RELICENSING STUDY 3.3.8

COMPUTATIONAL FLUID DYNAMICS MODELING IN THE VICINITY OF THE FISHWAY ENTRANCES AND POWERHOUSE FOREBAYS

ADDENDUM

Northfield Mountain Pumped Storage Project (No. 2485)

and Turners Falls Hydroelectric Project (No. 1889)

Prepared for:

FirstLight Power Resources

Prepared by:

Gomez and Sullivan Engineers

OCTOBER 2016

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LIST OF ABBREVIATIONS

CFD	Computational Fluid Dynamics
cfs	cubic feet per second
FERC	Federal Energy Regulatory Commission
NMFS	National Marine Fisheries Service
Northfield Mountain Project	Northfield Mountain Pumped Storage Project
SPDL	Study Plan Determination Letter
the Commission	Federal Energy Regulatory Commission
the Project	Northfield Mountain Pumped Storage and Turners Falls Hydroelectric Projects
Turners Falls Project	Turners Falls Hydroelectric Project
USFWS	United States Fish and Wildlife Service

1 INTRODUCTION

On March 1, 2016, FirstLight filed with the Federal Energy Regulatory Commission (FERC) Study Report No. 3.3.8 *Computational Fluid Dynamic Modeling in the Vicinity of the Fishway Entrances and Powerhouse Forebays*. On March 16, 2016, FirstLight held its study report meeting in which Study No. 3.3.8 was discussed. FirstLight filed its meeting minutes on March 31, 2016 and stakeholders had until April 30, 2016 to file comments. Comments on Study No. 3.3.8 were received from the United States Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS).

In FirstLight's responsiveness summary to comments, filed with FERC on May 30, 2016, it agreed to file an addendum to the report to address many of the comments raised by USFWS and NMFS. On June 29, 2016, FERC issued its Determination on Requests for Study Modifications and New Studies. FERC addressed two issues in its Determination relative to a) model verification and b) evaluation of component velocities. A summary of each of these issues is summarized below:

<u>Model Verification</u>

In its Determination, FERC discussed NMFS's request to "*collect additional field data using an Acoustic Doppler Current Profiler to better verify the models describing the Station No. 1 forebay and powerhouse entrance, Cabot forebay and powerhouse entrance, and Cabot ladder entrance over a range of flow conditions instead of a single-flow scenario used to verify the models*[1]*. NMFS also requests that FirstLight verify the Cabot Station forebay model with data collected during periods when water is being released from all discharge locations (i.e. releases through the powerhouse, existing fish weir, log boom emergency gate, and attraction flow emergency gate) instead of verifying the model during releases from only the powerhouse*".

In its reply comments, FirstLight indicated that a single verification run was conducted for each model at a mid-range flow (i.e., between a low-flow scenario when one unit was generating and a high-flow scenario when all units were generating). FirstLight indicated that the approved study plan does not specify the methodology and flow rates for verifying the models or require evaluating flows from the existing fish weir, log boom emergency gate, and the attraction flow emergency gate. FirstLight indicated that the methodology used for verifying the models is appropriate.

In its Determination, FERC stated the following: "*FirstLight conducted the study as required by the approved study plan; however, FirstLight's model verification using only a single run at a mid-range flow does not demonstrate that the models are accurate across the entire range of flows that were modeled. In addition, FirstLight's verification of the Cabot Station forebay and powerhouse model when only the powerhouse is operating does not demonstrate that the model is reliable or accurate for modeling scenarios with flows being released through the existing fish weir, log boom emergency gate, and attraction flow emergency gate. Therefore, we recommend that FirstLight either conduct the additional verification testing requested by NMFS or provide other details or information that demonstrate that the models are reliable over the entire range of modeled flows, including scenarios where the existing fish weir, log boom emergency gate, and attraction flow emergency gate are operating*".

As discussed below, FirstLight is not proposing to conduct additional model verification. We believe that additional data collection and verification runs does not further inform our understanding of the study reach, and is not justified given the high level of effort associated with additional field collection, modeling, license fees, and analysis. FirstLight proposes to instead consult further with NMFS and USFWS to find a mutually agreeable solution that does not involve additional data collection.

[1] "*NMFS states that no additional data is needed for the Spillway ladder entrance model given the difficulty in modeling high turbulent flow from the spillway and collecting field data at this location*."

Evaluation of Component Velocities

In its Determination, FERC discussed NMFS's request to "*..that FirstLight use a 3-D velocity probe to measure and evaluate sweeping and approaching velocities in front of the Station No. 1 and Cabot Station intake racks instead of further modeling. NMFS indicates that this information is needed to determine effects on fish entrainment and impingement during downstream passage."* In its Determination, FERC stated the following: *The Station No. 1 and Cabot Station forebay and powerhouse models provide information about approach velocities and sweeping velocities that can be used to analyze fish passage conditions at the Station No. 1 and Cabot Station intakes. In addition, studies 3.3.2, 3.3.3, 3.3.5, and 3.3.7 will provide information about fish passage through the forebay and intake area. Because the required studies should provide the information needed for staff's analysis of project effects on fish passage (section 5.9(b)(5)), we do not recommend requiring FirstLight to collect additional data at the Station No. 1 and Cabot Station intakes using a 3-D velocity probe.*

Consultation Record

March 31, 2016 Conference Call- USFWS, NMFS, FirstLight, Gomez and Sullivan

Following the study meeting, on March 31, 2016, FirstLight, USFWS and NMFS had a conference call to discuss the CFD models and the need to conduct a sensitivity analysis. Among other action items, FirstLight agreed to conduct a bed roughness sensitivity analysis using the Cabot Fishway model.

2 RESPONSES TO USFWS AND NFMS COMMENTS

As noted above, comments on Study No 3.3.8 were received from USFWS and NMFS. In its response to comments, FirstLight cataloged the comments received such as USFWS-1 (refers to the first USFWS comment on Study No. 3.3.8), USFWS-2 etc. In its response to comments, FirstLight indicated which comments (USFWS-1, NMFS-1, etc.) it would address in an addendum to Study No. 3.3.8. Using the same cataloging system, the subsections below list the comment (such as USFWS-1), which is then followed by FirstLight's 5/31/2016 response to comments filed on May 31, 2016 (5/31/2016 Response), and then FirstLight's final response for this addendum. Note that some comments were addressed in FirstLight's response and thus are not included below. FirstLight addresses comments herein only where it indicated a response would be provided in an addendum or FERC directed FirstLight to further address a specific comment (such as model validation).

2.1 USFWS-1 Production Runs for Two Additional Bypass Flow Scenarios

Comment: *Assessing fishway attraction in the presence of competing flows (i.e., spill) is critical when evaluating fish passage conditions. The operational scenarios modeled and summarized in the tables on pages iii and iv, while informative, do not reflect operational conditions we anticipate will be required under a new license, as flows for passage , spawning and rearing, and riverine fish habitat are likely to be required. In particular, the Cabot Fishway scenarios (5-x) and the Spillway Fishway models (6-x) need to be run at moderate flows to provide needed clarity on future conditions. While instream flow study and telemetry study reports have not been filed or reviewed, based on what we know at this time from past sturgeon spawning research and the preliminary instream flow study results for reach 2, we request that FL provide the results of two additional production runs:*

a) *a scenario that evaluates hydraulic conditions with a bypass reach flow between scenarios 5-3 and 5-4, or approximately 3,450 cfs; and*
b) *a scenario that evaluates hydraulic conditions with the discharge from Bascule Gate No.1 Flow between the flows modeled in scenarios 6-1 and 6-2, or 2,370 cfs.*

FirstLight's 5/31/2016 Response:

FL evaluated the scenarios specified in the RSP, but we agree to simulate the two additional production runs requested by USFWS. The results from these additional runs will be included in a study addendum. Note that reference to an addendum is noted several times in response to comments below. FL will file the addendum with FERC on October 14, 2016.

Addendum Response:

FirstLight has agreed to conduct these two additional model runs. Based on the response in section 2.2 below (USFWS-2 Channel Roughness), however, it appears that the model results are moderately sensitive to the assumed bed roughness. Before we conduct these additional production runs, we would like to consult further with NMFS and USFWS to determine the appropriate bed roughness, if any, that should be used for these and other future production runs.

2.2 USFWS-2 Channel Roughness

Comment: *As noted on pg. 2-2 and elsewhere, Gomez and Sullivan Engineers (GSE) have modeled all physical boundary conditions as hydraulically smooth. Implicit in this model simplification is the lack of calibration to real flows (which is distinct from the verification process). Hydraulically smooth boundaries are generally appropriate for shallow, low velocity turbulent flows. However, many of the modeled reaches/locations are of sufficient velocity and depth, with sufficient channel roughness, to be characterized as hydraulically rough. Hydraulically rough surfaces may produce a very different velocity distribution* *than hydraulically smooth surfaces; and velocity distributions are a key correlation to fish movement (along the bank, throughout the river, in the power canal, and approaching fishway entrances). As an example, this simplification may relate to the discrepancy between measured and simulated velocities downstream of the fishway entrance cited on pg. 6-5 of the study report. Unfortunately, the influence of this simplification on the overall modeling effort cannot be quantified apriori. The Service appreciates that software limitations, as described by GSE staff on a March 31, 2016 conference call on this report, may prevent incorporating accurate roughness elements throughout the model. Nevertheless, additional work is needed to reduce the uncertainty in the 3D distribution of velocity in GSE's model. If GSE believes that the hydraulically smooth assumption has a limited influence on the model results, we request that FL provide a sensitivity analysis that demonstrates this limited influence by comparing a hydraulically smooth boundary to one with appropriate channel roughness on a representative subsection of the overall model.*

FirstLight's 5/31/2016 Response:

We agree that conducting a sensitivity analysis is appropriate. FL agreed to do this during the March 31, 2016 conference call and is currently conducting a sensitivity analysis of the Cabot Fishway Entrance model. The sensitivity analysis is based on a hydraulic roughness of 1.635 feet, which is approximately equivalent to a Manning's 'n' roughness of 0.035 assuming an average river depth of 15 feet. The results of the sensitivity analysis will be included in the addendum.

Addendum Response:

On the March 31, 2016 conference call with NMFS and USFWS, FirstLight agreed to conduct a sensitivity analysis as requested above. FirstLight agrees that a sensitivity analysis is an appropriate tool for assessing how appropriate the previous assumption of all hydraulically smooth surfaces may or may not be. Specifically on the conference call, it was agreed that FirstLight would, as a first step, conduct a run of the Cabot Fishway model similar to production run scenario 5-2. FirstLight has completed this sensitivity analysis.

The model inflows for the new sensitivity run scenario, referred to as "Scenario 5-2-Alt1" are described below in Table 2.2-1. These are identical to the model inflows used for the original scenario 5-2.

Table 2.2-1: Cabot Station Scenario 5-2-Alt1 Model Inflows

Location	Flow (cfs)
Bypass Reach	400
Log Sluice	0
Cabot Fishway	368
Unit 1	1,875
Unit 2	1,875
Unit 3	1,875
Unit 4	1,875
Unit 5	0
Unit 6	0
Total River Flow	**8,268**

Bed Roughness Estimation

As discussed during the conference call, FirstLight agreed to conduct the sensitivity analysis using a bed roughness equating to a Manning's n roughness of approximately 0.035. We used formulas 8-26 and 8-27 from *Open-Channel Hydraulics* (Chow, 1957) and backwards-solved the following equations that relate

Manning's n and k-roughness: $n = \Phi\left(\frac{R}{k}\right) * k^{1/6}$, where k = bed roughness, and $\Phi\left(\frac{R}{K}\right) = \frac{(R/k)^{1/6}}{21.9*\log(12.2*R/k)}$ where R=hydraulic radius (approximated as water depth).

Assuming an average water depth of 15 feet and n = 0.035, then Φ(R/k) = 0.0322, and k = 1.635 ft. This was the value used in our sensitivity model run to represent the bed roughness.

The current version of Flow3D only allows a single surface roughness value to be set for each model component. We can only set a single surface roughness for the entire bed since the Cabot Fishway model represents the bed as a single component, even though in reality the bed roughness varies spatially as a function of bed substrate. A roughness of 0.01 ft was applied to the Cabot Station and Cabot fishway components (each represented as individual components), which is on the high end of the normal range for concrete surfaces (Crowe, Elger, and Roberson; Engineering Fluid Mechanics, Eighth Edition; Table 10.2).

Sensitivity Results

The model's sensitivity to roughness changes were assessed using three methods:

1) Comparing modeled water levels at various locations for both model runs;
2) A flow distribution analysis comparing average flow between the model's flow baffles; and
3) A visual analysis of depth-averaged water velocities throughout the modeled reach.

While additional methods could be used to further compare the differences between the two runs, we found that these three methods concisely summarized the model run differences.

Table 2.2-2 compares water levels at eight locations throughout the modeled area (Figure 2.2-1). These locations coincide with water level loggers 3-4 through 3-11 from the instream flow study (Study 3.3.1) reach 3 work. The results show that changing the bed roughness to 1.635 ft increased water levels throughout the model. Water levels were generally about between 0.1 and 1.5 ft higher than the hydraulically smooth run, depending on the location. One logger (3-8) was slightly lower after raising the bed roughness, but since the logger was located in an isolated side-channel this may be due to slight model oscillations in the channel since it experienced relatively little flow (1-2% of total model flows based on results in Table 2.2-3). Logger 3-11 is actually located about 13 feet upstream of the model's upstream inflow boundary, but it was considered to be at the same location as the inflow boundary for this analysis.

Flow was calculated at several flow baffles throughout the model to determine if the bed roughness changes altered the flow distribution between the multiple islands in the study reach. Figure 2.2-2 shows the location of the flow baffles. Table 2.2-3 shows the average flows at each of the baffles for the two runs. Flows are different for the upper left and upper right channel, however changes of up to 100-200 cfs are also possibly due to changes at the model's mesh boundaries between the runs where mesh size changes can result in small (as a percent of the total model flow) losses or introductions of water (i.e., mass is not always conserved at mesh boundaries).

Figure 2.2-3 shows depth-averaged water velocities in the entire model area for the original (hydraulically smooth) and bed-roughened (k=1.635 ft) model results. There are noticeable differences in depth-averaged velocity, particularly in the riffle area downstream of Cabot station. The velocities are noticeably lower (approximately 1-2 fps) with the roughened channel than they were with the smooth bed assumption. We did not conduct a more quantitative analysis as we believe these results show that the model is relatively sensitive to bed roughness adjustments.

Discussion

The model appears to be relatively sensitive to bed roughness changes when comparing k=0 (hydraulically smooth) to k=1.635 ft (roughly equivalent to n=0.035 in a 15-foot-deep channel). This may have implications for the other model runs that have been completed to-date.

One point to consider is that the Cabot Fishway validation run results (described in the original study report) showed that, at least visually, the hydraulically smooth bed model velocities seemed to match the observed velocity data reasonably well. Therefore, while it is clear that the model is sensitive to bed roughness changes (at least on the scale that they were changed for this analysis), we do not yet know which model (smooth or k=1.635) best matches field conditions.

To assess the question of which model best matches the observed water level and velocity data, FirstLight proposes to conduct four additional sensitivity runs. The proposed sensitivity runs will be completed for each of the four modeling areas' (Station No. 1 Forebay, Cabot Station Forebay, Cabot Station Fishway, Spillway Fishway) validation runs. FirstLight proposes to use the same roughness value of k=1.635 ft (equivalent to n=0.035) for the Spillway Fishway and Cabot Fishway sensitivity runs, and a bed roughness value of k=0.75 ft (equivalent to n=0.030) for the Station No. 1 and Cabot Station sensitivity runs. We propose a roughness of k=0.01 ft for all concrete surfaces in all models (e.g., canal walls, Powerhouse walls, Fishways). These runs are currently underway and results will be shared with NMFS and USFWS upon completion.

Table 2.2-2: Water level comparison between the hydraulically smooth and roughened (k=1.635 ft) model sensitivity runs.

Location	WSE (ft NGVD29) @ PR 5-2 (smooth)	WSE (ft NGVD29) @ PR 5-2alt (k=1.635)	Diff (ft)
3-4	109.1	109.2	+0.1
3-5	109.5	110.4	+0.9
3-6	110.8	111.9	+1.1
3-7	111.1	112.0	+0.9
3-8	109.3	109.2	-0.1
3-9	111.7	111.8	+0.1
3-10	111.8	111.9	+0.1
3-11	111.1	112.7	+1.6

Table 2.2-3: Sensitivity analysis results - flow baffle comparison.

	Flow (cfs) @ Hydraulically Smooth			Flow (cfs) @ Rough (k=1.635 ft)			Difference (cfs)		
Location	Average Flow (cfs)	2.5% Exceedance Flow (cfs)	97.5% Exceedance Flow (cfs)	Average Flow (cfs)	2.5% Exceedance Flow (cfs)	97.5% Exceedance Flow (cfs)	Average Flow (cfs)	2.5% Exceedance Flow (cfs)	97.5% Exceedance Flow (cfs)
Bypass Upstream	400	443	361	401	392	410	1	-51	49
Bypass Downstream	400	454	339	401	392	410	2	-63	70
Upper Left Channel	71	124	9	330	339	321	259	215	312
Upper Right Channel	131	165	103	65	70	60	-66	-95	-43
Cabot Powerhouse	7,500	7,500	7,500	7,500	7,500	7,500	0	0	0
Cabot Fishway	368	369	367	368	368	368	0	-1	1
Lower Left Channel	7,865	7,912	7,826	8,059	8,069	8,048	194	157	222
Lower Right Channel	89	332	-129	181	282	82	93	-50	211
Outflow	7,907	8,185	7,661	8,222	8,248	8,193	316	63	532

2.3 USFWS-3 Intake Rack Approach Velocity

Comment: *GSE provided colorized vector plots of the intake velocities in front of the racks at Station No. 1 and Cabot Station. To better evaluate the hazards of impingement and entrainment, we request that FL provide contour line maps of approach velocities 1 foot in front of the racks for scenarios 1-x and 3-x with color lines clearly labeled in 0.5 fps increments (or finer).*

FirstLight's 5/31/2016 Response:

We will generate additional plots showing the velocities in 0.5 fps increments, 1 foot in front of the racks and include them in the addendum. Generating actual contours from the data we have would be difficult, but we can create 0.5 fps "color bins" to achieve the same effect without actually generating contours.

Addendum Response:

Figure 2.3-1 shows the approach velocity as 0.5 fps-incremented color bins in front of the intake for Scenario 1-1. Figure 2.3-2 shows the approach velocity for Scenario 1-2. Figure 2.3-3 shows the approach velocity for Scenario 1-3.

Figure 2.3-4 shows the approach velocity as 0.5 fps-incremented color bins in front of the intake for Scenario 3-1. Figure 2.3-5 shows the approach velocity for Scenario 3-2. Figure 2.3-6 shows the approach velocity for Scenario 3-3.

The velocity color bins created for the approach velocity plots are labeled by their upper limit in the legend. For example, the color bin labeled 0.5 fps contains velocities between 0.0 and 0.5 fps.

2.4 USFWS-4 Station No. 1 and Cabot Intake Overview Plots

Comment: *To help us better understand the entrainment potential of juvenile alosines, we request that FL produce particle trace plots showing a similar perspective as the flow vector plots in figures 8.2.1-1, 8.2.1-2, 8.2.1-3, 8.2.2-1, 8.2.2-2, 8.2.2-3, 8.2.3-1, 8.2.3-2, and 8.2.3-3. If possible, for clarity, please include at least five seeds in each particle trace plot. It is our understanding that generating these plots will not necessitate new production runs. Relative to the Cabot Intake overview plots…. Similar to the above request, we request that FL produce particle trace plots similar to figures 8.3.1-1, 8.3.1-2, 8.3.2-1, 8.3.2-2, 8.3.3-1 and 8.3.3-2 for the Station No. 1 intake. If possible, for clarity, please include at least five seeds in each particle trace plot. It is our understanding that generating these plots will not necessitate new production runs.*

FirstLight's 5/31/2016 Response:

We agree to generate the additional particle trace plots and will include them in the addendum.

Addendum Response:

Particle trace plots for the flows in the Station No. 1 Power Canal and Forebay under Scenario 1-1 are shown in Figures 2.4-1 and 2.4-2, respectively. Particle trace plots for the Station No. 1 Power Canal and Forebay under Scenario 1-2 are shown in Figures 2.4-3 and 2.4-4, respectively. Particle trace plots for the Station No. 1 Power Canal and Forebay under Scenario 1-3 are shown in Figures 2.4-5 and 2.4-6, respectively.

An overview particle trace plot for the Cabot Station Forebay under Scenario 3-1 is shown in Figure 2.4-7, and a close-up view of the intake racks under the same scenario is shown in Figure 2.4-8. An overview particle trace plot for the Cabot Station Forebay under Scenario 3-2 is shown in Figure 2.4-9, and a close-up view of the intake racks under the same scenario is shown in Figure 2.4-10. An overview particle trace plot for the Cabot Station Forebay under Scenario 3-3 is shown in Figure 2.4-11, and a close-up view of the intake racks under the same scenario is shown in Figure 2.4-12.

2.5 USFWS-5 Fishway Entrance Velocity

Comment: *The Service evaluates fishway attraction in the context of location, flow, and velocity. While fishway entrance locations are known and flows from the existing fishways were fixed at 318 and 368 cfs, modeled velocities at the entrances (for which the Service has established criteria) are unknown. We request that FL provide tables for all scenarios (involving fishways) that include average entrance velocity as well as the other scenario parameters (i.e., scenario number, station discharge, fishway discharge, total flow).*

FirstLight's 5/31/2016 Response:

We will generate the requested tables and will include them in the addendum.

Addendum Response:

As agreed to in FirstLight's May 2016 response letter, the requested tables have been generated. Related to the bed roughness findings response in Section 2.2, these runs reflect the hydraulically smooth bed model results. Average entrance velocities were calculated by taking the modeled WSE inside of the ladder for each production run, calculating the height above the fixed weir crest (104.5 at the Cabot fishway, 133.6 ft at the Spillway Fishway), and multiplying by the combined entrance gate opening (8 ft for both ladders – each has two 4-ft gates) to get the flow area. Assuming equal flow through both of the gates, the average entrance velocity was then calculated as the modeled ladder flow (368 cfs at the Cabot fishway, 318 cfs at the Spillway Fishway) divided by the calculated water area. The results of this analysis are shown in Table 2.5-1 and Table 2.5-2.

As previously mentioned in the original report, in practice the fishways are not operated for a fixed flow as we have assumed here. The fishways operate with a fixed entrance gate opening of 133.6 ft NGVD29 for the spillway fishway and 104.5 ft NGVD29 for the Cabot fishway, and the flow is continuously adjusted automatically (based on real-time water depth sensors) to maintain a 1-foot differential between the tailrace water surface elevation and the water surface elevation just inside of each fishway entrance gate. This may create noticeable difference between the modeled results and field conditions under some flow conditions. We recommend modifying this assumption if the model is used to inform potential design changes inside the fishway or at/near the fishway entrance.

Table 2.5-1: Average fishway entrance velocities for each Cabot fishway model scenario. Water surfaces on the outside of the fishways are shown for reference.

Model Scenario	Cabot Station Total Flow (cfs)	Bypass Flow (cfs)	Total Reach Flow (cfs)	Cabot Fishway Flow (cfs)	WSE inside of fishway entrance gate (ft NGVD29)	WSE outside of fishway entrance gate (ft NGVD29)	Head Differential (ft)	Flow Area (ft^2)	Average Entrance Velocities (fps)
5-1	1,700	400	2,468	368	111.5	108.5	2.0	56.0	6.6
5-2	7,500	400	8,268	368	112.4	110.7	1.7	63.2	5.8
5-3	13,728	400	14,496	368	113.6	112.6	1.0	72.8	5.1
5-4	13,728	6,501	20,597	368	115.0	114.3	0.7	84.0	4.4
5-5	13,728	16,240	30,336	368	117.7	117.3	0.4	105.6	3.5

Table 2.5-2: Average fishway entrance velocities for each Spillway fishway model scenario. Water surfaces on the outside of the fishways are shown for reference.

Model Scenario	Bascule Gate 1 Flow (cfs)	Other Bascule Gate Flow (cfs)	Tainter Gate Flow (cfs)	Spillway Fishway Flow (cfs)	WSE inside of fishway entrance gate (ft NGVD29)	WSE outside of fishway entrance gate (ft NGVD29)	Head Differential (ft)	Flow Area (ft^2)	Average Entrance Velocities (fps)
6-1	400	0	0	318	137.9	136.4	1.5	34.4	9.2
6-2	4,341	0	0	318	139.3	138.7	0.6	45.6	7.0
6-3	7,500	6,580	0	318	141.5	140.9	0.6	63.2	5.0
6-4	7,500	12,460	10,000	318	142.2	142.6	0.4	68.8	4.6

2.6 USFWS-6 Station No. 1 Pass-Through Flow

Comment: *Starting on pg. 7-1, scenarios 1-x indicate a high degree of fluctuation in the canal pass-through flow. Is this simply because the pass-through flow was modeled as a pressure boundary (under which some variation is understandable) or is this indicative of a more serious convergence problem that would add uncertainty to the results, or is it something else altogether? In the interest of improving confidence in the model, we request that FL briefly expand the explanation of this variability.*

FirstLight's 5/31/2016 Response:

We do not believe that there is a convergence problem with the model. While the magnitude of the fluctuation in the pass-through flows is somewhat high, as a percentage of the total pass-through flows, the volume of fluid in the model is quite stable, and the magnitude of fluctuation is small compared to the flow rates in the rest of the domain. The fluctuations are the result of the pressure boundary used at the pass-through outlet to maintain a fixed tailwater elevation in the canal. The canal inlet and turbine flows are constant, and as a result the velocities in front of the intake racks (most important location) are stable. The variation in the pass-through flows is not believed to affect the results in front of the racks. We will expand on the explanation in the addendum.

Addendum Response:

We do not believe that there is a convergence problem with the model. While the magnitude of the fluctuation in the pass-through flows is somewhat high, as a percentage of the total pass-through flows, the volume of fluid in the model is quite stable, and the magnitude of fluctuation is small compared to the flow rates in the rest of the domain. The fluctuations are the result of the pressure boundary used at the pass-through outlet to maintain a fixed tailwater elevation in the canal.

The canal inlet and turbine flows are constant, and as a result, the velocities in front of the intake racks (most important location) are stable. The variation in the pass-through flows is not believed to affect the results in front of the racks. The fluctuations decreased as the model ran, but the run was stopped after 9,960 seconds as the model was stable enough to assess the velocities in the model as they relate to fish passage, particularly in front of the intake racks.

To further assess the magnitude of fluctuations, the canal pass-through flows were compared to the wetted area of the canal to determine the average velocity fluctuation. With a wetted area of approximately 2,963 square feet and a maximum fluctuation of 83 cfs, the maximum calculated velocity fluctuation is approximately 0.03 fps. We do not believe that this level of velocity fluctuation at the outlet impacts the study objectives.

2.7 USFWS-7 Cabot Fishway CFD Model Bypass Flow

Comment: *Similar to the concerns raised in the section above, we have concerns regarding fluctuations in the bypass flow as described on pg. 7-6. Please provide an explanation on these fluctuations as requested above.*

FirstLight's 5/31/2016 Response:

We do not believe that there is a convergence problem with the model and will provide an explanation in the addendum.

Addendum Response:

We do not believe that there is a convergence problem with the model. Each model run was stopped when we believed the model was stable enough to assess velocities throughout the study area. Table 2.7-1 is an expanded version of the study report's Table 7.3.1-2, though it also includes results for all five production runs. In addition to flow fluctuations, it shows wetted area and average velocity fluctuations over the final 600 seconds of simulation time. The results show that while flow fluctuations and resulting velocity fluctuations appear to change considerably as a percentage of flow, the absolute differences result in velocity swings of approximately ±0.5 fps at even the most sensitive flow baffle (Upper Left Channel).

Table 2.7-1: Flow Stability Results for the final 600 seconds of each Cabot Fishway production run.

PR 5-1									
	Flow (cfs)			Area (sq. ft)			Velocity (fps)		
Location	Avg.	2.5% Exc.	97.5% Exc.	Avg.	2.5% Exc.	97.5% Exc.	Avg.	2.5% Exc.	97.5% Exc.
Bypass Upstream	400	426	376	2,448	2,454	2,442	0.16	0.17	0.15
Bypass Downstream	399	446	354	1,780	1,785	1,776	0.22	0.25	0.20
Upper Left Channel	320	536	56	441	481	411	0.72	1.18	0.13
Upper Right Channel	17	43	-9	100	102	96	0.17	0.41	-0.09
Cabot Powerhouse	1,700	1,700	1,700	2,604	2,604	2,603	0.65	0.65	0.65
Cabot Fishway	368	368	368	107	108	107	3.43	3.43	3.42
Lower Left Channel	2,349	2,442	2,270	339	366	313	6.93	7.39	6.40
Lower Right Channel	16	26	6	94	95	93	0.17	0.27	0.06
Outflow	2,618	2,752	2,498	1,184	1,189	1,176	2.21	2.32	2.12
PR 5-2									
	Flow (cfs)			Area (sq. ft)			Velocity (fps)		
Location	Avg.	2.5% Exc.	97.5% Exc.	Avg.	2.5% Exc.	97.5% Exc.	Avg.	2.5% Exc.	97.5% Exc.
Bypass Upstream	400	445	358	2,651	2,655	2,647	0.15	0.17	0.14
Bypass Downstream	401	454	344	1,978	1,983	1,974	0.20	0.23	0.17
Upper Left Channel	71	131	8	891	915	871	0.08	0.14	0.01
Upper Right Channel	130	165	101	114	117	110	1.14	1.41	0.90
Cabot Powerhouse	7,500	7,500	7,500	2,607	2,607	2,607	2.88	2.88	2.88
Cabot Fishway	368	369	367	120	120	120	3.06	3.07	3.05
Lower Left Channel	7,870	7,917	7,828	1,017	1,022	1,014	7.74	7.77	7.69
Lower Right Channel	77	271	-129	403	434	379	0.18	0.65	-0.33
Outflow	7,914	8,185	7,661	2,721	2,735	2,706	2.91	3.01	2.82
PR 5-3									
	Flow (cfs)			Area (sq. ft)			Velocity (fps)		
Location	Avg.	2.5% Exc.	97.5% Exc.	Avg.	2.5% Exc.	97.5% Exc.	Avg.	2.5% Exc.	97.5% Exc.
Bypass Upstream	400	529	279	3,084	3,100	3,067	0.13	0.17	0.09
Bypass Downstream	401	639	164	2,407	2,421	2,395	0.17	0.27	0.07
Upper Left Channel	247	862	-142	1,566	1,616	1,508	0.16	0.54	-0.09
Upper Right Channel	198	318	71	210	233	191	0.95	1.48	0.33
Cabot Powerhouse	13,845	13,846	13,844	2,608	2,608	2,608	5.31	5.31	5.31
Cabot Fishway	368	370	366	137	138	137	2.68	2.70	2.66
Lower Left Channel	14,080	14,267	13,869	1,891	1,923	1,864	7.44	7.55	7.31
Lower Right Channel	480	654	227	887	899	877	0.54	0.73	0.26
Outflow	14,575	14,972	14,089	4,503	4,518	4,491	3.24	3.33	3.13

Table 2.7-1 (cont): Flow Stability Results for the final 600 seconds of each Cabot Fishway production run.

PR 5-4									
	Flow (cfs)			Area (sq. ft)			Velocity (fps)		
Location	Avg.	2.5% Exc.	97.5% Exc.	Avg.	2.5% Exc.	97.5% Exc.	Avg.	2.5 % Exc.	97.5% Exc.
Bypass Upstream	6,501	6,527	6,466	3,745	3,751	3,740	1.74	1.74	1.73
Bypass Downstream	6,501	6,580	6,438	3,140	3,147	3,136	2.07	2.10	2.05
Upper Left Channel	4,495	4,573	4,429	2,363	2,369	2,358	1.90	1.93	1.87
Upper Right Channel	2,002	2,052	1,955	839	845	833	2.39	2.46	2.32
Cabot Powerhouse	13,855	13,855	13,855	2,607	2,607	2,607	5.31	5.31	5.31
Cabot Fishway	367	369	365	158	158	157	2.33	2.35	2.32
Lower Left Channel	16,927	17,010	16,864	2,906	2,912	2,899	5.82	5.85	5.80
Lower Right Channel	3,700	3,803	3,583	1,320	1,327	1,312	2.80	2.88	2.72
Outflow	20,587	20,746	20,474	5,985	5,990	5,979	3.44	3.47	3.42

PR 5-5									
	Flow (cfs)			Area (sq. ft)			Velocity (fps)		
Location	Avg.	2.5% Exc.	97.5% Exc.	Avg.	2.5% Exc.	97.5% Exc.	Avg.	2.5 % Exc.	97.5% Exc.
Bypass Upstream	16,240	16,260	16,219	4,709	4,717	4,701	3.45	3.46	3.44
Bypass Downstream	16,239	16,309	16,169	4,218	4,226	4,208	3.85	3.87	3.83
Upper Left Channel	9,450	9,697	9,208	3,653	3,666	3,640	2.59	2.66	2.52
Upper Right Channel	6,781	6,965	6,475	1,830	1,848	1,813	3.71	3.82	3.55
Cabot Powerhouse	13,855	13,856	13,855	2,607	2,607	2,607	5.31	5.31	5.31
Cabot Fishway	368	371	365	197	198	197	1.87	1.88	1.85
Lower Left Channel	22,502	22,638	22,282	4,359	4,376	4,350	5.16	5.20	5.09
Lower Right Channel	7,828	8,058	7,534	1,987	1,998	1,978	3.94	4.06	3.79
Outflow	30,349	30,514	30,075	8,214	8,218	8,210	3.69	3.71	3.66

2.8 NMFS-2 Hydraulically Smooth Surfaces

Comment: *We understand the pragmatism of this assumption but this assumption is not valid for most bathymetric surfaces, particularly in areas with jagged ledge outcroppings which are found throughout the model domains. A sensitivity analysis should be conducted to evaluate the potential effect of this assumption on computed water surface elevations and water column velocities.*

FirstLight's 5/31/2016 Response:

As part of the addendum we are conducting a sensitivity analysis for the Cabot Fishway Entrance model to evaluate the effect this assumption has on the water levels and velocities and will include the results in the addendum.

Addendum Response:

See Section 2.2 for our response to USFWS-2. FirstLight agreed to conduct a bed roughness sensitivity analysis on the Cabot Fishway model, and has described the results. We found a moderate difference in results between the hydraulically smooth vs. roughened bed models. We will consult with NMFS and USFWS regarding the implications of our findings.

2.9 NMFS-3 Supplemental Bathymetric Data Collection

Comment: *Add text to clarify the extent/scope of this data. The report should make it clear whether the data consisted only of bathymetric survey point or if additional ADCP velocity measurements were also collected. What were the flow conditions in the river during this supplemental data collection? Can the collected ADCP data from Study No. 3.3.1 be used as another verification run?*

FirstLight's 5/31/2016 Response:

The addendum will clarify the extent and scope of the supplemental bathymetry data. The supplemental data was a combination of survey data collected via RTK-GPS and total station (i.e., bathymetry points only) and bathymetric depths collected via a boat using an ADCP.

The boat-collected bathymetric data (with the exception of a couple of transects) was collected using an ADCP, however generally when we are collecting bathymetric data, the boat speeds are much higher than recommended to collect velocity data. The downside of collecting ADCP data at higher boat speeds is that the accuracy of the velocity data is significantly degraded.

The ADCP manufacturer generally recommends that the boat travel at speeds equal to or less than the ambient river velocities to obtain accurate velocity data. Therefore when we are intending to collect velocity data, we generally keep the boat speeds targeted between 1-2 ft/s (~1 mph). When collecting only bathymetry data, the target boat speeds are usually in the 4-8 ft/s (~3-5 mph) range, which is higher than we generally prefer if using the data for water velocities. The increased boat speeds (within the range that we travel within) do not meaningfully impact the accuracy of the bathymetric data.

Additionally, because of the difficulty in coordinating flow releases, the bathymetry data were collected under a wide range of flows and under conditions that were not necessarily stable. When collecting water velocity data for this study and Study 3.3.1 we were careful to allow enough time (up to 1-2 hours) for the river to stabilize before collecting velocity data. This was not the case when we were collecting bathymetric data.

There are 2-3 transects collected at other flows for velocity purposes within the study area that could potentially be used for additional verification. As noted in our response below however, FL does not believe additional model verification efforts are within the scope specified in the RSP.

Addendum Response:

As noted in FirstLight's initial response, the supplemental bathymetry data was a combination of survey data collected via RTK-GPS and total station (i.e., bathymetry points only), plus bathymetric depths collected via a boat using an ADCP.

We noted that while most of the ADCP data were collected at boat speeds higher than what is recommended for velocity data collection (velocity data quality degrades at higher boat speeds, while bathymetric quality is less sensitive to higher boat speeds), there were 2-3 velocity transects collected in the vicinity of Cabot Station as part of the IFIM study (Study 3.3.1) at a different flow that may be sufficient for additional model validation, if FirstLight is required to do so. The dates and flows conditions associated with the additional suitable velocity data are summarized below.

4) 7/23/2014 – these data could potentially be used as a new validation run
    a. Bypass Flow: 285 cfs
    b. Log Sluice: 0 cfs
    c. Fishway Flow: 0 cfs
    d. Cabot Flow: 8,067 cfs
5) 8/6/2014 – this was already used for the first validation flow
    a. Bypass Flow: 625 cfs
    b. Log sluice: 184 cfs
    c. Fishway Flow: 368 cfs
    d. Cabot Station: 4,052 cfs
6) 8/28/2014 – these data are a near-repeat of the 8/6/2014 flow conditions
    a. Bypass Flow: 882 cfs
    b. Log sluice: 0 cfs
    c. Fishway Flow: 0 cfs
    d. Cabot Flow: 4,574 cfs

Of those dates, only the 7/23/2014 data is collected at a flow that is substantially different than the existing validation run. Figure 2.9-1 shows the approximate location of the supplemental ADCP data, as well as which data points may be used for velocity data.

2.10 NMFS-4 Intake Racks

Comment 1: *The Station No. 1 Forebay CAD model includes the power canal and forebay walls, trash boom and intake structures up to and including the penstocks. Based on our conference call with the Licensee's consultant on March 31, 2016, we understand that the intake racks including the bars were not physically included in the model structures. Please clarify.*

FirstLight's 5/31/2016 Response 1:

It is correct that the intake racks are not in the model. They were included in the figures for reference, but we agree that it is not as clear as it could be that they are not in the models. We will clarify the status of the intake racks in the text and add annotation to the figures indicating that the intake racks were not modeled in the addendum.

Addendum Response 1:

It is correct that the intake racks are not in the Station No. 1 Forebay model. The intake racks and bars are shown in the figures for reference but were not included in the model.

Comment 2: *The Cabot Station Forebay CAD model consists of the forebay and power canal walls, log sluice, fish weir and intake structures, including the intake racks and penstocks. Based on our conference call with the Licensee's consultant on March 31, 2016, we understand that the intake racks including the bars were not physically included in the model structures. Please clarify.*

FirstLight's 5/31/2016 Response 2:

It is correct that the intake racks are not in the model. They were included in the figures for reference, but we agree that it is not as clear as it could be that they are not in the models. We will clarify the status of the intake racks in the text and add annotation to the figures indicating that the intake racks were not modeled in the addendum.

Addendum Response 2:

It is correct that the intake racks are not in the Cabot Forebay model. The intake racks and bars are shown in the figures for reference but were not included in the model.

Comment 3: *The log boom is depicted in the figure, but there is no discussion of how the floating log boom is accounted for in the model.*

FirstLight's 5/31/2016 Response 3:

A discussion of how the log boom is included in the model will be included in the addendum.

Addendum Response 3:

The log boom in the Cabot Station model is modeled as a fixed object. Based on discussion with FirstLight staff the 4 foot tall log boom floats with approximately 3 feet below the water surface and 1 foot above. Because the water level in the Canals and Forebay do not fluctuate significantly during the scenarios modeled, assuming that the log boom is fixed is a reasonable assumption. Modeling the boom as a floating object would have further increased the model runtimes.

2.11 NMFS-5 Verification Run

Comment: *The verification run for the Cabot Station forebay is inadequate. The verification run involved Unit 1, 5, and 6 operating for a total discharge of 6,684 cfs (not including the log sluice at 1,290 cfs). The production runs to evaluate existing conditions at the power house involved Cabot Station flow at 1,700 cfs, 7,500 cfs, and 13,728 cfs with 200 cfs flowing over the fish weir down the log sluice. Therefore, the verification run does not appropriately validate the production runs with the exception of Scenario 3-2 (though different units were generating). In addition, the verification run does not account for discharge over the fish weir, the log boom emergency gate, or the attraction flow emergency gate. A more comprehensive verification approach would have been to collect field data at station capacity and minimum flow with all appropriate gates and weirs set to reflect conditions when downstream passage is occurr*ing.

FirstLight's 5/31/2016 Response:

We believe that the selected verification run was appropriate. The methodology and flow rates to be used during field collection were not specified in the RSP. The verification run was conducted for a mid-range flow between the minimum production run flow (1 unit generating) and the maximum production run flow (all units generating). The verification run was intended to verify the model under a single condition, not under every production model run scenario.

The log boom emergency gate and the attraction flow emergency gate were not in the production runs per the RSP.

FERC Determination:

FirstLight conducted the study as required by the approved study plan; however, FirstLight's model verification using only a single run at a mid-range flow does not demonstrate that the models are accurate across the entire range of flows that were modeled. In addition, FirstLight's verification of the Cabot Station forebay and powerhouse model when only the powerhouse is operating does not demonstrate that the model is reliable or accurate for modeling scenarios with flows being released through the existing fish weir, log boom emergency gate, and attraction flow emergency gate. Therefore, we recommend that FirstLight either conduct the additional verification testing requested by NMFS or provide other details or information that demonstrate that the models are reliable over the entire range of modeled flows, including scenarios where the existing fish weir, log boom emergency gate, and attraction flow emergency gate are operating.

Addendum Response:

FirstLight previously noted that we believe the additional validation runs requested by NMFS for the Station No. 1 forebay, the Cabot Station forebay, and the Cabot fishway model would not contribute to the understanding of the hydraulics in those areas.

In the case of the Station No. 1 forebay and Cabot forebay models, no additional velocity datasets exist beyond what has been previously discussed to further validate the model. The power canal operates at a nearly fixed water surface elevation, so it is not clear what an additional validation run (or calibration adjustments) would do to meaningfully change the model results beyond evaluating the velocity distribution within the nearly-fixed cross-sectional area of the canal.

While FirstLight disagrees on the merits of conducting further validation for the Cabot fishway/tailrace model, we have identified two additional data sources that may assist in further validating the model results if we are so directed. The first dataset is using water level logger data that we collected as part of Study 3.3.1 to check modeled water surface elevations. The location of the eight loggers was shown in Figure 2.2-1 as part of the channel roughness discussion in Section 2.2. The second data source is using velocity data collected at transects near Cabot Station as part of Study 3.3.1. This transect is shown in Figure 2.9-1. While there are many velocity transects collected as part of the supplemental data collection, only two or three of the transects close to Cabot Station are clearly within the Cabot fishway detailed study area. These data are discussed in response to NMFS-3 (Section 2.11). While the amount of supplemental water level and velocity data is not as detailed as the existing validation run, it does potentially cover a much larger range of flow conditions up to and greater than Cabot Station's flow capacity.

FirstLight is not proposing to conduct additional model verification. We believe that additional data collection and verification runs does not further inform our understanding of the study reach, and is not justified given the high level of effort associated with additional field collection, modeling, license fees, and analysis. FirstLight proposes to instead consult further with NMFS and USFWS to find a mutually agreeable solution that does not involve additional data collection.

2.12 NMFS-6 Verification Run (Second Comment)

Comment: [The report's] page 6-2, sixth paragraph states: *Based on a comparison of the ADCP and CFD model results it is believed that the results from the CFD model production runs are appropriate for meeting the objectives of this study.*

The visual comparison of the verification run and the measured data does look good with the exception of the cross section immediately in front of the intake racks. This is the most important area to evaluate for *this particular model. A quantitative evaluation should be completed to evaluate the validity of the verification run. We recommend developing a grid of the cross section in front of the rack with each grid representing no more than 5% of the total rack area. Calculate the average channel velocity in the grid for the measured and simulated flow and compare the results.*

FirstLight's 5/31/2016 Response:

The ADCP and CFD model results shown in the figure may need some additional explanation to help clarify what is being shown, and possibly an additional figure or two that show only the transects directly in front of the intake racks. Additional plots will be included in the addendum

Addendum Response:

A quantitative evaluation comparing the ADCP and CFD model results was not completed. It is anticipated that the instantaneous velocities collected with the ADCP unit would be somewhat higher and more scattered than the steady state average velocities generated from the CFD model.

Figures comparing the ADCP transect data to the CFD model data are provided.

Figure 2.12-1 shows the observed (ADCP) velocities for the verification run at Station 1 (top), and the simulated (CFD model) velocities for the same location (bottom).

Figure 2.12-2 shows the observed (ADCP) velocities for the verification run at 'Racks 1' at Cabot Station (top), and the simulated (CFD model) velocities for the same location (bottom). Figure 2.12-3 shows the observed (ADCP) velocities for the verification run at 'Racks 2' at Cabot Station (top), and the simulated (CFD model) velocities for the same location (bottom). Figure 2.12-4 shows the observed (ADCP) velocities for the verification run at 'Racks 3' at Cabot Station (top), and the simulated (CFD model) velocities for the same location (bottom).

2.13 NMFS-8 Flow Instabilities

Comment: *Briefly explain the flow instability in the [Cabot Fishway model] left and right, upper and lower channels.*

FirstLight's 5/31/2016 Response:

The flow instabilities in Table 7.3.1-2 [left and right, upper and lower channels, Cabot Fishway model] will be elaborated upon in the study addendum. As noted in the report, each model had a certain amount of flow oscillation. The lower-flow models generally had higher relative amounts of oscillation. The model was run for several of these oscillations until it was clear that it was not dampening out any more, at which time the model was stopped and the results were processed.

Addendum Response:

Please see the response to USFWS-7. That response includes Table 2.7-1, which further describes the channel hydraulics (flows, wetted area, and average velocity) in all of the relevant model flow baffles, including the upper left, upper right, lower left, and lower right channels. Generally the velocity fluctuations are small (± 0.25 fps) with the fluctuations in the upper left channel being slightly larger (± ~0.5 fps).

As noted in the response to USFWS-7 (Section 2.7), it appears that the sensitivity runs (Section 2.2) may alter how quickly and in what manner the model stabilizes. We propose to address outstanding model fluctuation and stability questions directly with USFWS and NMFS after concluding discussions relating to bed roughness sensitivity.

2.14 NMFS-11, Report Figures (1)

Comment: *For Figures 8.2.1-4 to 8.2.1-6; Figures 8.2.2-4 to 8.2.2-6; and Figures 8.2.3-4 to 8.2.3-6: Include additional intake rack figures to display component velocity. For figures showing approach velocity, the scale should have a maximum of 2 fps such that all approach velocities exceeding 2 fps are red. For figures showing the sweeping velocity, the color scale should be binary such that VS>VA is green and VS ⩽VA is red. The sweeping velocity figures should show directionality.*

FirstLight's 5/31/2016 Response:

An additional plot with a binary color scheme such that VS>VA is green and VS⩽VA is red will be added to the addendum.

Addendum Response:

Additional plots showing the component velocity (VS and VA) comparison in front of the intake racks with a binary color scheme such that VS>VA is green and VS⩽VA is red were generated for Scenarios 1-1, 1-2 and 1-3. Figure 2.14-1 shows the component velocity comparison for Scenario 1-1, Figure 2.14-2 shows the component velocity comparison for Scenario 1-2, and Figure 2.14-3 shows the component velocity comparison for Scenario 1-3.

2.15 NMFS-12, Report Figures (2)

Comment: *For Figures 8.3.1-3 to 8.3.1-6; Figures 8.3.2-3 to 8.3.2-6; and Figures 8.3.3-3 to 8.3.3-6: Include additional intake rack figures to display component velocity. For figures showing approach velocity, the scale should have a maximum of 2 fps such that all approach velocities exceeding 2 fps are red. For figures showing the sweeping velocity, the color scale should be binary such that VS>VA is green and VS ⩽VA is red. The sweeping velocity figures should show directionality.*

FirstLight's 5/31/2016 Response:

An additional plot with a binary color scheme such that VS>VA is green and VS⩽VA is red will be added to the addendum.

Addendum Response:

Additional plots showing the component velocity (VS and VA) comparison in front of the intake racks with a binary color scheme such that VS>VA is green and VS⩽VA is red were generated for Scenarios 3-1, 3-2 and 3-3. Figure 2.15-1 shows the component velocity comparison for Scenario 3-1, Figure 2.15-2 shows the component velocity comparison for Scenario 3-2, and Figure 2.15-3 shows the component velocity comparison for Scenario 3-3.

2.16 NMFS-13, Report Figures (3)

Comment: *For Figure 8.3.1-6; Figure 8.3.2-6; and Figure 8.3.3-6: Include profile views from the forebay across the fish weir to the boundary condition of the model showing acceleration and velocity.*

FirstLight's 5/31/2016 Response:

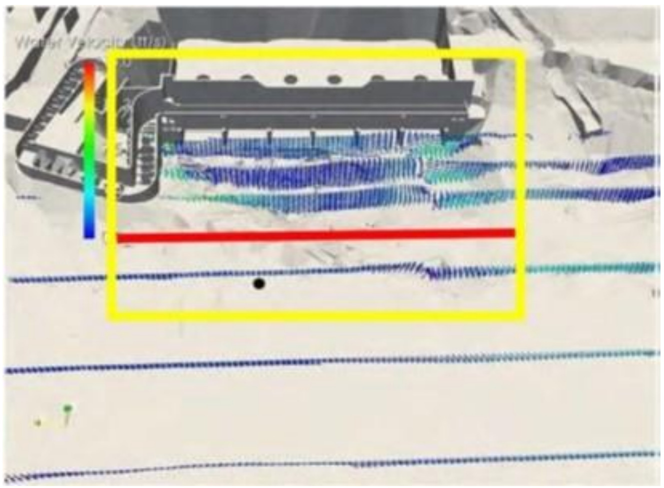
An additional plot across the fish weir to the boundary condition of the model showing velocity will be included in the addendum.

Addendum Response:

Figure 2.16-1 shows a velocity profile across the fish weir for Scenario 3-1, Figure 2.16-2 shows a velocity profile across the fish weir for Scenario 3-1, and Figure 2.16-3 shows a velocity profile across the fish weir for Scenario 3-3. The velocity profiles extend across the fish weir and extend downstream to the downstream end of the 0.5 foot mesh block (mesh block 3). The profiles do not extend to the downstream boundary because the model was not developed to model flows below the fish weir. Below the 0.5 foot mesh block the water is shallow compared to the mesh cell size such that the fluid fraction is less than 0.5 in many of the cells making it in inappropriate to extract results in this area. The fish weir serves as the control section for the water leaving the forebay.

2.17 NMFS-14, Report Figures (4)

Comment: For Production Runs 5-1 through 5-5: Figure 1 shows the area to be revised for several figures in the report whereby each of these types of figures should be zoomed into the yellow box and another cross section at the red line should be added.

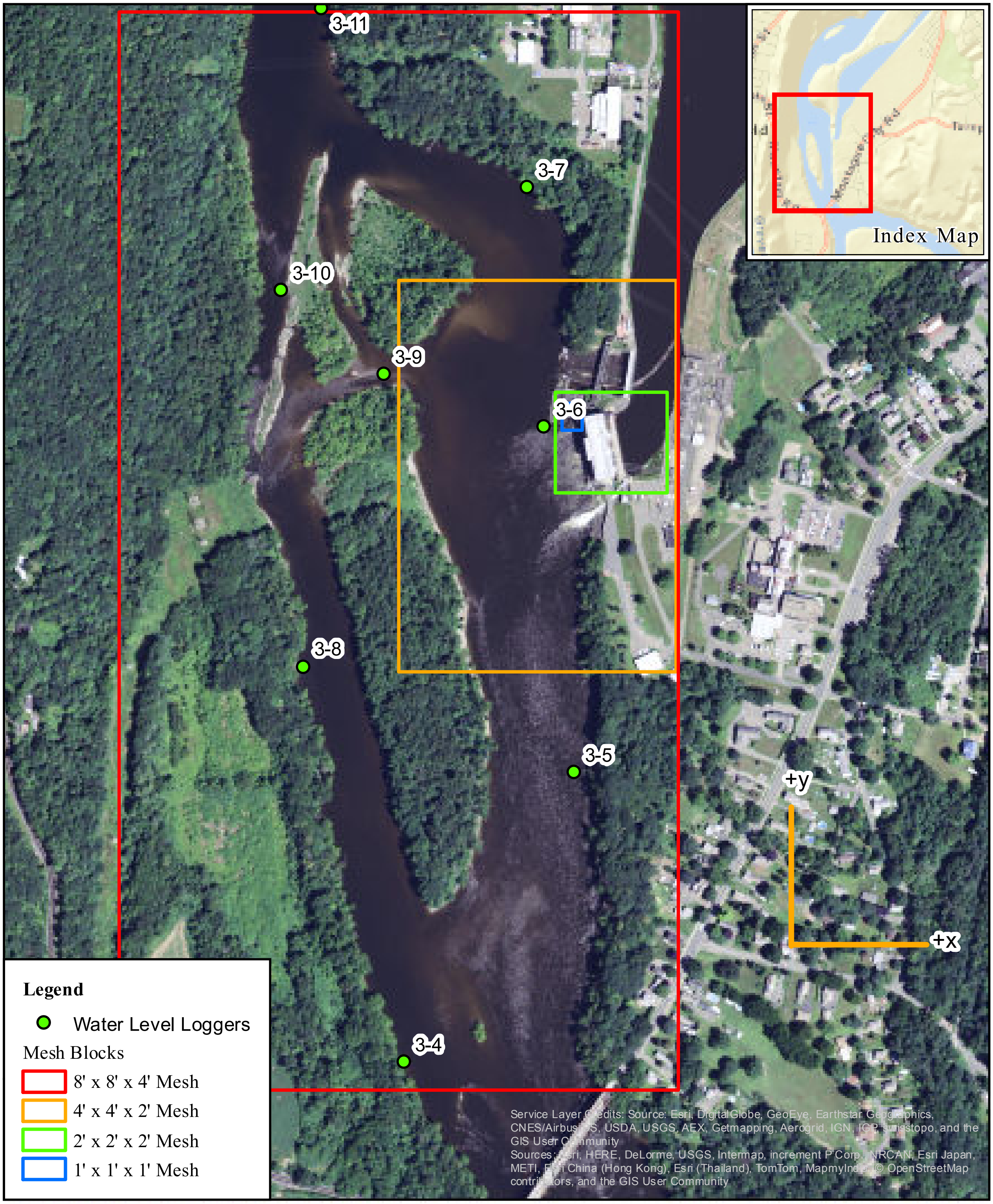


FirstLight's 5/31/2016 Response:

These type of figures will be modified as requested in the study addendum.

Addendum Response:

These figures have been generated and are shown in Figures 2.17-1 through 2.17-10.



FirstLight Power Resources

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

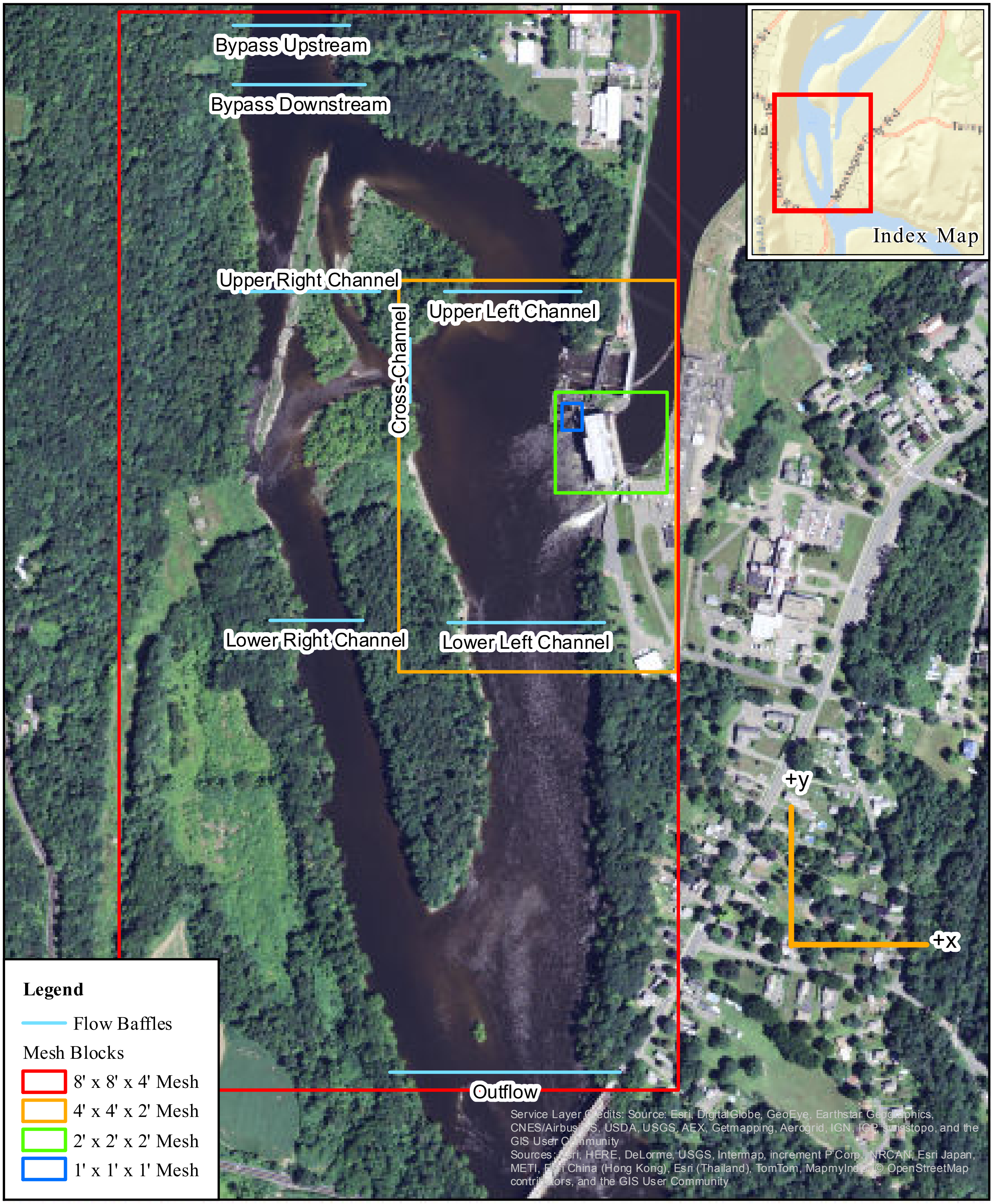
RELICENSING STUDY 3.3.8

N

0 100 200 400 Feet

Figure 2.2-1: Water level logger and comparison points in the Cabot Fishway model area.

Path: W:\gis\studies\3_3_08\maps\Figures\Addendum_Oct_2016\Cabot Fishway WSE Points.mxd



FirstLight Power Resources

N

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

RELICENSING STUDY 3.3.8

0 100 200 400 Feet

Figure 2.2-2: Flow baffles in the Cabot Fishway model area.

Path: W:\gis\studies\3_3_08\maps\Figures\Addendum_Oct_2016\Cabot Fishway Baffle Locations_F2.2-2.mxd

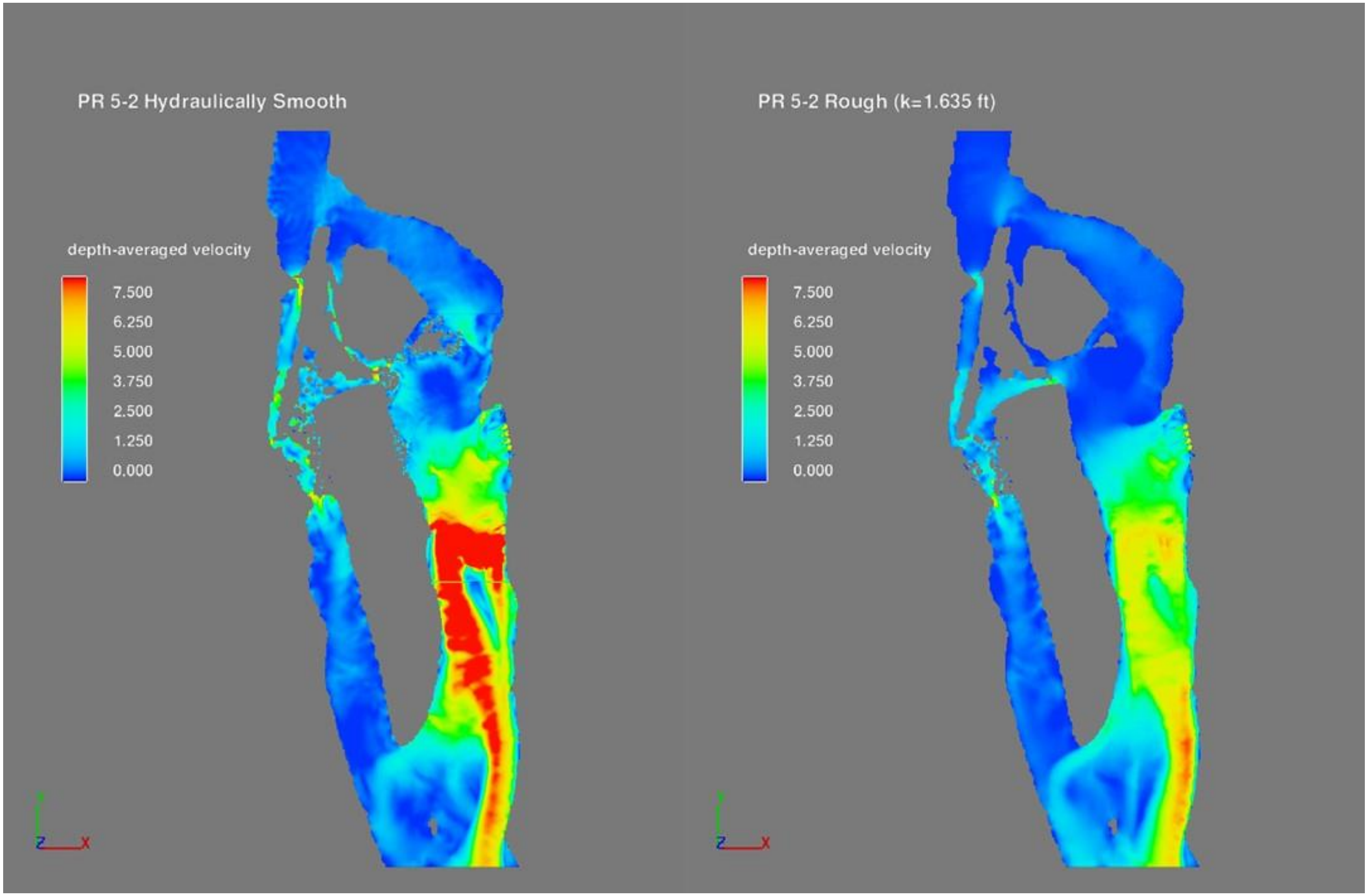


Figure 2.2-3: Comparison of depth-averaged water velocities between the two sensitivity analysis model runs

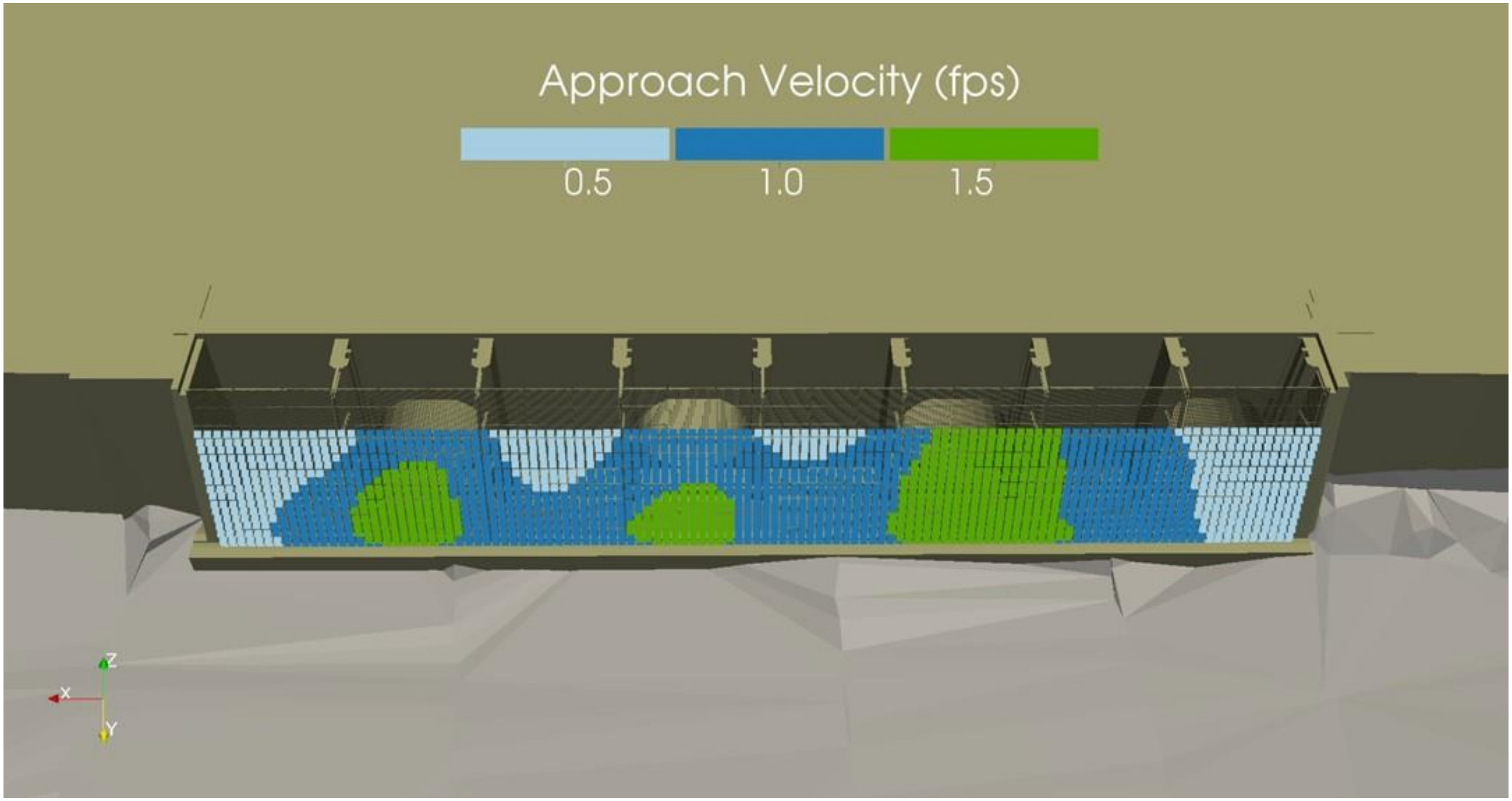


Figure 2.3-1: Station No. 1 Scenario 1-1 Intake Rack Approach Velocity

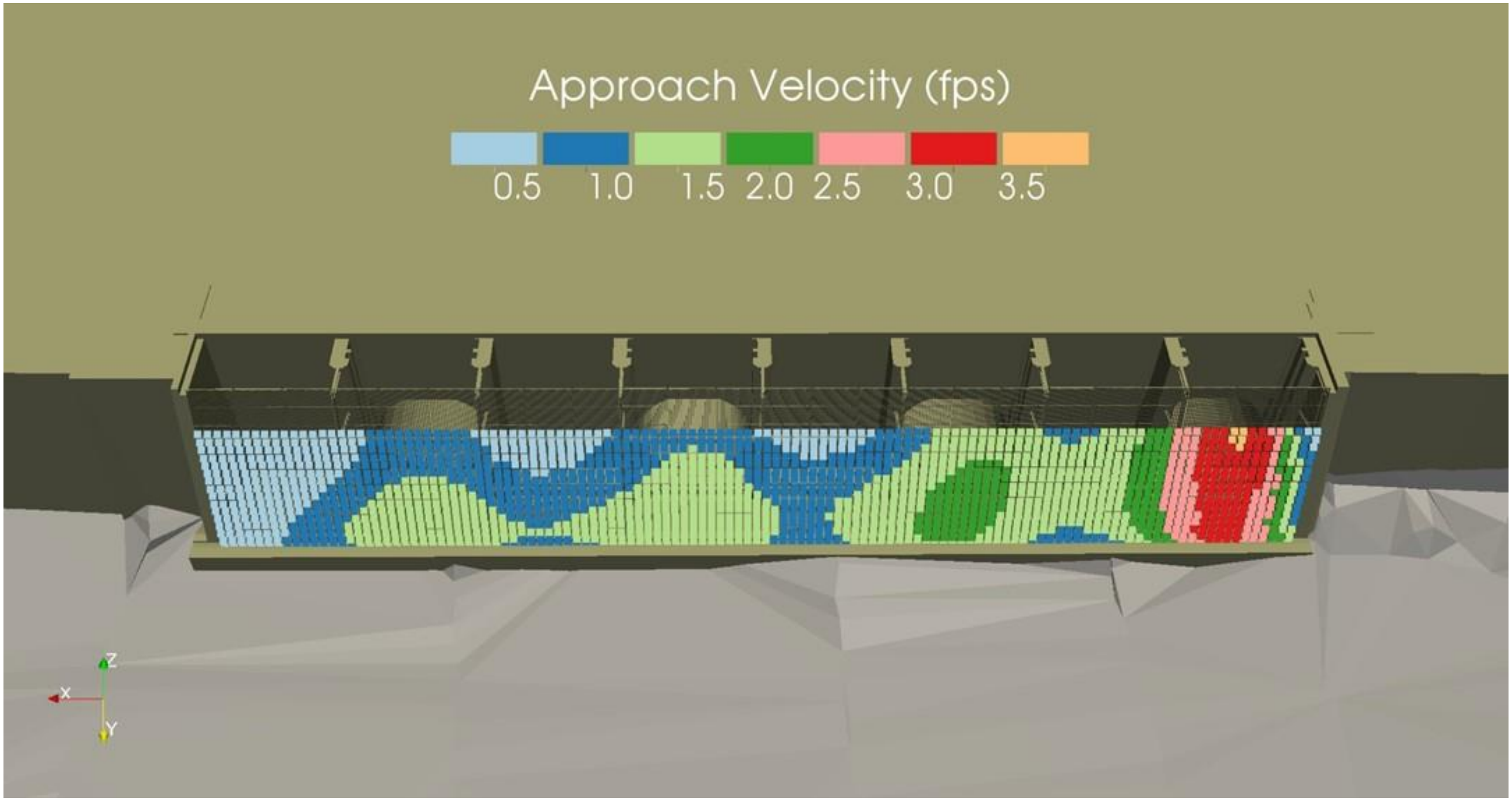


Figure 2.3-2: Station No. 1 Scenario 1-2 Intake Rack Approach Velocity

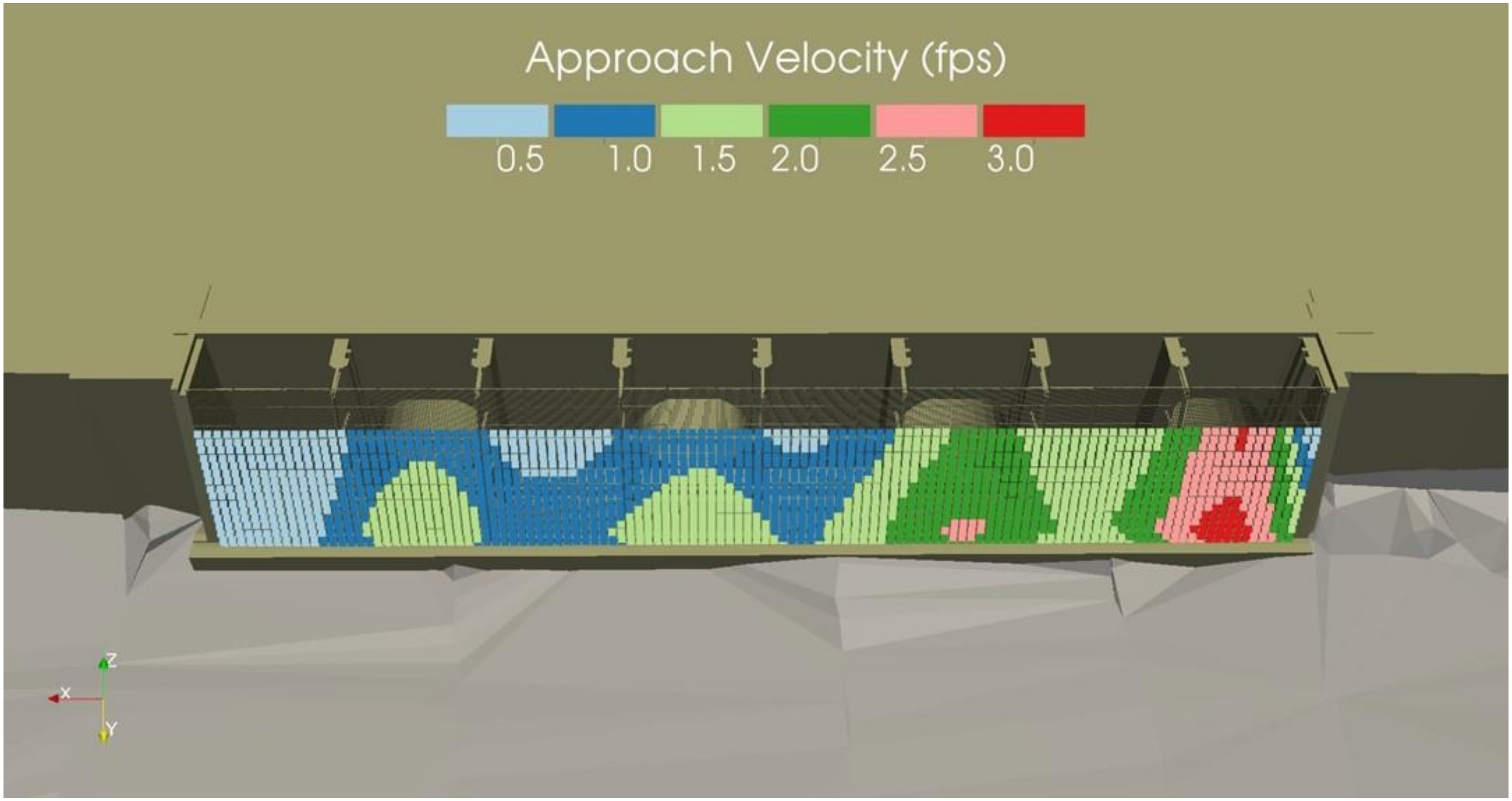


Figure 2.3-3: Station No. 1 Scenario 1-3 Intake Rack Approach Velocity

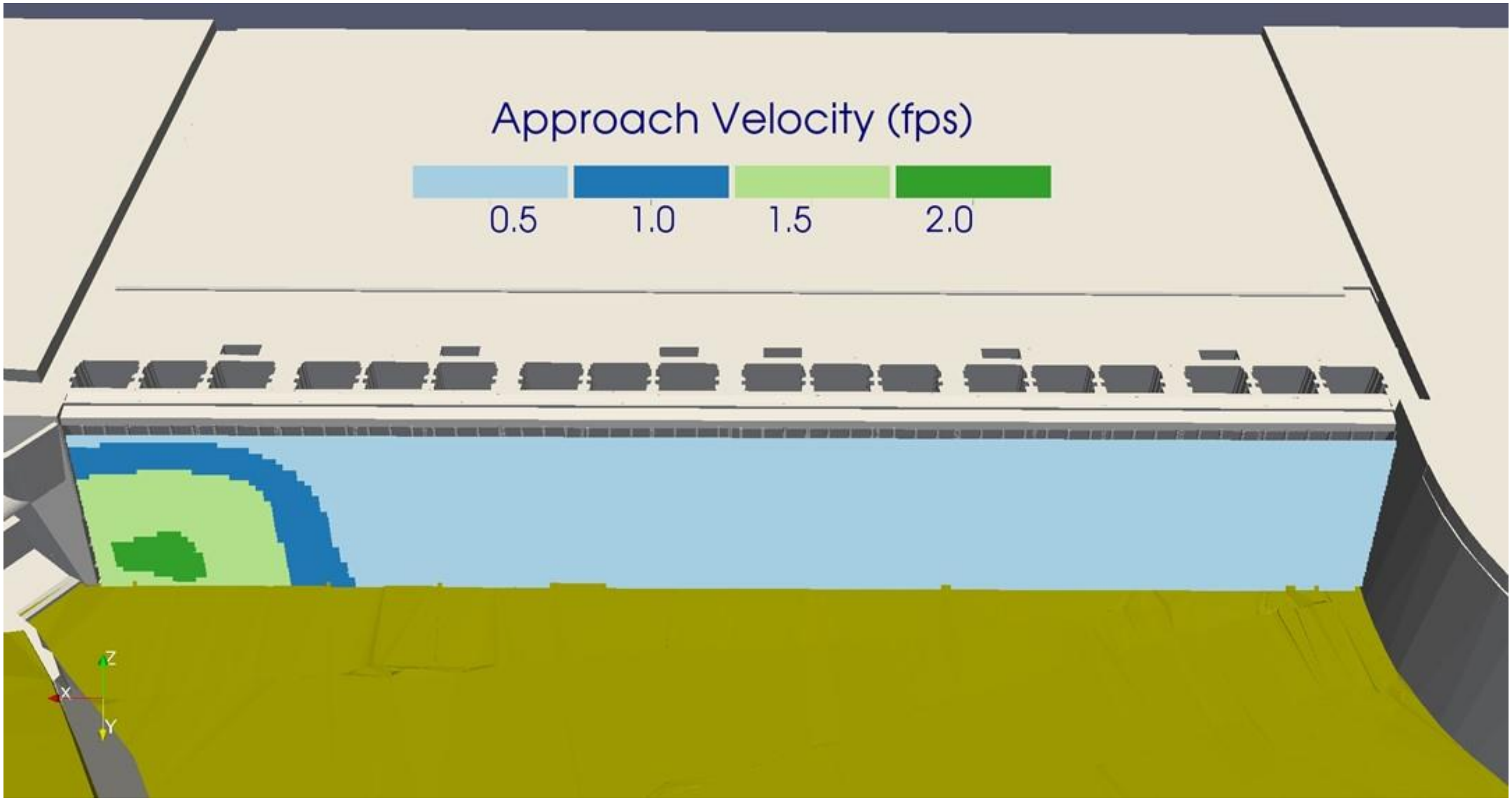


Figure 2.3-4: Cabot Station Scenario 3-1 Intake Rack Approach Velocity

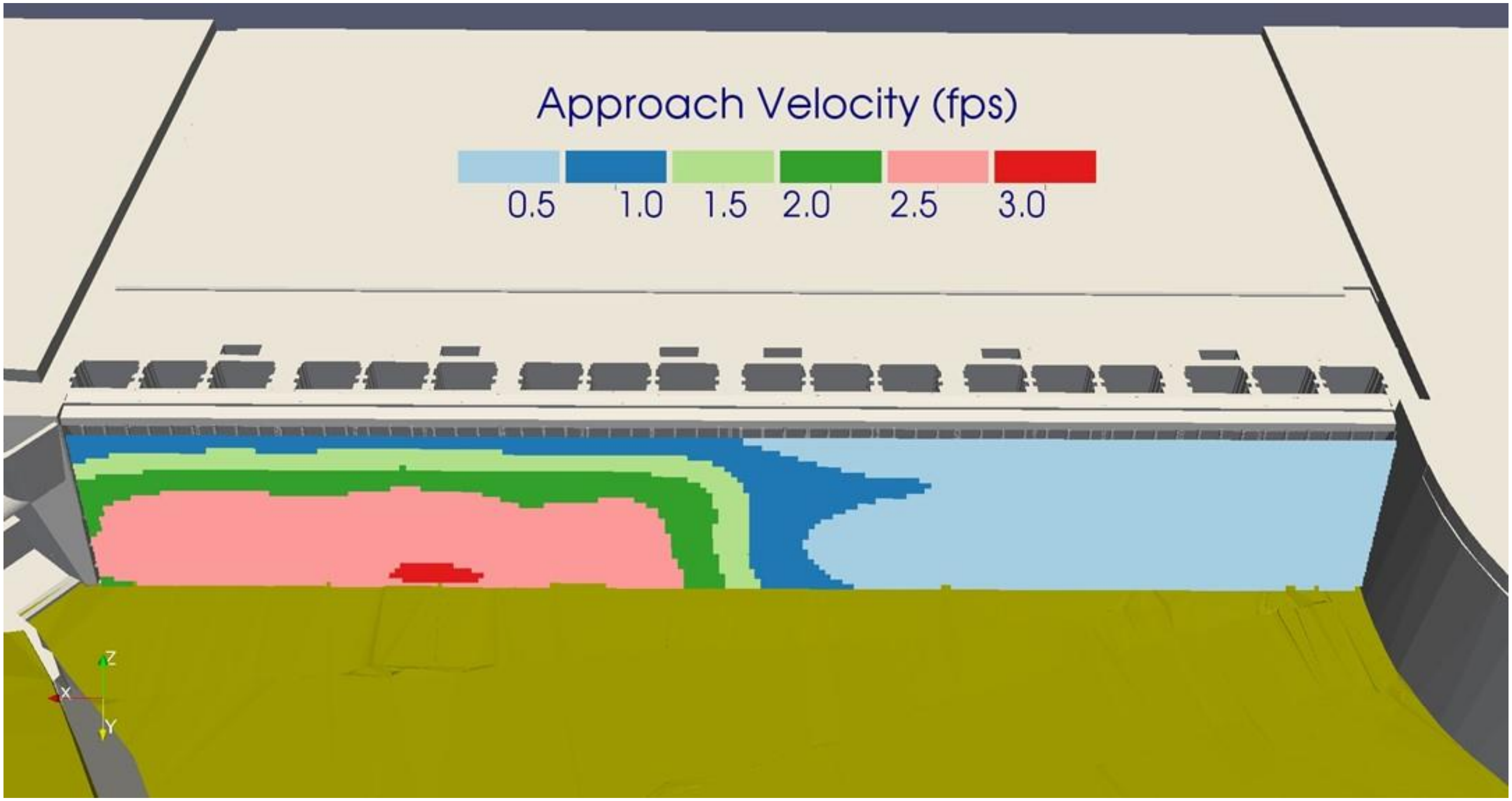


Figure 2.3-5: Cabot Station Scenario 3-2 Intake Rack Approach Velocity

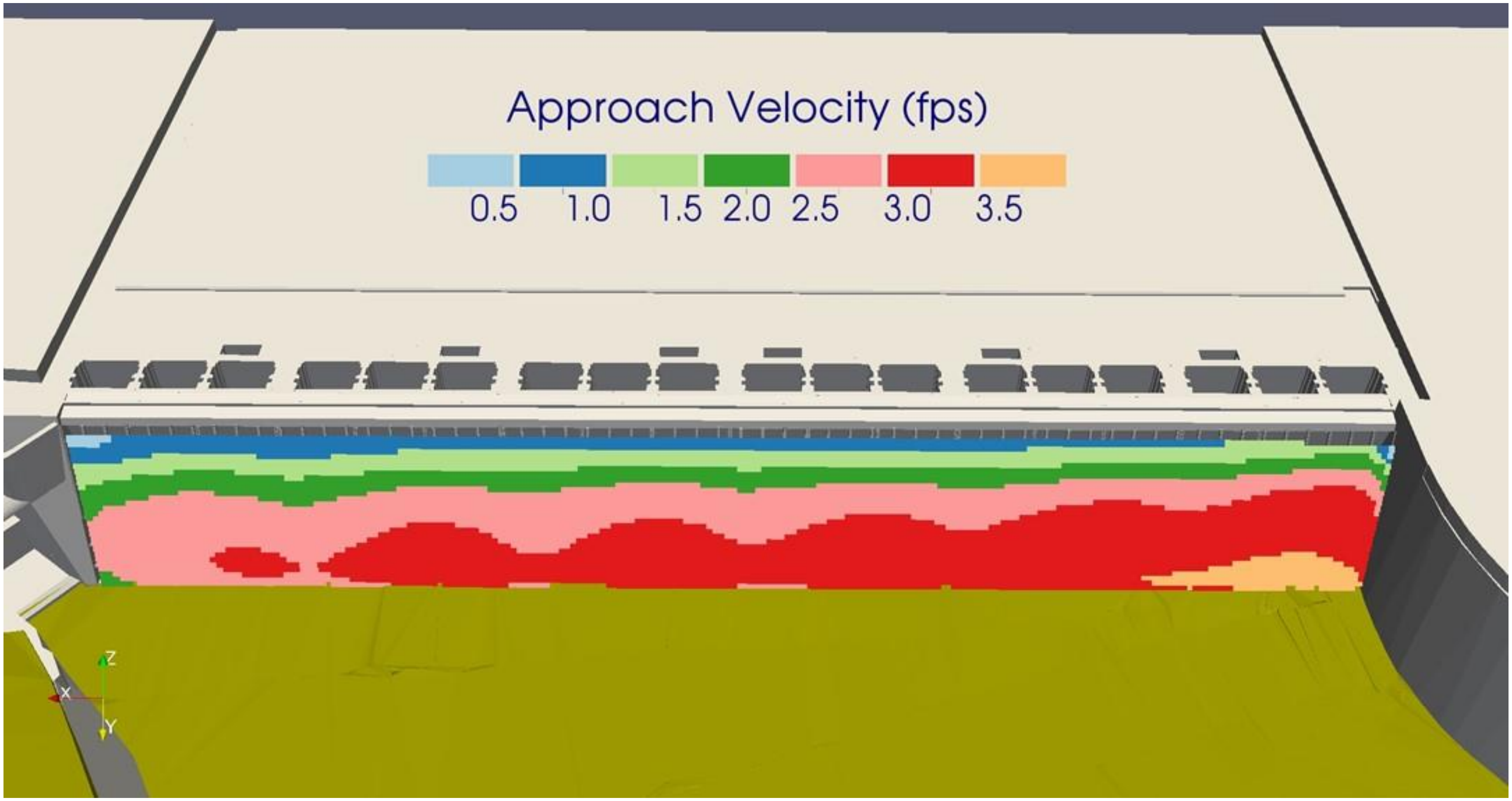


Figure 2.3-6: Cabot Station Scenario 3-3 Intake Rack Approach Velocity

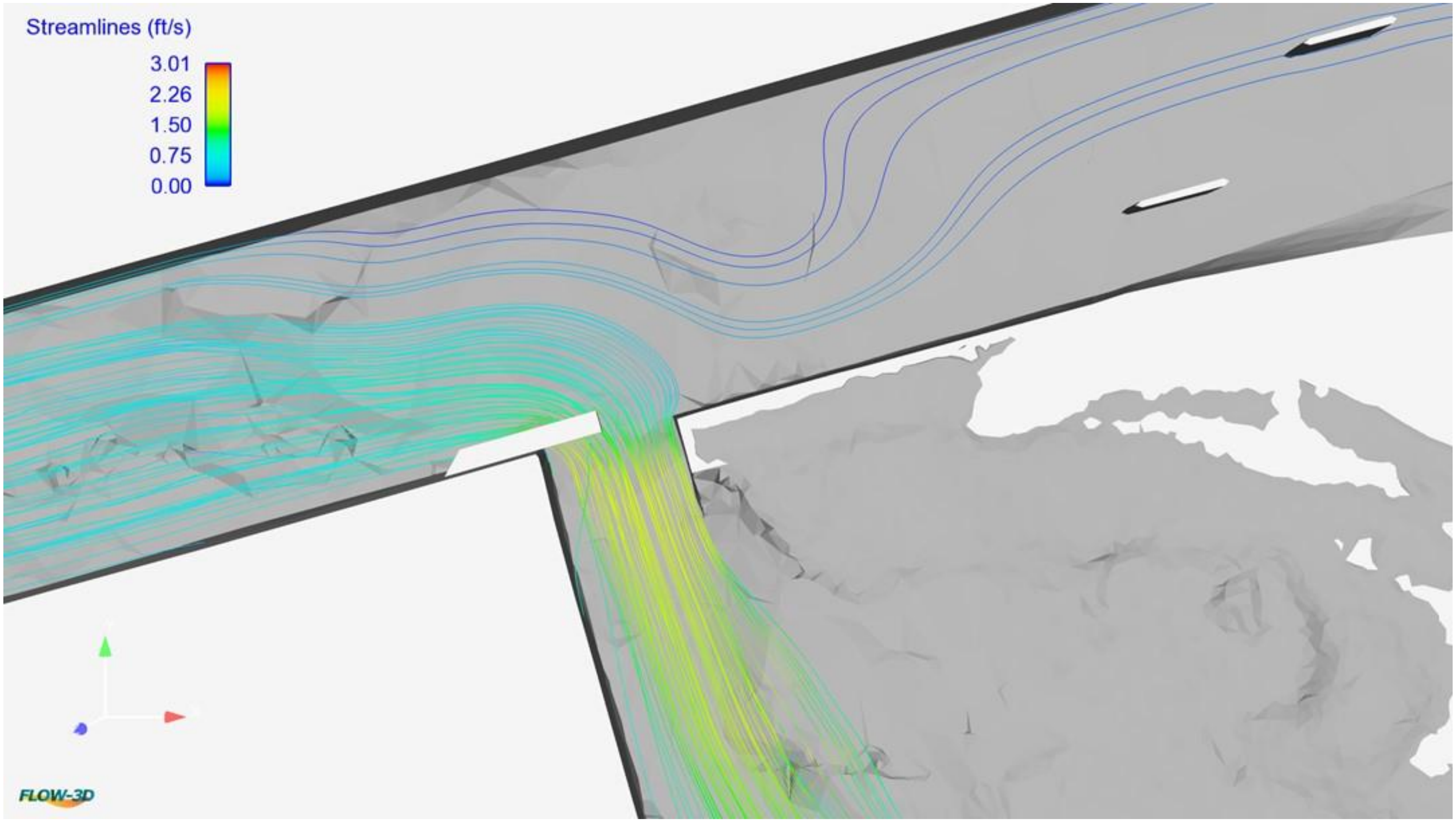


Figure 2.4-1: Station No. 1 Scenario 1-1 Canal Particle Trace Plots

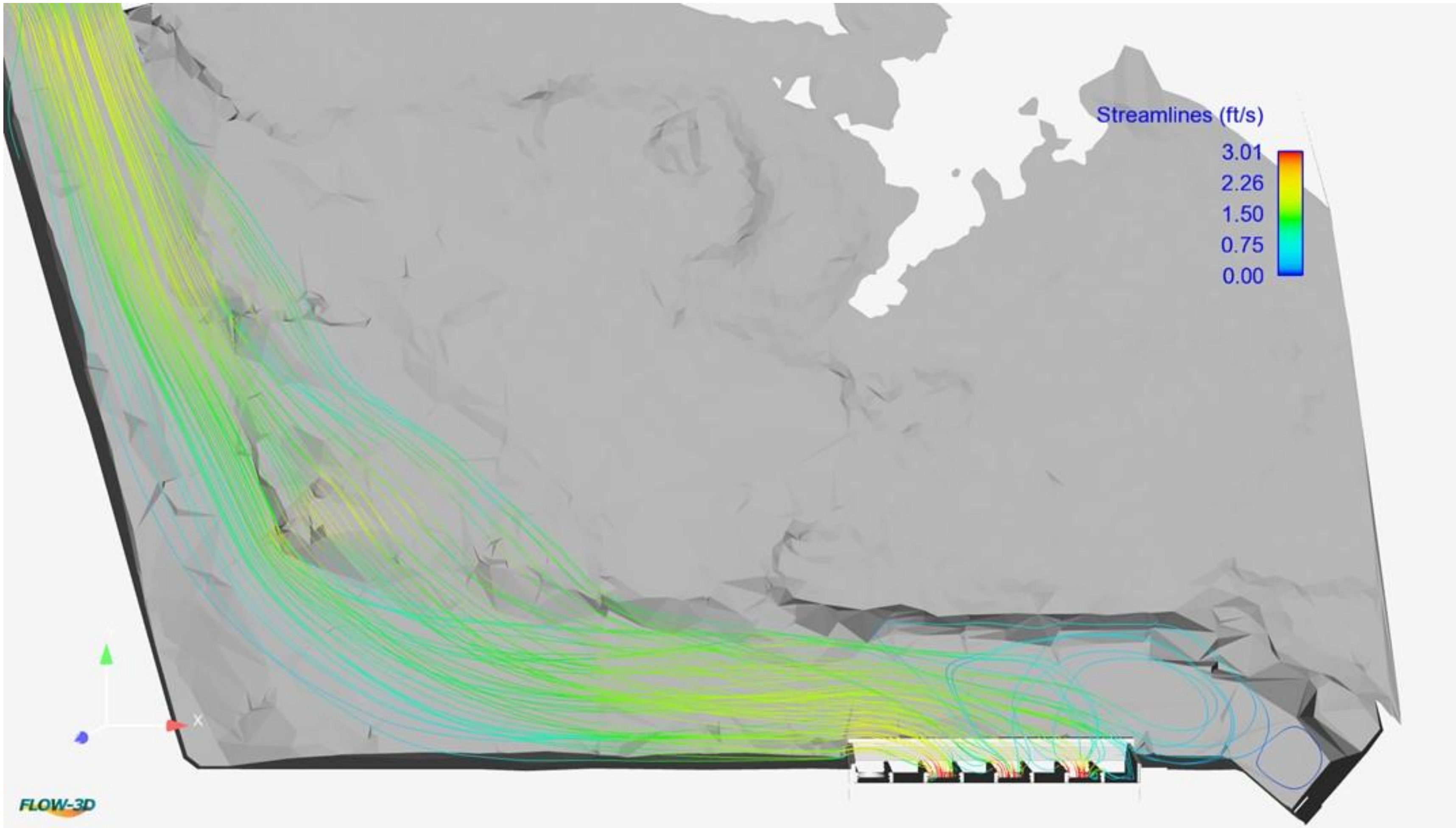


Figure 2.4-2: Station No. 1 Scenario 1-1 Forebay Particle Trace Plots

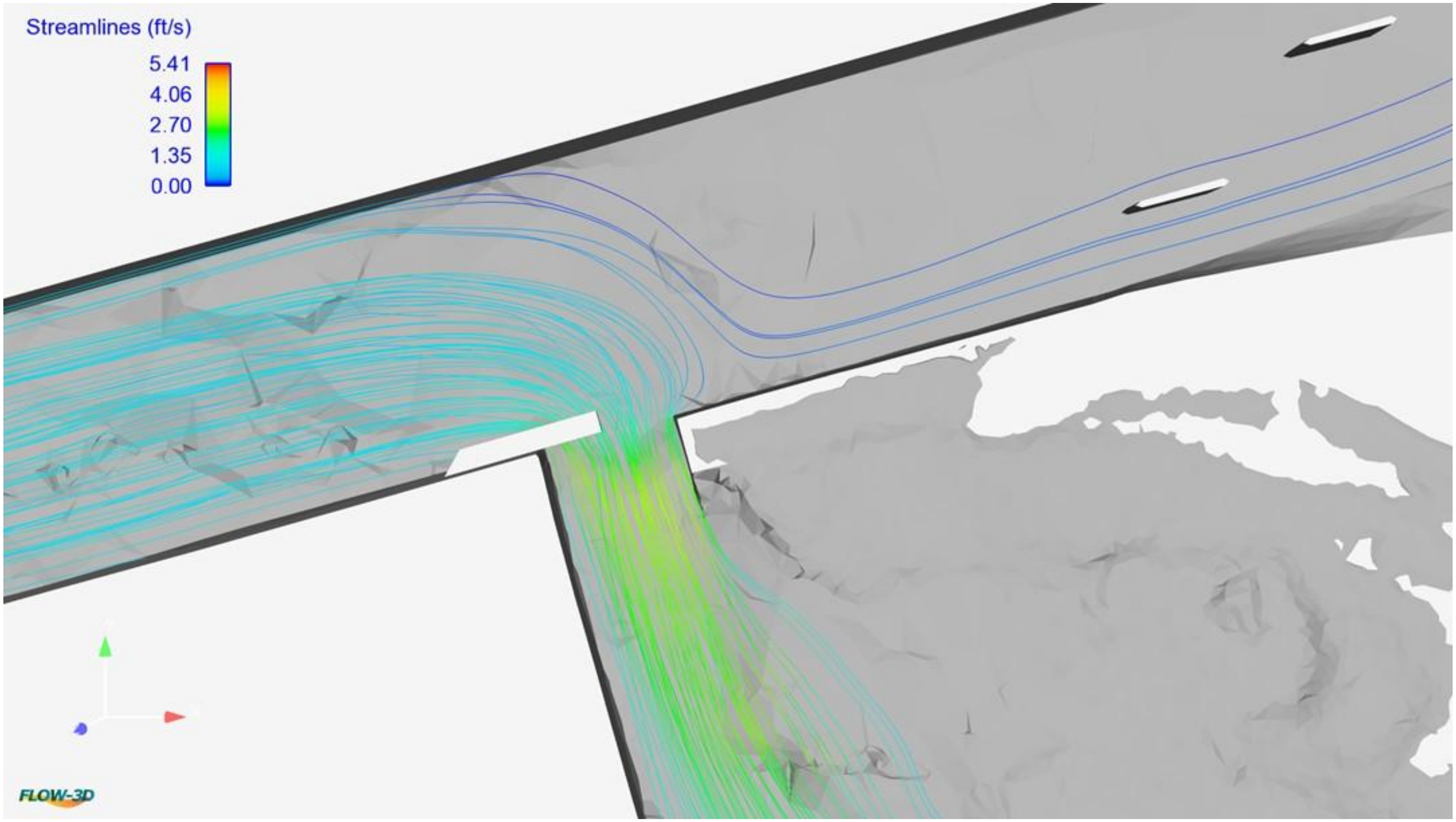


Figure 2.4-3: Station No. 1 Scenario 1-2 Canal Particle Trace Plots

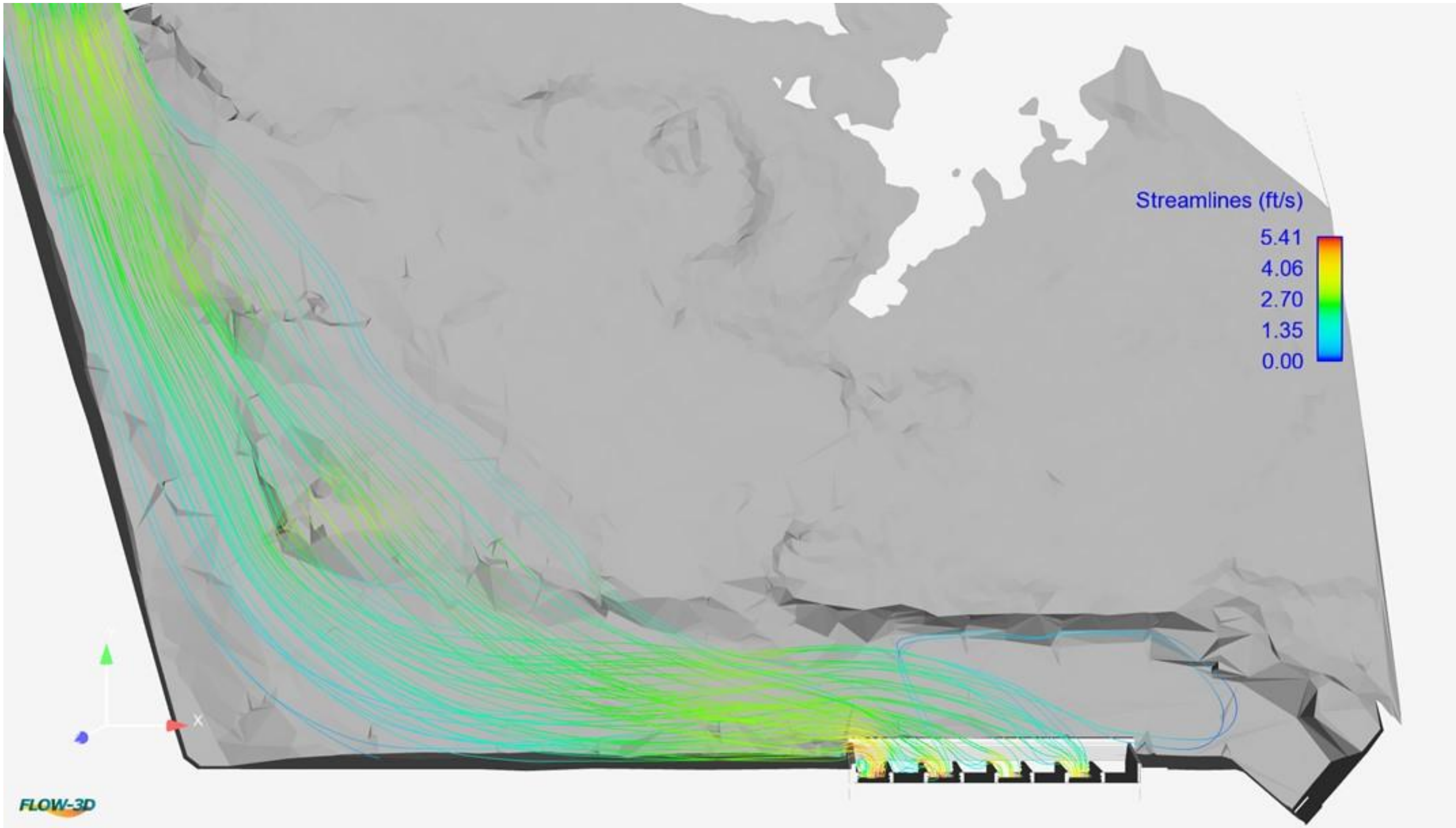


Figure 2.4-4: Station No. 1 Scenario 1-2 Forebay Particle Trace Plots

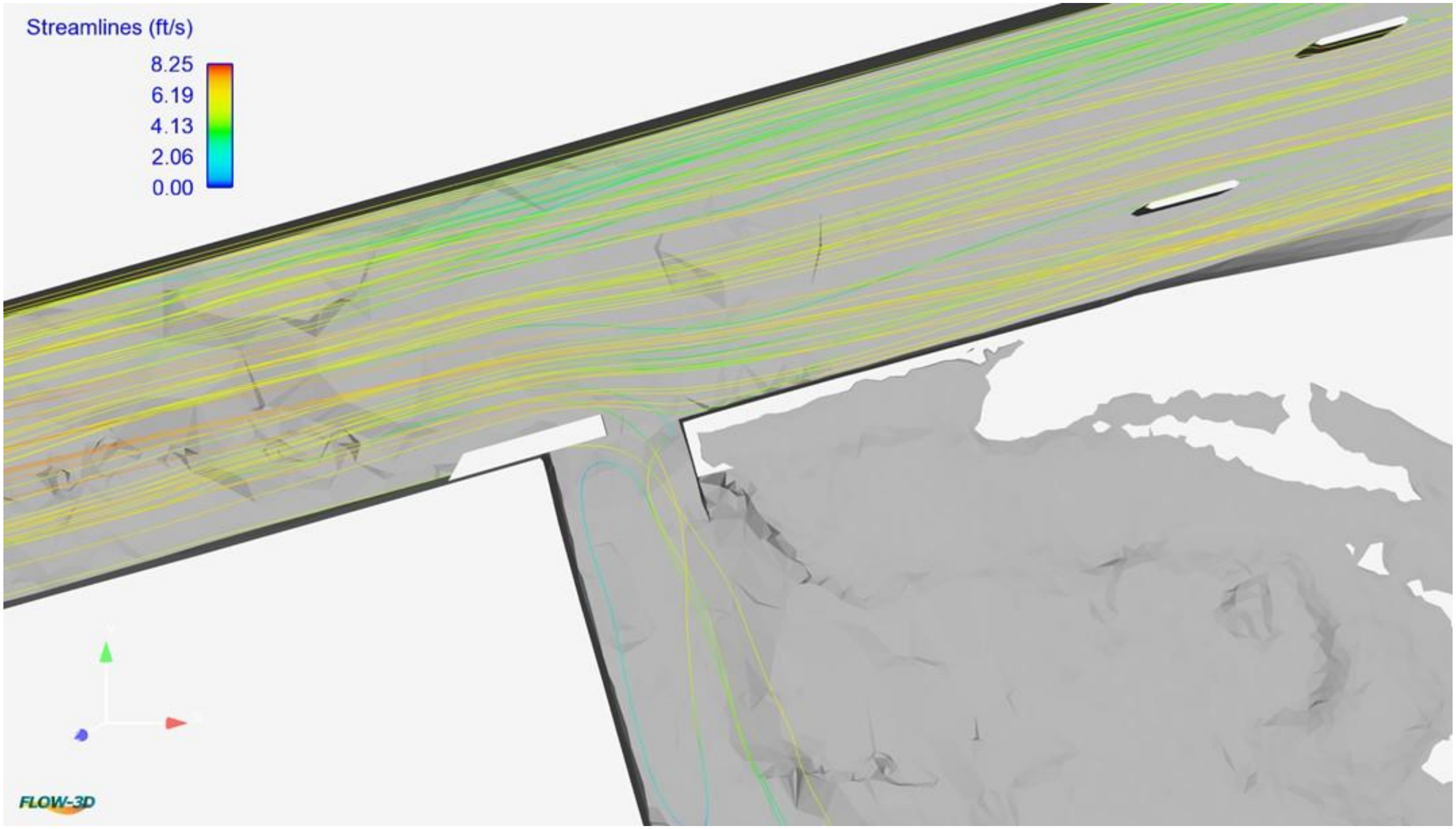


Figure 2.4-5: Station No. 1 Scenario 1-3 Canal Particle Trace Plots

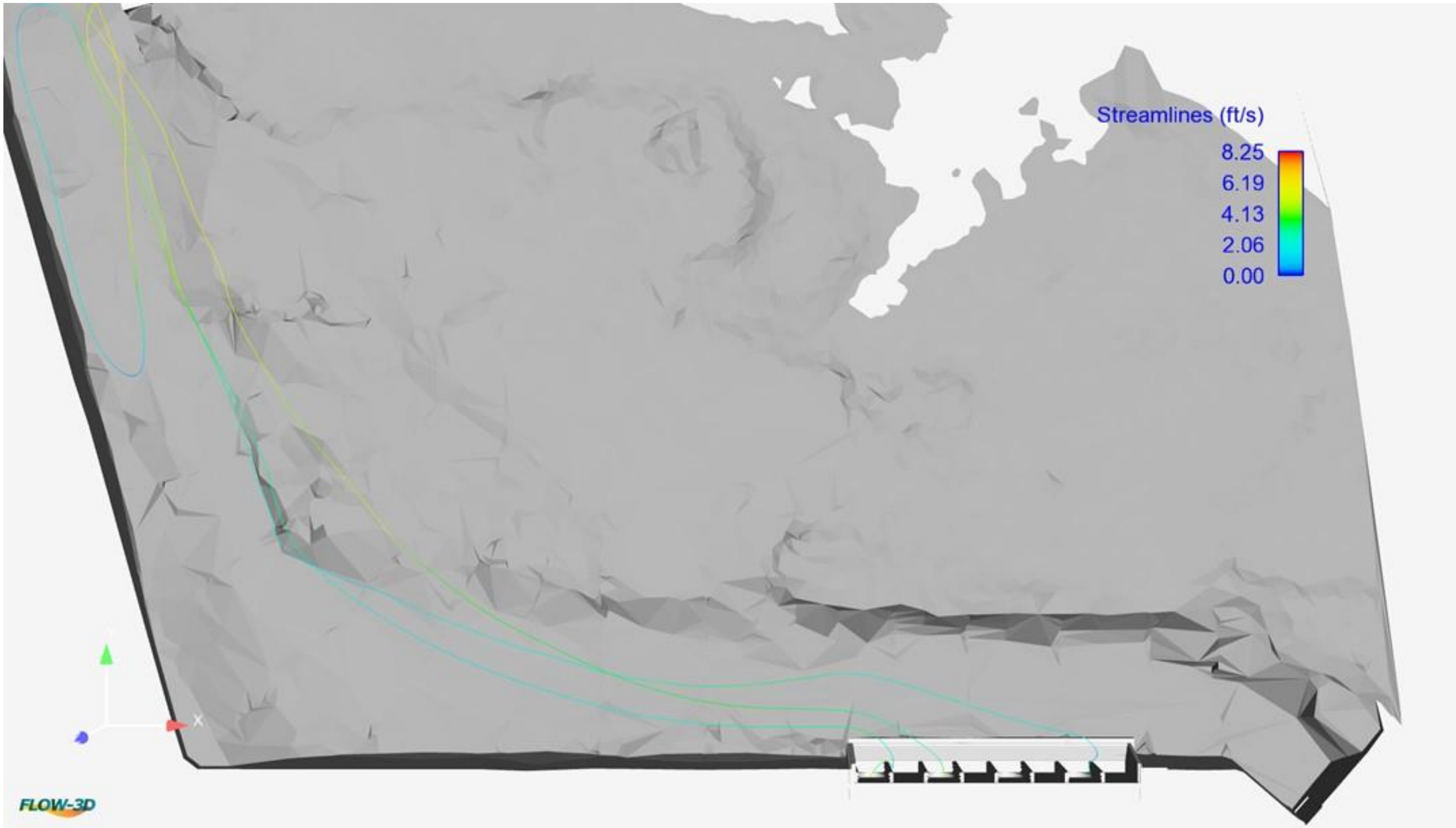


Figure 2.4-6: Station No. 1 Scenario 1-3 Forebay Particle Trace Plots

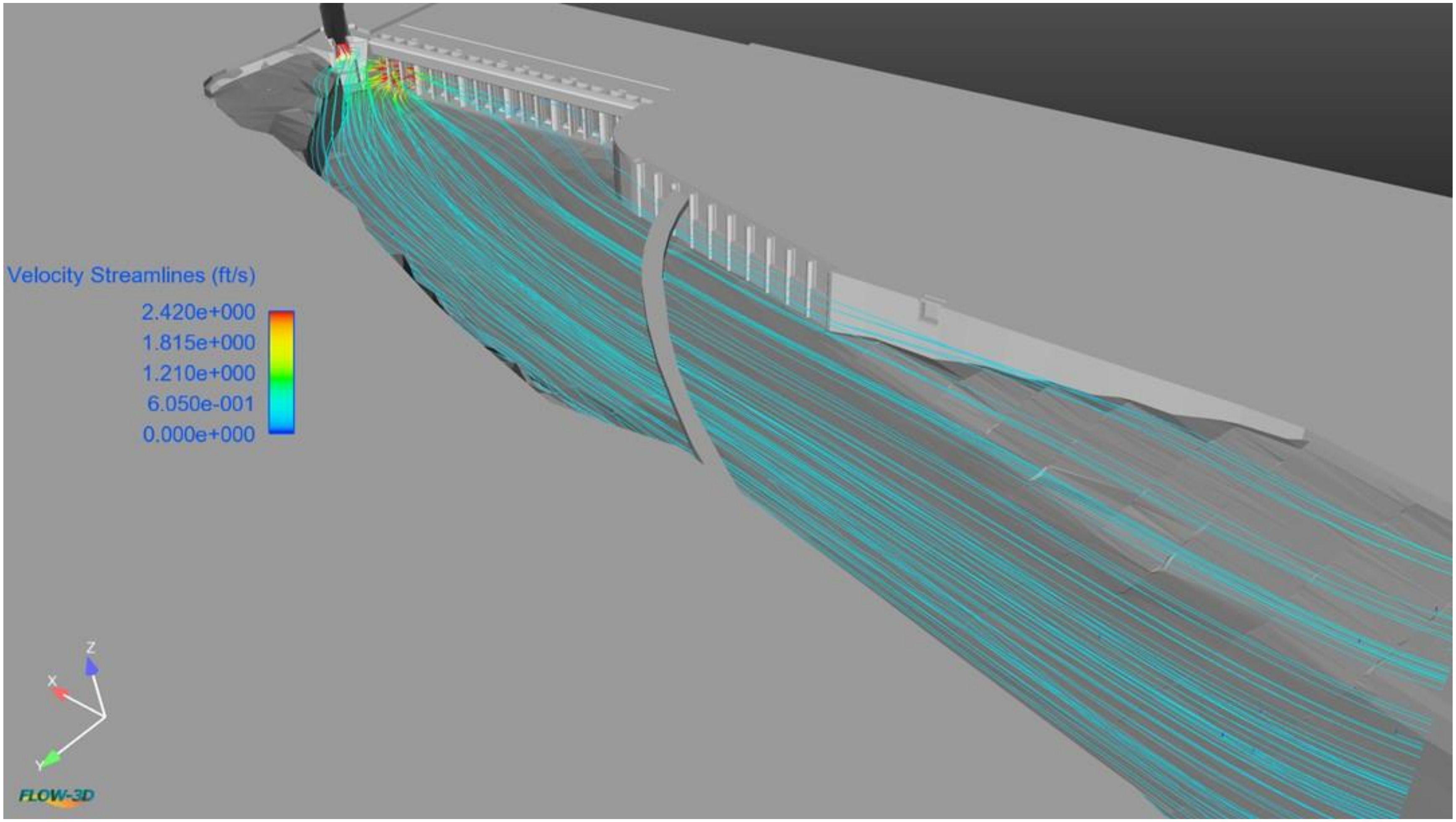


Figure 2.4-7: Cabot Station Scenario 3-1 Overview Particle Trace Plots

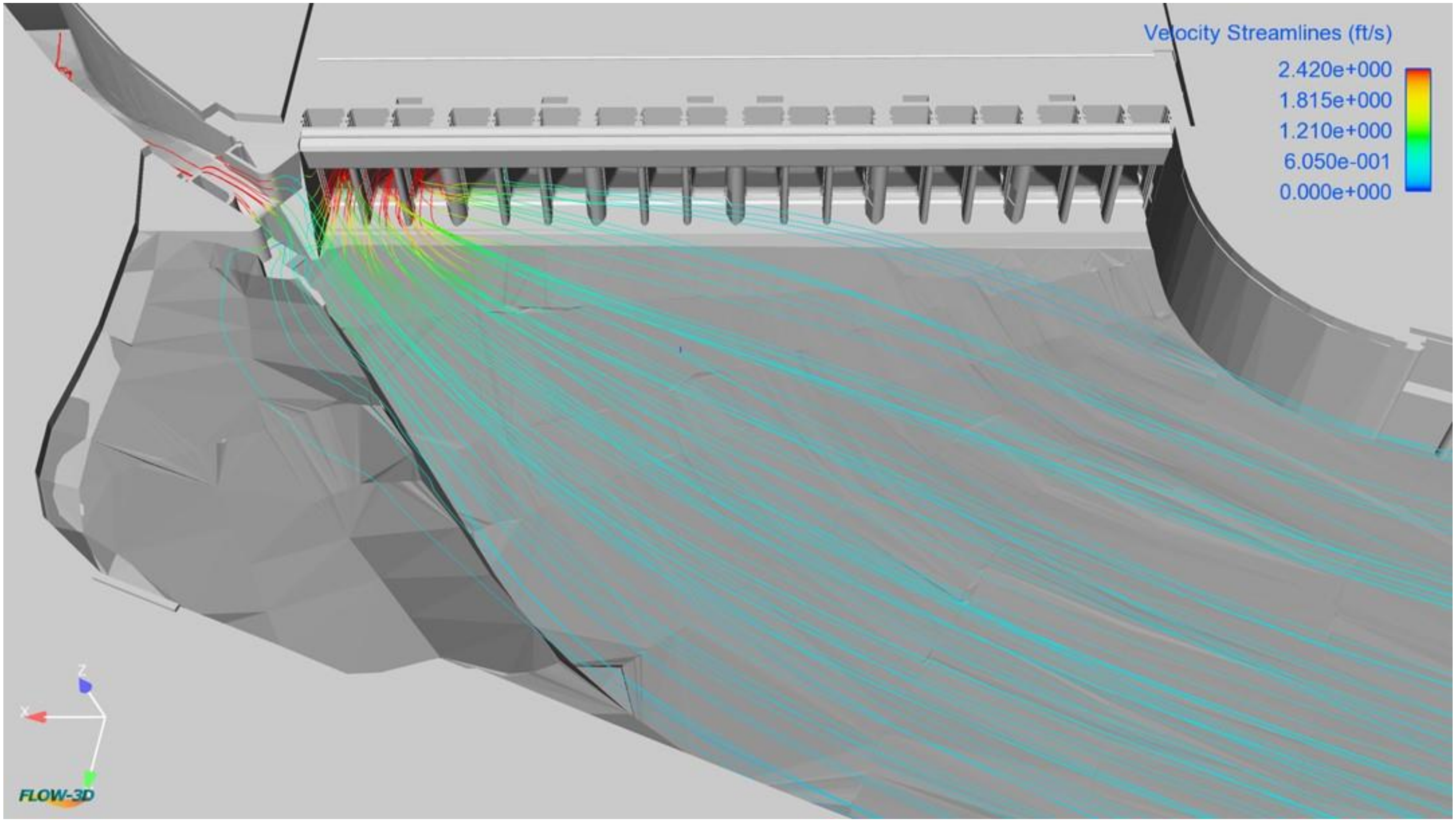


Figure 2.4-8: Cabot Station Scenario 3-1 Intake Rack Close-Up Particle Trace Plots

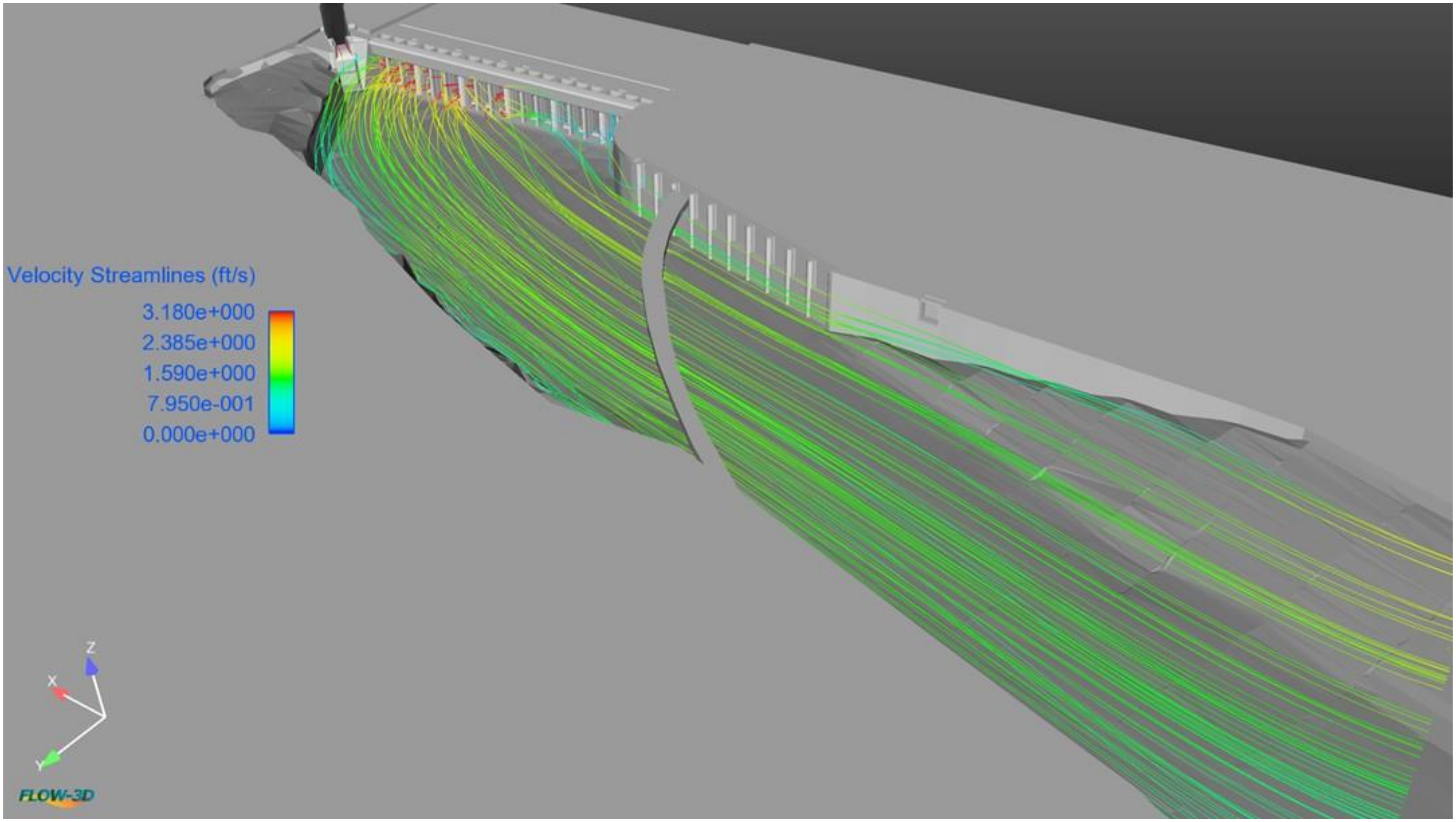


Figure 2.4-9: Cabot Station Scenario 3-2 Overview Particle Trace Plots

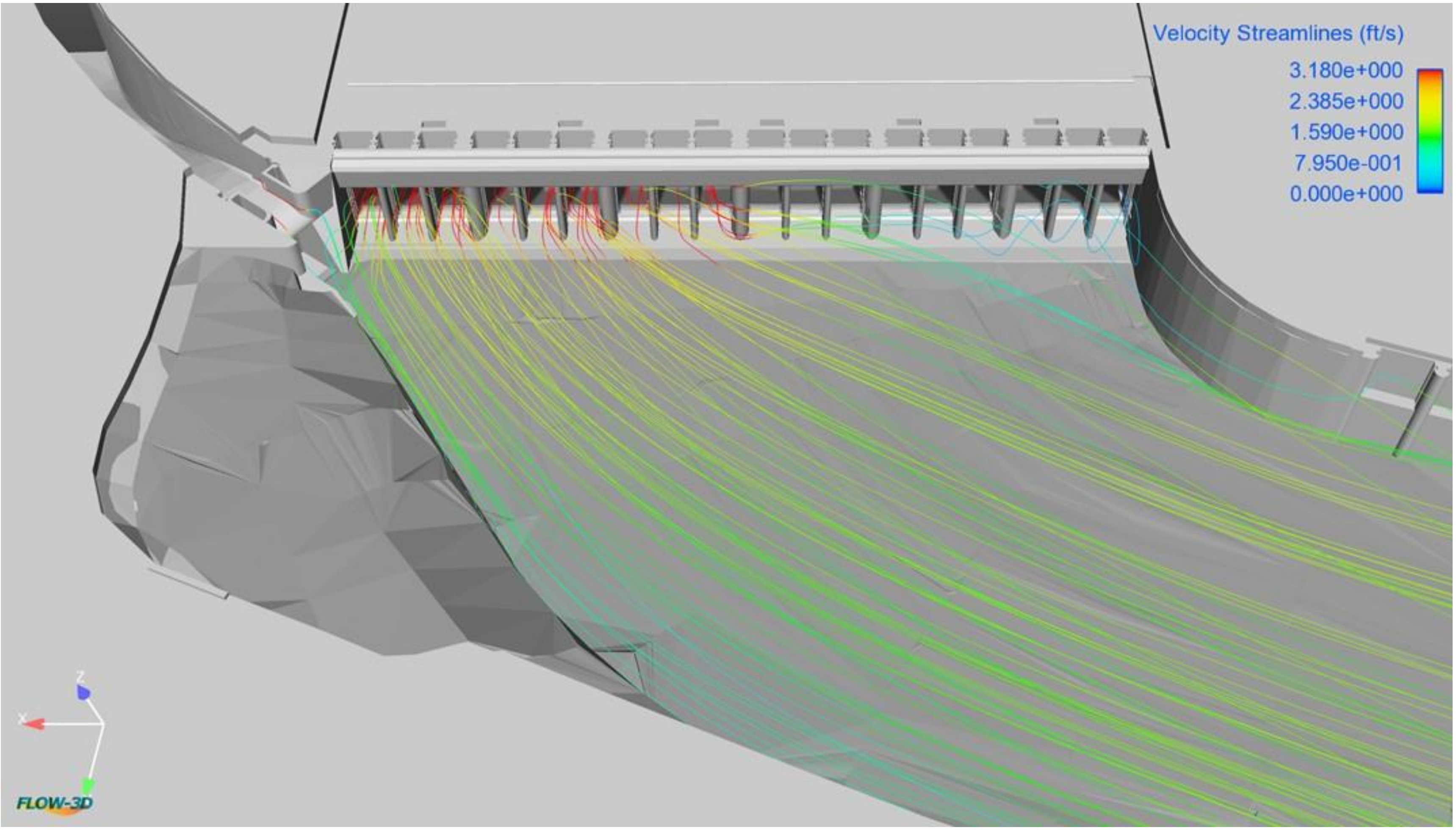


Figure 2.4-10: Cabot Station Scenario 3-2 Intake Rack Close-Up Particle Trace Plots

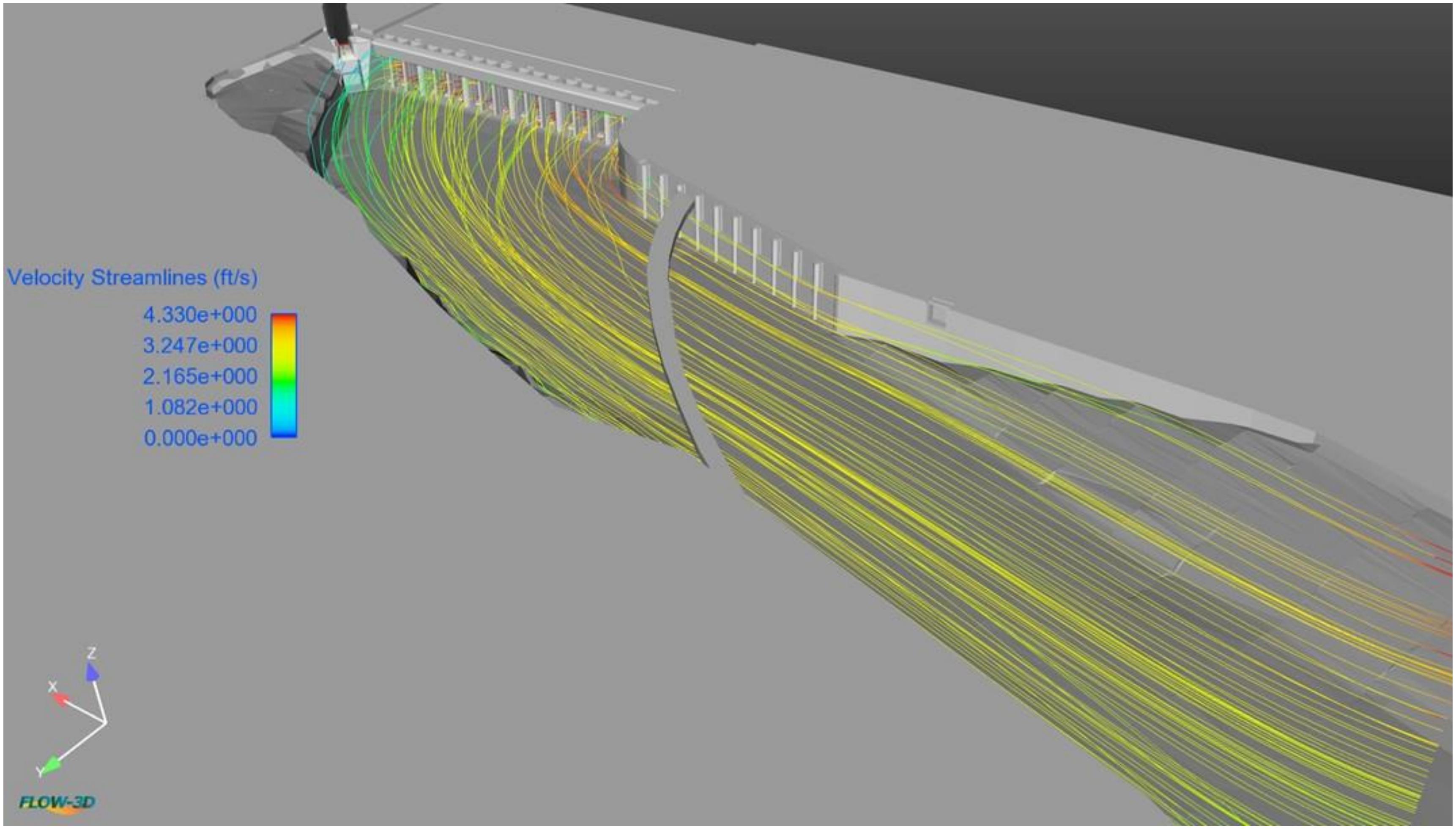


Figure 2.4-11: Cabot Station Scenario 3-3 Overview Particle Trace Plots

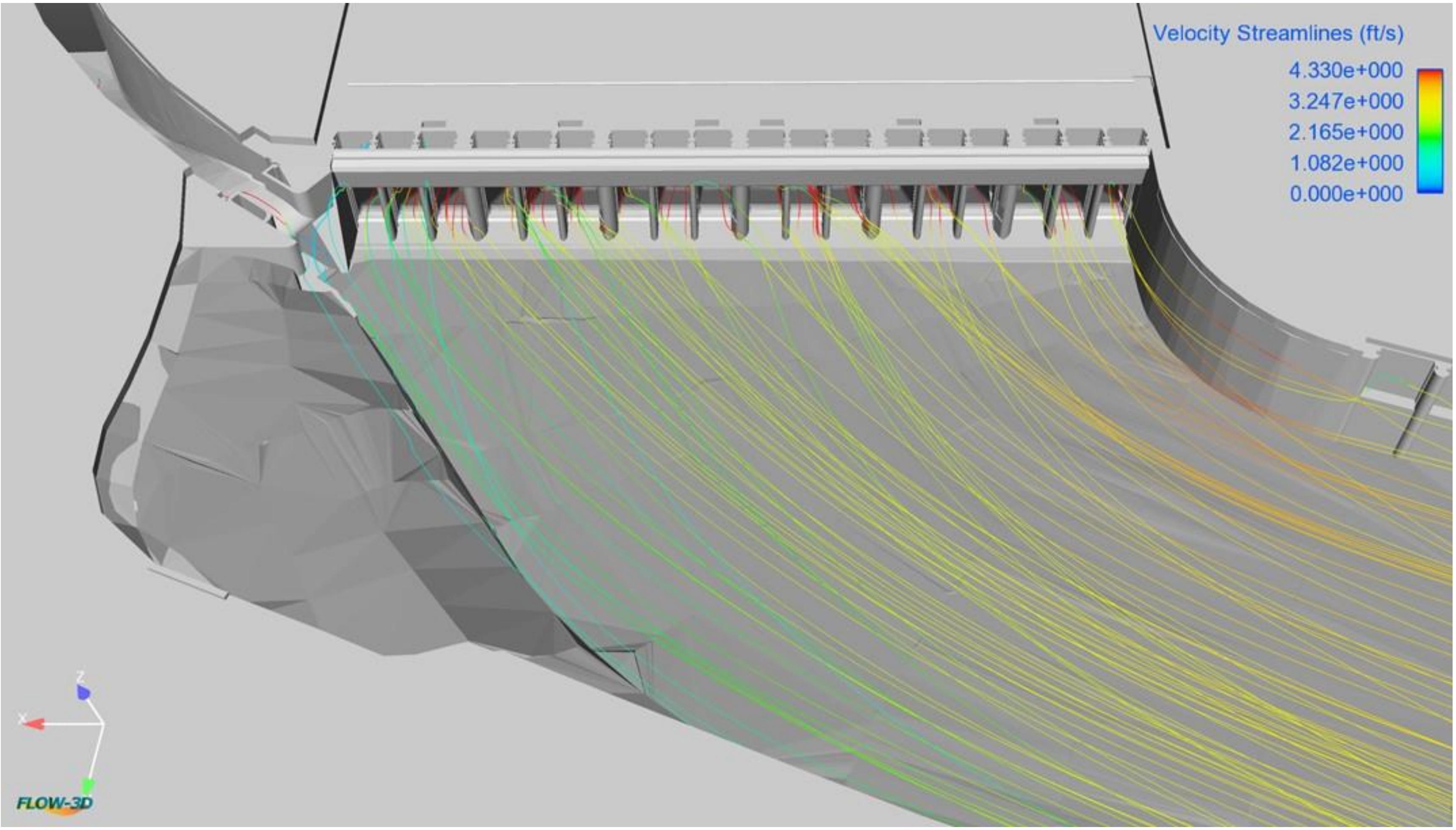
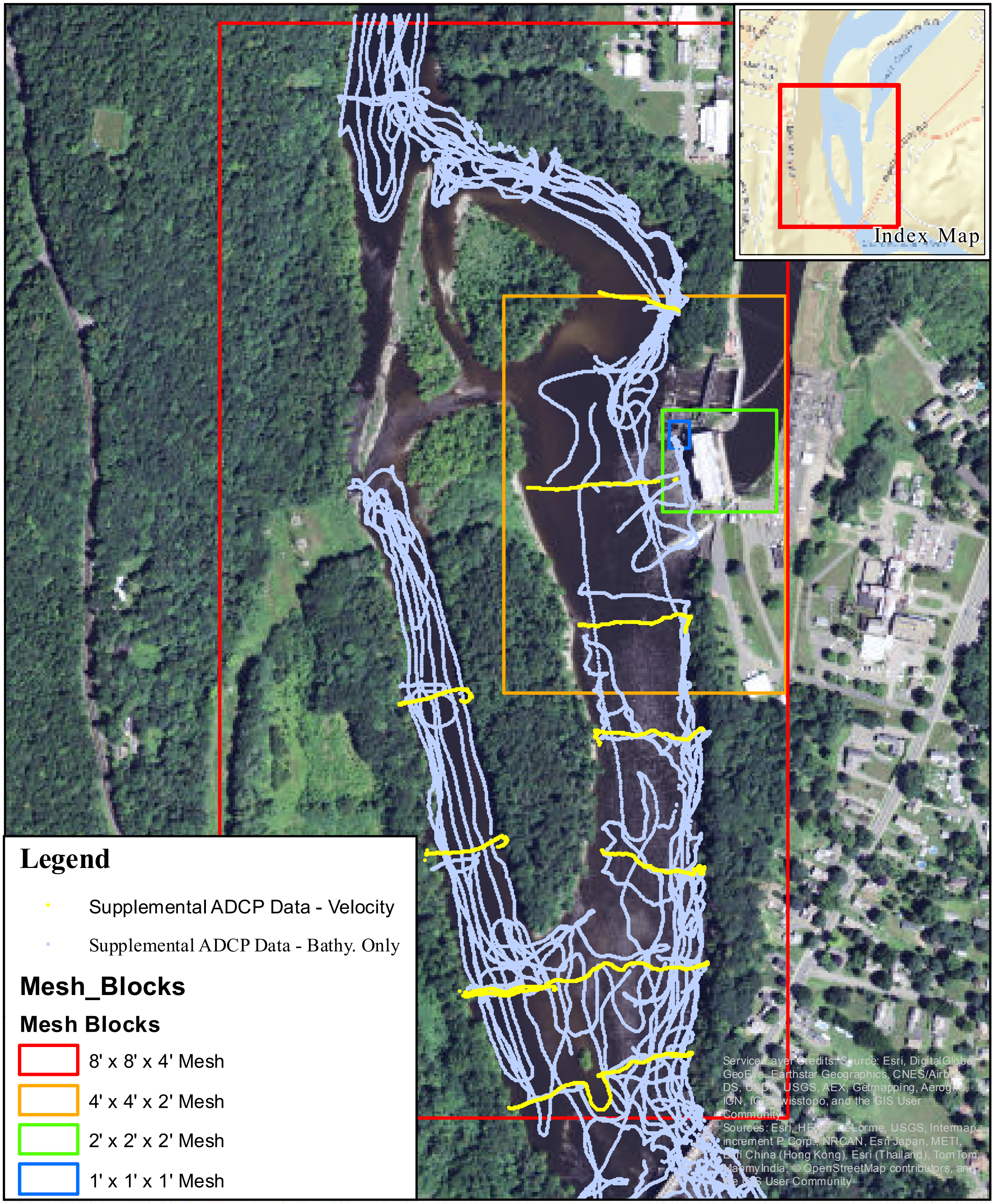


Figure 2.4-12: Cabot Station Scenario 3-3 Intake Rack Close-Up Particle Trace Plots



Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
RELICENSING STUDY 3.3.8

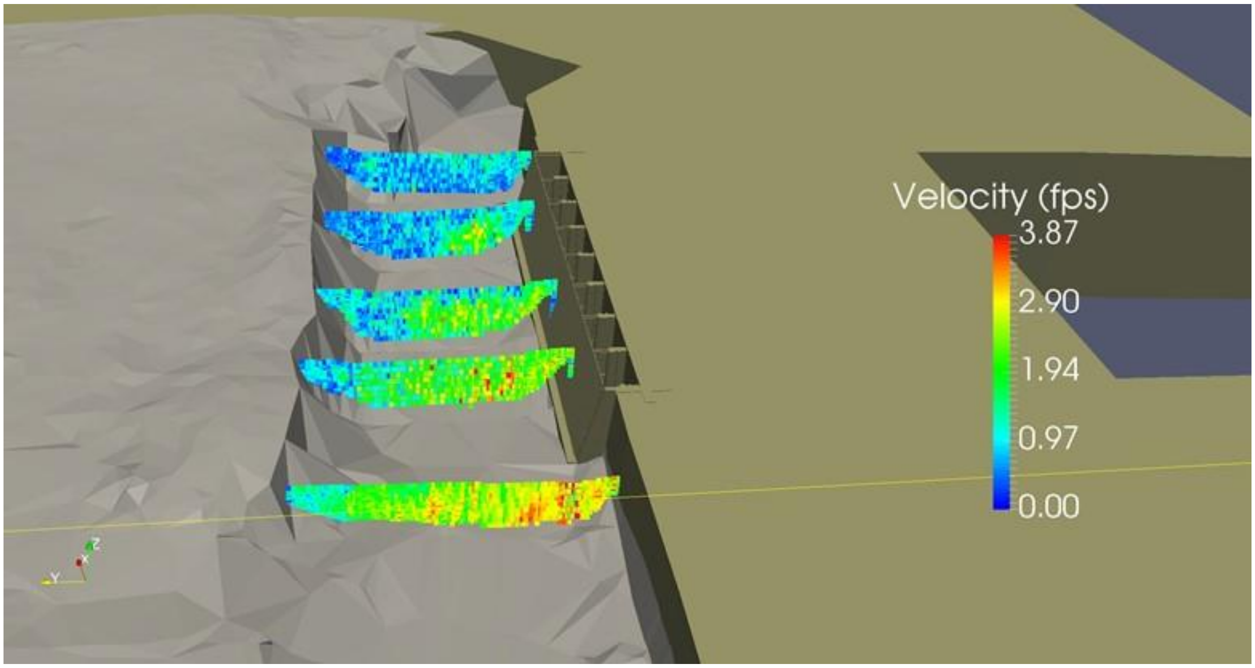
Figure 2.9-1: Cabot Fishway supplemental ADCP data.

FirstLight Power Resources

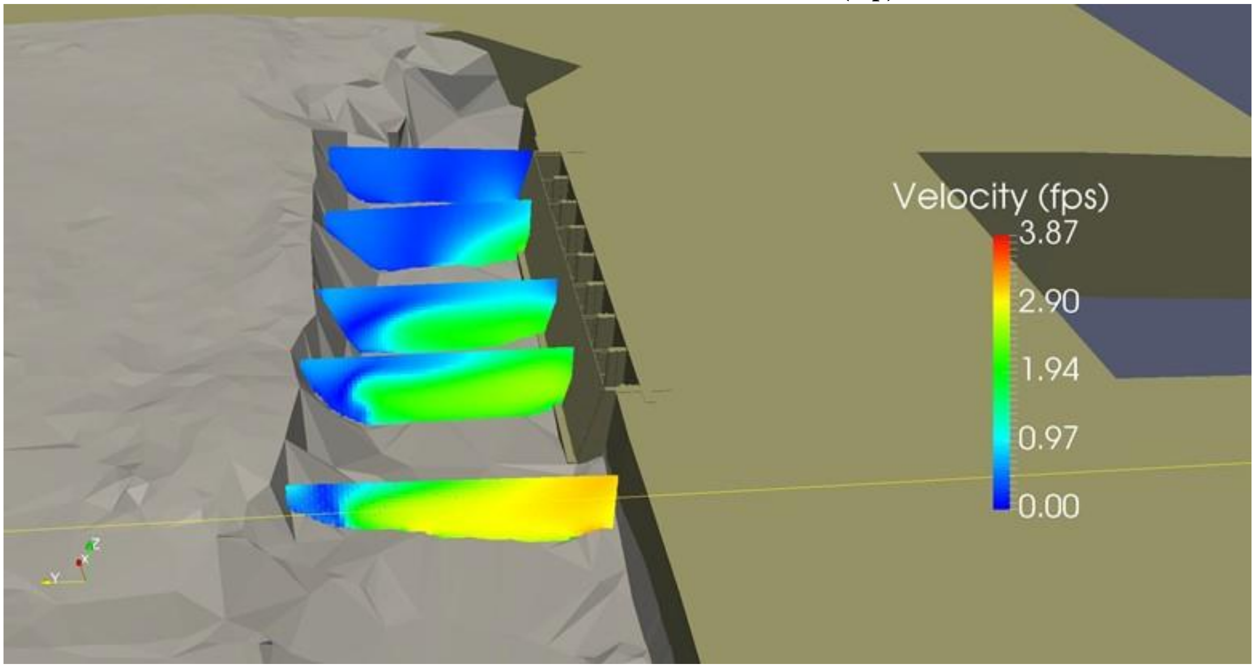
N

0 0.045 0.09 0.18 Miles

Path: W:\gis\studies\3_3_08\maps\Figures\Addendum_Oct_2016\Cabot Fishway ADCP Data.mxd

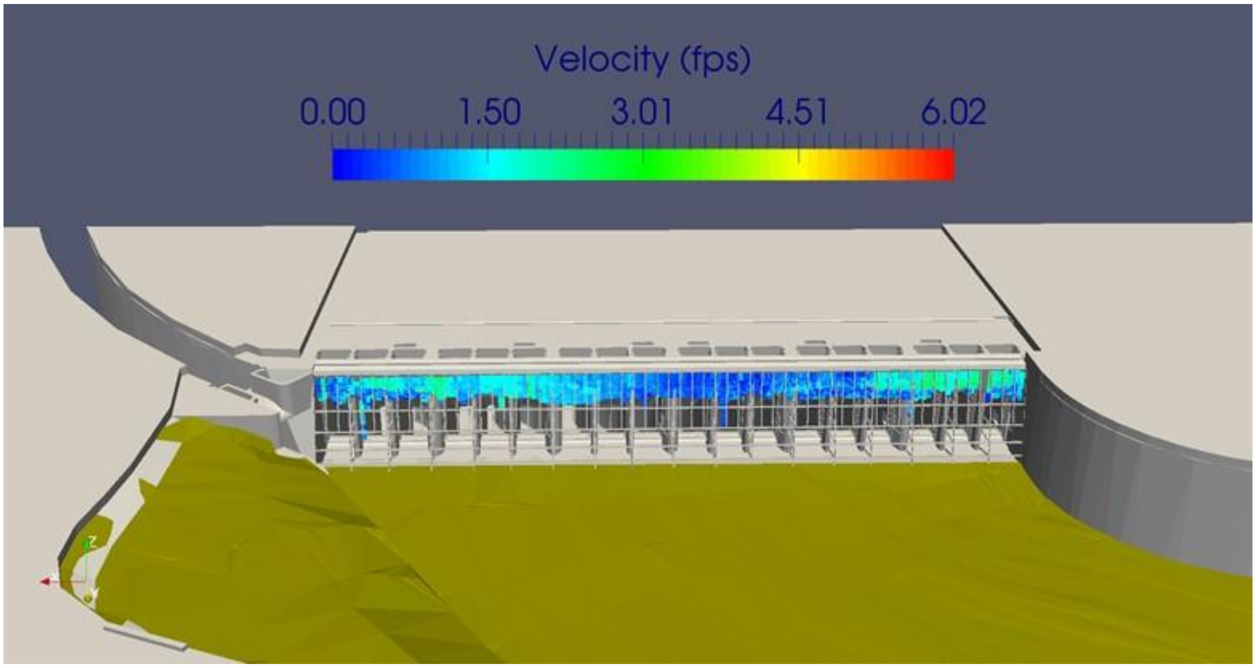


Station 1 Verification of Measured ADCP (top)

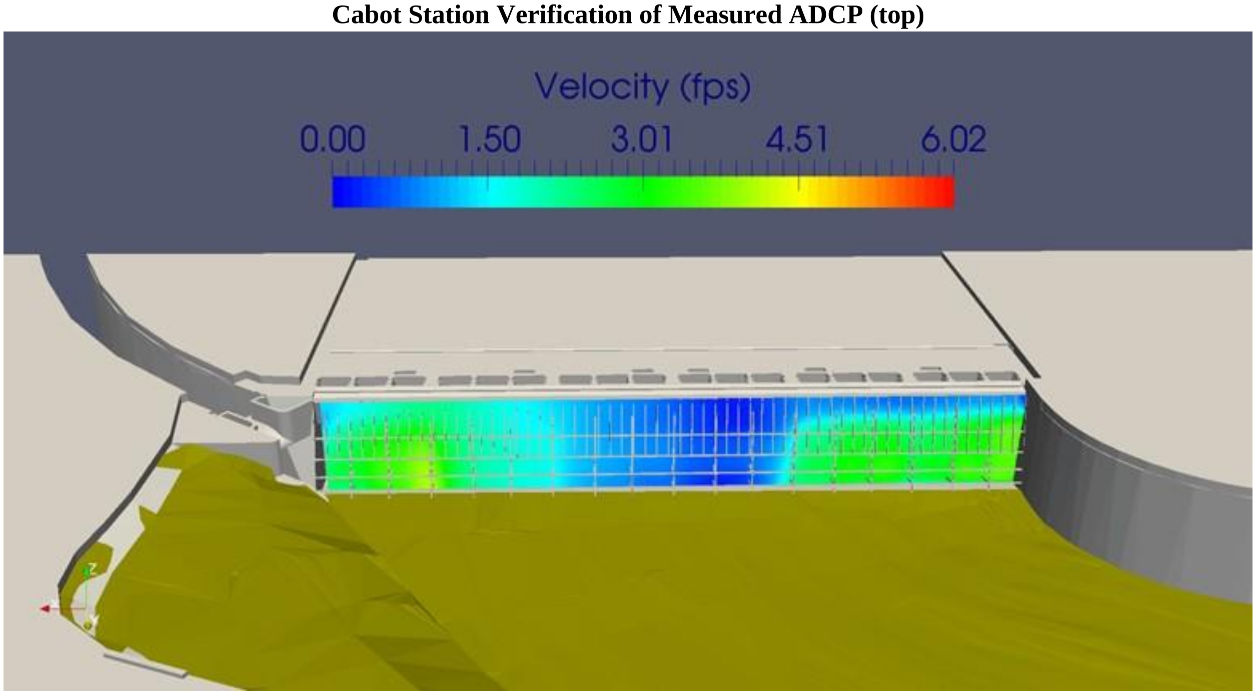


Station 1 Simulated Flow-3D (bottom)

Figure 2.12-1: Station 1 Verification of Measured ADCP (top) and Simulated Flow-3D (bottom) Water Velocities

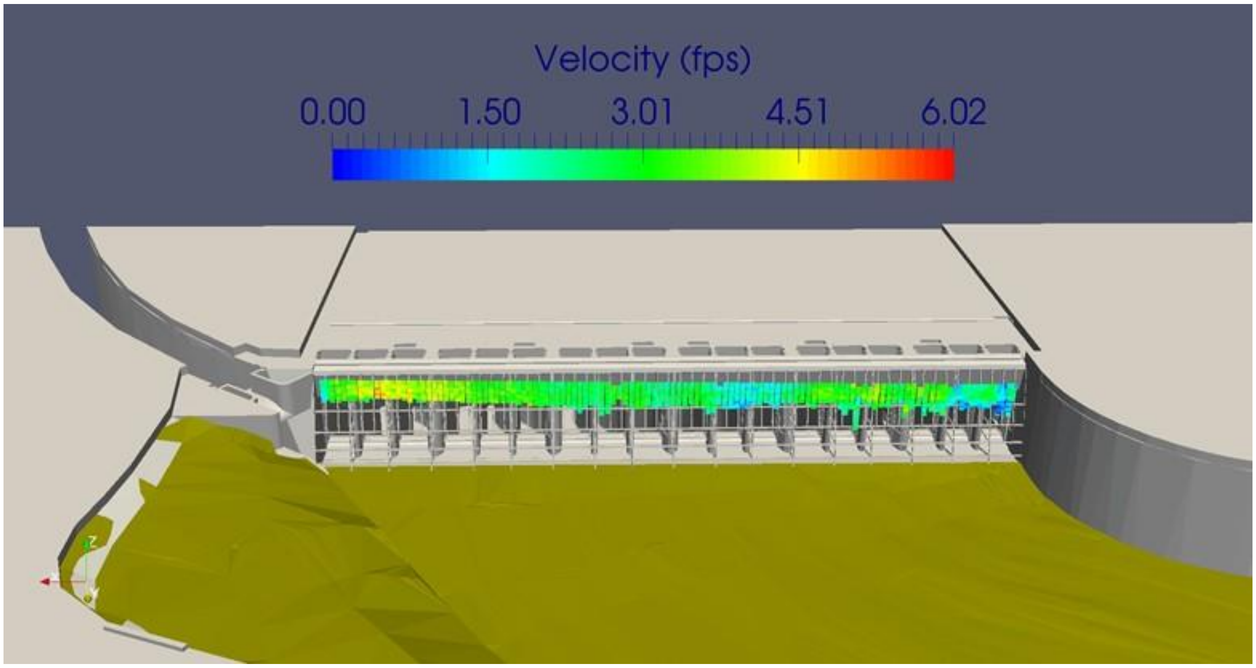


Cabot Station Verification of Measured ADCP (top)

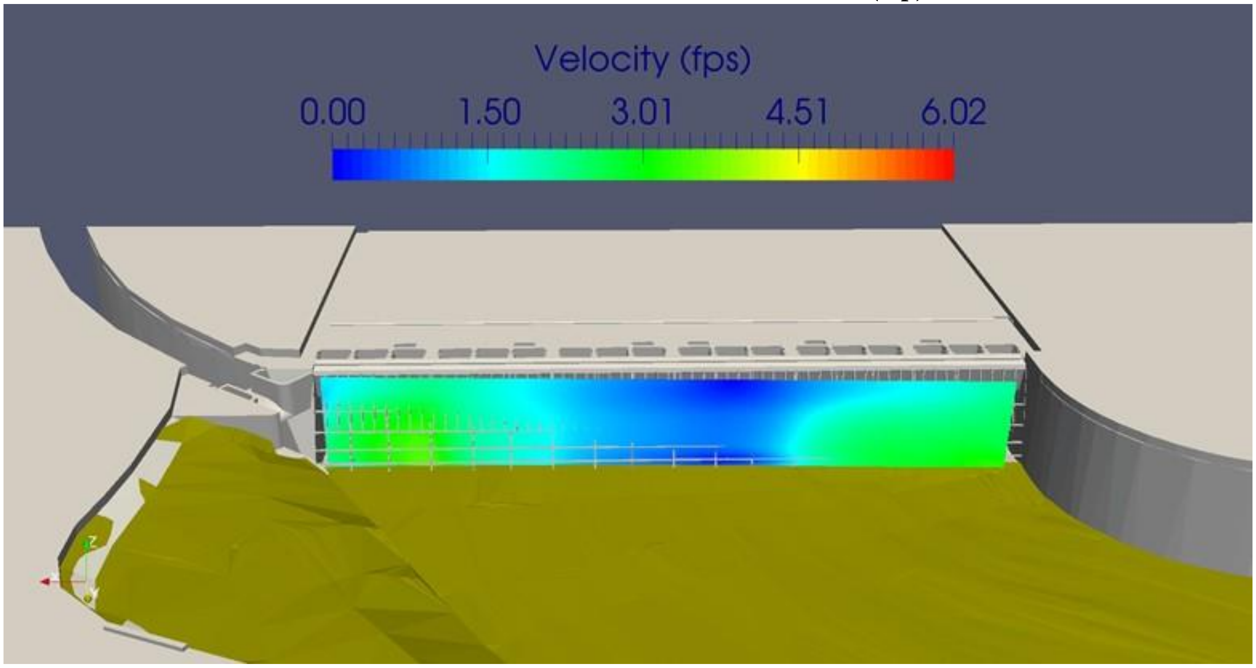


Cabot Station Simulated Flow-3D (bottom)

Figure 2.12-2: Cabot Station Verification of Measured ADCP (top) and Simulated Flow-3D (bottom) Water Velocities (Racks 1)

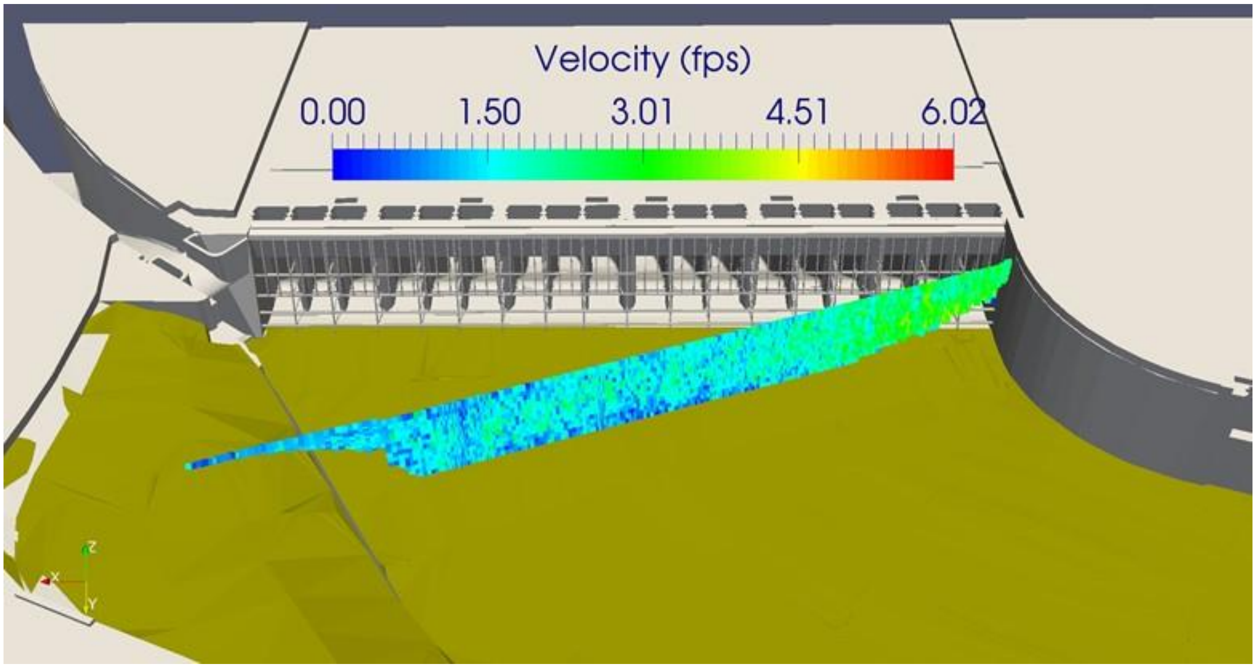


Cabot Station Verification of Measured ADCP (top)

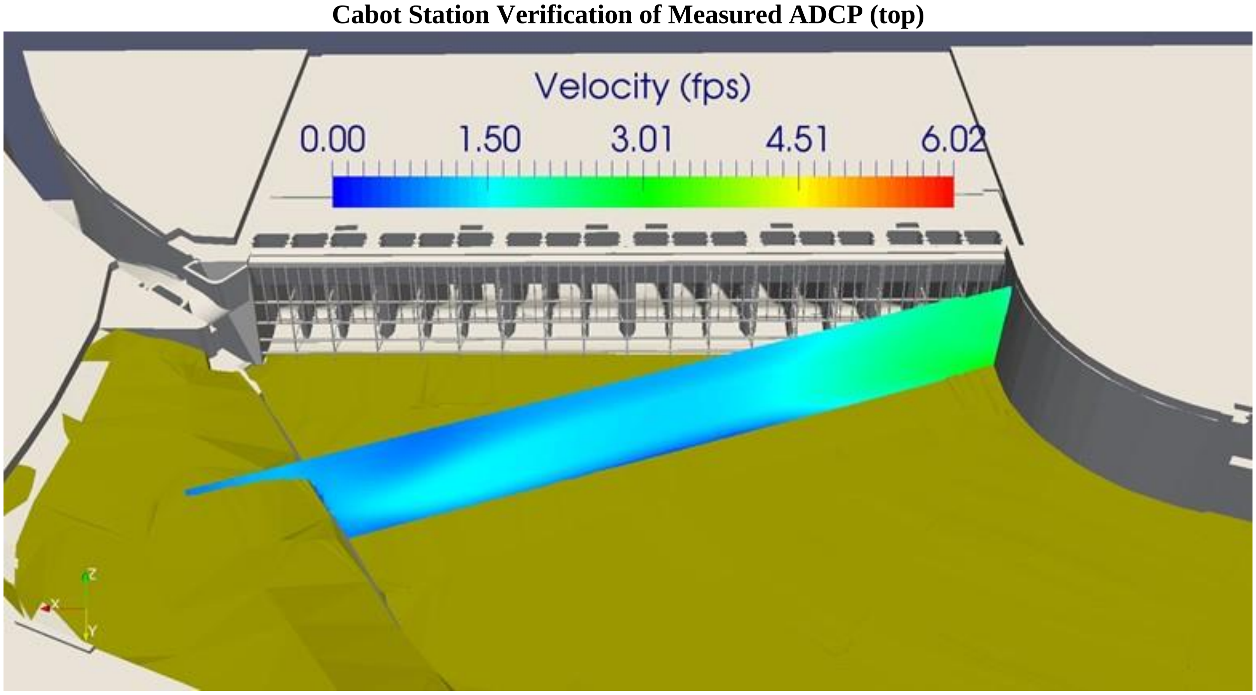


Cabot Station Simulated Flow-3D (bottom)

Figure 2.12-3: Cabot Station Verification of Measured ADCP (top) and Simulated Flow-3D (bottom) Water Velocities (Racks 2)



Cabot Station Verification of Measured ADCP (top)



Cabot Station Simulated Flow-3D (bottom)

Figure 2.12-4: Cabot Station Verification of Measured ADCP (top) and Simulated Flow-3D (bottom) Water Velocities (Racks 3)

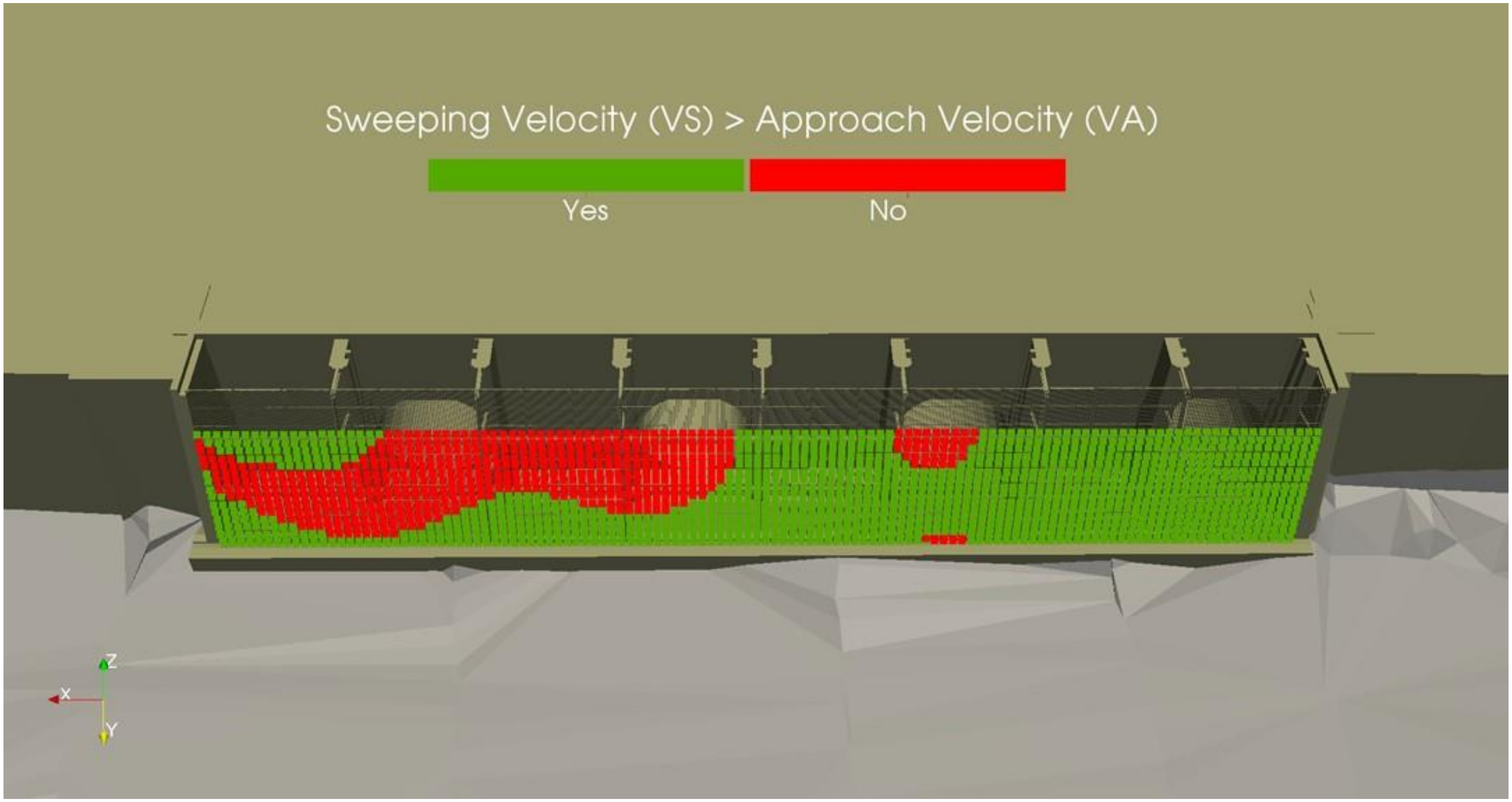


Figure 2.14-1: Station 1 Scenario 1-1 Intake Rack Component Velocity

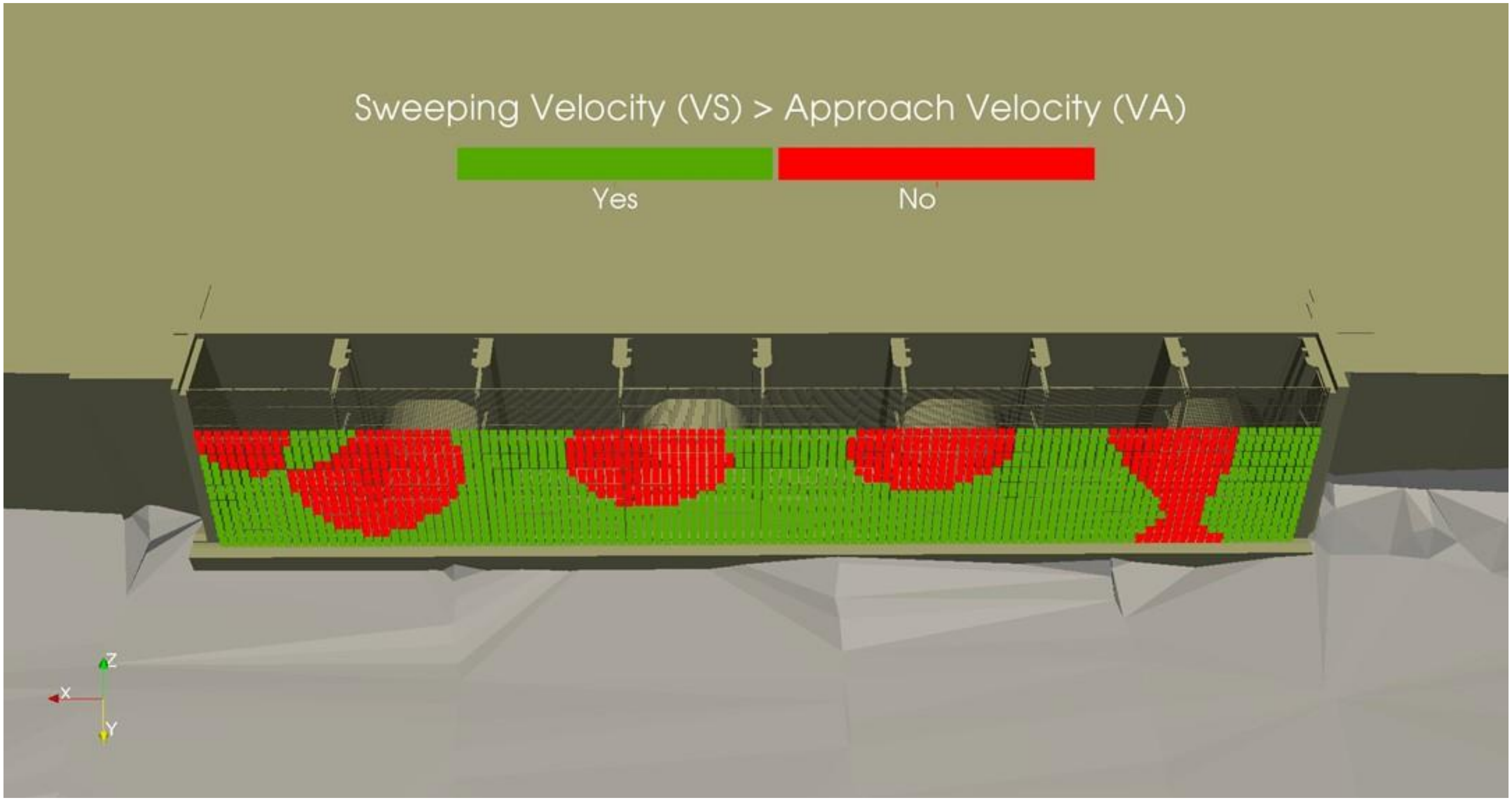


Figure 2.14-2: Station 1 Scenario 1-2 Intake Rack Component Velocity

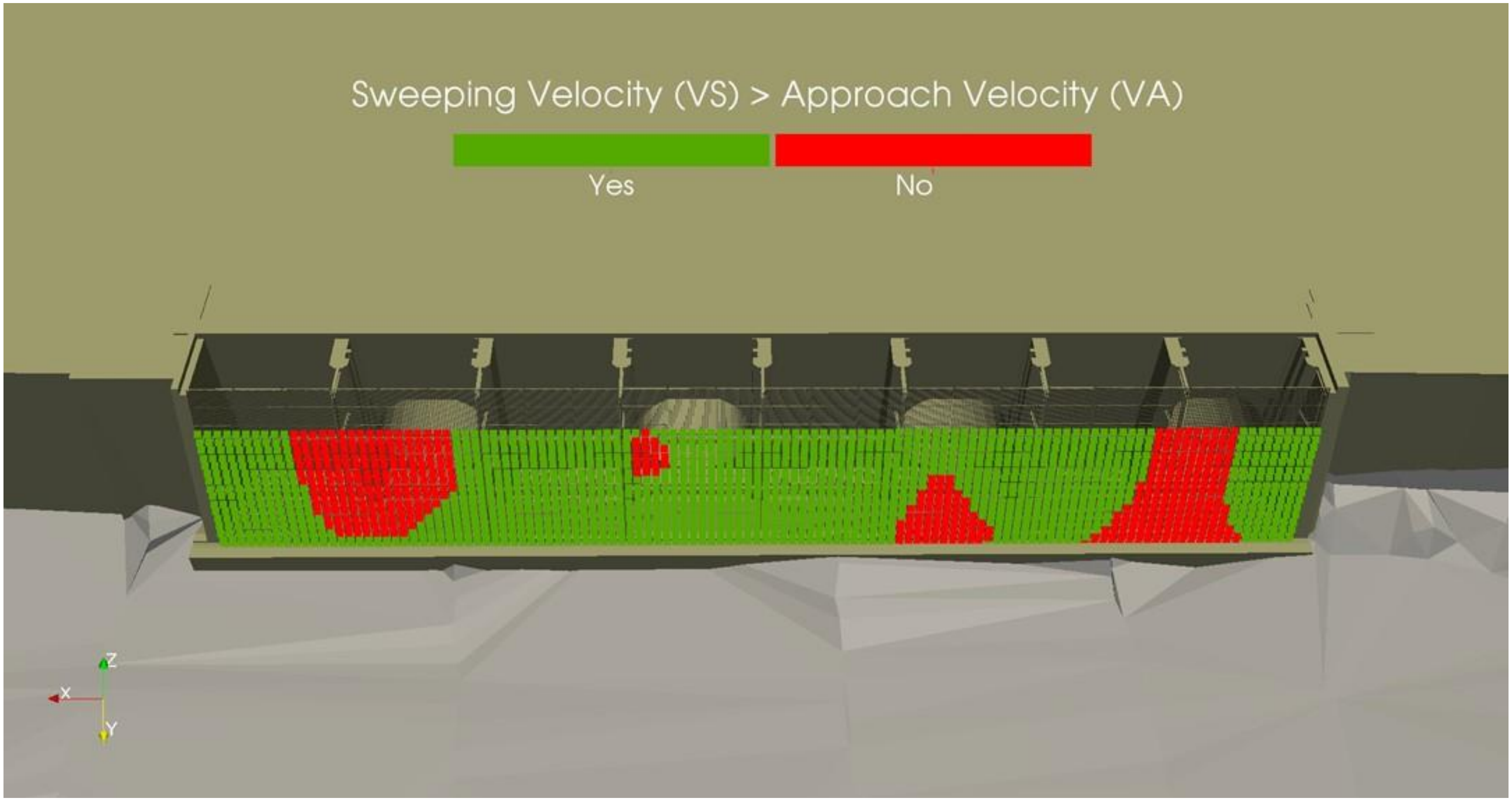


Figure 2.14-3: Station 1 Scenario 1-3 Intake Rack Component Velocity

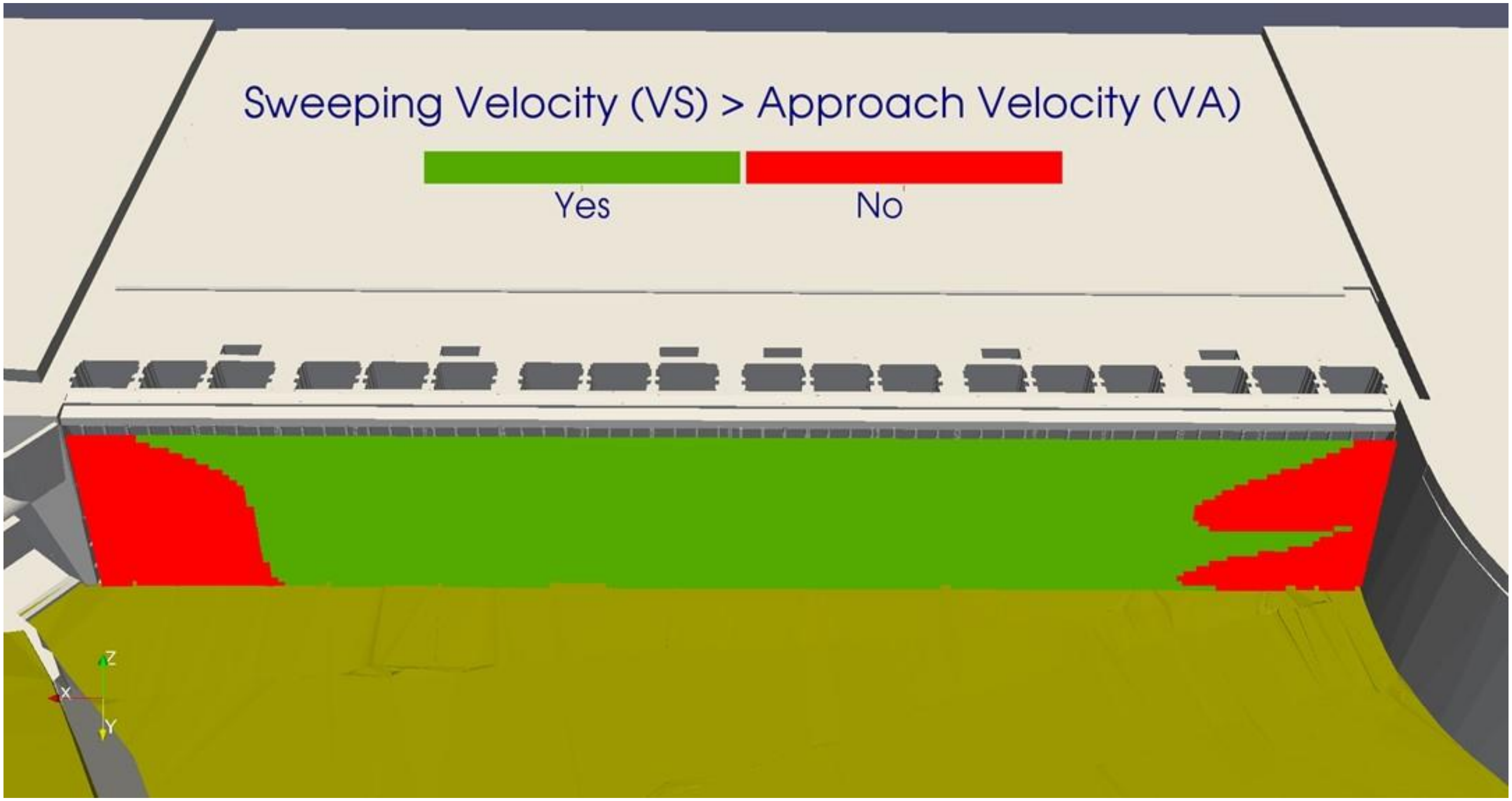


Figure 2.15-1: Cabot Station Scenario 3-1 Intake Rack Component Velocity

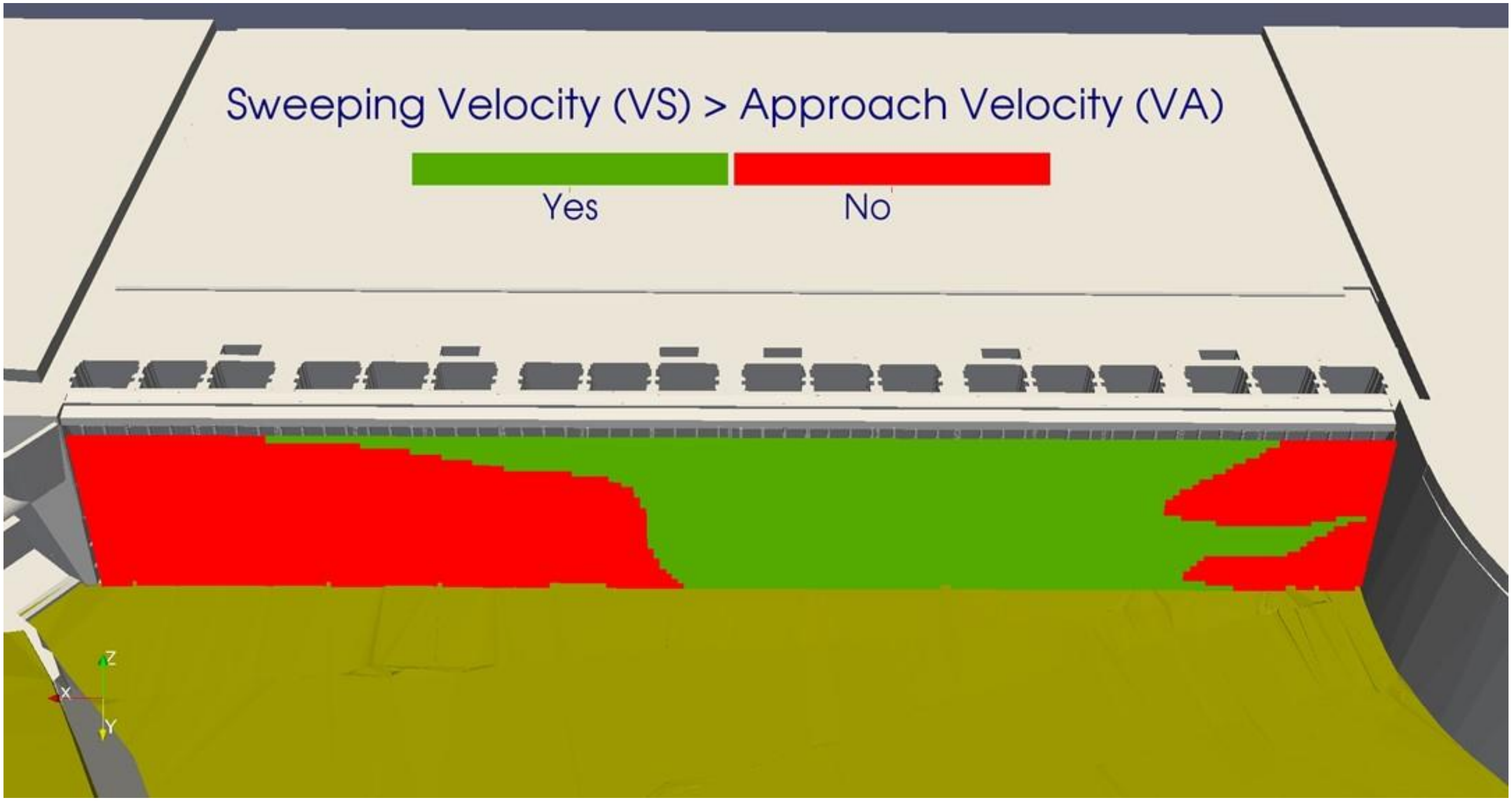


Figure 2.15-2: Cabot Station Scenario 3-2 Intake Rack Component Velocity

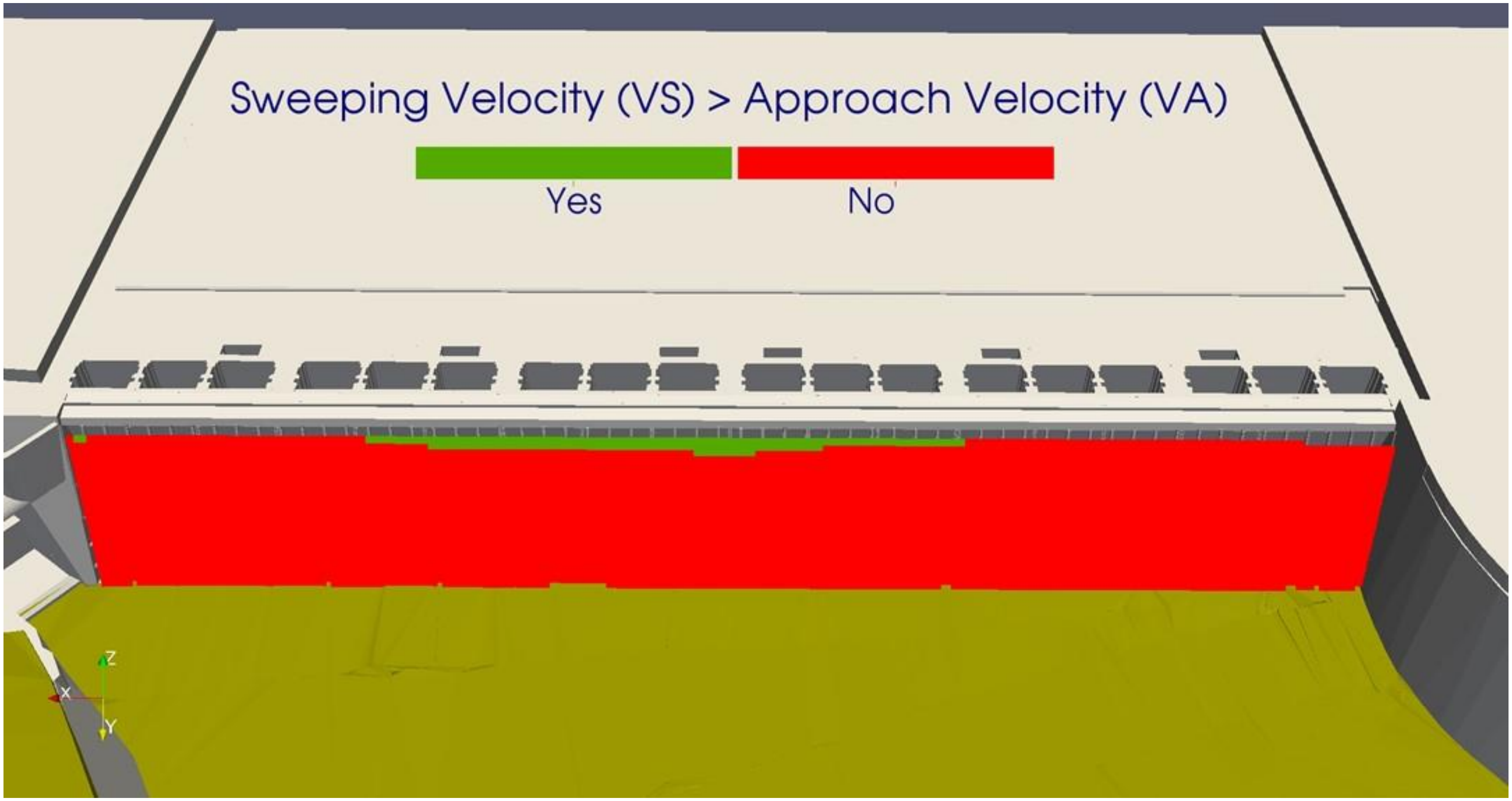


Figure 2.15-3: Cabot Station Scenario 3-3 Intake Rack Component Velocity

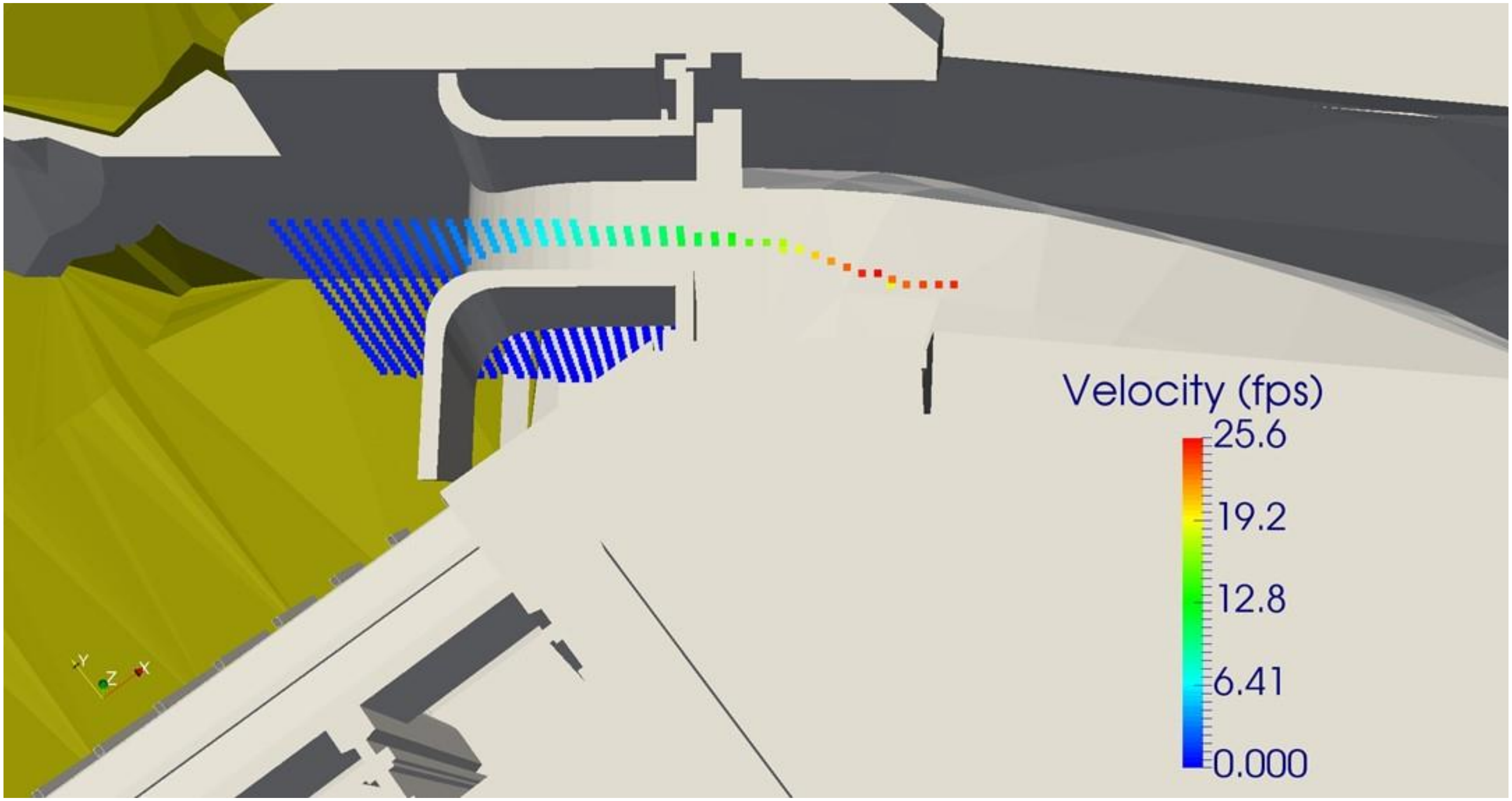


Figure 2.16-1: Cabot Station Scenario 3-1 Fish Weir Velocity

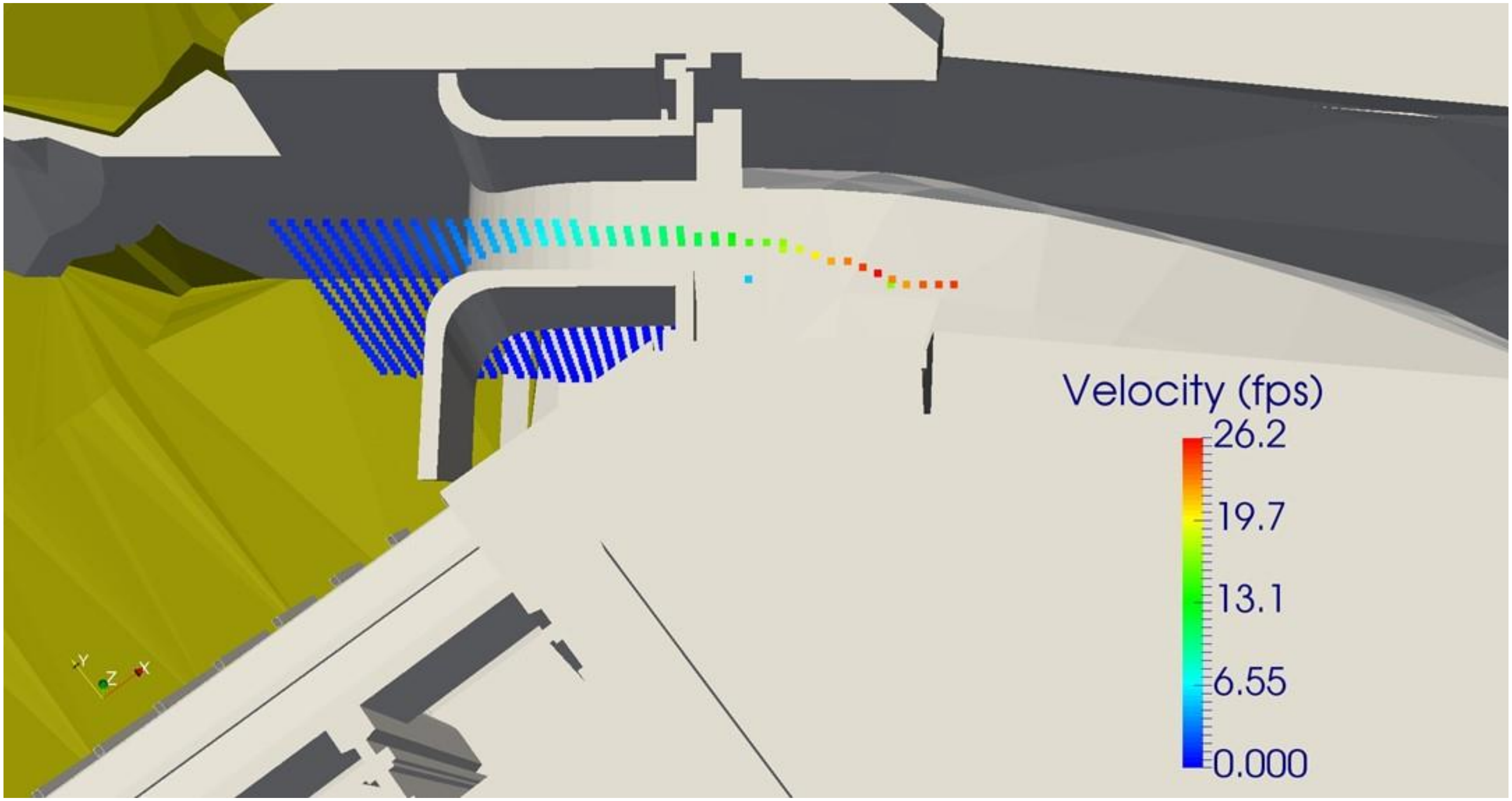


Figure 2.16-2: Cabot Station Scenario 3-2 Fish Weir Velocity

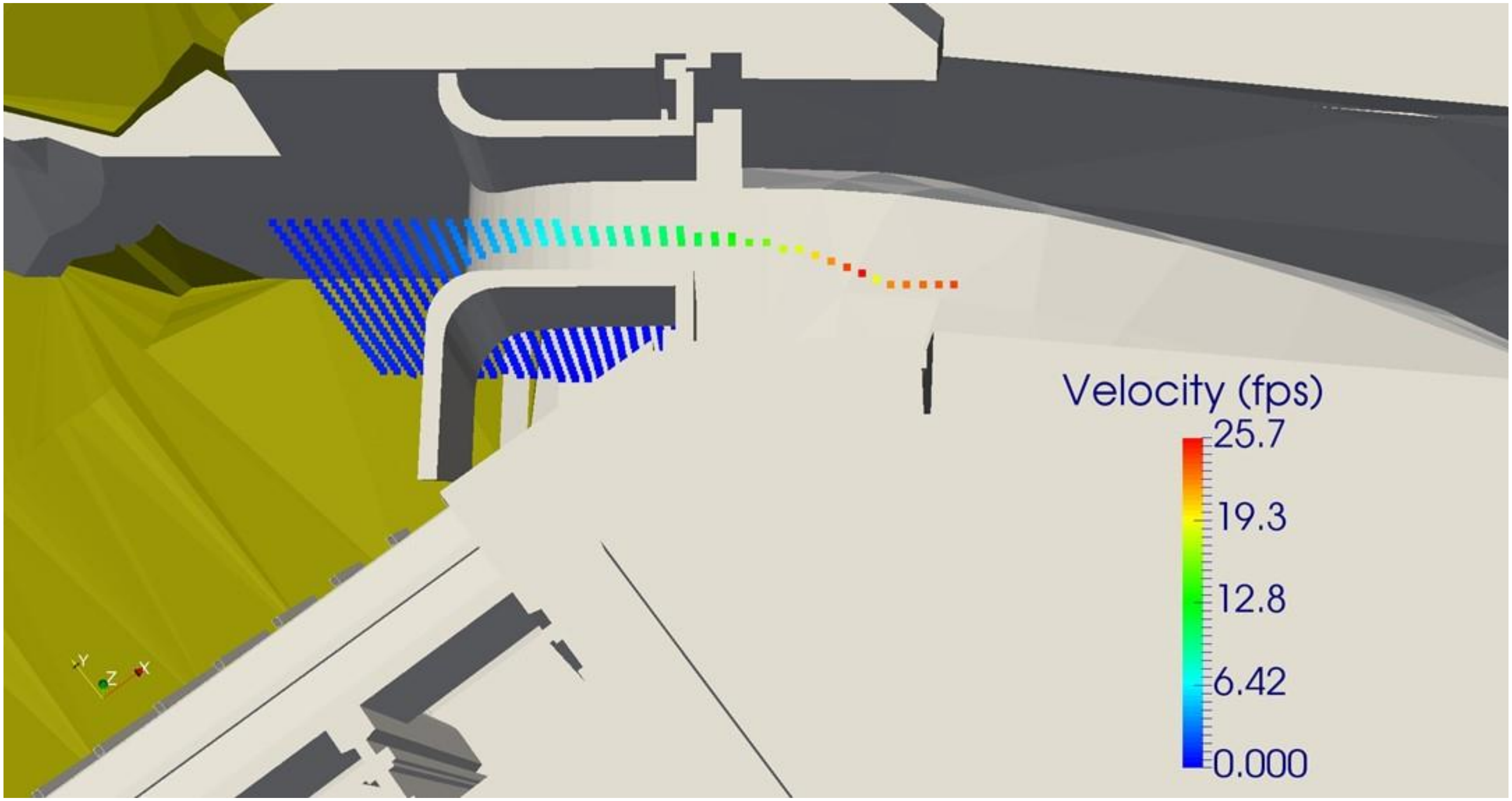


Figure 2.16-3: Cabot Station Scenario 3-3 Fish Weir Velocity

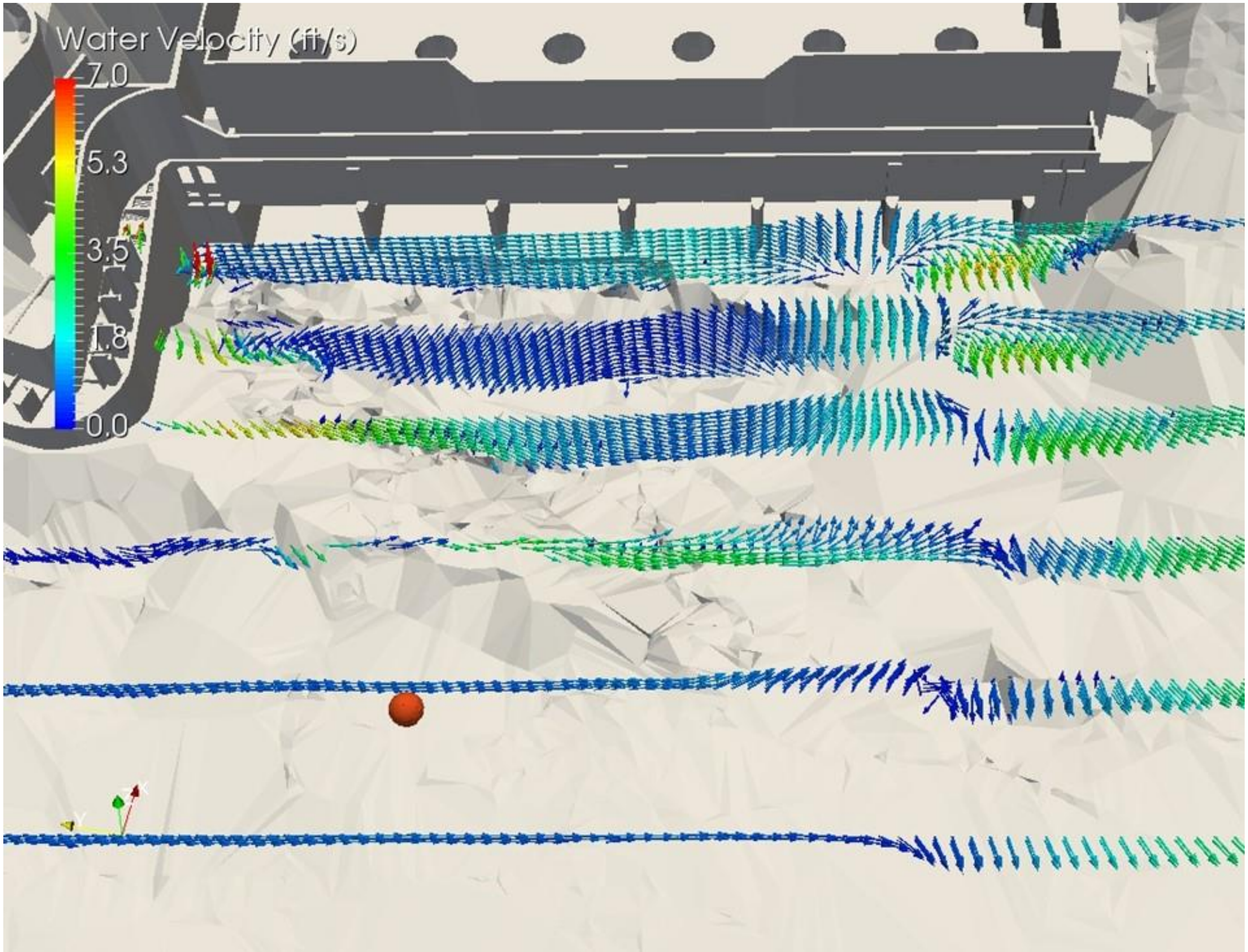


Figure 2.17-1: Cabot Fishway Scenario 5-1 Near-Powerhouse Velocities, Scaled to 0-7 fps

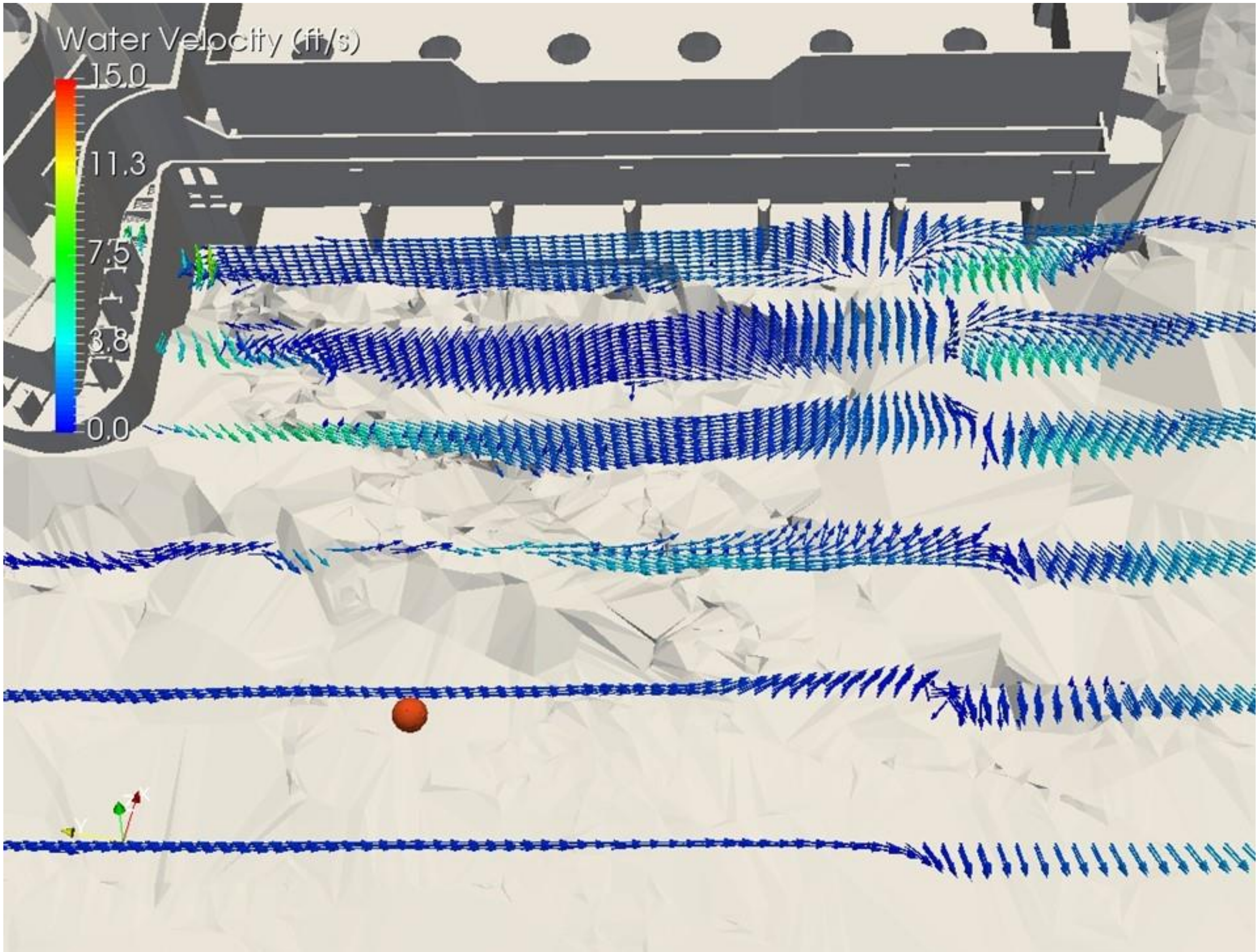


Figure 2.17-2: Cabot Fishway Scenario 5-1 Near-Powerhouse Velocities, Scaled to 0-15 fps

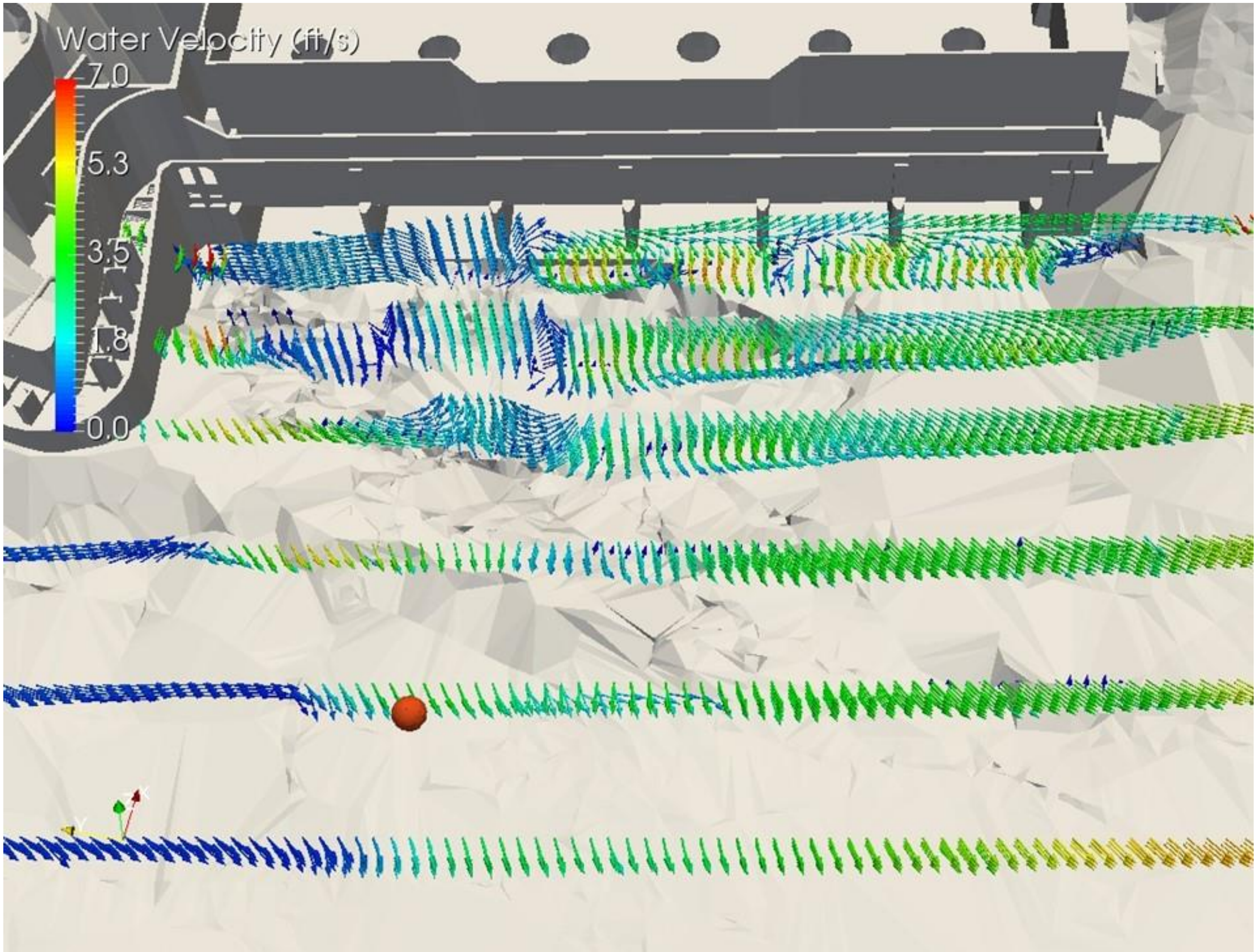


Figure 2.17-3: Cabot Fishway Scenario 5-2 Near-Powerhouse Velocities, Scaled to 0-7 fps

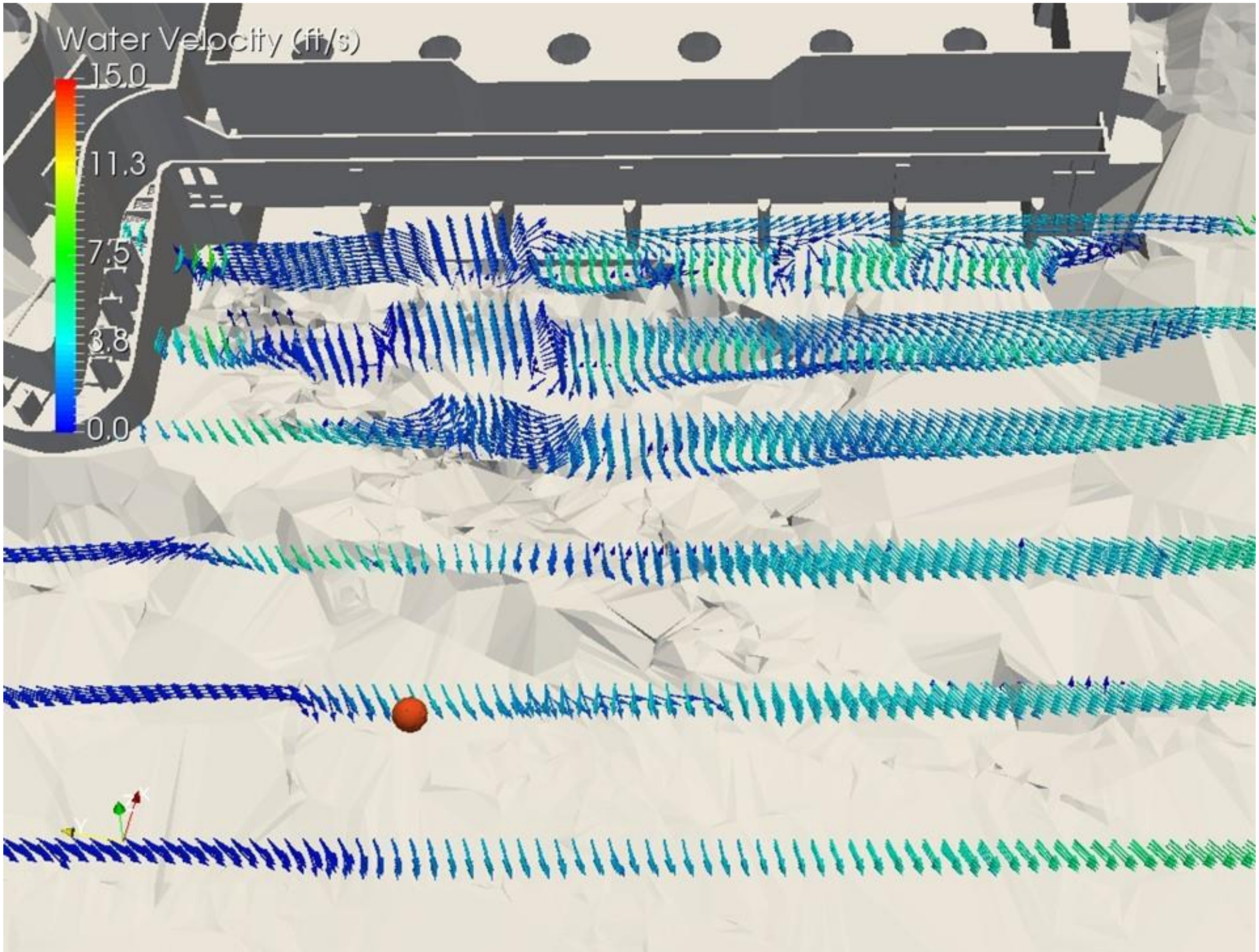


Figure 2.17-4: Cabot Fishway Scenario 5-2 Near-Powerhouse Velocities, Scaled to 0-15 fps

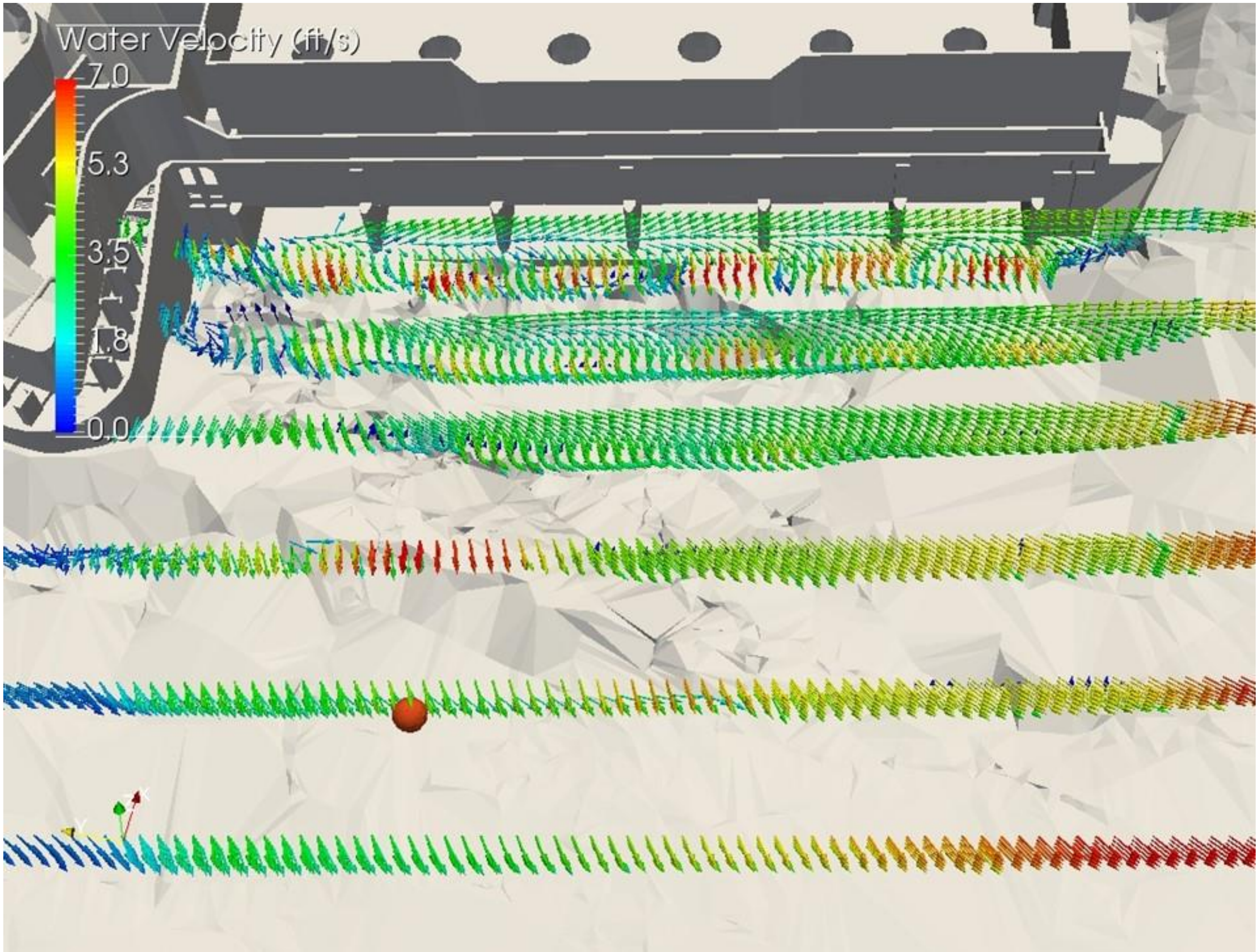


Figure 2.17-5: Cabot Fishway Scenario 5-3 Near-Powerhouse Velocities, Scaled to 0-7 fps

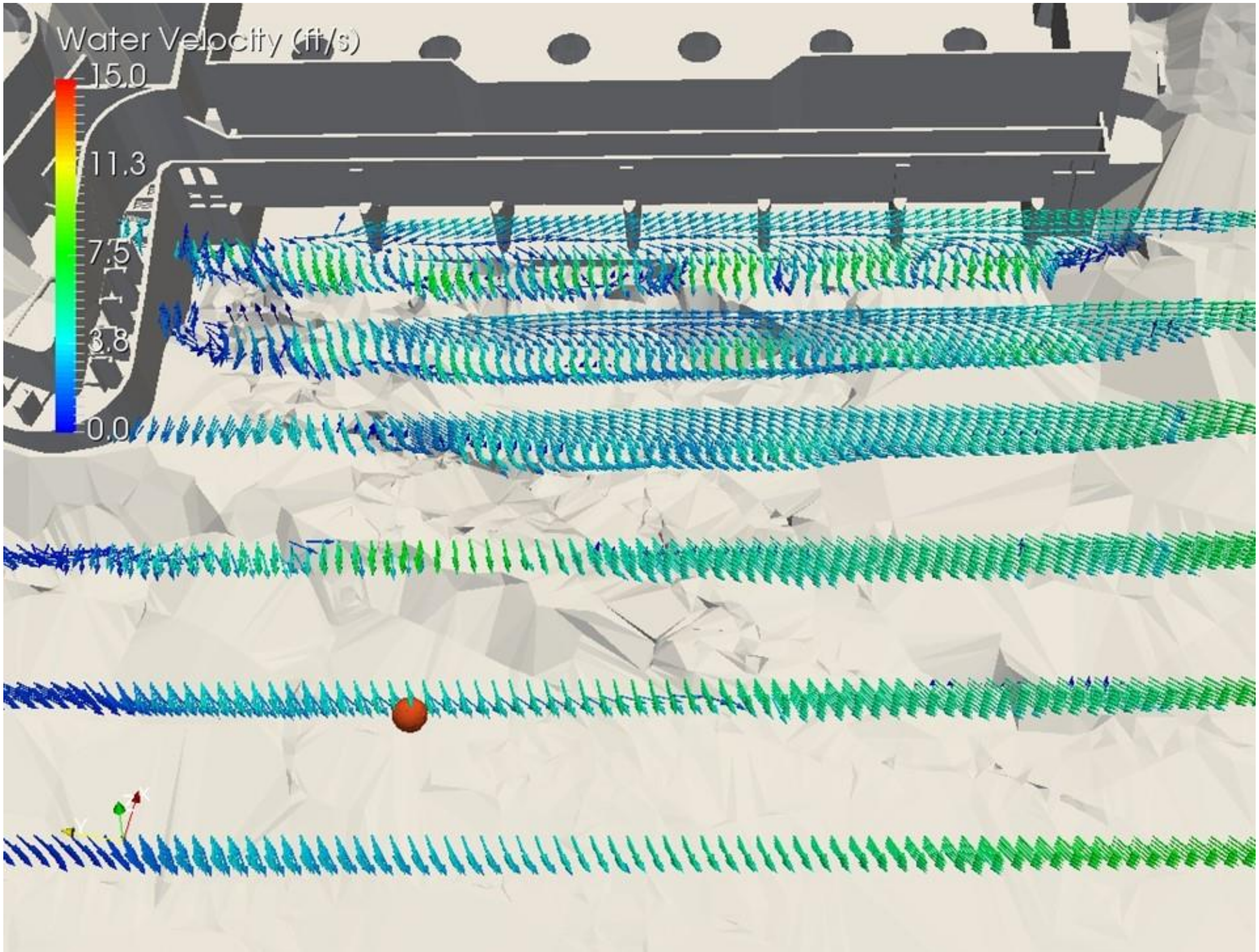


Figure 2.17-6: Cabot Fishway Scenario 5-3 Near-Powerhouse Velocities, Scaled to 0-15 fps

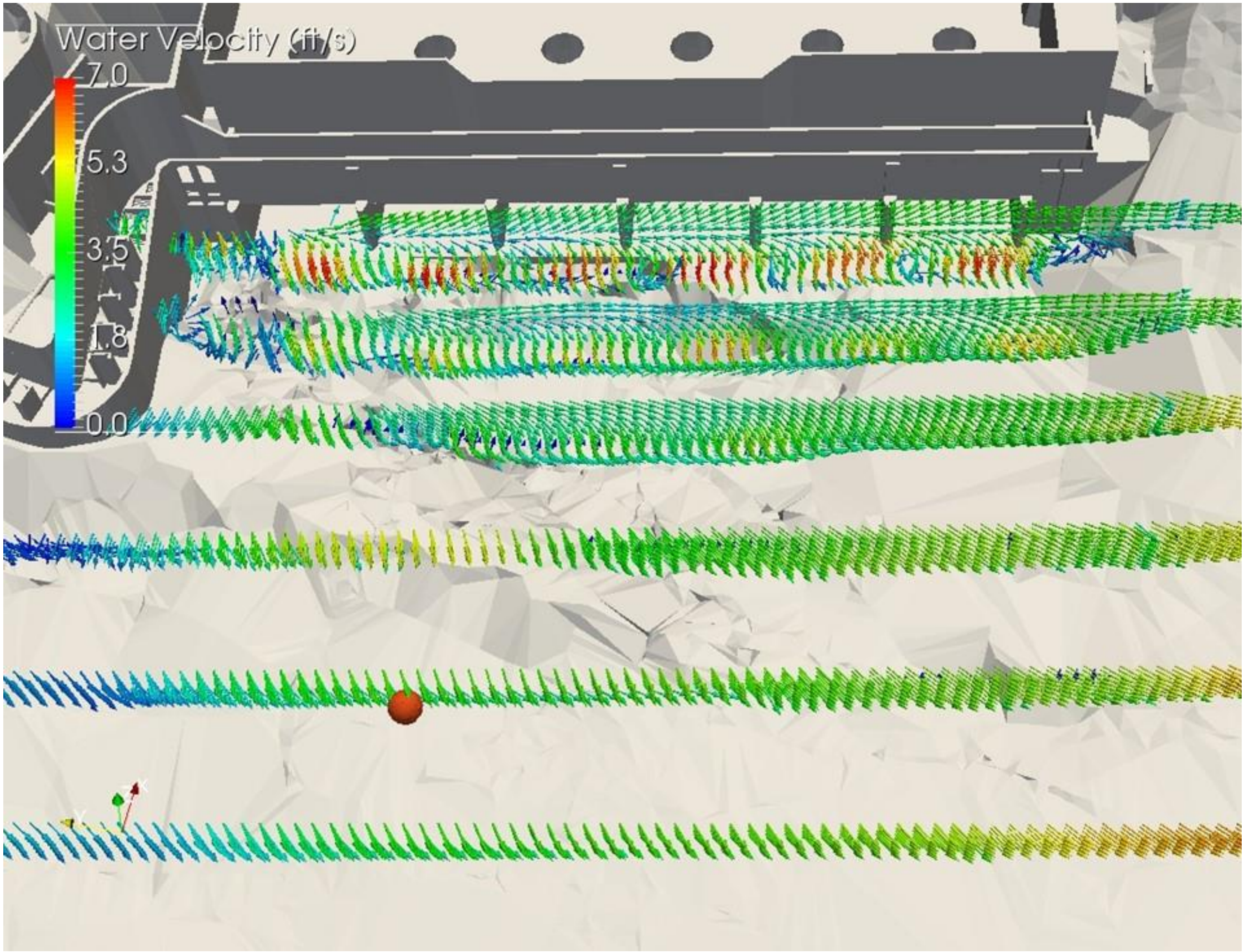


Figure 2.17-7: Cabot Fishway Scenario 5-4 Near-Powerhouse Velocities, Scaled to 0-7 fps

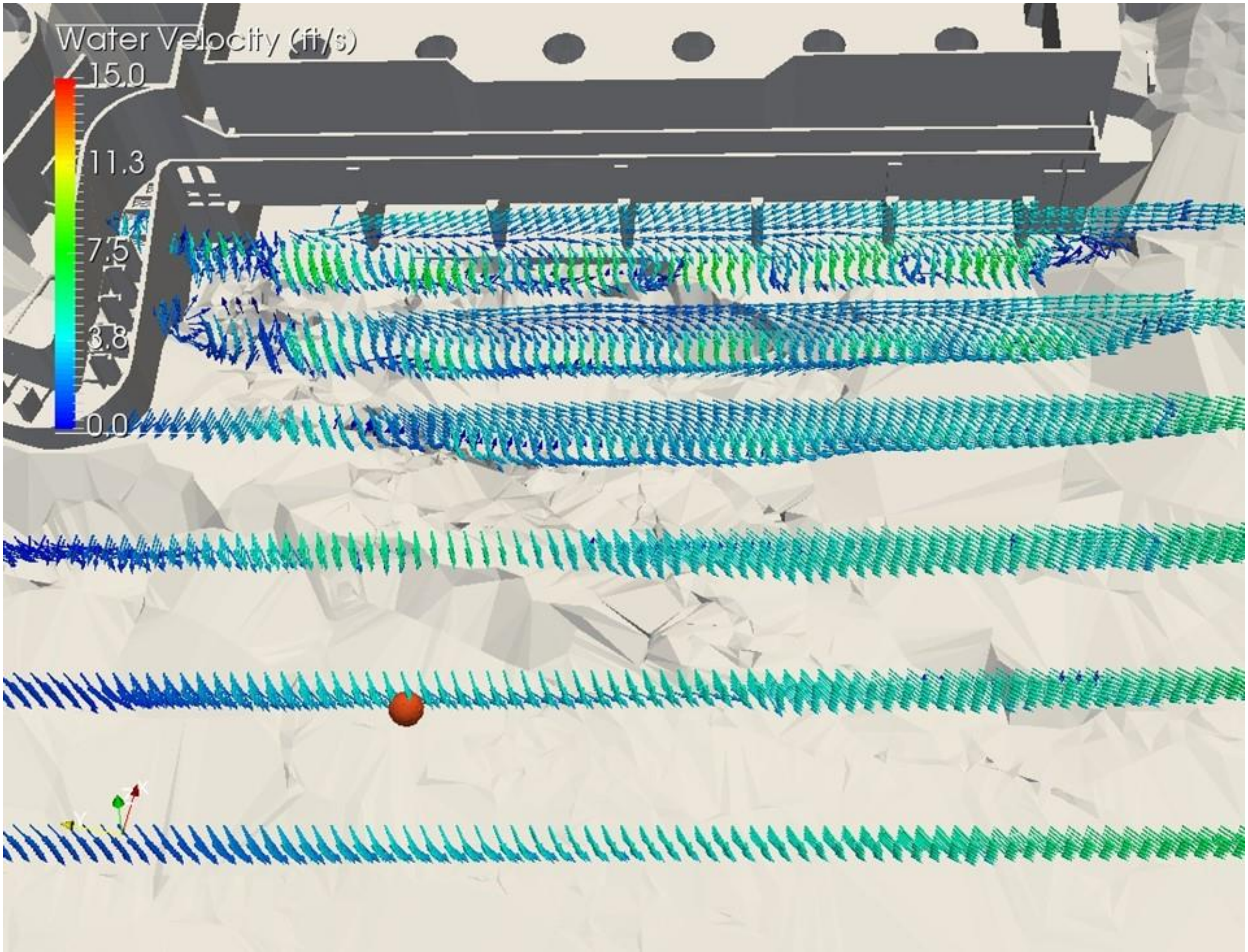


Figure 2.17-8: Cabot Fishway Scenario 5-4 Near-Powerhouse Velocities, Scaled to 0-15 fps

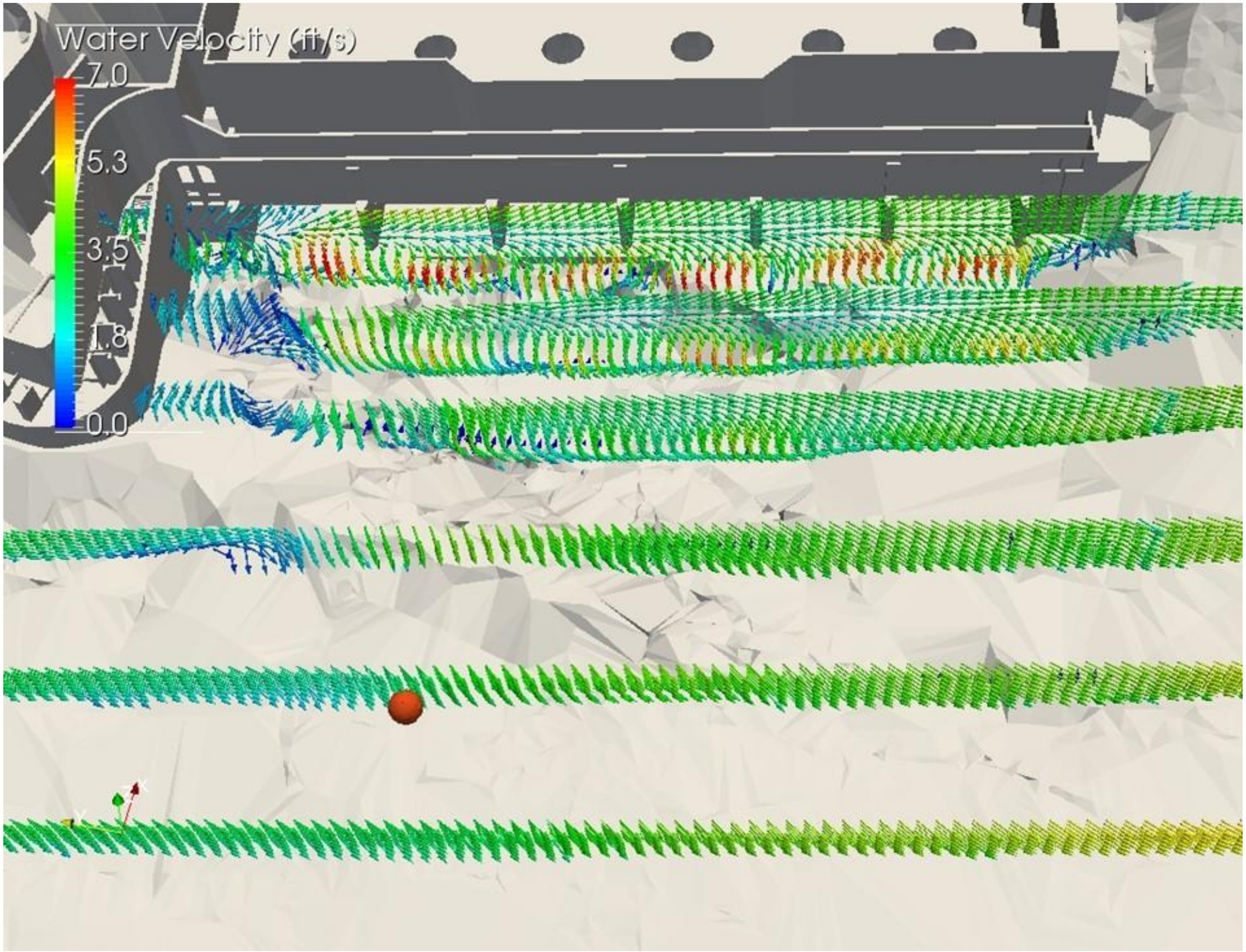


Figure 2.17-9: Cabot Fishway Scenario 5-5 Near-Powerhouse Velocities, Scaled to 0-7 fps

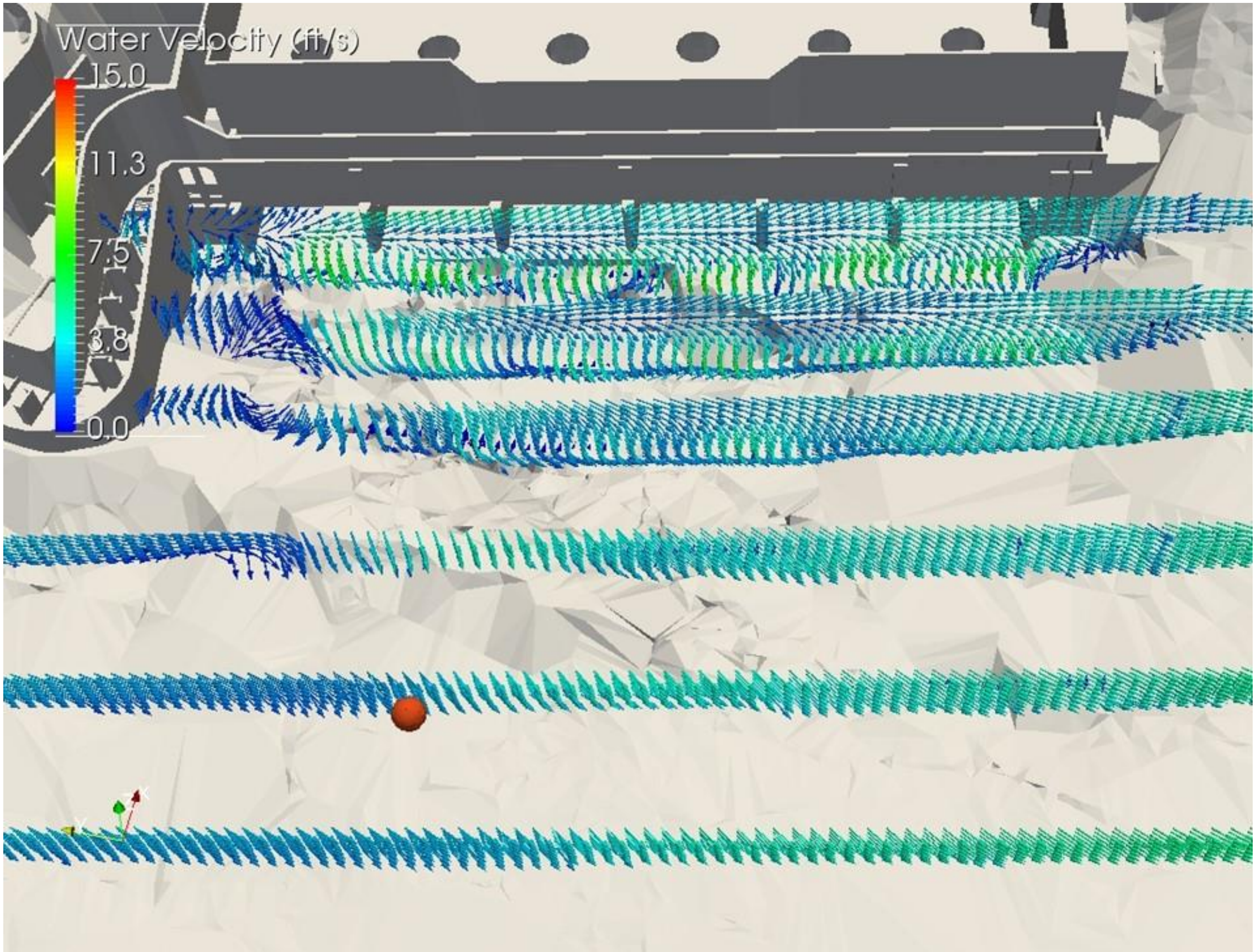


Figure 2.17-10: Cabot Fishway Scenario 5-5 Near-Powerhouse Velocities, Scaled to 0-15 fps