Northfield Mountain Station
99 Millers Falls Road
Northfield, MA 01360
Ph.: (413) 659-4489
Fax: (413) 659-4459
Email: Douglas.Bennett@firstlightpower.com

Douglas Bennett
Plant General Manager

May 10, 2018

VIA ELECTRONIC FILING

Ms. Kimberly D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

Re: FirstLight Hydro Generating Company, Turners Falls Hydroelectric Project (FERC No. 1889) and Northfield Mountain Pumped Storage Project (FERC No. 2485).
Additional Proposed Study- Barrier Net Assessment

Dear Secretary Bose:

FirstLight Hydro Generating Company (FirstLight) owns and operates the Turners Falls Hydroelectric Project and Northfield Mountain Pumped Storage Project. FirstLight is in the process of relicensing the facilities with the Federal Energy Regulatory Commission (FERC). On February 23, 2018, FirstLight filed a letter with FERC discussing its plans to evaluate the feasibility of installing a barrier net in the Northfield Mountain tailrace to protect juvenile shad and adult American eel from becoming entrained.

In 2017, FirstLight contracted to conduct a Computational Fluid Dynamics (CFD) analysis of a potential barrier net. The results of that CFD modeling is included in Attachment A: *Northfield Mountain Generation Station CFD Modeling for Fish Exclusion Net Forces* (Alden, 2018). In 2018, FirstLight is conducting in-situ testing of the barrier net mesh/material. Specifically, 2-ft by 2-ft panels of the barrier net mesh will be placed at different depths in the Connecticut River in proximity to the Northfield tailrace to document the level of biofouling. These panels will then be pulled and tested off-site in a flume to estimate drag. FirstLight is conducting this work to determine the drag on a full-scale net and what loads would be placed on the net when operating four pumps (full capacity). Assuming any necessary permits can be obtained, the field work is anticipated to occur over the period August 1 to November 30, the approximate period the barrier net would be in place. A final report is expected to be completed by March 1, 2019.

On March 2, 2018, FirstLight sent stakeholders a study plan (see Attachment B: *Barrier Net Study in the Northfield Mountain Tailrace*) to conduct the barrier net feasibility study and requested that comments be provided by March 23, 2018. Comments were received from the following:

- United States Fish and Wildlife Service (USFWS), March 22, 2018
- Massachusetts Division of Fisheries and Wildlife (MDFW), March 22, 2018 (MDFW stated it agreed with USFWS comments)
- National Marine Fisheries Service (NMFS), March 23, 2018
- Connecticut River Conservancy March 23, 2018

Alden (consultant for FirstLight on the Barrier Net feasibility study) and FirstLight addressed comments as shown in Attachment C: *Technical Memorandum, Response to Stakeholder Review Comments on Barrier Net Study Plan* (the above comment letters are appended to Attachment C).

FirstLight is not seeking FERC's review/approval of the barrier net feasibility study plan as the study is being conducted outside the FERC-required study plan. However, FirstLight wants FERC to be aware of the study. If you have any questions regarding this filing, please feel free to contact me.

Sincerely,

Douglas P Bennett

Douglas Bennett
Plant General Manager

Attachment A: Northfield Mountain Generation Station CFD Modeling for Fish Exclusion Net Forces
Attachment B: Barrier Net Study in the Northfield Tailrace
Attachment C: Technical Memorandum, Response to Stakeholder Review Comments on Barrier Net Study Plan, including comment letters

Attachment A: Northfield Mountain Generation Station CFD Modeling for Fish Exclusion Net Forces

Solving flow problems since 1894

Northfield Mountain Generation Station CFD Modeling for Fish Exclusion Net Forces

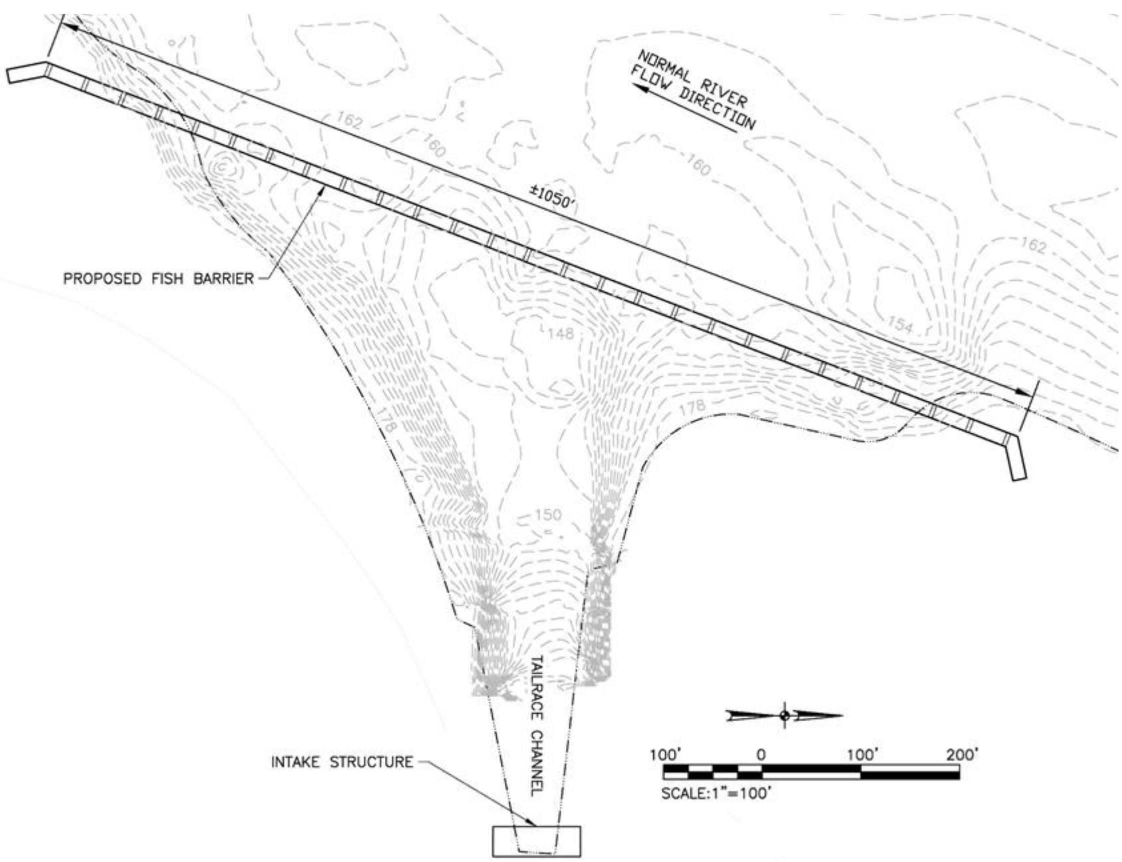
Alden Report No. : 1175QNorthfieldNet

Prepared for:

FirstLight Power Resources

FirstLight Hydro Generating

January 2018



ALDEN Research Laboratory, Inc.
30 Shrewsbury Street, Holden, Massachusetts 01520-1843

Massachusetts | Colorado | Oregon | Washington
508-829-6000 • www.aldenlab.com

Signature Block

Name/Title	Signature/Date	Preparer (P) Reviewer (R)
Mitchell Peters, PE Principal Engineer	1/12/18	P
Simon Schaad Engineer II	1/12/18	P
Daniel Gessler, P.E., Ph.D., D.WRE Vice President	1/12/18	R

Record of Revisions

Revision No.	Revision Date	Change Description	Reason for Change
0	1/12/2018	Initial Issue	

Table of Contents

List of Figures

List of Tables

Executive Summary

The Northfield Mountain Pumped-Storage Project (Project) is located on the Connecticut River, in Erving, Massachusetts. It is owned and operated by FirstLight Hydro Generating Company (FirstLight). The Project consists of a lower reservoir, called the Turners Falls Impoundment (TFI) that is created by the Turners Falls Dam and an Upper Reservoir atop Northfield Mountain. Pending energy demands, water is typically pumped from the TFI to the Upper Reservoir at night when the price of power is lower and is used for generation during the day when the price of power is higher.

When operating in a pumping mode the four equally-sized pump-turbines have a total hydraulic capacity of approximately 15,600 cfs. When in a generating mode, the four turbines have a total hydraulic discharge capacity of approximately 20,000 cfs.

The Turners Falls Dam is equipped with upstream (and downstream) migratory fish passage facilities that can pass American shad and American eel. There is the potential for further modifications and/or improvements to these fish passage structures as part of the Federal Energy Regulatory Commission (FERC) relicensing process which could result in greater numbers of migratory fish in the TFI. The resources agencies have raised concern that when the Project operates in a pumping mode, migratory fish can be entrained and lost from the river system.

As part of the FERC relicensing process, FirstLight is considering installing a fish exclusion net in the TFI at the Northfield Project intake/tailwater to protect migratory juvenile and adult American shad and adult American eel from becoming entrained. The resource agencies have indicated the exclusion net would be in place from approximately August 1 to November 15 covering the period when migratory fish are moving upstream and/or downstream. FirstLight's concern is the likelihood of plugging the exclusion net in the summer (when bio-fouling of the net is a concern) and fall (when leaf-off occurs), and the potential impacts on its ability to pump or generate with all four units. As part of its consideration of this potential protection, mitigation and enhancement (PME) measure, FirstLight requested Alden to conduct a feasibility study.

Design of the exclusion net requires determination of the forces acting on the net when in full pumping or generating mode. Alden previously developed a three-dimensional computational fluid dynamics (CFD) model of the intake/tailwater to study sediment exclusion strategies (Ref. [1]). The previously developed CFD model was used to simulate the flow patterns in the area of the exclusion net and use the computed water velocities to determine the drag force acting on the net. Combinations of plant operating conditions and river flow conditions expected to yield high hydraulic forces acting on the exclusion net were selected for simulation. The modeled flow conditions were for low TFI water surface elevations (WSEL) and low, medium, and high river flows. Flow conditions were tested with both project pumping and generating operations. The hydraulic forces acting on the exclusion net were computed from the velocity field at the location of the exclusion net. This report summarizes the CFD modeling effort and hydraulic forces calculations of the exclusion net.

1.0 Introduction

The Northfield Mountain Pumped-Storage Project (Project) is located on the Connecticut River, in Erving, Massachusetts. The project location is shown in Figure 1-1. Figure 1-2 shows a more detailed aerial view of the Connecticut River intake/tailwater area.

FirstLight is reviewing the efficacy of an exclusion net in front of the intake/tailwater to exclude fish from being entrained during pumping operations. The exclusion net would be deployed between August 1 and November 15 to protect migratory juvenile and adult American shad and adult American eel. The proposed exclusion net would span about 1,000 ft of the intake/tailwater entrance as shown in Figure 1-3. Figure 1-4 shows an elevation of the proposed net detailing the upper net panel (3/8-inch mesh size) and lower net panel (3/4-inch mesh size). The purpose of this CFD study is to evaluate hydraulic forces on the exclusion net caused by river conditions and Project operations.

The current CFD model study leveraged past modeling efforts to determine the velocity field near the proposed exclusion net. Alden previously developed a three-dimensional computational fluid dynamics (CFD) hydraulic model of the intake/tailwater to study sediment exclusion strategies (Ref. [1]). The CFD model extends approximately 1,200 ft upstream and 1,000 ft downstream from the intake/tailwater. The spatially varied hydraulic forces acting on the exclusion net were calculated from the velocity field and numerically integrated to calculate the total force on the exclusion net.

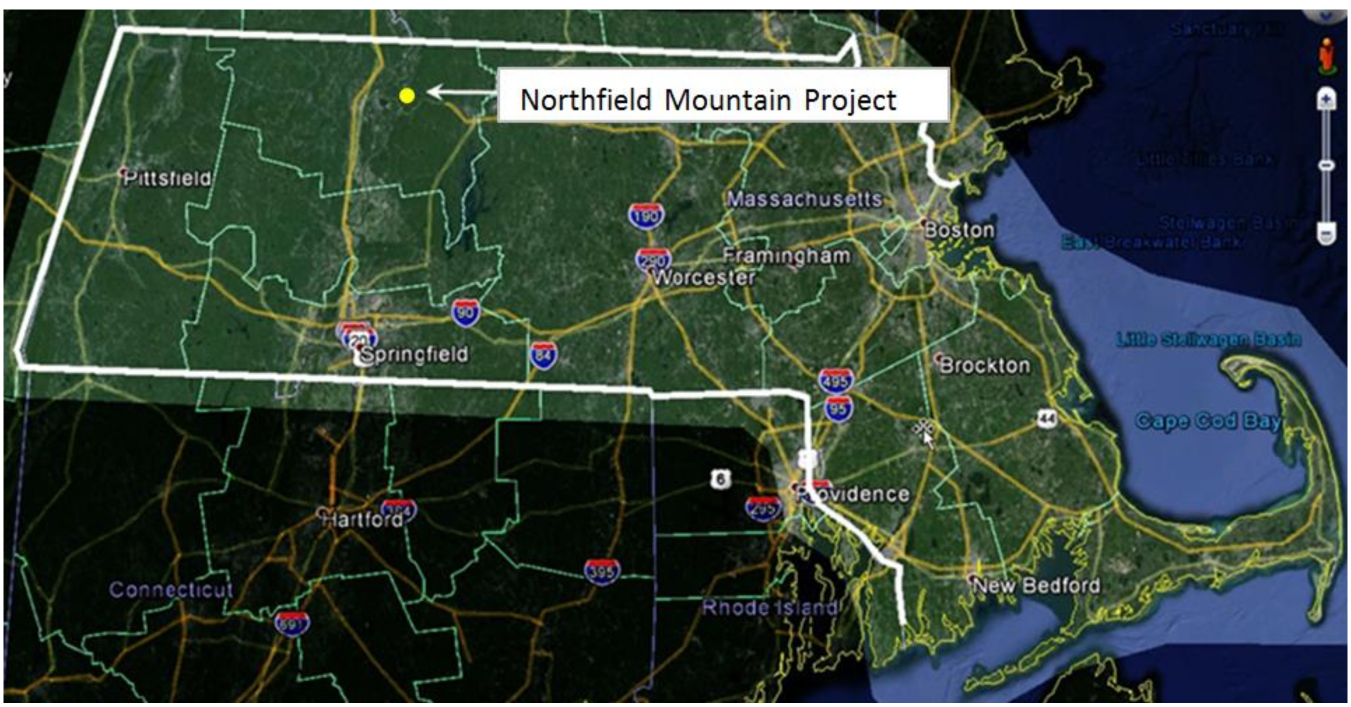


Figure 1-1: Northfield Mountain Project Location Map

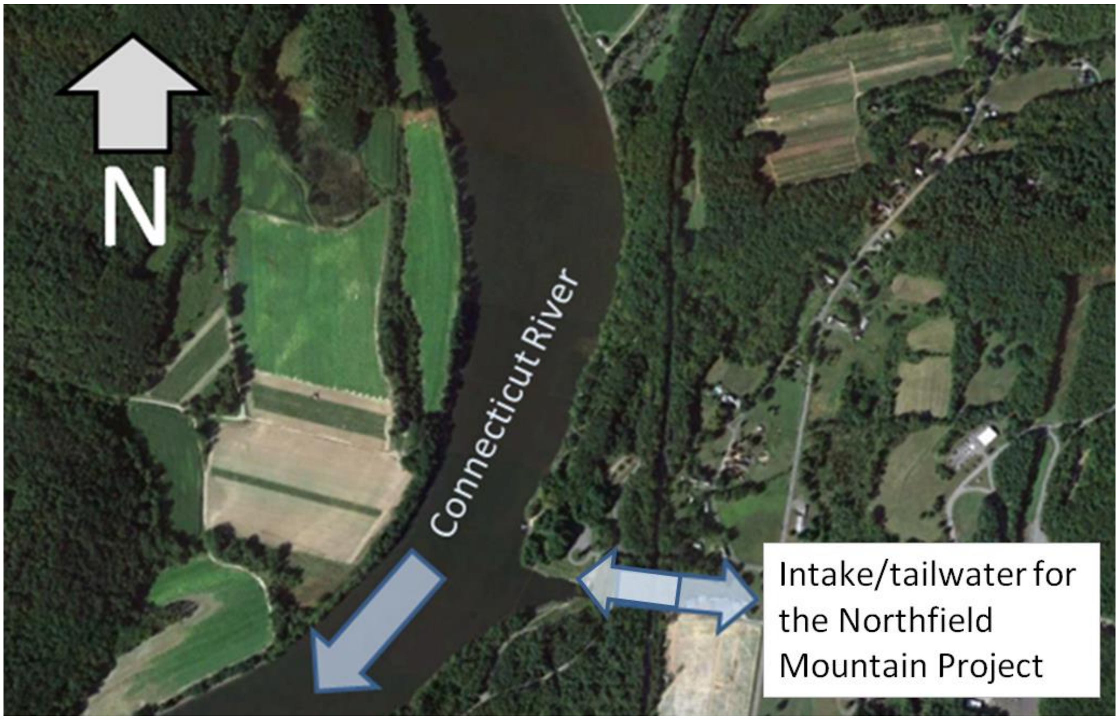


Figure 1-2: Detail of Northfield Mountain Project Intake/Tailwater

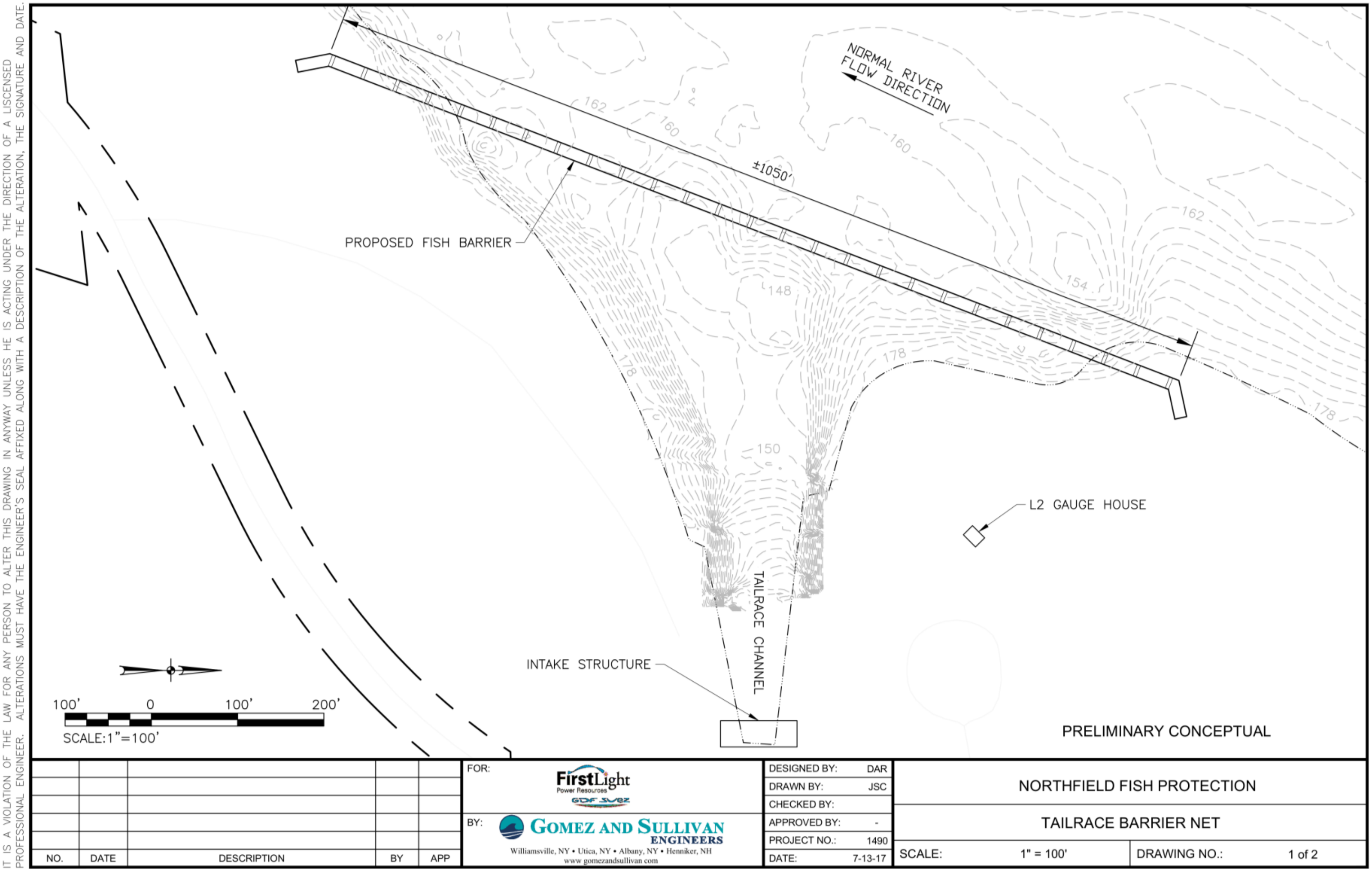


Figure 1-3: Exclusion net plan view (Ref. [2])

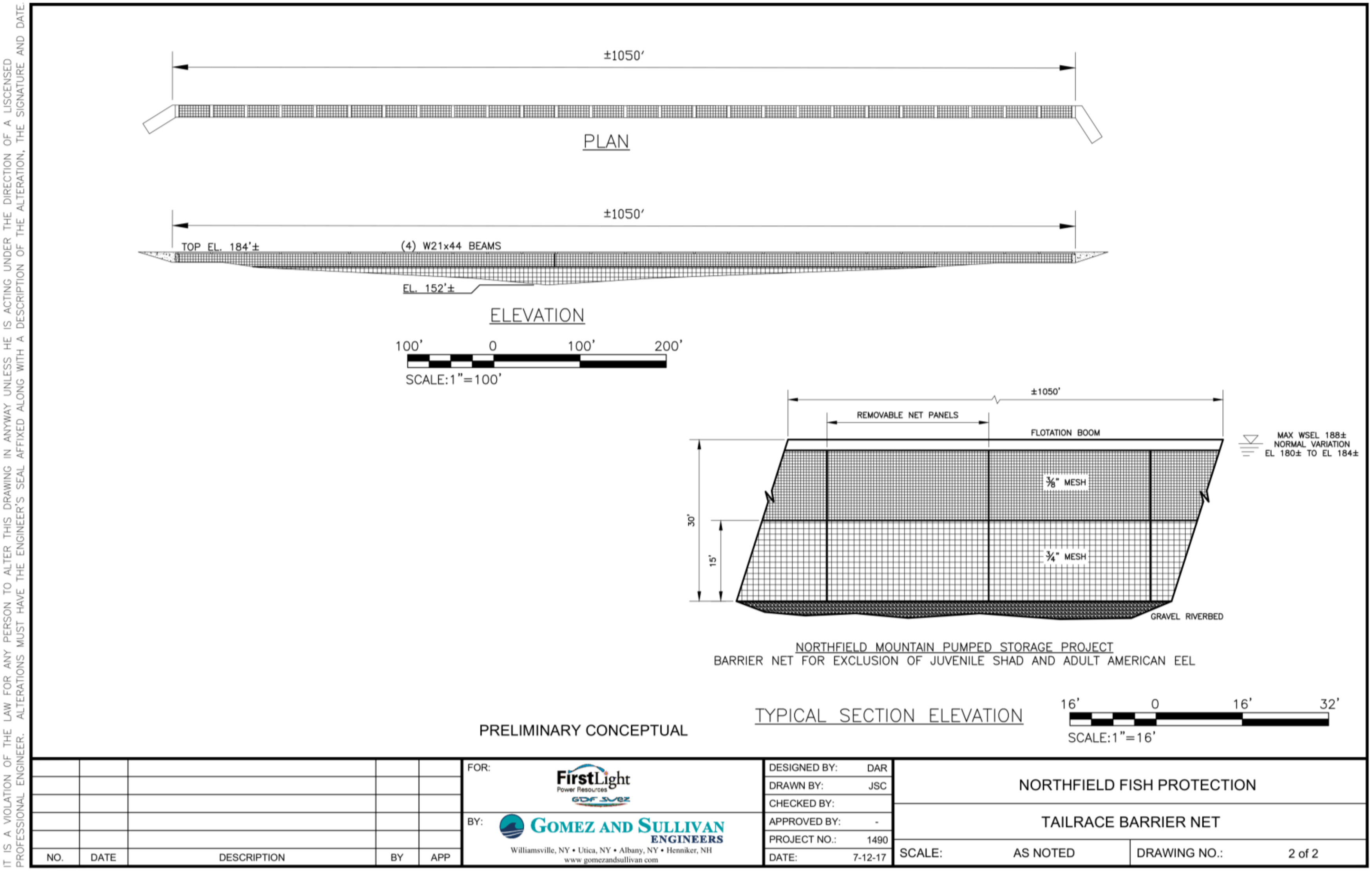


Figure 1-4: Exclusion net elevation (Ref. [2])

2.0 Model Selection

It is necessary to calculate the hydraulic forces acting on the exclusion net to design the anchoring system of the exclusion net. In principal, the drag on the net could be determined using a reduced scale physical model such as the one Alden constructed for testing sediment exclusion concepts in the Project intake/tailrace. A physical model of the netting would deform in response to the hydraulic forces and the flow field would adjust to the forces exerted by the netting. In theory, the tensile forces on cables and anchoring systems could be measured in a scale model. However, the existing 1:100 model is too small and cannot be used for this purpose because the netting will not satisfy scaling requirements. In the prototype, flow through the exclusion net is expected to be in the fully turbulent flow regime as defined by the net Reynolds number. The pore Reynolds number Re for flow through the net openings is

$$Re = \frac{u_{pore} D}{\nu} \qquad (1)$$

where u_{pore} is the pore velocity through the net, D is the mesh opening diameter, and ν = 1.21(10)$^{-5}$ ft^2/s is the kinematic viscosity of water. The pore velocity u_{pore} is defined as

$$u_{pore} = u_{norm}/A_{open} \qquad (2)$$

where u_{norm} is the normal superficial velocity (i.e. flow through net) and A_{open} is the ratio of open to closed area. For the 3/4-inch mesh size $D \approx$ 3/4 inch and A_{open} = 0.785 (Ref. [3]). If u_{norm} = 1 ft/s then the prototype pore Reynolds number is 6,500 which is fully turbulent. The model pore Reynolds number is 6.5 for the same conditions (physical model length scale is 1:100 and physical model velocity scale is 1:10). The flow is laminar when the pore Reynolds number is less than 200 and turbulent when the pore Reynolds number is greater than 1,000. It is critical that the turbulence regime of the prototype match the physical model for the hydraulic forces on the exclusion net to scale reliably. If prototype mesh is used in the physical model, then the model pore Reynolds number is 650 which is in the laminar-turbulent transition regime and does not match the fully turbulent prototype regime. Additionally, the total force on the net in the physical model is (Force) × (Area) and scales as (velocity squared) × (length squared) = (1:10)^2 × (1:100)^2 = 1:1,000,000. Measuring forces 1,000,000 times smaller than prototype is not feasible. Thus, due to turbulence scaling and difficulty of measuring very small forces it is not feasible to use the existing physical model to determine the hydraulic forces on the exclusion net. Therefore, it was necessary to approximate the forces on the exclusion net from the velocity field which is extracted from a CFD model.

3.0 CFD Model

3.1 Model Geometry

A FLOW-3D CFD model of the Connecticut River was previously developed by Alden to evaluate sediment exclusion strategies and is described in detail in Reference [1]. The CFD model was validated with Acoustic Doppler Current Profiler (ADCP) velocity measurements collected by Gomez and Sullivan directly in the tailrace. The CFD model was modified for the current study to improve the grid resolution in the region of interest around the exclusion net. The channel bathymetry is unchanged from Reference [1].

Figure 3-1 shows the four mesh blocks used for the modified CFD model. Mesh Block 1 (in the vicinity of the intake/tailwater) has a resolution of 5 ft in the X (north – south) direction, 4 ft in the Y (east-west) direction, and 2 ft in the Z (depth) direction. Mesh Blocks 2, 3, and 4 have a resolution of 10 ft in the X and Y directions, and 2 ft in the Z direction.

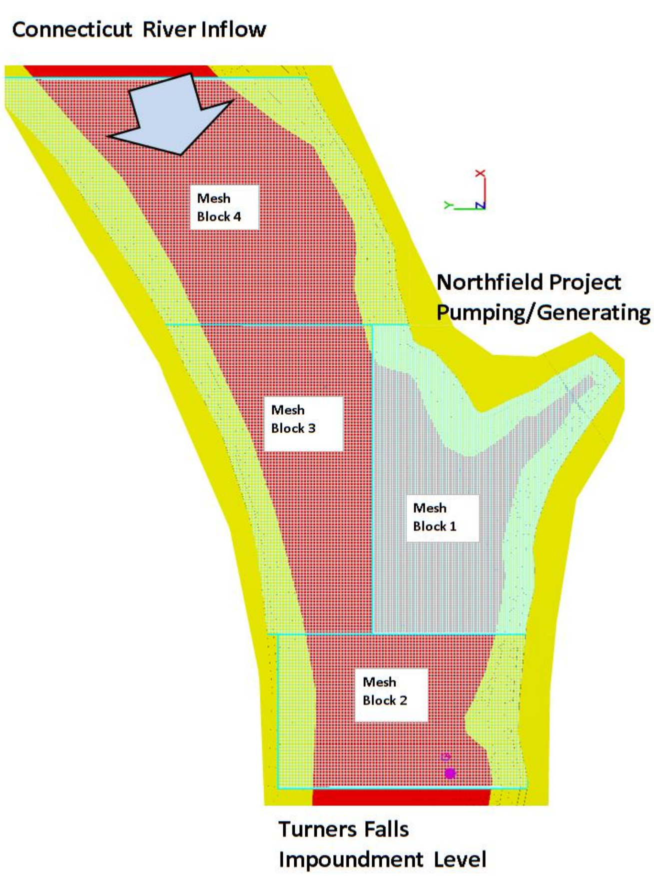


Figure 3-1: CFD model mesh block delineation and boundary conditions.

3.2 Model Boundary Conditions

The proposed annual deployment period of the exclusion net is from August 1 to November 15. The flow duration curve for the Connecticut River at Northfield from August 1 to November 15 is shown in Figure 3-2. The flow duration curve was modified from the annual flow duration curve from Reference [1]. The Connecticut River flow was higher than 50,000 cfs only 1% of the time within the 2000 to 2010 period of record. The number of days that the Connecticut River flow exceeds 30,000 cfs is 4%.

The river conditions that were hypothesized to produce the highest potential velocities through the exclusion net are given in Table 3-1. A low Impoundment level minimizes the cross-sectional area through the exclusion net and thereby results in higher velocities through the net. Low, medium, and high Connecticut River flows with corresponding low TFI tailwater levels were selected for the river conditions. The river water levels were conservatively selected from the stage-discharge rating curve in Figure 3-3. The stage-discharge rating curve was modified from the annual flow duration curve from Reference [1] to only reflect the August 1 to November 15 period. Each river condition was modeled with both the maximum pumping and generation operation. Six total scenarios were tested with the CFD model.

Table 3-1: River conditions and project operations for model runs

River Conditions	River Flow (cfs)	Water Level at Project Intake/Tailrace (ft)	Pumping Flow (cfs)	Generating Flow (cfs)
High River Flow, Low TFI Level	50,000	185		20,000
High River Flow, Low TFI Level	50,000	185	15,200	
Medium River Flow, Low TFI Level	30,000	182		20,000
Medium River Flow, Low TFI Level	30,000	182	15,200	
Low River Flow, Low TFI Level	5,000	179		20,000
Low River Flow, Low TFI Level	5,000	179	15,200	

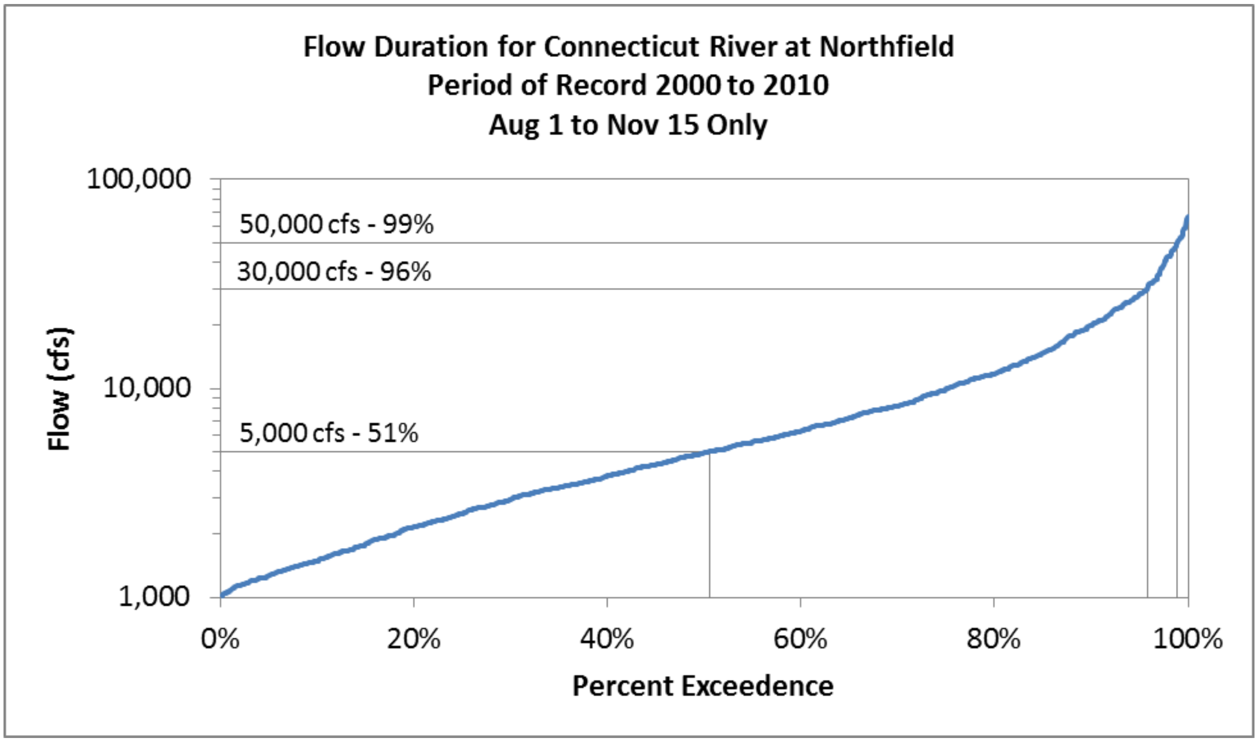


Figure 3-2: Connecticut River flow duration curve for August 1 to November 15 (Ref. [1])

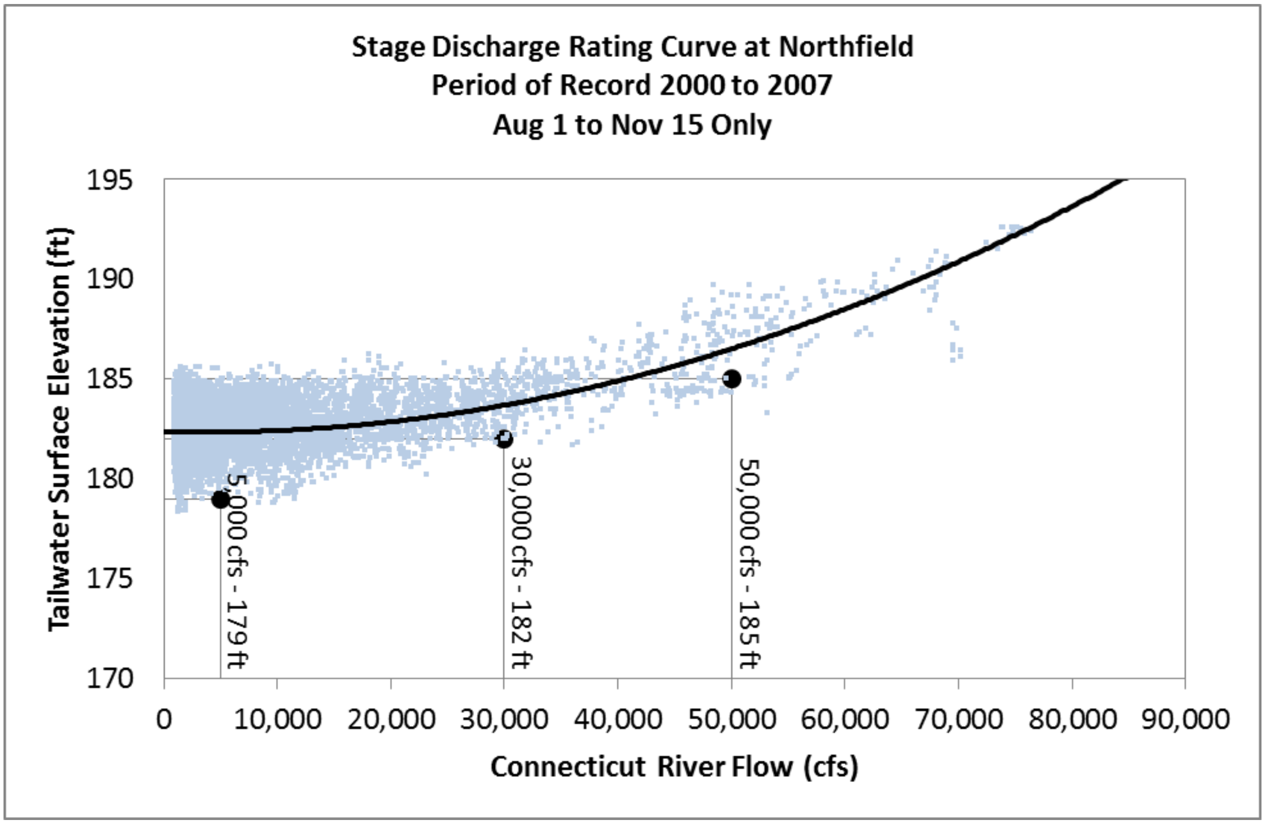


Figure 3-3: Historic stage-discharge relation at Northfield Project Intake/Tailwater

4.0 Force Calculations

4.1 Normal Force

The normal force F on the exclusion net was calculated with MATLAB using a typical drag formulation where drag proportional to the velocity squared

$$F = \frac{1}{2} C_D \rho u_{pore}^2 / g \tag{3}$$

where C_D is the drag coefficient, ρ = 1.94 slugs/ft^2 is the density of water, u_{pore} is the pore velocity, and g = 32.2 ft/s^2 is the acceleration of gravity. The pore velocity u_{pore} is defined as

$$u_{pore} = u_{norm} / A_{open} \tag{4}$$

where u_{norm} is the normal superficial velocity (i.e. flow through net) and A_{open} is the ratio of open to closed area. Pacific Netting provided the open area and drag coefficient through email communication (Ref. [3]). For the 3/8-inch mesh A_{open} = 0.586 (41.4% blocked) and for the 3/4-inch mesh A_{open} = 0.785 (21.5% blocked). The drag coefficient for both mesh sizes is C_D = 1.1.

The normal force on the exclusion net was calculated for both the upper and lower panels because the panels have different open areas. The exclusion net is approximately 30 ft tall (it will vary with depth) and two panels in the vertical direction that are each 15 ft tall. It was assumed that the exclusion net is taut and occupies a flat vertical plane. In reality, the exclusion net would bow and ripple with the current and not be perfectly vertical. The top panel has a lower open area and therefore higher normal forces. To be conservative, it was assumed that the top panel was always taut and 15 ft deep. The lower panel extends from the base of the top panel to the bathymetry.

The velocity across the exclusion net was extracted from the FLOW-3D model at a series of interpolation points at intervals smaller than the mesh resolution. The normal velocity u_{norm} was calculated at each point from the velocity components. The hydraulic force was calculated at each point using Equation (3) and numerically integrated across the exclusion net plane to determine the total force.

4.2 Shear Force

In addition to the normal force due to flow through the exclusion net, tangential velocities create a shear force across the face of the exclusion net. The shear force F_s is related to the shear stress τ as

$$\tau = F_s / A \tag{5}$$

where A is the area upon which the shear stress acts. Assuming the net acts as a no-slip boundary (extreme case) and the boundary layer is fully developed (i.e., infinitely long wall), the shear stress τ can be parameterized with a skin friction coefficient C_f as

$$\tau = \frac{1}{2} C_f \rho u_{tan}^2 \tag{6}$$

where u_{tan} is the tangential velocity. The tangential velocity along the net was found to range from 0 to 5 ft/s. The shear force was calculated at each point and numerically integrated across the exclusion net plane to determine the total shear force. There are many formulations for the skin friction coefficient C_f from literature, including the computation of the skin friction coefficient C_f as (Ref. [4])

$$C_f = \frac{0.455}{(\log_{10} Re)^{2.58}} \tag{7}$$

where Re is the free stream Reynolds number, not the pore Reynolds number defined previously. Equation (7) is valid for a smooth and flat surface. A conservative skin friction coefficient equal to 0.01 (approximately double C_f from Equation (7) is selected for purposes of this calculation because net fouling will increase C_f.

5.0 Results

The force on the exclusion net is summarized in Table 5-1. The lateral force distributions are given in Figure 5-1, Figure 5-2 and Figure 5-3 for high, medium and low river flow, respectively. Comprehensive statistics for all cases are attached in Table A- 1. It is important to recognize that the forces reported in Table 5-1 assumes that the net can be parameterized as flat and that the net does not bow. Simulating the deformation of the net was beyond the scope of work and is an extremely complex computation. Further, the results are based on the assumption that the net is clean. The impacts of the simplifications are discussed in the conclusions (Section 6.0)

The highest hydraulic force on the exclusion net was 5,000 lbs for the two generation operation cases. The corresponding river flows were 5,000 cfs (low flow) and 30,000 cfs (medium flow). The drag force on the exclusion net ranges from 2,300 to 4,500 lbs for all cases tested. The drag force is highly dependent on the velocity distribution because it quadratically scales with velocity. Spatial distribution of velocity and forces across the net and depth-averaged velocities are attached in Appendix A. The shear force on the exclusion net ranges from 200 to 1,000 lbs for all cases tested. The shear force generally increases with increasing river flow and is 7% to 32% of the drag force.

Table 5-1: Force on Exclusion Net

River Conditions	Project Operation	Drag Force	Shear Force	Combined Force
High River Flow, Low TFI Level	Generation	2,800 lbs	900 lbs	3,700 lbs
High River Flow, Low TFI Level	Pumping	3,700 lbs	1,000 lbs	4,700 lbs
Medium River Flow, Low TFI Level	Generation	4,300 lbs	700 lbs	5,000 lbs
Medium River Flow, Low TFI Level	Pumping	2,900 lbs	400 lbs	3,300 lbs
Low River Flow, Low TFI Level	Generation	4,500 lbs	500 lbs	5,000 lbs
Low River Flow, Low TFI Level	Pumping	2,300 lbs	200 lbs	2,500 lbs

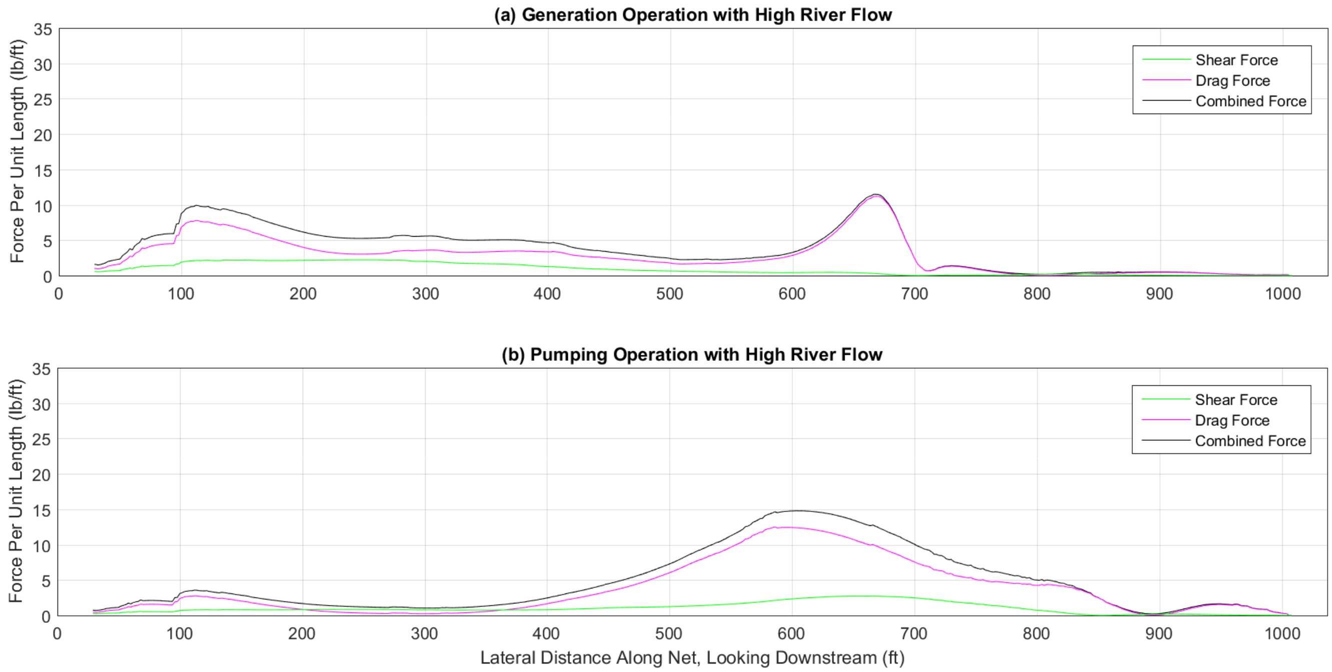


Figure 5-1: Force on Exclusion Net for High River Flow

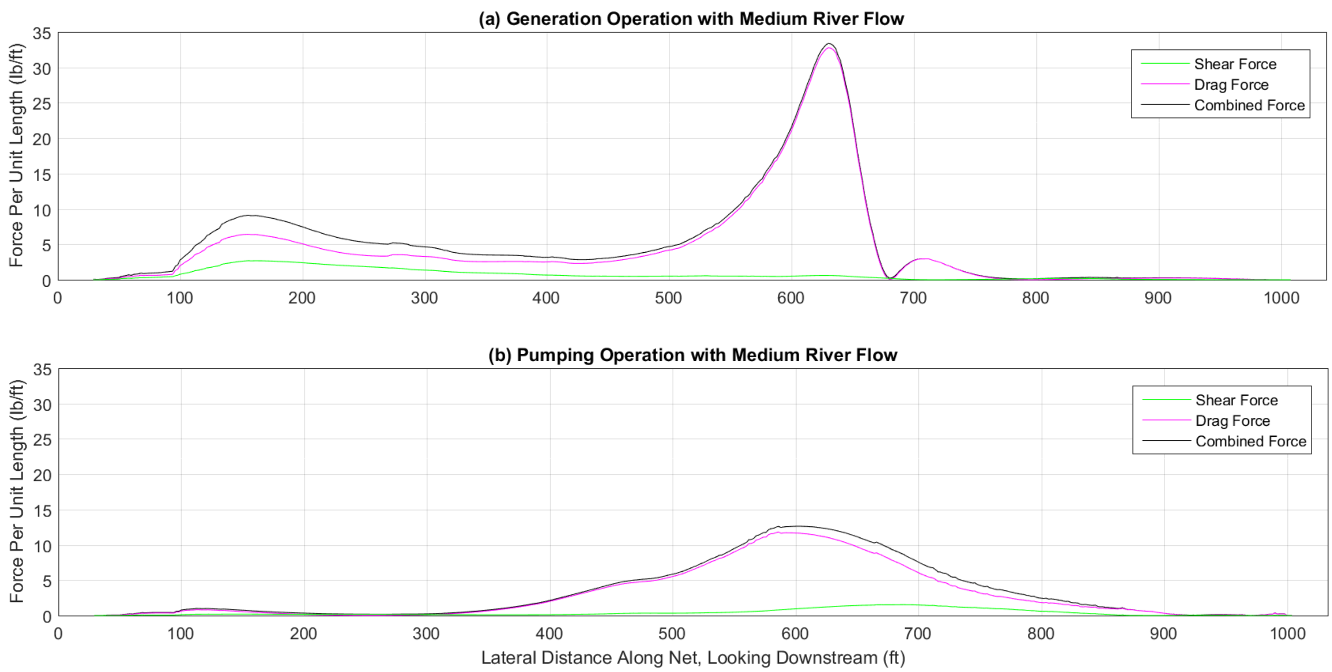


Figure 5-2: Force on Exclusion Net for Medium River Flow

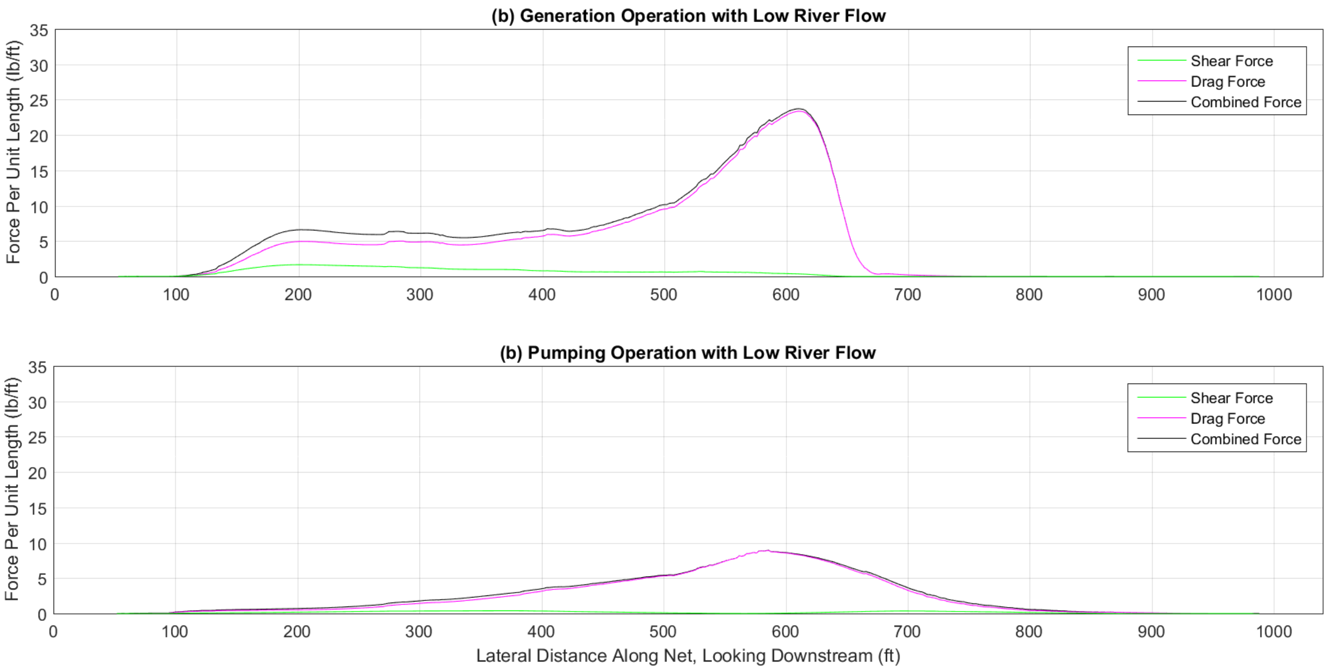


Figure 5-3: Force on Exclusion Net for Low River Flow

6.0 Conclusions

The highest calculated hydraulic force on the clean and flat exclusion net was 5,000 lbs for two cases; generation operation with low river flow and low TFI level and generation operation with medium river flow and low TFI level. The hydraulic force is due to both normal flow through the net and shear force along the net. The shear force generally increases with increasing river flow and is 7% to 32% of the drag force.

It was assumed that the exclusion net is taut and occupies a flat vertical plane. In reality, the exclusion net would bow with the current. The assumption that the exclusion net is taut minimizes the cross-sectional area of flow in/out of the intake/tailrace and thus could be considered to maximize normal forces on the exclusion net. However, if the exclusion net bows significantly, the location of the exclusion net will move, flow patterns through the exclusion net will be different and the open area of the net can change. Ripples in the exclusion net may actually increase the normal flow through the exclusion net because tangential flow along the net will pass through the net where it bows out. The calculations completed in this report provide an approximation of the forces but are likely not conservative because deformation of the net from a flat plane is expected to increase the drag.

Perhaps a more significant factor on the computed load is the degree of net fouling. As the net is in the water it will accumulate mossy growth and debris, both of which increase drag and shear. The force on the exclusion net is quadratically proportional to the pore velocity. Thus, a 50% blockage due to debris yields a 400% increase in force on the exclusion net. It is important that the anchoring structure be designed with a sufficiently high safety factor to account for debris blockage. It is not possible to estimate the effects of debris accumulation on the drag coefficient. While there is significant research that has been completed on the drag on clean nets, drag on fouled nets is less well understood. To more accurately determine the drag on the net, Alden suggests a field or laboratory test. The test can be completed in a very large flume such as the 10 ft x 20 ft flume in Holden or in the field. In a flume experiment, all of the test parameters can be controlled, however flow is one directional. An alternative to the flume experiment is an on-site test where the net can be tested with normal and tangential flow. Because of the complexity of completing an on-site test, a flume test may be a better way to start. Debris can be added to the flume to simulate the effects of debris.

8.0 References

[1] Sedimentation Studies at the Connecticut River Intake/Tailwater. Alden Research Laboratory, Inc. January, 2015.

[2] Northfield Fish Protection Tailrace Barrier Net Drawings. "Northfield Tailrace Fish Protection Prelim Draft 7_13_17.pdf". Gomez and Sullivan Engineers. July 2017.

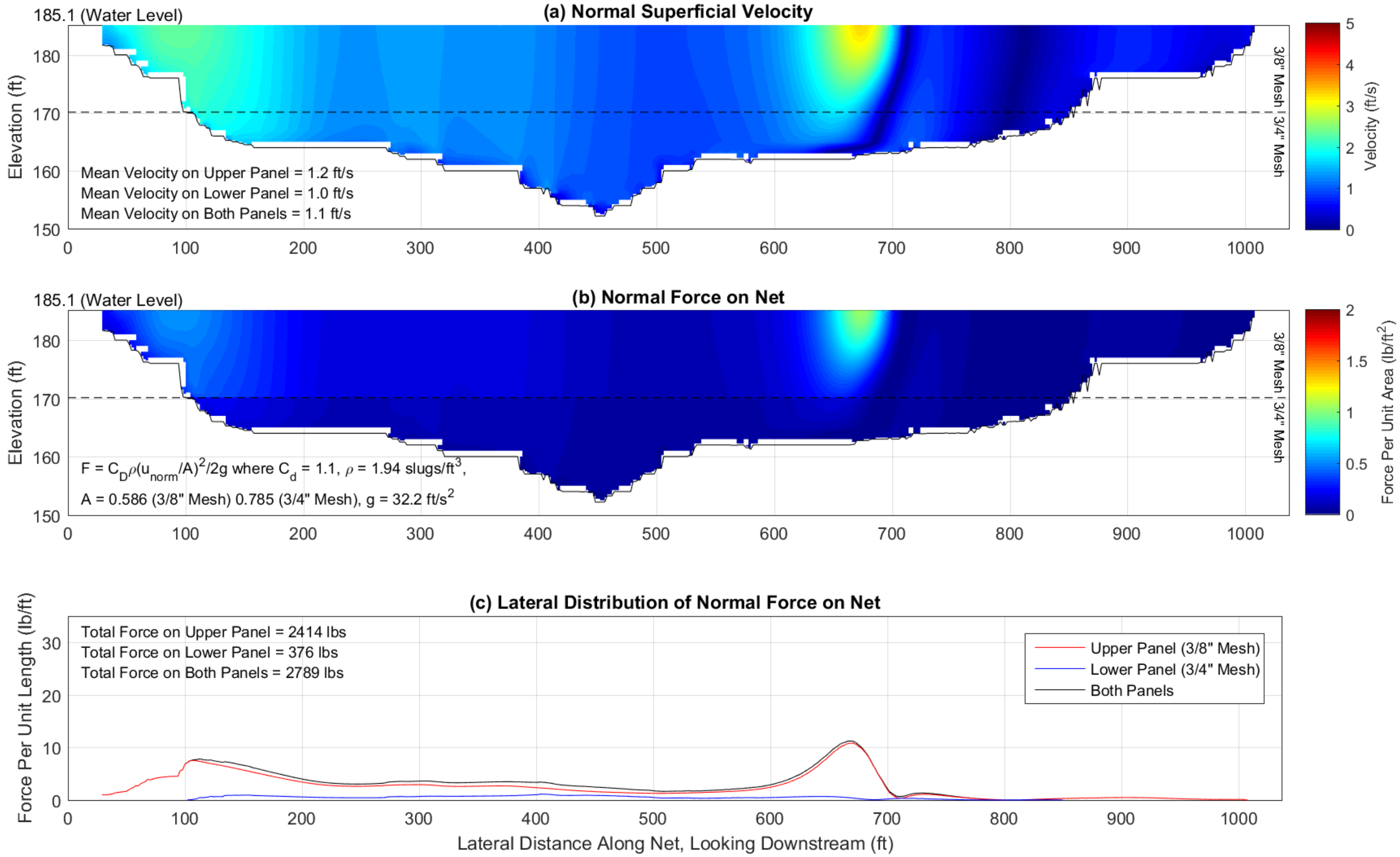
[3] Emails from Pacific Netting Products to Alden. Northfield Exclusion Net Drag Coefficient(s) and % blockage. Rich Pasma (Pacific Netting) to Mitch Peters (Alden). November 7 and 13, 2017.

[4] Schlichting, Hermann (1979), "Boundary Layer Theory", 7th Edition.

Appendix A Force Calculation Results

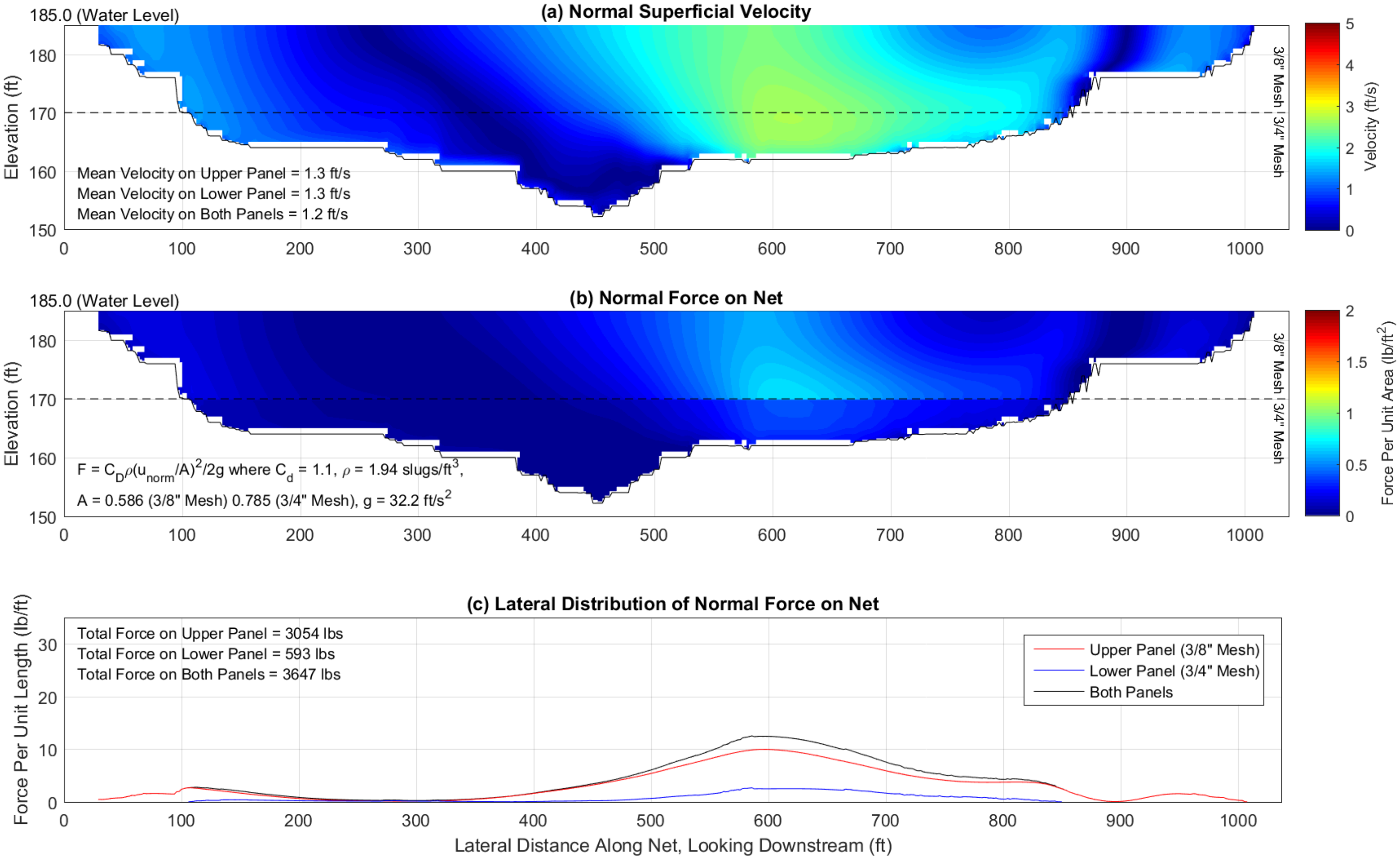
Table A- 1: Exclusion Net Statistics

	Upper Panel (3/8" Mesh)	Lower Panel (3/4" Mesh)	Both Panels
Generation, High River Flow, Low Turner Falls Impoundment level			
Normal Force (lbs)	2414	376	2789
Shear Force (lbs)	662	212	874
Mean Superficial Velocity (ft/s)	2.3	2.1	2.2
Mean Normal Superficial Velocity (ft/s)	1.2	1.0	1.1
Mean Tangential Superficial Velocity (ft/s)	1.9	1.8	1.9
Pumping, High River Flow, Low Turner Falls Impoundment level			
Normal Force (lbs)	3054	593	3647
Shear Force (lbs)	868	141	1009
Mean Superficial Velocity (ft/s)	2.7	2.1	2.4
Mean Normal Superficial Velocity (ft/s)	1.3	1.3	1.2
Mean Tangential Superficial Velocity (ft/s)	2.3	1.6	2.0
Generation, Medium River Flow, Low Turner Falls Impoundment level			
Normal Force (lbs)	3845	494	4339
Shear Force (lbs)	584	99	683
Mean Superficial Velocity (ft/s)	2.2	2.3	2.2
Mean Normal Superficial Velocity (ft/s)	1.3	1.4	1.3
Mean Tangential Superficial Velocity (ft/s)	1.7	1.7	1.6
Pumping, Medium River Flow, Low Turner Falls Impoundment level			
Normal Force (lbs)	2549	319	2868
Shear Force (lbs)	363	33	396
Mean Superficial Velocity (ft/s)	1.9	1.6	1.8
Mean Normal Superficial Velocity (ft/s)	1.1	1.1	1.1
Mean Tangential Superficial Velocity (ft/s)	1.4	1.0	1.3
Generation, Medium River Flow, Low Turner Falls Impoundment level			
Normal Force (lbs)	4095	394	4489
Shear Force (lbs)	420	52	472
Mean Superficial Velocity (ft/s)	1.9	2.4	1.9
Mean Normal Superficial Velocity (ft/s)	1.3	1.9	1.3
Mean Tangential Superficial Velocity (ft/s)	1.3	1.4	1.3
Pumping, Medium River Flow, Low Turner Falls Impoundment level			
Normal Force (lbs)	2075	214	2288
Shear Force (lbs)	144	11	155
Mean Superficial Velocity (ft/s)	1.5	1.7	1.4
Mean Normal Superficial Velocity (ft/s)	1.0	1.5	1.0
Mean Tangential Superficial Velocity (ft/s)	0.9	0.7	0.9



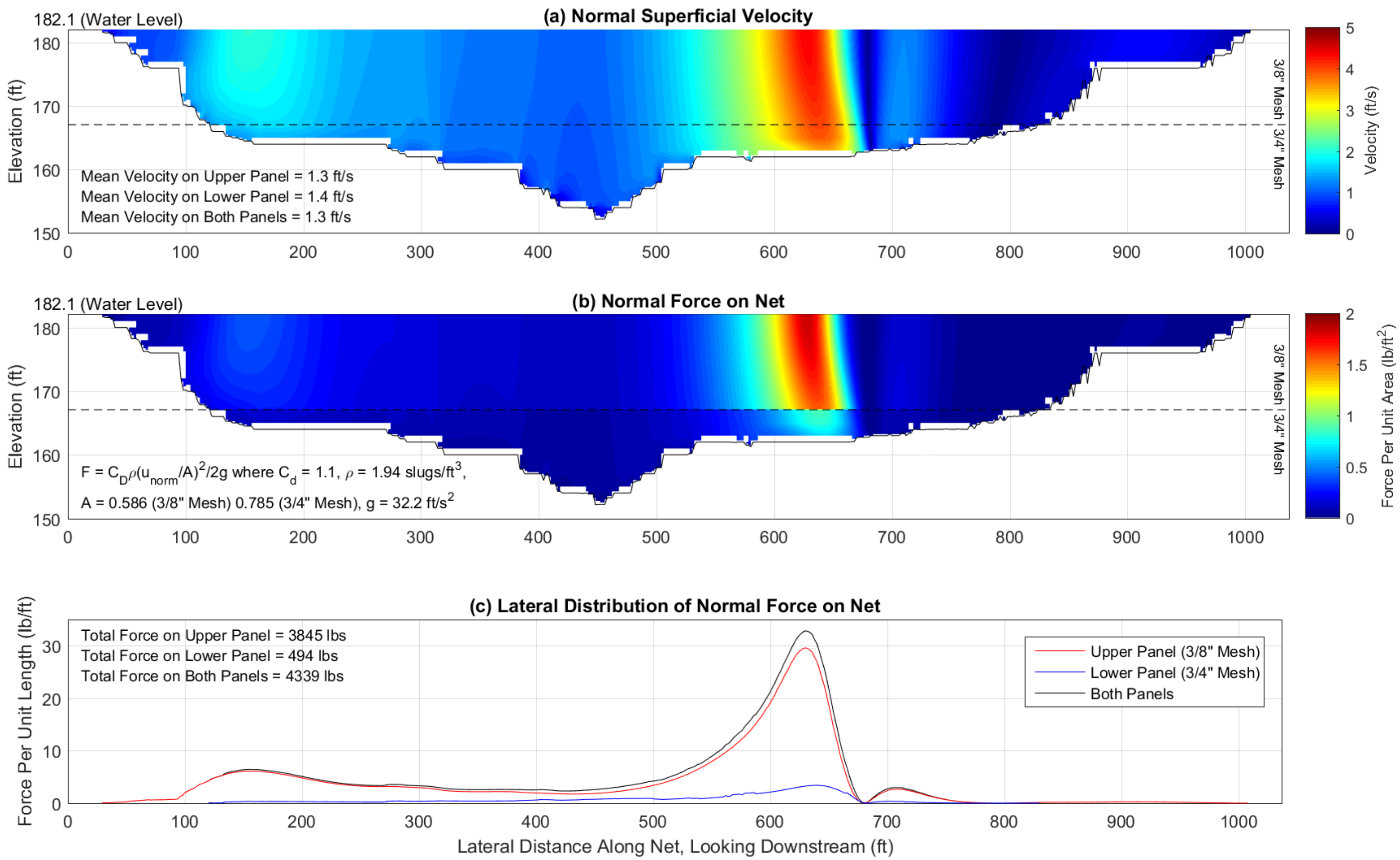
17NorthA1Gen

Figure A- 1: Force Distribution for Generation Operation with High River Flow



17NorthA1Pump

Figure A- 2: Force Distribution for Pumping Operation with High River Flow



17NorthB1Gen

Figure A- 3: Force Distribution for Generation Operation with Medium River Flow

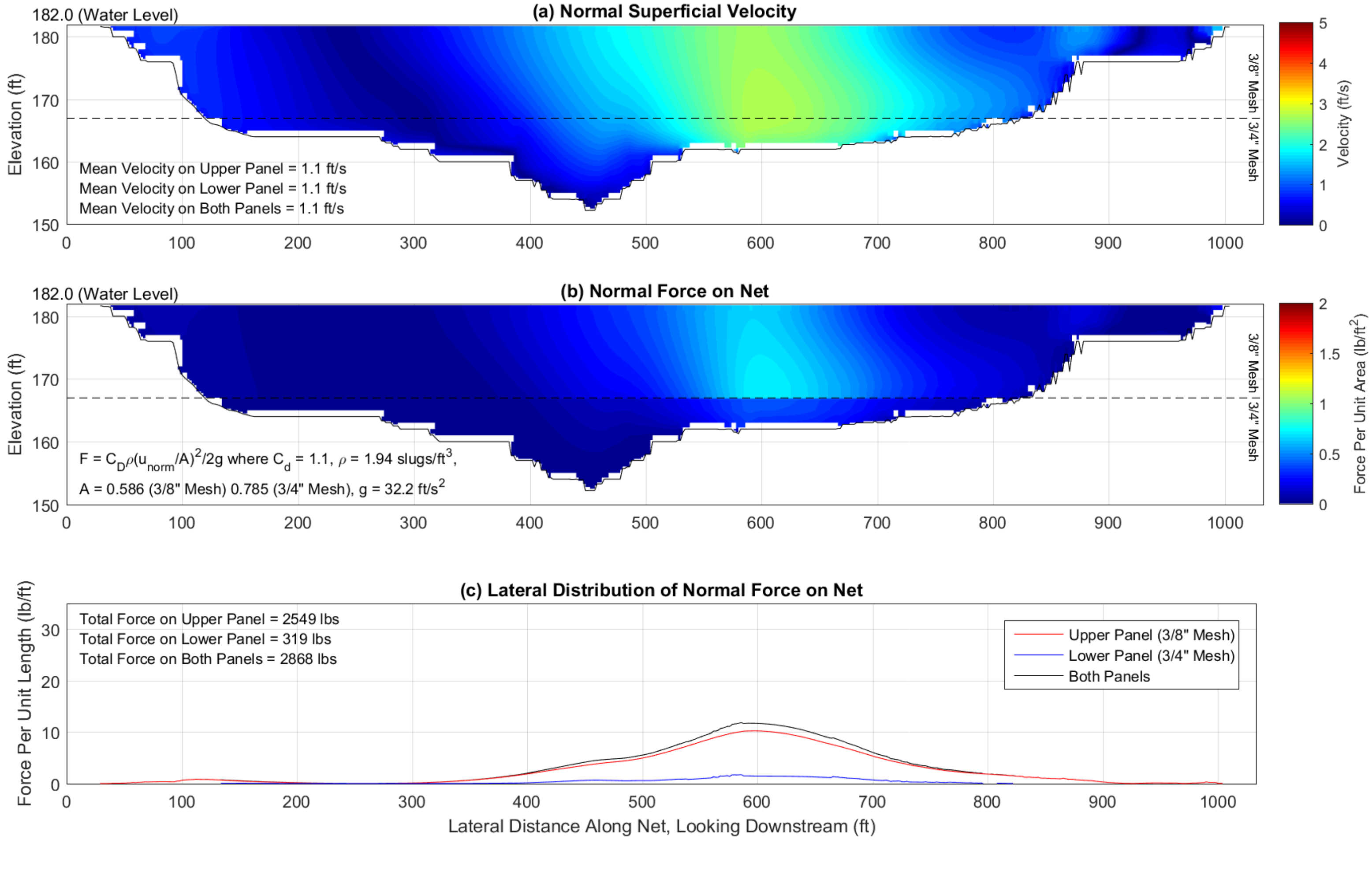


Figure A- 4: Force Distribution for Pumping Operation with Medium River Flow

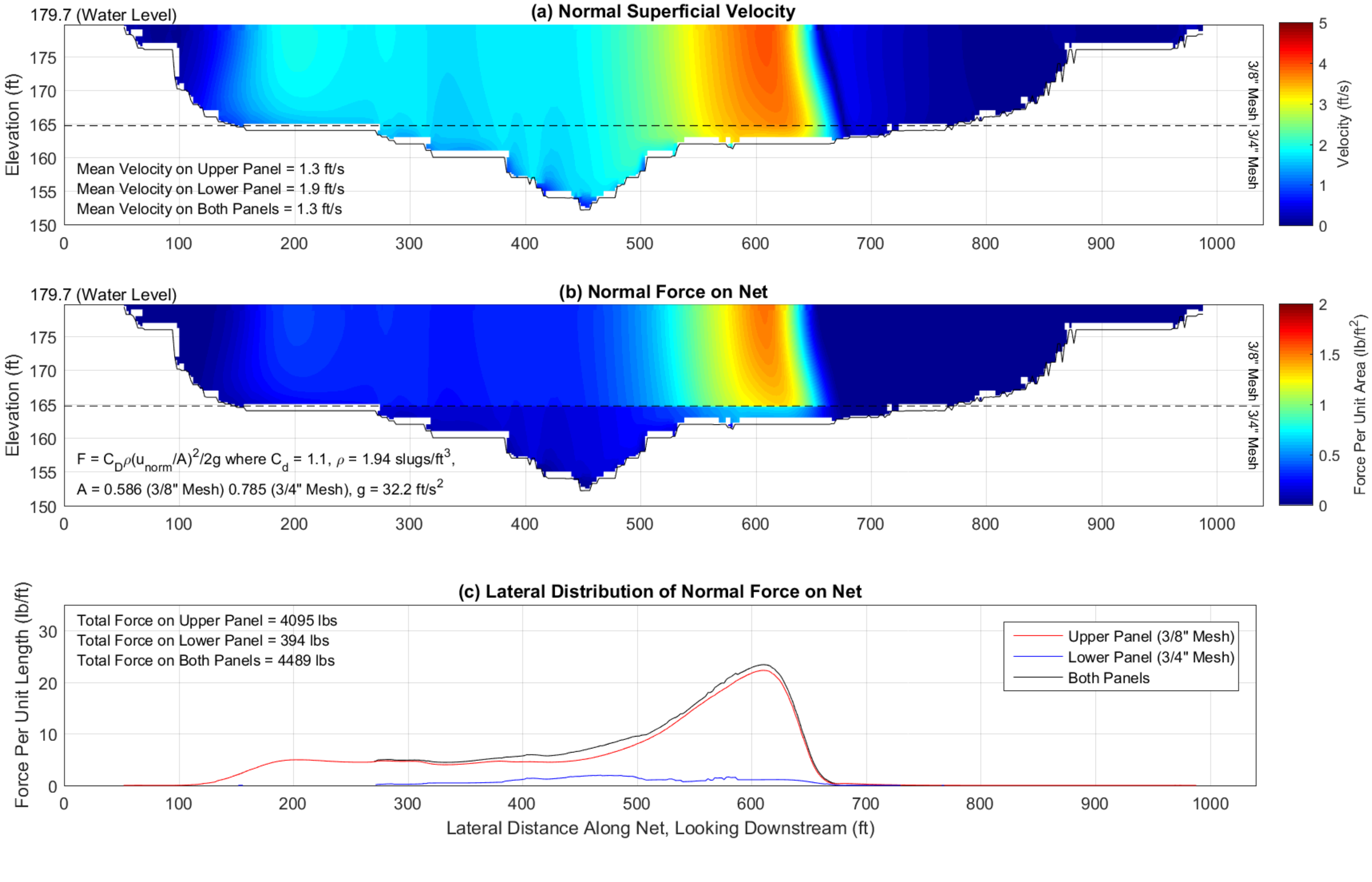


Figure A- 5: Force Distribution for Generation Operation with Low River Flow

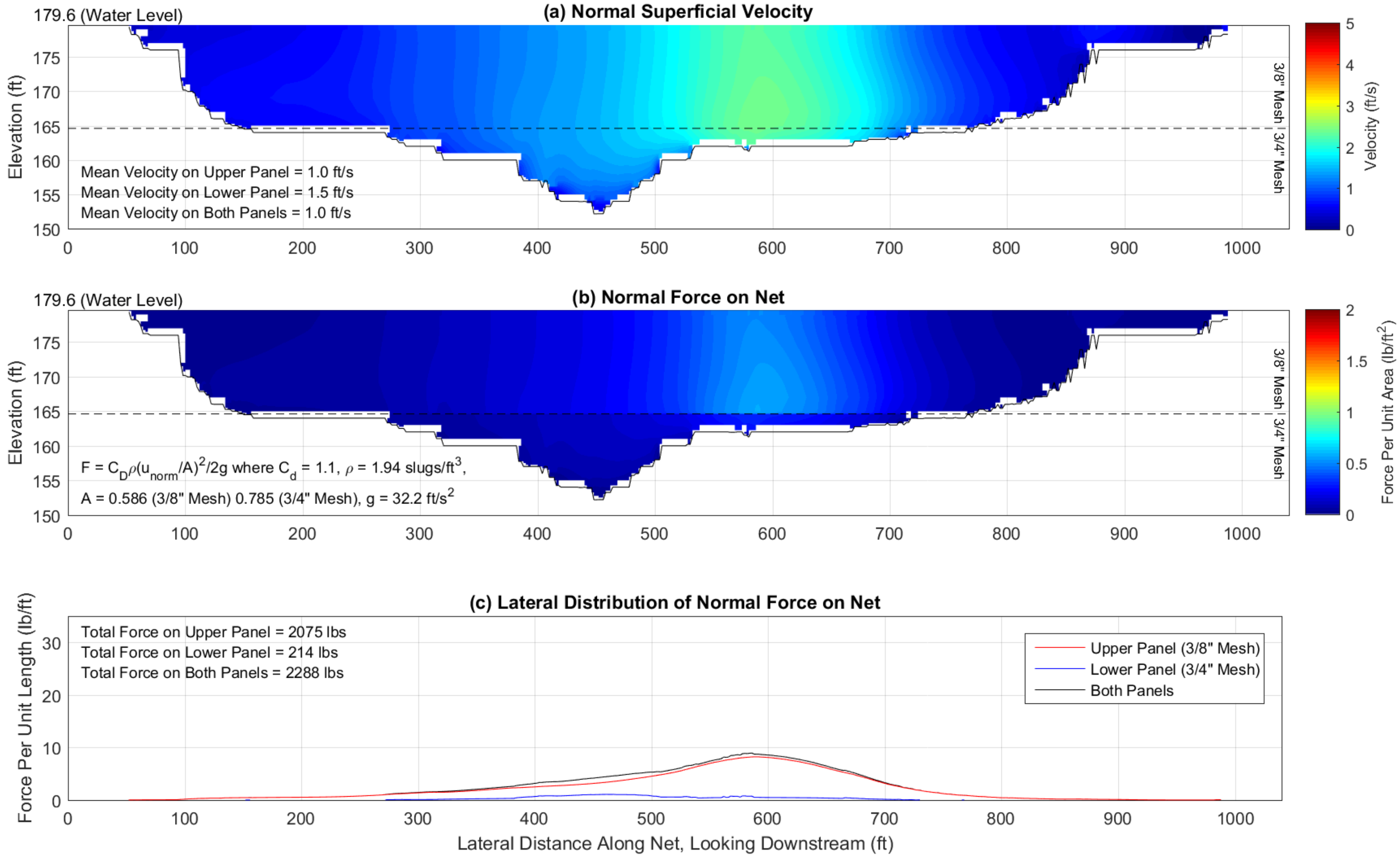
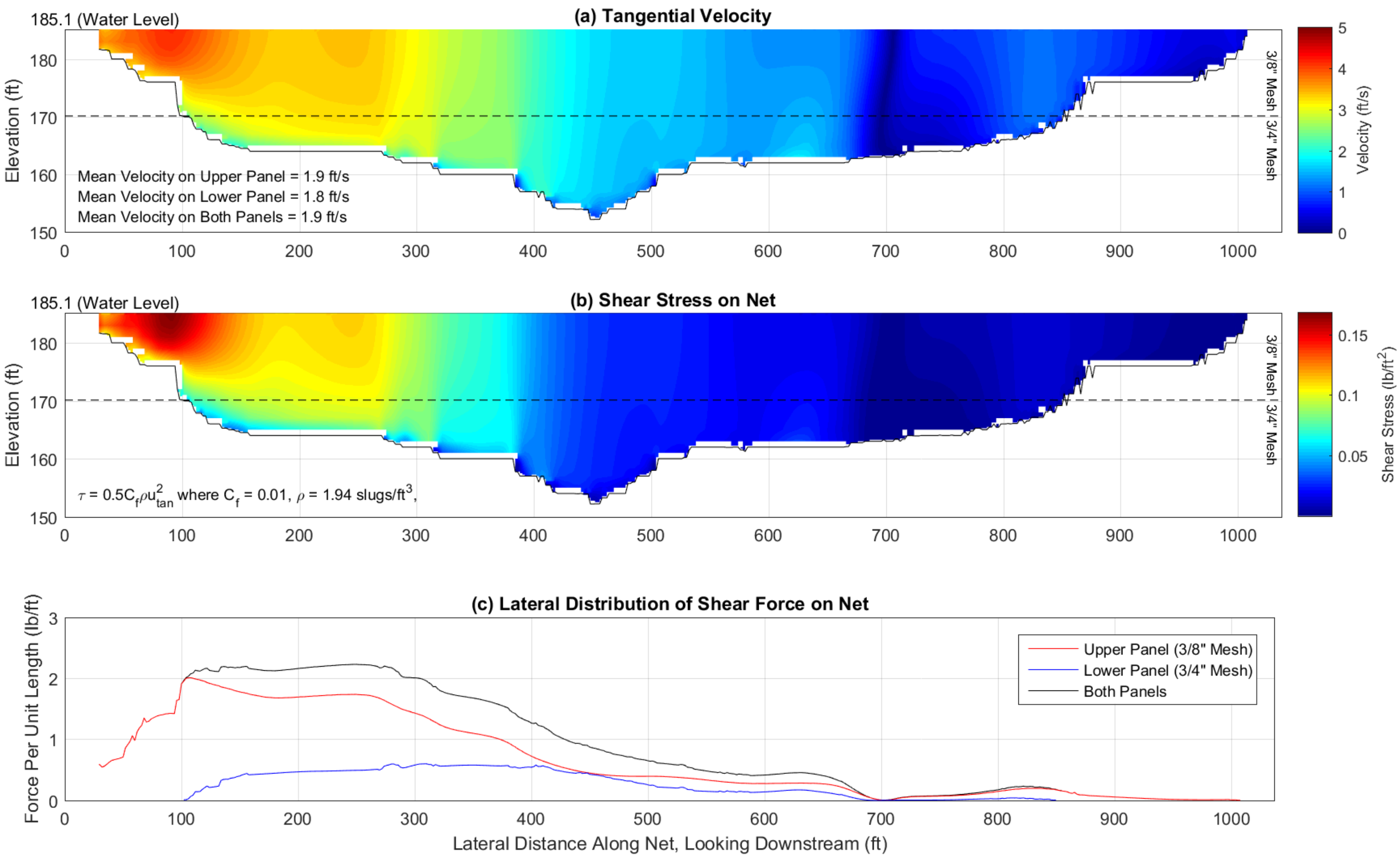


Figure A- 6: Force Distribution for Pumping Operation with Low River Flow



17NorthA1Gen

Figure A- 7: Shear Distribution for Generation Operation with High River Flow

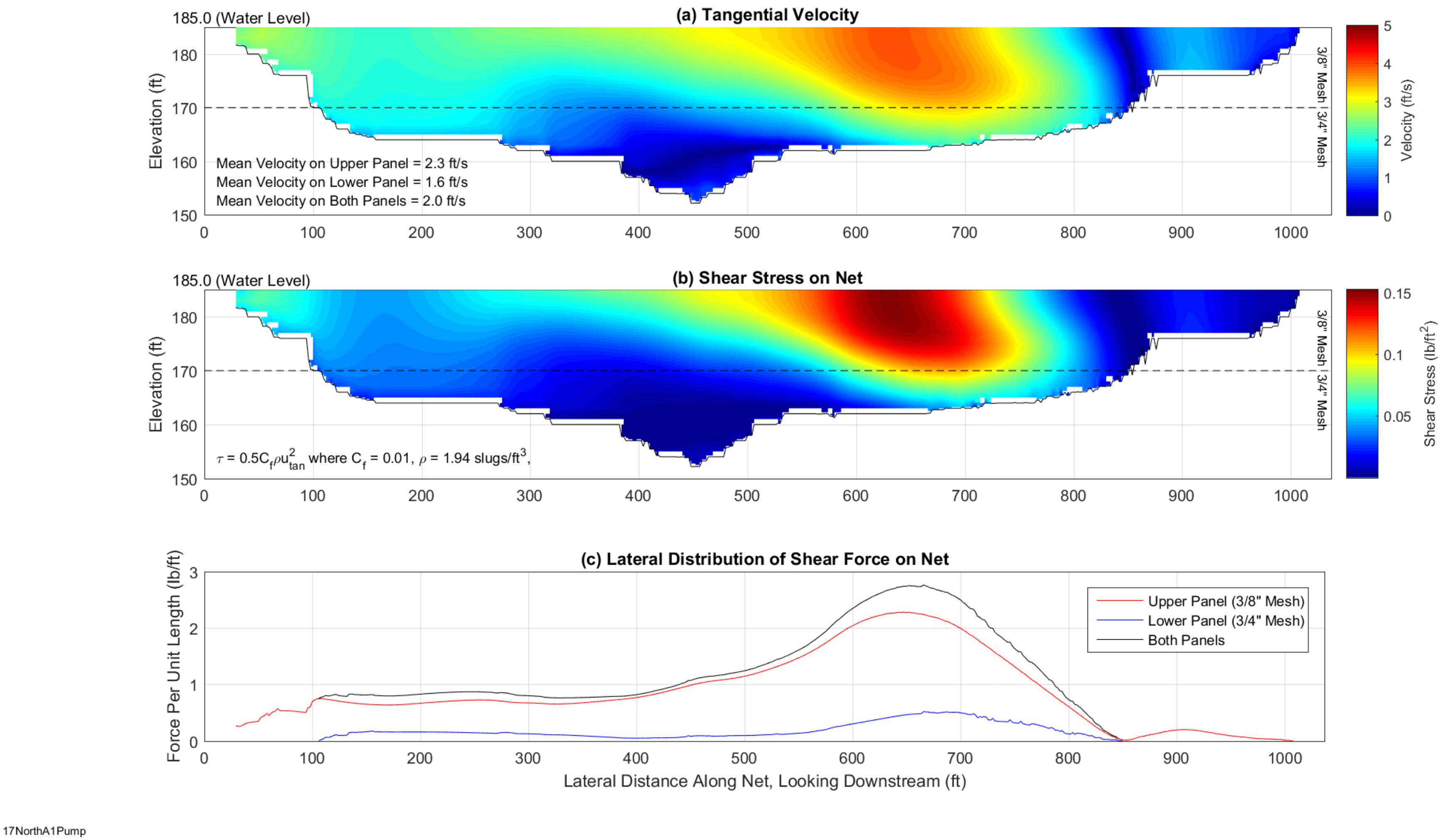
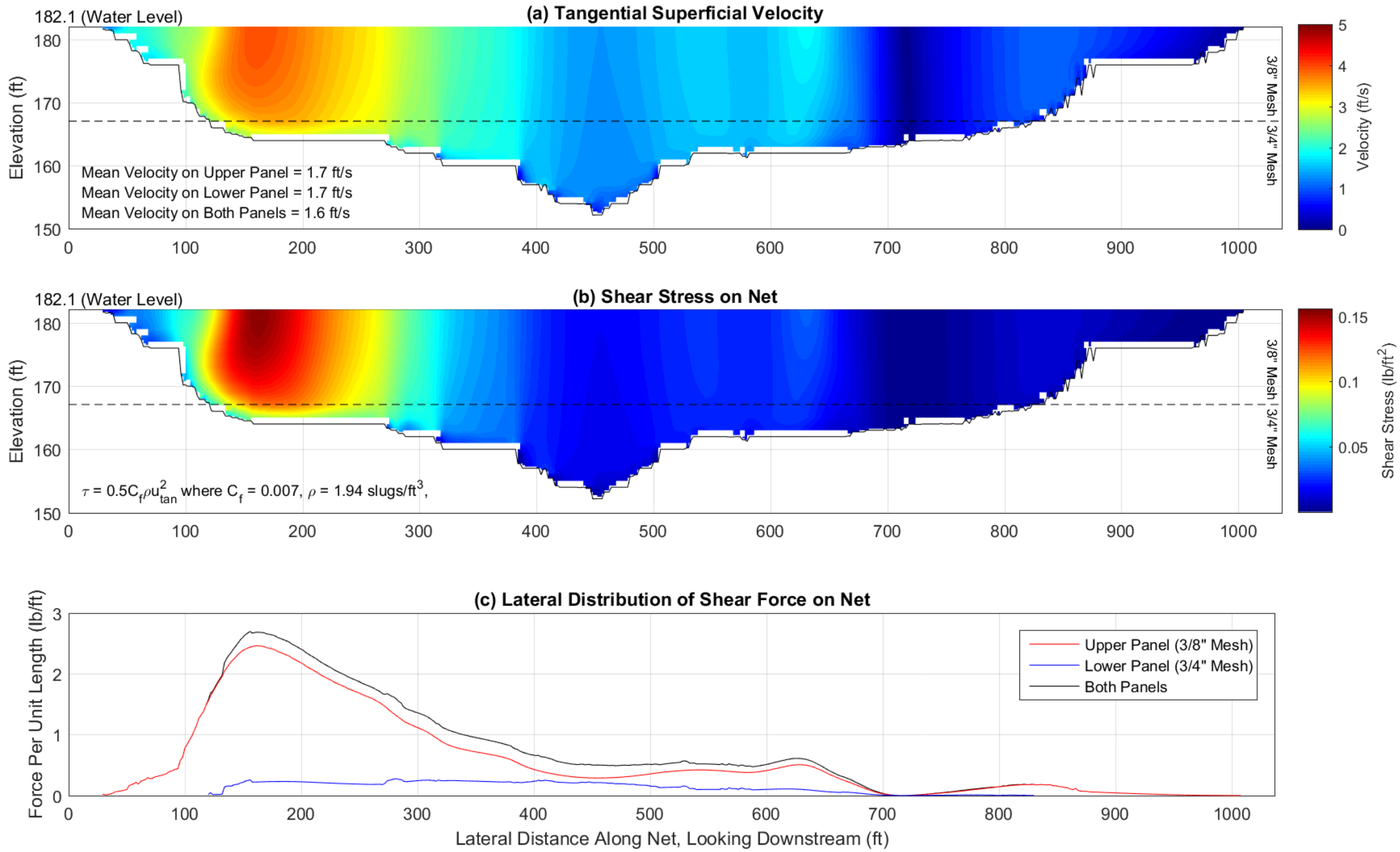


Figure A- 8: Shear Distribution for Pumping Operation with High River Flow



17NorthB1Gen

Figure A- 9: Shear Distribution for Generation Operation with Medium River Flow

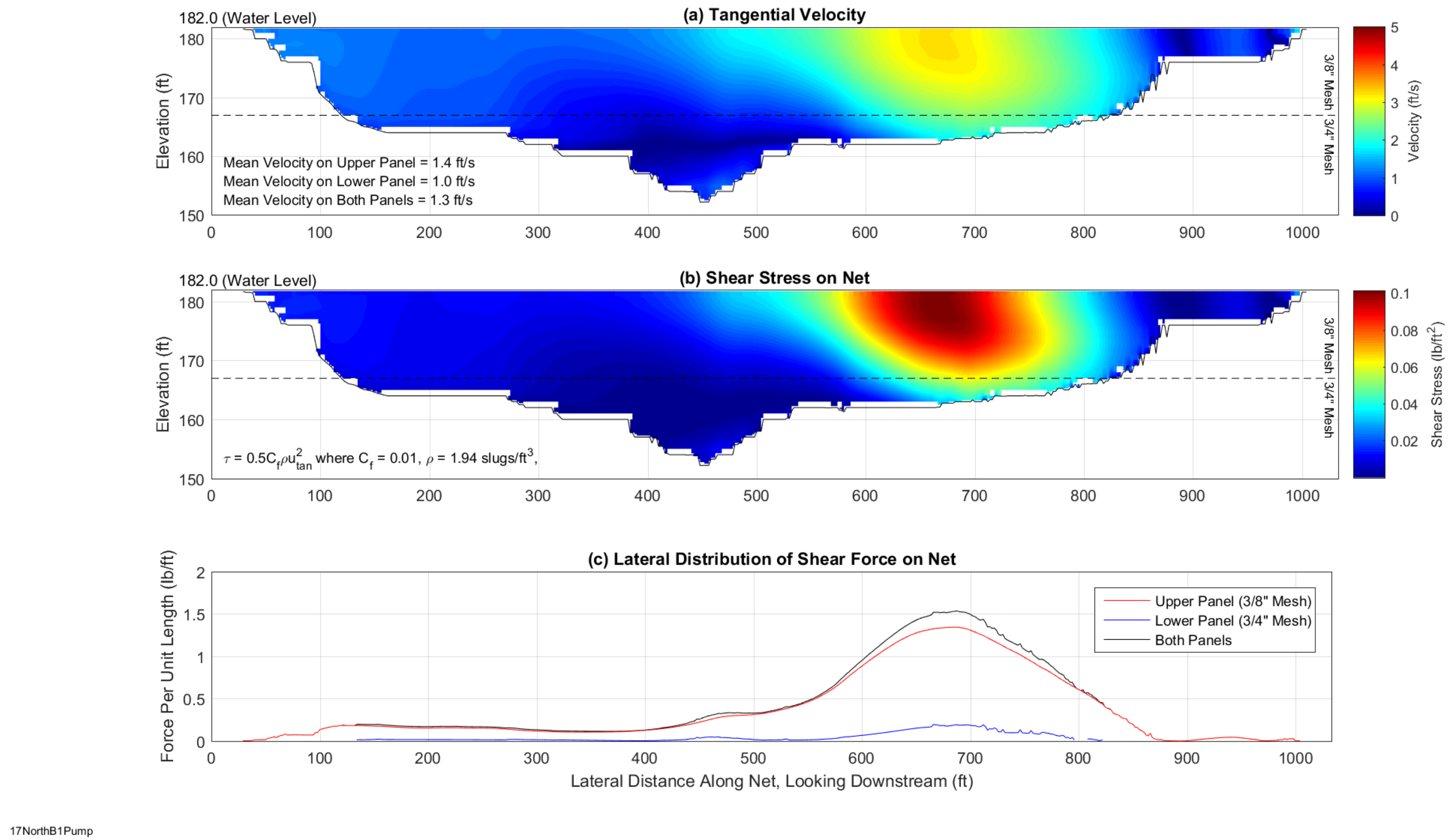


Figure A- 10: Shear Distribution for Pumping Operation with Medium River Flow

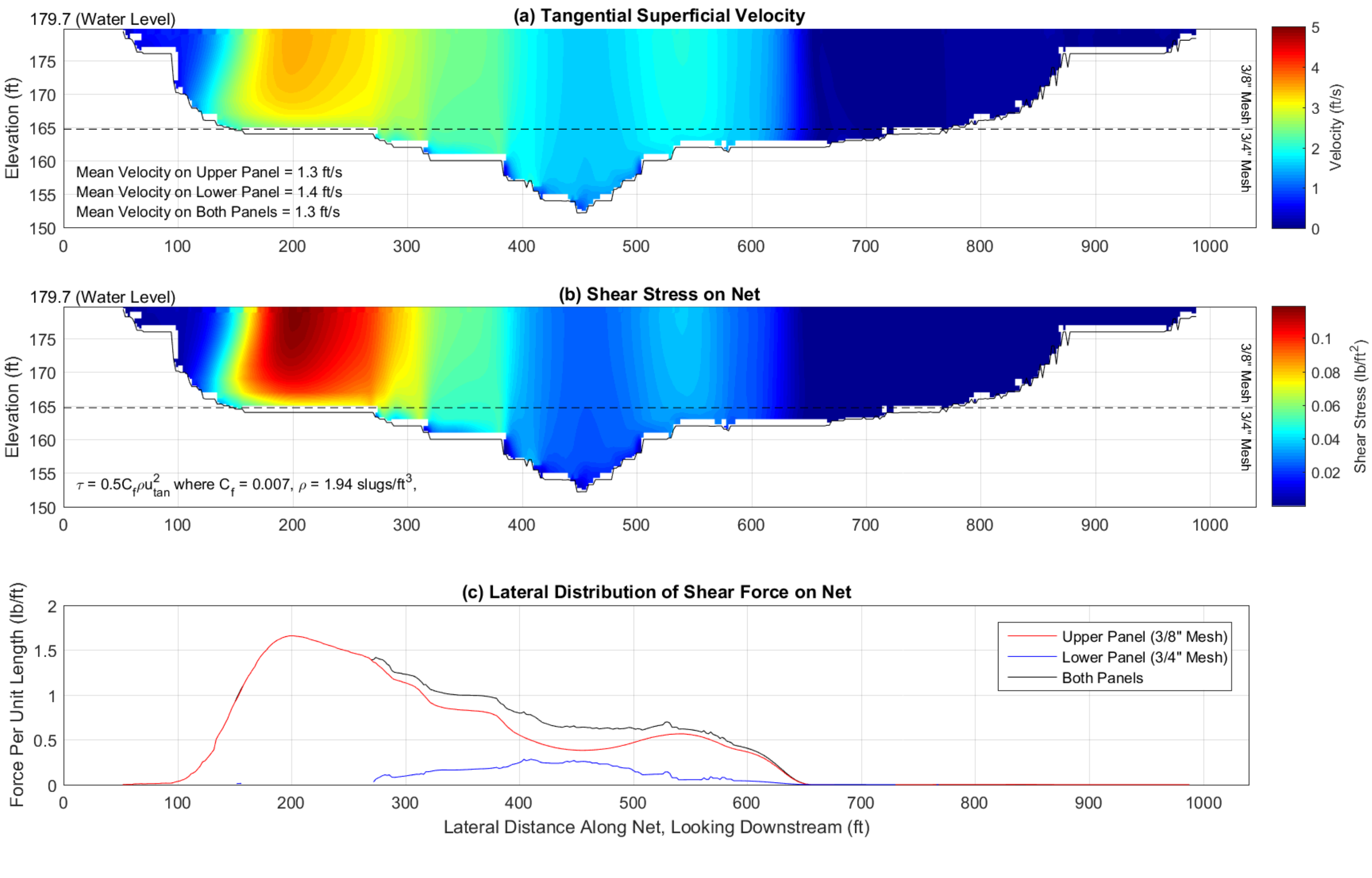


Figure A- 11: Shear Distribution for Generation Operation with Low River Flow

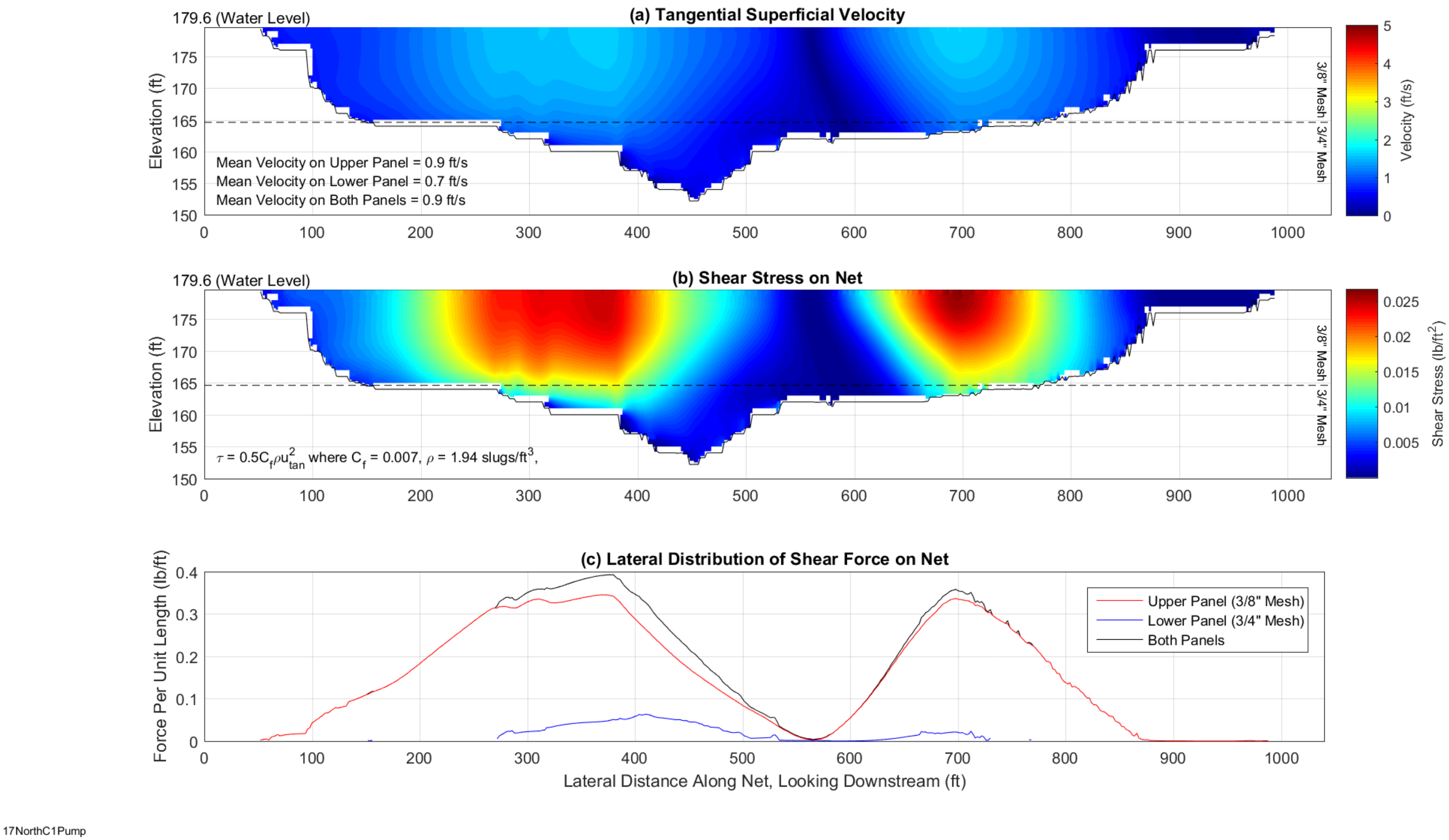
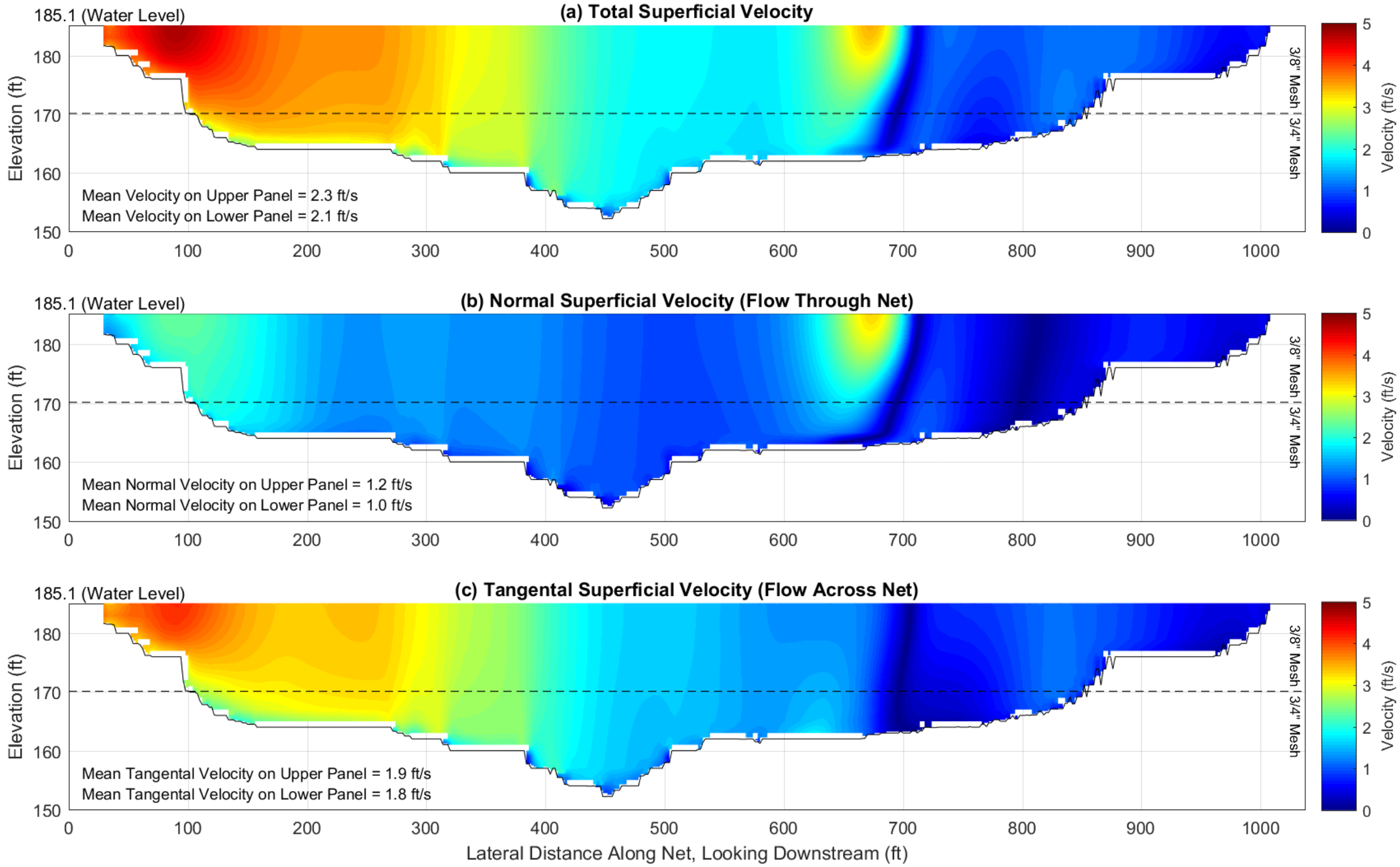
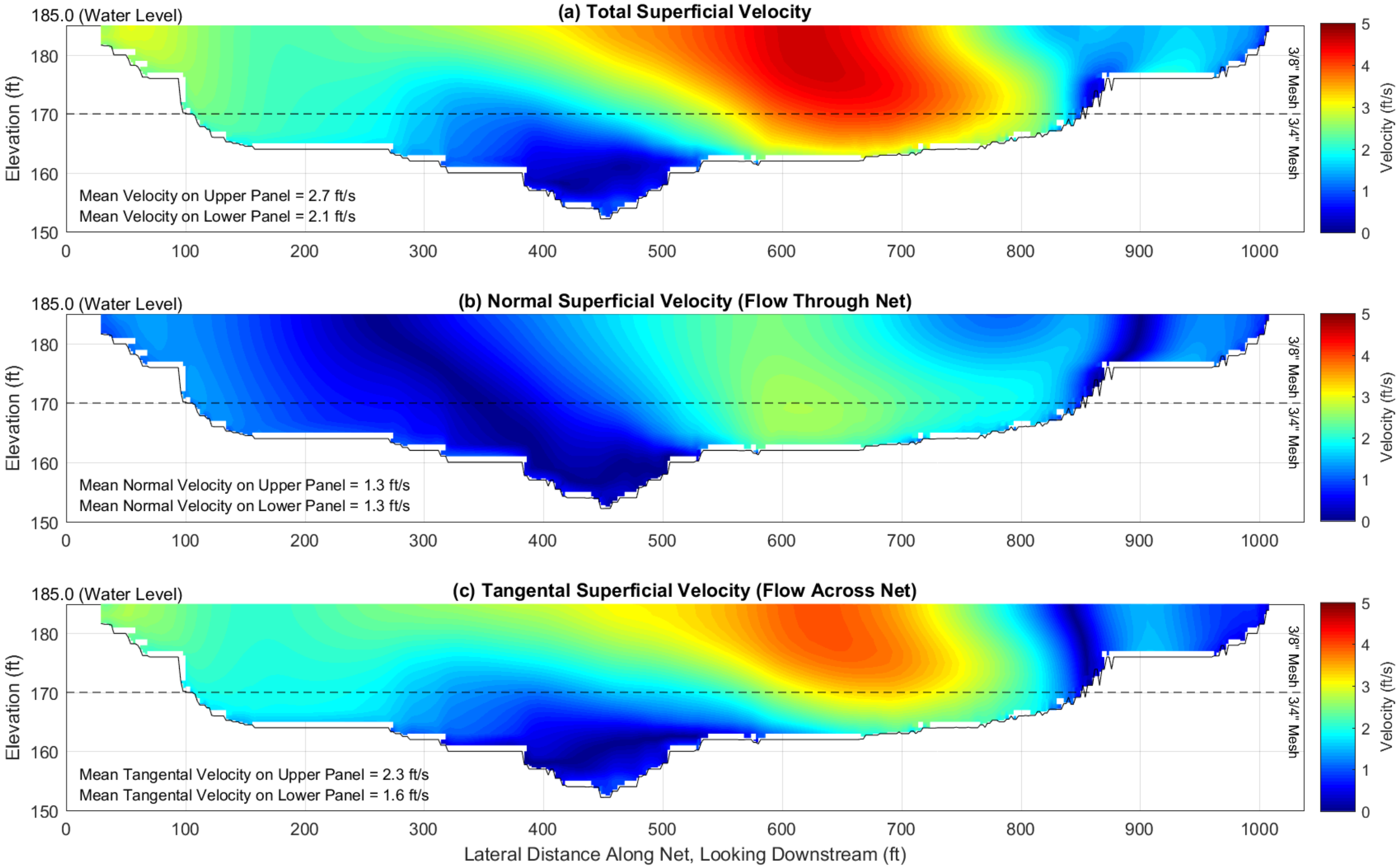


Figure A- 12: Shear Distribution for Pumping Operation with Low River Flow



17NorthA1Gen

Figure A- 13: Velocity Distribution for Generation Operation with High River Flow



17NorthA1Pump

Figure A- 14: Velocity Distribution for Pumping Operation with High River Flow

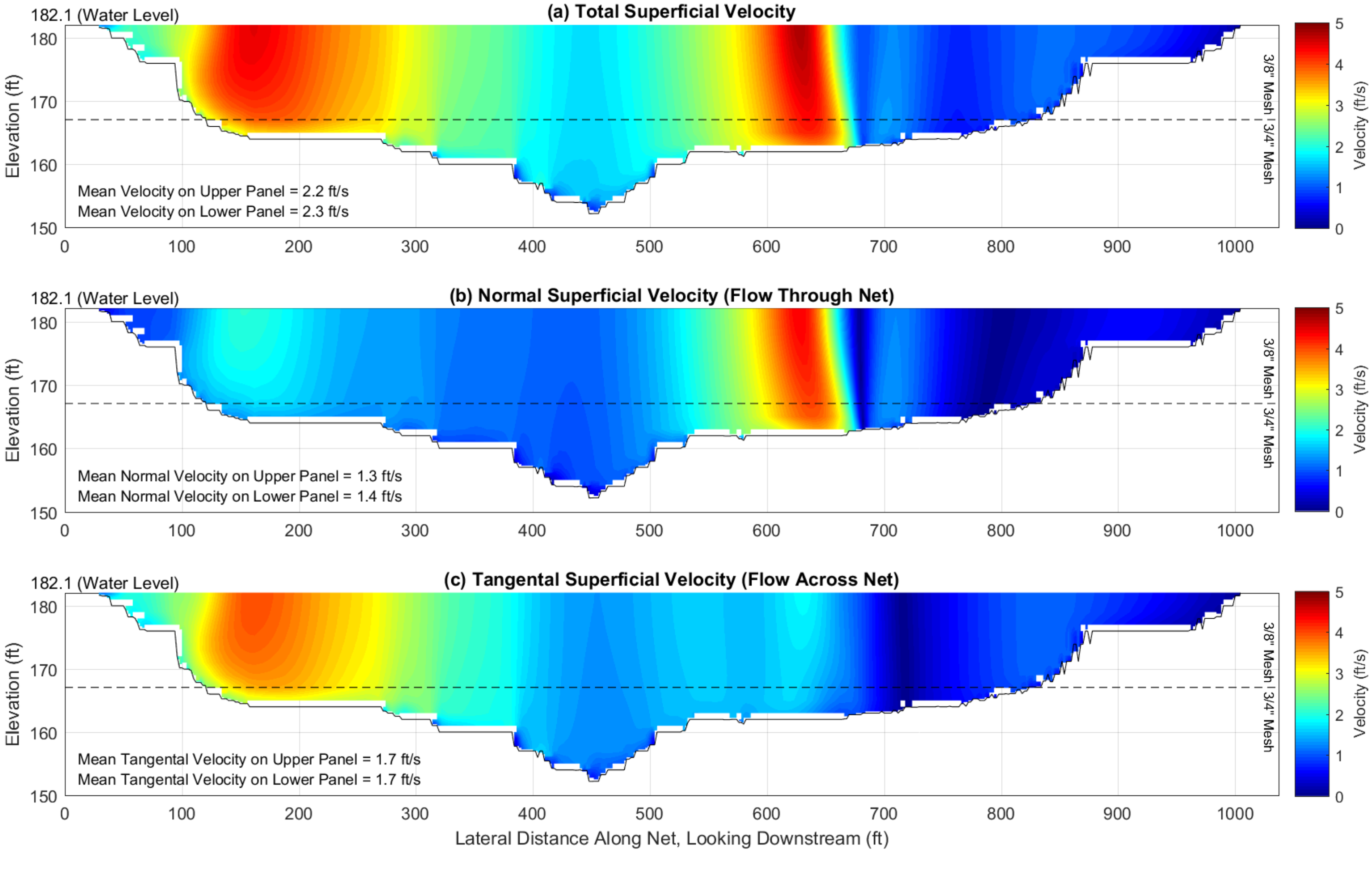
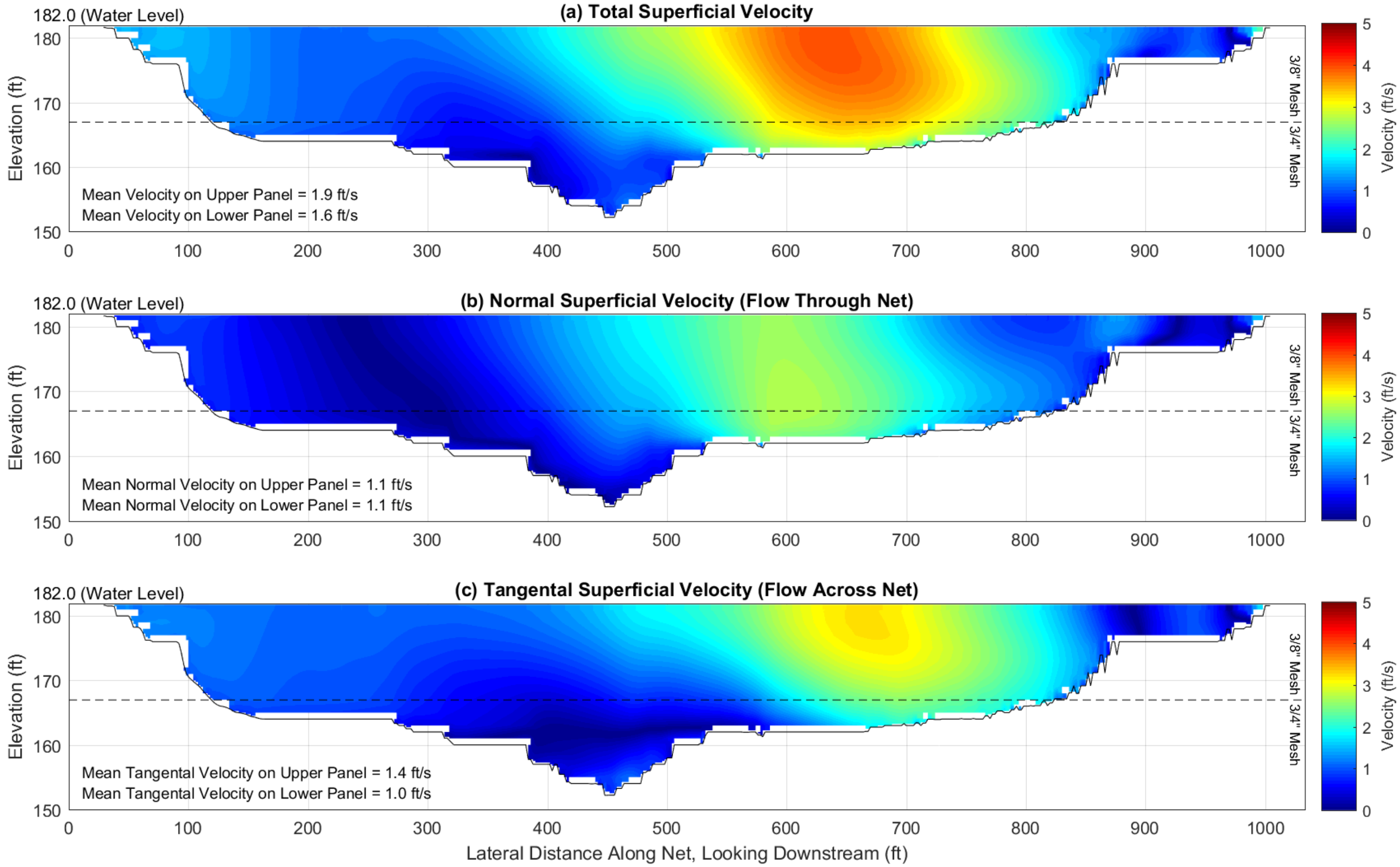
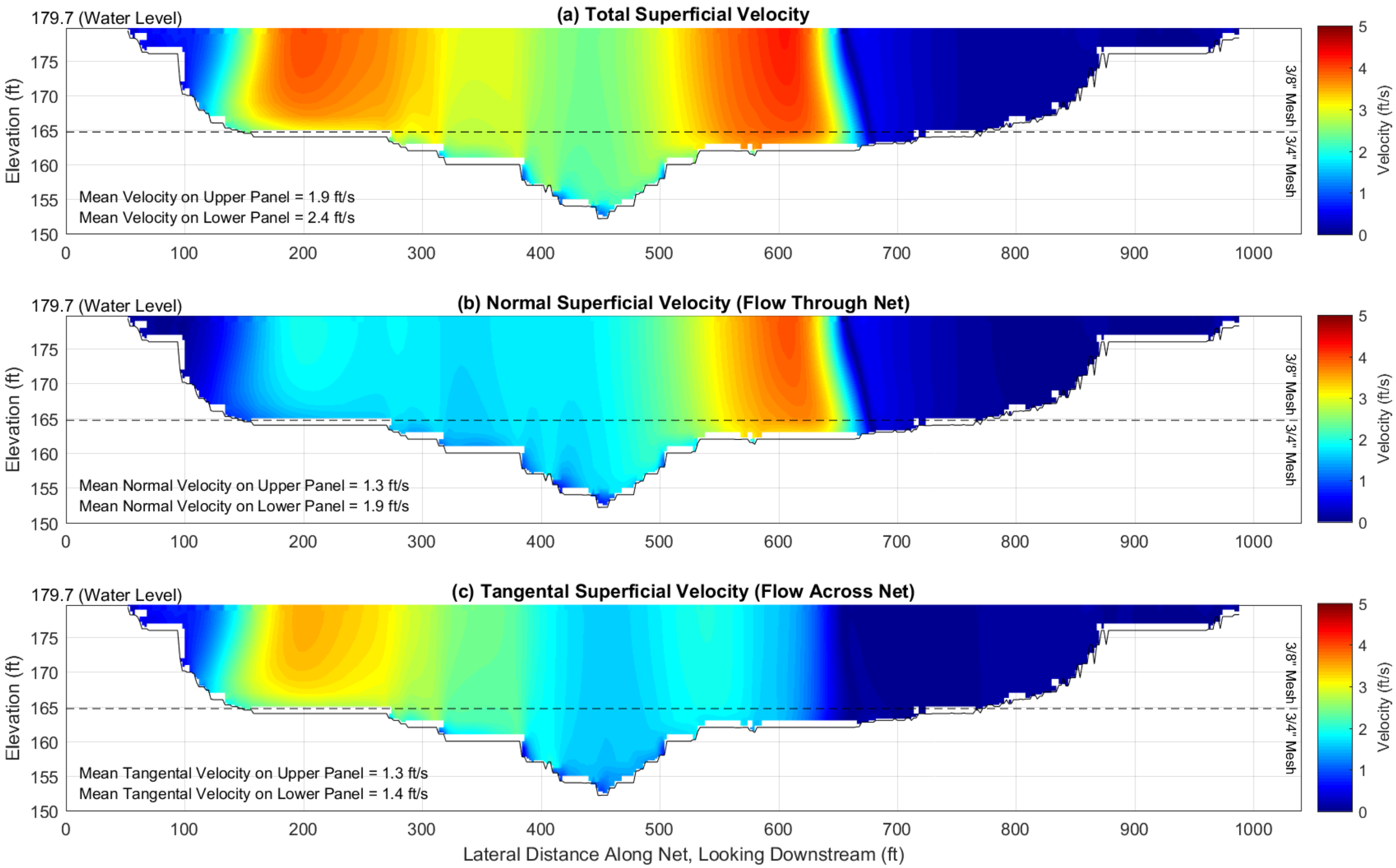


Figure A- 15: Velocity Distribution for Generation Operation with Medium River Flow



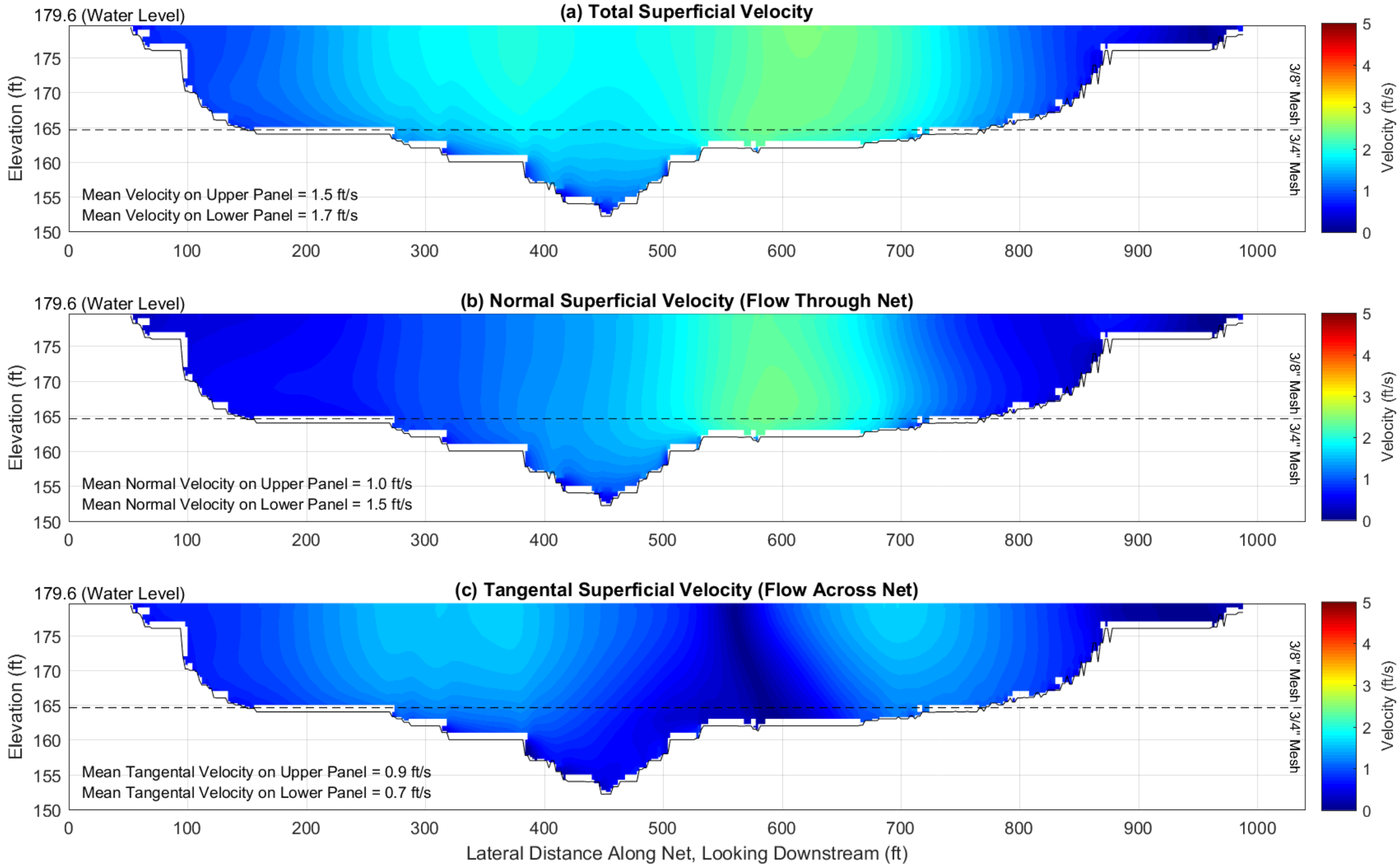
17NorthB1Pump

Figure A- 16: Velocity Distribution for Pumping Operation with Medium River Flow



17NorthC1Gen

Figure A- 17: Velocity Distribution for Generation Operation with Low River Flow



17NorthC1Pump

Figure A- 18: Velocity Distribution for Pumping Operation with Low River Flow

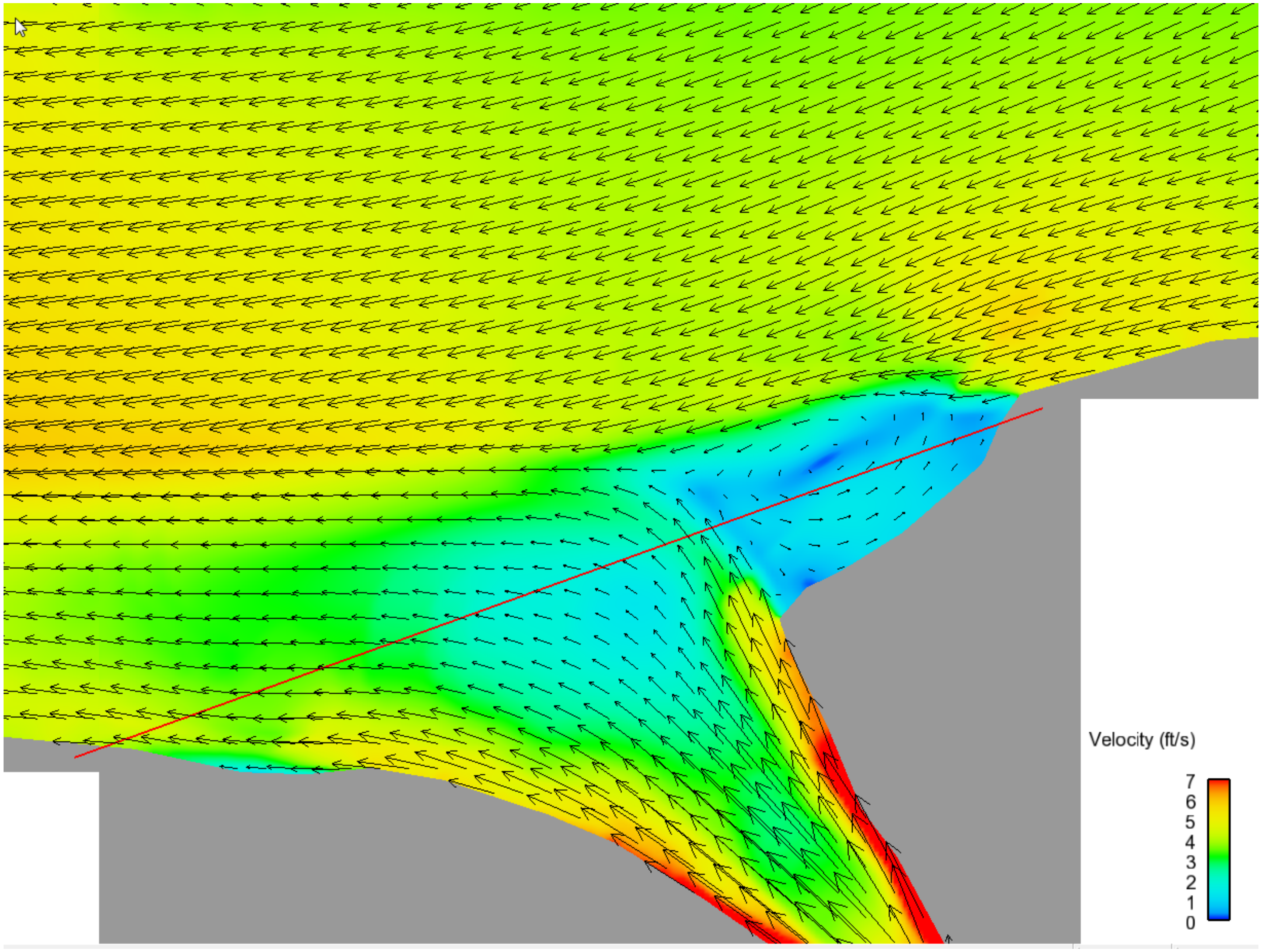


Figure A- 19: Depth-Averaged Velocity Distribution for Generation Operation with High River Flow

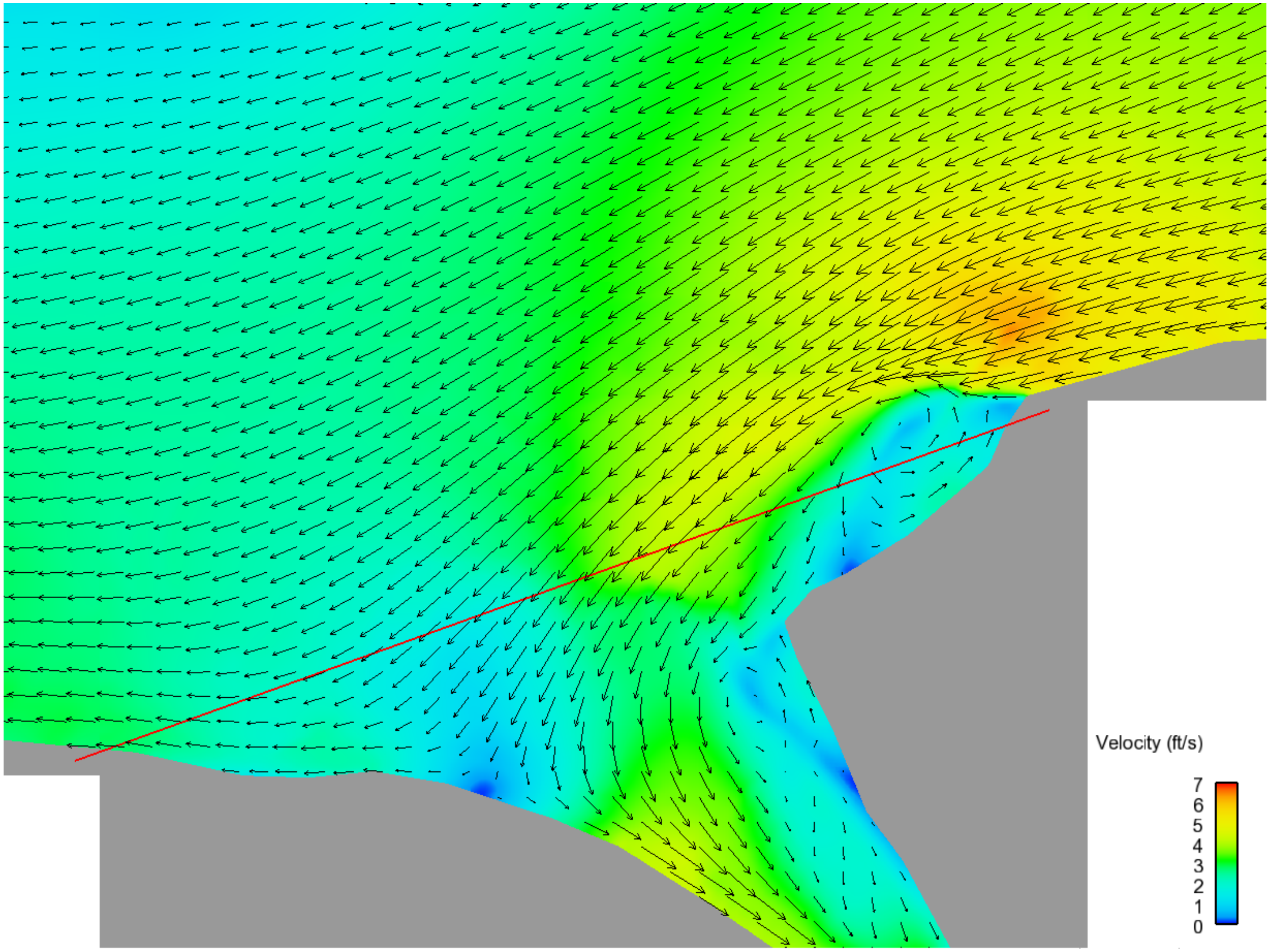


Figure A- 20: Depth-Averaged Velocity Distribution for Pumping Operation with High River Flow

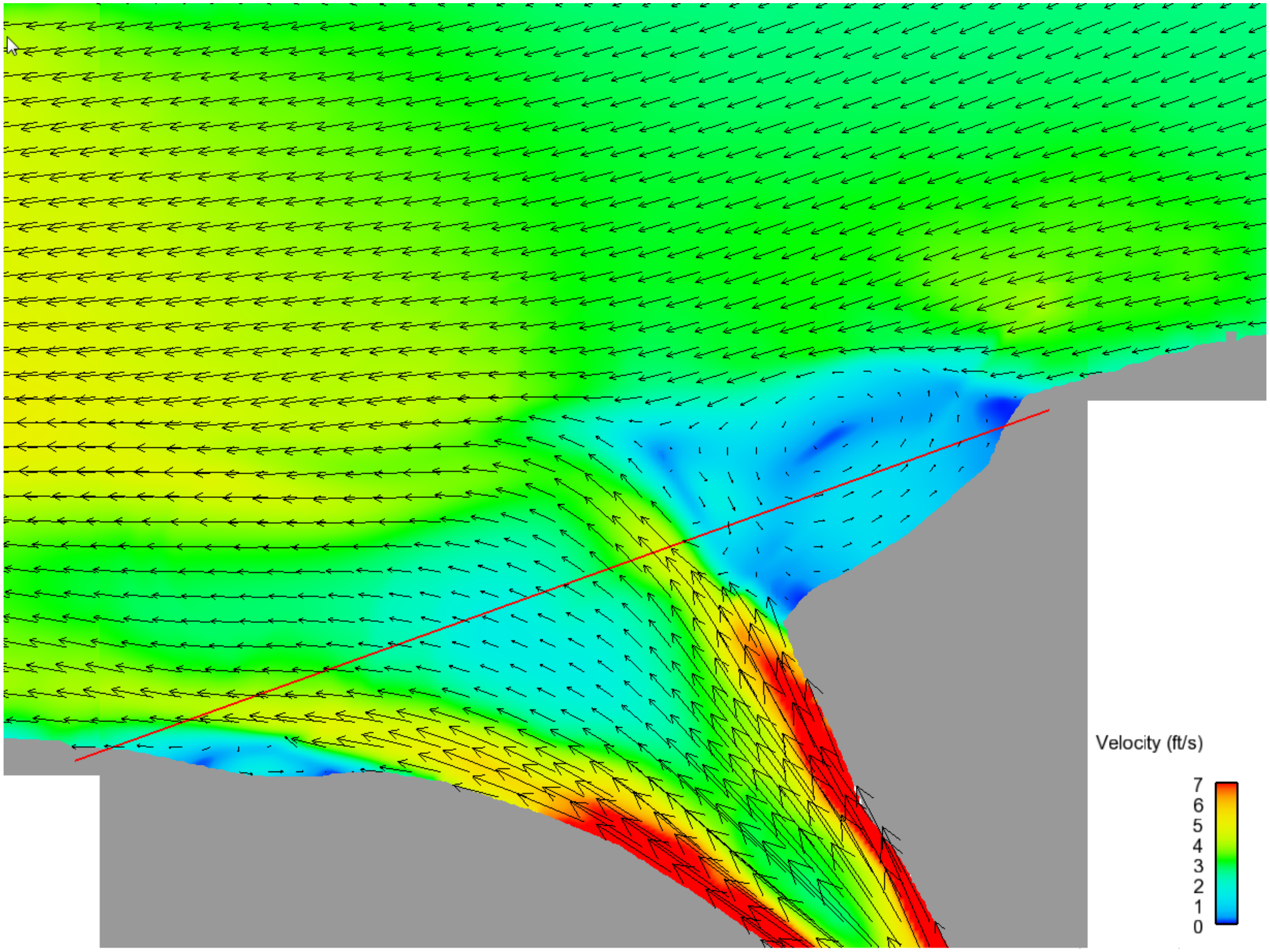


Figure A- 21: Depth-Averaged Velocity Distribution for Generation Operation with Medium River Flow

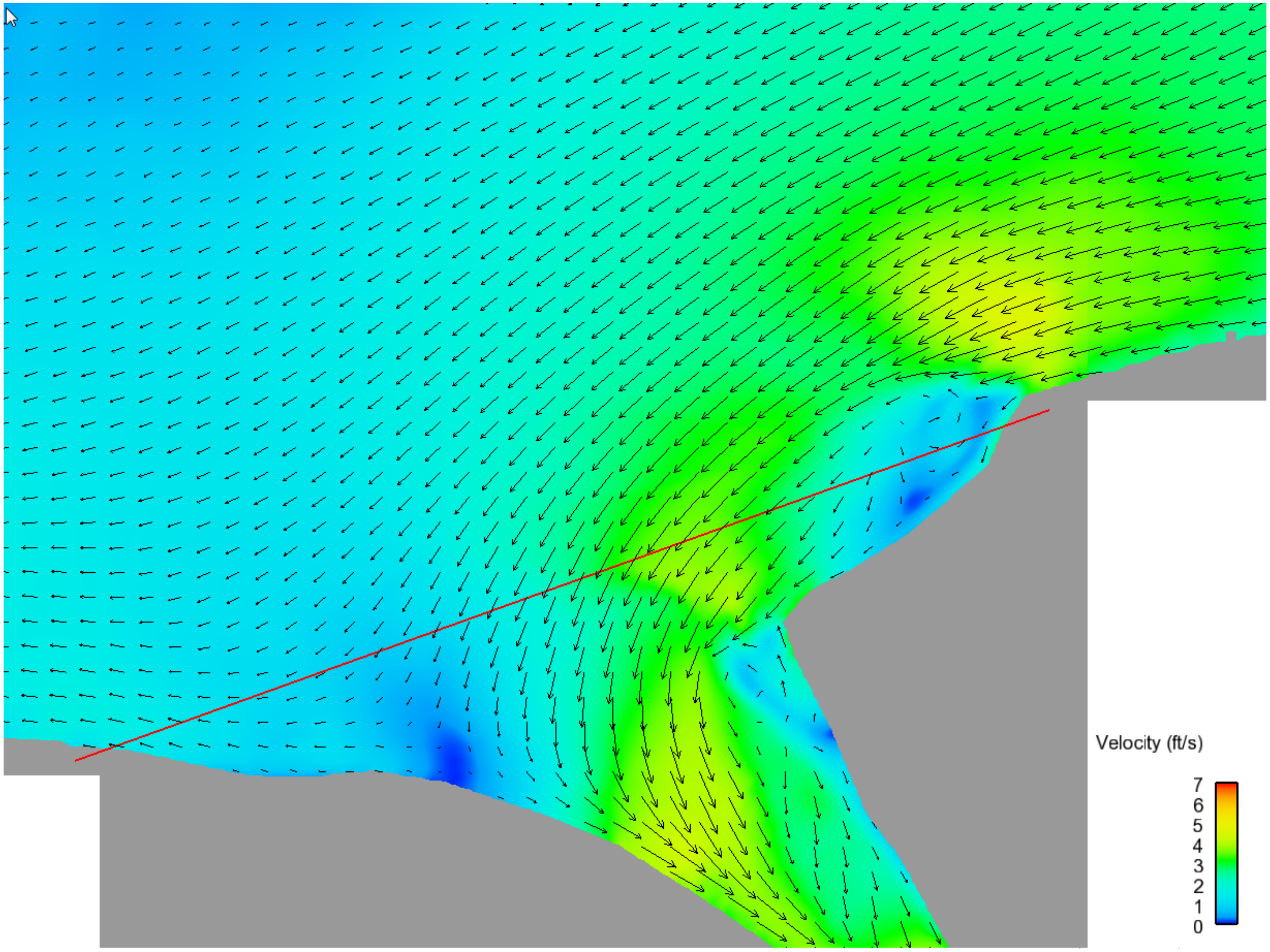


Figure A- 22: Depth-Averaged Velocity Distribution for Pumping Operation with Medium River Flow

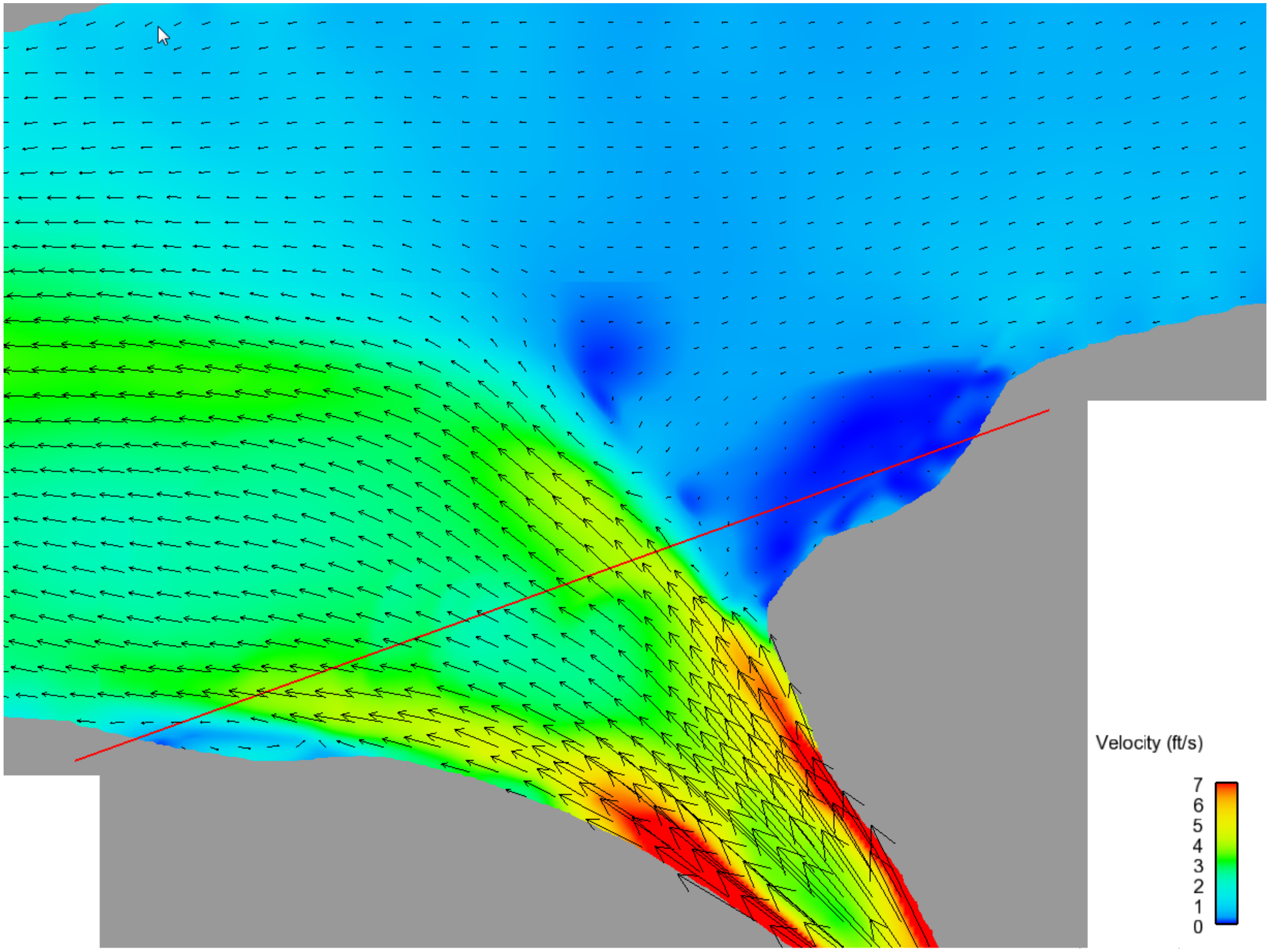


Figure A- 23: Depth-Averaged Velocity Distribution for Generation Operation with Low River Flow

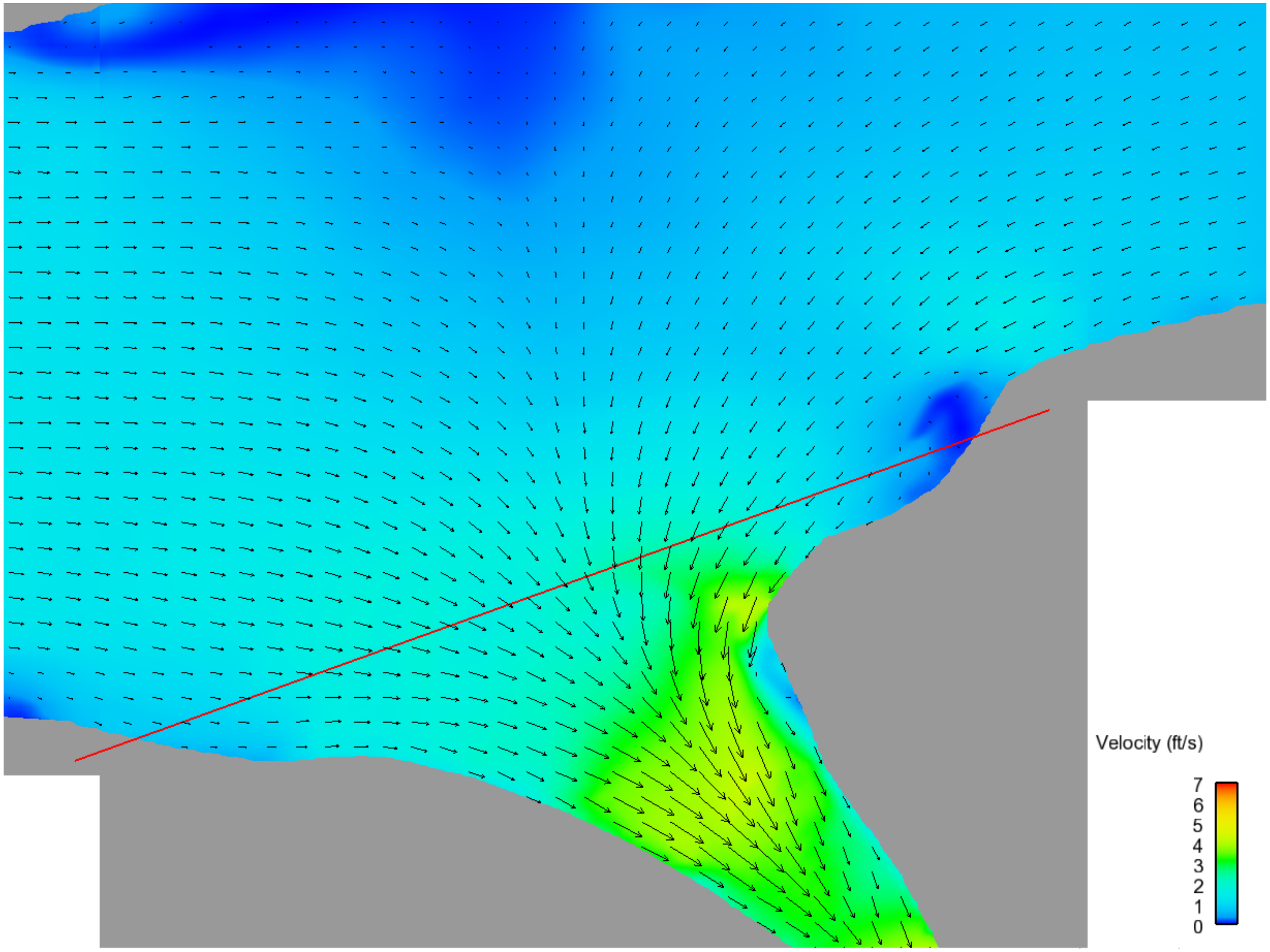


Figure A- 24: Depth-Averaged Velocity Distribution for Pumping Operation with Low River Flow

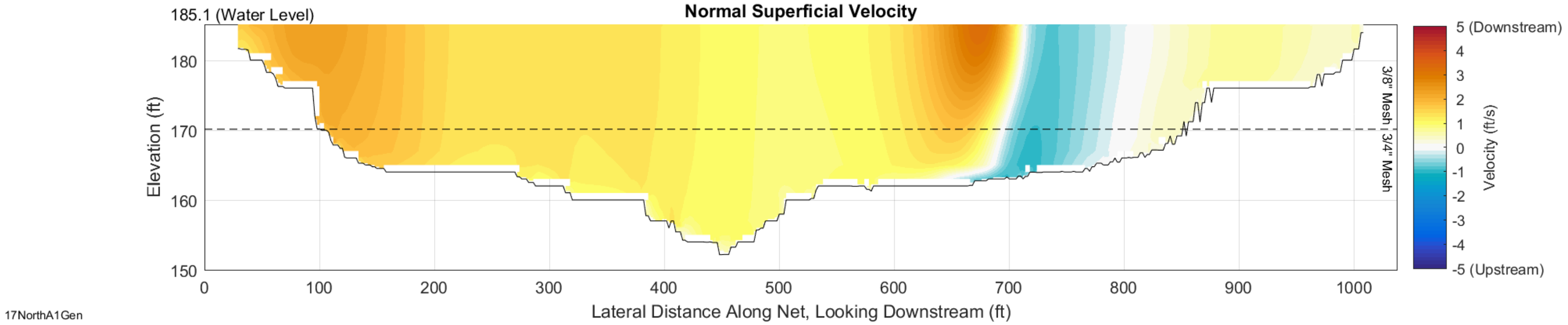


Figure A- 25: Flow Direction for Generation Operation with High River Flow

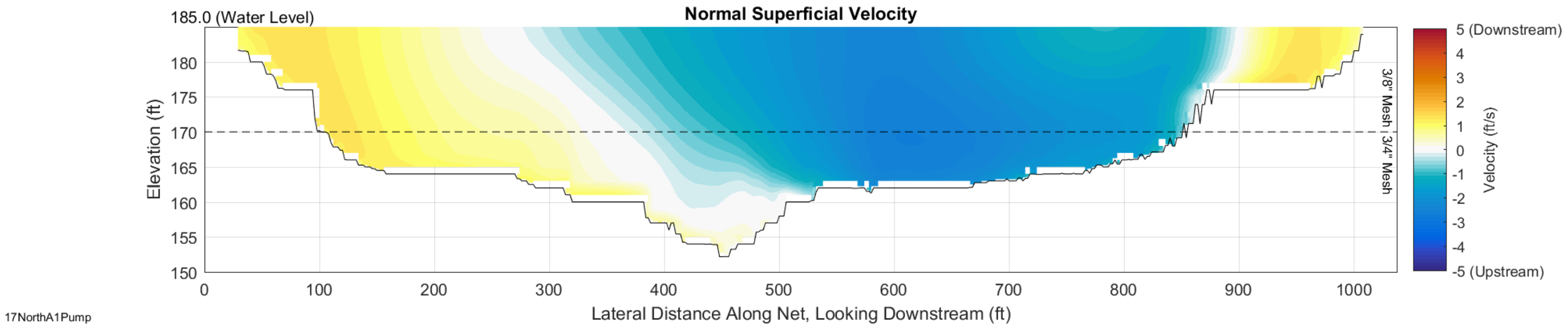


Figure A- 26: Flow Direction for Pumping Operation with High River Flow

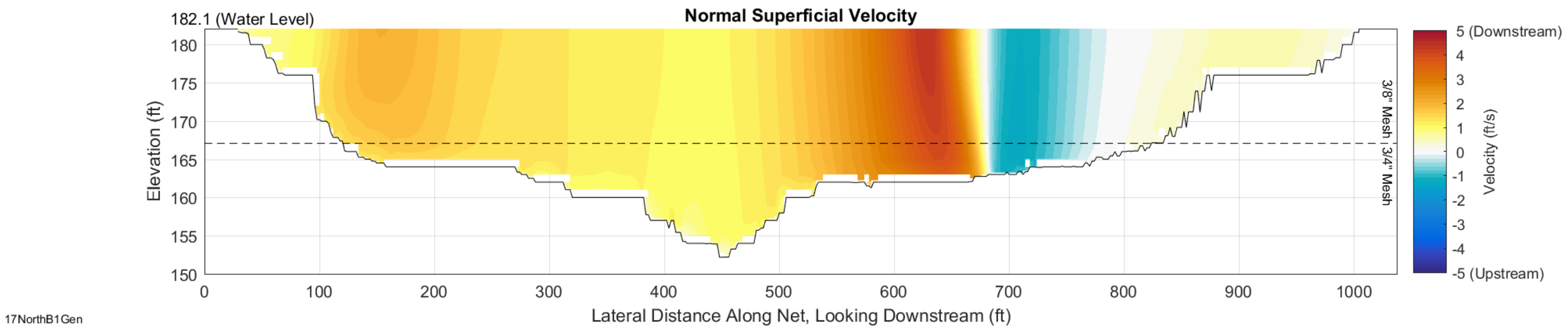


Figure A- 27: Flow Direction for Generation Operation with Medium River Flow

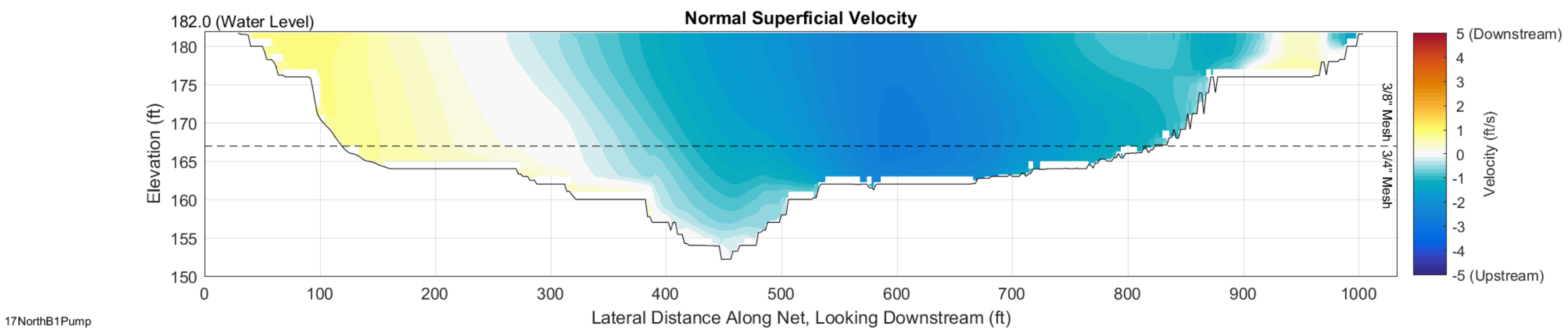


Figure A- 28: Flow Direction for Pumping Operation with Medium River Flow

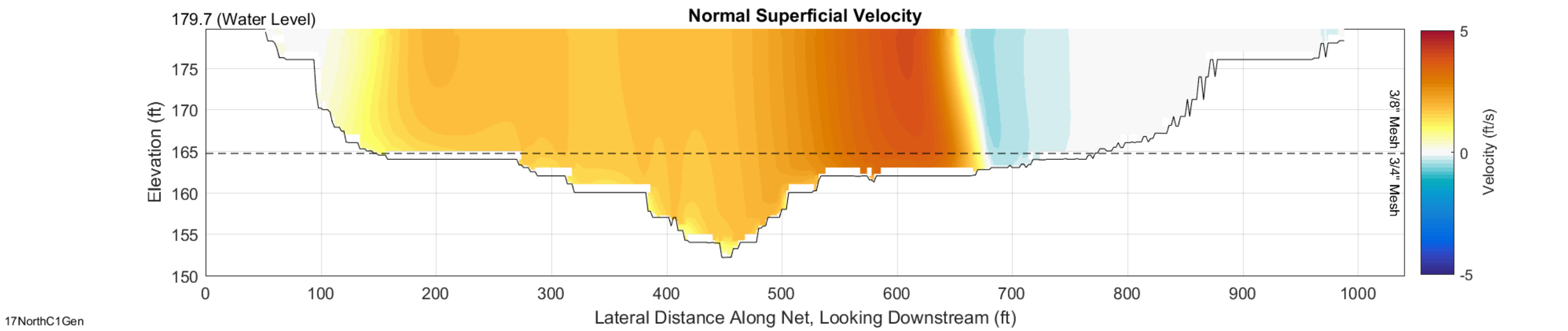


Figure A- 29: Flow Direction for Generation Operation with Low River Flow

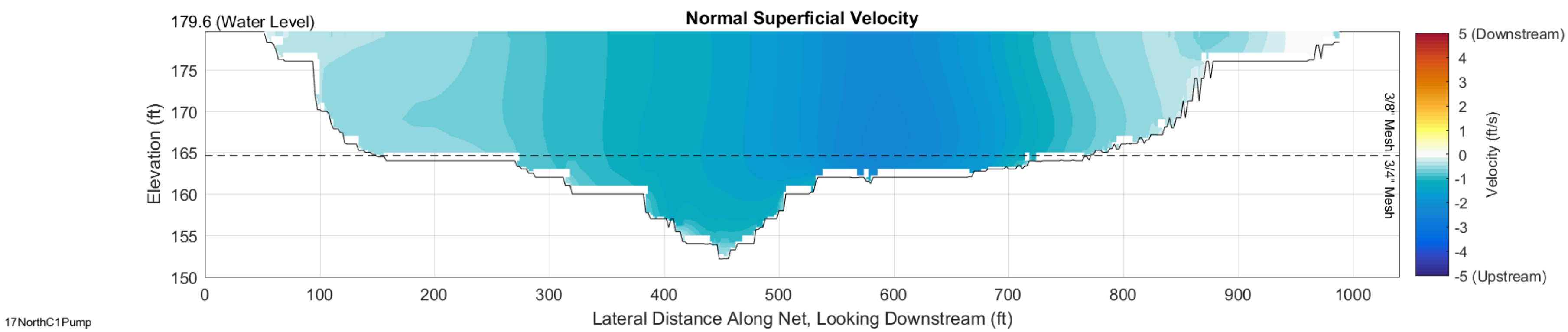


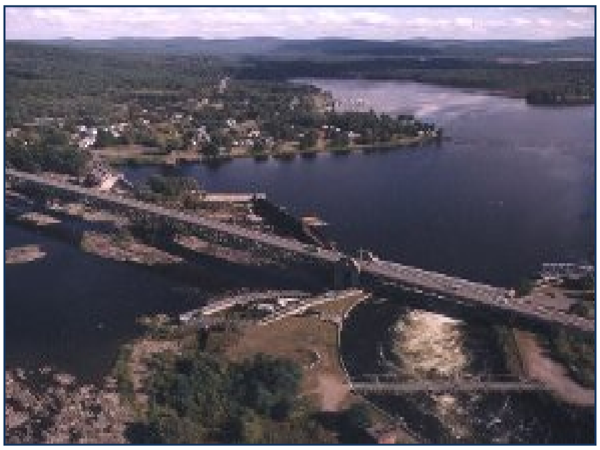
Figure A- 30: Flow Direction for Pumping Operation with Low River Flow

Attachment B: Barrier Net Study in the Northfield Tailrace

STUDY PLAN

FOR THE TURNERS FALLS HYDROELECTRIC PROJECT (NO. 1889) AND NORTHFIELD MOUNTAIN PUMPED STORAGE PROJECT (NO. 2485)

Barrier Net Study in the Northfield Mountain Tailrace



MARCH 2018

TABLE OF CONTENTS

LIST OF TABLES

1.0 INTRODUCTION AND OBJECTIVE

FirstLight is evaluating the feasibility of installing a barrier net in the Northfield Mountain tailrace to protect migratory fish (juvenile American shad and adult American eel) from becoming potentially entrained into the Northfield Mountain Upper Reservoir when the facility is operated in a pumping mode. In 2017, FirstLight conducted various steps to evaluate the feasibility of the net (as described below) and is also proposing to conduct further testing of the barrier net in 2018.

2017 Activities

- FirstLight consulted with a barrier net contractor; the same one that has a functional barrier net installed at the Luddington Pumped Storage Project. On September 19, 2017 Pacific Netting, the contractor, visited the Northfield Tailrace location to gain a better understanding of the issues and layout of the facility.
- FirstLight developed conceptual level drawings of a barrier net in front of the Northfield tailrace/intake (see Attachment A). As part of the layout, engineers evaluated the overall gross area of the net needed to maintain approach velocities less than 2 feet per second.
- FirstLight contracted with Alden Research Laboratory (Alden) to develop a computational fluid dynamics (CFD) model of the barrier net. The purpose for creating the model was to determine the forces on the barrier net when FirstLight was operating with four pumps at maximum capacity. In the end, Alden noted that it required additional information to determine the forces on the net when it is subject to debris loading and biofouling as the net would be installed over the approximate period August 1 to November 15.

2018 Activities

- To have a better understanding of the debris loading and biofouling of the net needed to determine if the net could still be operational and effective under 4 pump operations, Alden is proposing field testing of the barrier net in the Connecticut River near the Northfield Mountain Pumped Storage (NMPS) Project tailrace. The following study plan includes the methods for field testing the barrier net such that proper drag coefficients could be used in the CFD modeling to determine if the barrier net will remain functional and to determine the loads on the net under 4 pump operations.

The following is a scope of study to complete the field study.

The objective of the study is to develop information under various net biofouling and debris loading conditions. This information (drag force and head loss data) would then be used to update drag force calculations of the proposed barrier net in the NMPS tailrace under full pumping conditions.

2.0 FIELD DEPLOYMENT AND RETRIEVEL OF BARRIER NET PANELS

Alden will contact Pacific Netting to obtain barrier net panels. The panels would be deployed in the Connecticut River near the NMPS tailrace/intake. The net panels, approximately 2 ft by 2 ft in size, would be installed at various depths from August 1 through November 15 corresponding to the period of deployment of the prototype installation. Test panels would be removed at monthly intervals and tested in the laboratory to determine the extent of biofouling over time and to determine the associated drag coefficients and head loss. Alden anticipates the following study details (note drawings are shown in Attachment B):

- Net test panel size: 2 ft by 2 ft panels supported in a rigid frame
- Barrier net mesh size: 0.75 and 0.375-inch mesh
- Panel test depths: near surface, mid depth and near bottom.
- Sampling frequency: A total of 4 net panel retrieval events are included between August 1 and November 15. A group of 6 net panels will be retrieved at a time for laboratory testing. A group of 6 panels retrieved represent two net meshes (0.75 and 0.375 mesh) and three separate depths. A total of four groups of 6 net panels (total of 24 net panels) would be deployed by August 1.
- Installation: 4 groups of 6 net panels would be supported by floats, anchors and mooring lines. The 4 groups would be supported by a common topline float system and bottom ballasts. Each group of 6 would be installed for easy removal without interfering with the supports for the remaining groups and without the need for divers.
- An extra group of 6 net panels will be kept on hand as a contingency.
- Periodic inspections and debris collection trips are included

3.0 LABORATORY TESTING OF NET PANELS

Net panels once retrieved from the field will first be lab tested for biofouling and then woody and leafy debris will be introduced to the flume to determine debris drag coefficients. Net panel samples would be retrieved from the field and transported in the wet to Alden for testing. Each panel would be documented with photographs prior to transport and testing. Testing of samples in the laboratory would consist of the following:

Biofouling testing

- Install net panel in a small flume, approximately 2 ft wide by 1.5 ft deep
- Target velocity: 0.5, 1.0 and 2.0 ft/sec
- Barrier net configuration: perpendicular and 45 degrees to approach flow
- Drag force measurements: Load cells installed to measure force acting on barrier net panel
- Head loss measurements: Piezometer taps to measure water level upstream and downstream of the net panel
- Flow measurements: Venturi or orifice flow meter
- Video documentation

Debris testing

Debris will be collected from the Connecticut River for use in testing barrier net panels in the laboratory. Timing of debris collection will be closely coordinated with FirstLight staff and dependent on river conditions. Debris would be collected prior to retrieval of each group of 6 test panels. Locations for debris collections may include the NMPS tailrace area, Turners Falls or other locations identified between Turners Falls and NMPS.

At the conclusion of biofouling testing for a net panel, the net panel will be tested with corresponding river debris for a particular retrieval event. This program should encompass the various loading conditions expected for the prototype installation ranging from aquatic vegetation expected in August and September to woody and leafy debris expected in October and November. We anticipate debris testing to include the following;

- Net panel installed in small flume perpendicular to approach flow
- Target velocity: 1.5 ft/sec
- Debris loading: gradually introduce debris collected from the river until near net occlusion or to the extent possible. Debris would be quantified volumetrically as it is introduced to the flume. At the conclusion of the test, debris adhered to the net panel would be measured volumetrically.
- Drag force measurements via load cells
- Head loss measurements via piezometer taps
- Flow measurements: Venturi or orifice flow meter
- Video documentation

4.0 UPDATE CFD MODELING AND BARRIER NET CALCULATIONS

The hydraulic forces on a clean barrier net were previously estimated with Alden's CFD model as described earlier. The velocity cross section at the barrier net location was extracted from the CFD model. From the velocity cross section the hydraulic loadings were numerically integrated with MATLAB assuming a clean net drag coefficient C_D = 1.1. Once the fouled net drag coefficients are measured in the laboratory testing, the MATLAB calculations can be updated to estimate the hydraulic loading on a fouled net.

The barrier net was not modeled with the previous CFD model. Rather, the velocity cross section at the barrier net location was extracted from the CFD flow field and used for the hydraulic loading calculations. This approach does not consider how the barrier net alters the flow patterns. The clean net was assumed to minimally alter the flow patterns, but a fouled net will exert a greater influence on the flow patterns. The CFD model will be updated to include the barrier net to determine the effect on the flow field. The MATLAB calculations will be updated with the velocity from the barrier net CFD model to calculate the hydraulic forces on a clean barrier net.

The six scenarios that were simulated during the previous CFD modeling effort are listed in Table 4.0-1. The six simulations encompass three river flow scenarios: low, medium, and high river flow. A low Turners Falls Impoundment (TFI) level (as measured at the Turners Falls Dam) was used for each scenario because a low water level minimized the cross-sectional area through the barrier net and thereby results in higher velocities through the barrier net. Each river flow scenario was simulated with both pumping and generation operations. The fouled barrier net CFD simulations will be of the same six scenarios as the clean net simulations so results can be directly compared.

Table 4.0-1: River conditions and project operations for model runs

River Conditions	River Flow (cfs)	Water Level at Project Intake/Tailrace (ft)	Pumping Flow (cfs)	Generating Flow (cfs)
High River Flow, Low TFI Level	50,000	185		20,000
High River Flow, Low TFI Level	50,000	185	15,200	
Medium River Flow, Low TFI Level	30,000	182		20,000
Medium River Flow, Low TFI Level	30,000	182	15,200	
Low River Flow, Low TFI Level	5,000	179		20,000
Low River Flow, Low TFI Level	5,000	179	15,200	

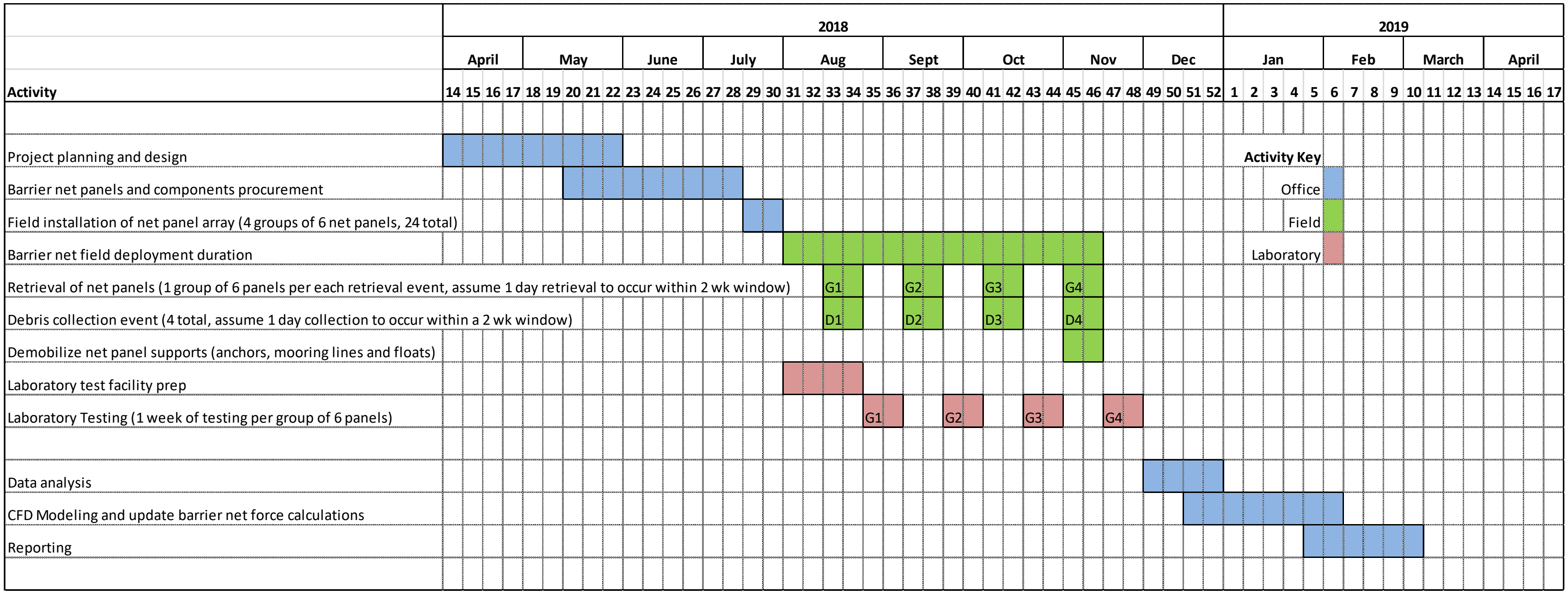
5.0 DELIVERABLES

Alden will prepare a report summarizing the results of the study. The report will include a description of the net panel field deployment, biofouling and debris conditions, laboratory testing, CFD modeling and updated barrier net calculations.

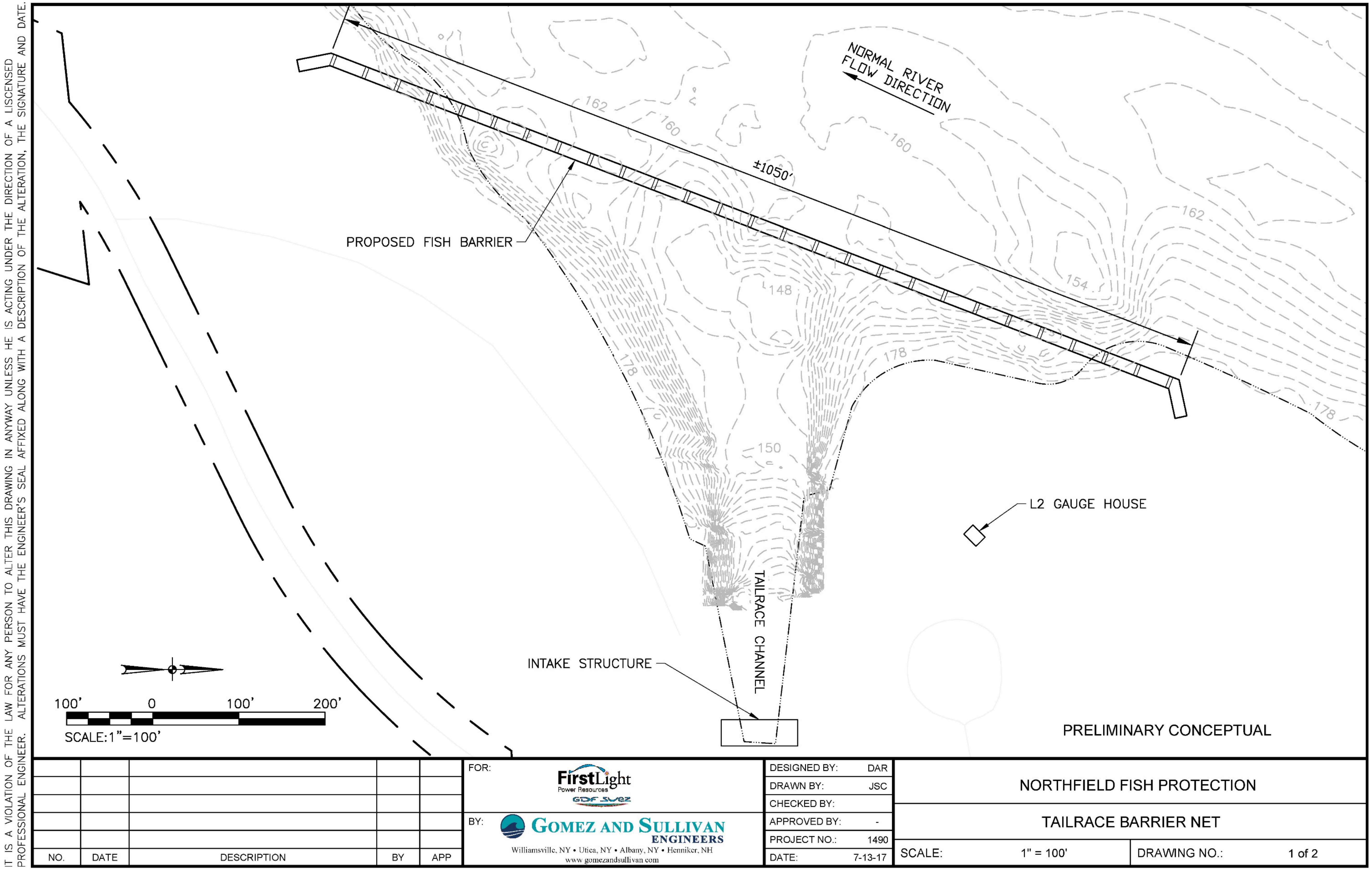
6.0 SCHEDULE

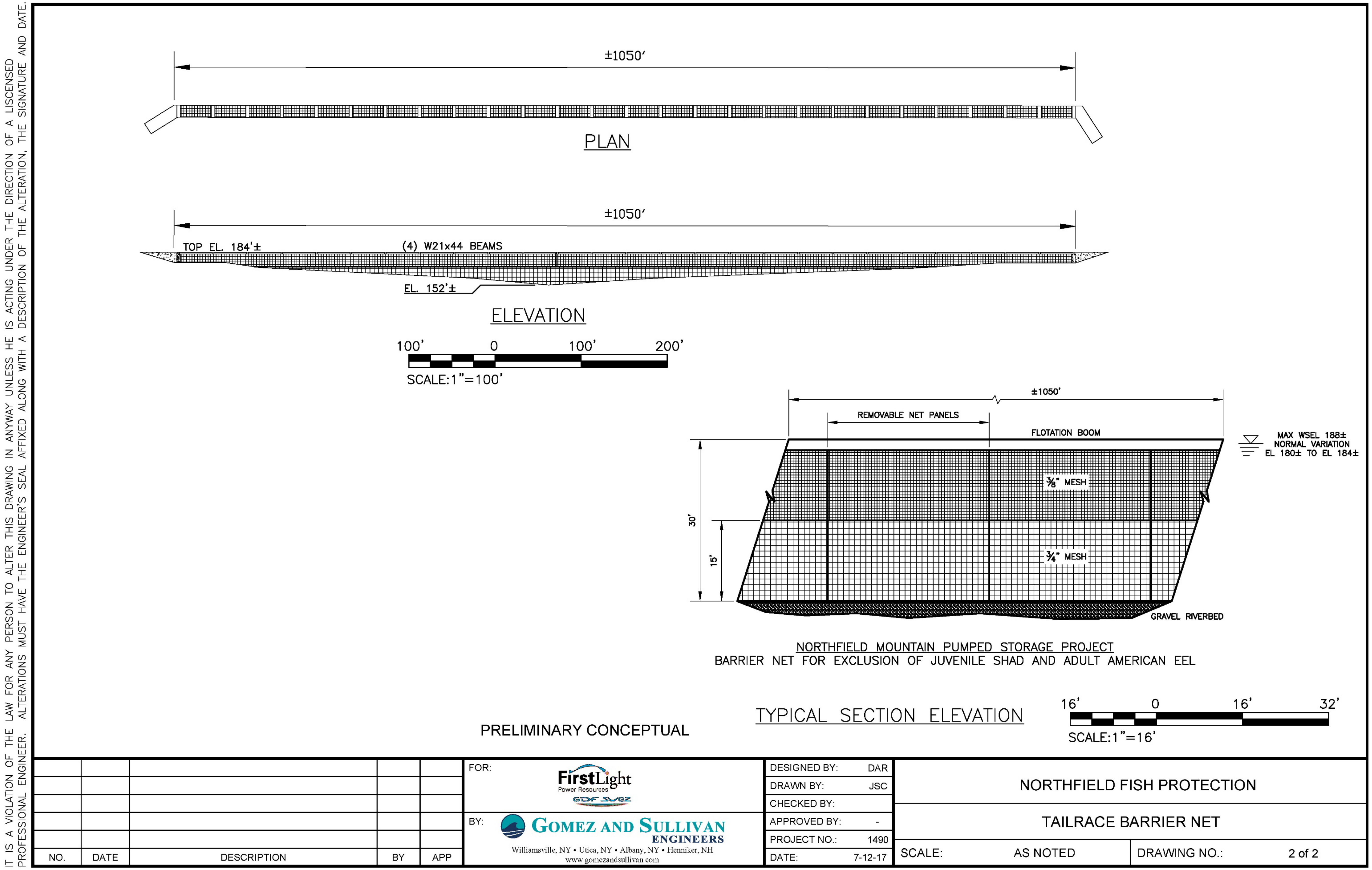
A schedule for study activities is provided below. The schedule assumes the project would be implemented in 2018 with a report complete by May 1, 2019.

Schedule


2018
2019
April May June July Aug Sept Oct Nov Dec Jan Feb March April
Activity
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Project planning and design
Barrier net panels and components procurement
Field installation of net panel array (4 groups of 6 net panels, 24 total)
Barrier net field deployment duration
Retrieval of net panels (1 group of 6 panels per each retrieval event, assume 1 day retrieval to occur within 2 wk window)
G1 G2 G3 G4
Debris collection event (4 total, assume 1 day collection to occur within a 2 wk window)
D1 D2 D3 D4
Demobilize net panel supports (anchors, mooring lines and floats)
Laboratory test facility prep
Laboratory Testing (1 week of testing per group of 6 panels)
G1 G2 G3 G4
Data analysis
CFD Modeling and update barrier net force calculations
Reporting
Activity Key
Office
Field
Laboratory

Attachment A

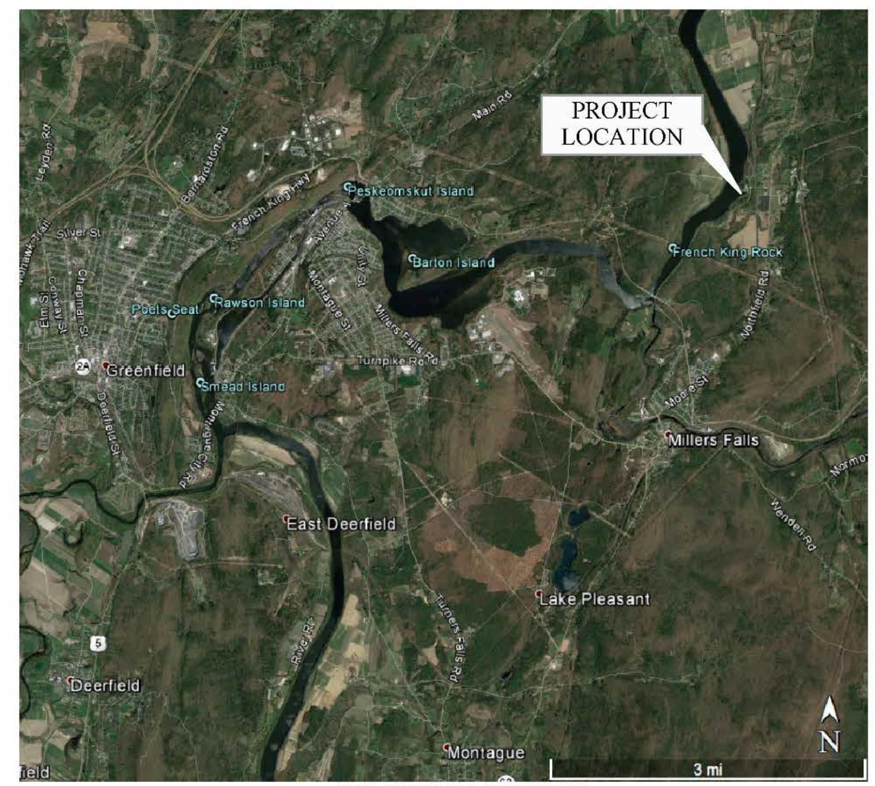



IT IS A VIOLATION OF THE LAW FOR ANY PERSON TO ALTER THIS DRAWING IN ANYWAY UNLESS HE IS ACTING UNDER THE DIRECTION OF A LISCENSED PROFESSIONAL ENGINEER. ALTERATIONS MUST HAVE THE ENGINEER'S SEAL AFFIXED ALONG WITH A DESCRIPTION OF THE ALTERATION, THE SIGNATURE AND DATE.
±1050'
PLAN
±1050'
TOP EL. 184'±
(4) W21x44 BEAMS
EL. 152'±
ELEVATION
100' 0 100' 200'
SCALE:1"=100'
±1050'
REMOVABLE NET PANELS
FLOTATION BOOM
MAX WSEL 188±
NORMAL VARIATION
EL 180± TO EL 184±
⅜" MESH
¾" MESH
30'
15'
GRAVEL RIVERBED
NORTHFIELD MOUNTAIN PUMPED STORAGE PROJECT
BARRIER NET FOR EXCLUSION OF JUVENILE SHAD AND ADULT AMERICAN EEL
TYPICAL SECTION ELEVATION
16' 0 16' 32'
SCALE:1"=16'
PRELIMINARY CONCEPTUAL
NO. DATE DESCRIPTION BY APP
FOR:
FirstLight Power Resources
GDF SUEZ
BY:
GOMEZ AND SULLIVAN ENGINEERS
Williamsville, NY • Utica, NY • Albany, NY • Henniker, NH
www.gomezandsullivan.com
DESIGNED BY: DAR
DRAWN BY: JSC
CHECKED BY:
APPROVED BY: -
PROJECT NO.: 1490
DATE: 7-12-17
NORTHFIELD FISH PROTECTION
TAILRACE BARRIER NET
SCALE: AS NOTED
DRAWING NO.: 2 of 2

Attachment B

NORTHFIELD MOUNTAIN PUMPED STORAGE PROJECT (NO. 2485)
BARRIER NET STUDY IN NORTHFIELD MOUNTAIN TAILRACE
FIRSTLIGHT POWER RESOURCES

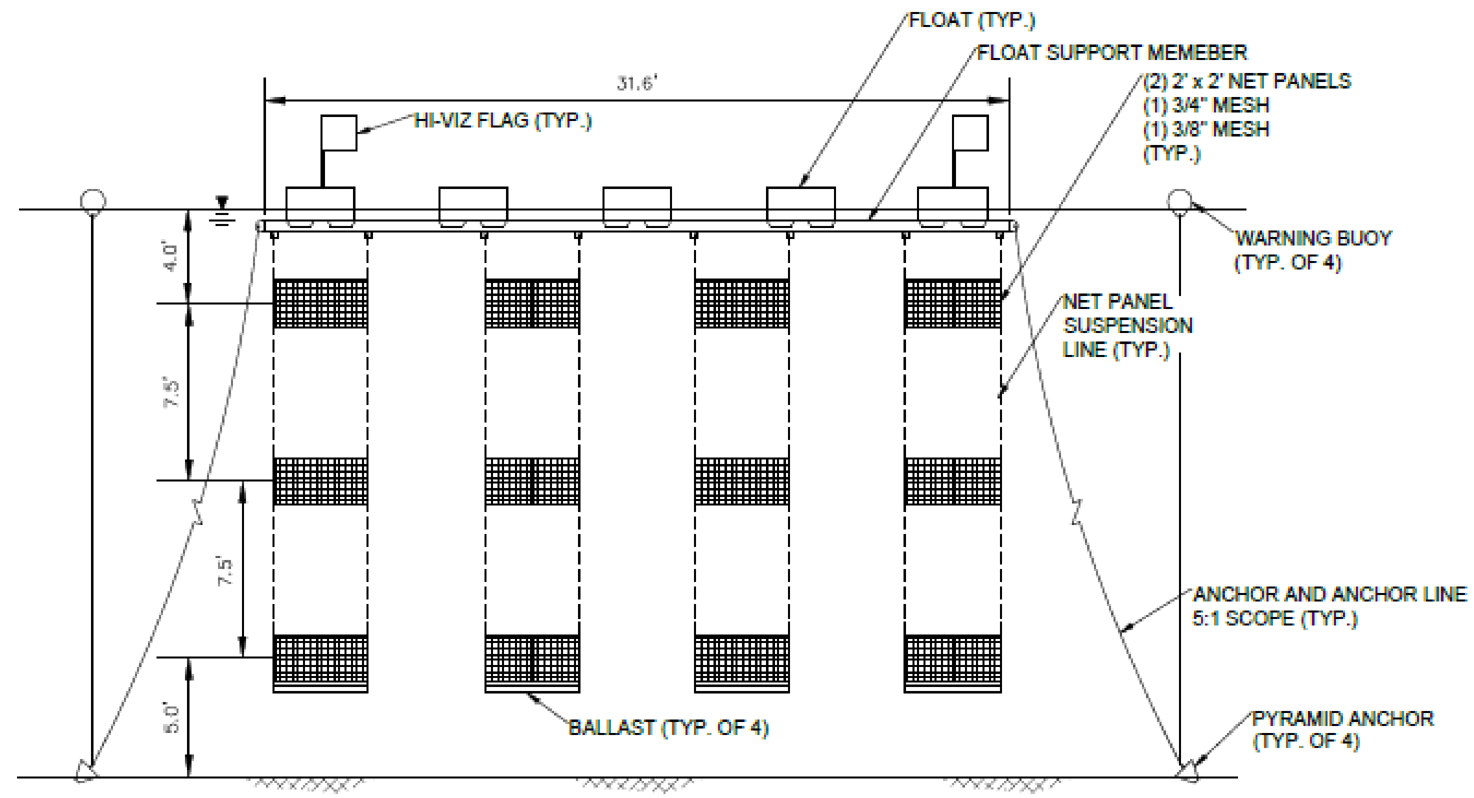
PROJECT VICINITY MAP



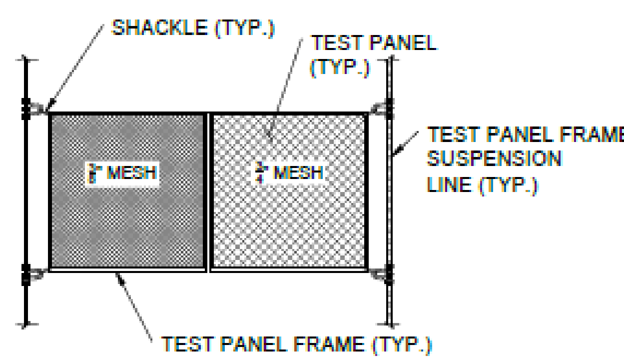
PROJECT LOCATION MAP

ALDEN RESEARCH LABORATORY 30 SHREWSBURY ST, HOLDEN, MA 01520 TEL: (508) 829-6000 www.aldenlab.com	REVISION: PERMITTING — REVISED BY: B. McMahon	VERIFY SCALE	NORTHFIELD MOUNTAIN PUMPED STORAGE PROJECT (NO. 2485) BARRIER NET STUDY FOR FIRSTLIGHT POWER RESOURCES	PROJECT VICINITY/ LOCATION	PROJECT: XXX DRAWN BY: BJM DESIGNED BY: BJM APPROVED BY: XXXXXX SHEET: 1 OF 2 DRAWING: G-1

1/C1 GENERAL ARRANGEMENT - PLAN

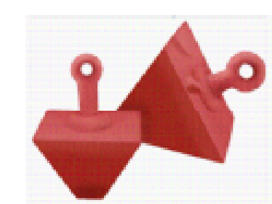


2/C1 GENERAL ARRANGEMENT - ELEVATION



3/C1 TEST PANEL - ELEVATION

Note:
1. (4) 75 lbs pyramid mooring anchors (approximately 12" x12" x 12") will be used for temporary mooring the test stand in place. (2) upstream and (2) downstream. Minimum anchor line scope of 5:1.



PYRAMID ANCHOR (TYP.)

ALDEN RESEARCH LABORATORY
30 SHREWSBURY ST, HOLDEN, MA 01520
TEL: (508) 829-6000 www.aldenlab.com

REVISION	DESCRIPTION OF ISSUE / REVISION	REVISED BY
⚠		
⚠		
⚠		
⚠		
⚠	PERMITTING	D. McMahon

VERIFY SCALE

NORTHFIELD MOUNTAIN PUMPED STORAGE PROJECT (NO. 2485) BARRIER NET STUDY FOR FIRSTLIGHT POWER RESOURCES

PROPOSED TEMPORARY TEST PANEL PLAN & ELEVATION

PROJECT: XXX
DRAWN BY: BJM
DESIGNED BY: BJM
APPROVED BY: XXXXXX
SHEET: 2 OF 2
DRAWING: G-1

Attachment C: Technical Memorandum, Response to Stakeholder Review Comments on Barrier Net Study Plan, including comment letters

Technical Memorandum

To: Stakeholders

From: Brian McMahon and Simon Schaad, Alden

Date: May 4, 2018

Re: **Responses to Stakeholder Comments on Barrier Net Study Plan for the Northfield Mountain Pumped Storage Project (FERC No. 2485)**

Alden Research Laboratory, Inc. (Alden) supported the development of a study plan (March 2018) for a barrier net study in the Northfield Mountain Pumped Storage Project tailrace (Northfield) for FirstLight Hydro Generating Company (FirstLight). FirstLight is proposing to conduct a feasibility study in 2018 to determine the loading on a potential future barrier net to exclude juvenile American shad, adult American eel and other fish from potential entrainment when Northfield operates in a pumping mode. On March 2, 2018, FirstLight emailed stakeholders a study plan and requested comments be provided by March 23, 2018. FirstLight received comments from the following stakeholders:

- United States Fish and Wildlife Service (USFWS), March 22, 2018
- Massachusetts Division of Fisheries and Wildlife (MDFW), March 22, 2018 (MDFW stated it agreed with USFWS comments)
- National Marine Fisheries Service (NMFS), March 23, 2018
- Connecticut River Conservancy March 23, 2018

The above comments, sent via email, are included in Attachment 1. This memorandum responds to the comments relative to the Field, Laboratory and CFD efforts to be conducted by Alden. Comments are shown below in bold, followed by Alden's responses.

United States Fish and Wildlife Service Comments:

Comment: Regarding 2017 Activities. The overall through net velocity was evaluated relative to achieving a velocity less than 2 feet per second. The Service's criteria for intake velocities for eels is 1.5 fps (a figure properly identified in section 3.0)

Response: While the model purpose was identified as evaluating the impacts on the net of 4 units pumping or generating, we will want to see the model outputs at pumping and generating cycles over a full range of unit operations under low, middle and high pond levels.

Comment: Regarding 2018 Activities. The debris loading assessment should not only assess the ability of the net to withstand the loading but also what the through-net velocities are relative to fish impingement risk.

Response: The lab testing of the mesh panels is intended to develop loads with biofouling and debris from the site for input in to the CFD model.

Comment: Regarding 2.0 Field Deployment and Retrieval. Inspections of the panels are to be done periodically. The number and frequency of these inspections should be more clearly specified.

Response: Inspection/ Retrieval of test panels will be conducted every 3 to 4 weeks. The exact day is subject to change due to weather conditions

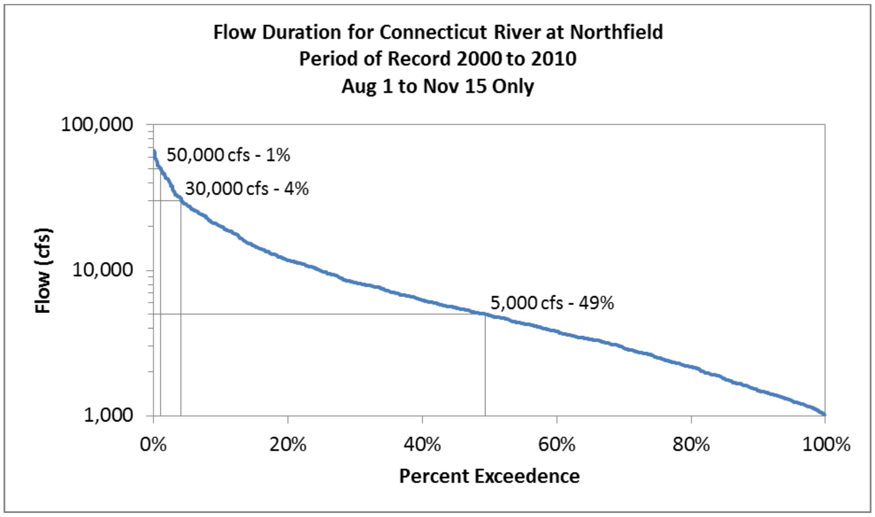
Deployment (week of): 7/23/2018
Inspection/ Retrieval No. 1 (week of): 8/13 or 8/20
Inspection/ Retrieval No. 2 (week of): 9/10 or 9/17
Inspection/ Retrieval No. 3 (week of): 10/8 or 10/15
Inspection/ Retrieval No. 4 (week of): 11/5 or 11/12

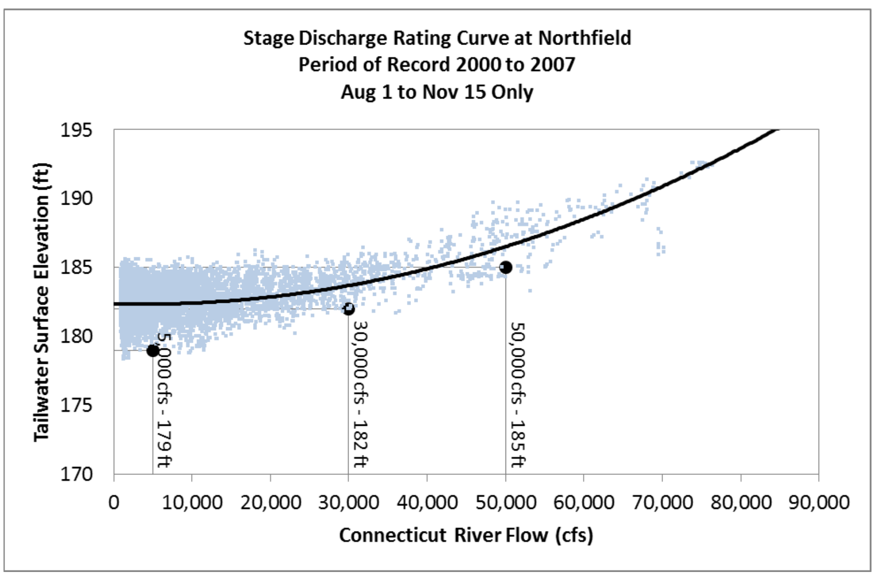
Comment: Regarding 3.0 Laboratory Testing and Debris Testing. While we agree with the concept of assessing debris loading, it is not clear that the assessment can provide a definitive estimate of actual net performance, since the small test panels do not function as a full net to evaluate debris loading. Therefore, the lab tests to introduce debris to the net panels can only provide information on the impacts of a range of potential debris loading scenarios.

Response: The fouled net panels retrieved from the field will be tested in the laboratory to estimate drag force coefficient and force/ loading data to the CFD model for the proposed mesh with expected loading conditions. The CFD model will be used to predict impacts to the full installation design.

Comment: Regarding 4.0 Update CFD Modeling. The proposed Net Study, describes the selected river test flows of low (5,000 CFS), medium (30,000 CFS), and high (50,000) CFS. We recommend natural flow conditions for the period from August 1 to November 15 be used to establish the low, medium and high river discharge values for use in the model to better represent the conditions during the eel migration period in question. This period includes the lowest flow months. The occurrence of river flow events as high as 30,000 or 50,000 CFS in the expected operational period of the net are both uncommon in frequency and brief in duration.

Response: Shown below is the flood frequency analysis and stage discharge rating curve for flows between Aug 1 and Nov 15. The low, medium, and high flows correspond with 51%, 96%, and 99% exceedance. The previous CFD analysis predicted that maximum drag forces occurred during the low flow. It would be informative to simulate a lower flow case (less than 5,000 cfs) to determine the velocities and drag forces. The previous CFD analysis predicted that maximum shear forces occurred during the 50,000 cfs flow. It may be valuable to simulate the same high flow case with updated drag coefficients to calculate the shear force on the barrier net. The CFD analysis can be simulated at additional flow conditions, as desired.





Comment: The evaluations should not be limited to only assessing pumping and generation using all 4 units. Through the period flows and pumping/generation will vary so the study examine barrier net performance should be conducted under a range of pumping and generation that would include, as in study 3.3.9, the use of only two units for pumping and for generation. In study 3.3.9, results for the scenario of two units pumping at low river discharges (1,760 and 4,900) suggested that surface velocities at the proposed net area were well aligned with both USFWS fish passage criteria and remained below the FLP preferred velocity at the higher impoundment level. As expected, an increase to 4 units

pumping demonstrated increases in modeled velocities that may be problematic for both fish passage and the company's proposed net velocity threshold limitations. We recommended that 2, 3, and 4 units pumping and generation and a range of pond levels be examined for effects on net performance , as it will provide important information relative to potential alternative mitigation measures should a 4-units pumping/generating prove to exceed Service's velocity criterion.

Response: We can model any combination of river flows and pump operations. The study plan includes six simulations (three river flows, each with pumping and generating operation). We can adjust the scope of CFD simulations to any combination of river flows and project operations.

Comment: The end of paragraph 2 should state "fouled barrier net" not "clean"

Response: Noted and will be changed.

Comment: Regarding 5.0 Deliverables. The report should include the data on forces on the net and through net velocities for both a clean net and various fouled net conditions at various pumping levels.

Response: Noted and will be included.

Connecticut River Conservancy Comments:

Comment: Regarding Section 3.0 Laboratory Testing of Net Panels. Biofouling testing lists target velocities of 0.5, 1.0, and 2.0 ft/sec. It seems that operational scenarios should be tested, along with velocities, rather than testing target velocities that may not be achievable or representative of typical conditions.

Response: Biofouling testing is intended to test a range of representative conditions to develop drag coefficients for biofouled mesh panels for input into the CFD model, which will run conditions reflecting operational scenarios.

Comment: Regarding Debris testing. The study plan says that debris will be collected from the Connecticut River for use in testing the barrier net panel. There is no information provided in the study plan how the debris would be collected, and whether the river conditions during collection will coincide with river conditions tested under the CFD scenarios.

Response: Debris will be collected from the Connecticut River for use in testing barrier net panels in the laboratory. Timing of debris collection will be closely coordinated with FirstLight's staff and dependent on river conditions. Debris would be collected prior to retrieval of each group of 6 test panels. Locations for debris collections may include the Northfield tailrace area, Turners Falls Dam or other locations identified between Turners Falls Dam and Northfield. Debris testing is intended to test a range of representative conditions to estimate drag force coefficients for input into the CFD model, which will run conditions reflecting operational scenarios.

Comment: Debris testing lists target velocity of 1.5 ft/sec. It seems that operational scenarios should be tested, along with velocities, rather than testing target velocities that may not be achievable or representative of typical conditions. We also wonder why the debris testing target velocity is different than the biofouling target velocities, so that the two factors will not be tested under similar situations.

Response: The laboratory debris and drag testing is intended to develop appropriate drag coefficients and loads for input into the CFD model to improve the CFD model accuracy, which will evaluate operating conditions.

Comment: Regarding Section 4.0 Update CFD Modeling and Barrier Net Calculations. The previous CFD model described earlier is not well described, and no information has been presented. MATLAB is a term not previously defined, and an explanation should be provided as to its use. There is mention of a clean net simulation, and we have not seen that. This section says that, "A low Turners Falls Impoundment (TFI) levels was used for each scenario." Please let us know what level this was.

Response: A FLOW-3D CFD model of the Connecticut River was previously developed by Alden to evaluate sediment exclusion strategies. Two reports were issued to FirstLight detailing the CFD model of the intake; "Sediment Studies of the Connecticut River Intake/Tailwater" (Jan 2015) and "Northfield Mountain Generation Station CFD Modeling for Fish Exclusion Net Forces" (Jan 2018). The previously developed CFD model will be used for the proposed analysis. The previously developed CFD model has the following features:

- The code used is FLOW-3D by FlowScience, which uses efficient methods to model the location of the free surface without requiring a multi-phase simulation.
- The CFD model domain extends approximately 2,000 feet upstream and 1,000 feet downstream of the intake. The model domain includes the bathymetry in the Connecticut River and the intake/tailwater structure.
- Total cell count is 3 million cells. Cell size is varied from 2 feet in the region of interest to 10 feet near the upstream/downstream boundaries.
- The previous CFD model did not include the exclusion net, meaning that the exclusion net did not impact the flow field near the net. For fouled net simulations, it is important that the exclusion net be included because the drag through the net is expected to alter the flow patterns. The proposed CFD model will include the exclusion net and it will be modeled as two-dimensional porous media plane.

MATLAB is a programming language developed by MathWorks that excels at matrix manipulation and plotting datasets. MATLAB was used in the previous CFD model study to process the raw output data from the CFD model to calculate the hydraulic forces on the exclusion net.

Following is the test matrix for the previous CFD model study that provides the TFI level used for each scenario:

Test matrix of previous CFD model study (Table 3-1 from January 2018 CFD Report)

River Conditions	River Flow (cfs)	Water Level at Project Intake/Tailrace (ft)	Pumping Flow (cfs)	Generating Flow (cfs)
High River Flow, Low TFI Level	50,000	185		20,000
High River Flow, Low TFI Level	50,000	185	15,200	
Medium River Flow, Low TFI Level	30,000	182		20,000
Medium River Flow, Low TFI Level	30,000	182	15,200	
Low River Flow, Low TFI Level	5,000	179		20,000
Low River Flow, Low TFI Level	5,000	179	15,200	

Comment: Table 4.0-1 provides 6 scenarios for three river flow levels – 5,000 cfs, 30,000 cfs, and 50,000 cfs. The 2013 Pre-Application Document (PAD) on page 3-26 indicates that when flows are between 30,000 cfs and 65,000 cfs, described as being in a "high range," then the U.S. Army Corps of Engineers requires that FirstLight draw the TF impoundment elevation down as far as possible, but not below elevation 176 ft. Given this requirement, it is not clear why the water level at the intake for high and "medium" (also a high flow) will be tested at 185 and 182 ft according to Table 4.0-1. The river elevation at high flows should be lower than those of lower flows, according to the information given in the PAD.

CRC recommends that the scenarios be revised using the following as references:

- **PAD Figures 4.3.1.3-15 through 18, which show flow duration curves for river elevation at the Northfield tailrace for the months of August through November**
- **PAD Figures 4.3.1.2-20 and 21, which shows flow duration curves for river flow at the Turners Falls Dam for the summer and fall months.**

Response: The tailwater for the previous CFD analysis was determined from the stage discharge rating curve at Northfield. The stage discharge rating curve was developed with gauge records between 2000 and 2007 for the annual period between Aug 1 and Nov 15 only. The tailwater will be updated from the information provided in PAD Figures 4.3.1.3-15 through 18 and PAD Figures 4.3.1.2-20 and 21.

Comment: An objective percentage of time exceeded should be picked (something like 20% and 80%, or 50%) and used to determine model scenarios. A river flow of 50,000 cfs is not even on the flow duration curves, and is too high and not representative of typical conditions. A flow of 30,000 cfs is not a medium flow. A flow of around 15,000 cfs should be incorporated into the mix. A flow of 5,000 cfs may be appropriate to model, but lower flows are also possible.

Response: Based on the above flow duration curve calculated by Alden, 20%, 50%, and 80% exceedance correspond with approximately 12,000 cfs, 5,000 cfs, and 2,200 cfs, respectively. A river flow of 15,000 cfs corresponds with an 15% exceedance. Any combination of river flow and tailwater can be modeled in the CFD model.

Comment: CFD model runs should look at use of 2, 3, and 4 pumps, not just 4 pumps.

If there is any chance the barrier will need to be in place year-round because of shortnose sturgeon, then additional flows and elevations should be modeled.

The clean net CFD runs should be re-done under new operational scenarios recommended here.

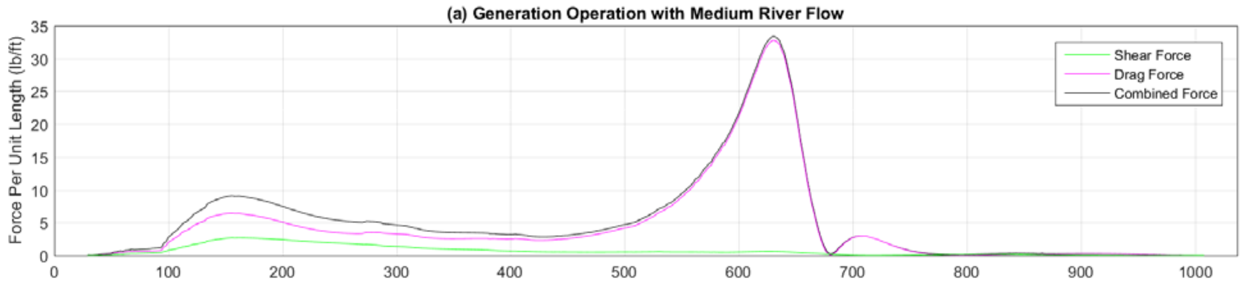
Section 5.0 Deliverables

A better description of deliverables is needed. How will the CFD model results be presented? How will the outputs of MATLAB be presented? See comments on Section 1.0. Stakeholders will need reassurance that we will get enough information to determine if the net is likely to work and not create other problems.

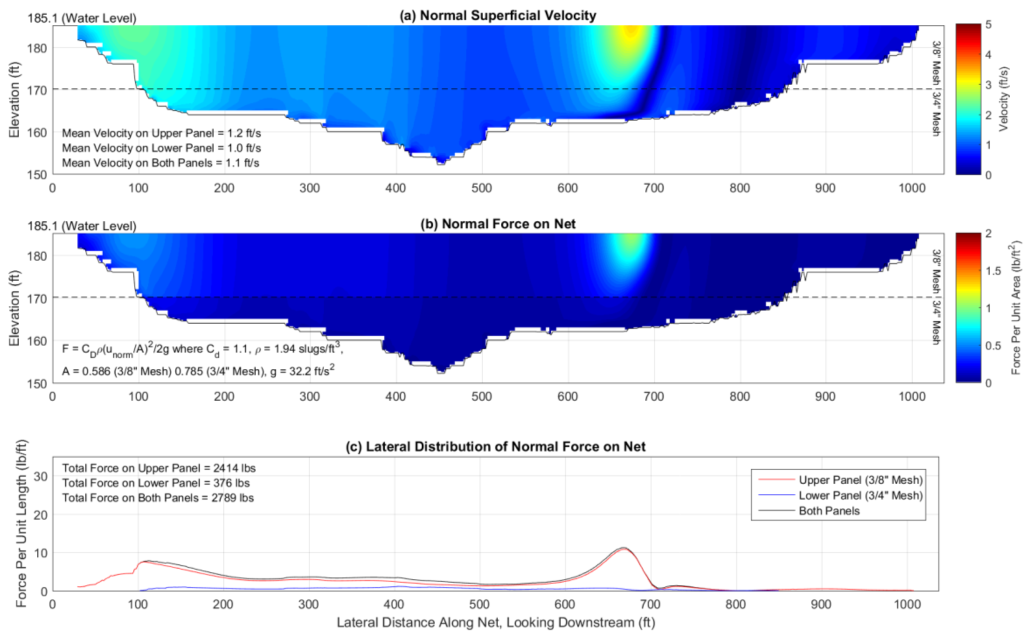
Response: Deliverables will include:

- Detailed report describing the CFD model methodology, results and analysis. This report will include a summary of the barrier net panel field deployments, laboratory testing and corresponding drag force data used as an input for the CFD model.

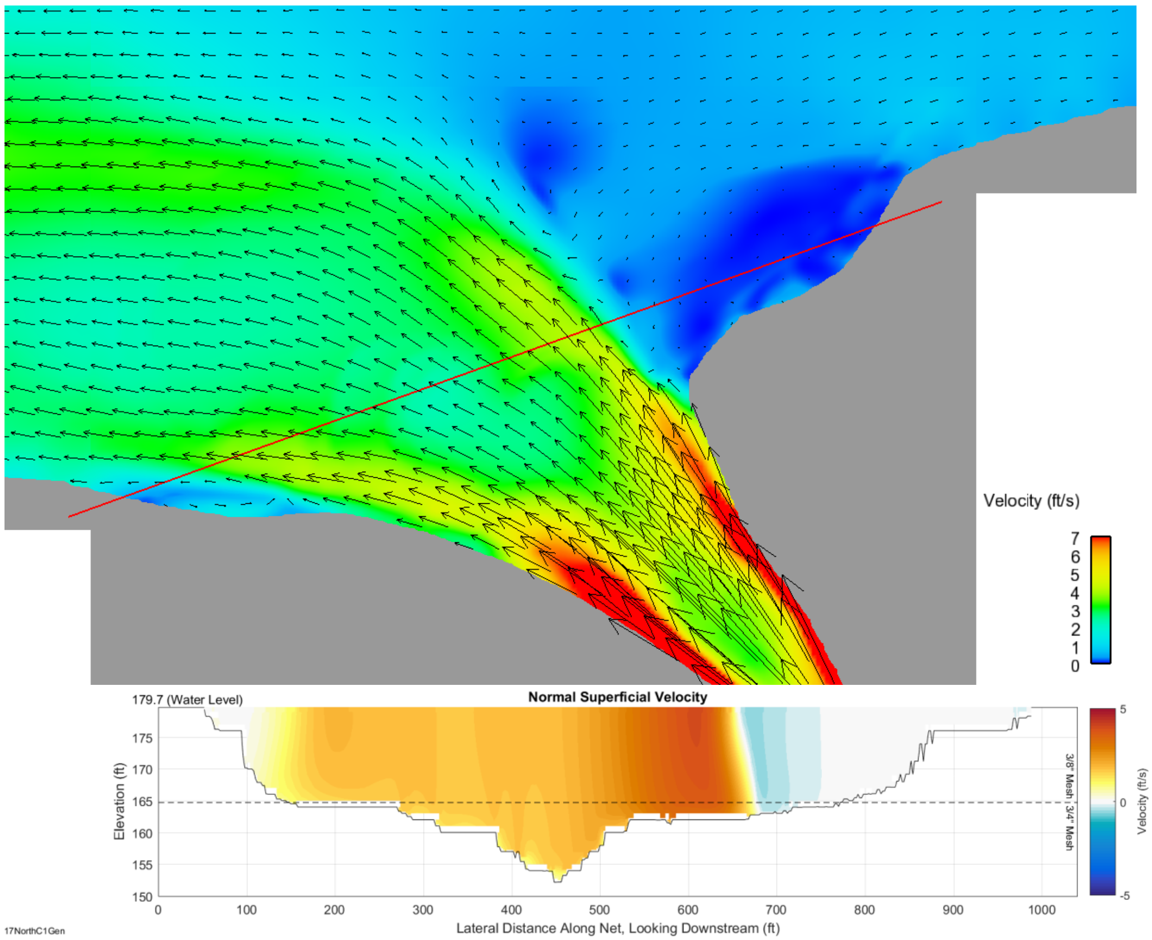
- Summary of forces acting on the net in tabular and graphical form. Example figure showing lateral distribution of forces is shown below:



- Figures showing the spatial distribution of normal and tangential velocity, drag and shear forces, and lateral distribution of drag and shear forces. Example figure for normal velocity and normal force is shown below:



- Figures showing flow patterns around the exclusion net. An example figure showing the plan view and cross-section through the exclusion net is shown below:



Comment: Information on how the CFD model was created needs to be included.

Response: See previous comment response giving detail on CFD model.

Comment: Regarding Section 6.0 Schedule. Stakeholders should not have to wait until May of 2019 to see the clean net simulation runs or any other information not dependent on the biofouling and debris testing that we'll need to assess whether the barrier net is a viable mitigation option.

Response: Per Gomez and Sullivan Engineers, at a meeting with stakeholders, it was agreed that the CFD modeling report can be provided. Gomez and Sullivan will provide this information in the near future.

Comment: Regarding Other comments. Study 3.3.9 showed surface velocities for 60 different river flow, impoundment elevation, and operational scenarios. The surface velocities in the area where the barrier net is proposed were often higher than 2 ft/sec.

The figures in Attachment A indicate that the fish barrier will lie outside the present location of the boat barrier. The figures indicate that the top elevation of the barrier will be at 184 ft elevation. Looking at the river elevations at the Northfield tailrace in PAD Figures 4.3.1.3-15 through 18, the fish barrier will be sticking up out of the water 70% of the time in August, October, and November; and 80% of the time in September. We conclude that 1) the fish barrier will present a navigational hazard that will have to

be addressed, and 2) the surface velocities shown in Study 3.3.9 are not irrelevant to impingement issues. Will other non-target fish become impinged against the barrier during pumping operations, and then flushed off the screen during generation operations??

We aren't sure why we are reviewing this study plan before seeing what we see as step 1 to the process – an initial evaluation about velocities at the net. Apparently, Alden created a CFD model using flow scenarios that we view as unrepresentative of typical conditions. We view 30,000 cfs and 50,000 cfs as likely showing velocities at the net that are lower than that of lower river flow levels (which are far more common), based on what we saw in study 3.3.9. The information we have seen thus far does not indicate promise for this mitigation alternative.

How will durability under all flow and operational scenarios be determined for the proposed time period that the net will be installed?

Response: The purpose of the CFD model study is to calculate the velocities and hydraulic loading on the exclusion net under various operational and river conditions. Assessing the durability of the exclusion net is not within the proposed scope of work.

Comment: Study 3.1.3, Sediment Management Plan, contained reports by Alden looking at a low level barrier to reduce sediment entrainment to the upper reservoir. The September 2016 Alden Report that was included as Appendix C in Study Report 3.1.3 concluded that a sediment exclusion structure could be expected to decrease sediment mobilization to the Upper Reservoir by 10-20%. CRC wonders if any of the extensive work completed by Alden for Study 3.1.3 and prior to relicensing could be incorporated into this work, and also if sediment exclusion could be built into the fish barrier at the same time, given the likely costs involved.

Response: Modeling the sediment exclusion structure, if needed, is included within the proposed scope of work.

Attachment 1

Stakeholder Review Comments

From: Slater, Caleb (FWE) [mailto:caleb.slater@state.ma.us]
Sent: Thursday, March 22, 2018 12:54 PM
To: Mark Wamser <mwamser@gomezandsullivan.com>
Subject: NMPS barrier net test

Mark,

The Division agrees with the USFWS comments (below).

Caleb

Caleb Slater, PhD
Anadromous Fish Project Leader
Massachusetts Division of Fisheries and Wildlife
1 Rabbit Hill Road, Westborough, MA 01581
p: (508) 389-6331 | e: Caleb.Slater@state.ma.us
mass.gov/masswildlife | facebook.com/masswildlife

USFWS Comments:

1.0 Introduction and Objective

2017 Activities

- The overall through net velocity was evaluated relative to achieving a velocity less than 2 feet per second. The Service's criteria for intake velocities for eels is 1.5 fps (a figure properly identified in section 3.0)

- While the model purpose was identified as evaluating the impacts on the net of 4 units pumping or generating, we will want to see the model outputs at pumping and generating cycles over a full range of unit operations under low, middle and high pond levels.

2018 Activities

- The debris loading assessment should not only assess the ability of the net to withstand the loading but also what the through-net velocities are relative to fish impingement risk

2.0 Field Deployment and Retrieval

- Inspections of the panels are to be done periodically. The number and frequency of these inspections should be more clearly specified.

3.0 Laboratory Testing

Debris Testing

- While we agree with the concept of assessing debris loading, it is not clear that the assessment can provide a definitive estimate of actual net performance, since the small test panels do not function as a full net to evaluate debris loading. Therefore, the lab tests to introduce debris to the net panels can only provide information on the impacts of a range of potential debris loading scenarios.

4.0 Update CFD Modeling

- The proposed Net Study, describes the selected river test flows of low (5,000 CFS), medium (30,000 CFS), and high (50,000) CFS. We recommend natural flow conditions for the period from August 1 to November 15 be used to establish the low, medium and high river discharge values for use in the model to better represent the conditions during the eel migration period in question. This period includes the lowest flow months. The occurrence of river flow events as high as 30,000 or 50,000 CFS in the expected operational period of the net are both uncommon in frequency and brief in duration.

- The evaluations should not be limited to only assessing umping and generation using all 4 units. Through the period flows and pumping/generation will vary so the study examine barrier net performance should be conducted under a range of pumping and generation that would include, as in study 3.3.9, the use of only two units for pumping and for generation. In study 3.3.9, results for the scenario of two units pumping at low river discharges (1,760 and 4,900) suggested that surface velocities at the proposed net area were well aligned with both USFWS fish passage criteria and remained below the FLP preferred velocity at the higher impoundment level. As expected, an increase to 4 units pumping demonstrated increases in modeled velocities that may be problematic for both fish passage and the company's proposed net velocity threshold limitations. We recommended that 2, 3, and 4 units pumping and generation and a range of pond levels be examined for effects on net performance , as it will provide important information relative to potential alternative mitigation measures should a 4-units pumping/generating prove to exceed Service's velocity criterion.

- The end of paragraph 2 should state "fouled barrier net" not "clean"

5.0 Deliverables

- The report should include the data on forces on the net and through net velocities for both a clean net and various fouled net conditions at various pumping levels.

Sean McDermott - NOAA Federal [mailto:sean.mcdermott@noaa.gov]

Mark,

We have reviewed the Northfield Mountain barrier net study plan, as well as the comments of the US Fish and Wildlife Service. We concur with USFWS' comments and support FL collecting data and evaluating preliminary options as part of the barrier net study for entrainment prevention at the Northfield Mountain Pumped Storage project. Additional data and analysis informing the design will improve the probability of success of the proposed protection measure. We note the state objective of this plan is to evaluate the feasibility of the net. We do not support the use of this study as an argument against installing entrainment prevention at the project. The data provided will support the design process.

-Sean

Connecticut River Conservancy

Clean water. Healthy habitat. Thriving communities
15 Bank Row, Greenfield, MA 01301
413.772.2020 · www.ctriver.org

March 23, 2018

(For FirstLight Power Resources)
Mark Wamser, PE
Senior Water Resource Engineer
Gomez and Sullivan Engineers, DPC
41 Liberty Hill Road
PO Box 2179
Henniker, NH 03242

Re: **Connecticut River Conservancy Comments on FirstLight's March 2018 Study Plan for the Barrier Net Study in the Northfield Mountain Tailrace**

Dear Mark,
We have reviewed the Study Plan dated March 2018 for the Barrier Net Study in the Northfield Mountain Tailrace. Below are our comments.

Section 1.0 Introduction and Objective

In order for us to agree that the barrier net is an appropriate mitigation measure to address entrainment of juvenile shad and eels, we need assurance of the following things:

☐ The velocities at the net will not impinge fish (target and non-target species)

☐ The net or barrier will hold up to the pumping and generating cycle, and river flow with debris

☐ The net or barrier will not be a safety hazard for motorized and non-motorized boats, or any other recreational use of the river

☐ Construction, inspection, and maintenance are all possible, affordable, and will be done at sufficient frequency

☐ The net or barrier does not pose any operational problems for FL

The study objectives should be expanded so we can address all these issues.

Section 3.0 Laboratory Testing of Net Panels

Biofouling testing lists target velocities of 0.5, 1.0, and 2.0 ft/sec. It seems that operational scenarios should be tested, along with velocities, rather than testing target velocities that may not be achievable or representative of typical conditions.

Debris testing. The study plan says that debris will be collected from the Connecticut River for use in testing the barrier net panel. There is no information provided in the study plan how the debris would be collected, and whether the river conditions during collection will coincide with river conditions tested under the CFD scenarios.

Debris testing lists target velocity of 1.5 ft/sec. It seems that operational scenarios should be tested, along with velocities, rather than testing target velocities that may not be achievable or representative of typical conditions. We also wonder why the debris testing target velocity is different than the biofouling target velocities, so that the two factors will not be tested under similar situations.

Section 4.0 Update CFD Modeling and Barrier Net Calculations

The previous CFD model described earlier is not well described, and no information has been presented. MATLAB is a term not previously defined, and an explanation should be provided as to its use. There is mention of a clean net simulation, and we have not seen that. This section says that, “A low Turners Falls Impoundment (TFI) levels was used for each scenario.” Please let us know what level this was.

Table 4.0-1 provides 6 scenarios for three river flow levels – 5,000 cfs, 30,000 cfs, and 50,000 cfs. The 2013 Pre-Application Document (PAD) on page 3-26 indicates that when flows are between 30,000 cfs and 65,000 cfs, described as being in a “high range,” then the U.S. Army Corps of Engineers requires that FirstLight draw the TF impoundment elevation down as far as possible, but not below elevation 176 ft. Given this requirement, it is not clear why the water level at the intake for high and “medium” (also a high flow) will be tested at 185 and 182 ft according to Table 4.0-1. The river elevation at high flows should be lower than those of lower flows, according to the information given in the PAD.

CRC recommends that the scenarios be revised using the following as references:

☐ PAD Figures 4.3.1.3-15 through 18, which show flow duration curves for river elevation at the Northfield tailrace for the months of August through November

☐ PAD Figures 4.3.1.2-20 and 21, which shows flow duration curves for river flow at the Turners Falls Dam for the summer and fall months.

An objective percentage of time exceeded should be picked (something like 20% and 80%, or 50%) and used to determine model scenarios. A river flow of 50,000 cfs is not even on the flow duration curves, and is too high and not representative of typical conditions. A flow of 30,000 cfs is not a medium flow. A flow of around 15,000 cfs should be incorporated into the mix. A flow of 5,000 cfs may be appropriate to model, but lower flows are also possible.

CFD model runs should look at use of 2, 3, and 4 pumps, not just 4 pumps.

If there is any chance the barrier will need to be in place year-round because of shortnose sturgeon, then additional flows and elevations should be modeled.
The clean net CFD runs should be re-done under new operational scenarios recommended here.

Section 5.0 Deliverables
A better description of deliverables is needed. How will the CFD model results be presented? How will the outputs of MATLAB be presented? See comments on Section 1.0. Stakeholders will need reassurance that we will get enough information to determine if the net is likely to work and not create other problems.

Information on how the CFD model was created needs to be included.

Section 6.0 Schedule
Stakeholders should not have to wait until May of 2019 to see the clean net simulation runs or any other information not dependent on the biofouling and debris testing that we'll need to assess whether the barrier net is a viable mitigation option.

Other comments
Study 3.3.9 showed surface velocities for 60 different river flow, impoundment elevation, and operational scenarios. The surface velocities in the area where the barrier net is proposed were often higher than 2 ft/sec.

The figures in Attachment A indicate that the fish barrier will lie outside the present location of the boat barrier. The figures indicate that the top elevation of the barrier will be at 184 ft elevation. Looking at the river elevations at the Northfield tailrace in PAD Figures 4.3.1.3-15 through 18, the fish barrier will be sticking up out of the water 70% of the time in August, October, and November; and 80% of the time in September. We conclude that 1) the fish barrier will present a navigational hazard that will have to be addressed, and 2) the surface velocities shown in Study 3.3.9 are not irrelevant to impingement issues. Will other non-target fish become impinged against the barrier during pumping operations, and then flushed off the screen during generation operations??

We aren't sure why we are reviewing this study plan before seeing what we see as step 1 to the process – an initial evaluation about velocities at the net. Apparently, Alden created a CFD model using flow scenarios that we view as unrepresentative of typical conditions. We view 30,000 cfs and 50,000 cfs as likely showing velocities at the net that are lower than that of lower river flow levels (which are far more common), based on what we saw in study 3.3.9. The information we have seen thus far does not indicate promise for this mitigation alternative.

How will durability under all flow and operational scenarios be determined for the proposed time period that the net will be installed?

Study 3.1.3, Sediment Management Plan, contained reports by Alden looking at a low level barrier to reduce sediment entrainment to the upper reservoir. The September 2016 Alden Report that was included as Appendix C in Study Report 3.1.3 concluded that a sediment exclusion structure could be expected to decrease sediment mobilization to the Upper Reservoir by 10-20%. CRC wonders if any of the extensive work completed by Alden for Study 3.1.3 and prior to relicensing could be incorporated into this work, and also if sediment exclusion could be built into the fish barrier at the same time, given the likely costs involved.

We appreciate the opportunity to provide comments on the barrier net study plan. I can be reached at adonlon@ctriver.org or (413) 772-2020 x.205.

Sincerely,
Andrea F. Donlon

River Steward