

Relicensing Study 3.3.9

**TWO-DIMENSIONAL
MODELING OF THE
NORTHFIELD MOUNTAIN
PUMPED STORAGE PROJECT
INTAKE/TAILRACE CHANNEL
AND CONNECTICUT RIVER
UPSTREAM AND
DOWNSTREAM OF THE
INTAKE/TAILRACE**

Updated Study Report Summary

**Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)**

Prepared for:



Prepared by:



SEPTEMBER 2015

1.1 Study Summary

The goal of this study is to model flow characteristics upstream and downstream of the Northfield Mountain Project tailrace under a variety of operating conditions to assess the potential for velocities and flow fields to interfere with migratory fish due to Northfield Mountain Project operations. The flow field conditions in the immediate vicinity of the Northfield Mountain Project intake/discharge structure (i.e. within the Northfield Mountain Project tailrace) were assessed using field data collected under both pumping and generating conditions. Field data were collected at three transect locations. Flow field conditions in the vicinity of the tailrace were assessed with a two-dimensional model. The model extents included a 10 kilometer portion of the Turners Falls Impoundment (TFI) surrounding the Northfield Mountain Project tailrace (5 km upstream, 5 km downstream). A series of “production runs” with the two-dimensional model was performed to evaluate velocity and water level fluctuations in the vicinity of the Northfield Mountain Project tailrace. The production runs included three model variables:

- TFI elevation was evaluated under 176 ft msl and 185 ft msl, the minimum and maximum FERC licensed operating band as measured at the Turners Falls Dam;
- Northfield Mountain Project flow varied from 2 pumps (7,600 cfs), 4 pumps (15,200 cfs), 2 generators (10,000 cfs), and 4 generators (20,000 cfs);
- Flow in the mainstem Connecticut River flow (base flow) varied from the 5% (40,100 cfs), 25% (15,700 cfs), 50% (8,440 cfs), 75% (4,900 cfs) and 95% (1,760 cfs) exceedance flows of the Connecticut River at Turners Falls Dam.

Consultation: FirstLight’s Initial Study Report (ISR) noted a variance from the Revised Study Plan. Specifically, one of the transects (Transect 4 of 4) recommended by the Federal Energy Regulatory Commission’s (FERC) Study Plan Determination Letter (SPDL) dated September 13, 2013 was located atop the Northfield tailrace intake, thus it was not possible to collect velocity data when in a pumping and generating mode. FERC’s January 22, 2015 Determination on Requests for Study Modifications and New Studies, stated “*Based on this new information, we conclude that the fourth transect is not necessary and recommend that FirstLight only be required to sample transects 1-3*”.

1.2 Study Progress Summary

Task 1: Review Existing Data and Identify Data Gaps

Review of the existing data is complete. Updated bathymetric data of the TFI was collected 5 km upstream and 5 km downstream of the Northfield Mountain Project tailrace. During this task it was also determined that two new water level loggers, in addition to those approved in the RSP, should be installed as part of Task 2. The first new logger was located in the TFI along the bank across from the Northfield Mountain Project tailrace. This logger was beneficial during model calibration for representation of the water level drawdown due to pumping and generating operations. The second new logger was installed on the concrete intake structure above the water level to correct all of the other loggers for atmospheric pressure. The location of the loggers is shown in [Figure 1](#).

Task 2: Bathymetric Survey Update & Post Processing

The bathymetric survey and post processing is complete. Bathymetric survey of the 10 km reach of the TFI was completed over four days (May 27, 2014, June 2-4, 2014). The bathymetric survey was collected using an Acoustic Doppler Channel Profiler (ADCP) linked to a GPS unit, and included the collection of both bathymetry and velocity data under the conditions at the time of survey. All information was collected in

the North American Vertical Datum of 1988 (NAVD88). A thorough review of the data was performed during post-processing to remove outliers from the dataset due to loss of satellite communication (this is often caused by overhead obstructions such as the French King Gorge Bridge and trees along the bank). Post-processing is complete, and the bathymetric data is available in both NAVD88 and the Northfield Mountain Project vertical datum (National Geodetic Vertical Datum of 1929, NGVD29). [Figure 2](#) is an overview of the bathymetric terrain developed from this dataset. Per the RSP, seven (7) water level loggers were installed, and data is periodically offloaded for analysis.

Task 3: Develop and Graph Water Column Velocity Profiles

Bathymetric and water column velocity data were collected at three transects within the Northfield Mountain Project tailrace under four different operating scenarios. Data for two units generating and pumping were collected on April 6, 2014 and April 7, 2014 respectively, while data for four units (pumping and generating) were collected on July 12, 2014. An Acoustic Doppler Channel Profiler (ADCP) linked to a GPS unit was utilized for the collection of this data. Similar to the bathymetric survey, these data were collected in NAVD88, and converted to NGVD29 during post-processing. The following figures reflect the empirical average column velocity and velocity direction:

- [Figure 3](#)- Observed Depth-Averaged Channel Velocities at Transects below Northfield tailrace (4 units at full hydraulic generating capacity of 20,000 cfs)
- [Figure 4](#)- Observed Depth-Averaged Channel Velocities at Transects below Northfield tailrace (2 units at full hydraulic generating capacity of 10,000 cfs)
- [Figure 5](#)- Observed Depth-Averaged Channel Velocities at Transects below Northfield tailrace (4 units at full hydraulic pumping capacity of 15,200 cfs)
- [Figure 6](#)- Observed Depth-Averaged Channel Velocities at Transects below Northfield tailrace (2 units at full hydraulic pumping capacity of 7,600 cfs)

Task 4: Build and Calibrate 2D Model

This task is complete. For calibration purposes, the water level logger and flow through the TFI study reach were reviewed to identify a period of time of low flow, no Northfield operations, and a low TFI elevation. The time period best meeting these criteria (i.e. 9/7/2014 10:00) only indicated a 0.07 foot difference (i.e. less than one (1) inch) in the WSEL from the downstream to upstream end of the study area under a total inflow of approximately 2,500 cfs. This was not ideal for trying to calibrate roughness values under low flow conditions, as a wide range of roughnesses could lead to acceptable results. Therefore, the high flow event (discussed below) was primarily used to determine appropriate roughness values, although the low flow scenario was still used as a check to ensure that the final roughness values are appropriate. The modeled WSELs were within 0.02 feet of the observed WSEL throughout the model for the low flow calibration run.

Calibration results for steady flow runs are more reliable when the observed inflows and WSELs were steady for a longer period of time rather than during an unsteady event (e.g. rising or falling limb of a storm event). The water level logger and flow data were reviewed to identify a period of time with high inflows, no Northfield operations, and a fairly steady TFI elevation. The time period best meeting these criteria (i.e. 5/24/2014 21:30) indicated approximately 3.0 feet of difference in the WSEL from the downstream to upstream end of the study area under a total inflow of approximately 31,360 cfs. The water level loggers indicated that most of this change in WSEL (i.e. approximately 2.2 feet) occurs in the downstream 4 km of the study area. The model confirmed that a majority of the change in WSEL occurs within the French King Gorge. The calibrated roughness values were thus significantly higher in the downstream portion of the

model. The modeled WSEL were generally within 0.1 feet of the observed WSELs throughout the model for the high flow calibration run.

Task 5: Conduct and Analyze Production Runs (or Scenarios)

This task is complete. A total of 40 scenarios have been simulated in the River 2D hydraulic model as shown in [Table 1](#).

Table 1: List of River2D Hydraulic Modeling Scenarios

Scenario No.	Northfield Mountain Generation Flow (cfs)	Northfield Mountain Pumping Flow (cfs)	Turners Falls Impoundment Elevation at Turners Falls Dam (ft)	Turners Falls Dam Flow (cfs)
1	10,000	0	176.0	1,760 (95% exceedance flow)
2	10,000	0	185.0	1,760
3	20,000	0	176.0	1,760
4	20,000	0	185.0	1,760
5	0	7,600	176.0	1,760
6	0	7,600	185.0	1,760
7	0	15,200	176.0	1,760
8	0	15,200	185.0	1,760
9	10,000	0	176.0	4,900 (75% exceedance flow)
10	10,000	0	185.0	4,900
11	20,000	0	176.0	4,900
12	20,000	0	185.0	4,900
13	0	7,600	176.0	4,900
14	0	7,600	185.0	4,900
15	0	15,200	176.0	4,900
16	0	15,200	185.0	4,900
17	10,000	0	176.0	8,440 (50% exceedance flow)
18	10,000	0	185.0	8,440
19	20,000	0	176.0	8,440
20	20,000	0	185.0	8,440
21	0	7,600	176.0	8,440
22	0	7,600	185.0	8,440
23	0	15,200	176.0	8,440
24	0	15,200	185.0	8,440
25	10,000	0	176.0	15,700 cfs (25% exceedance flow)
26	10,000	0	185.0	15,700
27	20,000	0	176.0	15,700
28	20,000	0	185.0	15,700
29	0	7,600	176.0	15,700
30	0	7,600	185.0	15,700
31	0	15,200	176.0	15,700
32	0	15,200	185.0	15,700
33	10,000	0	176.0	40,100 (5% exceedance flow)
34	10,000	0	185.0	40,100
35	20,000	0	176.0	40,100
36	20,000	0	185.0	40,100
37	0	7,600	176.0	40,100
38	0	7,600	185.0	40,100
39	0	15,200	176.0	40,100
40	0	15,200	185.0	40,100

For each scenario, the following maps were developed:

- Water Depth- One map was used to show the water depth (color-coded) over the 10 km reach. With 40 production runs there are a total of 40 water depth maps.
- Water Surface Elevation- One map was used to the water surface elevation (color-coded) over the 10 km reach. With 40 production runs there are a total of 40 water surface elevation maps.
- Velocity- Five (5) maps were used to show the water velocity (color-coded) over the 10km reach as was the velocity direction. With 40 productions runs and five (5) maps per production run there are a total of 200 velocity vector maps.

All 40 scenarios have been simulated in River2D and the above maps have been generated. For illustrative purposes the maps developed for Scenario 18 (2 units generating at 10,000 cfs, inflow to upper study reach of 8,440 cfs (50% exceedence flow) and under a downstream WSEL of 185 ft) are attached in [Appendix A](#) [the maps are sequenced as follows- depth (1 map), water surface elevation (1 map) and velocity (5 maps)]. The maps include the water depth, WSEL and five velocity vector maps.

Task 6: Report

The hydraulic modeling portion of the report is complete. Remaining components of the report include evaluating the hydraulic modeling results (primarily velocity) relative to the following study objectives pertaining to fish:

- Assess velocities and flow fields at, and in proximity to, the Northfield Mountain Project intake/discharge structure, when pumping or generating, and their potential to interfere with fish migration.
- Assess the potential for velocity barriers in the mainstem river to develop from pumping and generation flows at the Northfield Mountain Project, alone or in combination with generation flows from the upstream Vernon Project 1 and downstream Turners Falls Project.
- Assess the potential for Northfield Mountain Project operations to create undesirable attraction flows to the intake/discharge area that may result in entrainment or delay of migratory fish.
- Assess potential migratory fish impacts due to flow reversals under:
 - Pumping conditions, such that the river flows from the Turners Falls Dam toward the Northfield tailrace; and
 - Generating conditions, such that the river flows from the Northfield tailrace toward Vernon Dam.

The final study report is slated for completion on December 1, 2015.

1.3 Variances from Study Plan and Schedule

There are no variances to the study plan.

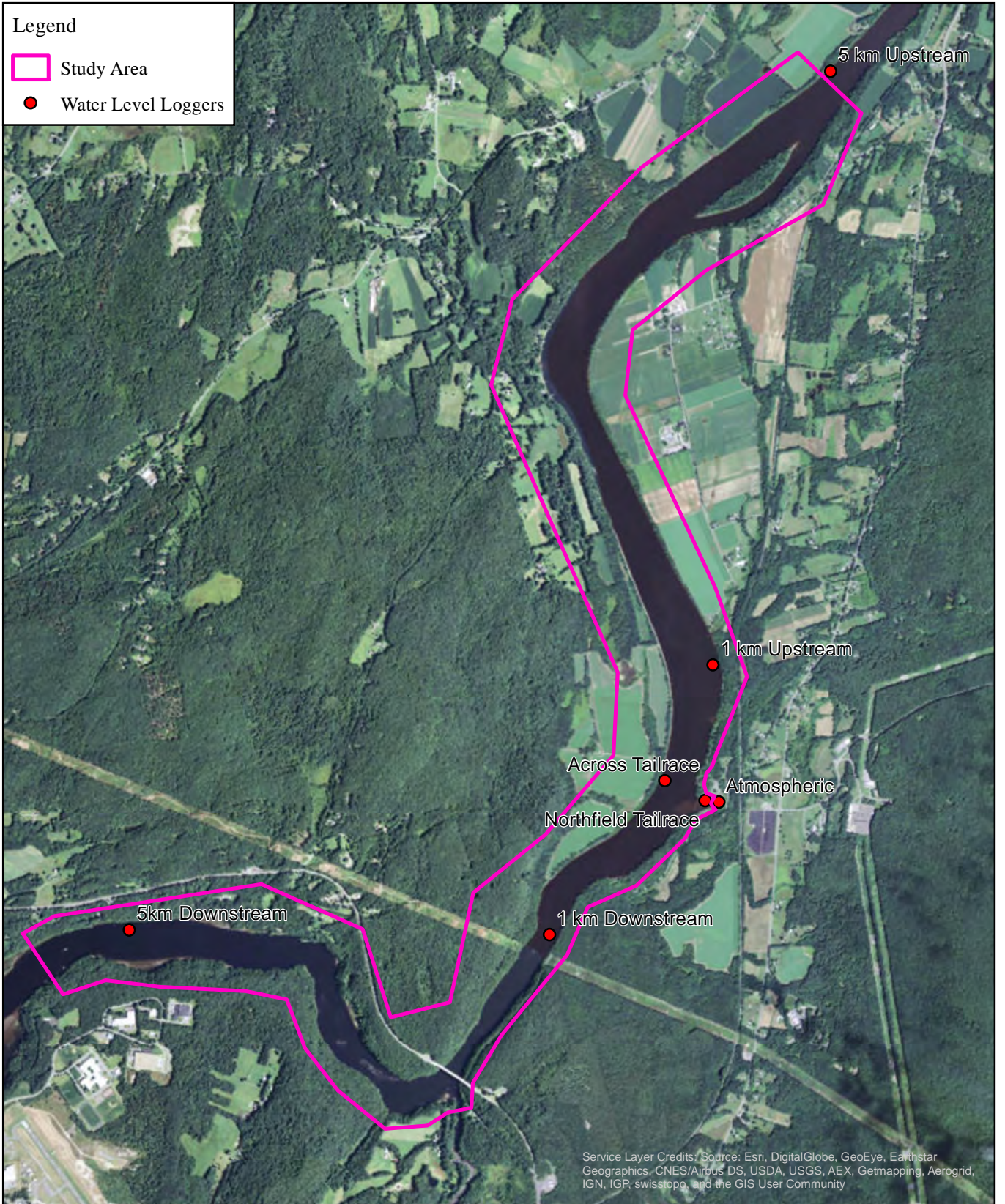
¹ The Vernon Hydroelectric Project is owned and operated by TransCanada. TransCanada is also in the process of relicensing three hydroelectric projects in series upstream of the Turners Falls Dam including from south to north the Vernon Hydroelectric Project (FERC No. 1904), Bellows Falls Hydroelectric Project (FERC No. 1855) and Wilder Hydroelectric Project (FERC No. 1892). All three TransCanada projects have the same license expiration date as the Northfield Mountain and Turners Falls Projects- April 30, 2018.

1.4 Remaining Activities

- Final Report.

Legend

- Study Area
- Water Level Loggers



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and Turners Falls Hydroelectric Project (No. 1889)**
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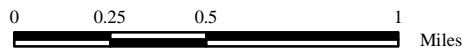



Figure 1
Water Level Logger
Locations

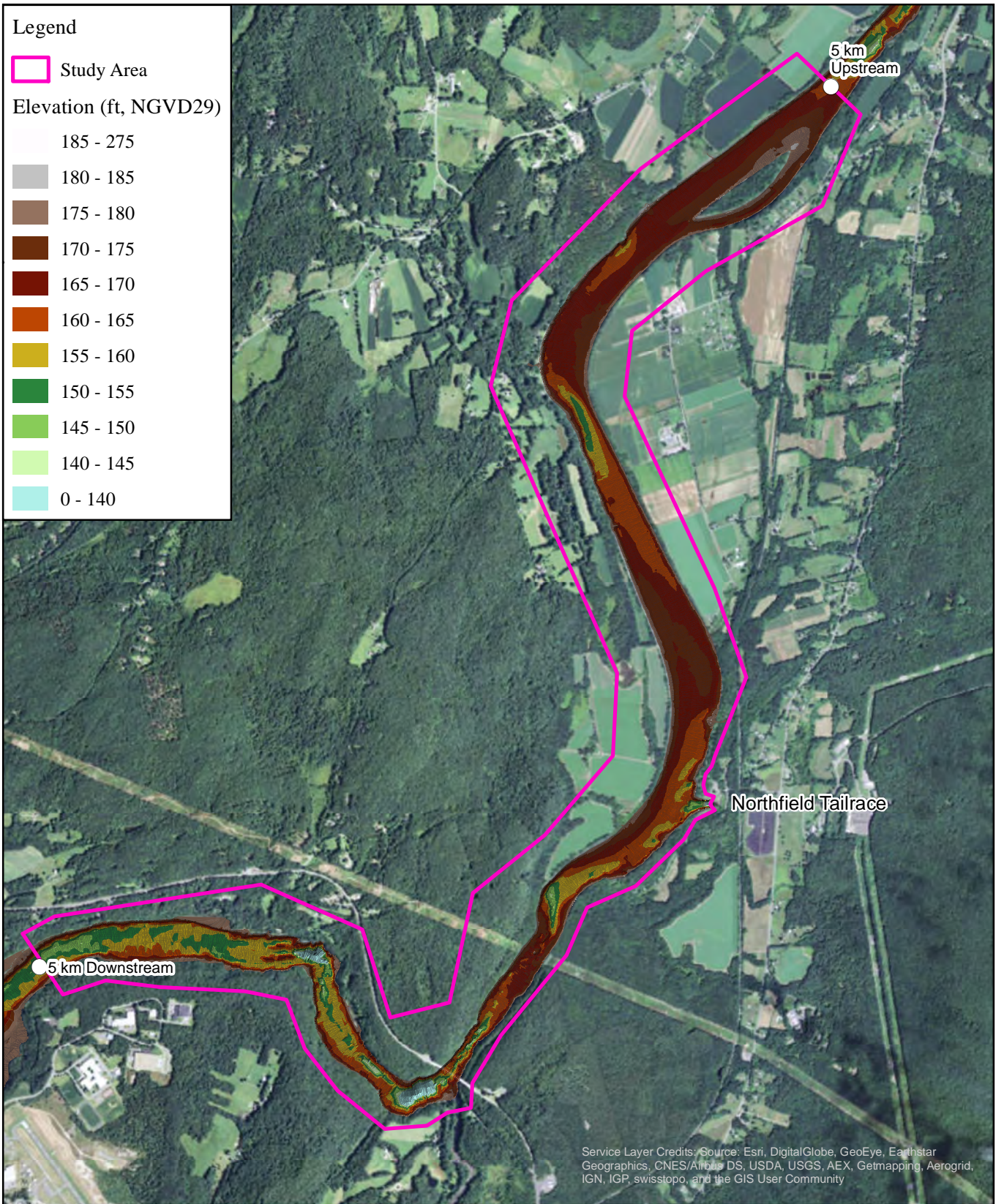
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Legend

 Study Area

Elevation (ft, NGVD29)

- 185 - 275
-  180 - 185
-  175 - 180
-  170 - 175
-  165 - 170
-  160 - 165
-  155 - 160
-  150 - 155
-  145 - 150
-  140 - 145
-  0 - 140



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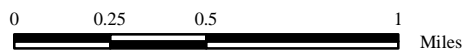
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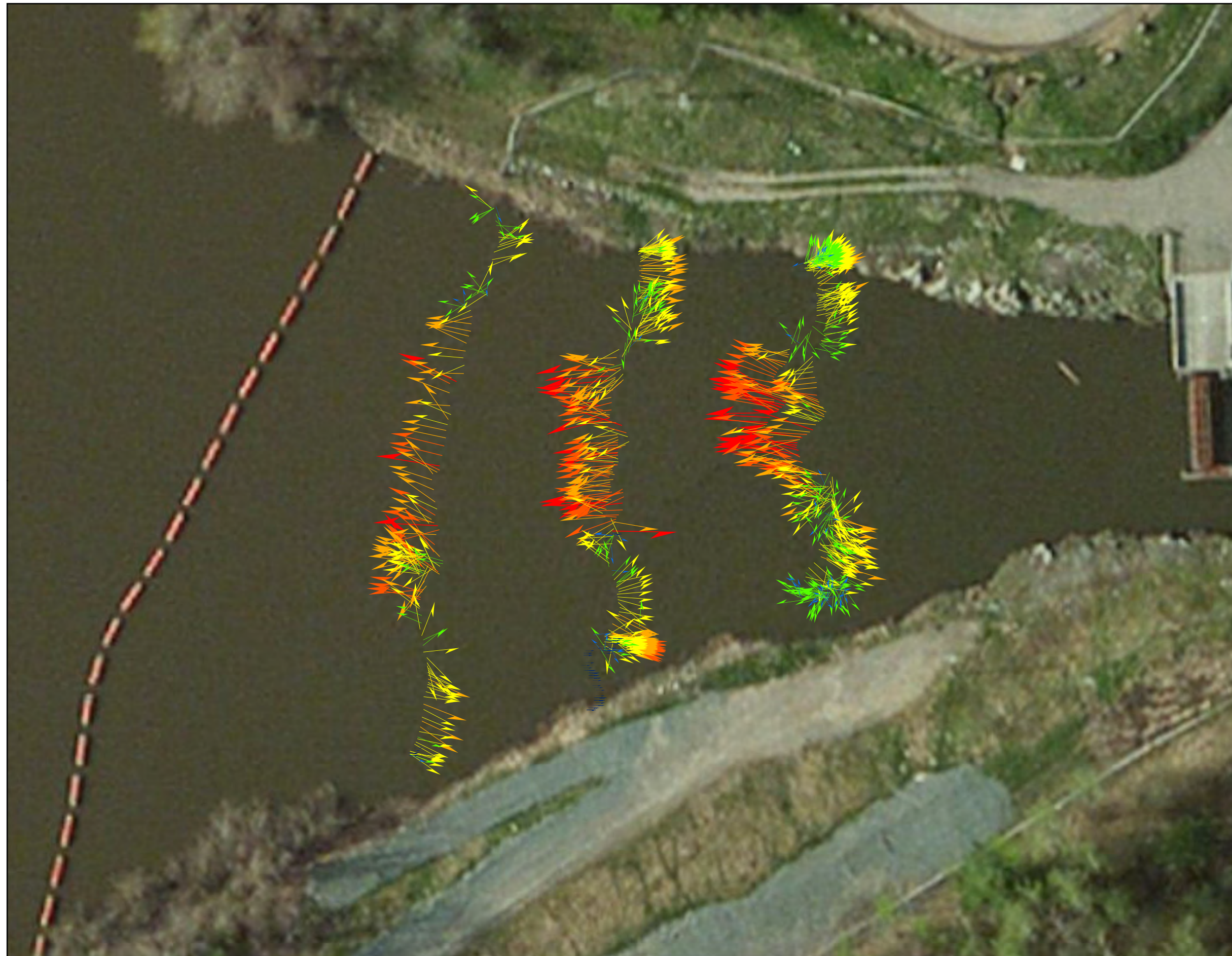
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Figure 2

Bathymetric/Topographic
Surface



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Figure 3
Observed Depth-Averaged Channel Velocities at Transects below Northfield tailrace (4 units at full hydraulic generating capacity ~20,000 cfs)

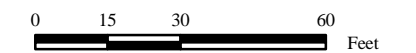
Legend

Depth-Averaged Velocity (ft/sec)

- 0.0 - 0.1
- 0.1 - 0.5
- 0.5 - 1.5
- 1.5 - 3.0
- 3.0 - 4.5
- 4.5 - 6.0
- 6.0 - 8.5



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1 inch = 40 feet



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Figure 4
Observed Depth-Averaged Channel Velocities at Transects below Northfield tailrace (2 units at full hydraulic generating capacity ~10,000 cfs)

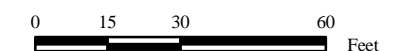
Legend

Depth-Averaged Velocity (ft/sec)

- 0.0 - 0.1
- 0.1 - 0.5
- 0.5 - 1.5
- 1.5 - 3.0
- 3.0 - 4.5
- 4.5 - 6.0
- 6.0 - 8.5



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Figure 5
Observed Depth-Averaged Channel Velocities at Transects below Northfield tailrace (4 units at full hydraulic pumping capacity ~15,200 cfs)

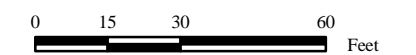
Legend

Depth-Averaged Velocity (ft/sec)

- 0.0 - 0.1
- 0.1 - 0.5
- 0.5 - 1.5
- 1.5 - 3.0
- 3.0 - 4.5
- 4.5 - 6.0
- 6.0 - 8.5



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Figure 6
Observed Depth-Averaged Channel Velocities at Transects below Northfield tailrace (2 units at full hydraulic pumping capacity ~7,600 cfs)

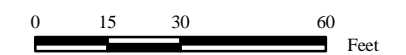
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Depth-Averaged Velocity (ft/sec)

- 0.0 - 0.1
- 0.1 - 0.5
- 0.5 - 1.5
- 1.5 - 3.0
- 3.0 - 4.5
- 4.5 - 6.0
- 6.0 - 8.5



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Appendix A- Example Hydraulic Modeling Output Maps (Scenario 18)

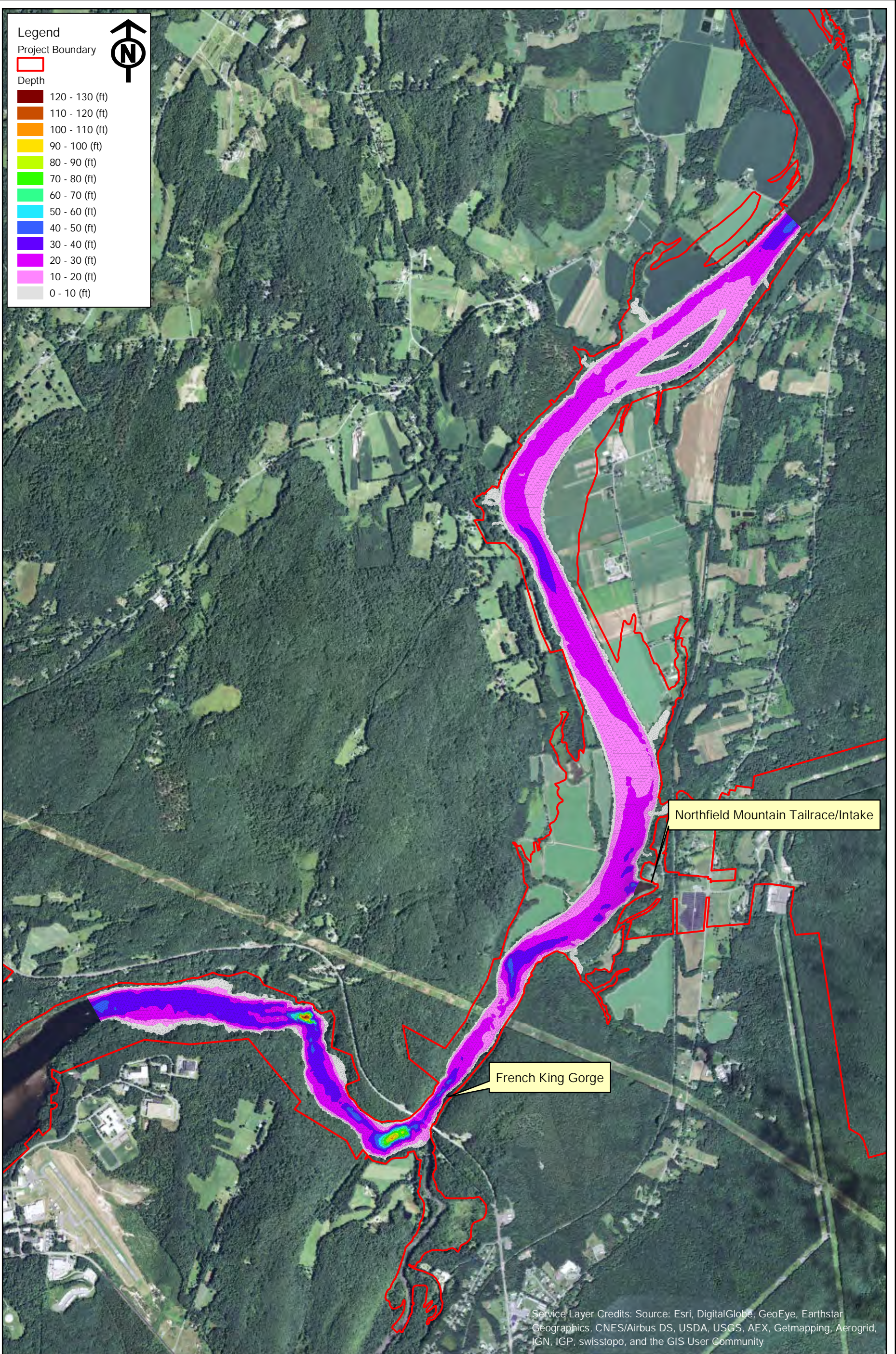
Legend

Project Boundary



Depth

-  120 - 130 (ft)
-  110 - 120 (ft)
-  100 - 110 (ft)
-  90 - 100 (ft)
-  80 - 90 (ft)
-  70 - 80 (ft)
-  60 - 70 (ft)
-  50 - 60 (ft)
-  40 - 50 (ft)
-  30 - 40 (ft)
-  20 - 30 (ft)
-  10 - 20 (ft)
-  0 - 10 (ft)

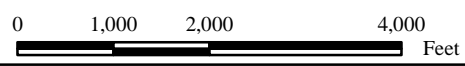


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Appendix B - Depth in the Turner Falls Impoundment 5 km Upstream and 5 km Downstream of the Northfield Tailrace

Scenario 18
50% Exceedance Flow (8,440 cfs), 2 Units
Generating (10,000 cfs), 185 WSEL at Dam

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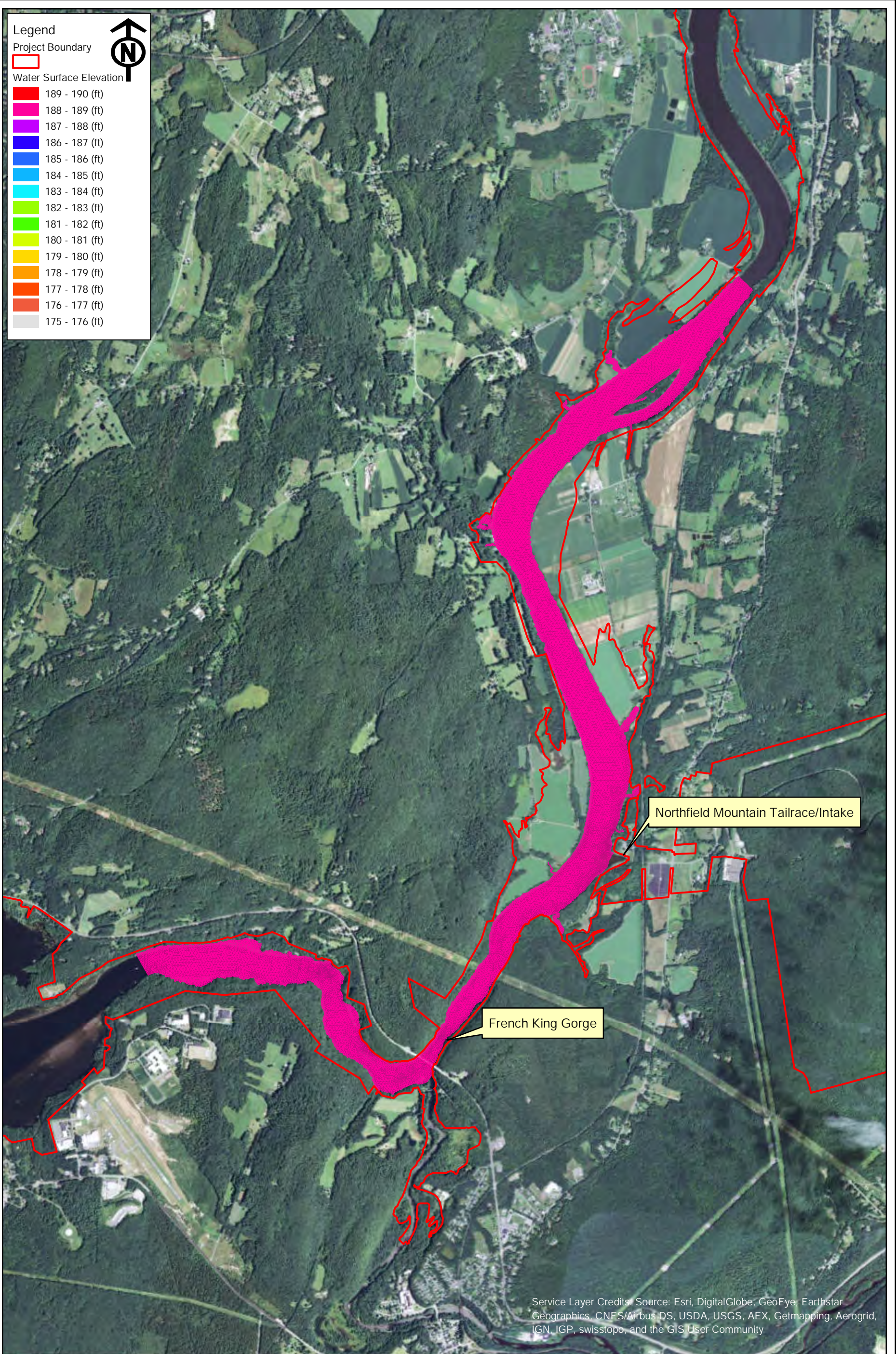
Legend

Project Boundary



Water Surface Elevation

- 189 - 190 (ft)
- 188 - 189 (ft)
- 187 - 188 (ft)
- 186 - 187 (ft)
- 185 - 186 (ft)
- 184 - 185 (ft)
- 183 - 184 (ft)
- 182 - 183 (ft)
- 181 - 182 (ft)
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- 179 - 180 (ft)
- 178 - 179 (ft)
- 177 - 178 (ft)
- 176 - 177 (ft)
- 175 - 176 (ft)

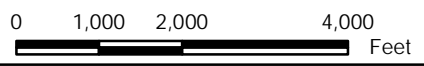


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Appendix B - Water Surface Elevation in the
Turner Falls Impoundment 5 km Upstream and
5 km Downstream of the Northfield Tailrace

Scenario 18
50% Exceedance Flow (8,440 cfs), 2 Units
Generating (10,000 cfs), 185 WSEL at

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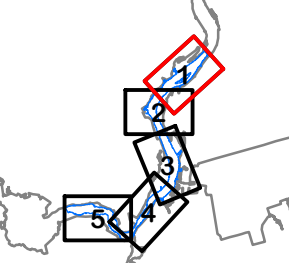
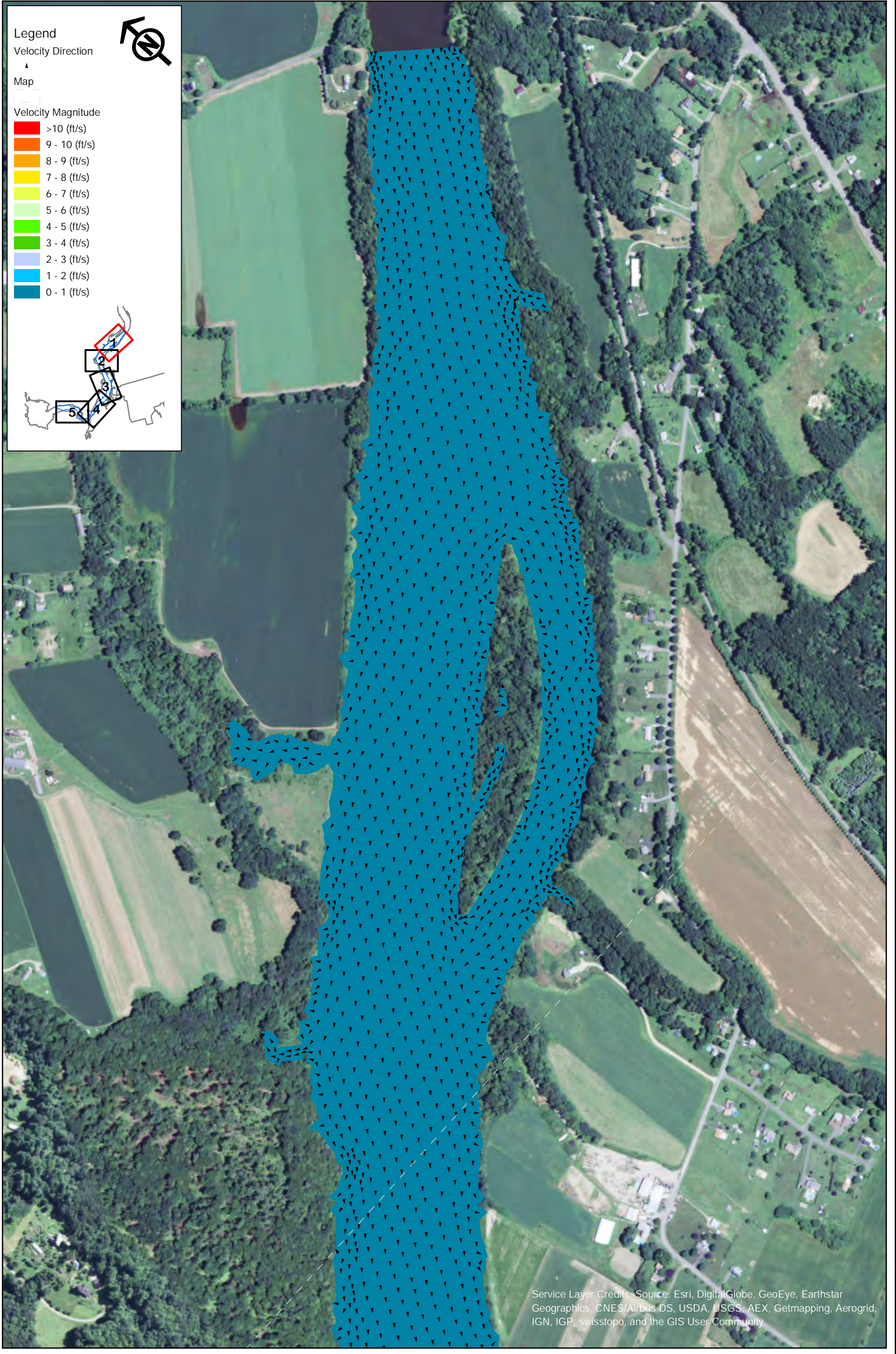
Legend

Velocity Direction
▲

Map
□

Velocity Magnitude

- >10 (ft/s)
- 9 - 10 (ft/s)
- 8 - 9 (ft/s)
- 7 - 8 (ft/s)
- 6 - 7 (ft/s)
- 5 - 6 (ft/s)
- 4 - 5 (ft/s)
- 3 - 4 (ft/s)
- 2 - 3 (ft/s)
- 1 - 2 (ft/s)
- 0 - 1 (ft/s)

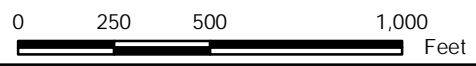



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Appendix B - Velocity in the Turner Falls Impoundment 5 km Upstream and 5 km Downstream of the Northfield Tailrace

Scenario 18 - Map 1
50% Exceedance Flow (8,440 cfs), 2 Units
Generating (10,000 cfs), 185 WSEL at

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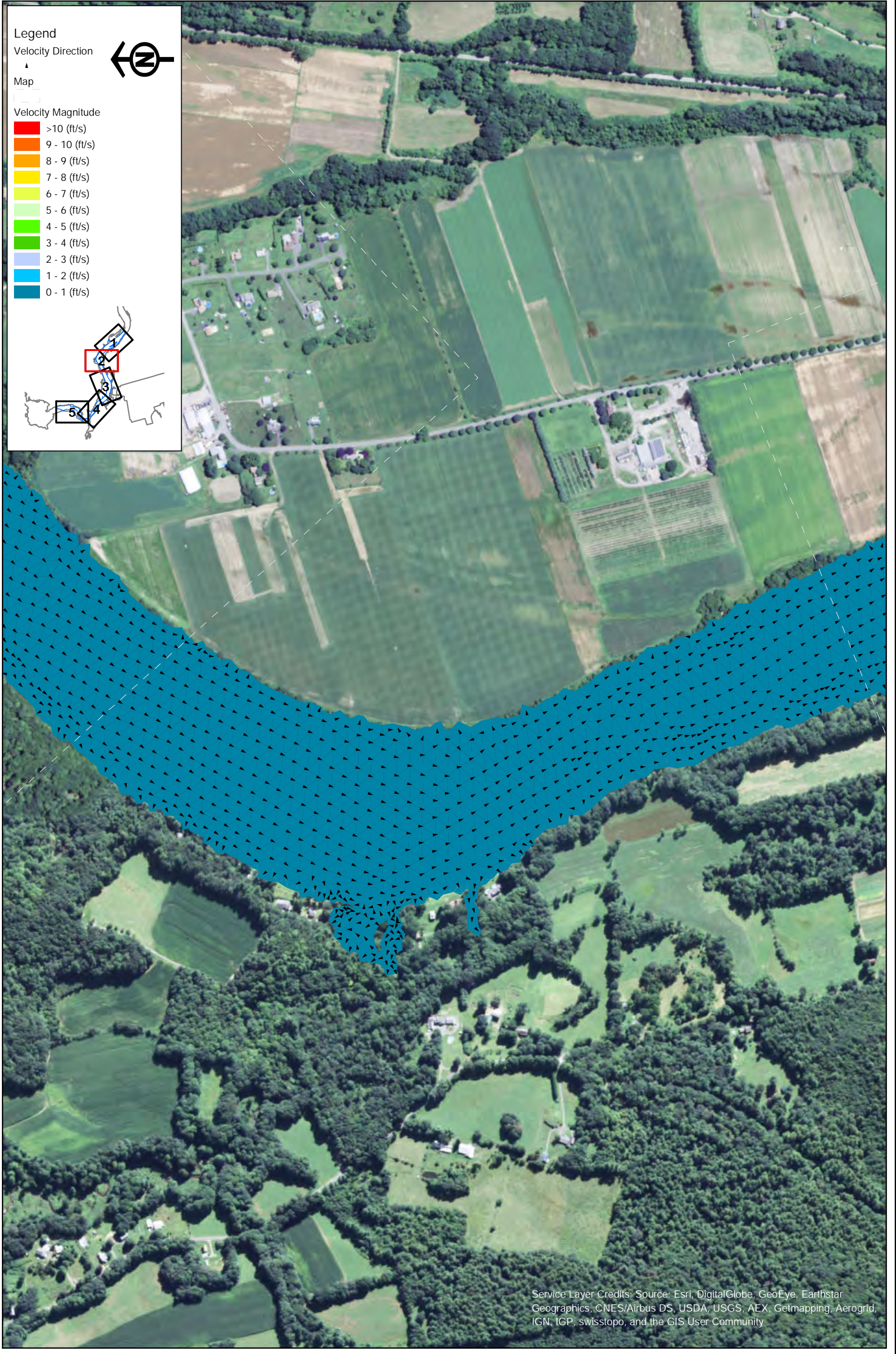
Legend

Velocity Direction


Map


Velocity Magnitude

-  >10 (ft/s)
-  9 - 10 (ft/s)
-  8 - 9 (ft/s)
-  7 - 8 (ft/s)
-  6 - 7 (ft/s)
-  5 - 6 (ft/s)
-  4 - 5 (ft/s)
-  3 - 4 (ft/s)
-  2 - 3 (ft/s)
-  1 - 2 (ft/s)
-  0 - 1 (ft/s)

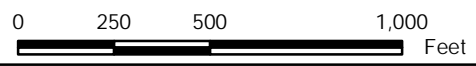


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Appendix B - Velocity in the Turner Falls Impoundment 5 km Upstream and 5 km Downstream of the Northfield Tailrace

Scenario 18 - Map 2
 50% Exceedance Flow (8,440 cfs), 2 Units
 Generating (10,000 cfs), 185 WSEL at

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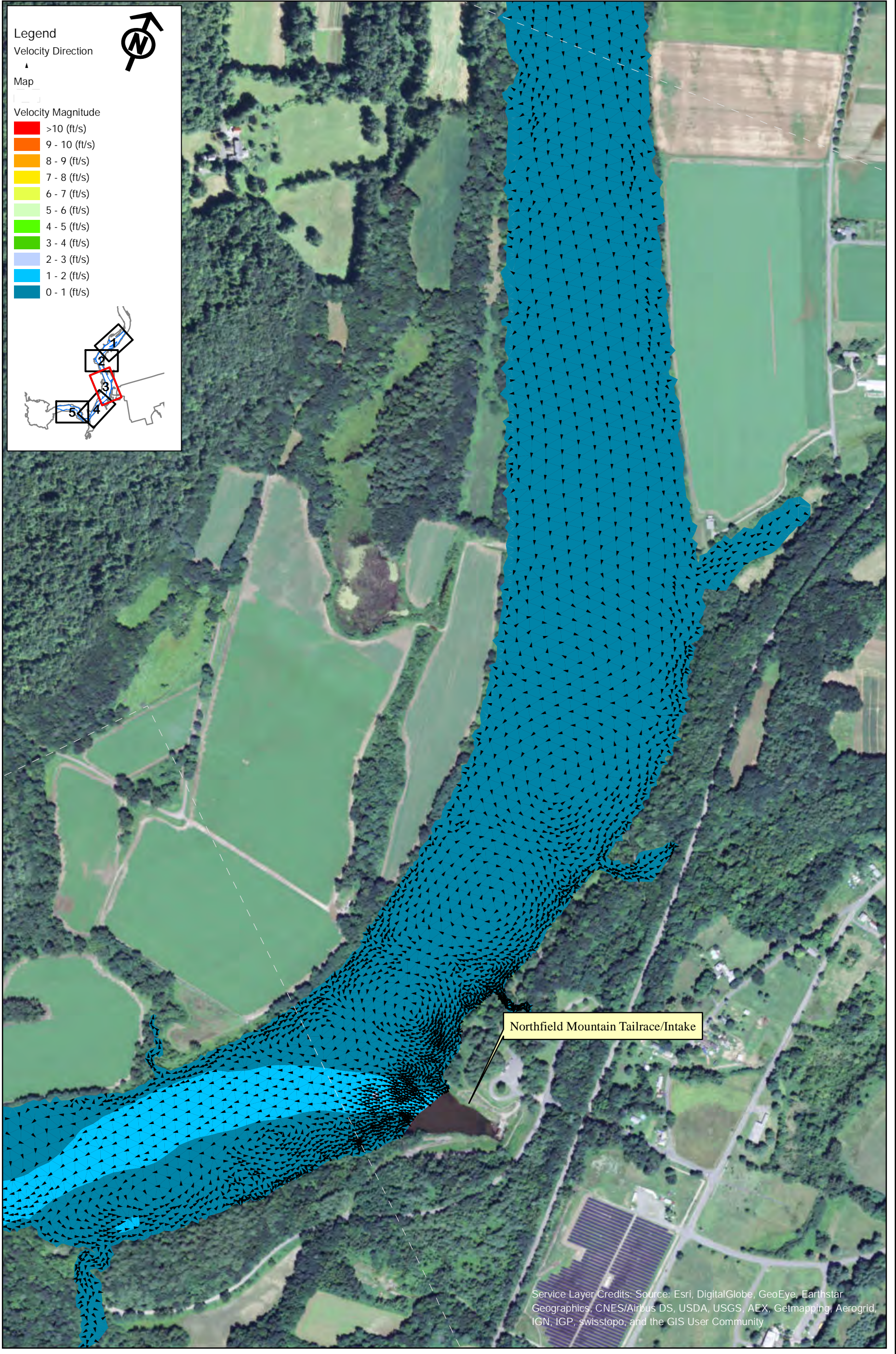
Legend

Velocity Direction
▲

Map
□

Velocity Magnitude

- >10 (ft/s)
- 9 - 10 (ft/s)
- 8 - 9 (ft/s)
- 7 - 8 (ft/s)
- 6 - 7 (ft/s)
- 5 - 6 (ft/s)
- 4 - 5 (ft/s)
- 3 - 4 (ft/s)
- 2 - 3 (ft/s)
- 1 - 2 (ft/s)
- 0 - 1 (ft/s)

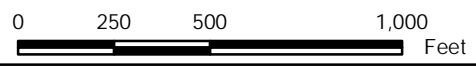


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Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)

STUDY REPORT
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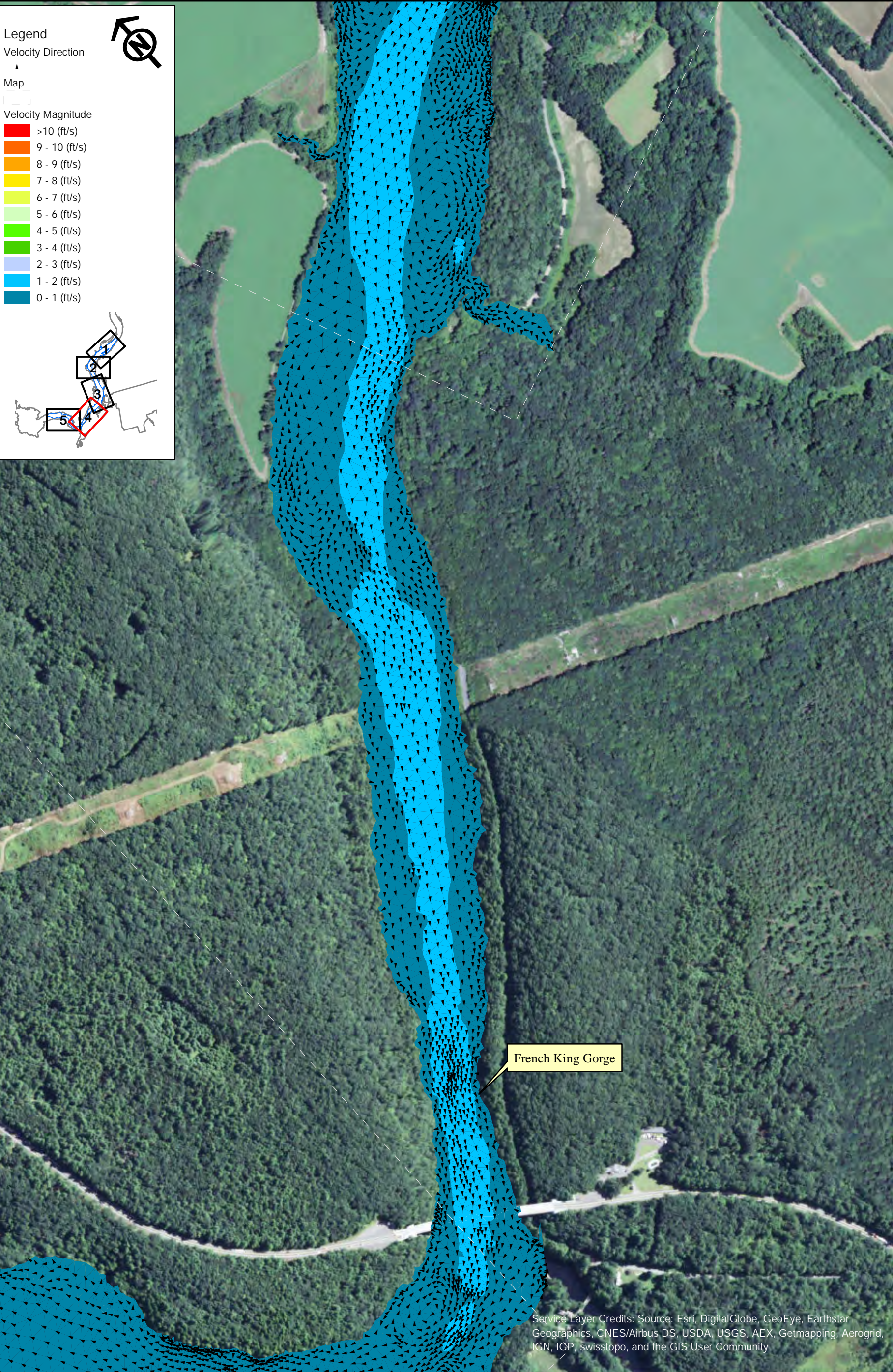


Appendix B - Velocity in the Turner Falls Impoundment 5 km Upstream and 5 km Downstream of the Northfield Tailrace

Scenario 18 - Map 3
50% Exceedance Flow (8,440 cfs), 2 Units
Generating (10,000 cfs), 185 WSEL at

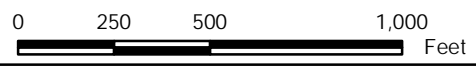
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Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)

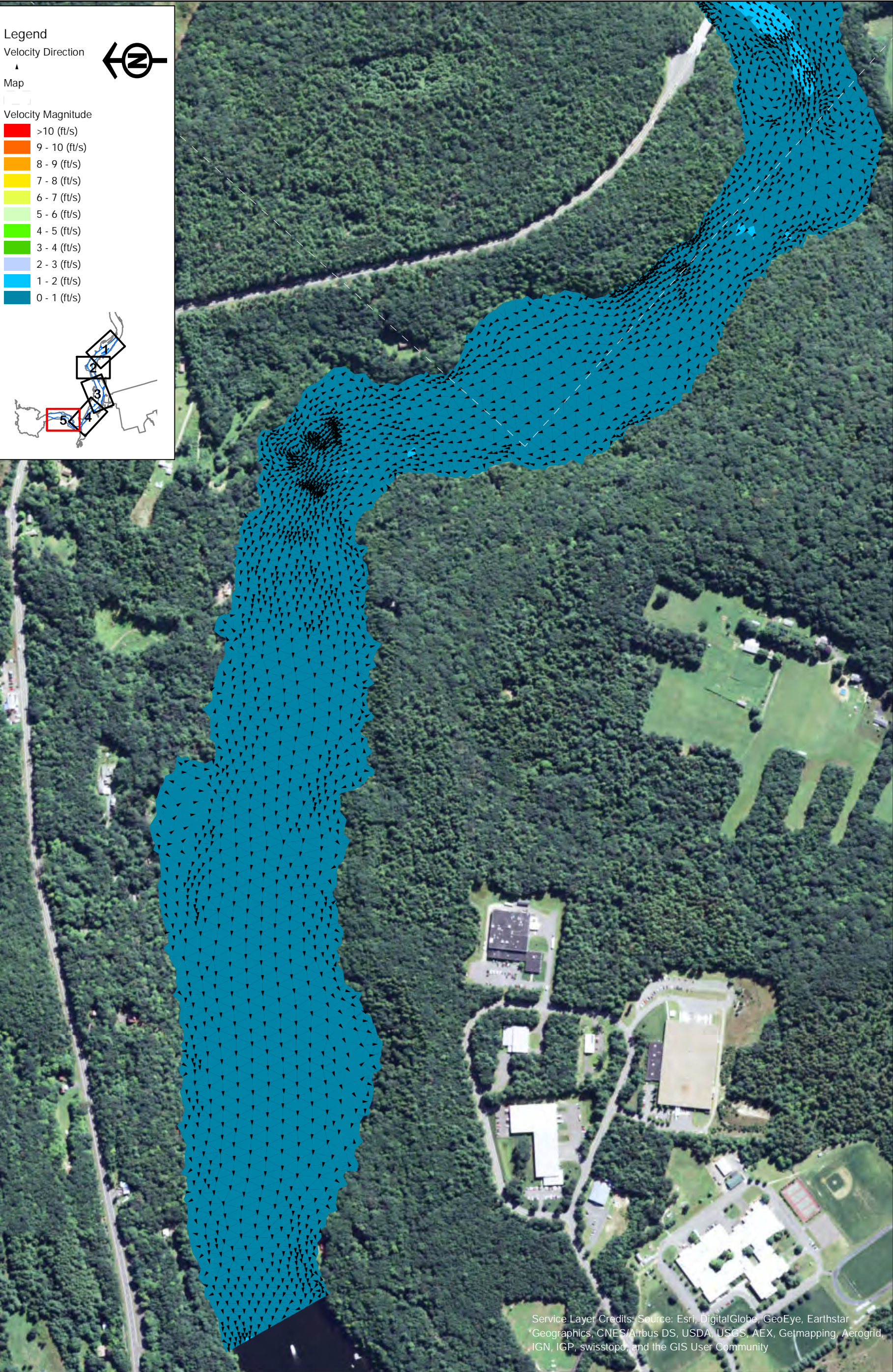
STUDY REPORT
RELICENSING STUDY 3.3.9



Appendix B - Velocity in the Turner Falls
Impoundment 5 km Upstream and 5 km
Downstream of the Northfield Tailrace

Scenario 18 - Map 4
50% Exceedance Flow (8,440 cfs), 2 Units
Generating (10,000 cfs), 185 WSEL at

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Legend

Velocity Direction

Map

Velocity Magnitude

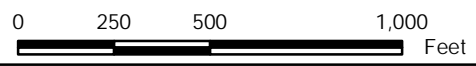
- >10 (ft/s)
- 9 - 10 (ft/s)
- 8 - 9 (ft/s)
- 7 - 8 (ft/s)
- 6 - 7 (ft/s)
- 5 - 6 (ft/s)
- 4 - 5 (ft/s)
- 3 - 4 (ft/s)
- 2 - 3 (ft/s)
- 1 - 2 (ft/s)
- 0 - 1 (ft/s)

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 *Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid,
 IGN, IGP, swisstopo, and the GIS User Community



Northfield Mountain Pumped Storage Project (No. 2485)
 and Turners Falls Hydroelectric Project (No. 1889)

STUDY REPORT
 RELICENSING STUDY 3.3.9



Appendix B - Velocity in the Turner Falls
 Impoundment 5 km Upstream and 5 km
 Downstream of the Northfield Tailrace

Scenario 18 - Map 5
 50% Exceedance Flow (8,440 cfs), 2 Units
 Generating (10,000 cfs), 185 WSEL at

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