the issuance of the SPD, the stakeholders agreed to reduce the focus of this study limiting it to the Upper Pawtucket Canal from the Merrimack River downstream to the Guard Locks and including a portion of the Project headpond in proximity to the Pawtucket Dam and the Northern Canal from the Pawtucket Dam to the E.L. Field Powerhouse.
  - Because of the current COVID-19 pandemic, neither multiple-party site visits nor public meetings were conducted as part of this study. Boott consulted with the NPS to identify previous damage to historic resources within the study area and to collect additional information on the nature and extent of the damage.




Historically Significant Waterpower Equipment Study

Historically Significant Waterpower Equipment Study: **Goals and Objectives**

- The goal of this study is to identify and document historically significant waterpower equipment. The specific objectives of this study are as follows:
  - Conduct a site visit to identify historically significant waterpower equipment of interest to the NPS for potential future interpretation, exhibition, or as scrap equipment to maintain and operate other historic machinery;
  - Photo-document historically significant waterpower equipment identified in consultation with the NPS;
  - Conduct background research on the history of identified waterpower equipment, including designer/engineer, dates of manufacture and use, and an explanation of how the equipment was or is used; and
  - Document current ownership of historically significant waterpower equipment.




Historically Significant Waterpower Equipment Study: **Study Methods**

- Documentary Research
  - Gray & Pape conducted documentary research in the records held by NPS at Lowell to identify the component elements of the larger canal system and the equipment used to operate water control devices.

  - In July 2020, a site visit was held at Lowell with NPS to visit various locations associated with the control of water through the canal system. This tour included inspection of the Swamp Locks Gate House, the Hamilton Wasteway Gate House, the Lower Locks Gate House, the Boott Dam Gate House, the Moody Street Feeder Gate House, and the Northern Canal Gate House. Various types of gate operating mechanisms were observed.




Historically Significant Waterpower Equipment Study: **Results Summary**

Documentary Research

- The results of the literature review are presented in the Study Report.
  - Removal and replacement of individual pieces of equipment was nearly continual, from the day the system first became operational.
  - It is the totality of the system of waterpower and water-control machinery at Lowell that is historically significant.
  - Several pieces of equipment appear to be historically significant, distinct from their role as a part of the larger system. These pieces of equipment include
    - The surviving 1870 hydraulic gate hoist system at the Pawtucket Canal Guard Locks;
    - The Francis turbine powered belt-and-line shafting gate operating system at the Pawtucket Gate House;
    - The extant gate operating system at the Moody Street Feeder Gate House.

Historically Significant Waterpower Equipment Study: **Results Summary**

Figure 5-4. Pawtucket Gate House, belt-and-line shaft system.

Figure 6-1. Moody Street Gate House, gate hoisting mechanisms.

The Historically Significant Waterpower Equipment Study: **Variances from FERC-approved Study Plan**

- The Historically Significant Waterpower Equipment Study was conducted in full accordance with the methods described in the FERC-approved study plan.




Operation Analysis of the Lowell Canal Study

Operation Analysis of the Lowell Canal Study: **Goals and Objectives**

- The goal of this study is to understand the operations of the Project's canal system.

- The specific objective of this study is to describe the operations of the canal system, which include, but are not limited to:
  - How all the canal units interact with the main units at the E.L. Field Powerhouse;
  - How the canal units are sequenced;
  - How often each of the canal units operate;
  - The prioritization sequence of canal unit operations; and
  - The amount of time the canal units are operated during the downstream passage season.




Operation Analysis of the Lowell Canal Study: **Study Area**

Operation Analysis of the Lowell Canal Study: **Study Methods**

- Literature Review
  - Boott conducted a desktop file review to examine current Project operational protocols and historical canal operations data.

- Generation Data Review
  - Boott reviewed data from a 10-year period of typical canal unit operations from 1998 – 2007.

  - Data from this period was utilized in this analysis as it represented a relatively normal period of canal operations in which many (although not necessarily all) of the canal units were available for dispatch at Merrimack River flows in excess of 6,600 cfs capacity of the E.L. Field Powerhouse units.

  - While the dataset does not indicate which specific units or powerhouses were operating, it does include aggregate records of generation (in kilowatts [kW]) for the downtown canal system recorded on a daily basis.




Operation Analysis of the Lowell Canal Study: **Results Summary**

Literature and Data Review

The results of the literature review and data analysis are presented in the Study Report and summarizes general project operations, canal unit dispatch sequence, and historical canal unit operations.

- The two generating units at the E.L. Field Powerhouse are the most efficient units and are, therefore, the priority first-on, last-off units. Boott dispatches the canal units when Merrimack River flows exceed the combined 6,600 cfs hydraulic capacity of the units at the E.L. Field Powerhouse.

- Historically, it has not been Boott's practice to log or otherwise record which of the individual canal units or powerhouses were in operation on a daily basis. Hamilton units would generally be the first units to be dispatched at Merrimack River flows in excess of 6,600 cfs. The Bridge Street units and the John Street units would then typically be sequenced to match.

- Generation from the canal units is marginal, inefficient, and uneconomical under current conditions. The canal system as a whole has not been operated for purposes of generation in more than a year.

Operation Analysis of the Lowell Canal Study: **Results Summary**

- Based on this analysis, the Project's canal units were operated on 34 percent of days during the total period of record (1998 – 2007).
- The Project's canal units were operated on 40 percent of days during the May – July fish passage season and on 15 percent of the days during the August – November fish passage season.

Table 5-2. Percentage of Days Canal Units were Operated by Year (1998 – 2007)

Year	Total Annual Percentage of Days Canal Units were Operated	Percentage of Days Canal Units were Operated May – July	Percentage of Days Canal Units were Operated August – November
1998	37%	54%	1%
1999	30%	7%	19%
2000	30%	38%	2%
2001	17%	24%	0%
2002	27%	49%	3%
2003	40%	36%	37%
2004	45%	35%	30%
2005	64%	78%	48%
2006	29%	53%	7%
2007	18%	30%	8%

Operation Analysis of the Lowell Canal Study: **Results Summary**

Table 5-3. Percentage of Days Canal Units were Operated by Month (1998 – 2007)

Month	Percentage of Days Canal Units were Operated
January	31%
February	23%
March	52%
April	81%
May	62%
June	43%
July	16%
August	6%
September	12%
October	15%
November	29%
December	35%

Operation Analysis of the Lowell Canal Study: **Results Summary**

- Based on the available data, canal unit operations varied considerably from year-to-year. In general, this can be attributed to two primary factors:

  - Merrimack River Flows: Boott prioritizes generation at the E.L. Field Powerhouse, and the downtown canal units are not dispatched until Merrimack River flows exceed the combined 6,600 cfs hydraulic capacity of the E.L. Field Powerhouse's two generation units;

  - Unit Maintenance and Operability: The majority of the canal units were last upgraded in the 1940s and are now almost 80 years old. These units are routinely out-of-service for maintenance or because they are simply inoperable.

Operation Analysis of the Lowell Canal Study: **Results Summary**

- Based on the available data, canal unit operations varied considerably from year-to-year. In general, this can be attributed to two primary factors:

  - Merrimack River Flows: Boott prioritizes generation at the E.L. Field Powerhouse, and the downtown canal units are not dispatched until Merrimack River flows exceed the combined 6,600 cfs hydraulic capacity of the E.L. Field Powerhouse's two generation units;

  - Unit Maintenance and Operability: The majority of the canal units were last upgraded in the 1940s and are now almost 80 years old. These units are routinely out-of-service for maintenance or because they are simply inoperable.

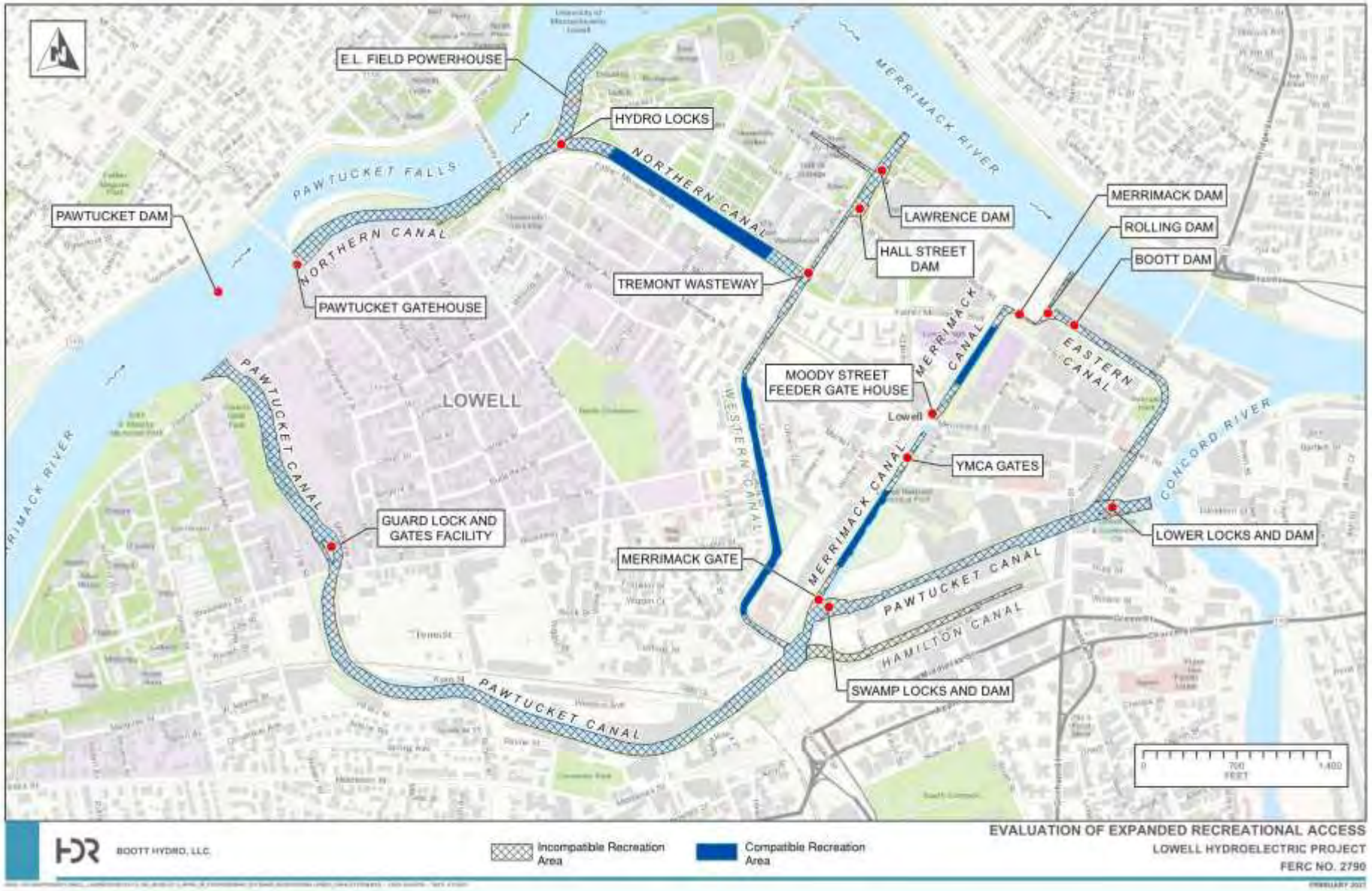
The Operation Analysis of the Lowell Canal Study: **Variances from FERC-approved Study Plan**

- The Operation Analysis of the Lowell Historically Significant Waterpower Equipment Study was conducted in full accordance with the methods described in the FERC-approved study plan except for the following:
  - The approved study plan directs Boott to describe how often each of the canal units operate and the amount of time canal units operate during the downstream passage season. As discussed in this study report, it has not been Boott's practice to record individual canal unit operations or document unit start/stop times. Accordingly, Boott reviewed and analyzed records from a period of relatively normal canal unit operations that reflect a daily "snapshot" of aggregate canal unit generation.




Updated Recreation and Aesthetics Study Report

Recreation and Aesthetics Study: **Results Summary**



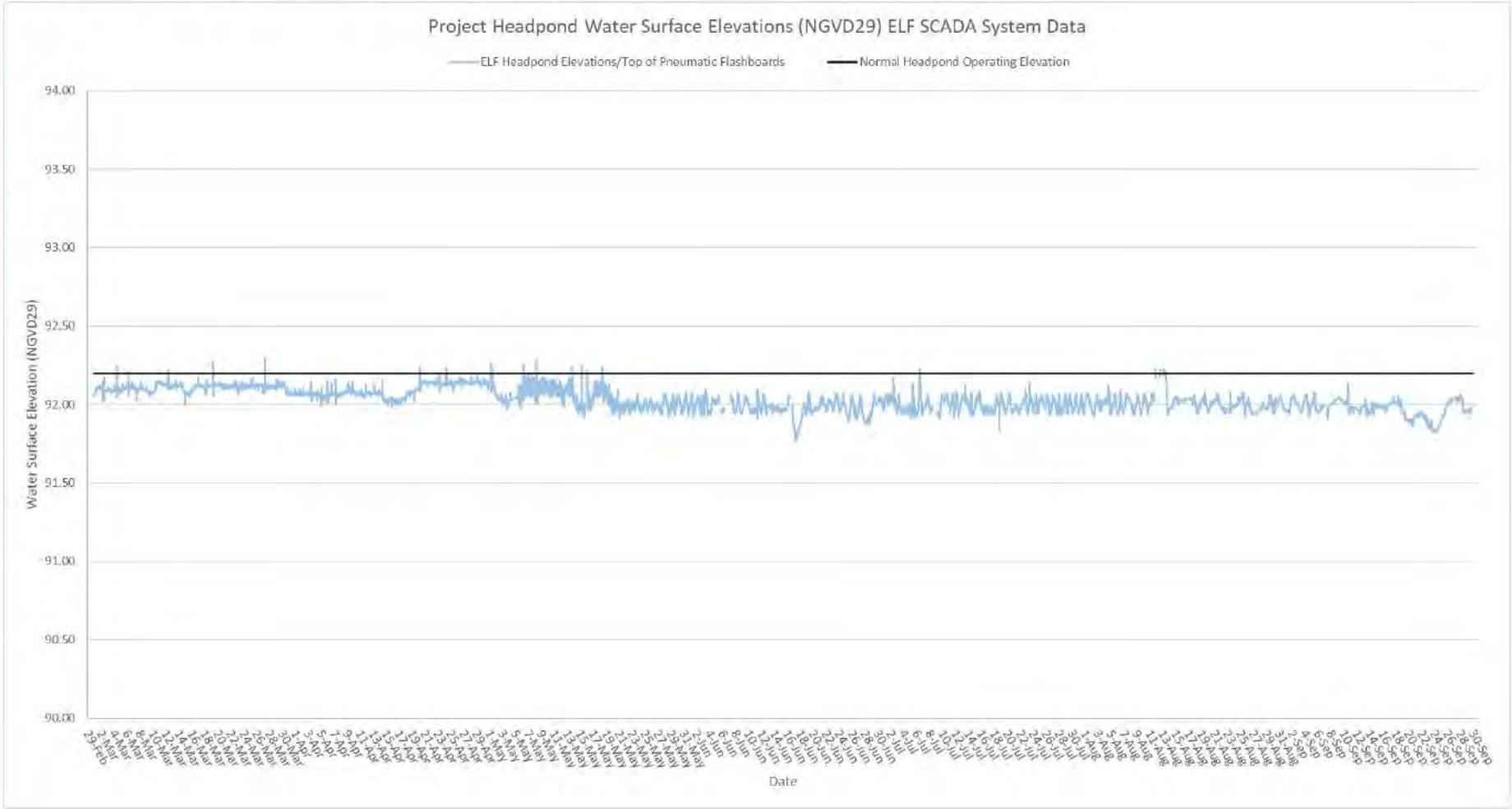
Recreation and Aesthetics Study: **Results Summary**

- Evaluation of Water Levels and Flows on NPS Boat Tours
  - With even a 1-foot elevation rise of the Project impoundment, NPS states their boats would be unable to pass under the Pawtucket Street Bridge.
  - The Project maintains a normal pond elevation of 92.2 ft NGVD 29 when flows in the Merrimack River are up to 8,600 cfs. When Merrimack River flows exceed 8,600 cfs, the crest elevation gradually rises to 93.2 ft NGVD 29 until flows reach 11,850 cfs.

Table 5-2. Lowell Hydroelectric Project Hydrologic Data (1987-2016)

Month	Minimum (cfs)	90% Exceedance (cfs)	Average (cfs)	10% Exceedance (cfs)	Maximum (cfs)
January	916	3,462	7,651	12,834	39,710
February	1,478	3,272	6,813	11,415	39,180
March	1,914	4,508	11,484	21,355	50,220
April	2,765	6,558	17,901	31,178	78,890
May	2,034	4,112	10,749	18,657	88,410
June	874	2,279	6,768	13,286	44,660
July	670	1,325	4,207	9,270	29,820
August	569	1,121	3,526	6,852	30,030
September	460	1,008	3,162	6,025	32,264
October	787	1,676	5,938	12,706	50,150
November	1,345	2,888	7,978	14,747	30,990
December	1,839	3,472	9,141	17,243	34,810
Annual	460	1,723	7,941	17,059	88,410

Figure 5-1. Project Headpond Water Surface Elevation During 2020 Monitoring Period



Recreation and Aesthetics Study: **Results Summary**

- Evaluation of Water Levels and Flows on Northern Canal Access
  - The Northern Canal Walkway opens seasonally (May 15 through October 15) when flow rates in the Merrimack River and Northern Canal are lower than 3,500 cfs. This threshold was determined because a study demonstrated that a surge wave above 3,500 cfs in the Northern Canal poses a risk of overtopping the Great River Wall.
  - The significant volume of discharge through the Surge Gate is hazardous to any persons in the riverbed below or near the gate. Accordingly, to be conservative and assure public safety, the 3,500 cfs threshold to open the Northern Canal Walkway remained despite the installation of the Surge Gate.

Closing

Upcoming ILP Milestones

- Based on FERC's June 12, 2020 *Revised Process Plan and Schedule and Determination on Requests for Study Modifications for the Lowell Hydroelectric Project*

Milestone	Responsible Party	Date
Revised Initial Study Report Meeting	All stakeholders	March 11, 2021
Revised Initial Study Report Meeting Summary	Boott	March 26, 2021
Any Disputes/Requests to Amend Study Plan Due	All stakeholders	April 25 (Sunday)/April 26, 2021
File Final License Application	Boott	April 30, 2021
Responses to Disputes/Amendment Requests Due	All stakeholders	May 25, 2021
Director's Determination on Disputes/Amendments	FERC	June 24, 2021

Any Disputes/Requests to Amend Study (18 C.F.R. § 5.15(d))

- *Criteria for modification of approved study.* Any proposal to modify an ongoing study must be accompanied by a showing of good cause why the proposal should be approved, and must include, as appropriate to the facts of the case, a demonstration that:
  - (1) Approved studies were not conducted as provided for in the approved study plan; or
  - (2) The study was conducted under anomalous environmental conditions or that environmental conditions have changed in a material way.

- If requesting new studies, stakeholders must consider FERC's Criteria (18 C.F.R. § 5.15(e)).

- www.LowellProjectRelicensing.com

Contact Information

- Stakeholders can contact Boott with questions or comments:

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