Appendix B – Resource Comments/Concerns and Response

Name	Representing	Comment	Response	Date
Jennifer Tufts	Northfield Open Space Committee (NOSC)	Filed Northfield 2011 Open Space and Recreation Survey.	Relevant portions of the Survey will be reviewed as part of implementation of recreation use/user contact surveys and during development of Final License Application.	1/31/2013
Thomas and Patricia Shearer	Public	Letter indicating FL is still required to repair Mr. Shearer's shoreline located on the Turners Falls Impoundment.	FirstLight is aware of the shoreline stabilization measure request.	1/31/2013
Board of Selectman	Town of Montague	Filed Conceptual Plan for the Great Falls Native Cultural Park.	Relevant portions of the Plan will be reviewed as part of implementation of the archaeological surveys and during development of a Historic Properties Management Plan.	2/6/2013
Mary Joe Maffei	Public, Manager of Amherst High Nordic Ski Team	Ms. Maffei raised concerns relative to x-country skiing. More specifically she would like more access, have the facility open later, and snowmaking.	Amount of snowfall in a given year is a natural phenomenon. The lack of sufficient snow for cross-country skiing has no nexus to Project operation. Licensee will use the results of its proposed recreation studies to develop relicensing proposals for recreational measures at the Project.	2/16/2013
• Peter Conway • Stanley and Geri Johnson • Robert and Linda Emond • Walter and Mary Ann Patenaude • Michael and Diane Kane • Cynthia Dale • Robert Strafford and Family • Leena Newcomb • Vivien Venskowski • Betsy and Jean Egan	River Residents Association (RRA)	RRA raised concerns about negative effects of Turners Falls Impoundment fluctuations and listed their observations of those effects. RRA favors a closed loop system. RRA are also concerned campsite license terms.	Several Turners Falls Impoundment water level fluctuation studies are being proposed to address the questions raised by the RRA. They include: erosion related studies, hydraulic study of the Turners Falls Impoundment, impact of project operations on fish spawning and habitat, and impact of project operations on floodplain, wetland and riparian habitat. FirstLight is not proposing to conduct a closed-loop system study.	Various times
Nathan L'Etoile, Co-Owner	Four Star Farms (FSF)	FSF raised concerns over their water withdrawals from Turners Falls Impoundment. Would like the FERC license amended to stipulate that FirstLight does not have authority over withdrawals for irrigation purposes.	FirstLight is not proposing to conduct a closed-loop system study. FirstLight wishes to resolve the outstanding issues related to irrigation intake structures located on the banks of the Turners Falls Impoundment. These irrigation structures are currently using federally-regulated hydro-electric project lands and waters, which require FirstLight's authorization via a permit for this use pursuant to Articles 43 (c) and (d) of the FERC license. FirstLight has granted permits to several entities to withdraw water for irrigation purposes and will continue to grant such permits, provided that the parties can come to an agreement regarding permit terms and upon FERC approval of the water withdrawal.	2/20/2013
Jeffrey Squire, President	Western Massachusetts Climbers' Coalition (WMCC)	WMCC requests that rock climbing be considered a valid and important recreational opportunity within the Project boundary. He notes that the Northfield Mountain Project contains two of the most significant rock climbing resources in southern New England, Rose Ledge and Farley Ledge (aka Rattlesnake Mountain). WMCC seeks to change the proposed recreation survey to include online surveys and/or surveys distributed through, or with the help of, organizations such as the WMCC. WMCC requests additional protection efforts as the Farley Ledge and its immediate surrounding have been identified by NHESP as Core Habitat containing Priority Natural Community and Species of Concern. WMCC is seeking additional protection efforts and conservation restrictions.	Several studies are being proposed by FirstLight that pertain to the comments of WMCC regarding rock climbing. These studies include surveys of recreation use and demand, recreation facilities inventory and assessments, and a recreation study at Northfield Mountain. Licensee is not proposing to use online surveys because online surveys of recreation use and demand do not provide always provide an accurate assessment of use and demand. FirstLight is proposing to conduct several wildlife and botanical surveys at the Northfield Mountain Project. These surveys will identify rare, threatened, and species of special concern and whether the Project has the potential to adversely affect such species.	
Bill Llewelyn, Chair	Town of Northfield Conservation Commission	NCC raised concerns over Turners Falls Impoundment fluctuations and impacts on the Northfield boat ramp, streambank erosion, water quality,	Several Turners Falls Impoundment water level fluctuation studies are being proposed to address the questions raised by the NCC. FirstLight is not proposing	2/22/2013

Name	Representing	Comment	Response	Date
	(NCC)	threatened and endangered species, fisheries, wetlands, and riparian and littoral habitat. They would like evaluation of a closed-loop system. Expressed concerns with 2008 Full River Reconnaissance Study.	to conduct a closed-loop system study.	
Barbara Skuly, Chairman	Ashuelot River Local Advisory Committee (ARLAC)	ARLAC raised concerns about upstream and downstream fish passage for migratory species. They would like consideration for operating upstream and downstream fish passage facilities year round. ARLAC is concerned about wide and frequent water level fluctuations and impacts on shoreline erosion, bird nesting areas, fish reproduction, and tributary access. Would like consideration of closed-loop system.	FirstLight is proposing to conduct upstream and downstream fish passage studies at the Turners Falls Project. Additionally, FirstLight is proposing to conduct studies to determine the impact of Turners Falls Impoundment fluctuations on various resources. FirstLight is not proposing to conduct a closed-loop system study.	2/24/2013
Karl Meyer	Public	Mr. Meyer raised concerns over the timing of the site visits prior to the scoping process, issuance of the instream flow study plan early, purported failure to comply with bypass minimum flow requirements, impacts of Turners Falls Impoundment fluctuations, fish passage. Noted that existing research has been conducted on sturgeon in project area.	Several studies are being proposed by FirstLight that will address the concerns raised by Mr. Meyer. They include fish and aquatic resource related studies, geology and soils related studies, and a hydraulic analysis within the Turners Falls Impoundment.	2/25/2013
Richard Bonanno, Director	Massachusetts Farm Bureau Federation, Inc (MFBF)	Similar to comments received by Four Star Farms, the MFBF raised concerns over water withdrawals from Turners Falls Impoundment.	FirstLight wishes to resolve the outstanding issues related to irrigation intake structures located on the banks of the Turners Falls Impoundment. These irrigation structures are currently using federally-regulated hydro-electric project lands and waters, which require FirstLight's authorization via a permit for this use pursuant to Articles 43 (c) and (d) of the FERC license. FirstLight has granted permits to several entities to withdraw water for irrigation purposes and will continue to grant such permits, provided that the parties can come to an agreement regarding permit terms and upon FERC approval of the water withdrawal.	2/25/2013
River Resident (no name given)	Public	Requester (unknown) favors a closed loop system.	FirstLight is not proposing to conduct a closed-loop system study.	2/26/2013
Chris Curtis	Public	Submittal included an article in the local paper regarding Turners Falls Impoundment low water levels.	FirstLight reviewed the newspaper article.	2/28/2013
Ken Kimball, Norm Sims	Appalachian Mountain Club (AMC)	AMC submitted specific study requests, which are addressed in the PSP. Submittal was a summary of requested studies, which focus primarily on conservation and recreation.	Several studies are being proposed by FirstLight that will address the comments in AMC's comment letter. These studies include surveys of recreation use and demand, recreation facilities inventory and assessments, a whitewater evaluation and assessment of access for non-motorized boating.	2/28/2013
Dr. Richard Palmer	University of Massachusetts at Amherst (UMass)	Dr. Palmer notes that the mission is to provide natural resource managers with the tools and information needed to develop and execute management strategies that address the impacts of climate and other ongoing global changes on fish and wildlife and their habitats.	FirstLight is using the HEC-ResSim model developed by Project Partners (UMass), TNC, US Army Corps of Engineers and US Geological Survey to evaluate the impact of current and proposed project operations on hydropower generation, as well as aquatic and botanical resources.	2/28/2013
Joseph Graveline, President	The Nolumbeka Project, Inc	**Study request 1** We are requesting a comprehensive investigation and mapping of the many ancient traversing trail systems and fishing stations as well as village locus and other special places that still exist all along the river's edge and up on the land of the Wissatinnewag village, as well as south down river to and beyond the area now known as Rock Dam. The northern section of this area is currently listed in the National Register of Historic Places as part of The Riverside Archaeological District. Our goal is to identify and recognize the hidden historical and cultural value in this land that will foster a stronger awareness and level of protection from the many poor development choices we experienced in the past and see on the horizon. **Part two of request 1** We are requesting to do additional comprehensive investigations,	 Archaeological surveys conducted in connection with the relicensing will result in reports that will discuss the cultural landscape as derived from the results of the surveys and how Native Americans may have used this landscape. FirstLight is proposing to conduct archaeological surveys on lands within the	2/28/2013

Name	Representing	Comment	Response	Date
		documents searches and other research and field studies and inventory and formal archaeological digs, to address the project areas north up to and around the Wilder and Vernon Falls (dam) on the New Hampshire, Vermont, and Massachusetts sides of the river. Any time there are obstructions on the river, like a falls, we understand that a fishing site and a village would have been a part of the landscape. This is where fish are held and create fishing opportunities. These areas hold a wealth of archaeological information that needs to be taken into account when projects are undertaken on the river's edge, or on infrastructure upgrades that are made inland of the project area and might cause the loss of those cultural assets. The Nolumbeka Project, Inc. sees the access to background literature reviews of previous cultural resources and archaeological study reports, and the development of archaeological sensitivity models and focused field reconnaissance studies, which include access to the existing archaeological study data in the files of the Vermont, New Hampshire, and the Massachusetts, State, corporate and other NGO archives, as an important component for use in our historical archive research library. This would add a centralized and accessible body of knowledge for use in determining the cultural assets at risk in the project scope area. Because of the current disconnect to the past cultural data, and lax attitude of past project's responsibility to that data, we see a need to organize that data in a central location and make it digitally available. At this point in the conversation, without knowing all the parties who would need or want to be involved, it would be nearly impossible to do a cost projection for this request.	FERC project boundary. The survey includes the shoreline within the Turners Falls Impoundment. (The Wilder and Vernon hydroelectric projects are not owned by FirstLight.) The surveys will consist of research at the SHPOs and local historical repositories, interviews with persons knowledgeable of the local cultural history, development of a sensitivity model, and field reconnaissance work. Survey reports will include reviews of previous archaeological research; provide detailed cultural contexts, and present results of field investigations. The reports will be made available as part of this relicensing process and will be filed with FERC and the SHPOs. Publicly available reports, however, will not contain precise location information regarding archaeological sites, as required by state and federal regulation.	
		Study request 2 We request that a comprehensive field survey of wildlife and botanical species/habitat to identify, catalogue, digitize, and show the association and use of the many indigenous plant species, both protected, and unprotected, that played a part in the cultural lifestyles of the people who used them. This information would prove to be useful for endangered species protection and life ways studies of the ancient river tribes. The cost of this process would be determined by the number of sites that give indication of Native land use in the projects areas, and that has yet to be fully determined.	FirstLight is proposing to conduct a terrestrial baseline survey of wildlife and botanical resources, including rare, threatened and endangered species within the Turners Falls Impoundment and below the Turners Falls Dam. The results of this survey will be available to parties interested in the relicensing process, such as The Nolumbeka Project, for their use in the study of past Native American use. FirstLight is also proposing to conduct archaeological surveys. The survey reports will discuss features from archaeological sites that may contain paleobotanical remains and present the results of any paleobotanical analysis conducted, if any paleobotanical remains are found. In accordance with state and federal regulations, however, the precise locations of archaeological sites may not be published.	
		Study request 3 We request a project be undertaken to stabilize the exposed sand bank and protect from erosion damages other disturbed areas on the Wissatinnewag property damaged during mining and contracting work or the result of storm damage experienced prior to the acquisition of the land by The Nolumbeka Project. The goal would be to return the site to a green-fields condition for use as a cultural educational resource. This should include planting of indigenous grasses and plants known to have existed here prior to the land being disturbed. In addition, this would allow an experienced team of botanists, historians and archaeologists to do the basic research to develop a more complete cultural profile on the Wissatinnewag site and other important sites on the river in the resource areas under the license obligations from the utilities. The cost for this process would be impacted by the results of the second study request, which we do not have at this time.	The Wissatinnewag property is not within the Project boundary as shown in Figure B1. It appears that the exposed bank referenced in the letter is within the Wissatinnewag property, which has no nexus to project operations. Therefore, FirstLight is not proposing to conduct studies or bank stabilization work on this property.	

Name	Representing	Comment	Response	Date
		Study request 4 We request a project be undertaken to identify and implement the formation of a National Historic Park around the Great Falls fight site in the Gill and Turners Falls area. A Historic Educational Park and self guided hiking trails, would allow the story of the May 19, 1676 attack on the refugee camp at the Wissatinnewag and the Peskeompskut village sites to be told from the indigenous point of view, and would help to educate and celebrate the importance of the relationship The Great Falls played in the lives of the indigenous people, who for over 200 generations, considered it to be a village of peace and place of cultural and technical exchange and celebration. This educational experience fits right into the Town of Montague's efforts to establish the River Culture and history of the Great Falls as a destination for historical tourism. The Town of Northfield is also talking about historic tourism as part of their new Master Plan. As part of this process we would like to also request a central housing facility in the Gill or Turners Falls area for our historic archives and study programs. Researchers, educators, and THPO's across the northeast and beyond could use this office. It could also be a central location for preservation efforts here in Western Massachusetts. A study needs to be done first to arrive at the cost of this project. An office location for the Nolumbeka Project might be incorporated into a River Culture complex with the Town of Montague and other NGO's, to offset the expense of the project.	FirstLight is proposing to conduct archaeological surveys, which will identify historic properties and whether the Projects have an adverse effect on historic properties. As part of the relicensing process, FirstLight will be required to develop an HPMP, which will address the protection of historic properties. The HPMP may include measures to provide cultural resources public outreach programs, but such programs typically would not include providing central housing facilities or offices for others.	
		Study request 5 In the early sixties a construction company mined the northern portion of the Wissatinnewag Village area we are responsible for preserving. During that time period sand and gravel from the Wissatinnewag Village site was taken for the building of Route 2 in Greenfield across the street and Route 10 in the Northfield area. During this phase of history on the site, part of the village was destroyed and untold numbers of unmarked burials were displaced. Sadly, human remains mixed in the sand and gravel often became part of the road base for the Route 2 and Route 10 road construction projects at that time. The construction company used the mined out portion of the village to deposit and bury construction debris. Old tires, discarded construction materials and steel barrels were buried there. That portion of the village leaches into Falls Brook, which goes into the Falls River and within a few hundred feet into the Connecticut River. We would like to clean up the pollution going into Falls Brook and restore the area to a clean and healthy ecosystem. Addressing this challenge would make the area safer and more useful in our educational and preservation programs on the site. The cost of this effort could only be determined by testing for the extent of the contamination on the site impacted, and that has yet to be done.	The Wissatinnewag site is not located within the Project boundary. The damage cited by the Nolumbeka Project was also not caused by Project operation but as noted in the study request, by non-Project construction projects. Thus, there is no nexus to the Project.	
Mike Bathory	LCCLC	LCCLC requests that FERC direct FirstLight to provide the data from Cross Section 8A from the start of erosion monitoring to the present and make it available on the licensing proceeding.	On January 22, 2013, FirstLight filed with FERC information on 22 long-term monitoring transects, including cross-section 8A.	3/1/2013
Roger Noonan, President	New England Farmers Union (NEFU)	Similar to comments received by Four Star Farms, the NEFU raised concerns over water withdrawals from Turners Falls Impoundment.	FirstLight wishes to resolve the outstanding issues related to irrigation intake structures located on the banks of the Turners Falls Impoundment. These irrigation structures are currently using federally-regulated hydro-electric project lands and waters, which require FirstLight's authorization via a permit for this use pursuant to Articles 43 (c) and (d) of the FERC license. FirstLight has granted permits to	3/1/2013

Name	Representing	Comment	Response	Date
			several entities to withdraw water for irrigation purposes and will continue to grant such permits, provided that the parties can come to an agreement regarding permit terms and upon FERC approval of the water withdrawal.	
Elizabeth Muzzey, Director and State Historic Preservation Officer	New Hampshire Division of Historical Resources (NHDHR)	The NHDHR comment letter refers specifically to the TransCanada Projects.	The letter does not pertain to the Turners Falls and Northfield Mountain Projects, although it was filed in the FERC dockets for the Turners Falls and Northfield Mountain Projects.	3/1/2013
Howard Fairman	Public	The commenter is concerned about the impact of project operations on migratory fish.	FirstLight is proposing studies to evaluate upstream and downstream of the fish passage facilities on migratory fish.	3/1/2013
Stephanie Krug, President	New England Biking Association (NEBA)	The commenter would like a study evaluating the trail system at Northfield Mountain for mountain biking. The comment letter notes that over the past few years, deep water bars have been dug diagonally across the 10th Mountain road at Northfield Mountain to help with drainage. These water bars have been challenging to negotiate on a bike or on horseback and she has witnessed two accidents.	FirstLight is proposing to conduct a recreation study at Northfield Mountain, including assessing shared-use trails.	3/1/2013
Joanne McGee	Public	The commenter would a new access spot for launching canoes and kayaks at the Bennett Brook Wildlife Management Area. She notes that there is ample parking and that canoes/kayaks will not disturb the wildlife in the area.	FirstLight is proposing to conduct surveys of recreation use and demand and an assessment of recreation facilities. These surveys along with others will inform the need for new access spots.	3/1/2013
Kurt Heidinger	Director, BioCitizens	The commenter would like a report to include information on various resources between Turners Falls and Rainbow Beach for educational purposes. He notes that a good report would collect data on how from Turners Falls to Rainbow Beach is a valuable educational resource, used by many schools and nonprofits, for many years. Notes that during an educational visit there were dead fish floating in the river and dessicating on the river banks.	FirstLight is proposing to conduct several surveys on various resources between Turners Falls and Rainbow Beach, including wildlife and botanical surveys. These reports will be part of the FERC relicensing record and available to interested parties.	3/1/2013
Don Stevens, Chief	Nulhegan Band of the Coosuk-Abenaki Nation	The Nulhegan Band of the Coosuk- Abenaki Nation would like to know if any Native sites have been identified and would like to know if there are plans to make sure that wildlife can move freely.	FirstLight is proposing to conduct standard archaeological surveys to identify cultural resources, including Native sites, and whether the Projects have any adverse effects on those resources. FirstLight is also proposing to conduct a survey to assess the effects of the Northfield Mountain Project's land-management practices and recreational use on terrestrial habitat.	3/18/2013

FIRSTLIGHT POWER RESOURCES

FirstLight Power Resources
GDF SUEZ

Figure B1: Location of the Friends of Wissatinnewag, Inc Property Relative to the FirstLight Project Boundary

Path: W:\gis\maps\Study_Plans\Figure B1.mxd

Appendix C – NRCS Chemical and Physical Soil Properties

Map Unit Legend

Cheshire County, New Hampshire

Map symbol	Map unit name
10B	Merrimac fine sandy loam, 3 to 8 percent slopes
10C	Merrimac fine sandy loam, 8 to 15 percent slopes
24A	Agawam very fine sandy loam, 0 to 3 percent slopes
24B	Agawam very fine sandy loam, 3 to 8 percent slopes
24C	Agawam very fine sandy loam, 8 to 15 percent slopes
26A	Windsor loamy fine sand, 0 to 3 percent slopes
26B	Windsor loamy fine sand, 3 to 8 percent slopes
26C	Windsor loamy fine sand, 8 to 15 percent slopes
26E	Windsor loamy fine sand, 15 to 50 percent slopes
30A	Unadilla very fine sandy loam, 0 to 3 percent slopes
30B	Unadilla very fine sandy loam, 3 to 8 percent slopes
30C	Unadilla very fine sandy loam, 8 to 15 percent slopes
60C	Tunbridge-Berkshire complex, 8 to 15 percent slopes, very stony
61C	Tunbridge-Lyman-Rock outcrop complex, 8 to 15 percent slopes
61D	Tunbridge-Lyman-Rock outcrop complex, 15 to 25 percent slopes
108	Hadley silt loam
230E	Poocham very fine sandy loam, 25 to 70 percent slopes

Map Unit Legend

Windham County, Vermont

Map symbol	Map unit name
1A	Unadilla silt loam, 0 to 3 percent slopes
1B	Unadilla silt loam, 3 to 8 percent slopes
1C	Unadilla silt loam, 8 to 15 percent slopes
1D	Unadilla silt loam, 15 to 25 percent slopes
1E	Udorthents, steep
5B	Windsor loamy fine sand, 2 to 8 percent slopes
5C	Windsor loamy fine sand, 8 to 15 percent slopes
5D	Windsor loamy fine sand, 15 to 25 percent slopes
5E	Windsor loamy fine sand, 25 to 60 percent slopes
10A	Agawam very fine sandy loam, 0 to 3 percent slopes
20B	Tunbridge-Lyman fine sandy loams, 3 to 8 percent slopes, very rocky
20C	Tunbridge-Lyman fine sandy loams, 8 to 15 percent slopes, very rocky
20D	Tunbridge-Lyman fine sandy loams, 15 to 25 percent slopes, very rocky
37	Hadley silt loam

Map Unit Legend

Franklin County, Massachusetts

Map symbol	Map unit name
90A	Hadley very fine sandy loam, 0 to 3 percent slopes, protected
96A	Hadley very fine sandy loam, 0 to 3 percent slopes, occasionally flooded
109B	Chatfield-Hollis complex, 3 to 8 percent slopes, rocky
109C	Chatfield-Hollis complex, 8 to 15 percent slopes, rocky
109D	Chatfield-Hollis complex, 15 to 25 percent slopes, rocky
109F	Chatfield-Hollis complex, 25 to 60 percent slopes, rocky
125B	Charlton-Chatfield-Hollis complex, 3 to 8 percent slopes, rocky
125C	Charlton-Chatfield-Hollis complex, 8 to 15 percent slopes, rocky
125D	Charlton-Chatfield-Hollis complex, 15 to 25 percent slopes, rocky
131B	Yalesville-Holyoke complex, 3 to 8 percent slopes, rocky
131C	Yalesville-Holyoke complex, 8 to 15 percent slopes, rocky
131D	Yalesville-Holyoke complex, 15 to 25 percent slopes, rocky
131F	Yalesville-Holyoke complex, 25 to 50 percent slopes, rocky
229F	Windsor and Merrimac soils, 25 to 60 percent slopes
230A	Unadilla silt loam, 0 to 3 percent slopes
230B	Unadilla silt loam, 3 to 8 percent slopes
235F	Poocham silt loam, 25 to 60 percent slopes
254A	Merrimac fine sandy loam, 0 to 3 percent slopes
254B	Merrimac fine sandy loam, 3 to 8 percent slopes
254C	Merrimac fine sandy loam, 8 to 15 percent slopes
254D	Merrimac fine sandy loam, 15 to 25 percent slopes
255A	Windsor loamy sand, 0 to 3 percent slopes
255B	Windsor loamy sand, 3 to 8 percent slopes
255C	Windsor loamy sand, 8 to 15 percent slopes
255D	Windsor loamy sand, 15 to 25 percent slopes
275A	Agawam fine sandy loam, 0 to 3 percent slopes
275B	Agawam fine sandy loam, 3 to 8 percent slopes
275C	Agawam fine sandy loam, 8 to 15 percent slopes
275D	Agawam fine sandy loam, 15 to 25 percent slopes
618F	Udorthents, 25 to 60 percent slopes, frequently flooded
651	Udorthents, smoothed
656	Udorthents-Urban land complex

Chemical Soil Properties

Cheshire County, New Hampshire

Map symbol and soil name	Depth	Cation-exchange capacity	Effective cation-exchange capacity	Soil reaction	Calcium carbon-ate	Gypsum	Salinity	Sodium adsorption ratio
	In	*meq/100 g*	*meq/100 g*	*pH*	*Pct*	*Pct*	*mmhos/cm*	
10B:								
Merrimac	0-19	---	1.0-7.1	3.6-6.0	---	---	---	---
	19-23	---	0.5-4.3	3.6-6.0	---	---	---	---
	23-28	---	0.5-3.3	3.6-6.0	---	---	---	---
	28-60	---	0.1-2.7	3.6-6.0	---	---	---	---
10C:								
Merrimac	0-19	---	1.0-7.1	3.6-6.0	---	---	---	---
	19-23	---	0.5-4.3	3.6-6.0	---	---	---	---
	23-28	---	0.5-3.3	3.6-6.0	---	---	---	---
	28-60	---	0.1-2.7	3.6-6.0	---	---	---	---
24A:								
Agawam	0-12	3.6-9.3	---	4.5-6.5	---	---	---	---
	12-20	1.2-8.5	---	4.5-6.5	---	---	---	---
	20-25	1.1-5.4	---	4.5-6.5	---	---	---	---
	25-52	0.7-2.0	---	4.5-6.5	---	---	---	---
	52-60	0.1-1.1	---	4.5-6.5	---	---	---	---
24B:								
Agawam	0-12	3.6-9.3	---	4.5-6.5	---	---	---	---
	12-20	1.2-8.5	---	4.5-6.5	---	---	---	---
	20-25	1.1-5.4	---	4.5-6.5	---	---	---	---
	25-52	0.7-2.0	---	4.5-6.5	---	---	---	---
	52-60	0.1-1.1	---	4.5-6.5	---	---	---	---
24C:								
Agawam	0-12	3.6-9.3	---	4.5-6.5	---	---	---	---
	12-20	1.2-8.5	---	4.5-6.5	---	---	---	---
	20-25	1.1-5.4	---	4.5-6.5	---	---	---	---
	25-52	0.7-2.0	---	4.5-6.5	---	---	---	---
	52-60	0.1-1.1	---	4.5-6.5	---	---	---	---
26A:								
Windsor	0-4	---	0.8-2.4	4.5-6.0	---	---	---	---
	4-26	---	0.1-2.2	4.5-6.0	---	---	---	---
	26-60	0.1-1.8	---	4.5-6.5	---	---	---	---
26B:								
Windsor	0-4	---	0.8-2.4	4.5-6.0	---	---	---	---
	4-26	---	0.1-2.2	4.5-6.0	---	---	---	---
	26-60	0.1-1.8	---	4.5-6.5	---	---	---	---

Map symbol and soil name	Depth	Cation-exchange capacity	Effective cation-exchange capacity	Soil reaction	Calcium carbon-ate	Gypsum	Salinity	Sodium adsorption ratio
	In	*meq/100 g*	*meq/100 g*	*pH*	*Pct*	*Pct*	*mmhos/cm*	
26C:								
Windsor	0-4	---	0.8-2.4	4.5-6.0	---	---	---	---
	4-26	---	0.1-2.2	4.5-6.0	---	---	---	---
	26-60	0.1-1.8	---	4.5-6.5	---	---	---	---
26E:								
Windsor	0-4	---	0.8-2.4	4.5-6.0	---	---	---	---
	4-26	---	0.1-2.2	4.5-6.0	---	---	---	---
	26-60	0.1-1.8	---	4.5-6.5	---	---	---	---
30A:								
Unadilla	0-8	---	1.5-13	4.5-6.0	---	---	---	---
	8-35	---	0.9-9.8	4.5-6.0	---	---	---	---
	35-60	0.7-2.8	---	5.1-7.8	---	---	---	---
30B:								
Unadilla	0-8	---	1.5-13	4.5-6.0	---	---	---	---
	8-35	---	0.9-9.8	4.5-6.0	---	---	---	---
	35-60	0.7-2.8	---	5.1-7.8	---	---	---	---
30C:								
Unadilla	0-8	---	1.5-13	4.5-6.0	---	---	---	---
	8-35	---	0.9-9.8	4.5-6.0	---	---	---	---
	35-60	0.7-2.8	---	5.1-7.8	---	---	---	---
60C:								
Tunbridge	0-4	---	---	3.6-6.0	---	---	---	---
	4-26	---	---	3.6-6.0	---	---	---	---
	26-30	---	---	---	---	---	---	---
Berkshire	0-3	---	---	3.6-6.0	---	---	---	---
	3-35	---	---	3.6-6.0	---	---	---	---
	35-60	---	---	3.6-6.0	---	---	---	---
61C:								
Tunbridge	0-4	---	---	3.6-6.0	---	---	---	---
	4-26	---	---	3.6-6.0	---	---	---	---
	26-30	---	---	---	---	---	---	---
Lyman	0-4	---	---	3.6-6.0	---	---	---	---
	4-16	---	---	3.6-6.0	---	---	---	---
	16-20	---	---	---	---	---	---	---
Rock outcrop	---	---	---	---	---	---	---	---

Chemical Soil Properties

Cheshire County, New Hampshire

Map symbol and soil name	Depth	Cation-exchange capacity	Effective cation-exchange capacity	Soil reaction	Calcium carbon-ate	Gypsum	Salinity	Sodium adsorption ratio
	In	*meq/100 g*	*meq/100 g*	*pH*	*Pct*	*Pct*	*mmhos/cm*	
61D:								
Tunbridge	0-4	---	---	3.6-6.0	---	---	---	---
	4-26	---	---	3.6-6.0	---	---	---	---
	26-30	---	---	---	---	---	---	---
Lyman	0-4	---	---	3.6-6.0	---	---	---	---
	4-16	---	---	3.6-6.0	---	---	---	---
	16-20	---	---	---	---	---	---	---
Rock outcrop	---	---	---	---	---	---	---	---
108:								
Hadley	0-11	3.7-8.9	---	4.5-7.3	---	---	---	---
	11-42	1.9-8.7	---	4.5-7.8	---	---	---	---
	42-60	0.8-6.8	---	5.1-7.8	---	---	---	---
230E:								
Poocham	0-2	2.8-9.3	---	4.5-6.5	---	---	---	---
	2-13	2.8-8.5	---	4.5-6.5	---	---	---	---
	13-60	1.6-10	---	4.5-6.5	---	---	---	---

Chemical Soil Properties

Windham County, Vermont

Map symbol and soil name	Depth	Cation-exchange capacity	Effective cation-exchange capacity	Soil reaction	Calcium carbon-ate	Gypsum	Salinity	Sodium adsorption ratio
	In	meq/100 g	meq/100 g	pH	Pct	Pct	mmhos/cm	
1A:								
Unadilla	0-10	---	1.5-12	4.5-6.0	0	0	0.0	0
	10-60	---	0.3-7.2	4.5-6.0	0	0	0.0	0
1B:								
Unadilla	0-10	---	1.5-12	4.5-6.0	0	0	0.0	0
	10-60	---	0.3-7.2	4.5-6.0	0	0	0.0	0
1C:								
Unadilla	0-10	---	1.5-12	4.5-6.0	0	0	0.0	0
	10-60	---	0.3-7.2	4.5-6.0	0	0	0.0	0
1D:								
Unadilla	0-10	---	1.5-12	4.5-6.0	0	0	0.0	0
	10-60	---	0.3-7.2	4.5-6.0	0	0	0.0	0
1E:								
Udorthents	0-60	---	0.1-6.1	4.5-6.0	0	0	0.0	0
5B:								
Windsor	0-3	---	0.8-2.4	4.5-6.0	0	0	0.0	0
	3-14	---	0.1-1.8	4.5-6.0	0	0	0.0	0
	14-60	0.0-1.8	---	4.5-6.5	0	0	0.0	0
5C:								
Windsor	0-3	---	0.8-2.4	4.5-6.0	0	0	0.0	0
	3-14	---	0.1-1.8	4.5-6.0	0	0	0.0	0
	14-60	0.0-1.8	---	4.5-6.5	0	0	0.0	0
5D:								
Windsor	0-3	---	0.8-2.4	4.5-6.0	0	0	0.0	0
	3-14	---	0.1-1.8	4.5-6.0	0	0	0.0	0
	14-60	0.0-1.8	---	4.5-6.5	0	0	0.0	0
5E:								
Windsor	0-3	---	0.8-2.4	4.5-6.0	0	0	0.0	0
	3-14	---	0.1-1.8	4.5-6.0	0	0	0.0	0
	14-60	0.0-1.8	---	4.5-6.5	0	0	0.0	0
10A:								
Agawam	0-10	3.6-9.1	---	4.5-6.5	0	0	0.0	0
	10-25	1.1-8.5	---	4.5-6.5	0	0	0.0	0
	25-60	0.7-2.0	---	4.5-6.5	0	0	0.0	0

Chemical Soil Properties

Windham County, Vermont

Map symbol and soil name	Depth	Cation-exchange capacity	Effective cation-exchange capacity	Soil reaction	Calcium carbon-ate	Gypsum	Salinity	Sodium adsorption ratio
	In	meq/100 g	meq/100 g	pH	Pct	Pct	mmhos/cm	
20B:								
Tunbridge	0-2	---	2.8-8.0	3.6-6.0	0	0	0.0	0
	2-27	---	1.4-6.7	3.6-6.0	0	0	0.0	0
	27-37	---	---	---	---	0	0.0	0
Lyman	0-5	---	1.7-9.0	3.6-6.0	0	0	0.0	0
	5-15	---	1.7-8.4	3.6-6.0	0	0	0.0	0
	15-25	---	---	---	---	0	0.0	0
20C:								
Tunbridge	0-2	---	2.8-8.0	3.6-6.0	0	0	0.0	0
	2-27	---	1.4-6.7	3.6-6.0	0	0	0.0	0
	27-37	---	---	---	---	0	0.0	0
Lyman	0-5	---	1.7-9.0	3.6-6.0	0	0	0.0	0
	5-15	---	1.7-8.4	3.6-6.0	0	0	0.0	0
	15-25	---	---	---	---	0	0.0	0
20D:								
Tunbridge	0-2	---	2.8-8.0	3.6-6.0	0	0	0.0	0
	2-27	---	1.4-6.7	3.6-6.0	0	0	0.0	0
	27-37	---	---	---	---	0	0.0	0
Lyman	0-5	---	1.7-9.0	3.6-6.0	0	0	0.0	0
	5-15	---	1.7-8.4	3.6-6.0	0	0	0.0	0
	15-25	---	---	---	---	0	0.0	0
37:								
Hadley	0-7	3.7-8.8	---	4.5-7.3	0	0	0.0	0
	7-60	1.8-8.2	---	4.5-7.8	0	0	0.0	0

Chemical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Cation-exchange capacity	Effective cation-exchange capacity	Soil reaction	Calcium carbon-ate	Gypsum	Salinity	Sodium adsorption ratio
	In	meq/100 g	meq/100 g	pH	Pct	Pct	mmhos/cm	
90A:								
Hadley, protected	0-9	---	0.7-11	4.5-6.5	0	0	0.0	0
	9-14	1.1-16	---	5.1-6.5	0	0	0.0	0
	14-26	1.1-16	---	5.1-6.5	0	0	0.0	0
	26-33	1.0-15	---	5.1-6.5	0	0	0.0	0
	33-65	1.0-15	---	5.1-6.5	0	0	0.0	0
96A:								
Hadley, occasionally flooded	0-9	---	0.7-11	4.5-6.5	0	0	0.0	0
	9-14	1.1-16	---	5.1-6.5	0	0	0.0	0
	14-26	1.1-16	---	5.1-6.5	0	0	0.0	0
	26-33	1.0-15	---	5.1-6.5	0	0	0.0	0
	33-65	1.0-15	---	5.1-6.5	0	0	0.0	0
109B:								
Chatfield, rocky	0-1	71-134	---	3.8-4.8	0	0	0.0	0
	1-4	---	3.2-7.4	4.5-6.0	0	0	0.0	0
	4-9	---	3.1-4.3	4.5-6.0	0	0	0.0	0
	9-19	---	3.1-4.3	4.5-6.0	0	0	0.0	0
	19-30	---	1.9-6.1	4.5-6.0	0	0	0.0	0
	30-34	---	1.2-5.8	4.5-6.0	0	0	0.0	0
	34-37	1.9-9.0	---	4.5-6.0	0	0	0.0	0
	37-65	---	---	---	0	0	0.0	0
Hollis, rocky	0-1	---	26-55	3.8-4.8	0	0	0.0	0
	1-3	---	26-55	3.8-4.8	0	0	0.0	0
	3-4	---	0.9-1.8	4.5-6.0	0	0	0.0	0
	4-15	2.8-4.4	---	4.5-6.0	0	0	0.0	0
	15-65	---	---	---	---	---	---	---
109C:								
Chatfield, rocky	0-1	71-134	---	3.8-4.8	0	0	0.0	0
	1-4	---	3.2-7.4	4.5-6.0	0	0	0.0	0
	4-9	---	3.1-4.3	4.5-6.0	0	0	0.0	0
	9-19	---	3.1-4.3	4.5-6.0	0	0	0.0	0
	19-30	---	1.9-6.1	4.5-6.0	0	0	0.0	0
	30-34	---	1.2-5.8	4.5-6.0	0	0	0.0	0
	34-37	1.9-9.0	---	4.5-6.0	0	0	0.0	0
	37-65	---	---	---	0	0	0.0	0

Chemical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Cation-exchange capacity	Effective cation-exchange capacity	Soil reaction	Calcium carbon-ate	Gypsum	Salinity	Sodium adsorption ratio
	In	meq/100 g	meq/100 g	pH	Pct	Pct	mmhos/cm	
109C:								
Hollis, rocky	0-1	---	26-55	3.8-4.8	0	0	0.0	0
	1-3	---	26-55	3.8-4.8	0	0	0.0	0
	3-4	---	0.9-1.8	4.5-6.0	0	0	0.0	0
	4-15	2.8-4.4	---	4.5-6.0	0	0	0.0	0
	15-65	---	---	---	---	---	---	---
109D:								
Chatfield, rocky	0-1	71-134	---	3.8-4.8	0	0	0.0	0
	1-4	---	3.2-7.4	4.5-6.0	0	0	0.0	0
	4-9	---	3.1-4.3	4.5-6.0	0	0	0.0	0
	9-19	---	3.1-4.3	4.5-6.0	0	0	0.0	0
	19-30	---	1.9-6.1	4.5-6.0	0	0	0.0	0
	30-34	---	1.2-5.8	4.5-6.0	0	0	0.0	0
	34-37	1.9-9.0	---	4.5-6.0	0	0	0.0	0
	37-65	---	---	---	0	0	0.0	0
Hollis, rocky	0-1	---	26-55	3.8-4.8	0	0	0.0	0
	1-3	---	26-55	3.8-4.8	0	0	0.0	0
	3-4	---	0.9-1.8	4.5-6.0	0	0	0.0	0
	4-15	2.8-4.4	---	4.5-6.0	0	0	0.0	0
	15-65	---	---	---	---	---	---	---
109F:								
Chatfield, rocky	0-1	71-134	---	3.8-4.8	0	0	0.0	0
	1-4	---	3.2-7.4	4.5-6.0	0	0	0.0	0
	4-9	---	3.1-4.3	4.5-6.0	0	0	0.0	0
	9-19	---	3.1-4.3	4.5-6.0	0	0	0.0	0
	19-30	---	1.9-6.1	4.5-6.0	0	0	0.0	0
	30-34	---	1.2-5.8	4.5-6.0	0	0	0.0	0
	34-37	1.9-9.0	---	4.5-6.0	0	0	0.0	0
	37-65	---	---	---	0	0	0.0	0
Hollis, rocky	0-1	---	26-55	3.8-4.8	0	0	0.0	0
	1-3	---	26-55	3.8-4.8	0	0	0.0	0
	3-4	---	0.9-1.8	4.5-6.0	0	0	0.0	0
	4-15	2.8-4.4	---	4.5-6.0	0	0	0.0	0
	15-65	---	---	---	---	---	---	---

Chemical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Cation-exchange capacity	Effective cation-exchange capacity	Soil reaction	Calcium carbon-ate	Gypsum	Salinity	Sodium adsorption ratio
	In	meq/100 g	meq/100 g	pH	Pct	Pct	mmhos/cm	
125B:								
Charlton, rocky	0-8	---	0.9-2.9	4.5-6.0	0	0	0.0	0
	8-15	---	1.0-1.9	4.5-6.0	0	0	0.0	0
	15-22	---	1.1-1.7	4.5-6.0	0	0	0.0	0
	22-31	---	0.9-2.3	4.5-6.0	0	0	0.0	0
	31-37	---	0.6-2.3	4.5-6.0	0	0	0.0	0
	37-43	---	0.6-2.3	4.5-6.0	0	0	0.0	0
	43-49	---	0.4-1.9	4.5-6.0	0	0	0.0	0
	49-65	---	0.4-1.9	4.5-6.0	0	0	0.0	0
Chatfield, rocky	0-1	---	20-55	3.8-4.8	0	0	0.0	0
	1-4	---	3.2-7.3	4.5-6.0	0	0	0.0	0
	4-9	---	3.1-4.3	4.5-6.0	0	0	0.0	0
	9-19	---	3.1-4.3	4.5-6.0	0	0	0.0	0
	19-30	---	1.9-6.1	4.5-6.0	0	0	0.0	0
	30-34	---	1.2-5.8	4.5-6.0	0	0	0.0	0
	34-37	1.9-9.0	---	4.5-6.0	0	0	0.0	0
	37-65	---	---	---	0	0	0.0	0
Hollis, rocky	0-1	---	26-55	3.8-4.8	0	0	0.0	0
	1-3	---	26-55	3.8-4.8	0	0	0.0	0
	3-4	---	0.9-1.8	4.5-6.0	0	0	0.0	0
	4-15	2.8-4.4	---	4.5-6.0	0	0	0.0	0
	15-65	---	---	---	---	---	---	---
125C:								
Charlton, rocky	0-8	---	0.9-2.9	4.5-6.0	0	0	0.0	0
	8-15	---	1.0-1.9	4.5-6.0	0	0	0.0	0
	15-22	---	1.1-1.7	4.5-6.0	0	0	0.0	0
	22-31	---	0.9-2.3	4.5-6.0	0	0	0.0	0
	31-37	---	0.6-2.3	4.5-6.0	0	0	0.0	0
	37-43	---	0.6-2.3	4.5-6.0	0	0	0.0	0
	43-49	---	0.4-1.9	4.5-6.0	0	0	0.0	0
	49-65	---	0.4-1.9	4.5-6.0	0	0	0.0	0
Chatfield, rocky	0-1	---	20-55	3.8-4.8	0	0	0.0	0
	1-4	---	3.2-7.3	4.5-6.0	0	0	0.0	0
	4-9	---	3.1-4.3	4.5-6.0	0	0	0.0	0
	9-19	---	3.1-4.3	4.5-6.0	0	0	0.0	0
	19-30	---	1.9-6.1	4.5-6.0	0	0	0.0	0
	30-34	---	1.2-5.8	4.5-6.0	0	0	0.0	0
	34-37	1.9-9.0	---	4.5-6.0	0	0	0.0	0
	37-65	---	---	---	0	0	0.0	0

Chemical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Cation-exchange capacity	Effective cation-exchange capacity	Soil reaction	Calcium carbon-ate	Gypsum	Salinity	Sodium adsorption ratio
	In	meq/100 g	meq/100 g	pH	Pct	Pct	mmhos/cm	
125C:								
Hollis, rocky	0-1	---	26-55	3.8-4.8	0	0	0.0	0
	1-3	---	26-55	3.8-4.8	0	0	0.0	0
	3-4	---	0.9-1.8	4.5-6.0	0	0	0.0	0
	4-15	2.8-4.4	---	4.5-6.0	0	0	0.0	0
	15-65	---	---	---	---	---	---	---
125D:								
Charlton, rocky	0-8	---	0.9-2.9	4.5-6.0	0	0	0.0	0
	8-15	---	1.0-1.9	4.5-6.0	0	0	0.0	0
	15-22	---	1.1-1.7	4.5-6.0	0	0	0.0	0
	22-31	---	0.9-2.3	4.5-6.0	0	0	0.0	0
	31-37	---	0.6-2.3	4.5-6.0	0	0	0.0	0
	37-43	---	0.6-2.3	4.5-6.0	0	0	0.0	0
	43-49	---	0.4-1.9	4.5-6.0	0	0	0.0	0
	49-65	---	0.4-1.9	4.5-6.0	0	0	0.0	0
Chatfield, rocky	0-1	---	20-55	3.8-4.8	0	0	0.0	0
	1-4	---	3.2-7.3	4.5-6.0	0	0	0.0	0
	4-9	---	3.1-4.3	4.5-6.0	0	0	0.0	0
	9-19	---	3.1-4.3	4.5-6.0	0	0	0.0	0
	19-30	---	1.9-6.1	4.5-6.0	0	0	0.0	0
	30-34	---	1.2-5.8	4.5-6.0	0	0	0.0	0
	34-37	1.9-9.0	---	4.5-6.0	0	0	0.0	0
	37-65	---	---	---	0	0	0.0	0
Hollis, rocky	0-1	---	26-55	3.8-4.8	0	0	0.0	0
	1-3	---	26-55	3.8-4.8	0	0	0.0	0
	3-4	---	0.9-1.8	4.5-6.0	0	0	0.0	0
	4-15	2.8-4.4	---	4.5-6.0	0	0	0.0	0
	15-65	---	---	---	---	---	---	---
131B:								
Yalesville, rocky	0-1	---	26-55	3.8-4.8	0	0	0.0	0
	1-3	---	0.9-2.7	4.5-5.5	0	0	0.0	0
	3-8	---	1.0-3.0	4.5-5.5	0	0	0.0	0
	8-17	---	1.1-3.6	4.5-5.5	0	0	0.0	0
	17-22	---	0.6-3.6	4.5-5.5	0	0	0.0	0
	22-33	---	0.7-3.5	4.5-5.5	0	0	0.0	0
	33-65	---	---	---	---	---	---	---

Chemical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Cation-exchange capacity	Effective cation-exchange capacity	Soil reaction	Calcium carbon-ate	Gypsum	Salinity	Sodium adsorption ratio
	In	meq/100 g	meq/100 g	pH	Pct	Pct	mmhos/cm	
131B:								
Holyoke, rocky	0-3	---	3.2-7.3	4.4-6.0	0	0	0.0	0
	3-6	---	3.1-7.1	4.4-6.0	0	0	0.0	0
	6-17	---	3.0-7.0	4.4-6.0	0	0	0.0	0
	17-65	---	---	---	---	---	---	---
131C:								
Yalesville, rocky	0-1	---	26-55	3.8-4.8	0	0	0.0	0
	1-3	---	0.9-2.7	4.5-5.5	0	0	0.0	0
	3-8	---	1.0-3.0	4.5-5.5	0	0	0.0	0
	8-17	---	1.1-3.6	4.5-5.5	0	0	0.0	0
	17-22	---	0.6-3.6	4.5-5.5	0	0	0.0	0
	22-33	---	0.7-3.5	4.5-5.5	0	0	0.0	0
	33-65	---	---	---	---	---	---	---
Holyoke, rocky	0-3	---	3.2-7.3	4.4-6.0	0	0	0.0	0
	3-6	---	3.1-7.1	4.4-6.0	0	0	0.0	0
	6-17	---	3.0-7.0	4.4-6.0	0	0	0.0	0
	17-65	---	---	---	---	---	---	---
131D:								
Yalesville, rocky	0-1	---	26-55	3.8-4.8	0	0	0.0	0
	1-3	---	0.9-2.7	4.5-5.5	0	0	0.0	0
	3-8	---	1.0-3.0	4.5-5.5	0	0	0.0	0
	8-17	---	1.1-3.6	4.5-5.5	0	0	0.0	0
	17-22	---	0.6-3.6	4.5-5.5	0	0	0.0	0
	22-33	---	0.7-3.5	4.5-5.5	0	0	0.0	0
	33-65	---	---	---	---	---	---	---
Holyoke, rocky	0-3	---	3.2-7.3	4.4-6.0	0	0	0.0	0
	3-6	---	3.1-7.1	4.4-6.0	0	0	0.0	0
	6-17	---	3.0-7.0	4.4-6.0	0	0	0.0	0
	17-65	---	---	---	---	---	---	---
131F:								
Yalesville, rocky	0-1	---	26-55	3.8-4.8	0	0	0.0	0
	1-3	---	0.9-2.7	4.5-5.5	0	0	0.0	0
	3-8	---	1.0-3.0	4.5-5.5	0	0	0.0	0
	8-17	---	1.1-3.6	4.5-5.5	0	0	0.0	0
	17-22	---	0.6-3.6	4.5-5.5	0	0	0.0	0
	22-33	---	0.7-3.5	4.5-5.5	0	0	0.0	0
	33-65	---	---	---	---	---	---	---

Chemical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Cation-exchange capacity	Effective cation-exchange capacity	Soil reaction	Calcium carbon-ate	Gypsum	Salinity	Sodium adsorption ratio
	In	meq/100 g	meq/100 g	pH	Pct	Pct	mmhos/cm	
131F:								
Holyoke, rocky	0-3	---	3.2-7.3	4.4-6.0	0	0	0.0	0
	3-6	---	3.1-7.1	4.4-6.0	0	0	0.0	0
	6-17	---	3.0-7.0	4.4-6.0	0	0	0.0	0
	17-65	---	---	---	---	---	---	---
229F:								
Windsor	0-1	---	26-55	3.8-4.8	0	0	0.0	0
	1-2	---	26-55	3.8-4.8	0	0	0.0	0
	2-7	---	1.3-4.6	4.5-5.5	0	0	0.0	0
	7-19	---	0.8-2.1	4.5-5.5	0	0	0.0	0
	19-25	---	0.0-0.8	4.5-5.5	0	0	0.0	0
	25-40	---	0.0-0.9	4.5-6.0	0	0	0.0	0
	40-59	---	0.0-0.9	4.5-6.0	0	0	0.0	0
	59-65	---	0.0-0.9	4.5-6.0	0	0	0.0	0
Merrimac	0-10	---	1.5-7.3	4.4-6.0	0	0	0.0	0
	10-15	---	0.9-5.6	4.4-6.0	0	0	0.0	0
	15-22	---	0.9-5.6	4.4-6.0	0	0	0.0	0
	22-26	1.4-5.6	---	4.5-6.0	0	0	0.0	0
	26-65	0.1-1.7	---	4.5-6.0	0	0	0.0	0
230A:								
Unadilla	0-1	---	19-55	3.8-4.8	0	0	0.0	0
	1-10	2.2-10	---	4.5-6.0	0	0	0.0	0
	10-21	2.2-9.8	---	4.5-6.0	0	0	0.0	0
	21-30	2.2-9.8	---	4.5-6.0	0	0	0.0	0
	30-55	0.1-9.6	---	4.5-6.2	0	0	0.0	0
	55-65	0.1-8.0	---	4.5-6.2	0	0	0.0	0
230B:								
Unadilla	0-1	---	19-55	3.8-4.8	0	0	0.0	0
	1-10	2.2-10	---	4.5-6.0	0	0	0.0	0
	10-21	2.2-9.8	---	4.5-6.0	0	0	0.0	0
	21-30	2.2-9.8	---	4.5-6.0	0	0	0.0	0
	30-55	0.1-9.6	---	4.5-6.2	0	0	0.0	0
	55-65	0.1-8.0	---	4.5-6.2	0	0	0.0	0

Chemical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Cation-exchange capacity	Effective cation-exchange capacity	Soil reaction	Calcium carbon-ate	Gypsum	Salinity	Sodium adsorption ratio
	In	meq/100 g	meq/100 g	pH	Pct	Pct	mmhos/cm	
235F:								
Poocham	0-2	---	19-55	3.8-4.8	0	0	0.0	0
	2-5	---	0.7-7.1	4.5-6.6	0	0	0.0	0
	5-14	---	0.9-8.3	4.5-6.6	0	0	0.0	0
	14-19	---	0.9-17	4.5-6.6	0	0	0.0	0
	19-33	---	0.9-17	4.5-6.6	0	0	0.0	0
	33-54	---	1.0-17	4.5-6.6	0	0	0.0	0
	54-65	2.1-24	---	5.1-7.0	0-1	0	0.0	0
Agawam	0-2	---	18-53	3.8-4.8	0	0	0.0	0
	2-4	---	0.2-1.9	4.5-6.2	0	0	0.0	0
	4-9	---	0.2-2.3	4.5-6.2	0	0	0.0	0
	9-21	---	0.2-2.3	4.5-6.2	0	0	0.0	0
	21-33	---	0.0-1.1	4.5-6.2	0	0	0.0	0
	33-65	---	0.0-1.1	4.5-6.2	0	0	0.0	0
254A:								
Merrimac	0-10	---	1.5-7.3	4.4-6.0	0	0	0.0	0
	10-15	---	0.9-5.6	4.4-6.0	0	0	0.0	0
	15-22	---	0.9-5.6	4.4-6.0	0	0	0.0	0
	22-26	1.4-5.6	---	4.5-6.0	0	0	0.0	0
	26-65	0.1-1.7	---	4.5-6.0	0	0	0.0	0
254B:								
Merrimac	0-10	---	1.5-7.3	4.4-6.0	0	0	0.0	0
	10-15	---	0.9-5.6	4.4-6.0	0	0	0.0	0
	15-22	---	0.9-5.6	4.4-6.0	0	0	0.0	0
	22-26	1.4-5.6	---	4.5-6.0	0	0	0.0	0
	26-65	0.1-1.7	---	4.5-6.0	0	0	0.0	0
254C:								
Merrimac	0-10	---	1.5-7.3	4.4-6.0	0	0	0.0	0
	10-15	---	0.9-5.6	4.4-6.0	0	0	0.0	0
	15-22	---	0.9-5.6	4.4-6.0	0	0	0.0	0
	22-26	1.4-5.6	---	4.5-6.0	0	0	0.0	0
	26-65	0.1-1.7	---	4.5-6.0	0	0	0.0	0
254D:								
Merrimac	0-10	---	1.5-7.3	4.4-6.0	0	0	0.0	0
	10-15	---	0.9-5.6	4.4-6.0	0	0	0.0	0
	15-22	---	0.9-5.6	4.4-6.0	0	0	0.0	0
	22-26	1.4-5.6	---	4.5-6.0	0	0	0.0	0
	26-65	0.1-1.7	---	4.5-6.0	0	0	0.0	0

Chemical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Cation-exchange capacity	Effective cation-exchange capacity	Soil reaction	Calcium carbon-ate	Gypsum	Salinity	Sodium adsorption ratio
	In	meq/100 g	meq/100 g	pH	Pct	Pct	mmhos/cm	
255A:								
Windsor	0-1	---	26-55	3.8-4.8	0	0	0.0	0
	1-2	---	26-55	3.8-4.8	0	0	0.0	0
	2-7	---	1.3-4.6	4.5-5.5	0	0	0.0	0
	7-19	---	0.8-2.1	4.5-5.5	0	0	0.0	0
	19-25	---	0.0-0.8	4.5-5.5	0	0	0.0	0
	25-40	---	0.0-0.9	4.5-6.0	0	0	0.0	0
	40-59	---	0.0-0.9	4.5-6.0	0	0	0.0	0
	59-65	---	0.0-0.9	4.5-6.0	0	0	0.0	0
255B:								
Windsor	0-1	---	26-55	3.8-4.8	0	0	0.0	0
	1-2	---	26-55	3.8-4.8	0	0	0.0	0
	2-7	---	1.3-4.6	4.5-5.5	0	0	0.0	0
	7-19	---	0.8-2.1	4.5-5.5	0	0	0.0	0
	19-25	---	0.0-0.8	4.5-5.5	0	0	0.0	0
	25-40	---	0.0-0.9	4.5-6.0	0	0	0.0	0
	40-59	---	0.0-0.9	4.5-6.0	0	0	0.0	0
	59-65	---	0.0-0.9	4.5-6.0	0	0	0.0	0
255C:								
Windsor	0-1	---	26-55	3.8-4.8	0	0	0.0	0
	1-2	---	26-55	3.8-4.8	0	0	0.0	0
	2-7	---	1.3-4.6	4.5-5.5	0	0	0.0	0
	7-19	---	0.8-2.1	4.5-5.5	0	0	0.0	0
	19-25	---	0.0-0.8	4.5-5.5	0	0	0.0	0
	25-40	---	0.0-0.9	4.5-6.0	0	0	0.0	0
	40-59	---	0.0-0.9	4.5-6.0	0	0	0.0	0
	59-65	---	0.0-0.9	4.5-6.0	0	0	0.0	0
255D:								
Windsor	0-1	---	26-55	3.8-4.8	0	0	0.0	0
	1-2	---	26-55	3.8-4.8	0	0	0.0	0
	2-7	---	1.3-4.6	4.5-5.5	0	0	0.0	0
	7-19	---	0.8-2.1	4.5-5.5	0	0	0.0	0
	19-25	---	0.0-0.8	4.5-5.5	0	0	0.0	0
	25-40	---	0.0-0.9	4.5-6.0	0	0	0.0	0
	40-59	---	0.0-0.9	4.5-6.0	0	0	0.0	0
	59-65	---	0.0-0.9	4.5-6.0	0	0	0.0	0

Chemical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Cation-exchange capacity	Effective cation-exchange capacity	Soil reaction	Calcium carbon-ate	Gypsum	Salinity	Sodium adsorption ratio
	In	meq/100 g	meq/100 g	pH	Pct	Pct	mmhos/cm	
275A:								
Agawam	0-2	---	18-53	3.8-4.8	0	0	0.0	0
	2-4	---	0.2-1.9	4.5-6.2	0	0	0.0	0
	4-9	---	0.2-2.3	4.5-6.2	0	0	0.0	0
	9-21	---	0.2-2.3	4.5-6.2	0	0	0.0	0
	21-33	---	0.0-1.1	4.5-6.2	0	0	0.0	0
	33-65	---	0.0-1.1	4.5-6.2	0	0	0.0	0
275B:								
Agawam	0-2	---	18-53	3.8-4.8	0	0	0.0	0
	2-4	---	0.2-1.9	4.5-6.2	0	0	0.0	0
	4-9	---	0.2-2.3	4.5-6.2	0	0	0.0	0
	9-21	---	0.2-2.3	4.5-6.2	0	0	0.0	0
	21-33	---	0.0-1.1	4.5-6.2	0	0	0.0	0
	33-65	---	0.0-1.1	4.5-6.2	0	0	0.0	0
275C:								
Agawam	0-2	---	18-53	3.8-4.8	0	0	0.0	0
	2-4	---	0.2-1.9	4.5-6.2	0	0	0.0	0
	4-9	---	0.2-2.3	4.5-6.2	0	0	0.0	0
	9-21	---	0.2-2.3	4.5-6.2	0	0	0.0	0
	21-33	---	0.0-1.1	4.5-6.2	0	0	0.0	0
	33-65	---	0.0-1.1	4.5-6.2	0	0	0.0	0
275D:								
Agawam	0-2	---	18-53	3.8-4.8	0	0	0.0	0
	2-4	---	0.2-1.9	4.5-6.2	0	0	0.0	0
	4-9	---	0.2-2.3	4.5-6.2	0	0	0.0	0
	9-21	---	0.2-2.3	4.5-6.2	0	0	0.0	0
	21-33	---	0.0-1.1	4.5-6.2	0	0	0.0	0
	33-65	---	0.0-1.1	4.5-6.2	0	0	0.0	0
618F:								
Udorthents, frequently flooded	0-6	---	2.2-12	4.5-6.2	0	0	0.0	0
	6-21	---	0.0-2.8	4.5-6.0	0	0	0.0	0
	21-34	---	0.0-2.7	4.5-6.0	0	0	0.0	0
	34-65	---	0.0-2.7	4.5-6.0	0	0	0.0	0
651:								
Udorthents, smoothed	0-6	0.2-7.4	---	4.4-6.2	0	0	0.0	0
	6-23	0.1-6.8	---	5.1-6.0	0	0	0.0	0
	23-42	0.1-6.7	---	5.1-6.0	0	0	0.0	0
	42-46	0.1-6.7	---	5.1-6.0	0	0	0.0	0
	46-65	0.1-6.7	---	5.1-6.0	0	0	0.0	0

Chemical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Cation-exchange capacity	Effective cation-exchange capacity	Soil reaction	Calcium carbon-ate	Gypsum	Salinity	Sodium adsorption ratio
	In	meq/100 g	meq/100 g	pH	Pct	Pct	mmhos/cm	
656:								
Udorthents	0-6	0.2-7.4	---	4.4-6.2	0	0	0.0	0
	6-23	0.1-6.8	---	5.1-6.0	0	0	0.0	0
	23-42	0.1-6.7	---	5.1-6.0	0	0	0.0	0
	42-46	0.1-6.7	---	5.1-6.0	0	0	0.0	0
	46-65	0.1-6.7	---	5.1-6.0	0	0	0.0	0
Urban land	---	---	---	---	---	---	---	---

Physical Soil Properties

Cheshire County, New Hampshire

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
10B:														
Merrimac	0-19	---	---	3-7	1.10-1.20	14.11-42.33	0.14-0.19	0.0-2.9	1.0-6.0	.24	.24	5	---	---
	19-23	---	---	1-4	1.20-1.40	14.11-42.33	0.14-0.17	0.0-2.9	0.5-3.0	.24	.24			
	23-28	---	---	1-3	1.20-1.40	14.11-141.11	0.03-0.12	0.0-2.9	0.5-2.0	.17	.20			
	28-60	---	---	0-3	1.30-1.50	42.33-141.11	0.01-0.06	0.0-2.9	0.0-1.0	.10	.17			
10C:														
Merrimac	0-19	---	---	3-7	1.10-1.20	14.11-42.33	0.14-0.19	0.0-2.9	1.0-6.0	.24	.24	5	---	---
	19-23	---	---	1-4	1.20-1.40	14.11-42.33	0.14-0.17	0.0-2.9	0.5-3.0	.24	.24			
	23-28	---	---	1-3	1.20-1.40	14.11-141.11	0.03-0.12	0.0-2.9	0.5-2.0	.17	.20			
	28-60	---	---	0-3	1.30-1.50	42.33-141.11	0.01-0.06	0.0-2.9	0.0-1.0	.10	.17			
24A:														
Agawam	0-12	---	---	4-10	1.10-1.20	14.11-42.33	0.15-0.21	0.0-2.9	1.0-6.0	.28	.28	3	3	86
	12-20	---	---	1-10	1.20-1.40	14.11-42.33	0.11-0.21	0.0-2.9	1.0-3.0	.37	.37			
	20-25	---	---	1-6	1.30-1.40	14.11-42.33	0.11-0.18	0.0-2.9	0.5-2.0	.28	.28			
	25-52	---	---	1-2	1.30-1.40	42.33-141.11	0.02-0.12	0.0-2.9	0.0-1.0	.17	.20			
	52-60	---	---	0-1	1.30-1.50	141.11-705.00	0.01-0.09	0.0-2.9	0.0-0.5	.10	.15			
24B:														
Agawam	0-12	---	---	4-10	1.10-1.20	14.11-42.33	0.15-0.21	0.0-2.9	1.0-6.0	.28	.28	3	3	86
	12-20	---	---	1-10	1.20-1.40	14.11-42.33	0.11-0.21	0.0-2.9	1.0-3.0	.37	.37			
	20-25	---	---	1-6	1.30-1.40	14.11-42.33	0.11-0.18	0.0-2.9	0.5-2.0	.28	.28			
	25-52	---	---	1-2	1.30-1.40	42.33-141.11	0.02-0.12	0.0-2.9	0.0-1.0	.17	.20			
	52-60	---	---	0-1	1.30-1.50	141.11-705.00	0.01-0.09	0.0-2.9	0.0-0.5	.10	.15			

Physical Soil Properties

Cheshire County, New Hampshire

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
24C:														
Agawam	0-12	---	---	4-10	1.10-1.20	14.11-42.33	0.15-0.21	0.0-2.9	1.0-6.0	.28	.28	3	3	86
	12-20	---	---	1-10	1.20-1.40	14.11-42.33	0.11-0.21	0.0-2.9	1.0-3.0	.37	.37			
	20-25	---	---	1-6	1.30-1.40	14.11-42.33	0.11-0.18	0.0-2.9	0.5-2.0	.28	.28			
	25-52	---	---	1-2	1.30-1.40	42.33-141.11	0.02-0.12	0.0-2.9	0.0-1.0	.17	.20			
	52-60	---	---	0-1	1.30-1.50	141. 11-705.00	0.01-0.09	0.0-2.9	0.0-0.5	.10	.15			
26A:														
Windsor	0-4	---	---	1-3	1.00-1.20	42.33-141.11	0.09-0.12	0.0-2.9	2.0-4.0	.17	.17	5	---	---
	4-26	---	---	0-3	1.30-1.55	42.33-141.11	0.07-0.10	0.0-2.9	0.5-3.0	.17	.17			
	26-60	---	---	0-2	1.40-1.65	42.33-141.11	0.04-0.10	0.0-2.9	0.0-0.5	.10	.10			
26B:														
Windsor	0-4	---	---	1-3	1.00-1.20	42.33-141.11	0.09-0.12	0.0-2.9	2.0-4.0	.17	.17	5	---	---
	4-26	---	---	0-3	1.30-1.55	42.33-141.11	0.07-0.10	0.0-2.9	0.5-3.0	.17	.17			
	26-60	---	---	0-2	1.40-1.65	42.33-141.11	0.04-0.10	0.0-2.9	0.0-0.5	.10	.10			
26C:														
Windsor	0-4	---	---	1-3	1.00-1.20	42.33-141.11	0.09-0.12	0.0-2.9	2.0-4.0	.17	.17	5	---	---
	4-26	---	---	0-3	1.30-1.55	42.33-141.11	0.07-0.10	0.0-2.9	0.5-3.0	.17	.17			
	26-60	---	---	0-2	1.40-1.65	42.33-141.11	0.04-0.10	0.0-2.9	0.0-0.5	.10	.10			
26E:														
Windsor	0-4	---	---	1-3	1.00-1.20	42.33-141.11	0.09-0.12	0.0-2.9	2.0-4.0	.17	.17	5	---	---
	4-26	---	---	0-3	1.30-1.55	42.33-141.11	0.07-0.10	0.0-2.9	0.5-3.0	.17	.17			
	26-60	---	---	0-2	1.40-1.65	42.33-141.11	0.04-0.10	0.0-2.9	0.0-0.5	.10	.10			

Physical Soil Properties

Cheshire County, New Hampshire

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
30A:														
Unadilla	0-8	---	---	2-18	1.20-1.50	4.23-14.11	0.18-0.21	0.0-2.9	2.0-8.0	.49	.49	5	---	56
	8-35	---	---	1-18	1.20-1.50	4.23-14.11	0.17-0.20	0.0-2.9	1.0-3.0	.64	.64			
	35-60	---	---	1-3	1.45-1.65	14.11-141.11	0.01-0.10	0.0-2.9	0.0-1.0	.17	.20			
30B:														
Unadilla	0-8	---	---	2-18	1.20-1.50	4.23-14.11	0.18-0.21	0.0-2.9	2.0-8.0	.49	.49	5	---	56
	8-35	---	---	1-18	1.20-1.50	4.23-14.11	0.17-0.20	0.0-2.9	1.0-3.0	.64	.64			
	35-60	---	---	1-3	1.45-1.65	14.11-141.11	0.01-0.10	0.0-2.9	0.0-1.0	.17	.20			
30C:														
Unadilla	0-8	---	---	2-18	1.20-1.50	4.23-14.11	0.18-0.21	0.0-2.9	2.0-8.0	.49	.49	5	---	56
	8-35	---	---	1-18	1.20-1.50	4.23-14.11	0.17-0.20	0.0-2.9	1.0-3.0	.64	.64			
	35-60	---	---	1-3	1.45-1.65	14.11-141.11	0.01-0.10	0.0-2.9	0.0-1.0	.17	.20			
60C:														
Tunbridge	0-4	---	---	5-9	0.80-1.20	4.23-42.33	0.11-0.21	0.0-2.9	2.0-8.0	.20	.24	2	---	0
	4-26	---	---	3-9	1.20-1.40	4.23-42.33	0.10-0.21	0.0-2.9	1.0-6.0	.20	.24			
	26-30	---	---	---	---	---	---	---	---	---	---			
Berkshire	0-3	---	---	3-10	1.10-1.15	4.23-42.33	0.06-0.22	0.0-2.9	2.0-6.0	.20	.24	5	8	0
	3-35	---	---	3-10	1.15-1.30	4.23-42.33	0.10-0.20	0.0-2.9	1.0-3.0	.32	.37			
	35-60	---	---	1-10	1.30-1.60	4.23-42.33	0.10-0.18	0.0-2.9	0.0-1.0	.24	.28			
61C:														
Tunbridge	0-4	---	---	5-9	0.80-1.20	4.23-42.33	0.11-0.21	0.0-2.9	2.0-8.0	.20	.24	2	---	0
	4-26	---	---	3-9	1.20-1.40	4.23-42.33	0.10-0.21	0.0-2.9	1.0-6.0	.20	.24			
	26-30	---	---	---	---	---	---	---	---	---	---			

Physical Soil Properties

Cheshire County, New Hampshire

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
61C:														
Lyman	0-4	---	---	2-10	0.75-1.20	14.11-42.33	0.13-0.24	0.0-2.9	1.0-6.0	.20	.28	1	---	---
	4-16	---	---	2-10	0.90-1.40	14.11-42.33	0.08-0.28	0.0-2.9	1.0-3.0	.32	.37			
	16-20	---	---	---	---	0.07-141.11	---	---	---	---	---			
Rock outcrop	---	---	---	---	---	---	---	---	---	---	---	---	---	---
61D:														
Tunbridge	0-4	---	---	5-9	0.80-1.20	4.23-42.33	0.11-0.21	0.0-2.9	2.0-8.0	.20	.24	2	---	0
	4-26	---	---	3-9	1.20-1.40	4.23-42.33	0.10-0.21	0.0-2.9	1.0-6.0	.20	.24			
	26-30	---	---	---	---	---	---	---	---	---	---			
Lyman	0-4	---	---	2-10	0.75-1.20	14.11-42.33	0.13-0.24	0.0-2.9	1.0-6.0	.20	.28	1	---	---
	4-16	---	---	2-10	0.90-1.40	14.11-42.33	0.08-0.28	0.0-2.9	1.0-3.0	.32	.37			
	16-20	---	---	---	---	0.07-141.11	---	---	---	---	---			
Rock outcrop	---	---	---	---	---	---	---	---	---	---	---	---	---	---
108:														
Hadley	0-11	---	---	4-10	1.20-1.50	4.23-14.11	0.15-0.25	0.0-2.9	2.0-6.0	.49	.49	5	---	---
	11-42	---	---	2-10	1.20-1.50	4.23-42.33	0.13-0.20	0.0-2.9	1.0-4.0	.49	.49			
	42-60	---	---	1-8	1.20-1.50	4.23-42.33	0.10-0.20	0.0-2.9	0.0-2.0	.49	.49			
230E:														
Poocham	0-2	---	---	3-10	1.00-1.30	4.23-14.11	0.18-0.30	0.0-2.9	1.0-6.0	.49	.49	5	---	86
	2-13	---	---	3-10	1.20-1.50	4.23-14.11	0.18-0.26	0.0-2.9	1.0-3.0	.49	.49			
	13-60	---	---	3-15	1.20-1.50	1.41-14.11	0.16-0.21	0.0-2.9	0.0-1.0	.49	.49			

Physical Soil Properties

Windham County, Vermont

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
1A:														
Unadilla	0-10	0-60	30-90	2-18	1.20-1.50	4.23-14.11	0.18-0.21	0.0-2.9	2.0-7.0	.49	.49	5	5	56
	10-60	0-60	30-90	1-18	1.20-1.50	4.23-14.11	0.17-0.20	0.0-2.9	0.0-1.0	.64	.64			
1B:														
Unadilla	0-10	0-60	30-90	2-18	1.20-1.50	4.23-14.11	0.18-0.21	0.0-2.9	2.0-7.0	.49	.49	5	5	56
	10-60	0-60	30-90	1-18	1.20-1.50	4.23-14.11	0.17-0.20	0.0-2.9	0.0-1.0	.64	.64			
1C:														
Unadilla	0-10	0-60	30-90	2-18	1.20-1.50	4.23-14.11	0.18-0.21	0.0-2.9	2.0-7.0	.49	.49	5	5	56
	10-60	0-60	30-90	1-18	1.20-1.50	4.23-14.11	0.17-0.20	0.0-2.9	0.0-1.0	.64	.64			
1D:														
Unadilla	0-10	0-60	30-90	2-18	1.20-1.50	4.23-14.11	0.18-0.21	0.0-2.9	2.0-7.0	.49	.49	5	5	56
	10-60	0-60	30-90	1-18	1.20-1.50	4.23-14.11	0.17-0.20	0.0-2.9	0.0-1.0	.64	.64			
1E:														
Udorthents	0-60	0-60	30-90	1-18	1.20-1.50	4.23-14.11	0.17-0.20	0.0-2.9	0.0-1.0	.64	.64	---	---	---
5B:														
Windsor	0-3	75-100	0-25	1-3	1.00-1.20	42.33-141.11	0.09-0.12	0.0-2.9	2.0-4.0	.17	.17	5	2	134
	3-14	75-100	0-25	0-3	1.30-1.55	42.33-141.11	0.07-0.10	0.0-2.9	0.5-2.0	.17	.17			
	14-60	85-100	0-15	0-2	1.40-1.65	42.33-141.11	0.04-0.10	0.0-2.9	0.0-0.5	.10	.10			
5C:														
Windsor	0-3	75-100	0-25	1-3	1.00-1.20	42.33-141.11	0.09-0.12	0.0-2.9	2.0-4.0	.17	.17	5	2	134
	3-14	75-100	0-25	0-3	1.30-1.55	42.33-141.11	0.07-0.10	0.0-2.9	0.5-2.0	.17	.17			
	14-60	85-100	0-15	0-2	1.40-1.65	42.33-141.11	0.04-0.10	0.0-2.9	0.0-0.5	.10	.10			

Physical Soil Properties

Windham County, Vermont

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
5D:														
Windsor	0-3	75-100	0-25	1-3	1.00-1.20	42.33-141.11	0.09-0.12	0.0-2.9	2.0-4.0	.17	.17	5	2	134
	3-14	75-100	0-25	0-3	1.30-1.55	42.33-141.11	0.07-0.10	0.0-2.9	0.5-2.0	.17	.17			
	14-60	85-100	0-15	0-2	1.40-1.65	42.33-141.11	0.04-0.10	0.0-2.9	0.0-0.5	.10	.10			
5E:														
Windsor	0-3	75-100	0-25	1-3	1.00-1.20	42.33-141.11	0.09-0.12	0.0-2.9	2.0-4.0	.17	.17	5	2	134
	3-14	75-100	0-25	0-3	1.30-1.55	42.33-141.11	0.07-0.10	0.0-2.9	0.5-2.0	.17	.17			
	14-60	85-100	0-15	0-2	1.40-1.65	42.33-141.11	0.04-0.10	0.0-2.9	0.0-0.5	.10	.10			
10A:														
Agawam	0-10	40-75	15-50	4-10	1.10-1.20	14.11-42.33	0.15-0.21	0.0-2.9	1.0-5.0	.28	.28	3	3	86
	10-25	40-75	15-50	1-10	1.20-1.40	14.11-42.33	0.11-0.21	0.0-2.9	0.5-3.0	.37	.37			
	25-60	85-100	0-15	1-2	1.30-1.40	42.33-141.11	0.02-0.12	0.0-2.9	0.0-1.0	.17	.20			
20B:														
Tunbridge	0-2	40-75	15-50	5-9	0.80-1.20	4.23-42.33	0.11-0.21	0.0-2.9	2.0-8.0	.20	.24	2	8	0
	2-27	40-75	15-50	3-9	1.20-1.40	4.23-42.33	0.10-0.21	0.0-2.9	0.5-4.5	.20	.24			
	27-37	---	---	---	---	0.07-141.11	---	---	---	---	---			
Lyman	0-5	30-75	15-65	2-10	0.75-1.20	14.11-42.33	0.13-0.24	0.0-2.9	2.0-8.0	.20	.28	1	8	0
	5-15	40-75	15-50	2-10	0.90-1.40	14.11-42.33	0.08-0.28	0.0-2.9	2.0-8.0	.32	.37			
	15-25	---	---	---	---	0.07-141.11	---	---	---	---	---			
20C:														
Tunbridge	0-2	40-75	15-50	5-9	0.80-1.20	4.23-42.33	0.11-0.21	0.0-2.9	2.0-8.0	.20	.24	2	8	0
	2-27	40-75	15-50	3-9	1.20-1.40	4.23-42.33	0.10-0.21	0.0-2.9	0.5-4.5	.20	.24			
	27-37	---	---	---	---	0.07-141.11	---	---	---	---	---			

Physical Soil Properties

Windham County, Vermont

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
20C:														
Lyman	0-5	30-75	15-65	2-10	0.75-1.20	14.11-42.33	0.13-0.24	0.0-2.9	2.0-8.0	.20	.28	1	8	0
	5-15	40-75	15-50	2-10	0.90-1.40	14.11-42.33	0.08-0.28	0.0-2.9	2.0-8.0	.32	.37			
	15-25	---	---	---	---	0.07-141.11	---	---	---	---	---			
20D:														
Tunbridge	0-2	40-75	15-50	5-9	0.80-1.20	4.23-42.33	0.11-0.21	0.0-2.9	2.0-8.0	.20	.24	2	8	0
	2-27	40-75	15-50	3-9	1.20-1.40	4.23-42.33	0.10-0.21	0.0-2.9	0.5-4.5	.20	.24			
	27-37	---	---	---	---	0.07-141.11	---	---	---	---	---			
Lyman	0-5	30-75	15-65	2-10	0.75-1.20	14.11-42.33	0.13-0.24	0.0-2.9	2.0-8.0	.20	.28	1	8	0
	5-15	40-75	15-50	2-10	0.90-1.40	14.11-42.33	0.08-0.28	0.0-2.9	2.0-8.0	.32	.37			
	15-25	---	---	---	---	0.07-141.11	---	---	---	---	---			
37:														
Hadley	0-7	0-60	30-90	4-10	1.20-1.50	4.23-14.11	0.15-0.25	0.0-2.9	2.0-5.0	.49	.49	5	5	56
	7-60	0-60	30-90	2-10	1.20-1.50	4.23-42.33	0.13-0.20	0.0-2.9	0.5-2.0	.49	.49			

Physical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
90A:														
Hadley, protected	0-9	5-70	20-85	1-18	1.10-1.46	4.23-14.11	0.17-0.22	0.0-1.0	1.0-9.0	.55	.55	5	3	86
	9-14	5-70	20-90	1-18	1.10-1.65	4.23-14.11	0.17-0.22	0.0-1.0	0.3-3.0	.64	.64			
	14-26	5-70	20-90	1-18	1.10-1.65	4.23-14.11	0.17-0.22	0.0-1.0	0.3-3.0	.64	.64			
	26-33	5-70	20-90	1-18	1.20-1.65	4.23-14.11	0.17-0.22	0.0-1.0	0.1-1.5	.64	.64			
	33-65	5-90	10-90	1-18	1.20-1.65	4.23-705.00	0.07-0.22	0.0-1.0	0.1-1.5	.64	.64			
96A:														
Hadley, occasionally flooded	0-9	5-70	20-85	1-18	1.10-1.46	4.23-14.11	0.17-0.22	0.0-1.0	1.0-9.0	.55	.55	5	3	86
	9-14	5-70	20-90	1-18	1.10-1.65	4.23-14.11	0.17-0.22	0.0-1.0	0.3-3.0	.64	.64			
	14-26	5-70	20-90	1-18	1.10-1.65	4.23-14.11	0.17-0.22	0.0-1.0	0.3-3.0	.64	.64			
	26-33	5-70	20-90	1-18	1.20-1.65	4.23-14.11	0.17-0.22	0.0-1.0	0.1-1.5	.64	.64			
	33-65	5-90	10-90	1-18	1.20-1.65	4.23-705.00	0.07-0.22	0.0-1.0	0.1-1.5	.64	.64			
109B:														
Chatfield, rocky	0-1	---	---	---	0.20-0.75	14.11-42.34	0.45-0.55	---	50-100	---	---	2	3	86
	1-4	45-70	25-50	5-12	0.80-1.20	4.23-42.34	0.16-0.25	0.0-1.0	3.5-9.0	.24	.24			
	4-9	50-70	25-50	5-7	0.80-1.30	4.23-42.34	0.08-0.22	0.0-1.0	2.5-4.5	.20	.28			
	9-19	50-70	25-50	5-7	0.80-1.40	4.23-42.34	0.08-0.22	0.0-1.0	1.2-3.0	.24	.37			
	19-30	50-70	25-50	3-10	0.80-1.40	4.23-42.34	0.08-0.22	0.0-1.0	0.5-6.0	.32	.32			
	30-34	50-70	25-50	2-10	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.24	.43			
	34-37	50-70	25-50	2-10	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.20	.43			
	37-65	---	---	---	---	1.00-100.00	---	---	---	---	---			

Physical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
109B:														
Hollis, rocky	0-1	---	---	---	0.20-1.00	42.34-141.14	0.55-0.65	---	75-100	---	---	1	3	86
	1-3	---	---	---	0.20-1.00	1.41-4.23	0.35-0.45	---	75-100	---	---			
	3-4	50-70	25-50	5-8	0.80-1.20	4.23-42.33	0.08-0.14	0.0-1.0	3.5-9.0	.24	.24			
	4-15	50-70	25-50	5-8	0.80-1.30	4.32-42.33	0.06-0.18	0.0-1.0	2.5-4.5	.24	.32			
	15-65	---	---	---	---	1.00-100.00	---	---	---	---	---			
109C:														
Chatfield, rocky	0-1	---	---	---	0.20-0.75	14.11-42.34	0.45-0.55	---	50-100	---	---	2	3	86
	1-4	45-70	25-50	5-12	0.80-1.20	4.23-42.34	0.16-0.25	0.0-1.0	3.5-9.0	.24	.24			
	4-9	50-70	25-50	5-7	0.80-1.30	4.23-42.34	0.08-0.22	0.0-1.0	2.5-4.5	.20	.28			
	9-19	50-70	25-50	5-7	0.80-1.40	4.23-42.34	0.08-0.22	0.0-1.0	1.2-3.0	.24	.37			
	19-30	50-70	25-50	3-10	0.80-1.40	4.23-42.34	0.08-0.22	0.0-1.0	0.5-6.0	.32	.32			
	30-34	50-70	25-50	2-10	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.24	.43			
	34-37	50-70	25-50	2-10	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.20	.43			
	37-65	---	---	---	---	1.00-100.00	---	---	---	---	---			
Hollis, rocky	0-1	---	---	---	0.20-1.00	42.34-141.14	0.55-0.65	---	75-100	---	---	1	3	86
	1-3	---	---	---	0.20-1.00	1.41-4.23	0.35-0.45	---	75-100	---	---			
	3-4	50-70	25-50	5-8	0.80-1.20	4.23-42.33	0.08-0.14	0.0-1.0	3.5-9.0	.24	.24			
	4-15	50-70	25-50	5-8	0.80-1.30	4.32-42.33	0.06-0.18	0.0-1.0	2.5-4.5	.24	.32			
	15-65	---	---	---	---	1.00-100.00	---	---	---	---	---			

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
109D:														
Chatfield, rocky	0-1	---	---	---	0.20-0.75	14.11-42.34	0.45-0.55	---	50-100	---	---	2	3	86
	1-4	45-70	25-50	5-12	0.80-1.20	4.23-42.34	0.16-0.25	0.0-1.0	3.5-9.0	.24	.24			
	4-9	50-70	25-50	5-7	0.80-1.30	4.23-42.34	0.08-0.22	0.0-1.0	2.5-4.5	.20	.28			
	9-19	50-70	25-50	5-7	0.80-1.40	4.23-42.34	0.08-0.22	0.0-1.0	1.2-3.0	.24	.37			
	19-30	50-70	25-50	3-10	0.80-1.40	4.23-42.34	0.08-0.22	0.0-1.0	0.5-6.0	.32	.32			
	30-34	50-70	25-50	2-10	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.24	.43			
	34-37	50-70	25-50	2-10	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.20	.43			
	37-65	---	---	---	---	1.00-100.00	---	---	---	---	---			
Hollis, rocky	0-1	---	---	---	0.20-1.00	42.34-141.14	0.55-0.65	---	75-100	---	---	1	3	86
	1-3	---	---	---	0.20-1.00	1.41-4.23	0.35-0.45	---	75-100	---	---			
	3-4	50-70	25-50	5-8	0.80-1.20	4.23-42.33	0.08-0.14	0.0-1.0	3.5-9.0	.24	.24			
	4-15	50-70	25-50	5-8	0.80-1.30	4.32-42.33	0.06-0.18	0.0-1.0	2.5-4.5	.24	.32			
	15-65	---	---	---	---	1.00-100.00	---	---	---	---	---			
109F:														
Chatfield, rocky	0-1	---	---	---	0.20-0.75	14.11-42.34	0.45-0.55	---	50-100	---	---	2	3	86
	1-4	45-70	25-50	5-12	0.80-1.20	4.23-42.34	0.16-0.25	0.0-1.0	3.5-9.0	.24	.24			
	4-9	50-70	25-50	5-7	0.80-1.30	4.23-42.34	0.08-0.22	0.0-1.0	2.5-4.5	.20	.28			
	9-19	50-70	25-50	5-7	0.80-1.40	4.23-42.34	0.08-0.22	0.0-1.0	1.2-3.0	.24	.37			
	19-30	50-70	25-50	3-10	0.80-1.40	4.23-42.34	0.08-0.22	0.0-1.0	0.5-6.0	.32	.32			
	30-34	50-70	25-50	2-10	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.24	.43			
	34-37	50-70	25-50	2-10	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.20	.43			
	37-65	---	---	---	---	1.00-100.00	---	---	---	---	---			

Physical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
109F:														
Hollis, rocky	0-1	---	---	---	0.20-1.00	42.34-141.14	0.55-0.65	---	75-100	---	---	1	3	86
	1-3	---	---	---	0.20-1.00	1.41-4.23	0.35-0.45	---	75-100	---	---			
	3-4	50-70	25-50	5-8	0.80-1.20	4.23-42.33	0.08-0.14	0.0-1.0	3.5-9.0	.24	.24			
	4-15	50-70	25-50	5-8	0.80-1.30	4.32-42.33	0.06-0.18	0.0-1.0	2.5-4.5	.24	.32			
	15-65	---	---	---	---	1.00-100.00	---	---	---	---	---			
125B:														
Charlton, rocky	0-8	45-70	25-50	5-12	0.80-1.20	4.23-42.34	0.16-0.25	0.0-1.0	3.5-9.0	.24	.24	5	3	86
	8-15	50-70	25-50	5-8	0.80-1.30	4.23-42.34	0.08-0.22	0.0-1.0	2.5-4.5	.28	.28			
	15-22	50-70	25-50	5-7	0.80-1.40	4.23-42.34	0.08-0.22	0.0-1.0	1.2-3.0	.37	.37			
	22-31	50-70	25-50	4-7	0.80-1.40	4.23-42.34	0.08-0.22	0.0-1.0	0.1-1.5	.43	.43			
	31-37	50-70	25-50	3-7	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.28	.43			
	37-43	50-70	25-50	3-7	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.43	.43			
	43-49	50-70	20-45	2-6	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.17	.28			
	49-65	50-70	20-45	2-6	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.17	.28			
Chatfield, rocky	0-1	---	---	---	0.20-0.75	14.11-42.34	0.45-0.55	---	50-100	---	---	2	3	86
	1-4	45-70	25-50	5-12	0.80-1.20	4.23-42.34	0.16-0.25	0.0-1.0	3.5-9.0	.24	.24			
	4-9	50-70	25-50	5-7	0.80-1.30	4.23-42.34	0.08-0.22	0.0-1.0	2.5-4.5	.20	.28			
	9-19	50-70	25-50	5-7	0.80-1.40	4.23-42.34	0.08-0.22	0.0-1.0	1.2-3.0	.24	.37			
	19-30	50-70	25-50	3-10	0.80-1.40	4.23-42.34	0.08-0.22	0.0-1.0	0.5-6.0	.32	.32			
	30-34	50-70	25-50	2-10	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.24	.43			
	34-37	50-70	25-50	2-10	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.20	.43			
	37-65	---	---	---	---	1.00-100.00	---	---	---	---	---			

Physical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
125B:														
Hollis, rocky	0-1	---	---	---	0.20-1.00	42.34-141.14	0.55-0.65	---	75-100	---	---	1	3	86
	1-3	---	---	---	0.20-1.00	1.41-4.23	0.35-0.45	---	75-100	---	---			
	3-4	50-70	25-50	5-8	0.80-1.20	4.23-42.33	0.08-0.14	0.0-1.0	3.5-9.0	.24	.24			
	4-15	50-70	25-50	5-8	0.80-1.30	4.32-42.33	0.06-0.18	0.0-1.0	2.5-4.5	.24	.32			
	15-65	---	---	---	---	1.00-100.00	---	---	---	---	---			
125C:														
Charlton, rocky	0-8	45-70	25-50	5-12	0.80-1.20	4.23-42.34	0.16-0.25	0.0-1.0	3.5-9.0	.24	.24	5	3	86
	8-15	50-70	25-50	5-8	0.80-1.30	4.23-42.34	0.08-0.22	0.0-1.0	2.5-4.5	.28	.28			
	15-22	50-70	25-50	5-7	0.80-1.40	4.23-42.34	0.08-0.22	0.0-1.0	1.2-3.0	.37	.37			
	22-31	50-70	25-50	4-7	0.80-1.40	4.23-42.34	0.08-0.22	0.0-1.0	0.1-1.5	.43	.43			
	31-37	50-70	25-50	3-7	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.28	.43			
	37-43	50-70	25-50	3-7	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.43	.43			
	43-49	50-70	20-45	2-6	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.17	.28			
	49-65	50-70	20-45	2-6	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.17	.28			
Chatfield, rocky	0-1	---	---	---	0.20-0.75	14.11-42.34	0.45-0.55	---	50-100	---	---	2	3	86
	1-4	45-70	25-50	5-12	0.80-1.20	4.23-42.34	0.16-0.25	0.0-1.0	3.5-9.0	.24	.24			
	4-9	50-70	25-50	5-7	0.80-1.30	4.23-42.34	0.08-0.22	0.0-1.0	2.5-4.5	.20	.28			
	9-19	50-70	25-50	5-7	0.80-1.40	4.23-42.34	0.08-0.22	0.0-1.0	1.2-3.0	.24	.37			
	19-30	50-70	25-50	3-10	0.80-1.40	4.23-42.34	0.08-0.22	0.0-1.0	0.5-6.0	.32	.32			
	30-34	50-70	25-50	2-10	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.24	.43			
	34-37	50-70	25-50	2-10	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.20	.43			
	37-65	---	---	---	---	1.00-100.00	---	---	---	---	---			

Physical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
125C:														
Hollis, rocky	0-1	---	---	---	0.20-1.00	42.34-141.14	0.55-0.65	---	75-100	---	---	1	3	86
	1-3	---	---	---	0.20-1.00	1.41-4.23	0.35-0.45	---	75-100	---	---			
	3-4	50-70	25-50	5-8	0.80-1.20	4.23-42.33	0.08-0.14	0.0-1.0	3.5-9.0	.24	.24			
	4-15	50-70	25-50	5-8	0.80-1.30	4.32-42.33	0.06-0.18	0.0-1.0	2.5-4.5	.24	.32			
	15-65	---	---	---	---	1.00-100.00	---	---	---	---	---			
125D:														
Charlton, rocky	0-8	45-70	25-50	5-12	0.80-1.20	4.23-42.34	0.16-0.25	0.0-1.0	3.5-9.0	.24	.24	5	3	86
	8-15	50-70	25-50	5-8	0.80-1.30	4.23-42.34	0.08-0.22	0.0-1.0	2.5-4.5	.28	.28			
	15-22	50-70	25-50	5-7	0.80-1.40	4.23-42.34	0.08-0.22	0.0-1.0	1.2-3.0	.37	.37			
	22-31	50-70	25-50	4-7	0.80-1.40	4.23-42.34	0.08-0.22	0.0-1.0	0.1-1.5	.43	.43			
	31-37	50-70	25-50	3-7	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.28	.43			
	37-43	50-70	25-50	3-7	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.43	.43			
	43-49	50-70	20-45	2-6	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.17	.28			
	49-65	50-70	20-45	2-6	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.17	.28			
Chatfield, rocky	0-1	---	---	---	0.20-0.75	14.11-42.34	0.45-0.55	---	50-100	---	---	2	3	86
	1-4	45-70	25-50	5-12	0.80-1.20	4.23-42.34	0.16-0.25	0.0-1.0	3.5-9.0	.24	.24			
	4-9	50-70	25-50	5-7	0.80-1.30	4.23-42.34	0.08-0.22	0.0-1.0	2.5-4.5	.20	.28			
	9-19	50-70	25-50	5-7	0.80-1.40	4.23-42.34	0.08-0.22	0.0-1.0	1.2-3.0	.24	.37			
	19-30	50-70	25-50	3-10	0.80-1.40	4.23-42.34	0.08-0.22	0.0-1.0	0.5-6.0	.32	.32			
	30-34	50-70	25-50	2-10	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.24	.43			
	34-37	50-70	25-50	2-10	0.80-1.40	4.23-42.34	0.08-0.20	0.0-1.0	0.1-1.5	.20	.43			
	37-65	---	---	---	---	1.00-100.00	---	---	---	---	---			

Physical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
125D:														
Hollis, rocky	0-1	---	---	---	0.20-1.00	42.34-141.14	0.55-0.65	---	75-100	---	---	1	3	86
	1-3	---	---	---	0.20-1.00	1.41-4.23	0.35-0.45	---	75-100	---	---			
	3-4	50-70	25-50	5-8	0.80-1.20	4.23-42.33	0.08-0.14	0.0-1.0	3.5-9.0	.24	.24			
	4-15	50-70	25-50	5-8	0.80-1.30	4.32-42.33	0.06-0.18	0.0-1.0	2.5-4.5	.24	.32			
	15-65	---	---	---	---	1.00-100.00	---	---	---	---	---			
131B:														
Yalesville, rocky	0-1	---	---	---	0.21-0.33	14.11-42.33	0.45-0.55	---	75-100	---	---	2	5	56
	1-3	45-65	20-50	5-12	1.00-1.20	4.23-42.33	0.10-0.21	0.0-1.0	6.0-9.0	.37	.37			
	3-8	45-65	20-50	5-12	1.00-1.40	4.23-42.34	0.08-0.21	0.0-1.0	2.5-5.0	.37	.37			
	8-17	45-65	20-50	5-12	1.00-1.40	4.23-42.34	0.08-0.21	0.0-1.0	0.5-3.0	.43	.43			
	17-22	45-65	20-50	3-12	1.00-1.40	4.23-42.34	0.08-0.21	0.0-1.0	0.5-3.0	.49	.49			
	22-33	45-65	20-50	3-10	1.20-1.50	4.23-42.34	0.03-0.16	0.0-1.0	0.1-1.0	.24	.43			
	33-65	---	---	---	---	0.00-1.00	---	---	---	---	---			
Holyoke, rocky	0-3	45-62	25-50	5-12	1.00-1.20	4.23-14.11	0.10-0.19	0.0-1.0	6.0-9.0	.43	.43	1	3	86
	3-6	45-62	25-50	5-12	1.20-1.40	4.23-14.11	0.08-0.21	0.0-1.0	2.5-5.0	.43	.43			
	6-17	45-62	25-50	5-12	1.20-1.40	4.23-14.11	0.08-0.21	0.0-1.0	0.5-3.0	.37	.55			
	17-65	---	---	---	---	0.00-1.00	---	---	---	---	---			

Physical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi- bility	Organic matter	Erosion factors			Wind erodi- bility group	Wind erodi- bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
131C:														
Yalesville, rocky	0-1	---	---	---	0.21-0.33	14.11-42.33	0.45-0.55	---	75-100	---	---	2	5	56
	1-3	45-65	20-50	5-12	1.00-1.20	4.23-42.33	0.10-0.21	0.0-1.0	6.0-9.0	.37	.37			
	3-8	45-65	20-50	5-12	1.00-1.40	4.23-42.34	0.08-0.21	0.0-1.0	2.5-5.0	.37	.37			
	8-17	45-65	20-50	5-12	1.00-1.40	4.23-42.34	0.08-0.21	0.0-1.0	0.5-3.0	.43	.43			
	17-22	45-65	20-50	3-12	1.00-1.40	4.23-42.34	0.08-0.21	0.0-1.0	0.5-3.0	.49	.49			
	22-33	45-65	20-50	3-10	1.20-1.50	4.23-42.34	0.03-0.16	0.0-1.0	0.1-1.0	.24	.43			
	33-65	---	---	---	---	0.00-1.00	---	---	---	---	---			
Holyoke, rocky	0-3	45-62	25-50	5-12	1.00-1.20	4.23-14.11	0.10-0.19	0.0-1.0	6.0-9.0	.43	.43	1	3	86
	3-6	45-62	25-50	5-12	1.20-1.40	4.23-14.11	0.08-0.21	0.0-1.0	2.5-5.0	.43	.43			
	6-17	45-62	25-50	5-12	1.20-1.40	4.23-14.11	0.08-0.21	0.0-1.0	0.5-3.0	.37	.55			
	17-65	---	---	---	---	0.00-1.00	---	---	---	---	---			
131D:														
Yalesville, rocky	0-1	---	---	---	0.21-0.33	14.11-42.33	0.45-0.55	---	75-100	---	---	2	5	56
	1-3	45-65	20-50	5-12	1.00-1.20	4.23-42.33	0.10-0.21	0.0-1.0	6.0-9.0	.37	.37			
	3-8	45-65	20-50	5-12	1.00-1.40	4.23-42.34	0.08-0.21	0.0-1.0	2.5-5.0	.37	.37			
	8-17	45-65	20-50	5-12	1.00-1.40	4.23-42.34	0.08-0.21	0.0-1.0	0.5-3.0	.43	.43			
	17-22	45-65	20-50	3-12	1.00-1.40	4.23-42.34	0.08-0.21	0.0-1.0	0.5-3.0	.49	.49			
	22-33	45-65	20-50	3-10	1.20-1.50	4.23-42.34	0.03-0.16	0.0-1.0	0.1-1.0	.24	.43			
	33-65	---	---	---	---	0.00-1.00	---	---	---	---	---			
Holyoke, rocky	0-3	45-62	25-50	5-12	1.00-1.20	4.23-14.11	0.10-0.19	0.0-1.0	6.0-9.0	.43	.43	1	3	86
	3-6	45-62	25-50	5-12	1.20-1.40	4.23-14.11	0.08-0.21	0.0-1.0	2.5-5.0	.43	.43			
	6-17	45-62	25-50	5-12	1.20-1.40	4.23-14.11	0.08-0.21	0.0-1.0	0.5-3.0	.37	.55			
	17-65	---	---	---	---	0.00-1.00	---	---	---	---	---			

Physical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
131F:														
Yalesville, rocky	0-1	---	---	---	0.21-0.33	14.11-42.33	0.45-0.55	---	75-100	---	---	2	5	56
	1-3	45-65	20-50	5-12	1.00-1.20	4.23-42.33	0.10-0.21	0.0-1.0	6.0-9.0	.37	.37			
	3-8	45-65	20-50	5-12	1.00-1.40	4.23-42.34	0.08-0.21	0.0-1.0	2.5-5.0	.37	.37			
	8-17	45-65	20-50	5-12	1.00-1.40	4.23-42.34	0.08-0.21	0.0-1.0	0.5-3.0	.43	.43			
	17-22	45-65	20-50	3-12	1.00-1.40	4.23-42.34	0.08-0.21	0.0-1.0	0.5-3.0	.49	.49			
	22-33	45-65	20-50	3-10	1.20-1.50	4.23-42.34	0.03-0.16	0.0-1.0	0.1-1.0	.24	.43			
	33-65	---	---	---	---	0.00-1.00	---	---	---	---	---			
Holyoke, rocky	0-3	45-62	25-50	5-12	1.00-1.20	4.23-14.11	0.10-0.19	0.0-1.0	6.0-9.0	.43	.43	1	3	86
	3-6	45-62	25-50	5-12	1.20-1.40	4.23-14.11	0.08-0.21	0.0-1.0	2.5-5.0	.43	.43			
	6-17	45-62	25-50	5-12	1.20-1.40	4.23-14.11	0.08-0.21	0.0-1.0	0.5-3.0	.37	.55			
	17-65	---	---	---	---	0.00-1.00	---	---	---	---	---			
229F:														
Windsor	0-1	---	---	---	0.20-0.60	42.34-141.14	0.55-0.65	---	75-100	---	---	5	2	134
	1-2	---	---	---	0.20-0.60	1.41-4.23	0.35-0.45	---	75-100	---	---			
	2-7	76-80	15-19	2-5	1.30-1.60	42.34-705.00	0.09-0.12	0.0-1.0	2.0-7.0	.15	.15			
	7-19	76-82	15-19	2-5	1.30-1.60	42.34-705.00	0.08-0.11	0.0-1.0	0.5-1.0	.24	.24			
	19-25	80-99	1-18	0-2	1.30-1.60	42.34-705.00	0.05-0.11	0.0-1.0	0.1-0.5	.05	.05			
	25-40	77-100	0-20	0-3	1.30-1.60	42.34-705.00	0.05-0.10	0.0-1.0	0.0-0.3	.05	.05			
	40-59	77-100	0-20	0-3	1.30-1.60	42.34-705.00	0.05-0.10	0.0-1.0	0.0-0.3	.20	.20			
	59-65	77-100	0-20	0-3	1.30-1.60	42.34-705.00	0.05-0.10	0.0-1.0	0.0-0.3	.05	.05			

Physical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
229F:														
Merrimac	0-10	47-78	20-45	2-8	1.10-1.20	4.23-141.14	0.10-0.21	0.0-1.0	2.0-5.0	.28	.28	3	3	86
	10-15	53-78	14-45	2-8	1.20-1.40	4.23-141.14	0.08-0.18	0.0-1.0	0.3-2.0	.37	.37			
	15-22	53-78	14-45	2-8	1.20-1.40	4.23-141.14	0.08-0.18	0.0-1.0	0.3-2.0	.24	.37			
	22-26	53-86	12-39	2-8	1.20-1.60	14.11-141.14	0.06-0.12	0.0-1.0	0.1-0.5	.10	.15			
	26-65	86-96	2-14	0-2	1.30-1.60	42.34-705.00	0.01-0.04	0.0-1.0	0.0-0.3	.02	.02			
230A:														
Unadilla	0-1	---	---	---	0.21-0.30	14.11-42.33	0.45-0.55	---	48-100	---	---	4	5	56
	1-10	5-60	40-85	4-18	0.59-1.46	4.23-14.11	0.20-0.24	0.0-1.0	2.0-7.5	.37	.37			
	10-21	5-75	40-85	4-18	1.15-1.46	4.23-14.11	0.18-0.24	0.0-1.0	0.5-2.0	.55	.55			
	21-30	5-75	40-85	4-18	1.15-1.46	4.23-14.11	0.17-0.24	0.0-1.0	0.5-3.0	.55	.55			
	30-55	5-91	15-85	0-18	1.30-1.50	4.23-14.11	0.17-0.22	0.5-1.5	0.1-0.5	.55	.55			
	55-65	70-100	0-30	0-15	1.45-1.60	14.11-141.14	0.02-0.12	0.0-1.0	0.1-0.8	.10	.20			
230B:														
Unadilla	0-1	---	---	---	0.21-0.30	14.11-42.33	0.45-0.55	---	48-100	---	---	4	5	56
	1-10	5-60	40-85	4-18	0.59-1.46	4.23-14.11	0.20-0.24	0.0-1.0	2.0-7.5	.37	.37			
	10-21	5-75	40-85	4-18	1.15-1.46	4.23-14.11	0.18-0.24	0.0-1.0	0.5-2.0	.55	.55			
	21-30	5-75	40-85	4-18	1.15-1.46	4.23-14.11	0.17-0.24	0.0-1.0	0.5-3.0	.55	.55			
	30-55	5-91	15-85	0-18	1.30-1.50	4.23-14.11	0.17-0.22	0.5-1.5	0.1-0.5	.55	.55			
	55-65	70-100	0-30	0-15	1.45-1.60	14.11-141.14	0.02-0.12	0.0-1.0	0.1-0.8	.10	.20			

Physical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors Kw	Kf	T	Wind erodi-bility group	Wind erodi-bility index
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
235F:														
Poocham	0-2	---	---	---	0.21-0.30	14.11-42.33	0.45-0.55	---	48-100	---	---	5	5	56
	2-5	5-50	40-85	4-25	0.59-1.46	4.23-14.11	0.18-0.24	0.0-1.0	2.0-8.0	.37	.37			
	5-14	5-60	40-85	4-25	1.15-1.46	4.23-14.11	0.18-0.24	0.0-1.0	0.5-1.0	.55	.55			
	14-19	5-90	0-90	4-40	1.30-1.50	1.41-14.11	0.17-0.22	0.5-1.5	0.1-1.0	.55	.55			
	19-33	5-90	0-90	4-40	1.30-1.50	1.41-14.11	0.17-0.22	0.5-1.5	0.1-1.0	.55	.55			
	33-54	5-90	0-90	4-40	1.30-1.50	1.41-14.11	0.17-0.22	0.5-1.5	0.1-0.8	.55	.55			
	54-65	5-90	0-90	4-45	1.30-1.50	1.41-14.11	0.17-0.22	0.5-1.5	0.1-0.8	.55	.55			
Agawam	0-2	---	---	---	1.10-1.20	1.41-4.23	0.08-0.40	---	45-95	---	---	3	3	86
	2-4	54-74	30-40	1-8	1.10-1.40	4.23-42.33	0.12-0.15	0.0-0.4	2.0-5.0	.37	.37			
	4-9	53-74	30-40	1-7	1.30-1.50	4.23-42.33	0.12-0.17	0.0-0.4	0.1-0.5	.55	.55			
	9-21	53-74	30-40	1-7	1.30-1.50	4.23-42.33	0.12-0.17	0.0-0.4	0.1-0.5	.55	.55			
	21-33	77-95	5-20	0-3	1.40-1.60	42.33-141.00	0.03-0.11	0.0-0.2	0.0-0.2	.17	.17			
	33-65	77-95	5-20	0-3	1.40-1.60	42.33-141.00	0.03-0.11	0.0-0.2	0.0-0.2	.17	.17			
254A:														
Merrimac	0-10	47-78	20-45	2-8	1.10-1.20	4.23-141.14	0.10-0.21	0.0-1.0	2.0-5.0	.28	.28	3	3	86
	10-15	53-78	14-45	2-8	1.20-1.40	4.23-141.14	0.08-0.18	0.0-1.0	0.3-2.0	.37	.37			
	15-22	53-78	14-45	2-8	1.20-1.40	4.23-141.14	0.08-0.18	0.0-1.0	0.3-2.0	.24	.37			
	22-26	53-86	12-39	2-8	1.20-1.60	14.11-141.14	0.06-0.12	0.0-1.0	0.1-0.5	.10	.15			
	26-65	86-96	2-14	0-2	1.30-1.60	42.34-705.00	0.01-0.04	0.0-1.0	0.0-0.3	.02	.02			

Physical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
254B:														
Merrimac	0-10	47-78	20-45	2-8	1.10-1.20	4.23-141.14	0.10-0.21	0.0-1.0	2.0-5.0	.28	.28	3	3	86
	10-15	53-78	14-45	2-8	1.20-1.40	4.23-141.14	0.08-0.18	0.0-1.0	0.3-2.0	.37	.37			
	15-22	53-78	14-45	2-8	1.20-1.40	4.23-141.14	0.08-0.18	0.0-1.0	0.3-2.0	.24	.37			
	22-26	53-86	12-39	2-8	1.20-1.60	14.11-141.14	0.06-0.12	0.0-1.0	0.1-0.5	.10	.15			
	26-65	86-96	2-14	0-2	1.30-1.60	42.34-705.00	0.01-0.04	0.0-1.0	0.0-0.3	.02	.02			
254C:														
Merrimac	0-10	47-78	20-45	2-8	1.10-1.20	4.23-141.14	0.10-0.21	0.0-1.0	2.0-5.0	.28	.28	3	3	86
	10-15	53-78	14-45	2-8	1.20-1.40	4.23-141.14	0.08-0.18	0.0-1.0	0.3-2.0	.37	.37			
	15-22	53-78	14-45	2-8	1.20-1.40	4.23-141.14	0.08-0.18	0.0-1.0	0.3-2.0	.24	.37			
	22-26	53-86	12-39	2-8	1.20-1.60	14.11-141.14	0.06-0.12	0.0-1.0	0.1-0.5	.10	.15			
	26-65	86-96	2-14	0-2	1.30-1.60	42.34-705.00	0.01-0.04	0.0-1.0	0.0-0.3	.02	.02			
254D:														
Merrimac	0-10	47-78	20-45	2-8	1.10-1.20	4.23-141.14	0.10-0.21	0.0-1.0	2.0-5.0	.28	.28	3	3	86
	10-15	53-78	14-45	2-8	1.20-1.40	4.23-141.14	0.08-0.18	0.0-1.0	0.3-2.0	.37	.37			
	15-22	53-78	14-45	2-8	1.20-1.40	4.23-141.14	0.08-0.18	0.0-1.0	0.3-2.0	.24	.37			
	22-26	53-86	12-39	2-8	1.20-1.60	14.11-141.14	0.06-0.12	0.0-1.0	0.1-0.5	.10	.15			
	26-65	86-96	2-14	0-2	1.30-1.60	42.34-705.00	0.01-0.04	0.0-1.0	0.0-0.3	.02	.02			

Physical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
255A:														
Windsor	0-1	---	---	---	0.20-0.60	42.34-141.14	0.55-0.65	---	75-100	---	---	5	2	134
	1-2	---	---	---	0.20-0.60	1.41-4.23	0.35-0.45	---	75-100	---	---			
	2-7	76-80	15-19	2-5	1.30-1.60	42.34-705.00	0.09-0.12	0.0-1.0	2.0-7.0	.15	.15			
	7-19	76-82	15-19	2-5	1.30-1.60	42.34-705.00	0.08-0.11	0.0-1.0	0.5-1.0	.24	.24			
	19-25	80-99	1-18	0-2	1.30-1.60	42.34-705.00	0.05-0.11	0.0-1.0	0.1-0.5	.05	.05			
	25-40	77-100	0-20	0-3	1.30-1.60	42.34-705.00	0.05-0.10	0.0-1.0	0.0-0.3	.05	.05			
	40-59	77-100	0-20	0-3	1.30-1.60	42.34-705.00	0.05-0.10	0.0-1.0	0.0-0.3	.20	.20			
	59-65	77-100	0-20	0-3	1.30-1.60	42.34-705.00	0.05-0.10	0.0-1.0	0.0-0.3	.05	.05			
255B:														
Windsor	0-1	---	---	---	0.20-0.60	42.34-141.14	0.55-0.65	---	75-100	---	---	5	2	134
	1-2	---	---	---	0.20-0.60	1.41-4.23	0.35-0.45	---	75-100	---	---			
	2-7	76-80	15-19	2-5	1.30-1.60	42.34-705.00	0.09-0.12	0.0-1.0	2.0-7.0	.15	.15			
	7-19	76-82	15-19	2-5	1.30-1.60	42.34-705.00	0.08-0.11	0.0-1.0	0.5-1.0	.24	.24			
	19-25	80-99	1-18	0-2	1.30-1.60	42.34-705.00	0.05-0.11	0.0-1.0	0.1-0.5	.05	.05			
	25-40	77-100	0-20	0-3	1.30-1.60	42.34-705.00	0.05-0.10	0.0-1.0	0.0-0.3	.05	.05			
	40-59	77-100	0-20	0-3	1.30-1.60	42.34-705.00	0.05-0.10	0.0-1.0	0.0-0.3	.20	.20			
	59-65	77-100	0-20	0-3	1.30-1.60	42.34-705.00	0.05-0.10	0.0-1.0	0.0-0.3	.05	.05			

Physical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
255C:														
Windsor	0-1	---	---	---	0.20-0.60	42.34-141.14	0.55-0.65	---	75-100	---	---	5	2	134
	1-2	---	---	---	0.20-0.60	1.41-4.23	0.35-0.45	---	75-100	---	---			
	2-7	76-80	15-19	2-5	1.30-1.60	42.34-705.00	0.09-0.12	0.0-1.0	2.0-7.0	.15	.15			
	7-19	76-82	15-19	2-5	1.30-1.60	42.34-705.00	0.08-0.11	0.0-1.0	0.5-1.0	.24	.24			
	19-25	80-99	1-18	0-2	1.30-1.60	42.34-705.00	0.05-0.11	0.0-1.0	0.1-0.5	.05	.05			
	25-40	77-100	0-20	0-3	1.30-1.60	42.34-705.00	0.05-0.10	0.0-1.0	0.0-0.3	.05	.05			
	40-59	77-100	0-20	0-3	1.30-1.60	42.34-705.00	0.05-0.10	0.0-1.0	0.0-0.3	.20	.20			
	59-65	77-100	0-20	0-3	1.30-1.60	42.34-705.00	0.05-0.10	0.0-1.0	0.0-0.3	.05	.05			
255D:														
Windsor	0-1	---	---	---	0.20-0.60	42.34-141.14	0.55-0.65	---	75-100	---	---	5	2	134
	1-2	---	---	---	0.20-0.60	1.41-4.23	0.35-0.45	---	75-100	---	---			
	2-7	76-80	15-19	2-5	1.30-1.60	42.34-705.00	0.09-0.12	0.0-1.0	2.0-7.0	.15	.15			
	7-19	76-82	15-19	2-5	1.30-1.60	42.34-705.00	0.08-0.11	0.0-1.0	0.5-1.0	.24	.24			
	19-25	80-99	1-18	0-2	1.30-1.60	42.34-705.00	0.05-0.11	0.0-1.0	0.1-0.5	.05	.05			
	25-40	77-100	0-20	0-3	1.30-1.60	42.34-705.00	0.05-0.10	0.0-1.0	0.0-0.3	.05	.05			
	40-59	77-100	0-20	0-3	1.30-1.60	42.34-705.00	0.05-0.10	0.0-1.0	0.0-0.3	.20	.20			
	59-65	77-100	0-20	0-3	1.30-1.60	42.34-705.00	0.05-0.10	0.0-1.0	0.0-0.3	.05	.05			
275A:														
Agawam	0-2	---	---	---	1.10-1.20	1.41-4.23	0.08-0.40	---	45-95	---	---	3	3	86
	2-4	54-74	30-40	1-8	1.10-1.40	4.23-42.33	0.12-0.15	0.0-0.4	2.0-5.0	.37	.37			
	4-9	53-74	30-40	1-7	1.30-1.50	4.23-42.33	0.12-0.17	0.0-0.4	0.1-0.5	.55	.55			
	9-21	53-74	30-40	1-7	1.30-1.50	4.23-42.33	0.12-0.17	0.0-0.4	0.1-0.5	.55	.55			
	21-33	77-95	5-20	0-3	1.40-1.60	42.33-141.00	0.03-0.11	0.0-0.2	0.0-0.2	.17	.17			
	33-65	77-95	5-20	0-3	1.40-1.60	42.33-141.00	0.03-0.11	0.0-0.2	0.0-0.2	.17	.17			

Physical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
275B:														
Agawam	0-2	---	---	---	1.10-1.20	1.41-4.23	0.08-0.40	---	45-95	---	---	3	3	86
	2-4	54-74	30-40	1-8	1.10-1.40	4.23-42.33	0.12-0.15	0.0-0.4	2.0-5.0	.37	.37			
	4-9	53-74	30-40	1-7	1.30-1.50	4.23-42.33	0.12-0.17	0.0-0.4	0.1-0.5	.55	.55			
	9-21	53-74	30-40	1-7	1.30-1.50	4.23-42.33	0.12-0.17	0.0-0.4	0.1-0.5	.55	.55			
	21-33	77-95	5-20	0-3	1.40-1.60	42.33-141.00	0.03-0.11	0.0-0.2	0.0-0.2	.17	.17			
	33-65	77-95	5-20	0-3	1.40-1.60	42.33-141.00	0.03-0.11	0.0-0.2	0.0-0.2	.17	.17			
275C:														
Agawam	0-2	---	---	---	1.10-1.20	1.41-4.23	0.08-0.40	---	45-95	---	---	3	3	86
	2-4	54-74	30-40	1-8	1.10-1.40	4.23-42.33	0.12-0.15	0.0-0.4	2.0-5.0	.37	.37			
	4-9	53-74	30-40	1-7	1.30-1.50	4.23-42.33	0.12-0.17	0.0-0.4	0.1-0.5	.55	.55			
	9-21	53-74	30-40	1-7	1.30-1.50	4.23-42.33	0.12-0.17	0.0-0.4	0.1-0.5	.55	.55			
	21-33	77-95	5-20	0-3	1.40-1.60	42.33-141.00	0.03-0.11	0.0-0.2	0.0-0.2	.17	.17			
	33-65	77-95	5-20	0-3	1.40-1.60	42.33-141.00	0.03-0.11	0.0-0.2	0.0-0.2	.17	.17			
275D:														
Agawam	0-2	---	---	---	1.10-1.20	1.41-4.23	0.08-0.40	---	45-95	---	---	3	3	86
	2-4	54-74	30-40	1-8	1.10-1.40	4.23-42.33	0.12-0.15	0.0-0.4	2.0-5.0	.37	.37			
	4-9	53-74	30-40	1-7	1.30-1.50	4.23-42.33	0.12-0.17	0.0-0.4	0.1-0.5	.55	.55			
	9-21	53-74	30-40	1-7	1.30-1.50	4.23-42.33	0.12-0.17	0.0-0.4	0.1-0.5	.55	.55			
	21-33	77-95	5-20	0-3	1.40-1.60	42.33-141.00	0.03-0.11	0.0-0.2	0.0-0.2	.17	.17			
	33-65	77-95	5-20	0-3	1.40-1.60	42.33-141.00	0.03-0.11	0.0-0.2	0.0-0.2	.17	.17			

Physical Soil Properties

Franklin County, Massachusetts

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi- bility	Organic matter	Erosion factors			Wind erodi- bility group	Wind erodi- bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
618F:														
Udorthents, frequently flooded	0-6	5-85	15-70	3-18	1.10-1.46	4.23-141.14	0.10-0.24	0.0-1.0	3.0-6.0	.43	.43	5	3	86
	6-21	5-91	0-90	0-5	1.10-1.60	4.23-141.14	0.07-0.22	0.0-1.0	0.1-2.0	.24	.24			
	21-34	5-91	0-90	0-5	1.10-1.60	4.23-141.14	0.07-0.22	0.0-1.0	0.1-1.8	.55	.55			
	34-65	5-91	0-90	0-5	1.10-1.60	4.23-141.14	0.07-0.22	0.0-1.0	0.1-1.8	.24	.24			
651:														
Udorthents, smoothed	0-6	5-85	10-90	0-8	1.10-1.46	4.23-141.14	0.10-0.24	0.0-1.0	3.0-6.0	.37	.37	4	3	86
	6-23	5-95	0-90	0-8	1.10-1.60	4.23-705.00	0.04-0.22	0.0-1.0	0.1-2.0	.55	.55			
	23-42	5-95	0-90	0-8	1.10-1.60	4.23-705.00	0.04-0.22	0.0-1.0	0.1-1.8	.55	.55			
	42-46	5-95	0-90	0-8	1.10-1.60	4.23-705.00	0.04-0.22	0.0-1.0	0.1-1.8	.24	.24			
	46-65	5-95	0-90	0-8	1.10-1.60	4.23-705.00	0.04-0.22	0.0-1.0	0.1-1.8	.28	.28			
656:														
Udorthents	0-6	5-85	10-90	0-8	1.10-1.46	4.23-141.14	0.10-0.24	0.0-1.0	3.0-6.0	.37	.37	4	3	86
	6-23	5-95	0-90	0-8	1.10-1.60	4.23-705.00	0.04-0.22	0.0-1.0	0.1-2.0	.55	.55			
	23-42	5-95	0-90	0-8	1.10-1.60	4.23-705.00	0.04-0.22	0.0-1.0	0.1-1.8	.55	.55			
	42-46	5-95	0-90	0-8	1.10-1.60	4.23-705.00	0.04-0.22	0.0-1.0	0.1-1.8	.24	.24			
	46-65	5-95	0-90	0-8	1.10-1.60	4.23-705.00	0.04-0.22	0.0-1.0	0.1-1.8	.28	.28			
Urban land	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Selected Soil Interpretations

Cheshire County, New Hampshire

[The information in this table indicates the dominant soil condition but does not eliminate the need for onsite investigation. The table shows only the top five limitations for any given soil. The soil may have additional limitations]

*This soil interpretation was designed as a "limitation" as opposed to a "suitability". The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the potential limitation.

Map symbol and soil name	Pct. of map unit	FOR - Potential Erosion Hazard (Off-Road/Off-Trail) *		FOR - Potential Erosion Hazard (Road/Trail) *	
		Rating class and limiting features	Value	Rating class and limiting features	Value
10B:					
Merrimac	85	Slight		Moderate	
				Slope/erodibility	0.50
10C:					
Merrimac	85	Slight		Severe	
				Slope/erodibility	0.95
24A:					
Agawam	75	Slight		Slight	
24B:					
Agawam	70	Slight		Moderate	
				Slope/erodibility	0.50
24C:					
Agawam	75	Slight		Severe	
				Slope/erodibility	0.95
26A:					
Windsor	85	Slight		Slight	
26B:					
Windsor	85	Slight		Moderate	
				Slope/erodibility	0.50
26C:					
Windsor	85	Slight		Moderate	
				Slope/erodibility	0.50
26E:					
Windsor	85	Moderate		Severe	
		Slope/erodibility	0.50	Slope/erodibility	0.95
30A:					
Unadilla	75	Slight		Slight	
30B:					
Unadilla	80	Slight		Moderate	
				Slope/erodibility	0.50

Selected Soil Interpretations

Cheshire County, New Hampshire

Map symbol and soil name	Pct. of map unit	FOR - Potential Erosion Hazard (Off-Road/Off-Trail) *		FOR - Potential Erosion Hazard (Road/Trail) *	
		Rating class and limiting features	Value	Rating class and limiting features	Value
30C:					
Unadilla	70	Moderate		Severe	
		Slope/erodibility	0.50	Slope/erodibility	0.95
60C:					
Tunbridge	50	Slight		Moderate	
				Slope/erodibility	0.50
Berkshire	30	Slight		Moderate	
				Slope/erodibility	0.50
61C:					
Tunbridge	40	Slight		Moderate	
				Slope/erodibility	0.50
Lyman	25	Slight		Moderate	
				Slope/erodibility	0.50
Rock outcrop	20	Not rated		Not rated	
61D:					
Tunbridge	40	Moderate		Severe	
		Slope/erodibility	0.50	Slope/erodibility	0.95
Lyman	25	Moderate		Severe	
		Slope/erodibility	0.50	Slope/erodibility	0.95
Rock outcrop	20	Not rated		Not rated	
108:					
Hadley	90	Slight		Slight	
230E:					
Poocham	80	Very severe		Severe	
		Slope/erodibility	0.95	Slope/erodibility	0.95

Selected Soil Interpretations

Windham County, Vermont

[The information in this table indicates the dominant soil condition but does not eliminate the need for onsite investigation. The table shows only the top five limitations for any given soil. The soil may have additional limitations]

*This soil interpretation was designed as a "limitation" as opposed to a "suitability". The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the potential limitation.

Map symbol and soil name	Pct. of map unit	FOR - Potential Erosion Hazard (Off-Road/Off-Trail) *		FOR - Potential Erosion Hazard (Road/Trail) *	
		Rating class and limiting features	Value	Rating class and limiting features	Value
1A:					
Unadilla	85	Slight		Slight	
1B:					
Unadilla	85	Slight		Moderate	
				Slope/erodibility	0.50
1C:					
Unadilla	85	Moderate		Severe	
		Slope/erodibility	0.50	Slope/erodibility	0.95
1D:					
Unadilla	85	Moderate		Severe	
		Slope/erodibility	0.50	Slope/erodibility	0.95
1E:					
Udorthents	85	Not rated		Not rated	
5B:					
Windsor	85	Slight		Moderate	
				Slope/erodibility	0.50
5C:					
Windsor	85	Slight		Moderate	
				Slope/erodibility	0.50
5D:					
Windsor	85	Moderate		Severe	
		Slope/erodibility	0.50	Slope/erodibility	0.95
5E:					
Windsor	85	Severe		Severe	
		Slope/erodibility	0.75	Slope/erodibility	0.95
10A:					
Agawam	85	Slight		Slight	
20B:					
Tunbridge	50	Slight		Moderate	
				Slope/erodibility	0.50

Selected Soil Interpretations

Windham County, Vermont

Map symbol and soil name	Pct. of map unit	FOR - Potential Erosion Hazard (Off-Road/Off-Trail) *		FOR - Potential Erosion Hazard (Road/Trail) *	
		Rating class and limiting features	Value	Rating class and limiting features	Value
20B:					
Lyman	30	Slight		Moderate	
				Slope/erodibility	0.50
20C:					
Tunbridge	45	Slight		Moderate	
				Slope/erodibility	0.50
Lyman	30	Slight		Moderate	
				Slope/erodibility	0.50
20D:					
Tunbridge	50	Moderate		Severe	
		Slope/erodibility	0.50	Slope/erodibility	0.95
Lyman	35	Moderate		Severe	
		Slope/erodibility	0.50	Slope/erodibility	0.95
37:					
Hadley	85	Slight		Slight	

Selected Soil Interpretations

Franklin County, Massachusetts

[The information in this table indicates the dominant soil condition but does not eliminate the need for onsite investigation. The table shows only the top five limitations for any given soil. The soil may have additional limitations]

*This soil interpretation was designed as a "limitation" as opposed to a "suitability". The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the potential limitation.

Map symbol and soil name	Pct. of map unit	FOR - Potential Erosion Hazard (Road/Trail) *		FOR - Potential Erosion Hazard (Off-Road/Off-Trail) *	
		Rating class and limiting features	Value	Rating class and limiting features	Value
90A:					
Hadley, protected	80	Slight		Slight	
96A:					
Hadley, occasionally flooded	88	Slight		Slight	
109B:					
Chatfield, rocky	55	Moderate		Slight	
		Slope/erodibility	0.50		
Hollis, rocky	25	Moderate		Slight	
		Slope/erodibility	0.50		
109C:					
Chatfield, rocky	60	Severe		Slight	
		Slope/erodibility	0.95		
Hollis, rocky	20	Severe		Slight	
		Slope/erodibility	0.95		
109D:					
Chatfield, rocky	60	Severe		Moderate	
		Slope/erodibility	0.95	Slope/erodibility	0.50
Hollis, rocky	34	Severe		Moderate	
		Slope/erodibility	0.95	Slope/erodibility	0.50
109F:					
Chatfield, rocky	47	Severe		Severe	
		Slope/erodibility	0.95	Slope/erodibility	0.75
Hollis, rocky	41	Severe		Severe	
		Slope/erodibility	0.95	Slope/erodibility	0.75
125B:					
Charlton, rocky	50	Moderate		Slight	
		Slope/erodibility	0.50		
Chatfield, rocky	28	Moderate		Slight	
		Slope/erodibility	0.50		

Selected Soil Interpretations

Franklin County, Massachusetts

Map symbol and soil name	Pct. of map unit	FOR - Potential Erosion Hazard (Road/Trail) *		FOR - Potential Erosion Hazard (Off-Road/Off-Trail) *	
		Rating class and limiting features	Value	Rating class and limiting features	Value
125B:					
Hollis, rocky	15	Moderate		Slight	
		Slope/erodibility	0.50		
125C:					
Charlton, rocky	45	Severe		Slight	
		Slope/erodibility	0.95		
Chatfield, rocky	37	Severe		Slight	
		Slope/erodibility	0.95		
Hollis, rocky	11	Severe		Slight	
		Slope/erodibility	0.95		
125D:					
Charlton, rocky	45	Severe		Moderate	
		Slope/erodibility	0.95	Slope/erodibility	0.50
Chatfield, rocky	35	Severe		Moderate	
		Slope/erodibility	0.95	Slope/erodibility	0.50
Hollis, rocky	11	Severe		Moderate	
		Slope/erodibility	0.95	Slope/erodibility	0.50
131B:					
Yalesville, rocky	50	Moderate		Slight	
		Slope/erodibility	0.50		
Holyoke, rocky	30	Moderate		Slight	
		Slope/erodibility	0.50		
131C:					
Yalesville, rocky	55	Severe		Moderate	
		Slope/erodibility	0.95	Slope/erodibility	0.50
Holyoke, rocky	35	Severe		Moderate	
		Slope/erodibility	0.95	Slope/erodibility	0.50
131D:					
Yalesville, rocky	65	Severe		Moderate	
		Slope/erodibility	0.95	Slope/erodibility	0.50
Holyoke, rocky	25	Severe		Moderate	
		Slope/erodibility	0.95	Slope/erodibility	0.50

Selected Soil Interpretations

Franklin County, Massachusetts

Map symbol and soil name	Pct. of map unit	FOR - Potential Erosion Hazard (Road/Trail) *		FOR - Potential Erosion Hazard (Off-Road/Off-Trail) *	
		Rating class and limiting features	Value	Rating class and limiting features	Value
131F:					
Yalesville, rocky	60	Severe		Severe	
		Slope/erodibility	0.95	Slope/erodibility	0.75
Holyoke, rocky	25	Severe		Severe	
		Slope/erodibility	0.95	Slope/erodibility	0.75
229F:					
Windsor	60	Severe		Severe	
		Slope/erodibility	0.95	Slope/erodibility	0.75
Merrimac	20	Severe		Moderate	
		Slope/erodibility	0.95	Slope/erodibility	0.50
230A:					
Unadilla	88	Slight		Slight	
230B:					
Unadilla	90	Moderate		Slight	
		Slope/erodibility	0.50		
235F:					
Poocham	89	Severe		Very severe	
		Slope/erodibility	0.95	Slope/erodibility	0.95
Agawam	2	Severe		Very severe	
		Slope/erodibility	0.95	Slope/erodibility	0.95
254A:					
Merrimac	73	Slight		Slight	
254B:					
Merrimac	80	Moderate		Slight	
		Slope/erodibility	0.50		
254C:					
Merrimac	75	Severe		Slight	
		Slope/erodibility	0.95		
254D:					
Merrimac	75	Severe		Moderate	
		Slope/erodibility	0.95	Slope/erodibility	0.50
255A:					
Windsor	81	Slight		Slight	

Map symbol and soil name	Pct. of map unit	FOR - Potential Erosion Hazard (Road/Trail) *		FOR - Potential Erosion Hazard (Off-Road/Off-Trail) *	
		Rating class and limiting features	Value	Rating class and limiting features	Value
255B:					
Windsor	86	Moderate		Slight	
		Slope/erodibility	0.50		
255C:					
Windsor	90	Moderate		Slight	
		Slope/erodibility	0.50		
255D:					
Windsor	90	Severe		Moderate	
		Slope/erodibility	0.95	Slope/erodibility	0.50
275A:					
Agawam	85	Slight		Slight	
275B:					
Agawam	75	Moderate		Slight	
		Slope/erodibility	0.50		
275C:					
Agawam	82	Severe		Moderate	
		Slope/erodibility	0.95	Slope/erodibility	0.50
275D:					
Agawam	90	Severe		Moderate	
		Slope/erodibility	0.95	Slope/erodibility	0.50
618F:					
Udorthents, frequently flooded	95	Severe		Very severe	
		Slope/erodibility	0.95	Slope/erodibility	0.95
651:					
Udorthents, smoothed	80	Slight		Slight	
656:					
Udorthents	50	Slight		Slight	
Urban land	45	Not rated		Not rated	

Appendix D – 2013 Full River Reconnaissance Study and Quality Assurance Project Plan

Quality Assurance Project Plan (QAPP)

2013 Full River Reconnaissance
Turners Falls Impoundment of the Connecticut River

Prepared by:
Simons & Associates
New England Environmental, Inc.

Prepared for:
FirstLight Power Resources Services, LLC
c/o FirstLight Hydro Generating Company
99 Millers Falls Road
Northfield, MA 01360

April 15, 2013

2013 Full River Reconnaissance
Turners Falls Impoundment of the Connecticut River

Approved by:

Signature:____________________________________ Date:_______________
John Howard
FirstLight Power Resources Services, LLC
FERC Hydro Compliance/ Project Director

Signature:____________________________________ Date:_______________
Charles Momnie
FirstLight Power Resources Services, LLC
Project QA\QC Engineer

Signature:____________________________________ Date:_______________
Dr. Robert Simons
Simons & Associates
Project Director, Fluvial Geomorphologist

Signature:____________________________________ Date:_______________
Michael Marcus
New England Environmental, Inc.
Project Manager

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FIGURES

TABLES

APPENDICES

1.0 Distribution List

This QAPP and any subsequent revisions will be distributed to those personnel listed in Table 1 who would be directly involved with project management, quality assurance and implementation of the 2013 Full River Reconnaissance (FRR).

Table 1: QAPP Distribution List

QAPP Recipient Name	Project Role	Organization	Telephone Number and Email Address
John Howard	Director, FERC Hydro Compliance, Project Director for FirstLight	FirstLight Power Resources Services, LLC	413-659-4489 John.howard@gdfsuezna.com
Charles Momnie	Senior Engineer, Project Coordinator /Project Review for FirstLight	FirstLight Power Resources Services, LLC	413-659-4472 Charles.momnie@gdfsuezna.com
Robert Simons	Project Director/Fluvial Geomorphologist	Simons & Associates	970-988-2880 rksimons@rksimons.com
Michael Marcus	Senior Scientist/Project Manager	New England Environmental, Inc.	413-658-2050 mmarcus@neeinc.com
Gregg Simons	Hydraulic Engineer, data collection, ArcGIS map preparation and analysis	Simons & Associates	970-988-2880 greggrsimons@gmail.com
Christin McDonough	Staff Scientist, data collection, preparation of ArcGIS maps, documentation	New England Environmental, Inc.	413-658-2063 cmcdonough@neeinc.com
Sean Werle	Staff Scientist, equipment maintenance	New England Environmental, Inc.	413-658-2051 swerle@neeinc.com

2.0 Project Organization

The individuals and their roles in completing tasks associated with the 2013 FRR are presented in Figure 1 and Table 2. These qualified professionals have completed similar projects on the Connecticut River, as well as throughout the United States. They are qualified in the fields of river reconnaissance, fluvial geomorphology, river hydraulics and\or river assessments and will be supported by trained field assistants.

Figure 1: Project Organizational Chart

QAPP for Connecticut River Reconnaissance Survey

Project Organization

The following project organizational chart lists the roles and lines of communication among those individuals or organizations involved in this project.

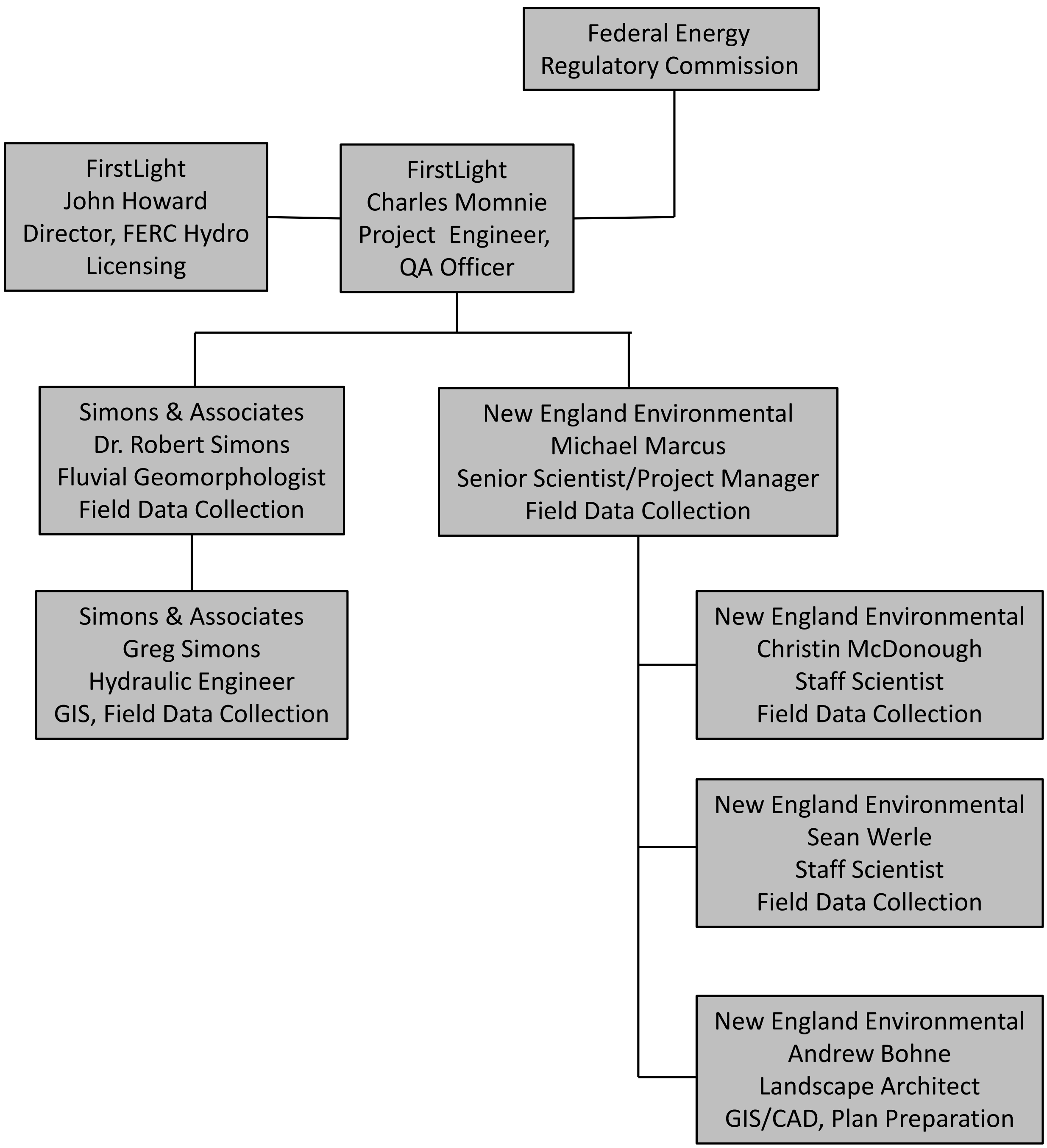

Table 2: Names, Organizations and Responsibilities Associated with 2013 FRR

Name	Organization	Responsibility
John Howard	FirstLight	QAPP Review, draft and final document review
Charles Momnie	FirstLight, Project Engineer /Quality Assurance Officer	QAPP Review, draft and final document review Responsible for overall project management and completion
<u>Project Director</u>		
Dr. Robert Simons	Simons & Associates (S&A)	Responsible for overall project design and completion. Data collection, data management and analysis, documentation of results and report
<u>Project Manager</u>		
Michael J. Marcus	New England Environmental (NEE)	Supervision of scientific staff, supervision of data collection, staff training, data management
<u>Field Assistant/Hydraulic Engineer</u>		
Gregg Simons	S&A	Field work, data logging, ArcGIS mapping and analysis
<u>Field Assistant/Staff Scientist</u>		
Christin McDonough	NEE.	Field work, data entry develop ArcGIS maps
<u>Field Assistant/Staff Scientist</u>		
Sean Werle	NEE.	Boat Operator, maintenance of instruments
Andrew Bohn	NEE.	Landscape Architect/Planner

This Quality Assurance Project Plan (QAPP) was prepared by Simons & Associates (S&A) and New England Environmental, Inc. (NEE) for FirstLight Power Resources Services, LLC c/o FirstLight Hydro Generating Company (FirstLight) for completing the 2013 FRR. As described later, FirstLight is required by the Federal Energy Regulatory Commission (FERC) to conduct FRRs every 3-5 years in accordance with the Northfield Mountain Project's Erosion Control Plan and to satisfy compliance requirements associated with the Turners Falls Project (FERC No. 1889) and Northfield Mountain Project (FERC No. 2485) licenses.

3.0 Problem Definitions/Background

FirstLight owns and operates the Northfield Mountain Pumped Storage Project (Northfield Mountain Project), a 1,119 -MW pumped storage hydroelectric project constructed in 1972 along the Connecticut River near Northfield, MA. The Northfield Mountain Project consists of an upper reservoir, an underground pressure shaft and four unit penstocks, an underground powerhouse, four reversible pump-turbine generators, and a mile-long tailrace tunnel connecting the powerhouse to a 20-mile-long reach of the Connecticut River known as the Turners Falls Impoundment, which functions as a lower reservoir. The manmade upper reservoir was formed with four earth-core rock fill embankment structures and a concrete gravity dam.

FirstLight also owns and operates the Turners Falls Project, a 67.709 MW hydroelectric project located in Montague MA, in the village of Turners Falls. The Turners Falls Dam forms the Turners Falls Impoundment, shown in Figure 2.

The Turners Falls Project and Northfield Mountain Project are licensed by the FERC. In compliance with relevant articles of the FERC licenses for both projects, a reconnaissance survey of the Turners Falls Impoundment was conducted in 1998 to map riverbank characteristics and to prioritize erosion sites to be considered for stabilization. As a result of this work, an "*Erosion Control Plan for the Turners Falls Pool of the Connecticut River*," (S&A, 1998) – commonly referred to as the Erosion Control Plan (ECP) was developed. The ECP provides for FirstLight to conduct FRR studies to document existing riverbank conditions within the Turners Falls Impoundment every 3 to 5 years. Since the development of the initial ECP, which included an FRR, four FRRs (1998, 2001, 2004, and 2008) have been conducted to date. The next FRR is scheduled for 2013, and the purpose of this document is to provide a QAPP for the 2013 FRR.

Although not germane to this QAPP, the FERC licenses for both projects expire on April 30, 2018. FirstLight has initiated the process of relicensing the Turners Falls and Northfield Mountain Projects, using FERC's Integrated Licensing Process (ILP), with the filing of their Pre-Application Document (PAD) and Notice of Intent (NOI) with FERC on October 31, 2012. FERC has requested that although the 2013 FRR is being conducted to comply with the ECP developed in 1998 for the Turners and Northfield Mountain Projects, it be included as part of the relicensing process. More specifically, FERC noted that potential field data collection needs arising from study requests relative to the relicensing process could be included in the 2013 FRR. Further details relative to the FERC relicensing schedule is provided later in this document.

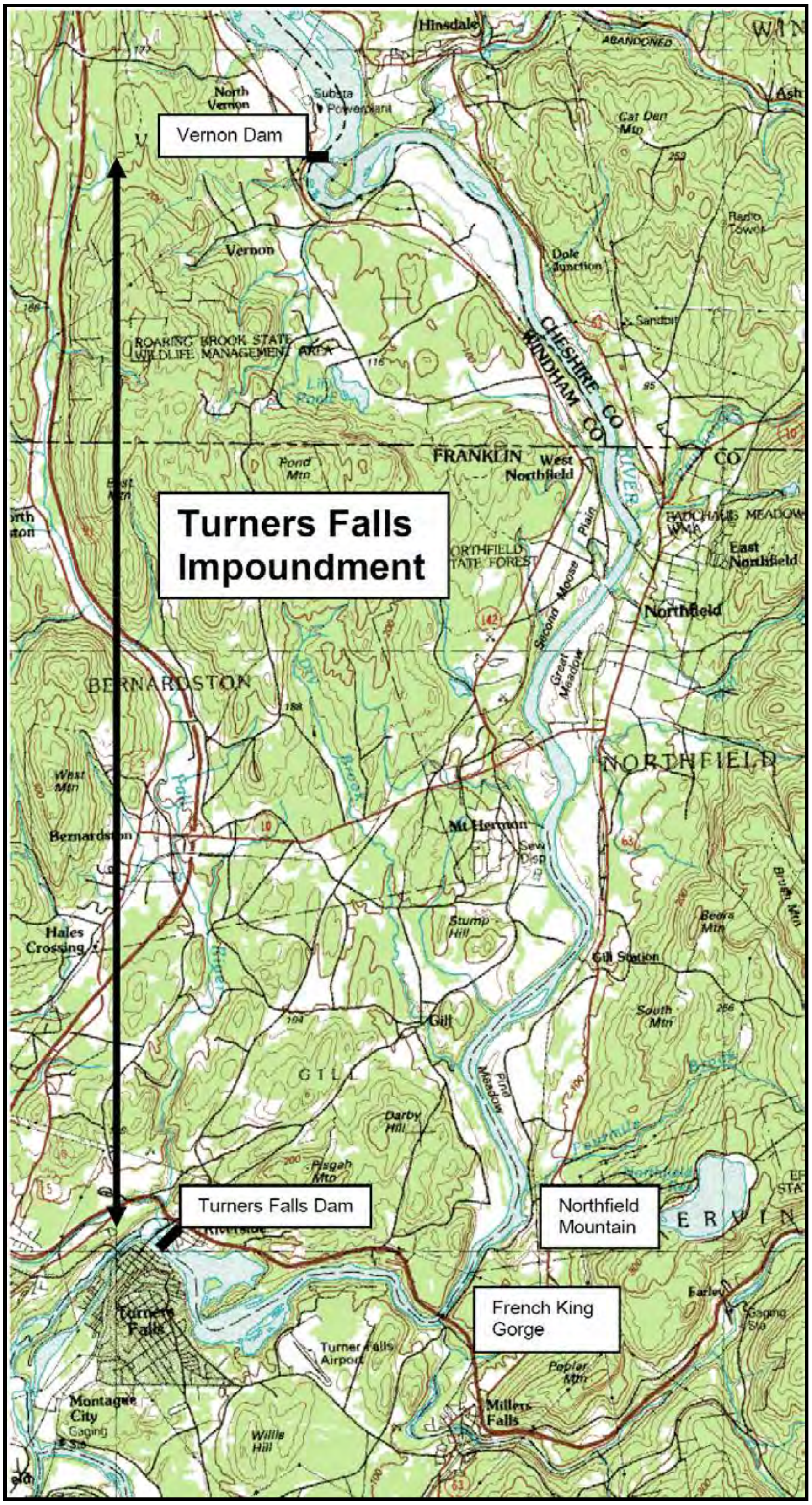

Figure 2: Turners Falls Impoundment

3.1 Existing Rationale

Riverbank erosion is caused by several natural factors such as floods and spring freshets and their associated high water velocity, wind waves, seepage forces, ice, and freeze-thaw. Erosion is also caused by human influences such as dams, bridges and other structures within the river, land-use, poor farming practices, boating and recreation, and other disturbances to the natural river conditions including hydropower operations. Water level fluctuations occur in the Turners Falls Impoundment naturally but also due to hydropower operations, which include releases emanating from the Vernon Hydroelectric Project, Turners Falls Project and the Northfield Mountain Project.

Erosion can impact water quality, causes loss of habitat, loss of private property, and potentially affect historical features along the river bank. Documentation of erosion is being assessed in the 2013 FRR. The extent and severity of erosion will be evaluated through mapping and classification of riverbank erosion as described later.

3.2 Statement of Purpose and Objectives

The objective of the 2013 FRR is to utilize a classification of riverbank conditions that prioritizes bank erosion sites and allows for the collection of scientifically sound data that may be used for planning and analysis purposes, as well as to determine locations of potential future restoration work. The 2013 FRR will document existing riverbank features and characterize and analyze changes in the condition of the riverbank and trends. To achieve this objective, this QAPP has been prepared for the 2013 FRR. The process involves the integration of two key aspects of the mechanics of producing a FRR:

- Observe/document riverbank features and characteristics using a technical approach to spatially represent transition points or end points where riverbank features and characteristics change from one category to another using a definable and repeatable methodology;
- Develop maps and analyze the data to develop an understanding of the riverbank condition, and riverbank stability over time. The information may be used to identify potential sites for stabilization and those sites contributing sedimentation to the river.

The classification system will provide a set of conditions that can be assessed and verified in relation to a reference condition. The classification system will also be used to document changes over time. Prioritization of eroded sites will be conducted so that any restoration plans may be developed, if appropriate.

Study Objectives include:

- Develop a QAPP for the FRR;
- Document existing riverbank features and characteristics;
- Accurately map and scientifically describe all portions of the Turners Falls Impoundment where active or recent bank erosion is occurring;
- Spatially define, using GPS, the transition points or end points where riverbank characteristics or features change from one classification to another;
- Map land use practices adjacent to the river (note that land use maps along the riverbanks are being developed as part of the FERC relicensing process). Describe areas that are directly observed and linked to bank erosion;
- Develop classification techniques of observations into a definable and repeatable methodology;
- Develop distribution and summary statistics of conditions in 2013; assess changes in riverbank conditions in context of the ECP since implementation. Analyze any change in condition of the riverbank since the 2008 FRR, and;
- Develop a final report, including maps delineating features identified in the field that will document and summarize the findings of the 2013 FRR.

4.0 Project Description, Study Methods and Schedule

Project Description

Classification of riverbanks along the Turners Falls Impoundment will be conducted by identifying the key features and characteristics of riverbanks playing a significant role in their stability or their potential for erosion. Key factors to be evaluated include bank material, bank geometry, vegetation, and erosion/bank stability characteristics.

As a result of previous FRRs on the Turners Falls Impoundment, riverbank characteristics of importance, as well as experience on other river systems, have been refined and a matrix of these riverbank characteristics developed for the Connecticut River. These characteristics are discussed later in this document.

Ground-based field work for the 2013 FRR is proposed for the summer and fall of 2013, with the majority of mapping occurring in November, 2013, when leaf-off conditions allow optimum viewing conditions of riverbanks. Mapping work will be conducted in three phases as follows:

1. Video-recording the riverbanks with a system linked to a GPS system resulting in a geo-referenced digital video of the entire Turners Falls Impoundment.

2. Data-logging riverbank features and characteristics at points along Turners Falls Impoundment and surveying the locations where significant changes in features and characteristics occurred by laser-rangefinder and GPS technology.

3. Land-based observation and documentation of erosion features utilizing data-logging, GPS, and video or still photography.

Study Methods

The study will focus on the riverbanks along the Turners Falls Impoundment. The following methods will be used to document existing riverbank features and characteristics and to analyze any change in riverbank conditions since the 2008 FRR. Study methods will include:

- Document existing riverbank features and characteristics;
- Spatially define riverbank feature transition points;
- Map and develop distribution of riverbank features and characteristics including summary statistics and evaluation of conditions in 2013 in context with historical changes since implementation of the ECP, and analyze changes in conditions from previous FRRs;
- Develop a final report and mapping.

Schedule

Table 3 includes the project schedule. Given that FERC has requested this FRR be folded into the FERC relicensing process, review and approval of this document is subject to the timelines dictated by the ILP. The milestones highlighted in green are dictated by the ILP (the FERC regulation is cited in the table). As part of the relicensing process, stakeholders submitted study requests by March 1, 2013. FirstLight is required to address the study requests in the form of a Proposed Study Plan (PSP), which must be filed with FERC by April 15, 2013. Many stakeholders submitted study requests pertaining to erosion issues in the Turners Falls Impoundment that were incorporated into the 2013 FRR and this QAPP. Given this, FirstLight has developed a separate study plan for the FRR (see FirstLight PSP, study entitled "2013 Full River Reconnaissance Study") that is written to meet the specific FERC study criteria. This QAPP will be incorporated into FirstLight's PSP as an Appendix to the aforementioned study plan and thus will be subject to review and comment from stakeholders based on the schedule below.

Table 3: Project Schedule/Timeline

Milestone	Schedule
Conduct full river boat tour and discussion with CRSEC and FERC Staff	November 9, 2012
Develop technical approach for field data collection (river based and ground based observation, survey, data collection)	November 2012
Develop Quality Assurance Project Plan; distribute to CRSEC	
Meet with CRSEC to discuss proposed technical approach and QAPP	December 5, 2012
Draft Review of QAPP by Ct. River Streambank Erosion Committee and landowners	February 4, 2013
QAPP Preparation	March 2013
Stakeholders submit study requests (§5.9)	March 1, 2013
FirstLight files its PSP, which includes the FRR and QAPP (§5.11a)	April 15, 2013
Stakeholder Meetings to Discuss PSP (§5.11e)- specifically geology and soils	May 14-15, 2013
Stakeholders file written comments on PSP (§5.12)	July 14, 2013
FirstLight files its Revised Study Plan (RSP) (§5.13a)	August 13, 2013
Stakeholders file comments on RSP, if necessary (§5.13b)	August 28, 2013
FERC Issues their Study Plan Determination Letter (§5.13b)	September 12, 2013
[1]Notice of Formal Study Dispute (if necessary) (§5.14a)	October 2, 2013
Study Dispute Determination (§5.14 (1))	December 2, 2013
Conduct FRR Mapping Survey	November 2013
File FRR Report with FERC	April 2014

5.0 Project Quality Control and Measurements of Performance Criteria

Quality control will be provided by a comparing the data logging files of riverbank features and characteristics to the digital video showing the riverbank feature and characteristics at the time of the FRR. An appendix to the FRR report will include a comparison of the specific riverbank features and characteristics from the data logging files conducted during the field survey to a photograph of that same segment of riverbank captured from the digital geo-referenced video file for each representative bank segment. A discussion will be presented in the FRR report based on this comparison. Since the entire riverbank of the Turners Falls Impoundment will be surveyed and digitally videoed, if a question arises concerning the classification of any segment; information in the data logging file can be compared to an image or video of any such segment. The process of comparing the data logging file of riverbank features and characteristics to video/still images of a selected percentage of segments or any segment of particular interest provides a high level of quality assurance and control on the field data collection and subsequent interpretation of the field survey data since there is a complete record of the condition of the riverbanks at the time of the FRR.

6.0 Professional Qualifications and Training Requirements

The field crew conducting the 2013 FRR includes Dr. Robert Simons of S&A, Michael Marcus of NEE, two senior staff scientists from NEE and one from S&A. Dr. Simons has extensive expertise in river mechanics, fluvial geomorphology, riverine habitat, riparian vegetation modeling, erosion and

[1] Note that only agencies with mandatory conditioning authority can file for dispute resolution.

sedimentation, sediment transport and hydrology. He has conducted work on numerous projects involving riverbank erosion and bank stabilization throughout the United States and internationally. Mr. Marcus is the principal and senior scientist for NEE. He is an expert in the ecological restoration of rivers. He has professional training in River Restoration design, natural river mechanisms, river engineering, morphology and management, natural channel design and river restoration, river morphology and applied fluvial geomorphology. He has overseen the design and construction of river restoration projects within the Turners Falls Impoundment since 1998. Both he and Dr. Simons have completed similar FRR efforts along the Turners Falls Impoundment in 1998, 2001, 2004 and 2008 and Dr. Simons has conducted river reconnaissance and riverbank mapping efforts on other river systems. Dr. Simons will personally conduct the classification of riverbank features and characteristics in the field based on the matrix outlined later in consultation with Mr. Marcus and/or field assistants.

Geo-referenced video will be taken of the riverbanks as part of the FRR field work. This work will be conducted by Dr. Simons and a field assistant. This is the standard type of field documentation they have conducted on the Connecticut River, including the Turners Falls Impoundment twice as well as other segments of the Connecticut River both upstream and downstream of the Turners Falls Impoundment and other river systems.

The land-based observation and documentation of erosion features will be conducted by a combination of Dr. Simons, Mr. Marcus, and field assistants. Features of interest will be characterized and developed into a set of observation criteria and made familiar to those participating in the field work.

Simons and Marcus will be responsible for training field scientists. The field scientists have completed similar work related to river morphology and will be re-familiarized with the elements of survey data collection, data entry and QA/QC. As this field crew has worked together on previous projects, they are familiar with the project materials and survey requirements and have developed a level of competence with the methods that will be implemented in the field.

7.0 Documentation and Digital Records

Michael Marcus will be responsible for ensuring project staff review the QAPP, understand the data forms, and are fully trained in operating project equipment. All field data will be obtained in digital form as recorded on the data-logger and digital video/still photography. This information will be stored on various computer systems and servers at S&A and NEE offices.

To ensure that digital data files are secure, data logging files will be downloaded onto two computers at the end of each field day. At the end of the field data collection process, all digital files will be stored on computers/servers at S&A and NEE. Digital files of data logging and the geo-referenced video files will also be provided to FirstLight.

Field mapping equipment includes a sub-meter Global Positioning System (GPS), data-logger, and laser range-finder. Equipment maintenance schedule records will be maintained by Michael Marcus at NEE in Amherst, MA. Copies of all maintenance records will be maintained by Dr. Simons at his office.

8.0 Survey Methods

Survey methods for the FRR include three independent techniques including:

- Boat-based classification of riverbank features and characteristics using GPS, data-logger, and laser-rangefinder;
- Boat-based geo-referenced digital video, and
- Land-based observation of localized erosion using GPS and data-logger.

Details of these survey methods are presented below.

8.1 Boat-based classification of riverbank features and characteristics

8.1.1 Spatial delineation of segment endpoints

To produce results that spatially represent the endpoints where riverbank features and characteristics change from one category to another, the 2013 FRR will determine the location of these transition points in a standard coordinate system (such as latitude and longitude or UTM coordinates). FirstLight will utilize standard field equipment including three field instruments: 1) a sub-meter GPS; 2) a data-logger; and 3) a laser range-finder as shown in Figure 3.

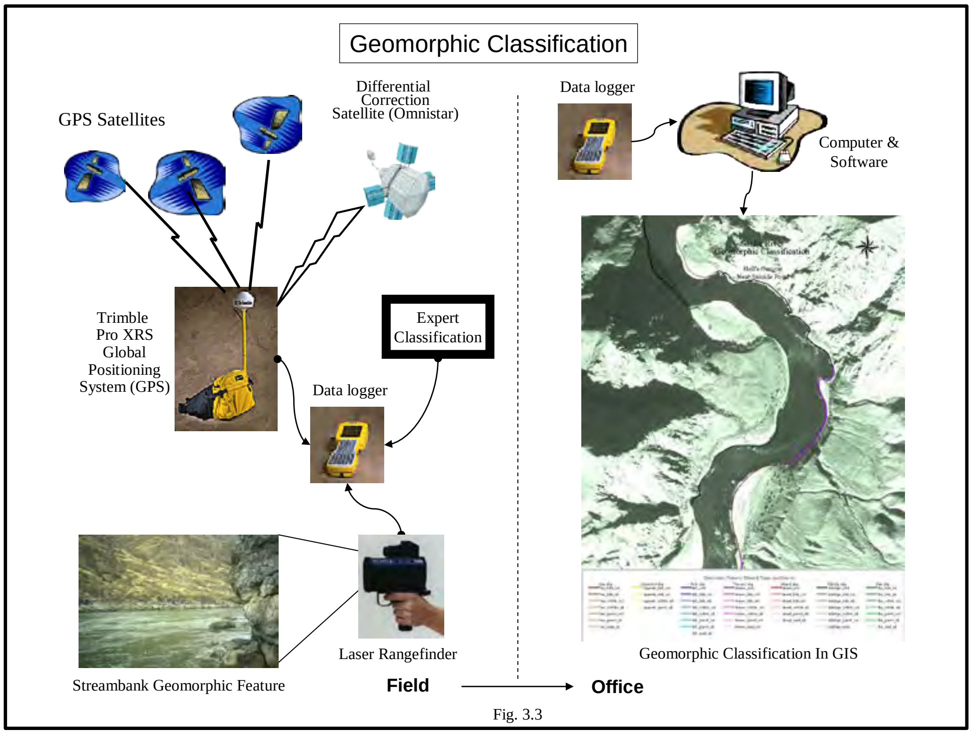

Figure 3: Riverbank Classification Equipment and Process Schematic

The individual conducting the classification will select a point of transition from one category of riverbank to another and "shoot" this point with the laser range-finder. The features and characteristics of the next riverbank segment will be classified and verbally transmitted from the individual conducting the expert classification to the individual operating the data logger who then records the observational data while the position information (location of the GPS antenna and distance and azimuth from the laser rangefinder to the selected point on the riverbank) is automatically recorded when the trigger is pulled on the laser rangefinder. The data logger acknowledges that the positional data has been recorded and the individual operating the data logger can ensure that the observations corresponding to that point have been entered.

Several brands and models of equipment exist to conduct the riverbank classification. Example equipment is provided in Appendix A for the sub-meter GPS and Appendix B for the laser range-finder. The equipment and models selected for the 2013 FRR work will meet accuracy criteria as exemplified by the equipment discussed below.

The accuracy of a sub-meter GPS is assumed to be less than one meter; however, the accuracy of any GPS in the field depends on the availability of a sufficient number of satellites and the correction that is applied that ultimately defines the actual accuracy when locating a point on the ground. Prior to initiation of GPS mapping, the location/time of day of the satellites will be determined for optimal GPS readings. The GPS determines the location of the boat from where the observation of the riverbank features and characteristics is made, and the offset and azimuth to the riverbank is made using the laser rangefinder.

The position of the riverbank point will be shot from the boat using a laser rangefinder. The accuracy of a mapping grade laser rangefinder is +/- 1 foot for distance and +/- 1 degree for azimuth. Assuming the length of the shots from the laser rangefinder is 100 feet, an accuracy of one degree translates into about +/- 1.7 feet distance when projected along the length of the bank (100 times sine of 1 degree).

The combination of the accuracy of the sub-meter GPS and the laser rangefinder would then be approximately +/-6 feet, with an estimated accuracy of within 10 feet for 90% of the measurements made.

Prior to initiation of the FRR mapping, a field test will be conducted by locating a known fixed point on the bank from a slow moving boat using the GPS/laser rangefinder system to determine the accuracy of determining the location of a fixed point. The point will be surveyed multiple times and the difference in location will be determined. This will determine the actual accuracy of locating points in the field.

The approach of using sub-meter GPS with laser rangefinder is an accurate technique to map bank erosion in long river reaches. There can be legitimate discussion and debate as to the specific transition point between one riverbank segment and another; which may be greater than the accuracy of the technology. There is no justification for using more accurate position determining technology than the accuracy of actually defining the "specific" location of the transition between one classification and another. For example, identification of specifically where an upper riverbank changes from heavily vegetated to moderately vegetated could be defined by one to be several feet differently than another; whereas the difference in technology by going from a land-based sub-meter GPS to a boat-based sub-meter GPS with laser rangefinder to determine actual position on the riverbank by azimuth and distance from the boat-based GPS is within the potential interpretation range of selecting the "point" of transition between heavily and moderately vegetated.

The level of discretization of riverbank segments depends on the frequency of transitions between the various features and characteristics observed in the field. There is no set distance of segmentation along the river. Previous FRRs have resulted in a range of segment lengths from 20 to over 4000 feet, with average segment lengths from 480 to 1267 feet. The 2008 FRR resulted in the smallest average segment length and greatest degree of discretization of the various FRRs compared ("*Response to Field Geology Services' 2011 'Detailed Analysis of the 2008 Full River Reconnaissance of the Turners Falls Pool on the Connecticut River," July, 2012*). The 2013 FRR will result in a range of segment lengths and degree of discretization consistent with the frequency of transitions of features and characteristics found in the Turners Falls Impoundment and will likely result in similar level of discretization as the 2008 FRR. Segments as short as 20 feet will be documented based on the observation of features and characteristics. The speed at which the survey will be conducted is dictated by the efficiency of the observer/data logging team and is constantly varied to match field conditions, including reversing the boat and passing by riverbank features again.

8.1.2 Direct Observations of Features and Characteristics

The system of classification follows a pre-determined matrix of features and characteristics. The matrix of features and characteristics utilized in 2008 was based on experience from previous FRR efforts and discussion with the Connecticut River Streambank Erosion Committee (CRSEC). The matrix consists of 9 riverbank features that include such items as riverbank geometry (upper and lower riverbank slope and upper riverbank height), riverbank materials (upper and lower riverbank sediment), vegetation (upper and lower riverbank degree of vegetation), and erosion (mass wasting and erosion type. The same matrix of riverbank features and characteristics is proposed for the boat-based portion of the 2013 FRR providing a consistent basis for comparison with the 2008 FRR (see Table 4). The boat-based component of field work follows the riverbank features and characteristics as outlined in the 2008 FRR.

A riverbank consists of a combination of features with a range of characteristics that either work together in resisting erosive forces, or together suffer various degrees of failure or susceptibility to erosion. Riverbanks in the Turners Falls Impoundment generally consist of an upper bank that is often above water except during high flow conditions, and a lower bank that is frequently submerged. These banks consist of a range of materials from silt or sand to solid rock. The banks support a range of vegetation conditions and a range of heights. The riverbanks experience a range of conditions of stability or erosion. This combination of features and associated range of characteristics or attributes are described in the following matrix (see Table 5). This matrix represents one of several approaches in understanding and evaluating the data and was developed based on input received at the meeting with the CRSEC in 2008 and experience from previous reconnaissance efforts.

Table 4: Connecticut River – Turners Falls Impoundment Riverbank Characteristics Matrix, Boat-based field data logging worksheet

Upper Riverbank Slope	Overhanging	Vertical	Steep (>2:1)	Moderate (4-2:1)	Flat (<4:1)	
Lower Riverbank Slope	Vertical	Steep (>2:1)	Moderate (4-2:1)	Flat (<4:1)		
Upper Riverbank Sediment	Silt/Sand	Gravel	Cobbles	Boulders	Rock	Clay
Lower Riverbank Sediment	Silt/Sand	Gravel	Cobbles	Boulders	Rock	Clay
Upper Riverbank Height	Low (<8 ft)	Medium (8-12 ft)	High (>12 ft)			
Degree Upper Riverbank Vegetation	Heavily Vegetated	Moderately Vegetated	Sparsely Vegetated	None to Very Sparse		
Mass Wasting	Little/None	Some	Extensive			
Erosion Type	None	Overhanging Bank	Undercut Toe	Notching	Slide	
Lower Riverbank Vegetation	None	Heavy	Moderate	Sparse		

Table 5: Riverbank Characterization Groups

Group	Mass Wasting	Erosion Type	Degree Upper Riverbank Vegetation	Upper Riverbank Slope	Upper Riverbank Sediment	Lower Riverbank Slope	Lower Riverbank Sediment	Upper Riverbank Height	Lower Riverbank Vegetation
1	Extensive	Overhanding to Slide	None to Heavy	Flat to Overhanging	non-Rock	Flat to Vertical	Silt/Sand to Rock	Low to High	None to Heavy
2	Some	Overhanding to Slide	None to Heavy	Flat to Overhanging	non-Rock	Flat to Vertical	Silt/Sand to Rock	Low to High	None to Heavy
3	Little/None	None	None to Sparse	Flat to Overhanging	non-Rock	Flat to Vertical	Silt/Sand to Rock	Low to High	None to Heavy
4	Little/None	None	Moderate to Heavy	Steep to Overhanging	non-Rock	Flat to Vertical	Silt/Sand to Rock	Low to High	None to Heavy
5	Little/None	None	Moderate to Heavy	Moderate	non-Rock	Moderate to Vertical	Silt/Sand to Rock	Low to High	None to Heavy
6	Little/None	None	Moderate to Heavy	Moderate	non-Rock	Flat	Silt/Sand to Rock	Low to High	None to Heavy
7	Little/None	None	Moderate to Heavy	Flat	non-Rock	Flat to Vertical	Silt/Sand to Rock	Low to High	None to Heavy
8	Little/None	None	None to Heavy	Flat to Overhanging	Rock	Flat to Vertical	Silt/Sand to Rock	Low to High	None to Heavy

The FRR report will include maps for each of the 9 riverbank features in the matrix (Table 4, vertical left-hand column) with each segment categorized as shown in the other columns (2-7). For example, in the case of upper riverbank sediment, maps will be developed showing all segments surveyed covering the length of the Turners Falls Impoundment and the particular type of upper riverbank sediment associated with each segment. A statistical summary of each riverbank feature and the extent of each characteristic within each feature will be provided. These data will allow for the evaluation of individual features (e.g.

mass wasting), or for the entire spectrum of features and characteristics. The grouping approach consolidates riverbank segments into key associations that can provide insight into which features and characteristics are associated with stability and which are associated with erosion. Statistical distributions of characteristics within each group can aid in further understanding erosion and stability issues such as which combination of features and characteristics trend towards stability, and which trend towards erosion. Such information and understanding can aid in the planning process in developing appropriate approaches in addressing erosion issues.

A key aspect of the FRR is how the range of riverbank features and characteristics are classified in the field. To understand and demonstrate the classification process, photographs were taken in November 2012 during leaf-off conditions, representing similar conditions for the 2013 FRR. Appendix C contains photographs covering the features and range of characteristics from Table 4. The photographs also include some photographs from previous years to ensure complete coverage of the matrix. To put the range of riverbank characteristics into proper historic perspective regarding erosion, it is appropriate to include photographs covering the period from the 1998 ECP. Exclusion of the full range of conditions and changes that have occurred since implementation of the ECP would distort the perspective necessary to fully understand the Turners Falls Impoundment.

These photographs provide a guide as to how riverbank features and characteristics will be classified. When a riverbank is observed to have certain features and characteristics as shown in the photographs, this is how the particular segment of riverbank will be classified and entered into the data logger. As discussed earlier, geo-referenced digital video provides a means of verifying the observed features and characteristics of any riverbank segment in comparison to the observations entered in the data-logger; this approach may be utilized to evaluate the classification of any segment of interest.

8.1.3 Geo-Referenced Video

As a means of data control and reference checking, a geo-referenced video will be taken of the riverbanks of the entire Turners Falls Impoundment. This technique captures digital video images as well as the location so both a video image and location is recorded all along the riverbanks. This provides a method to verify what the riverbanks looked like during the 2013 FRR along with the locations of the video scenes along the length of the Turners Falls Impoundment. If questions arise as to how a riverbank segment was classified, the videotape can be checked to evaluate the specific features and characteristics. Video of the riverbank will be taken either before or after the riverbank classification from a boat at approximately 50 to 150 feet from the bank line.

The geo-referenced videotaping will be conducted using the Red Hen Systems equipment (which was utilized in 1998, 2001, 2004 and 2008). Red Hen Systems provide hardware and software to collect geo-referenced video and photo data in the field, and brings that data into desktops and Web-based maps for analysis and decision making processes. Red Hen Systems includes three components, the VMS-HDII (which includes the VMS-333 geo-referencing equipment and the nanoFlash video recorder from Convergent) and MediaMapper Software. Appendix D provides detailed information on this system from the Red Hen Systems website (www.redhensystems.com).

8.2 Land-Based Observations

Land-based observations will be made on the riverbanks by walking along the top of the bank in select reaches of the Turners Falls Impoundment. Observations will be documented of any erosion or riverbank stability issue using geo-referenced photographs. Specific erosion phenomena to be observed (see Table 6 below) include such items as tension cracks, gullying, removal of riparian vegetation, slips or slides, or other erosional features. Observations will be entered into the data-logger along with the location using

Table 6: Ground-Based Erosion Evaluation Form

Town / East or West Bank	Coordinates Start-End	Distance from River	Height above River	Type of Erosion*	Description/Comments

* Type of Erosion: Types of erosion will include, but not be limited to, the following: tension cracks, gullies, slides, slips, slumps, falls, etc.

9.0 Analytical Methods

The analysis of collected data, protocols and explanations are described under each corresponding task item or in the supplemental Appendix documents. Original statistical data, GIS data, survey data, and field data will be maintained in a raw unformatted file for review or evaluation. Maps of all riverbank features and characteristics will be developed showing the longitudinal extent and distribution along the Turners Falls Impoundment. Summary statistics quantifying the lengths of features and characteristics will be calculated. Conditions in 2013 will be evaluated based on comparisons over time of the river going back as far as the implementation of the ECP.

Once all field efforts, post processing, and analysis of field data is completed a comparison of the 2013 FRR data versus past FRR efforts will be conducted to determine changes in erosion activity. Comparisons of GPS collected data and geo-referenced videos and photos will provide quantitative evidence of changes in erosion activity and the status of erosion remediation efforts. Photographs and classification matrices will provide additional support in determining the levels of change, if any, in erosion activity. Comparison efforts may include analyzing changes in the length of riverbank shoreline experiencing erosion, severity of erosion, length of riverbank stabilization, success of erosion remediation efforts, identification of new erosion areas. GPS data, analyzed in ArcGIS, will spatially display and analyze changes in erosion activity over the past several years. All findings resulting from this comparison analysis will be documented in the final report.

Sediment classification of the upper and lower riverbanks is included in the matrix of features and characteristics, with maps showing location and extent of the range of sediment types included in the FRR. Sediment classification is sub-divided into 6 key categories ranging from clay, silt/sand, up through boulders and bedrock; allowing easy understanding of which areas consist of erodible soils and non-erodible material (including the location and extent of bedrock).

10.0 Quality Control Requirements

To improve bank visibility the 2013 FRR will be conducted in November 2013 during leaf-off. A land-based bank survey and evaluation will be conducted prior to the FRR to serve as a control, and to provide additional site specific data. Pre-survey field trials were conducted in November, 2012 by S&A and NEE to calibrate sampling techniques and methods with all field staff.

The mapping and identification of erosion features has a degree of subjectivity which may lead to reduced accuracy or quantification errors. The protocols, data collection methods, and verification of data are intended to permit subsequent river surveys to show long term bank stability and bank erosion trends. All photographs, data collected, field forms, video, and survey information is to be maintained in its original format for use by future researchers. Collected field data will be reviewed to document any inconsistencies in the data. All discrepancies need to be researched, and if the error is not determined, the necessary data will be measured again. If error results from improper use of equipment, or operator error, then retraining must occur before new data collection may proceed.

Field data will be checked at the end of each day by the Project Manager to ensure data are properly collected. All data entered on the data forms will then be checked by the QA/AC Manager. Any problems identified will be discussed with the staff and corrected in the field the following day.

11.0 Instrument/Equipment Inspection and Maintenance

Records will be maintained for all instruments used to ensure conformance to the specified requirements. The instruments are to be evaluated before use to confirm proper working function to the degree of accuracy necessary to accomplish the task for which it has been assigned.

Field equipment used by the field personnel will include a sub-meter GPS, a data-logger, and a laser range-finder. Regular maintenance procedures will be conducted in accordance with the instrument manufacturer and a log of the regular maintenance will be kept. All mechanical and electronic equipment will be cleaned and dried each day. Spare parts and batteries will be readily available so there will be no interference with data collection in the case of mechanical breakdown.

GPS units must be turned on for a minimum of 15 minutes before data collection begins to ensure the current satellite almanac has been transmitted and received by the unit. The GPS unit will be benchmarked with a position of known geographic location at the beginning and at the end of the collection period, and average precision/error can be calculated for points collected. If the error is > 49 feet, then satellite coverage was insufficient at that time, and the data will need to be recollected.

12.0 Instrument Calibration and Frequency

Equipment and instruments used for this effort do not require calibration.

13.0 Inspection and Acceptance Requirements for Supplies

General supplies will be purchased from different suppliers. These supplies will be purchased as needed by field staff and should not require special inspection.

14.0 Non-Direct Measurements

The non-direct methods that will be used as part of the 2013 FRR include: 1) USGS topographic maps for locations in VT, NH and MA, 2) ortho-photographs for these same states and 3) historical data, previously published and prepared in ArcGIS. All non-direct methods and materials will be used to support the field work. Additional data and information will be used to determine changes in bank location over time, and to map land use site conditions. These data will include: historical and recent aerial photography; flood insurance rate maps and flood studies; existing bathymetry (2006) and hydraulic model, GIS data layers from MA, VT and NH; current and historical USGS maps; and, if available, town GIS maps of property boundaries.

15.0 Data Management

Data collected in the field are all digital, including the data-logger files of riverbank features and characteristics, the geo-referenced digital video, digital photos and date-logger files of the land-based field work. These files will be downloaded to computers at the end of each field day. After verification and validation is completed, the reviewed and finalized data files will be downloaded to computers/servers at both S&A and NEE.

All field data sheets will be checked for completeness after each survey, and at the end of each day. The team leader will inspect all field records before leaving the site, and field data sheets will be reviewed by the Project Manager each day. Any omissions or discrepancies will be addressed immediately. Original field data sheets will remain in the possession of the field team member, and a copy will be placed in the electronic project file along with any other pertinent site information. Any secondary data will be stored in the project file, in either hardcopy, or electronic format.

All computer generated documents will be inspected for validity, completeness and accuracy by the QC Manager and Project Manager. All project files and drawings will have a unique file name including the project number and name. Every drawing will have a backup copy. Paper files will be maintained in a secure filing cabinet. Electronic files will be password protected and will not be modified without proper authorization. Electronic files will be backed up every night and stored off site. Inactive files are archived, and once archived they are changed to read-only status.

16.0 Assessment and Response Actions

Audits will be conducted. If the audit indicates there are problems with data collection, entry, or equipment use, these will be documented. All actions requiring correction will be brought to the attention of the appropriate staff member so that changes are made. The Project Manager will monitor and address all activities of the data collection process. Field assistants will review field techniques as needed and have a review performed by the Project Manager at the end of each field season. Data collection methods are standardized and the reporting method is consistent. The QA manager will ensure that field team members are performing all data collection as prescribed by the QAPP.

All field activities may be reviewed and the project sites may be visited by the QA officers as requested.

17.0 Reports to Management

A report will be generated which will include documentation of the methodology, results, and analysis. Maps will be produced in ArcView delineating all features and characteristics that were observed from the boat-based and ground-based matrices. Geo-referenced digital video will be provided documenting the riverbanks during the time of the field work.

A draft outline of the report is shown below.

Executive Summary

Introduction

Geomorphology of Turners Falls Impoundment

History of FRRs 1979-2008

Discussion of Erosion Control Plan (erosion site stabilization)

Discussion of riverbank stabilization work in the Turners Falls Impoundment (USACE, FirstLight, landowners)

Objectives of 2013 FRR

Riverbank features and characteristics observed, recorded in 2013

FRR features and characteristics, mapping results

Prediction of Future Erosion Trends

Evaluation and discussion of 2013 results

Recommendations for stabilization

Conclusion and Summary

18.0 Data Review, Validation and Verification

The project QA Officer will review all data collected as well as subsequent calculations to evaluate whether QC requirements have been met and whether data are usable to obtain the stated objectives of the project based on criteria contained in the QAPP. Subsequent final review and approval will be made by the Project Manager.

Validation and verification of field data will be conducted on a daily basis by reviewing the data-logger files to ensure that all riverbank segments observed are fully completed, covering all features and characteristics in the classification matrix. GPS location data will be checked comparing the segment of riverbank observed each day with the locations plotted on the computer.

Field observations of riverbank features and characteristics will be compared with images captured from the geo-referenced digital video files. Since geo-referenced video will be available for the entire Turners Falls Impoundment, the classification of any riverbank segment can be verified by comparing the observations in the data-logger to the geo-referenced video.

When it is found that data do not meet the quality objectives of the QAPP, or do not adhere to the QC measures, the Project Manager may determine what corrective action must be taken:

- Incomplete data may lead to re-surveying of river bank segments if the available data are insufficient to meet project goals
- When data quality is poor, the Project Manager will apply one of the following actions.
    1. Systems audit for measurements in questions;
    2. Immediate re-survey of the river bank segments in question;
    3. Revise riverbank segment classification based on geo-referenced video;
    4. Rejection of identified data with a written explanation; or
    5. Rejection of survey segments from the assessment with recommendation for re-survey.

19.0 Reconciliation with Data Quality Objectives

The first objective of the field data collection is to ensure that a complete set of riverbank features and characteristics is obtained for all segments. The second objective is to ensure that the features and characteristics observed are consistent with those presented in Appendix C that were used to guide the classification process. As previously discussed, the classification of any particular segment can be compared against the photographs guiding the classification by utilizing images from the corresponding geo-referenced video images taken during the field survey. If the project objectives are met, the user requirements have been met. If the project objectives have not been met, the corrective actions will be established by the Project Manager.

20.0 References

Connecticut River Joint Commissions and Trails Conservation Assistance Program of the National Park Service through the Connecticut Valley Partnership, “River Dynamics and Erosion.”

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APPENDIX A - TRIMBLE GEOXT SUB-METER GPS SPECIFICATIONS

Trimble GeoXT Sub-Meter GPS - Rugged and reliable data collection

The Trimble® GeoXT™ handheld from the GeoExplorer® 3000 series is the essential tool for maintaining your GIS. A high performance GPS receiver combined with a rugged handheld computer, the GeoXT handheld is optimized to provide reliable location data, when and where you need it.

It's ideal for use by utility companies, local government organizations, federal agencies, or anyone managing assets or mapping critical infrastructure who needs accurate data to do the job right—the first time. With EVEREST™ multipath rejection technology onboard, the GeoXT handheld records quality GPS positions even under canopy, in urban canyons, and in all the everyday environments you work in, so you know your GIS has the information that others can depend on.

And if you need that extra edge in precision, you can collect data with Trimble TerraSync™ software, Trimble GPScorrect™ extension for Esri ArcPad software, or Trimble Positions™ Mobile extension and then postprocess it back in the office with Trimble GPS Pathfinder® Office software, Trimble GPS Analyst™ extension for Esri ArcGIS Desktop software, or Trimble Positions Desktop add-in. These office processing suites use the new Trimble DeltaPhase™ technology to achieve 50 cm accuracy for GPS code measurements after postprocessing, and even higher levels of postprocessed accuracy are possible when you log GPS carrier data for extended periods.

With a powerful 520 MHz processor, 128 MB RAM, and 1 GB of on board storage, the GeoXT handheld is a high performance device designed to work as hard as you do. The handheld gives you all the power you need to work with maps and large data sets in the field, and its high resolution VGA display allows for crisp and clear viewing of your data.

With the GeoXT handheld you have the flexibility to work exactly the way you want to. The handheld is powered by the industry-standard Windows Mobile® version 6.1 operating system, so you can choose a software solution designed for your field requirements, whether off-the-shelf or purpose-built. And you can use the built-in wireless LAN connection to access your organization's secure network and get the most up-to-date information. You can also wirelessly connect to other devices such as Bluetooth-enabled laser rangefinders and barcode scanners for convenient cable-free solutions that keep you productive in the field.

Rugged design and powerful functionality are the hallmarks of the GeoExplorer® series. When accuracy is critical, the GeoXT handheld delivers with unprecedented efficiency and reliability, when and where you need it.

Key features:

- Real-time submeter GPS with integrated SBAS and EVEREST multipath rejection technology

- 50 cm accuracy after postprocessing with Trimble DeltaPhase technology
- High-resolution VGA display for crisp and clear map viewing
- Bluetooth and wireless LAN connectivity options
- 1 GB on board storage plus SD slot for removable cards
- Windows Mobile version 6.1 operating system

Rugged handheld with all-day battery

APPENDIX B – LASER RANGE FINDER EQUIPMENT SPECIFICATIONS

LTI TruPulse 360B

Laser Technology, Inc. http://www.quantumgear.com/trupulse-360b/

LTI TruPulse 360B

Now with TruVector Compass Technology™ and BlueTooth™ wireless transfer of data!

$1,695.00

enlarge

Quantity: 1

Detailed Description

The TruPulse 360B includes all of the features of the 360 plus BlueTooth™ wireless data transfer

This model is the only all-in-one compass/laser that produces the best possible azimuth accuracy regardless of what angle you shoot from. So, whether you need accurate distance and height measurements or you want to expand your capabilities with a compass, there is a TruPulse model designed just for you. Nothing on the market offers this kind of functionality, with such a compact design and low price point. Start mapping more and moving less today.

Industries: Forestry, Natural Resources, GIS/GPS, Construction, Mining, Utilities, Telecom

Quick Links:
TruPulse Series Specs

By embedding TruVector compass technology™ into the TruPulse 360, this unit is transformed into an integrated compass, distance and height laser range finder that delivers mapping-grade accuracy without inclination limitations. With the TruPulse 360 rangefinder you can acquire multiple targets from a single location, without ever having to worry about compromising your data.

The TruPulse 360B offers increased productivity

Tilt the TruPulse 360 89 degrees, turn it on its side, or even hold it upside down, and the TruPulse 360 will give you accurate azimuth in any direction it's aimed. It even has a built in system that will alert you if you need to recalibrate the unit.

The TruPulse 360 is small enough to fit in your pocket, yet powerful enough to deliver professional, mapping-grade accuracy in a hand-held, point-and-shoot package.

Find a safe convenient point of view and start collecting field data.

(All specifications are subject to change without notice.)
Dimensions: 5 inches x 2inches x 3.5 inches (12 cm x 5 cm x 9 cm)
Weight: 8 ounces (220 g)
Data Communication: Serial, via wired RS232 (standard) or wireless Bluetooth (optional)
Power: 3.0 volts DC nominal
Battery Type: (1) CRV3 or (2) AA
Battery Duration: CRV3 - Approx. 15,000 measurements (12,000 w/Bluetooth enabled);
AA - Approx. 7,500 measurements (6,000 w/Bluetooth enabled)
Display: In-scope LCD displays menu options and data values
Units: Feet, Yards, Meters, and Degrees
Monopod/tripod Mount: 1/4inches - 20 female thread
Eye Safety: FDA Class 1 (CFR 21)
Environmental: Impact, water and dust resistant. NEMA 3, IP 54
Temperature: -4 F to +140 F (-20 C to +60 C)
Optics: 7x magnification (field of view: 330 ft @ 1,000 yds)
Measurement Solutions:
Distance (Horizontal, Vertical, Slope)
Inclination (Degrees and Percent Slope)
Height (Flexible three-shot routine)
Azimuth (Compass bearing for single-shot positioning)
Missing Line (Distance, Inclination and Azimuth between any two remote points)
Measurement Range:
Distance: 0 to 3,280 ft (1,000 m); typical,
6,560 ft (2,000 m); max to reflective target
Inclination: ±90 degrees
Azimuth: 0 to 359.9 degrees
Accuracy:
Distance: ±1 ft (±30 cm); typical± yd (±1 m); max
Inclination: ±0.25 degrees
Azimuth: ±1 degree; typical
Targeting Modes:
Standard, Closest, Farthest, Continuous, and Filter (requires reflector and foliage filter)
TruTargeting:
Automatically provides best possible accuracy and acquisition distance to a given target
TruVector Compass Technology™:
Provides the best possible compass accuracy regardless of the laser’s inclination. It even warns you when the compass needs calibrating.

APPENDIX C – RIVERBANK CLASSIFICATION MATRIX PHOTOGRAPHS

Upper Riverbank Slope:

Flat

Moderate

Steep

Vertical


Overhanging

Lower Riverbank Slope:

Flat

Moderate


Steep


Vertical

Upper Riverbank Sediment:

Silt/Sand

Rock

Lower Riverbank Sediment:

Silt/Sand

Gravel

Cobbles

Boulders

Rock

Clay

Upper Riverbank Height:

Low

Medium

High

Degree of Upper Riverbank Vegetation:

Heavy

Moderate

Sparse

None to very sparse

Lower Riverbank Vegetation:

Heavy

Moderate

Sparse

None

Mass Wasting:

Little/None

Little/None


Little/None


Some


Some

Extensive

Extensive


Extensive

Erosion Type:

None

Notching


Overhanging bank

Undercut Toe

Slide

APPENDIX D – RED HEN SYSTEMS GEO-REFERENCED VIDEO MAPPING

Red Hen Systems Geo-Referenced Video Mapping

VMS-HD Complete System Bundle Includes:

- Red Hen VMS Hardware
- Convergent Design nanoFlash HD/SD Digital Video Recorder/Player
- Desktop GIS Software: MediaMapper 5.3*
- GPS Antenna/Receiver
- Feature Trigger (on board)
- 4" Microphone Jack Cable
- Power Adapter with International Plugs
- Hirose Power Cable
- Flash Card Reader/USB Cable
- Pelican Case
- Manuals

Convergent Design nanoFlash HD/SD Digital Video Recorder/Player

Introducing the World's smallest high quality HD/SD-SDI / HDMI Recorder/Player. The nanoFlash by Convergent Design is the most versatile Recorder/Player in the World in terms of bit-rates, recording options and formats. By adding the nanoFlash , one can meet the acquisition requirements, 50 Mbps, for many networks. The nanoFlash is a state-of-the-art miniature CompactFlash HD/SD SDI and HDMI Recorder/Player. Red Hen Systems is pleased to have been selected as the premier Spatial Multimedia Reseller and GIS Integration partner for the nanoFlash by Convergent Design.

- Improves the image quality of most cameras as the HD/SD-SDI and HDMI outputs are before the compression stages.
- Many cameras only record highly compressed 4:2:0 while outputting 4:2:2 over HD-SDI or HDMI.
- The nanoFlash uses these high-quality uncompressed 4:2:2 images to produce higher quality recordings.

The nanoFlash offers a dramatically better image, free from motion artifacts and other image problems, such as mosquito noise. Typically the nanoFlash offers a better image, even from many high-end cameras.

Wide Range of Bit-Rates

- 4:2:2 Long-GOP from 50 to 180 Mbps Long-GOP
- 4:2:2 I-Frame Only from 100 to 280 Mbps
- 4:2:0 Long-GOP from 18 to 35 Mbps
- SD 5/6/7/8/9 Mbps

Wide Range of Frame Rates

- Supports HD-SDI, SD-SDI and HDMI inputs
- Works with most any camera with HD/SD-SDI or HDMI outputs HD/SD-SDI and HDMI outputs active simultaneously
- Long, Uninterrupted Recording Times

Records in:

- Native Quicktime for Final Cut Pro
- Native MXF for Avid, Sony Vegas, Edius, others
- MPG Format in SD for quick same day creation of DVD's
- MPG Format in HD - Realtime Rendering of Blu-Ray disks
- No Mandatory Transcoding - Drag and Drop Editing

- All Solid-State - No Moving Parts - No Fans - No Noise - Field Proven Rugged - Withstands Extreme Temperatures - High Humidity - High Altitudes - High Vibration - High G-Forces
- Camera Mountable - 0.85 Pounds - 1/4" x 20 Tripod Thread
- Very Low Power - 5.6 Watts maximum, 0.2 watts standby Wide Voltage Range - 6.5 to 19.5 Volts DC - Uses most any battery type - International AC Power Supply included

- Supports Timecode and Audio embedded in HD/SD-SDI
- Supports Audio embedded in HDMI
- Supports Analog Audio, 24-Bit/48K, with up to 44 dB of gain via 3.5 mm audio input, compatible with tape-out signals
- One Channel balanced audio consumer line level / mic, orT
- Two Channel unbalanced audio consumer line level / mic

All audio recorded at 24-Bit/48K Uncompressed
Headphone / Consumer line-level outputs

2 CompactFlash card slots - Records seamlessly from one card to the next
The image quality produced by the nanoFlash is exactly the same as the Flash XDR.

VMS-HDII

Our easy-to-use digital camera accessories and GPS video digital recorders let you collect video imagery - along with essential location information. Our GIS software lets you process the imagery and generate multimedia maps that bring vital information to the eyes and fingertips of decision-makers. With the click of a button you know where something is, as well as what it looks like. And you can share the maps with others over the Internet.

This system combines Red Hen's VMS-333 with the nanoFlash recorder from Convergent. Completely customizable, now add up to 4 channels of recording for UltraViolet, Infrared, Standard Definition, and/or High Definition. Expand the information in your data collect for more comprehensive results. In our most portable, light-weight size yet, the HDII is especially suited to collect geo-tagged "path" HD video from all mobile platforms, such as aircraft, ground vehicles and marine vessels.

Features:
• Format: Record in High-Definition or standard definition
• Recording: All video and GPS data encapsulated in a single file on compact flash card, seamlessly switches recording from card 1 to card 2
• GPS: WAAS-enabled for greater location accuracy in the US; supports international SBAS (Satellite Based Augmentation System) in Europe and Asia
• Feature Trigger: Allows you to "mark" points of interest for quick analysis
• Photo Capture: Automatically capture geo-referenced still photos from High-Definition video
• Analysis: MediaMapper 5.3 software allows for subject matter experts to create electronic work products

Benefits:
• Competitive price, with unprecedented High-Def and multimedia mapping functionality
• Light weight, portable — easily switch between aircraft and vehicles, or carry on foot
• Removable compact flash cards allow for archiving of original recording — ideal for law enforcement
• All Solid-State design - Ideal for Extreme Environments

Supported Video Input Formats:
· 1920x1080i @ 60, 59.94, 50 Hz
· 1920x1080p @ 30, 29.97, 25, 24, 23.98 Hz
· 1920x1080psf, @ 30, 29.97, 25, 24, 23.98 Hz
· 1280x720p @ 60, 59.94, 50 Hz
· 720x486 @ 29.97 Hz
· 720x576 @ 25 Hz

.mts & .m2ts file types may not work correctly and therefore are not supported.

Appendix E – Previous data and information for Adult American shad

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Appendix F – Turners Falls Upstream Fish Passage CFD Modeling of Gatehouse Entrance

Turners Falls Upstream Fish Passage CFD Modeling of Gatehouse Entrance

By:

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Submitted to:

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Hartford, CT

February 2013

1115TFCFD-R1

ALDEN RESEARCH LABORATORY, INC

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ABSTRACT

Observation of 2010 fish passage revealed that only about 50% of Shad in the power canal passed the Turners Falls gatehouse fishway. Various modifications had been made over a number of years to improve passage, including the construction of an additional entrance in the canal and internal changes to the original ("old") canal entrances. To better understand the effects on the hydraulics of the modifications made to date, to improve flow and velocity conditions in the fishway at the old entrance, and to develop concepts for possible further enhancements at the old entrance, Alden was contracted by FirstLight to model the gatehouse ladder and its canal entrances from the upstream pool to the downstream junction with the spillway ladder. This model included the gate house with all its gates and the upstream end of the canal.

In order to achieve the objectives, a three-dimensional (3D) computational fluid dynamics (CFD) model was first developed for the available canal bathymetry and present (2012) fishway structures, using Flow3D by Flow Science. The model was then validated using field data from 3/16/2006 (head gates operating without fishway flow) and 5/27/2009 (both fishway and head gates operating). Following these validation cases, the model was run for two additional field scenarios corresponding to conditions on 5/24/2008 (low flow) and 5/20/2009 (moderately high flow). For both of the additional scenarios, both the head gates and fishway were in operation.

The CFD results of the validation cases showed good agreement with the field data indicating that the model was accurately reproducing the hydraulic conditions of interest. Further, the validation cases as well as the base low and moderately high flow scenarios revealed some flow conditions that can be improved for fish passage in the fishway, at the old entrances and in the canal downstream of the gatehouse.

Based on the results of the CFD model with the existing geometric configuration, it was decided to investigate modifications that would enhance fish passage. The first modification considered, Modification 0 (abbreviated as Mod 0), was the design of an additional section of fish ladder extending from the remaining old entrance into the canal. Design parameters included a flow rate

of 180 cfs and a total water drop of 2.5 ft. After some consideration, it was concluded that this new ladder may be less effective than Modification 1 (discussed below) and therefore no CFD simulations were conducted for Mod 0.

Modification 1 (abbreviated as Mod 1) focused on the region inside the old entrance in the sloped diffuser area to achieve a design flow rate of 180 cfs through the old entrance. Modifications included: 1) adding a vertical concrete wall to create a channel separating the flow to the old entrance (left) from that flowing to the new entrance and spillway ladder (right); 2) closing the existing three upstream openings in the floor of the fish way just upstream of the diffuser; 3) keeping a left diffuser opening of 18 ft and closing the remaining part of the left diffuser; 4) adding two single slotted weirs in the left channel; 5) adding an orifice at the entrance of the left tunnel to the diffuser; 6) cutting down the sill at the old entrance from El. 168.2 ft to El. 166 ft and removing the stop-logs. A CFD simulation was conducted with Modification 1 using Validation Case 2 flow conditions but with new gate openings.

Lastly, Mod 1 was further refined to arrive at Modification 2 (abbreviated as Mod 2) which included: 1) adding a baffle at the right side of the new left channel; 2) narrowing the slot width of the added upstream slot in Mod 1; 3) removing the existing baffle at the left side of the old entrance and adding a new wider baffle at the right side of the old entrance ; 4) re-aligning the angled wooden diffuser in the left channel; 5) enlarging the orifice at the entrance of the left tunnel . Mod 2 was then tested with new gate openings and pond water level.

1. INTRODUCTION

1.1 Background

With the old and new entrances operating, following the last round of operational and structural improvements, even with the latest changes, only about 50% of the fish in the power canal passed through the gatehouse fishway in 2010. In order to better understand the effects on the hydraulics of the modifications made to date, to improve flow and velocity conditions in the fishway at the old entrance, and to develop concepts for possible further enhancements at the old entrance, FirstLight contracted Alden Research Laboratory (Alden) to conduct a Computational Fluid Dynamics (CFD) model study of the modified Tuners Falls gatehouse fishway including gatehouse ladder, its entrances to the upper end of the spillway ladder.

1.2 Project Description

The Turners Falls Gatehouse is located at the upstream end of the Cabot Station power canal in Turners Falls, MA. The gate house has 14 operating gates and one gate opening plugged with concrete during the renovation of the gatehouse for the Northfield pumped storage project. Width and height of each gate opening is listed in Table 1. Each gate is operated independently and field experience has indicated a generally preferred operating sequence to control canal flow patterns and water levels.

The power canal between the Turners Falls Dam Gatehouse and Cabot Station is approximately 2.2 miles in length. The canal width varies. The width at the gatehouse is approximately 180 ft while 360 ft downstream of the gatehouse the width decreases to 120 ft. From this point downstream, the width increases and opens out into the forebay of Cabot Station. The unlined canal is excavated in rock and concrete walls are constructed from the top of the rock to the top of the canal, some of the rock above the top of the canal is exposed. Canal walls south of the railroad bridge are rock lined embankments.

The Turners Falls Pond level varies between El. 184.0 and El. 176.0 ft when fishway is operating and not flood flows. The power canal water level at the downstream side of the gatehouse varies.

The level on the left side of the canal commonly gets down to 173.5 ft (ever lower at times), and doesn't exceed 175 ft very often. The right side of the canal may be somewhat higher than the left side, but not much at medimum to low canal flow. Due to the bend in the canal immediately downstream of the gatehouse, the canal water surface tends to be super elevated across the downstream face of the gatehouse, with higher water level on the right side of the canal looking downstream.

The Turners Falls Fish Passage Facilities consist of three separate structures: the Cabot fishway, Gatehouse fishway, and Spillway fishway. The Cabot Fishway, located at Cabot Station, enables upstream migrating fish to ascend to the power canal from the river. Once in the power canal, the fish swim two miles to reach the Turners Falls Gatehouse. The Spillway Fishway, located at the spillway of the Turners Falls Dam, permits any fish which have by-passed Cabot Station and arrived at the base of the dam, to ascend up into the Gatehouse Fishway where they can continue their upstream migration. The Gatehouse Fishway enables fish to swim from the power canal, through the south end of the Gatehouse and up into the Turners Falls Pond.

There are two entrances to the Gatehouse fishway. The original entrance is located on the left end of the gatehouse (looking downstream) and originally utilized three 5 ft wide openings each with a sill elevation of 170.0 ft. Currently, two of the three entrances are closed (to provide the required attraction flow to the new fish entrance) and only the southwestern most entrance is used for passage. Internal changes were also made to better guide the flow to the old entrance and for the remaining flow to turn 90 degrees into the gatehouse gallery. The new second entrance is located near the right end of the gatehouse and canal, looking downstream, immediately adjacent to the top of the spillway fish ladder.

1.3 Prior Studies

Hydraulic model studies of portions of the spillway and gatehouse fishways at Turners Falls were performed at Alden in 1975 (Pennino and Hecker 1975). The objective of that study was to locate the spillway fish ladder entrance in relation to spillway flow over the dam so that flows from the entrance would be effective in attracting fish. Model testing of the gatehouse fishway with the slotted weirs showed that a wall parallel to the shoreline would allow satisfactory flow pattern at the fishway exit. Testing also showed that an increase from six to seven weirs would beneficially reduce the average head drop across the weirs and the maximum velocities at the additional slots.

1.4 Study Scope

The scope of work for the current study included the followings:

1.4.1 Model Development

The proposed model simulations were conducted using the commercial code FLOW-3D by Flow Science. Setup of a FLOW-3D model requires development of solid models to represent the canal bed, fishways, gatehouse gallery geometry, etc. The canal bottom was based on the available bathymetric data. The model included the area downstream of the existing sluice and gate structures, the gatehouse fishway, the spillway fish ladder, the entrance gallery and all related internal geometry that would affect flow patterns, and the spillway fishway attraction water entrance geometry. The model initially represented the existing field configuration.

A computational mesh was applied to the model with structured variable grid spacing. The model was tested for numeric stability and to ensure the grid resolution is sufficient.

1.4.2 Model Validation

Model validation was completed using available field data related to flow and water level. Water level information for selected low and moderately high flow conditions was used to validate and potentially calibrate the numeric model such that observed and predicted water surface profiles are in agreement.

1.4.3 Base Model Runs

The model was run at two operating conditions of interest, selected with FirstLight, to evaluate existing hydraulic conditions and to be used as a basis for development of potential modifications. These flow conditions, not necessarily the same as used in the model validation task, were envisioned to include unique combinations of canal water level, gate opening and total flow. These simulations bounded the performance of the fishway entrances and provide a basis upon which modifications were considered and evaluated. Consequently, there are two model runs using the base (existing) geometry and varying only the site flow conditions.

For each simulation, a series of plots were created showing horizontal and vertical planes colored by water velocity and showing velocity vectors in selected planes at the entrances and within the fishway and gallery. A series of plots showing vertical planes through the power canal were created to show the water velocity and depth along the length of the canal. Plots of pathlines were created to show the general flow patterns throughout the model domain. Animations were used to help visualize flow patterns.

1.4.4 Fishway Modifications and Simulations

Three modifications to the gatehouse fishway geometry were included to improve hydraulic conditions at the fishway entrances and in the entrance gallery. Two geometric modifications were evaluated at flow conditions studied in base model runs or other selected flow condition. Comparisons were made between the geometric modifications to select the most promising option.

1.5 Objectives

The main objective of the modeling is to study and improve the hydraulic conditions for upstream passage of American Shad at the original gatehouse fish entrance (the old entrance). Specifically, topics of interest include flow patterns in the canal approaching the fishway entrance and the water level drop(s) and internal flow patterns at the old entrance.

2. CFD MODEL

2.1 Model Description

Prior to the development of the model, the following principal aspects need to be considered:

- The three dimensional (3D) complex geometry and the complicated 3D dynamic features of flow require a full 3D model for this study.
- Water is the working fluid in this study and the changes in water density are sufficiently small to be ignored, therefore, the flow was modeled as an incompressible fluid.
- Water is a Newtonian fluid. Its shear stress is essentially linearly related with strain by a coefficient of viscosity.
- Is the flow inviscid or viscous? In viscous flow, fluid friction has significant impacts on the fluid motion. The Reynolds number is usually used to evaluate whether viscous or inviscid equations are appropriate. Using the flow rate of about 8000 cfs (5/27/2009 data of Validation 2) and the average canal width of 180 ft and water depth of 18.5 ft, the flow Reynolds number, defined as $Re = \rho U D_H / \mu$, in which U=mean velocity, ρ=water density, μ=dynamic viscosity, $D_H = 4A/P_W$ =hydraulic diameter, A=area, P_W = wetted perimeter, is found to be in the order of 1.4×10^7. This is much higher than the value of 2000 that is usually used to determine the transition from laminar to turbulent flow. Although the high flow Reynolds number indicates that inertial forces are much more significant than the viscous (friction) forces, however, the presence of solid boundaries does require that fluid viscosity be included. The "no-slip" condition (velocities relative to solid walls are zero) can generate a thin boundary layer with large strain rate (velocity gradient), which will affect the outer fully-developed turbulent flow and generate internal eddies and losses. Therefore, viscous flow was used for this study.
- Laminar or turbulent flow. Turbulence can usually be characterized by random eddies with different length scales. In turbulent flow any instantaneous quantity can be mathematically expressed as the summation of an average (mean) and a fluctuating term by the so-called Reynolds decomposition. Turbulent flow can be well described by the Navier-Stokes equation which is derived from Newton's Second Law of Motion. Judging from the flow Reynolds number of 1.4×10^7, the flow in the present study is turbulent. This Reynolds number is too high for application of a Direct Numerical Simulation (DNS) due to the lack of current computer power. However, only the mean flow features are of interest in real-life engineering problems. Substituting the Reynolds decomposition into the instantaneous Navier-Stokes equations yields the Reynolds-Averaged-Navier-Stokes (RANS) equations. The averaging process creates a new term,

the so-called Reynolds stress, in the equation system. The RANS equations used in this study combined with turbulence modeling provides an effective way to simulate the effects of turbulent flow.

- Steady (no variations with time) or unsteady (time varying) flow. Unsteady-state flow refers to the flow condition where flow properties (such as velocities, pressure, temperature) at any point in the system do change over time. Free surface flow is the most important characteristic of flow in this study. For such kind of flow with sharp surface formation a necessary approach is to solve the RANS equations with time variation, seeking the results when the flow is developed close to a steady-state situation.
- Fluid temperature. Change of water temperature through the entire computational domain is negligible. There was no need to include the internal energy (or temperature) equation.

Based on the above consideration, the governing equations to be solved are the RANS and turbulence modeling equations for 3D, transient, Newtonian, incompressible, viscous flows without heat transfer.

The commercial CFD code FLOW-3D by Flow Science was used. FLOW-3D solves the fully three dimensional Navier-Stokes equations on a structured hexagonal grid. Several turbulence models are included in the solver for computing the creation, transport and dissipation of turbulent kinetic energy.

The Boussinesq hypothesis is used to relate the Reynolds stress tensor in the RANS equations proportionally to the mean strain rate tensor via a scalar property called eddy viscosity μ_t. This eddy viscosity becomes an unknown parameter and needs to be calculated. The turbulence model serves this purpose. There is no single turbulence model that is best for all kinds of flow problems. Selecting a turbulence model is based on the physics of the problems to be solved, the level of accuracy required, available computer resources, allowed computing time, even personal preference and established practice for a specific class of flow problems. Therefore, it is usually a challenging task to select a suitable turbulence model for hydraulic flow simulations. It is necessary to choose a more refined turbulence model to predict more complex flow patterns such as separating flows, rotating flows, and flows strongly affected by secondary-flows. The common choices for this kind of complex flows are the two-equation turbulence models which are widely used in real-life engineering problems. This usually includes the standard k-ε model, Renormalization-group (RNG) k-ε model, Realizable k-ε model, standard k-ω model, shear-stress transport (SST) k-ω model, etc. Two-equation turbulence models usually overproduce turbulent energy within regions with strong velocity gradients, and different models behave differently in these regions. It has been shown that the k-ε model is useful for free-shear layer flows with relatively small pressure gradients. Relatively speaking, the standard k-ε is probably the worst choice, its variant models (RNG and Realizable k-ε models) may behave better. For this application, the Renormalized Group (RNG) k-ε model was used.

FLOW-3D model uses the Fractional Area/Volume Obstacle Representation (FAVOR) for the modeling of solid obstacles, such as topology, structure members. The FAVOR method allows complex shapes to be simulated without resorting to stair stepping the boundaries. The location of the free surface is computed using the Volume of Fluid (VOF) method. This formulation consists of a scheme to describe the shape and location of the free surface, a method to track the evolution of the shape and location of the free surface through time and space, and a means for applying boundary conditions to the free surface.

2.2 Assumption and Limitation

Impact of air motion above the water surface to the water flow is assumed negligible. Therefore, air movement was not included in the simulation and only water flow was simulated. This simplification yields a considerable reduction in required computational resources and is reasonable for this application.

The Weber number of flow is defined as: $We = \rho V^2 L/\sigma$, in which σ=surface tension of water, V=velocity, ρ=water density, L=characteristic length. Using the mean canal velocity of 2.4 ft/s (for Validation 2 data) and hydraulic diameter for characteristic length L=62 ft, water density ρ=62.37 lbm/ft^3, and σ=5.04x10^{-3} lbf/ft (60F degrees of water), the calculated Weber Number (We) =4419, which is much larger than 1. Therefore, effect of the water surface tension is negligible.

2.3 Geometry and Computational Mesh

Based on the geometry information provided, a solid model was created of the bathymetry and structures in AutoCAD, and STL format files were output. Then the STL files were imported into FLOW-3D model for mesh generation.

Figure 1 shows the general 2D view of the CFD model with the current geometry and structure configuration. The coordinates (X, Y, and Z) are in unit of foot throughout the report. The model consists of several main parts:

- **The whole length of the upstream slotted weir channel (see** Figure 2**):** Initially it was proposed to just model a couple of the downstream slotted weirs (#7 and #6). However, the lack of suitable data at weir #6 made it impossible to set up the appropriate boundary condition at this location. Practically this location is not ideal for a boundary for a free surface flow problem. Therefore, the model at the slotted weir area needed to be extended all the way upstream to the pond. Including all the seven weirs and the entire channel to the pond facilitated the upstream boundary condition.
- **Attraction water tunnel:** The attraction water tunnel is underneath the slotted weir channel except the most upstream inlet portion which turns at an angle. The flow into the attraction tunnel is through and controlled by two separated adjustable gates AGW 15 and AGW 16 (see Figure 2). The openings of the gates are adjusted to provide the attraction flow that maintains the desired water surface elevation difference between the galley and the canal. This elevation difference can be varied by the operator.
- **Sloped floor diffuser** (Figure 3): Figure 4 shows a zoom-in view of the sloped floor diffuser channel. Attraction flow from the tunnel underneath passes the sloped diffuser to join the flow from the slotted weir channel above, providing fish passage attraction flow to the old entrance and gallery to the new entrance and spillway ladders. At the upstream end of the sloped diffuser, there are three separated openings connecting the underneath attraction flow tunnel to the slotted weir channel above.
- **Gatehouse:** In total, there are 15 individual gates, as shown in Figure 5. Gate 6 is plugged with concrete. The opening of each gate is determined by the operating condition being simulated.

- **Gallery Turning Vanes:** There are turning vanes to the new entrance in the gallery which will impact the flow patterns in the gallery.
- **New entrance:** The whole length of the new entrance was modeled, as shown in Figure 3.
- **Power Canal**: At the right side canal bank downstream of the new entrance there are two gates (AWG 27 and AWG 28, see Figure 6) to control attraction flow to the spillway fish ladders. The CFD model downstream boundary is located at about 700 ft upstream of Keith Bridge. This location was selected to assure the boundary was far enough from the gatehouse so as not to affect results but not too far downstream (to reduce necessary computational cells and computational time). To account for the impact of the roughness of the canal bathymetry to the flow field, the canal bed was divided into several zones with different roughness heights, and couple runs were tested to determine the roughness heightness, as shown in Figure 7. Basically the roughness height is about 2 ft at the right side of the canal, 1 foot at the left side of the canal, and 1 foot in the downstream section of the canal. For Validation 2, there was a rock ramp just downstream from the old entrance, the roughness height for which was set to 2 ft.

Grid generation included the creation of multiple structured mesh blocks over the entire model domain. Cell spacing varied along the three coordinate directions, however, variations in the grid spacing are required to be carried through the entire mesh block. The ability of the model to accurately reproduce the flow field is dependent on the grid resolution in the area of interest. A finer grid requires more computational time to arrive at a final solution. Often, multi-block meshing is used to reduce the overall size of the model domain. In a multi-block mesh flow passes from one mesh block to another at the mesh block interface where the computational mesh of the two neighbor blocks is not required to match. Much finer mesh was required at the slotted weir channel, gallery, and new entrance area. Due to the meshing considerations above it was not practical to model the turning vanes to the new entrance in the gallery as thin plates. A commonly used approach which has little impact on the simulation results is to model the vanes as zero thickness baffles (blockage). Since Flow3D uses a Cartesian mesh these zero thickness baffles need to be located along a cell face. Hence the curved portion of the vanes was approximated using small straight segments as shown in Figure 8. This approximation does not have an impact on the bulk flow patterns created by the turning vanes. The resulting model meshes for the existing and modified geometries included about 3.6 million and 4.5 million active cells, respectively.

2.4 Boundary Conditions

There are six side face boundaries in each single structured mesh block that require boundary conditions to conduct the simulation. At the interface connecting the neighbor mesh blocks, a symmetry boundary condition was usually applied. Special attention was needed for model boundaries and these are prescribed as follows:

- At the pond side, a pressure boundary condition was applied by specifying the appropriate water level where the flow entered the upstream slotted weir channel, the attraction flow tunnel, and the gatehouse gates. It should be pointed out that the gatehouse gates and attraction water gates are not model boundaries where boundary condition should be applied, but internal flow restrictions where an appropriate opening was set up for each gate.
- For the downstream spillway attraction flow at the right bank downstream of the new entrance, based on the fact that the flow from underneath the control gates AWG 27 or AWG 28 is free discharge, an extension mesh block was built to cover about 5 times the length of the gate width, a pressure boundary condition was specified at the most downstream mesh boundary by specifying a water depth less than the height of the gate opening to assure a free discharge from the gate.
- At the downstream canal boundary of the model, a pressure boundary condition was applied by specifying the appropriate water level. Since there was no readily available water level data at this boundary but water level was available at Keith Bridge, an interpolation was required to obtain the water level at the model downstream boundary.
- At the downstream end of the gallery, a pressure boundary condition was applied by specifying an appropriate water height above the weir top.

The boundary conditions for all the runs are shown in Table 2. Table 2 also lists the openings of the adjustable gates to the attraction flow tunnel, downstream spillway attraction flow, and the adjustable weir at the downstream end of the gallery.

3. RESULTS

For each simulation, a complete presentation of the results was provided to FirstLight, and is included in a CD as an appendix of this report.

3.1 Model Validation

3.1.1 Validation Case 1

Validation Case 1 (3/16/2006 data) was selected to represent a moderately high flow condition (about 12,100 cfs) prior to installation of the new entrance. There was no fishway flow and only head gate flow. Results of the CFD simulation are discussed below. Figure 9 and Figure 10 show the total velocity contours and in-plane velocity vectors at elevations 172 and 163 ft. Elevation 172 ft represents shallow water depth (close to water surface) and elevation 163 ft deep water depth. Figure 11 and Figure 12 show the same content but in vertical planes through some of the gate centerlines. Flow pathlines downstream of the gatehouse are shown inFigure 13. Higher velocities are seen in the center of the canal as a result of the gate settings and more flow passing through the middle gates. The velocity vectors and 3D pathlines clearly indicate swirling flow downstream the gatehouse. The flow from the right side gates, particularly Gates 2 and 3, impinges on the right side bank walls and climbs up from deep water to the surface, forming a swirl moving toward the left bank. A counter-clockwise eddy is formed at the left bank downstream of the old entrance. These general flow patterns have been confirmed by the field observation.

Figure 14 shows an overall view of the water surface elevations in the canal. It can be seen that the water level is higher along the right side and lower along the left side of the canal. This coincides with the field observation. Figure 15 shows a zoom-in view of the water level downstream of the gate house. Water levels were measured at points A and B at the old entrance and points C through F along the right bank. CFD calculated and field measured water surface elevations at these points are listed in the figure. Comparison of the water surface elevation at these points is listed in Table 3. The CFD model predicted water surface elevations varied from the measured field data by about 0.1 to 0.3 ft with exception of point C, which showed a difference of about 0.5 ft. It was noticed that flow in the area of point C and its vicinity is unsteady and turbulent, making measurement of water level difficult. Therefore, higher variability and differences in the measurements in this region would be expected.

The canal bed was initially simulated as hydraulically smooth. However, the corresponding simulation results showed lower water level than the measured field data. The exposure of the canal bed when dewatered in the pictures provided by FirstLight suggested that the effect of the roughness of the canal bed to the water level cannot be ignored. Therefore, different values for canal bed roughness were tested to determine the final roughness distribution as shown in Figure 7. This roughness distribution was fixed for all the remaining runs.

3.1.2 Validation Case 2

Validation Case 2 (5/27/2009 data) was selected to represent a mid-range flow condition (about 7500 cfs) with the fishway in operation. Results of the CFD simulation are discussed below.

Figure 16 shows an overall view of the velocity magnitude contours and in-plane velocity vectors at elevation 172 ft. A zoom-in view in the vicinity of the old entrance at elevation 172 ft is shown in Figure 17. Figure 18 shows the same content but in vertical planes through centerlines of gates. A zoom-in view through the centerlines of the old and new entrance is shown in Figure 19. Flow pathlines are shown in Figure 20. Similar to validation case 1, higher velocity flow is seen in the center of the canal as a result of gate settings and more flow passing through the middle gates. The swirling flow, similar to Validation Case 1, is from the right side toward left side downstream of the gatehouse. The flow from the old entrance was apparently deflected by the counter-clockwise eddy at the left bank downstream the old entrance.

Figure 21 shows the velocity in plane at elevation 172 ft at the gallery and slotted weirs. Symmetrical flow patterns are seen through the slotted weirs. In the fishway channel through the gatehouse, there is higher velocity close to the right side channel wall after exiting the last slotted weir (#7). Part of the flow turns right to follow the gallery to the new entrance and spillway ladder, and part of the flow turns left to approach the old entrance. A large counter clockwise back flow eddy was formed at the left side of the fishway channel between the old entrance and the last slotted weir.

Velocities in the attraction flow tunnel are shown in Figure 22 (at elevations 163 and 162 ft) and Figure 23 through Figure 25 (vertical planes through the Sloped diffuser). Some flow patterns can be improved:

- Flow approaches the sloped diffuser at velocity about 3 ft/s which may be considered attractive to fish, fish may be misled by this flow and possibly delay the migration to upstream;
- Back flow occurs above the sloped diffuser in the left channel;
- Flow moves into the tunnel from above through the floor openings upstream of the sloped diffuser in the left channel;
- Flow moves from the tunnel to above through the floor opening upstream the sloped diffuser in the middle channel;
- Flow moves from above into the tunnel with high velocity through the floor opening upstream of the sloped diffuser in the right channel.

Figure 26 shows a zoom-in view of the water surface elevation in the canal downstream of the gate house near the old and new entrances. The water level is higher at the new entrance side compared to the old entrance side. Figure 27 shows the water surface elevation near the old entrance where water levels were measured at points A and B. CFD model predicted and field measured water surface elevations at these points are shown in the figure and compared in Table 4. The comparison shows that the CFD model results are in good agreement with the field measurements (within 0.1 ft).

3.2 Base Conditions

3.2.1 Base 1: Low Flow

A CFD simulation was conducted for Base Case 1, a low flow condition (about 4900 cfs) with both the old and new entrances in operation corresponding to field conditions on 5/24/2008.

Figure 28 shows the total velocity contours and in-plane velocity vectors in plane at elevation 172 ft. Figure 29 shows a zoom-in view in the vicinity of the old entrance. Velocities in vertical planes through centerlines of the gates are shown in Figure 30, and a zoom-in view through the centerlines of the old and new entrances are shown in Figure 31. Figure 32 shows the 3D flow pathlines. Higher velocity flow can be seen in the center of the canal as a result of gate settings and more flow passing through the middle gates. The swirling flow from right side toward left side downstream of the gatehouse is significantly weaker compared with the intensity in the validation cases. A large counter-clockwise eddy is seen at the left bank downstream the old entrance. As a result, the attraction flow from the old entrance is deflected toward the center of the canal.

Figure 33 shows the velocity at elevation 172 ft in the gallery and slotted weirs. As expected, flow through the slotted weirs is symmetrical. In the fishway channel through the gatehouse, higher velocity flow is seen near the right side channel wall after exiting the last slotted weir. A large counter clockwise eddy forms along the left side of the fishway channel between the old entrance and the last slotted weir.

Velocities in the attraction flow tunnel are shown in Figure 34 (at elevations 163 and 162 ft) and Figure 35 through Figure 37 (vertical planes through the sloped diffuser). Some flow patterns similar to Validation Case 2 exist in the fish way channel through the gatehouse. Figure 38 shows a zoom-in view of the water surface elevation in the vicinity of the old and new entrances downstream the gate house in the canal. The water level is higher near the new entrance when compared to the old entrance side. Figure 39 shows the water surface elevation in the vicinity of the old entrance. Water levels were measured at points A and B. The CFD calculated and measured water surface elevations at these points are listed in the figure. Comparison of the CFD model predicted and field measured water surface elevations at these points is listed in Table 5. The differences between the CFD model and field data are within 0.1ft.

3.2.2 Base 2: High Flow

Another CFD simulation was also conducted (Base 2) for a moderately high flow condition (about 13,800 cfs) with both the old and new entrances in operation corresponding to field conditions on 5/20/2009.

Contours of velocity magnitude and in-plane velocity vectors at elevation 172 ft are shown in Figure 40. A zoom-in view in the vicinity of the old entrance is shown in Figure 41. Velocities in vertical planes through gate centerlines are shown in Figure 42, and a zoom-in view through the centerlines of the old and new entrances are shown in Figure 43. 3D flow pathlines are shown in Figure 44. Higher velocities are observed in the center of the canal. The swirling flow from the right side toward the left side downstream the gatehouse persisted. The counter-clockwise eddy along the left bank downstream the old entrance is significantly reduced when compared to previous simulations. The attraction flow from the old entrance moves straightly downstream. Backflow can be seen at the right side near the old entrance.

Velocity contours in the slotted weirs and gallery at elevation 172 ft are shown in Figure 45. Flow patterns in the upstream slotted weirs and fish way channel through the gatehouse are similar to that of the Base 1 Low Flow condition.

Velocities contours of the attraction flow are shown in Figure 46 (at elevations 163 and 162 ft) and Figure 47 through Figure 49 (vertical planes through the sloped diffuser). Again, some flow patterns similar to the Base 1 Low Flow case are observed in the fishway channel between the old entrance and the last slotted weir.

A zoom-in view of the water surface elevation in the vicinity of the old and new entrance downstream the gate house in the canal is shown in Figure 50. The water level is higher at new entrance side than at the old entrance. Figure 51 shows the water surface elevation contours in the vicinity of the old entrance. Water surface elevations were measured at points A and B. CFD calculated and measured water levels at these point are shown in the figure and compared in Table 4. The CFD model predicted water surface elevations are higher than the measured data by 0.2 to 0.3 ft.

3.3 Modifications

Based on the results of the validation and base cases, some flow patterns in the fishway channel through the gatehouse can be further improved and are summarized as follows:

- The velocity approaching the sloped diffuser is high and uneven. The high velocity may be delaying upstream movement;
- Back flow exists above the sloped diffuser in the left channel between the old entrance and the last slotted weir;
- Flow moves from above into the tunnel through the floor opening upstream of the sloped diffuser in the left and right channels;
- Flow moves from the tunnel to above through the floor opening upstream of the sloped diffuser in the middle channel;
- The water drop through the old entrance is too high. The near surface velocity is too high (about 13 ft/s) downstream the old entrance for Base 2.

3.3.1 Mod 1

Mod 0, as shown in Figure 52, was considered less effective than Mod 1 and therefore not considered for any further CFD simulations. Mod 1 was developed, as shown in Figure 53 and Figure 54. Mod 1 focused on the region inside the old entrance in the sloped diffuser area to achieve a design flow rate of 180 cfs through the old entrance. Modifications included:

- Adding a vertical concrete wall sitting on the existing left separation wall of the sloped diffuser to create a channel separating the flow to the old entrance from that flowing to the new entrance and spillway ladder;
- Closing the existing three upstream openings in the floor of the fish way just upstream of the diffuser (these openings were blocked for the 2012 season);
- Keeping a left diffuser opening of 18 ft at its downstream end and closing the remaining part of the left diffuser to form an extended floor for the left channel;
- Adding two single slotted weirs in the left channel between the 1st upstream slotted weir to the beginning of the opening of the left diffuser at about 10 ft spacing;

- Adding an orifice (3 ft wide by 4 ft high) at the entrance of the left tunnel to the diffuser to better control the desired flow (about 80 cfs) from the tunnel to the left channel through the reduced diffuser opening;
- Cutting down the sill at the old entrance from El. 168.2 to El. 166 and removing the stop-logs.

A simulation was conducted using the Mod 1 geometry with modified gates openings and Validation Case 2 flow conditions (Table 1), both the old and new entrances in operation. The purpose of modifying the gate openings was to try to reduce or eliminate the back eddy that formed on the left side of the canal in Validation Case 2 and Base Case 1. After discussion of limitations and alternatives, FirstLight suggested that the simplest arrangement was to open gates 14 and 15 by 6 ft, with the remaining gates open 3 ft. After discussion of the proposed gate arrangement, ALDEN suggested that Gate 2 be closed and Gate 13 opened 6 ft to compensate for closing Gate 2 (Table 1). Previous model runs indicated that the outflow from Gate 2 hits the right canal bank corner at about 45 deg toward the left, causing cross flow in the canal. Closing Gates 1 and 2 was intended to help minimize the cross flow to the left of the canal. It was also suggested that Gate 15 be opened no more than 6 ft. If opened greater than 6 ft, the flow quantity (momentum) would be high compared to flow from the old entrance, resulting in high velocity gradients and a larger back eddy.

Figure 55 shows the velocity magnitude contours and in-plane velocity vectors at elevation 172 ft. A zoom-in view in the vicinity of the old entrance is shown in Figure 56. Velocity in vertical planes through centerlines of gates 12 to 15 is shown in Figure 57, and a zoom-in view through the centerlines of the old and new entrance is shown in Figure 58. Figure 59 shows 3D flow pathlines downstream of the gatehouse. Flow with higher velocity is in the center of the canal. The swirling flow from right side toward left side downstream of the gatehouse is still clearly shown. A counter-clockwise eddy forms along the left bank downstream of the old entrance. The flow from the old entrance is significantly deflected by this eddy.

Velocities at elevation 172 ft within the gallery and slotted weirs is shown in Figure 60. Flow patterns in the upstream slotted weirs are similar to Validation Case 2. The new division wall separates the fishway between the old entrance and the existing last slotted weir into two channels: the right side, unchanged from the existing configuration, and the left side, with separate channel and additional slotted weirs. Flow exits the right slot of the last slotted weir toward the division wall, forming a small counter-clockwise eddy zone at the left corner and a clockwise eddy at the right side of the right channel. Flow smoothly follows the dividing wall and the transition connecting the dividing wall and left gallery wall. In the new left channel, flow passes through the two new slots and approaches the old entrance fairly uniformly.

Velocities contours of the attraction flow are shown in Figure 61 (at elevations 163 and 162 ft) and Figure 62 through Figure 64 (vertical planes through the sloped diffuser). Flow from the orifice in the attraction water tunnel is toward the left wall of the left diffuser channel, forming a high velocity zone along the left wall, the flow is a fairly uniform approaching the sloped diffuser, except for an area of higher flow at the upper corner of the sloped diffuser. Flow in the middle and right diffuser channels is fairly uniform.

Figure 65 shows the water surface elevation contours in the vicinity of the old and new entrances downstream of the gate house in the canal. The water level is higher at new entrance side than at the old entrance side. Figure 66 shows the water surface elevations in the modified area of the fish way. The averaged water drops along the pools are shown in Figure 67. Averaged water drops are about 0.8 ft between the 5th and 4th pools, 1.2 ft between 4th and 3rd pools, 0.4 ft between 3rd and 2nd pools, 1 foot between 2nd and upstream portion of 1st pool, and 0.1 ft between the downstream portion of 1st pool and the canal downstream of the old entrance. The water surface elevation is about 176.4 ft in the right side channel.

The flow rates through various locations is listed in Table 7. For a general clarification, the CFD calculated flow rates for the validation and base cases and Mod 2 are also listed in the same table. If the referred flow in the table does not apply for the case, a N/A (not available) note is shown. The calculated total gate flow is about 7940 cfs, the upstream slotted weir flow is 254 cfs of which 112 cfs passes through the new left channel and 142 cfs passes through the right channel. The attraction flow is 188 cfs of which 105 cfs passes through the left diffuser channel (through the orifice) and 83 cfs passes through the middle and right diffuser channels. The flow through the old and new entrance is 217 cfs and 185 cfs, respectively. The flow to the adjustable weir downstream of the gallery at the top of the spillway fishway is 40 cfs. The downstream spillway attraction flow is 228 cfs.

3.3.2 Mod 2

Based on the CFD results with Mod 1 the following conclusions are drawn:

- With the proposed modifications flow patterns inside the fishway were improved;
- The eddy on the left side of the canal side was not eliminated by more uniform gate openings. The main reason for the persistent eddy is that there is no flow from the gatehouse between the left bank of canal and Gate 15 (Gate 15 is about 30 ft away from the left bank of the canal), therefore, there is no reason to remove the rocky outcrop of the left bank. The eddy was minimized in Base 2 for the high flow condition;
- Refinement of the geometry is necessary to further improve flow conditions.

Building on Mod 1 results, additional refinements were made which resulted in Mod 2, shown in Figure 68 through Figure 70. Mod 1 was further refined to arrive at Mod 2 which included:

- Rev. 2.1: Adding a 1.5 ft wide baffle at the right side of the new left channel;
- Rev. 2.2: Narrowing the slot width of the added upstream slot in Mod 1 from 1 foot 9 inches in Mod 1 to about 1 foot 4 inches;
- Rev. 2.3: Removing the existing 1 foot wide baffle at the left side of the old entrance (which exists in all the simulations of Validation Case 1, Validation Case 2, Base 1, Base 2, and Mod 1) and adding a new 2.7 ft wide baffle at the right side of the old entrance to form a 3.3 ft opening;
- Rev. 2.4: Re-aligning the angled wooden diffuser in the left channel below the fishway to the end of the new extended fishway floor;
- Rev. 2.5: Enlarging the orifice at the entrance of the left tunnel to 4 ft wide by 4 ft high from 3 ft wide by 4 ft high.

Mod 2 was then tested under a pond level of 181.5 ft with a new gate openings provided by FirstLight (Table 8). The new gate openings were based on field observation of the canal at flows similar to the flow tested in Mod 2. Following this gate sequence and maintaining the total opening area as used in Mod 1, the final gate openings for Mod 2 are shown in Table 1.

Contours of velocity magnitude and in-plane velocity vectors at elevation 172 ft are shown in Figure 71. Figure 72 is a zoom-in view of the same content in the vicinity of the old entrance in the canal. Velocity in vertical planes through centerlines of gates 12 to 15 are shown in Figure 73, and a zoom-in view through the centerlines of the old and new entrances is shown in Figure 74. Figure 75 shows 3D flow pathlines in the canal. In general, flow shows a pattern of low velocity along the left side of the canal, then a high velocity zone, then a low velocity zone, and then high velocity along the right side of canal. This general canal flow pattern reflects the gate opening distribution. The swirling flow from the right side toward the left side downstream of the gatehouse is weakened. An upwelling is seen roughly in the middle of canal and at about 40 ft downstream from the gallery. Closer to the old entrance, a counter-clockwise eddy is formed along the left bank. The flow from the old entrance is initially oriented toward the left bank and straight downstream. The deflection by the back eddy of the flow from the old entrance has been reduced significantly.

Velocity contours at elevation 172 ft of the gallery and slotted weirs are shown inFigure 76. Flow patterns in the upstream slotted weirs, the right channel, and the gallery are similar to that of Mod 1. In the left new channel, flow passes through the two new slots and two baffles and approaches the old entrance fairly uniformly.

Velocities contours of the attraction flow are shown in Figure 77 (at elevations 163 and 162 ft) and Figure 78 through Figure 80 (vertical planes through the sloped diffuser). In the left diffuser channel, flow from the orifice is toward the left wall of the left diffuser channel, forming a high velocity zone along the left wall; but the flow adjusted fairly quickly to uniformly approach the re-oriented sloped diffuser. Although some higher velocity regions are still seen at the upper portion of the sloped diffuser, the velocity is significantly lower than in the flow from the slotted weir. Therefore, fish would not be attracted by the diffuser flow. Flow in the middle and right diffuser channels is fairly uniform.

Figure 81 shows the water surface elevations in the vicinity of the old and new entrance downstream of the gate house in the canal. The water level is higher at the new entrance side than at the old entrance side. Figure 82 shows the water surface elevation in the modified area of the fish way and Figure 83 shows the averaged water drops along the pools. The water surface elevation is about 176.4 ft in the right side channel. The averaged water drop is about 0.7 ft between the 5th and 4th pools, 0.7 ft between the 4th and 3rd pools, 0.7 ft between the 3rd and 2nd pools, 0.6 ft between the 2nd and upstream portion of 1st pool, 0.5 ft between the upstream portion and the downstream portion of 1st pool, and 1.2 ft between the downstream portion of the 1st pool and the canal downstream from the old entrance.

Flow distribution between various locations is listed in Table 7 and illustrated in Figure 84. The calculated total gate flow is Q3=7230 cfs. The upstream slotted weir flow is Q1=232 cfs, of which Q6=99 cfs through the left new channel and Q7=133 cfs to the right channel. The attraction flow is Q2=195 cfs of which Q4=102 cfs through the left diffuser channel through the orifice and Q5=93 cfs through the middle and right diffuser channels. The flow through the old entrance is Q8=201 cfs, the gallery flow is Q9=226 cfs which is split into the new entrance flow Q10=194 cfs and the adjustable weir (spillway) flow Q11=31 cfs. The spillway ladder flow Q11 is less than that of Mod 1 because the top of the weir was increased from El. 173.7 ft for Mod 1 to 174.5 ft for Mod 2. In Mod 1 simulation, the upstream water level is 175.7 ft and the adjustable weir top elevation is 173.7 ft, the corresponding water depth over the weir is 2 ft which is deeper than the normal water depth of 1.2 ft. During the meeting on 5/7/2012 with FirstLight, it was decided to raise the weir top elevation to 174.5 ft to have 1.2 ft water over the weir for Mod 2 simulation. The downstream spillway attraction flow is Q12=220 cfs.

4. CONCLUSIONS AND DISCUSSION

CFD modeling was used to better understand the characteristics of flow inside the fishway at the Turners Falls Gatehouse and derive conceptual modifications for improving the hydraulic condition for more efficient fish passage through the fishway. A 3D CFD model was developed for the existing geometry and structure configuration. The model was first validated using two flow conditions for which field data existed and then tested for two additional flow conditions.

The validations showed that the model was accurately reproducing the hydraulic conditions of interest. Based on the results of these simulations, three conceptual modifications (Mod 0, Mod 1, and Mod 2) were proposed. Geometric changes to the CFD model were then made to incorporate Mod 1 and Mod 2 and additional simulations were conducted to evaluate the effectiveness of the modifications. The model results of the currently existing (2012) configuration revealed flow patterns inside the fishway and in the canal that could be improved. In summary, this includes: 1) high and uneven approach velocities to the sloped diffuser which may be attractive to fish causing possible delay of migration, 2) a large eddy above the sloped diffuser at the left channel, 3) exaggerated flow complexity due to flow through the three floor openings upstream of the sloped diffusers, 4) larger than desired water drop through the old entrance, 5) a counter-clockwise eddy at the left bank of the canal downstream the old entrance deflecting the flow from the old entrance, and 6) cross flow from right to left side of the canal.

Results of Mod 1 can be summarized as follows: 1) the modifications showed improvement to the flow patterns inside the fishway, 2) further improvements were needed to lower the water drops between the upstream portion of the 1st pool and 2nd pool, and between the 3rd pool and the 4th pool inside the fishway, 3) the back eddy along the left side of canal downstream of the old entrance had significant impact on the flow from the old entrance and that eddy was not eliminated by more uniform gate openings.

Results of Mod 2 can be summarized as follows: 1) Flow patterns inside the fishway and in the canal downstream of the old entrance and gatehouse were further improved compared to Mod 1, 2) averaged water drop was about 0.7 ft between the 5th and 4th pools, 0.7 ft between the 4th and 3rd pools, 0.7 ft between the 3rd and 2nd pools, 0.6 ft between the 2nd and upstream portion of the 1st pool, 0.5 ft between the upstream portion and downstream portion of the 1st pool, and 1.2 ft between the downstream portion of the last section of pool and the canal downstream of the old entrance, 3) flow from the old entrance is affected less by the back eddy on the left side of the canal, 4) A gate operating sequence was developed to improve the flow pattern in the canal. The back eddy persisted at the left side of the canal downstream from the old entrance and the eddy was not eliminated by manipulations of different gate openings. However, its impact on the flow from the old entrance was limited with the Mod 2 configuration and flow conditions.

CFD modeling results indicate that Mod 2 would provide enhanced hydraulic condition for fish passage. Some fine tuning and optimization of this concept may be conducted in the field.

5. REFERENCES

Bruce J. Pennino and George E. Hecker, 1975 "Model Studies of the Proposed Turners Falls Fish Passage Facilities for Northeast Utilities Service Company", Alden Research Laboratory, Worcester Polytechnic Institute, Holden, Massachusetts.

Table 1 Width and Height and Openings of Each Gate for CFD Simulations

Gate	Number	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
	Width ft	8	8	8	8	8	8.7	9.25	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
	Height ft	10	10	10	10	10	10	12	12	12	12	12	12	12	12	12
Openings ft	Validation 1	8.7	9.3	5.9	9.6	9.4	9.7	11.3	8.2	closed	Blocked	3	3	3	2.9	Closed
	Validation 2	0.3	Closed	Closed	4.9	9.5	9.2	2.9	3	3.3	Blocked	3	3	3	3	Closed
	Base 1	0.3	Closed	Closed	Closed	Closed	7.8	3	2.9	3	Blocked	3	3	3	3	Closed
	Base 2	8.9	8.9	9.4	10	9.5	9.2	10.5	3	3.1	Blocked	2.9	3	2.9	3	Closed
	Mod 1	6	6	6	3	3	3	3	3	3	Blocked	3	3	3	Closed	Closed
	Mod 2	10	10	2	2	2	2	2	2	2	Blocked	2	2	7	closed	Closed

Table 2 Boundary Conditions

	Pond Water Level	Keith Bridge Water Level	CFD Downstream Boundary Water Level	Spillway Adjustable Weir		AWG 15 Opening	AWG 16 Opening	AWG 27 Opening	AWG 28 Opening
				Upstream Water Level	Weir Top El.				
	ft	ft	ft	ft	ft	ft	ft	ft	ft
Validation 1	180.2	173.9	174.1	Not Operating					
Validation 2	182.0	173.7	173.8	175.7	173.7	Closed	2.1	Closed	1.9
Base 1	182.2	173.7	173.7	175.1	173.4	1.0	Closed	Closed	1.4
Base 2	181.5	173.6	173.6	176.0	173.8	2.7	Closed	Closed	2.0
Mod 1	182.0	173.7	173.8	175.7	173.7	Closed	2.1	Closed	1.9
Mod 2	181.5	173.7	173.8	175.7	174.5	Closed	2.1	Closed	1.9

Table 3 Water Surface Elevation Comparison of Validation Case 1

Point	Water Surface Elevation (ft)		
	Measured	CFD	Difference
A	174.2	174	0.2
B	174.1	174	0.1
C	175.1	174.6	0.5
D	175	174.7	0.3
E	174.9	174.8	0.1
F	175.1	174.9	0.2

Table 4 Water Surface Elevation Comparison of Validation Case 2

Point	Water Surface Elevation (ft)		
	Measured	CFD	Difference
A	173.5	173.5	0.0
B	176.0	175.9	0.1

Table 5 Water Surface Elevation Comparison of Base 1 Low Flow

Point	Water Surface Elevation (ft)		
	Measured	CFD	Difference
A	173.5	173.6	0.1
B	175.2	175.3	0.1

Table 6 Water Surface Elevation Comparison of Base 2 High Flow

Point	Water Surface Elevation (ft)		
	Measured	CFD	Difference
A	173.8	174.0	0.2
B	176.1	176.4	0.3

Table 7 Calculated Flow Distribution

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Validation 1	N/A	N/A	13,400	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Validation 2	254	202	7,732	N/A	N/A	N/A	N/A	260	196	162	34	218
Base Case 1	271	105	5,605	N/A	N/A	N/A	N/A	228	148	132	16	180
Base Case 2	208	327	12,562	N/A	N/A	N/A	N/A	320	215	184	31	258
Mod 1	254	188	7935	105	83	112	142	217	225	185	40	228
Mod 2	232	195	7230	102	93	99	133	201	226	194	31	220
Note: 1) Flow rate in cfs; 2) Refer to Figure 84 for locations. Q1: Upstream slotted weir flow; Q2: Upstream attraction flow; Q3: Gate flow; Q4: Orifice flow; Q5: Middle and right diffuser flow; Q6: Left new channel flow; Q7: Right channel flow; Q8: Old entrance flow; Q9: Gallery flow; Q10: New entrance flow; Q11: Adjustable weir flow; Q12: Spillway attraction flow												

Table 8 A New Set of Gate Openings Provided by FirstLight

Step	Action	Step	Action
1	Open gate 15 through 3 two ft, starting with gate 15 towards gate 3;	13	Open Gate 7 seven ft;
2	Open Gate 15 all the way;	14	Open Gate 13 all the way;
3	Open Gate 14 all the way;	15	Open Gate 12 all the way;
4	Open Gate 3 seven ft;	16	Open Gate 4 all the way;
5	Open Gate 13 six ft;	17	Open Gate 11 all the way;
6	Open Gate 12 six ft;	18	Open Gate 10 all the way;
7	Open Gate 4 seven ft;	19	Open Gate 5 all the way;
8	Open Gate 11 six ft;	20	Open Gate 9 all the way;
9	Open Gate 10 six ft;	21	Open Gate 8 all the way;
10	Open Gate 5 seven ft;	22	Open Gate 7 all the way;
11	Open Gate 9 seven ft;	23	Open Gate 3 all the way;
12	Open Gate 8 seven ft;	24	Open Gate 2 all the way.
Closing gates should be in reverse order.			

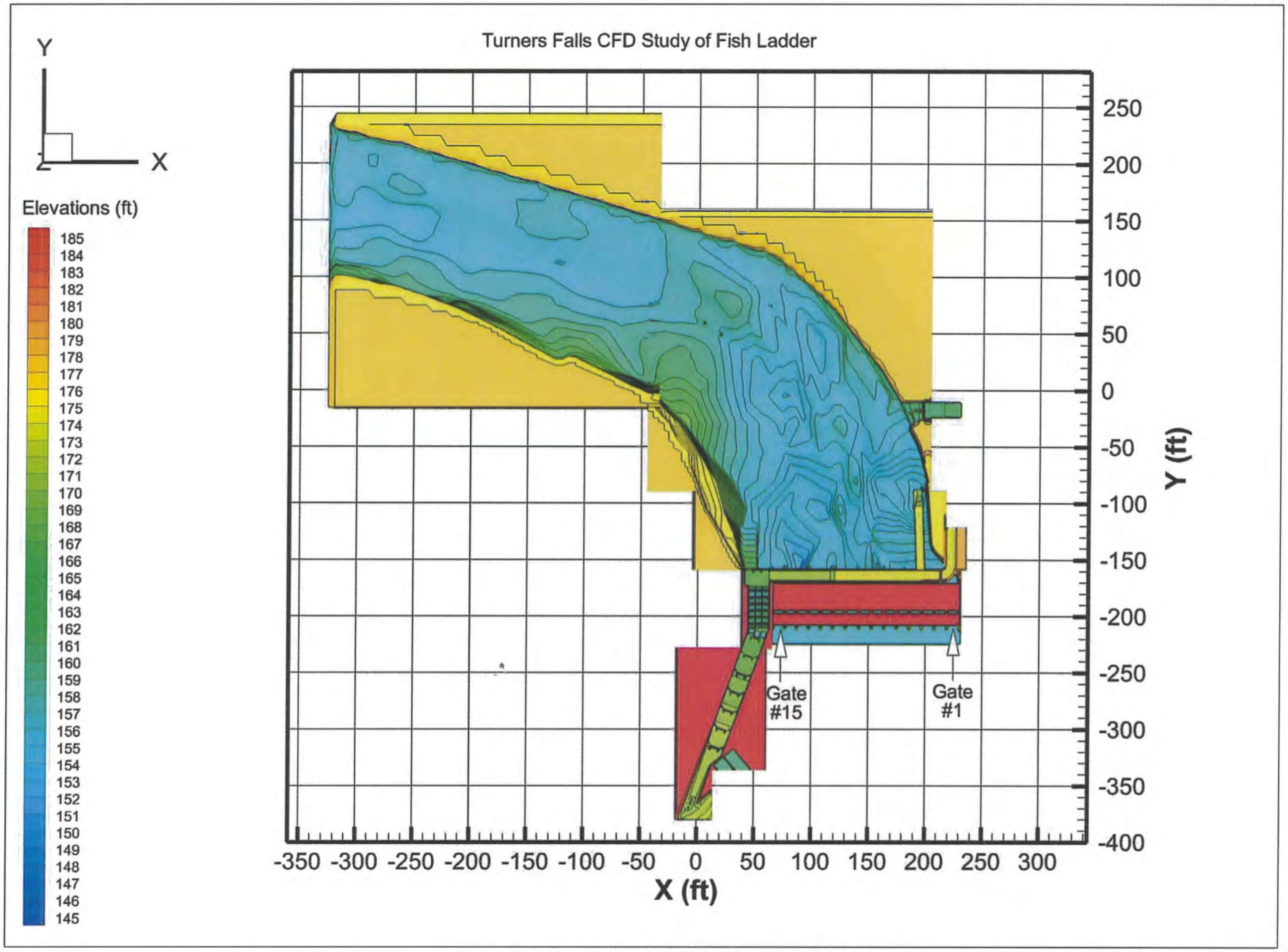


Figure 1 Plan View of the CFD Model

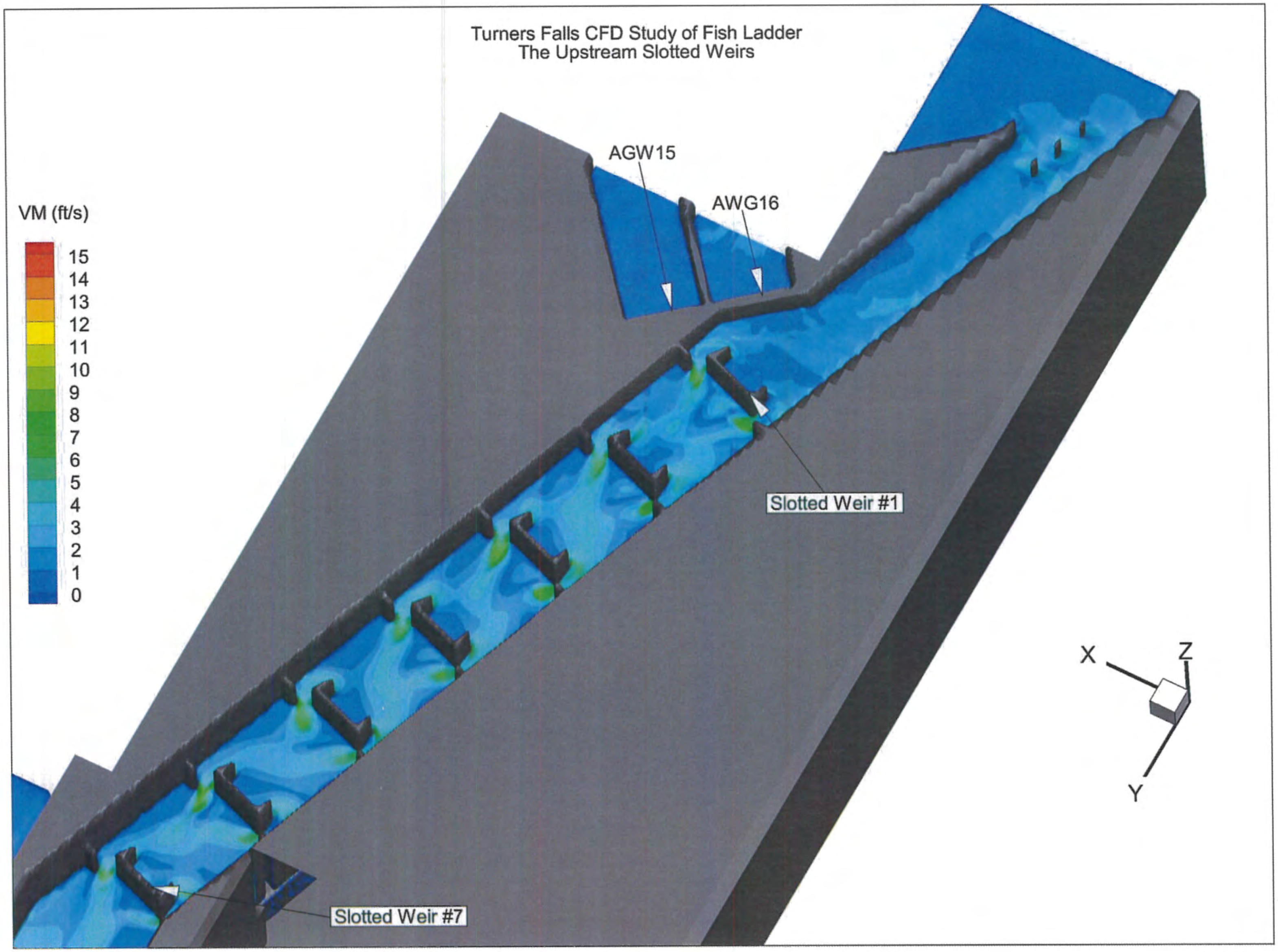


Figure 2 Zoom-in View of the Upstream Slotted Weirs

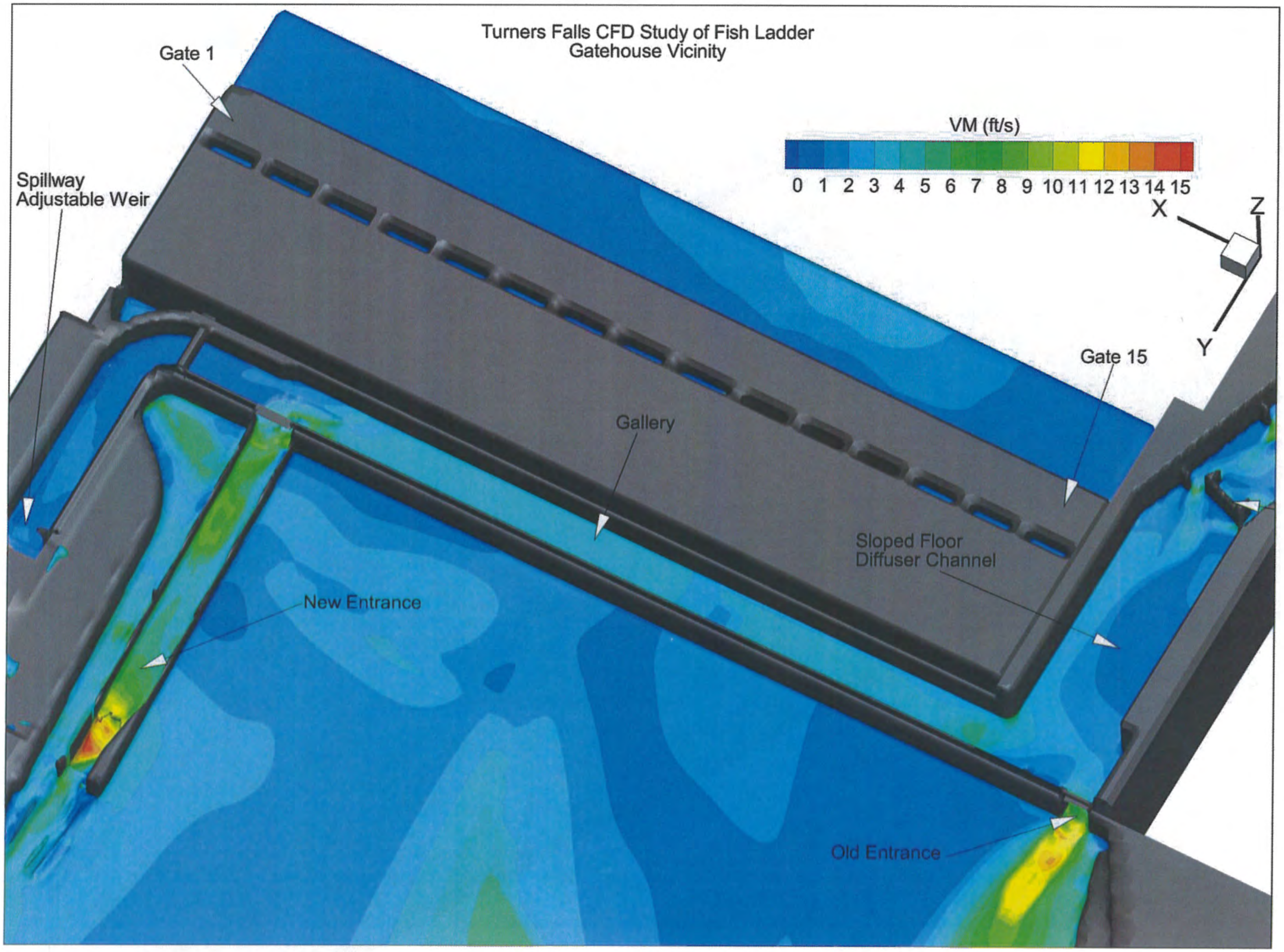


Figure 3 Zoom-in View of the Gatehouse and Vicinity

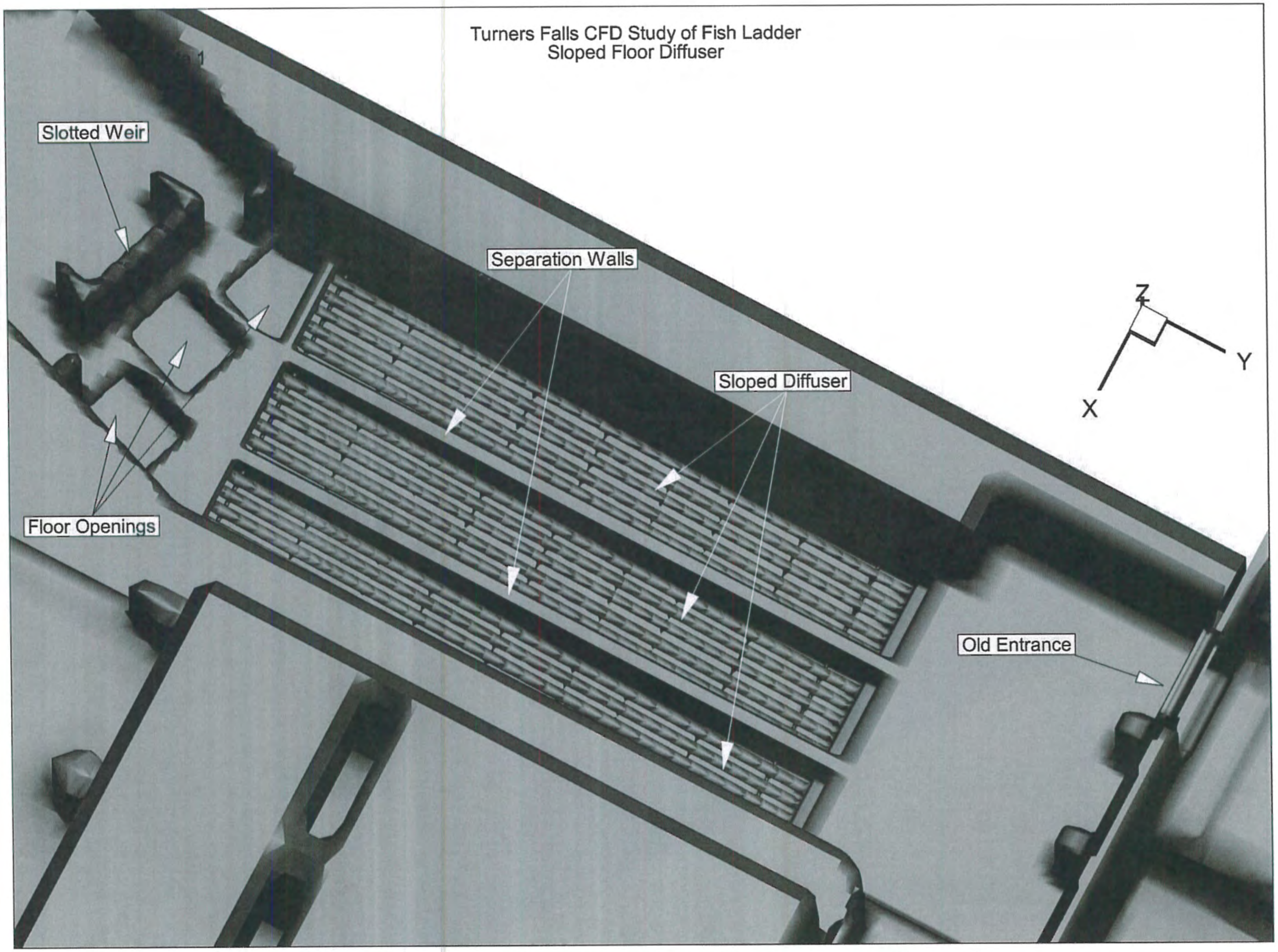


Figure 4 Zoom-in View of the Sloped Floor Diffuser Channel

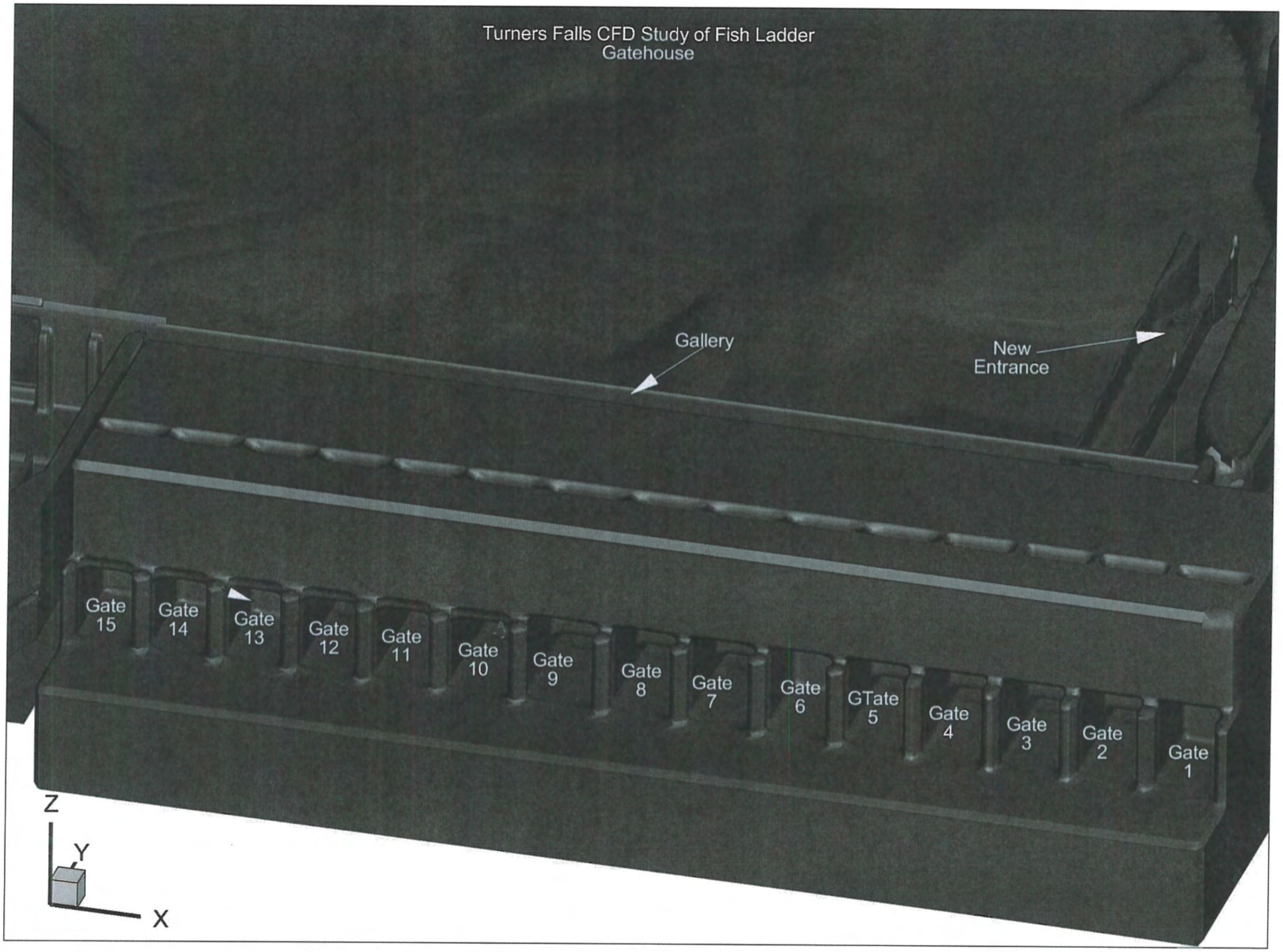


Figure 5 Zoom-in View of the Gatehouse Gates and Vicinity

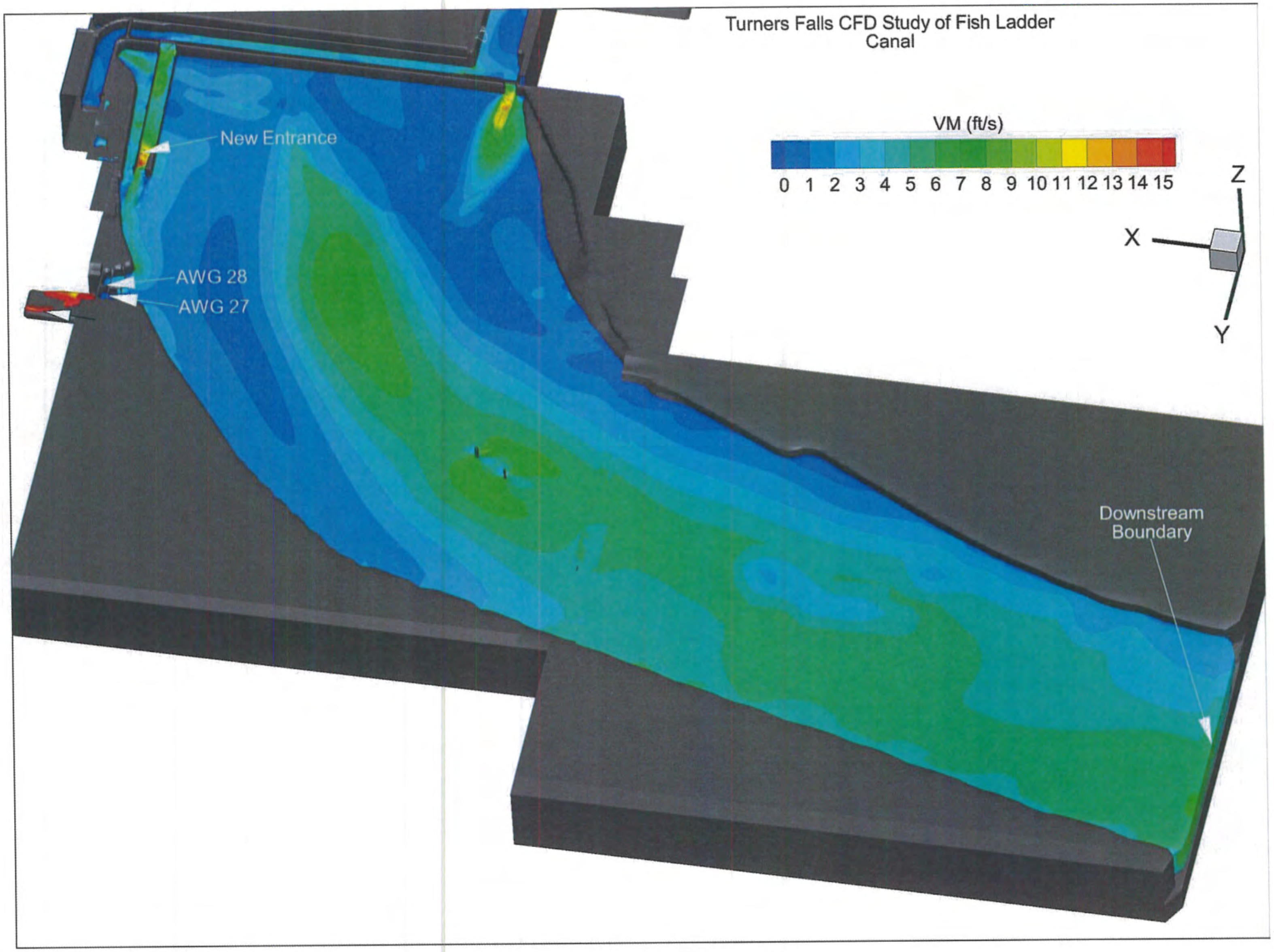


Figure 6 Canal Channel

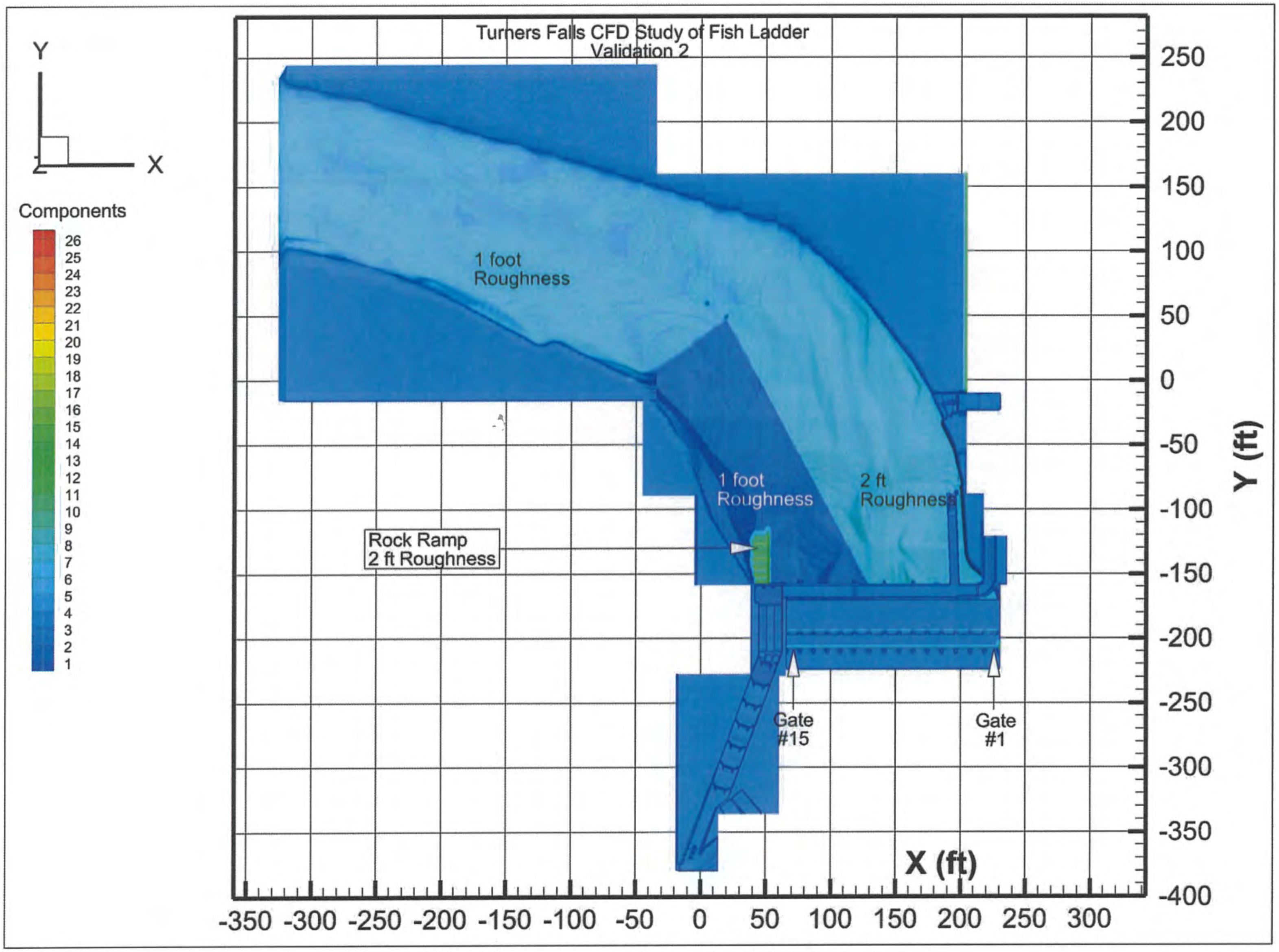


Figure 7 Roughness Height Distribution in the Canal

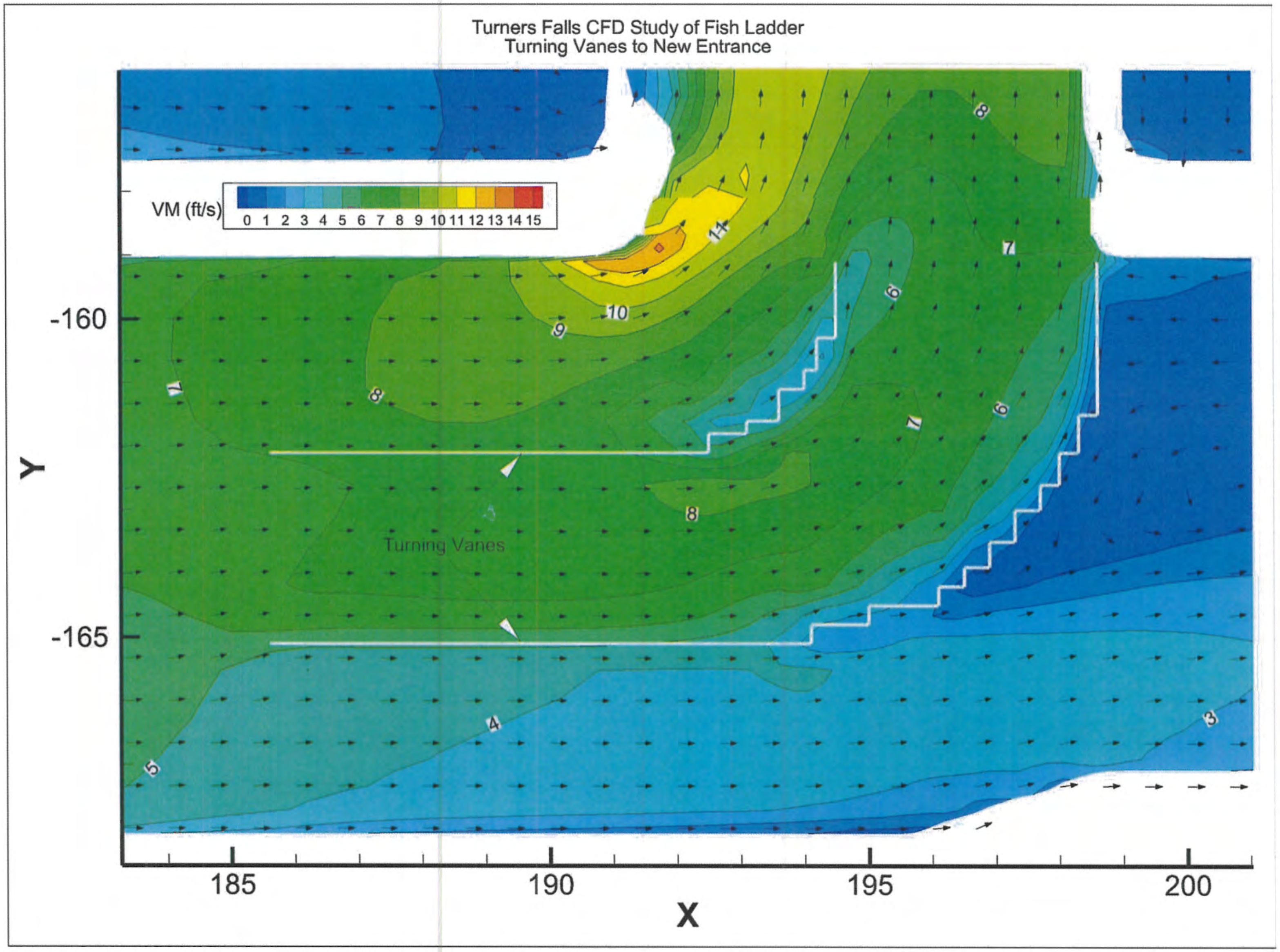


Figure 8 Simplification of Turning Vanes to New Entrance in the Gallery

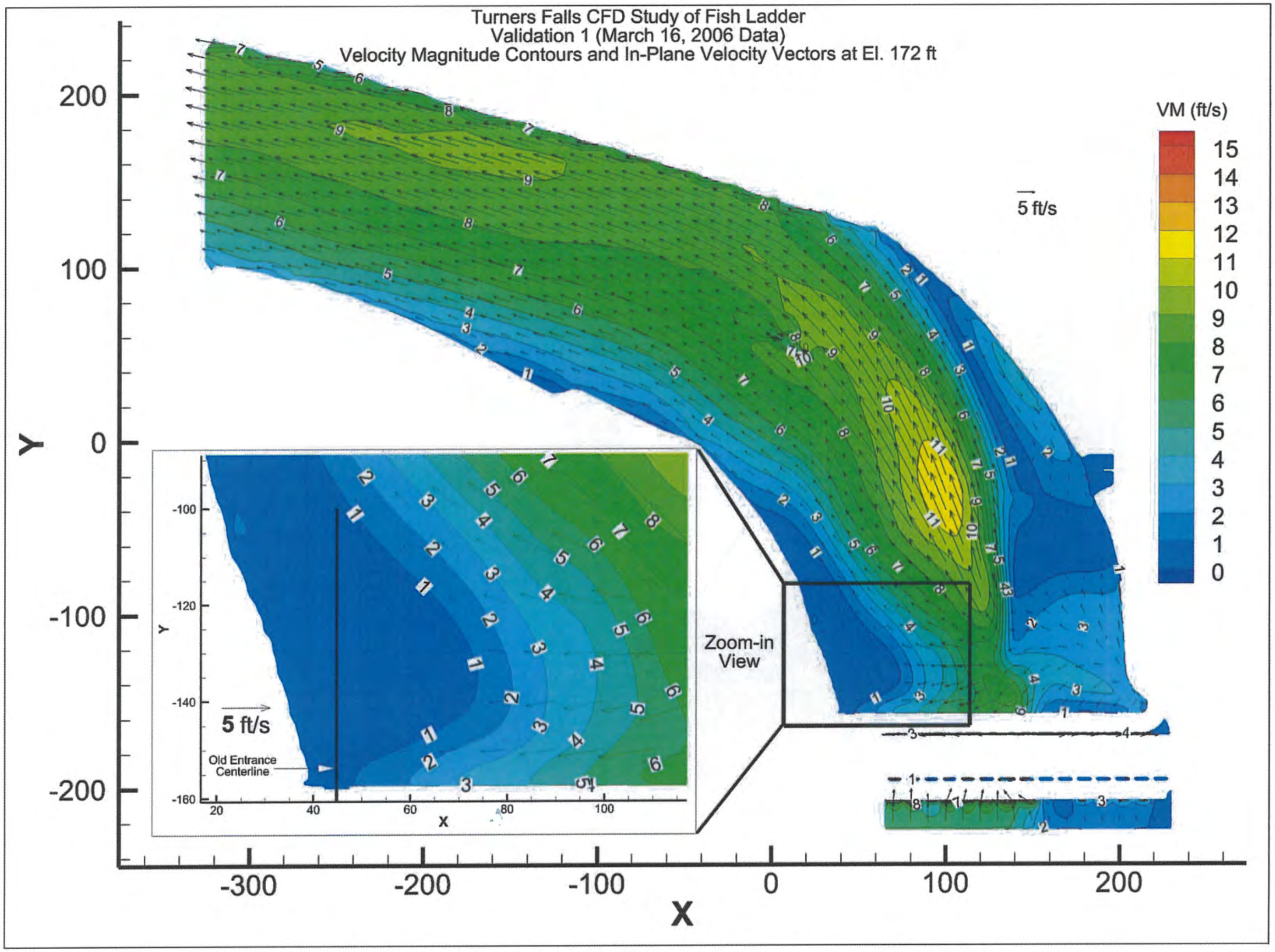


Figure 9 Validation Case 1: Velocity in Plane at Elevation 172 ft

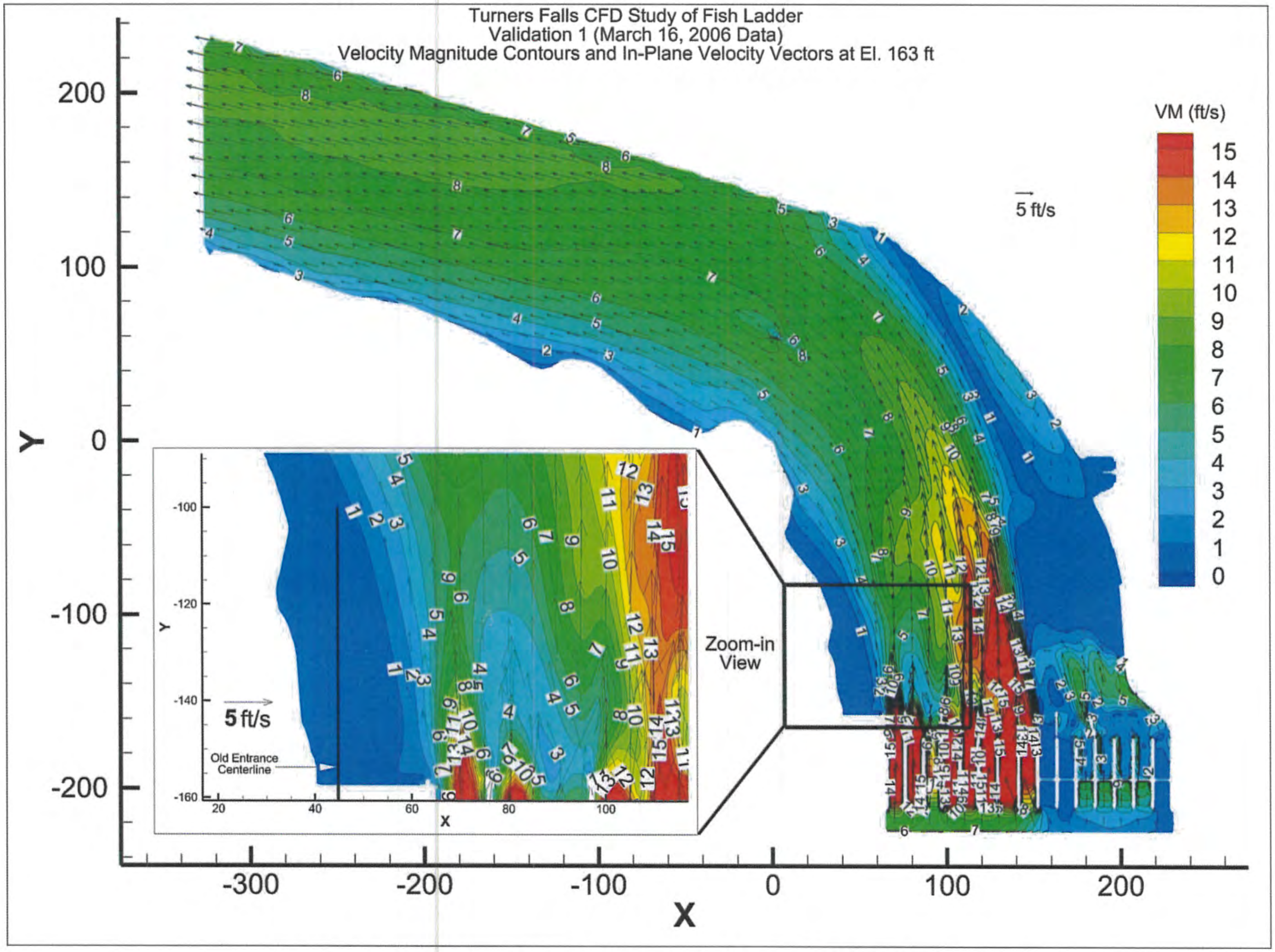


Figure 10 Validation Case 1: Velocity in Plane at Elevation 163 ft

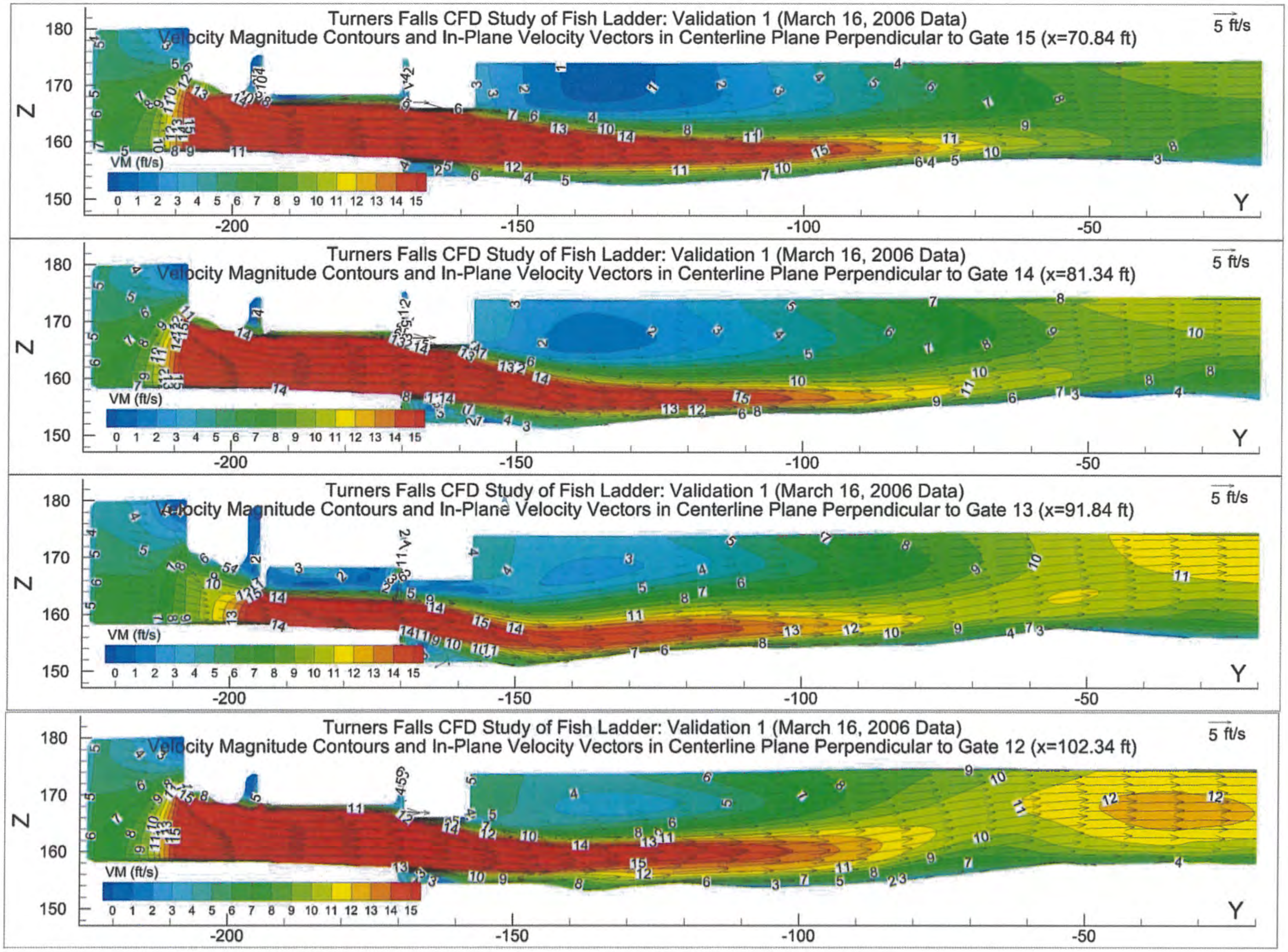


Figure 11 Validation Case 1: Velocity in Sectional Planes (Gates 12 through 15)

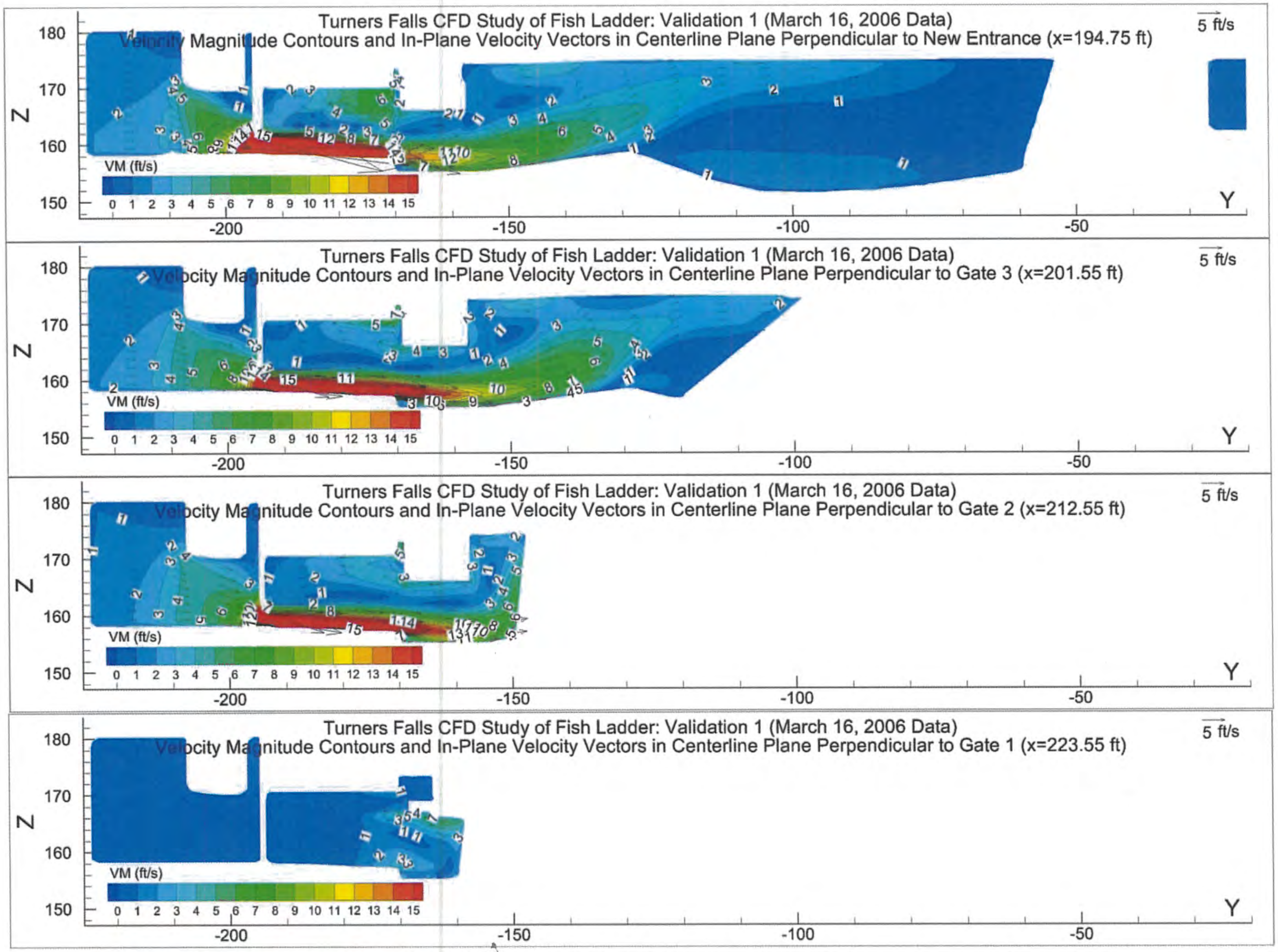


Figure 12 Validation Case 1: Velocity in Sectional Planes (Gates 1 through 3 and New Entrance)

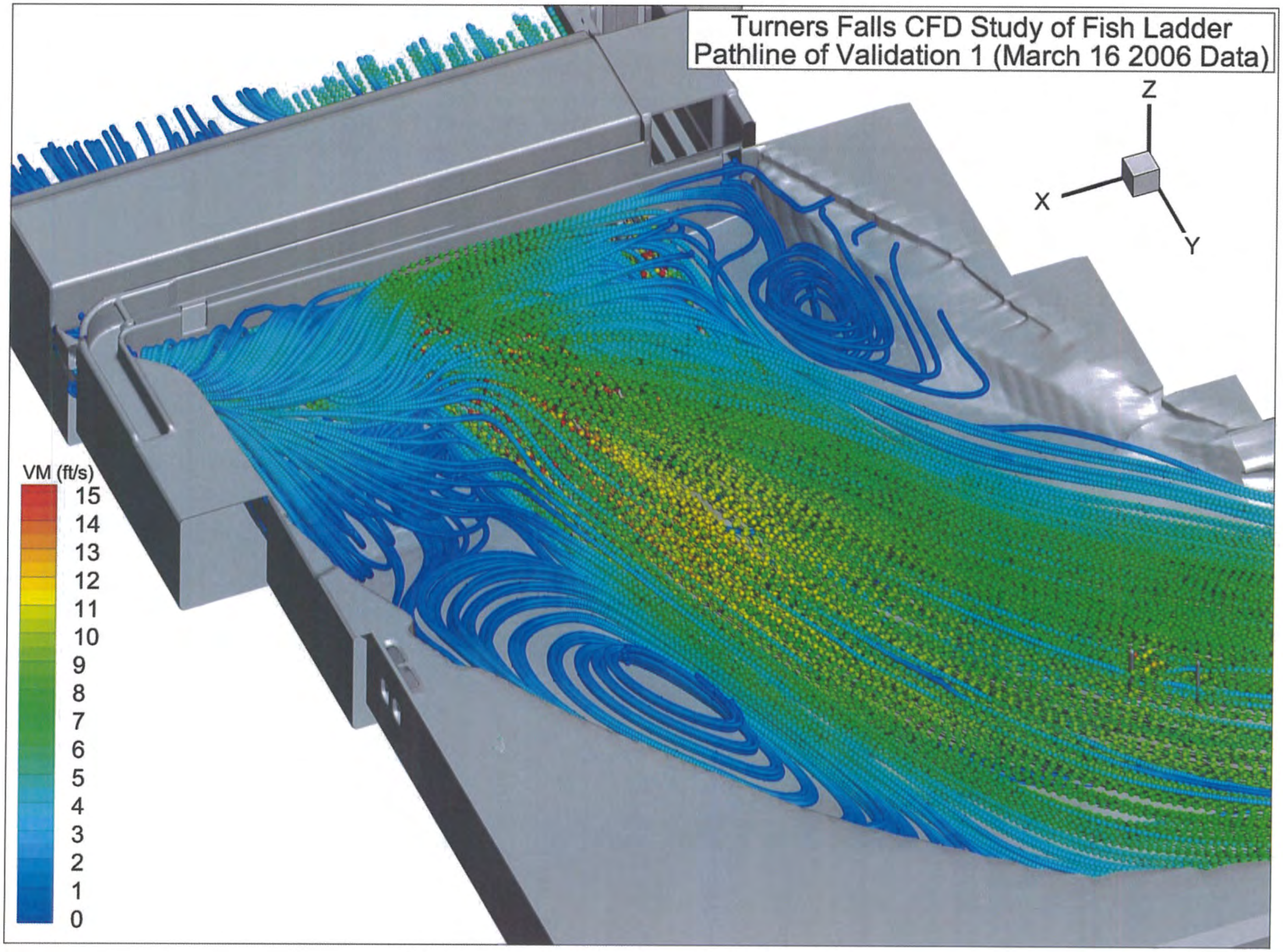


Figure 13 Validation Case 1: 3D Pathlines

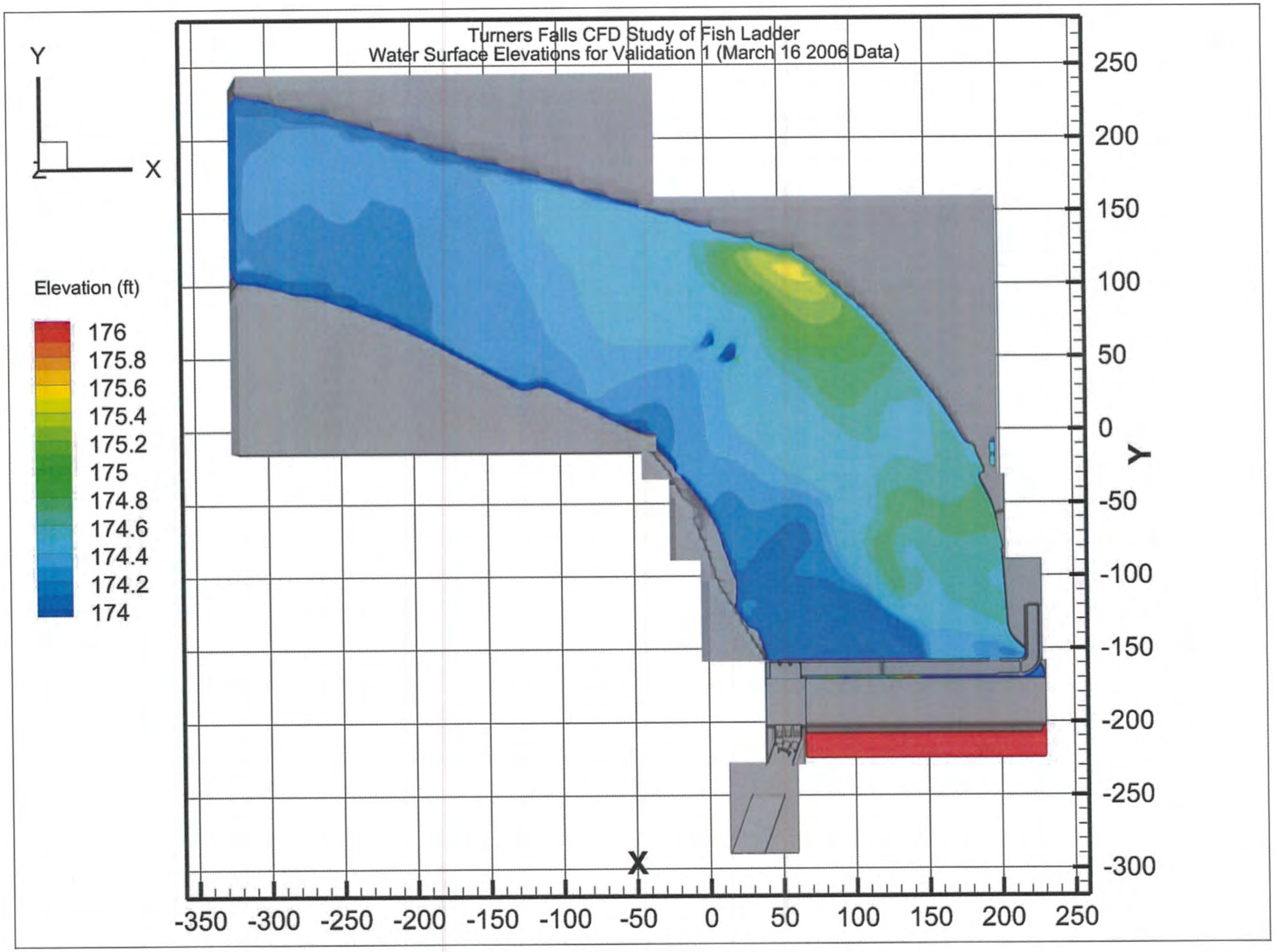


Figure 14 Validation Case 1: Water Surface Elevation

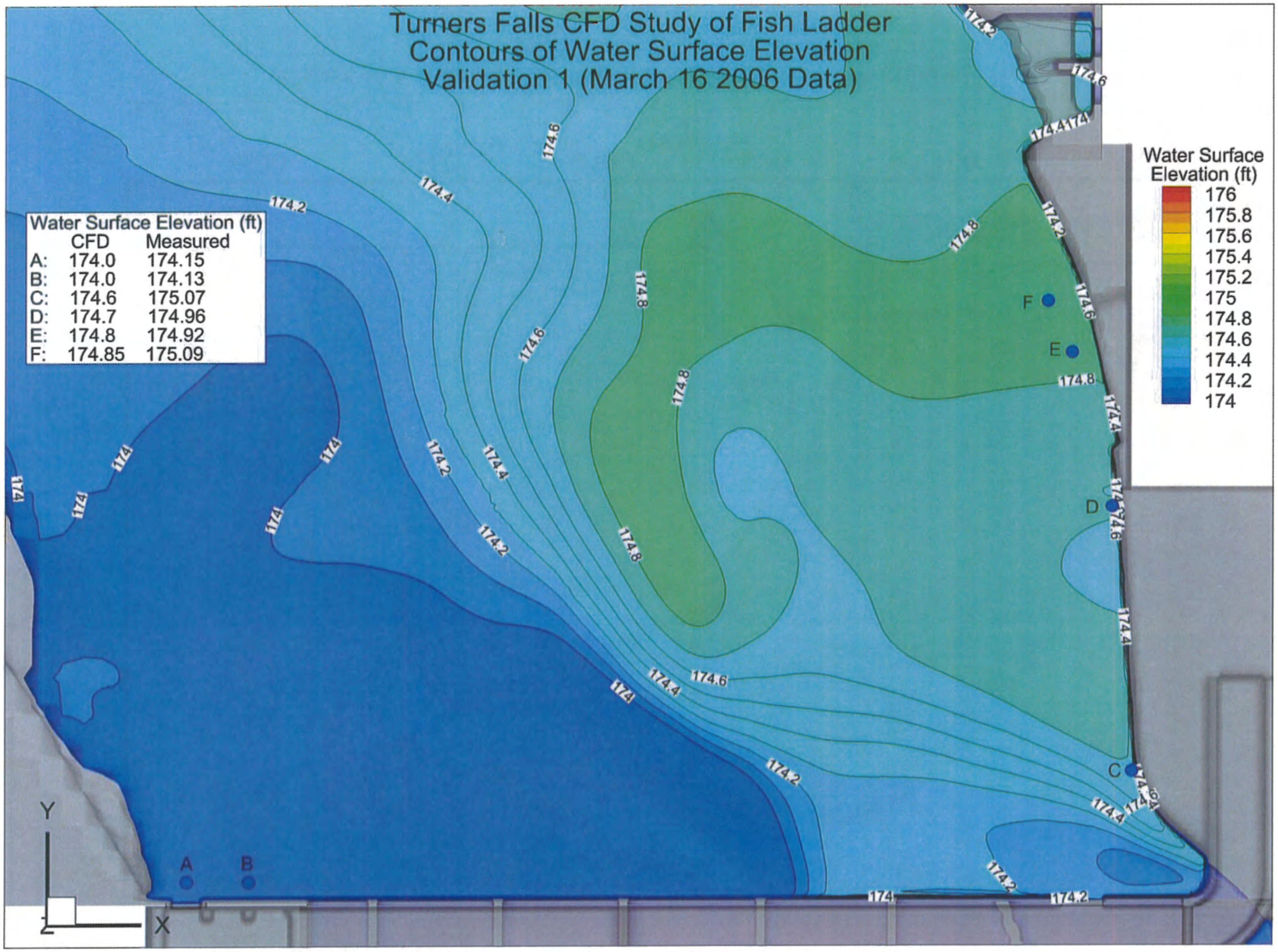


Figure 15 Validation Case 1: Water Surface Elevations and Measurement Points

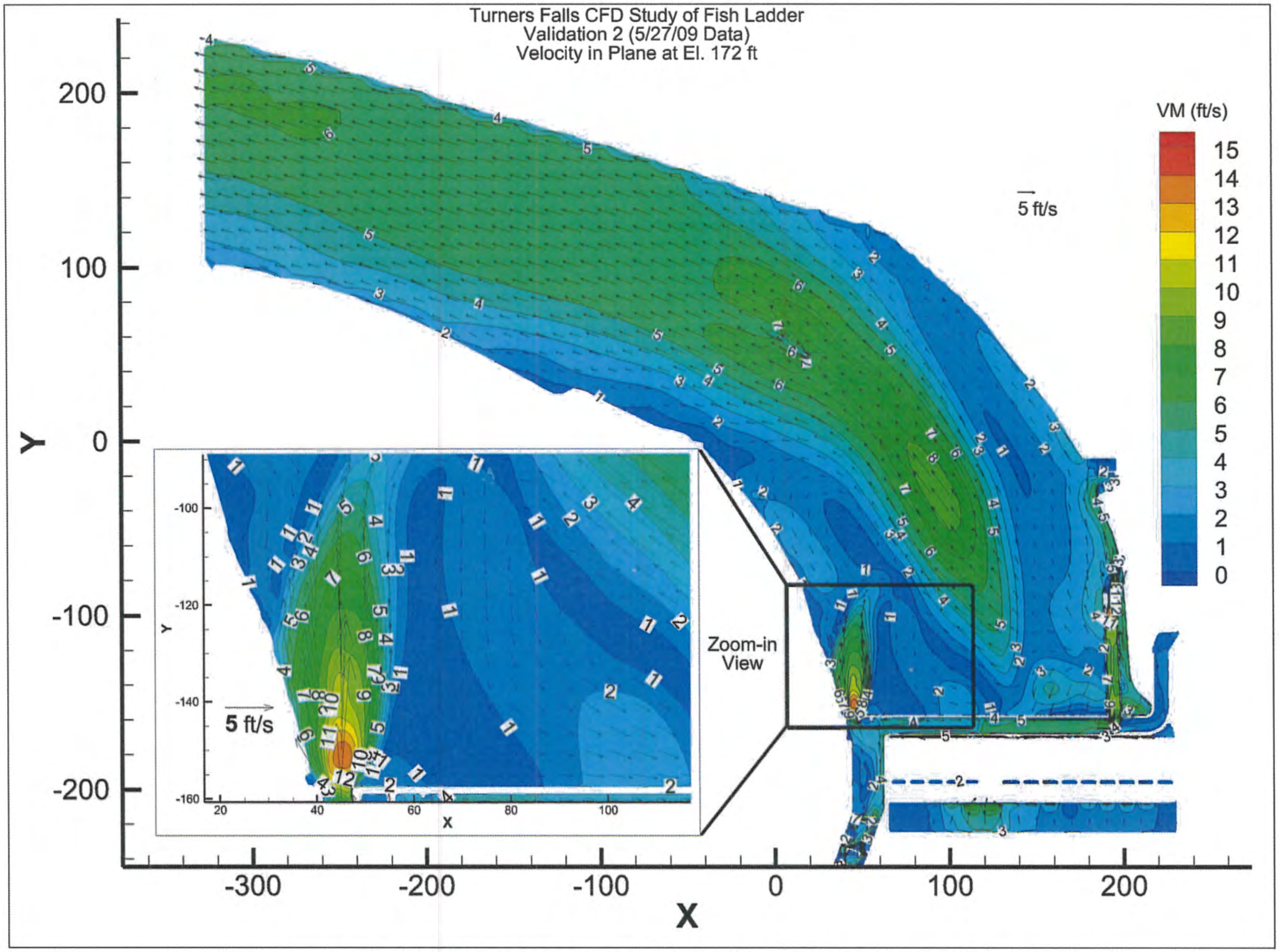


Figure 16 Validation Case 2: Velocity in Plane at Elevation 172 ft

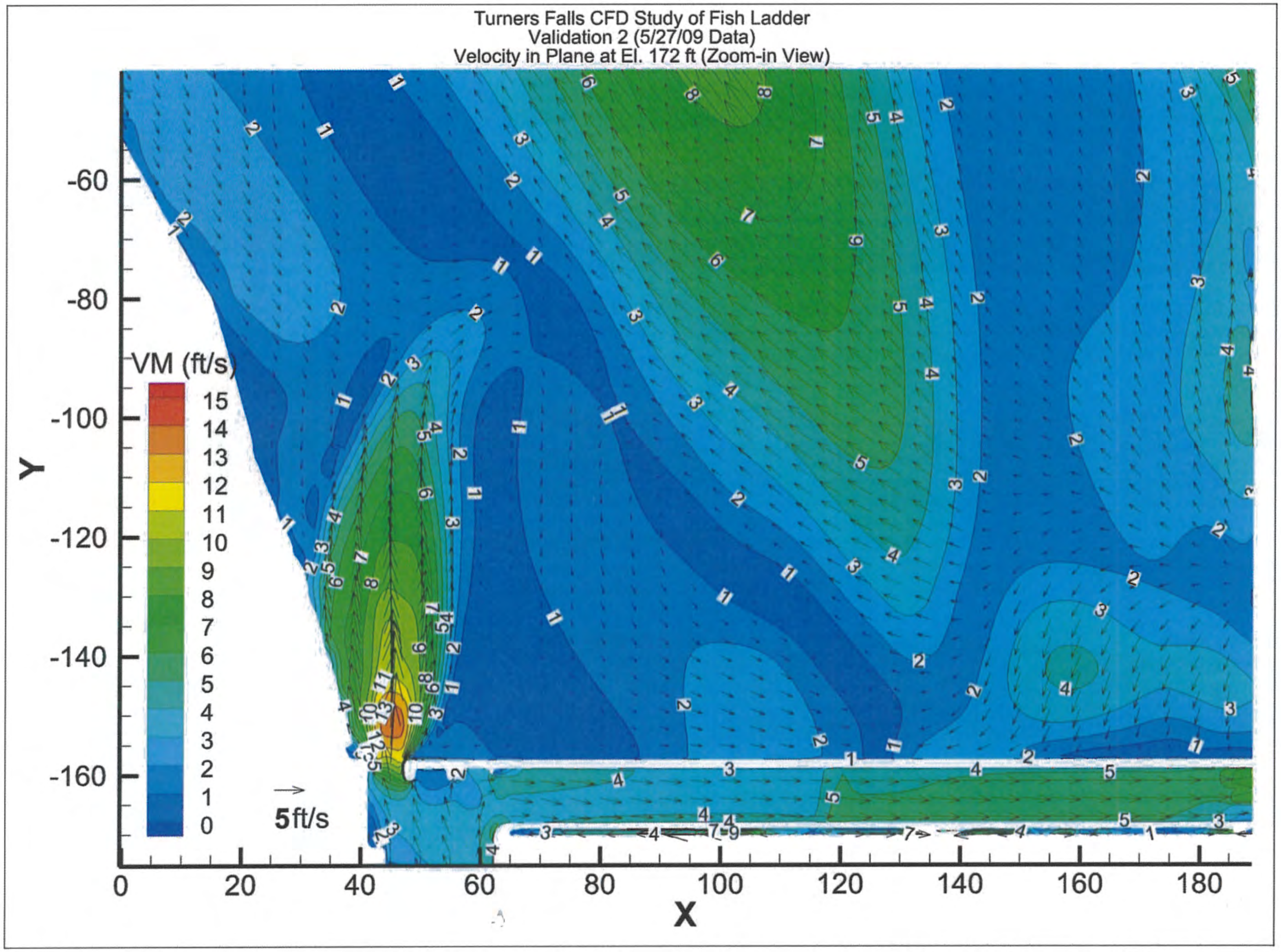


Figure 17 Validation Case 2: Velocity in the Vicinity of Old Entrance in the Canal in Plane at El. 172 ft

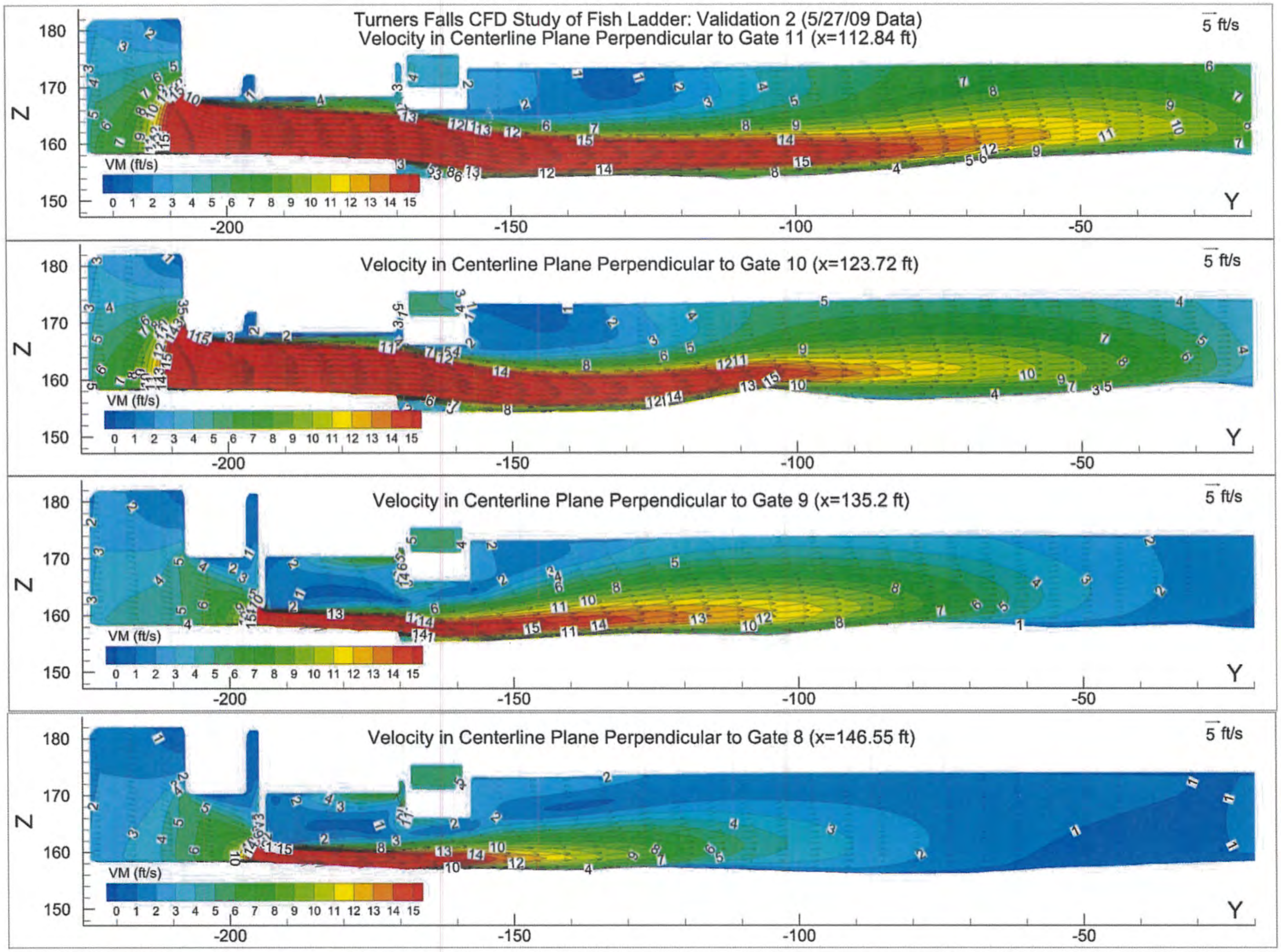
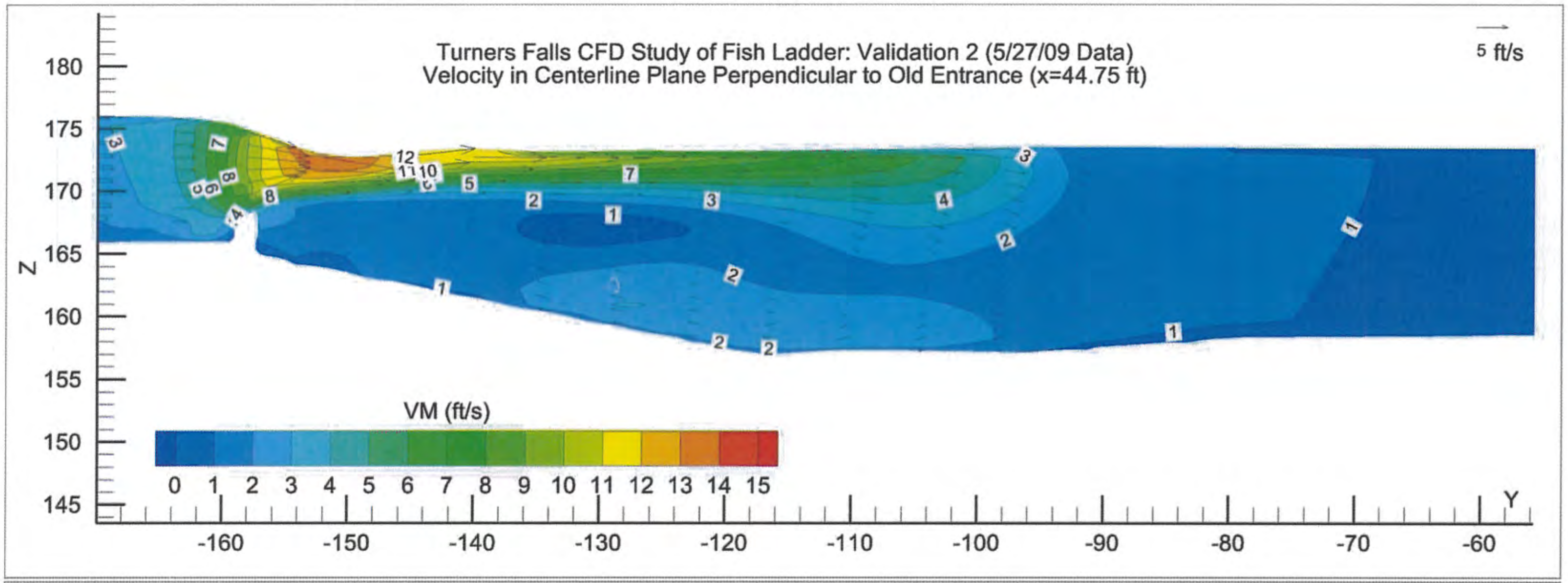


Figure 18 Validation Case 2: Velocity in Centerlines Planes of Gates 8 through 11



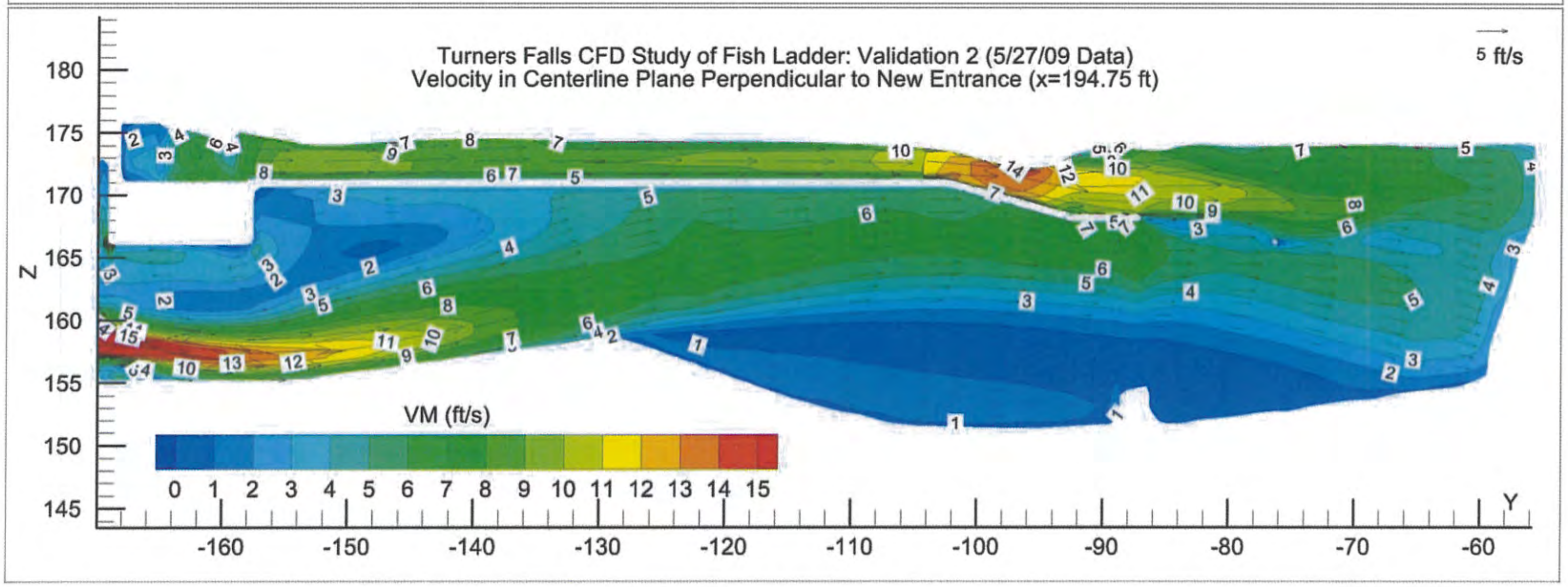


Figure 19 Validation Case 2: Velocity in Centerline Planes of Old and New Entrances

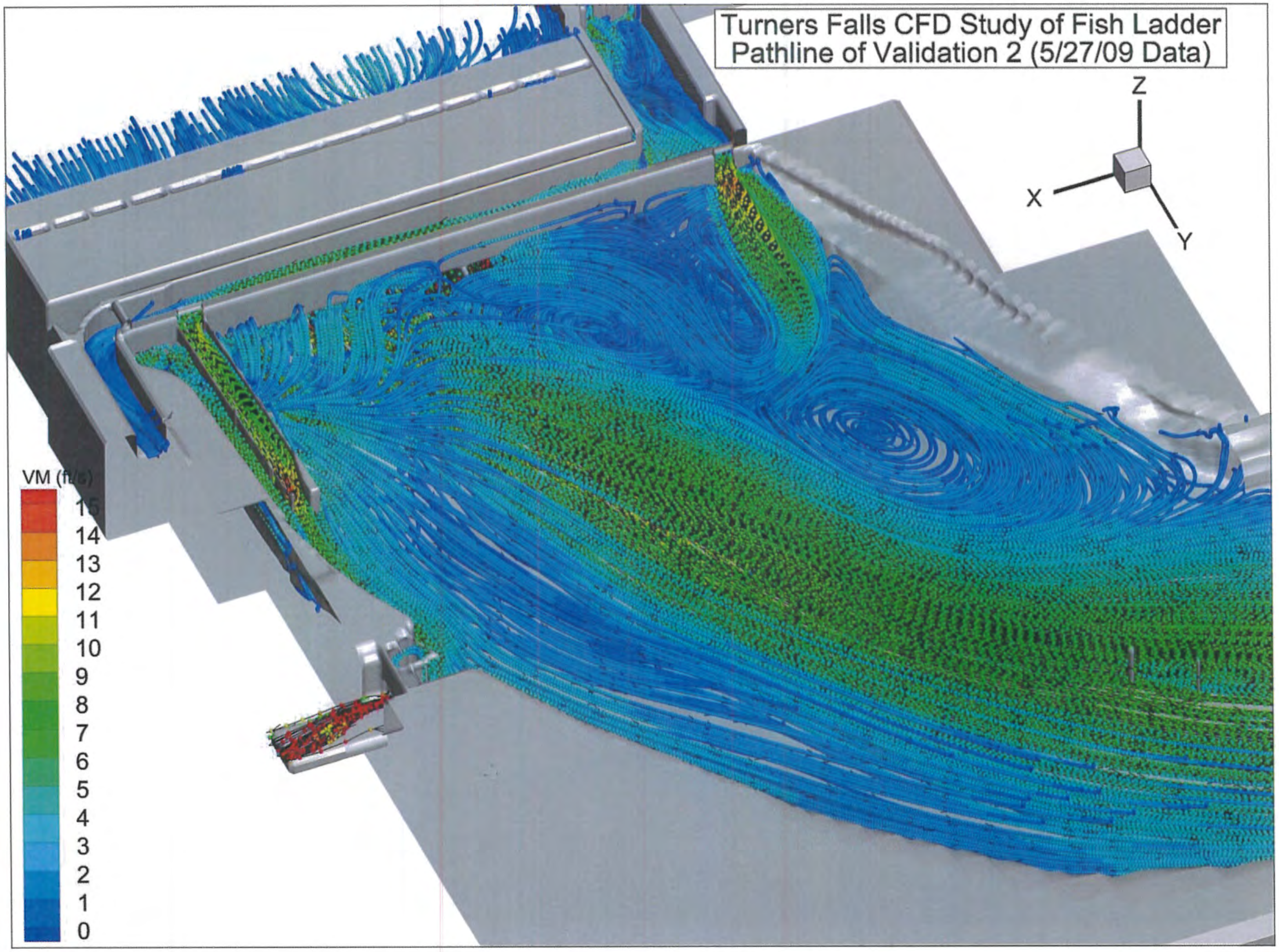


Figure 20 Validation Case 2: 3D Pathlines

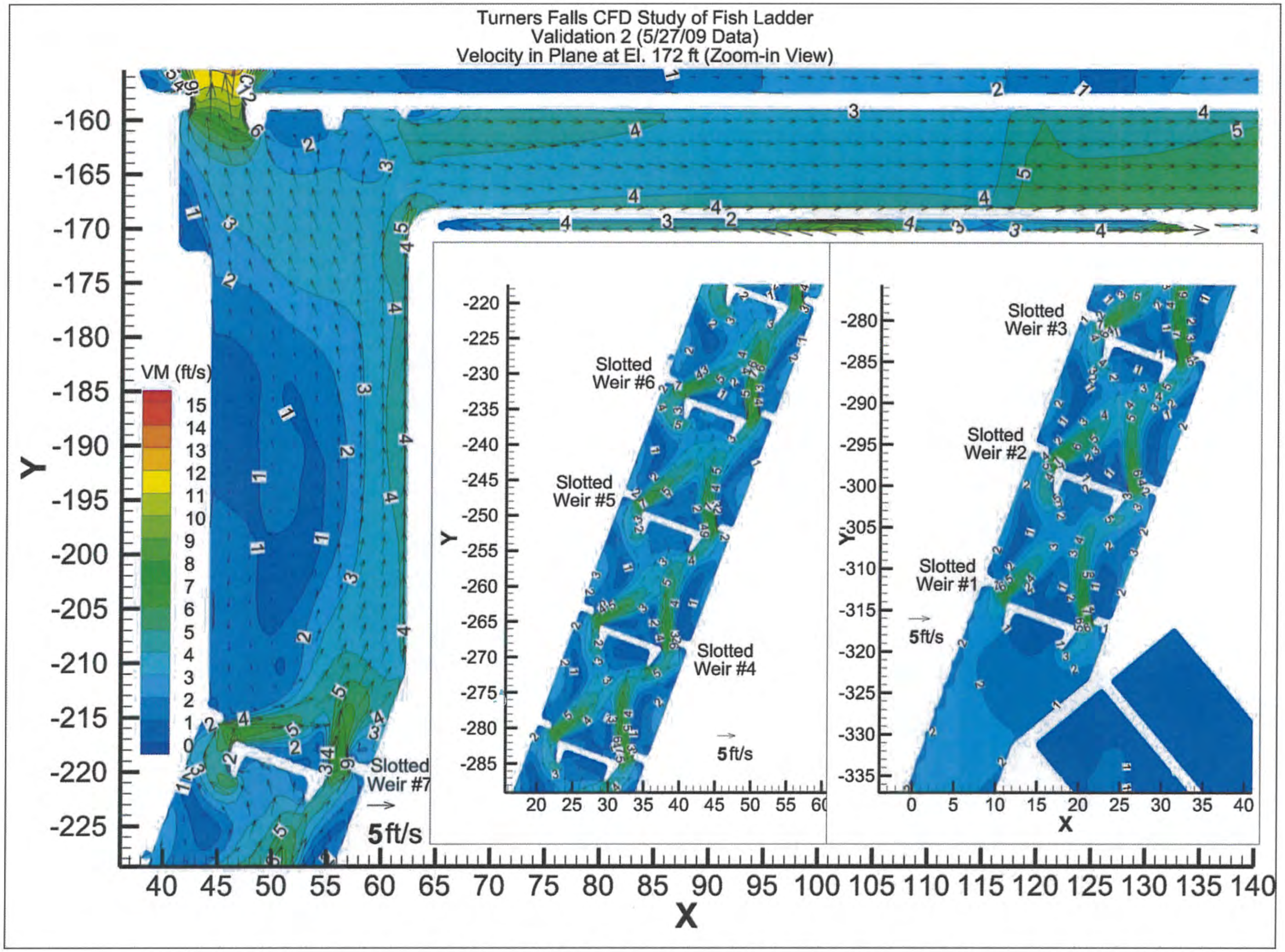


Figure 21 Validation Case 2: Velocity in the Gallery and Slotted Weirs in Plane at El. 172 ft

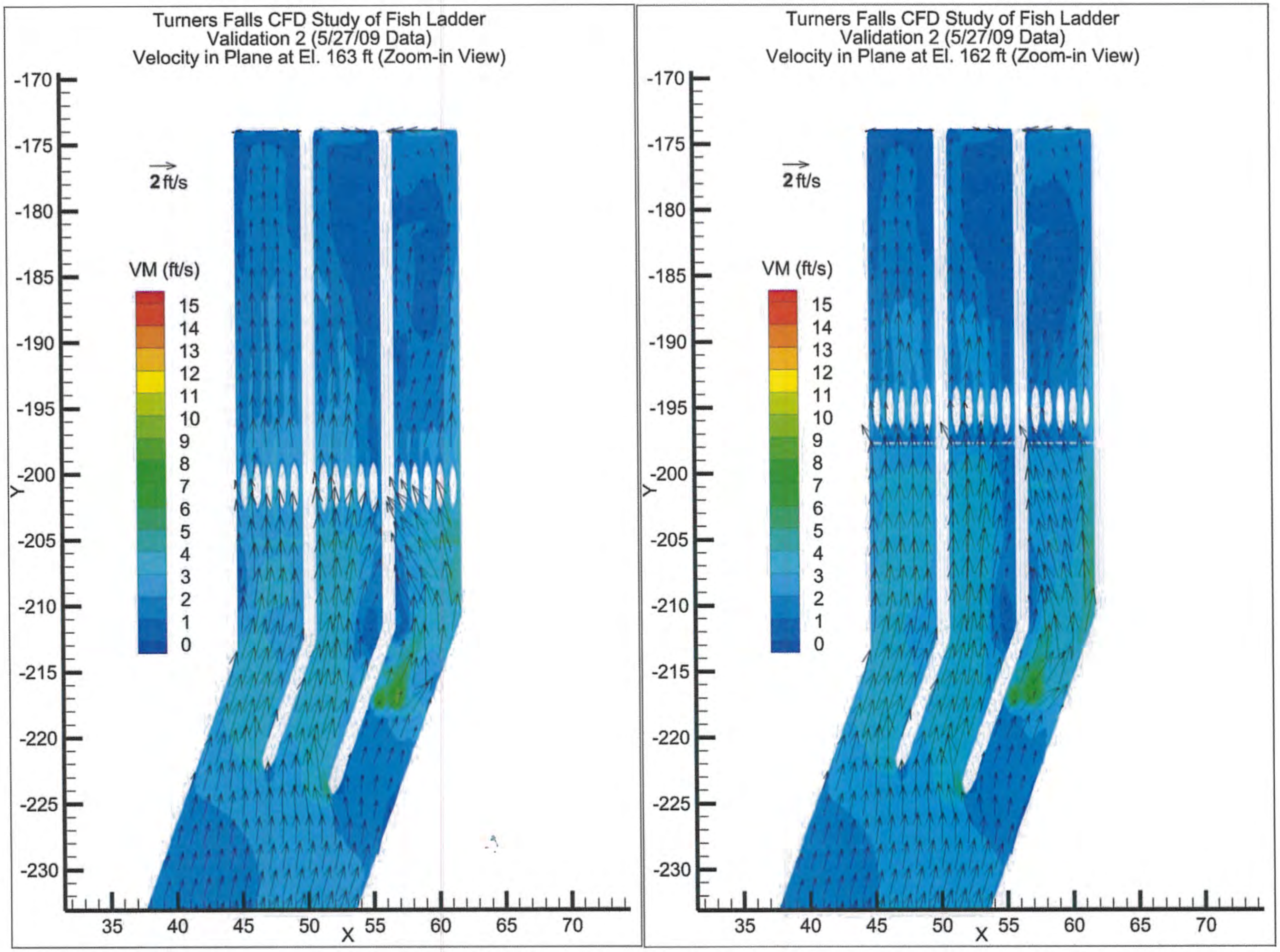
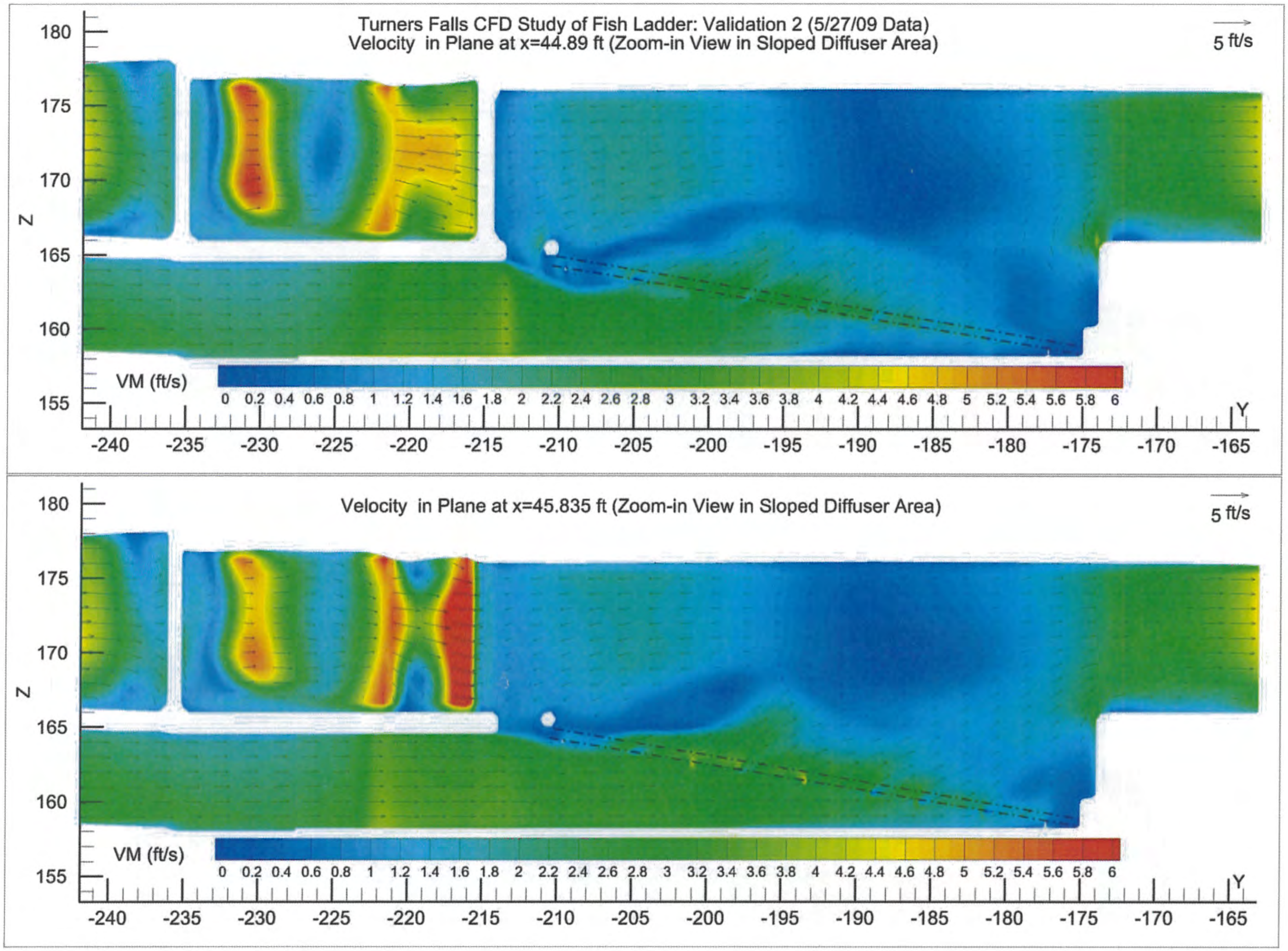
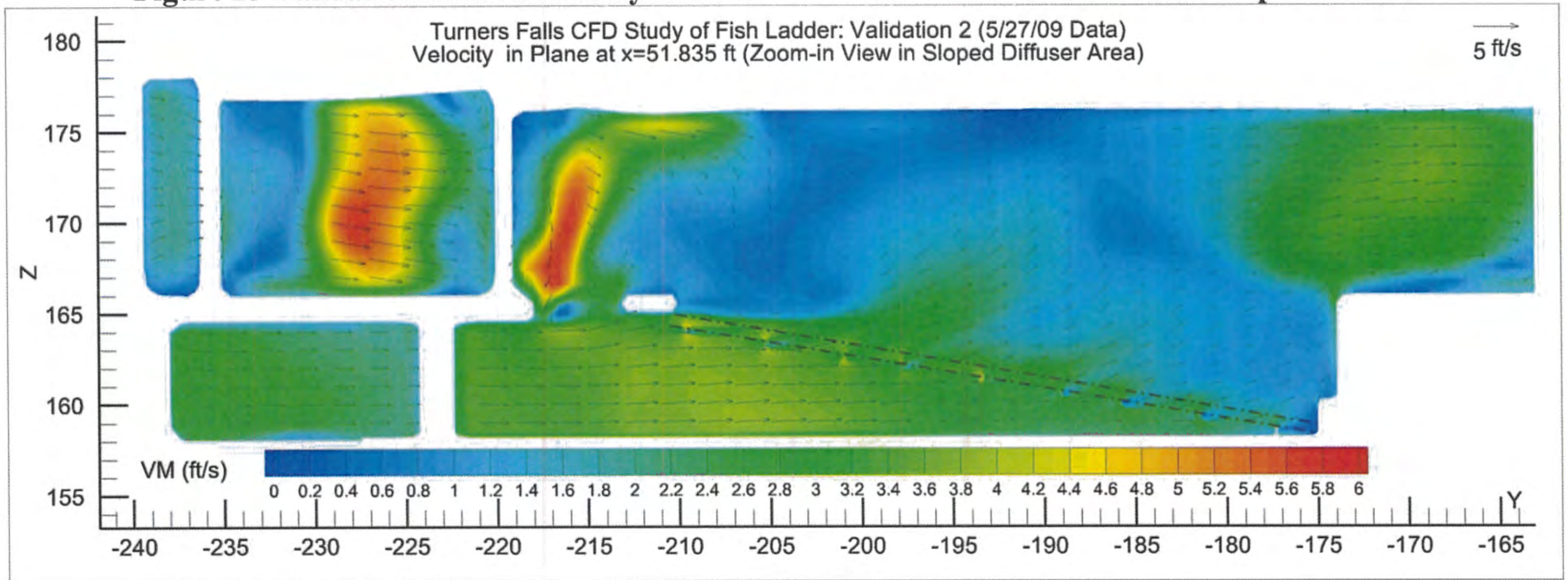


Figure 22 Validation Case 2: Velocity in Fish Way Channel through Gatehouse in Planes at El. 163 and El. 162 ft



Turners Falls CFD Study of Fish Ladder: Validation 2 (5/27/09 Data)
Velocity in Plane at x=44.89 ft (Zoom-in View in Sloped Diffuser Area)
5 ft/s
Z
VM (ft/s)
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4 4.2 4.4 4.6 4.8 5 5.2 5.4 5.6 5.8 6
Y
155 160 165 170 175 180
-240 -235 -230 -225 -220 -215 -210 -205 -200 -195 -190 -185 -180 -175 -170 -165
Velocity in Plane at x=45.835 ft (Zoom-in View in Sloped Diffuser Area)
5 ft/s
Z
VM (ft/s)
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4 4.2 4.4 4.6 4.8 5 5.2 5.4 5.6 5.8 6
Y
155 160 165 170 175 180
-240 -235 -230 -225 -220 -215 -210 -205 -200 -195 -190 -185 -180 -175 -170 -165

Figure 23 Validation Case 2: Velocity in Vertical Planes in the Left Channel of Sloped Diffuser



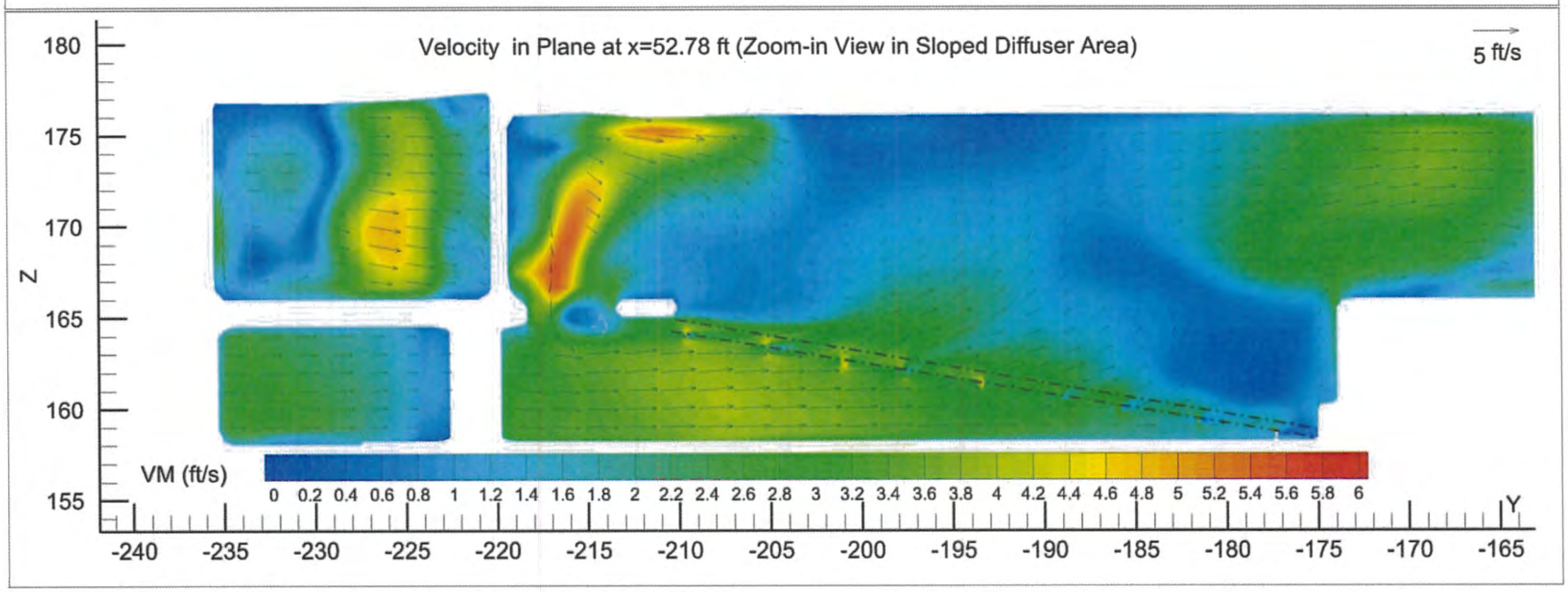


Figure 24 Validation Case 2: Velocity in Vertical Planes in the Middle Channel of Sloped Diffuser

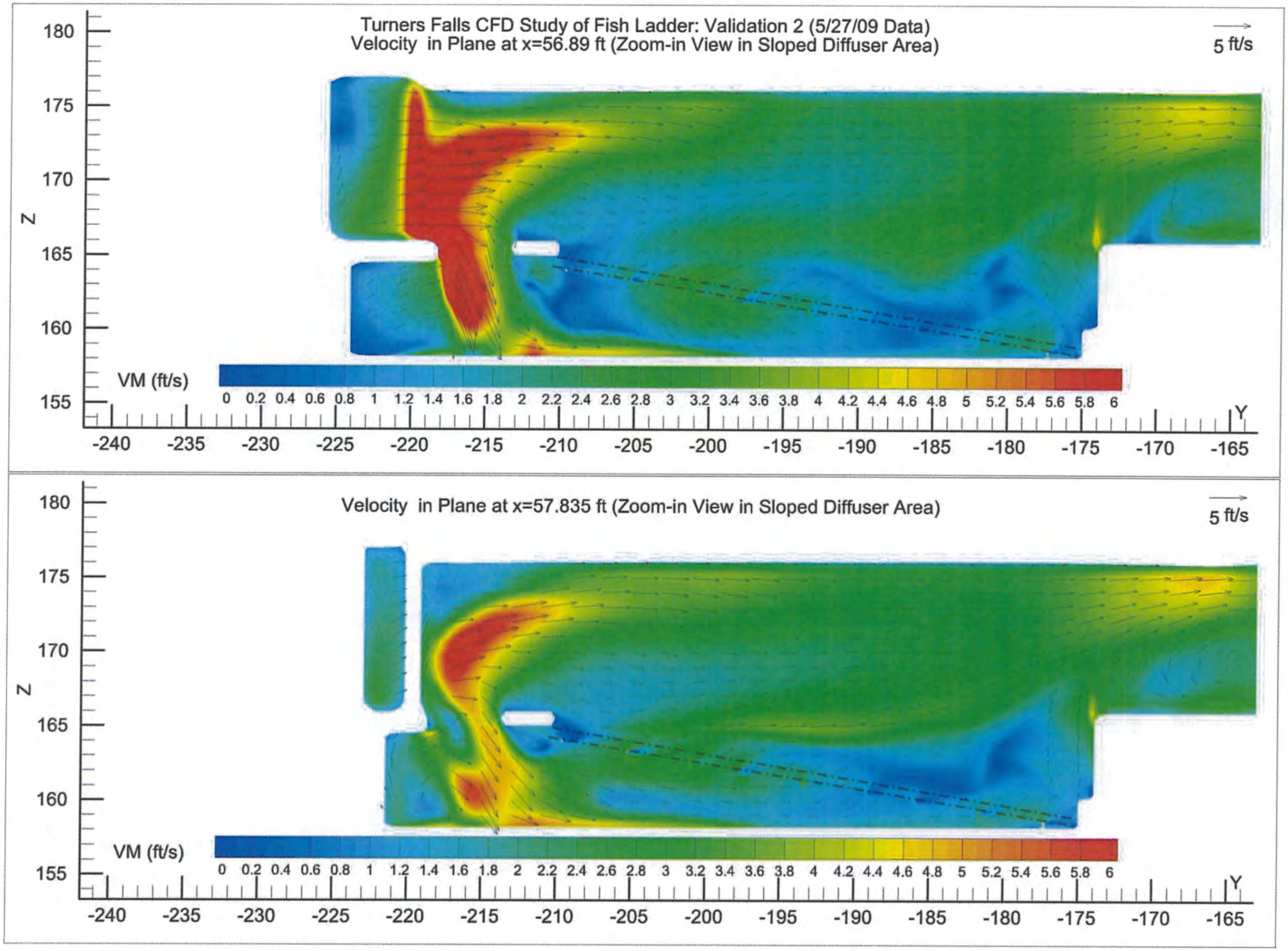


Figure 25 Validation Case 2: Velocity in Vertical Planes in the Right Channel of Sloped Diffuser

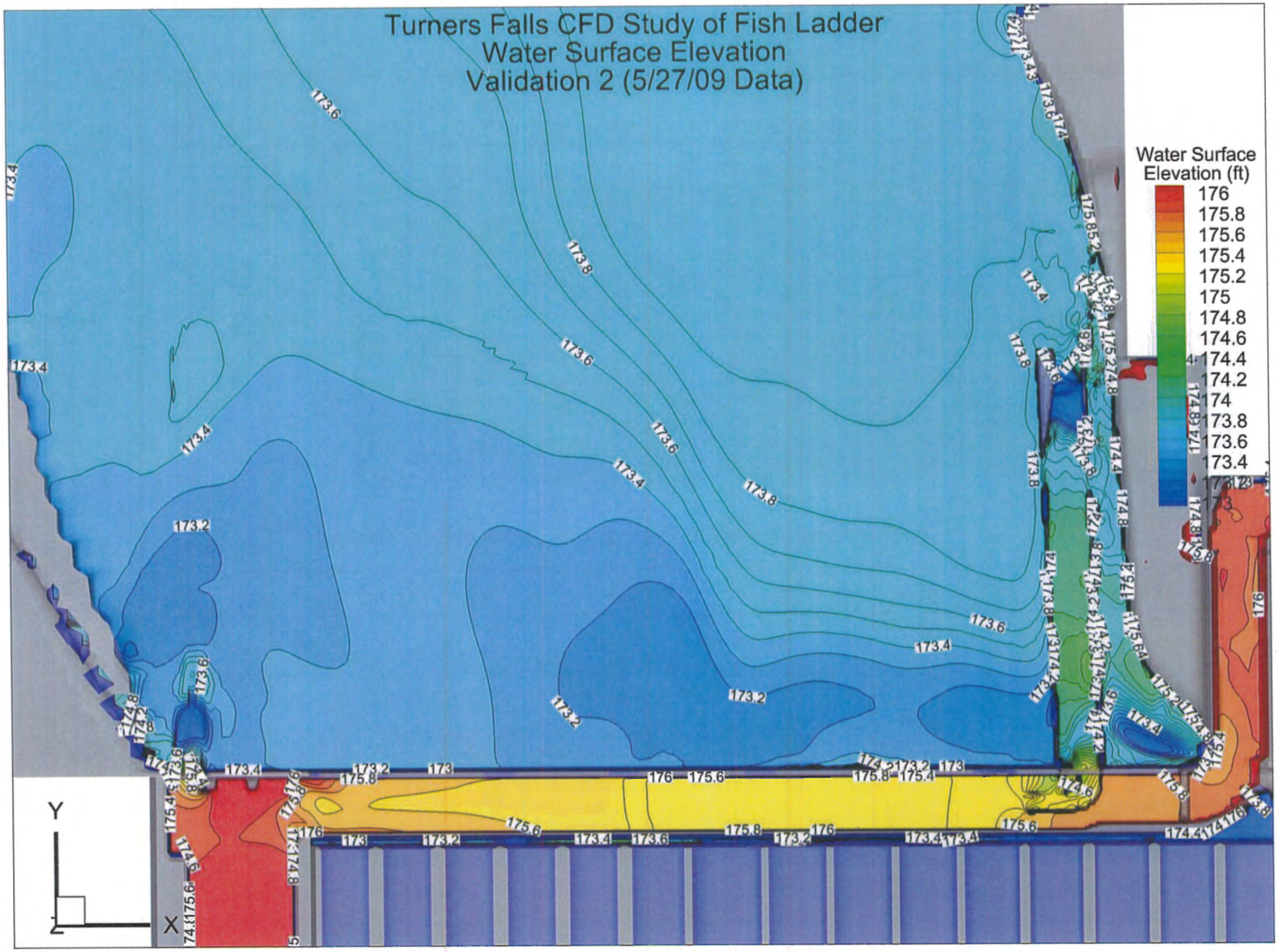


Figure 26 Validation Case 2: Water Surface Elevation in the Vicinity of Old and New Entrances in the Canal

Figure 27 Validation Case 2: Water Surface Elevation in the Vicinity of Old Entrance and Measurement Points Locations

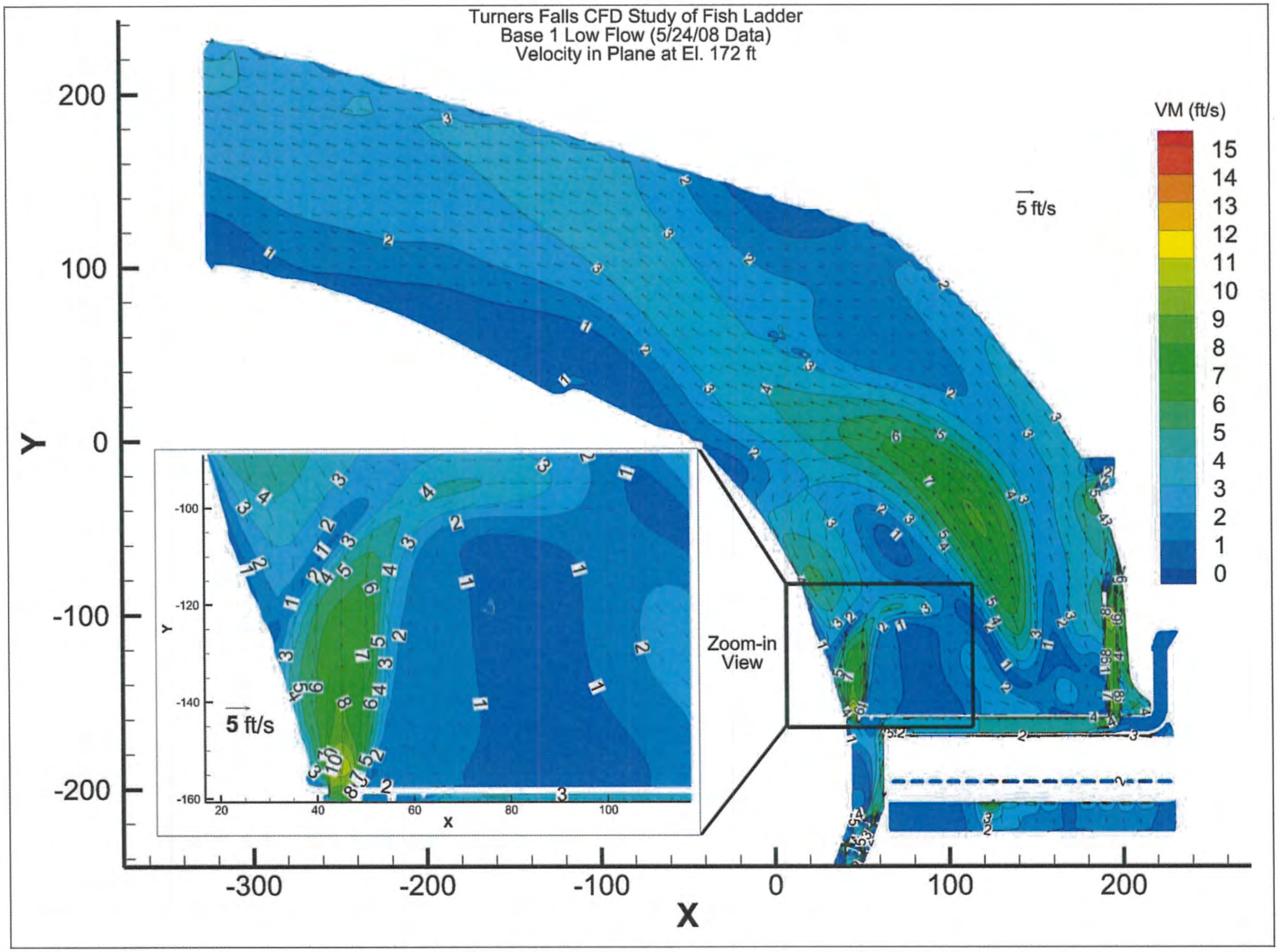


Figure 28 Base 1 Low Flow: Velocity in Plane at El. 172 ft

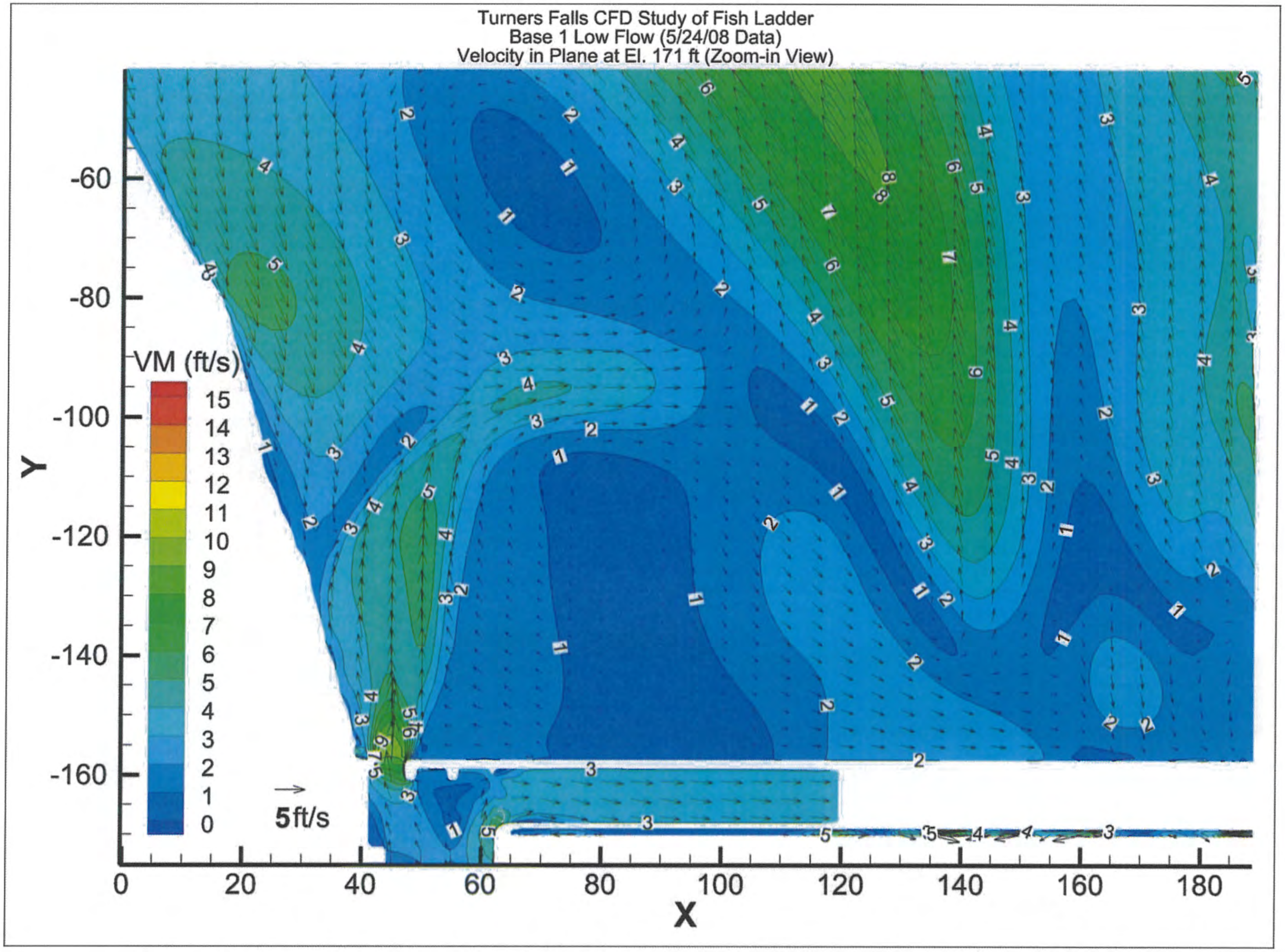


Figure 29 Base 1 Low Flow: Velocity in the Vicinity of Old Entrance in Plane at El. 172 ft

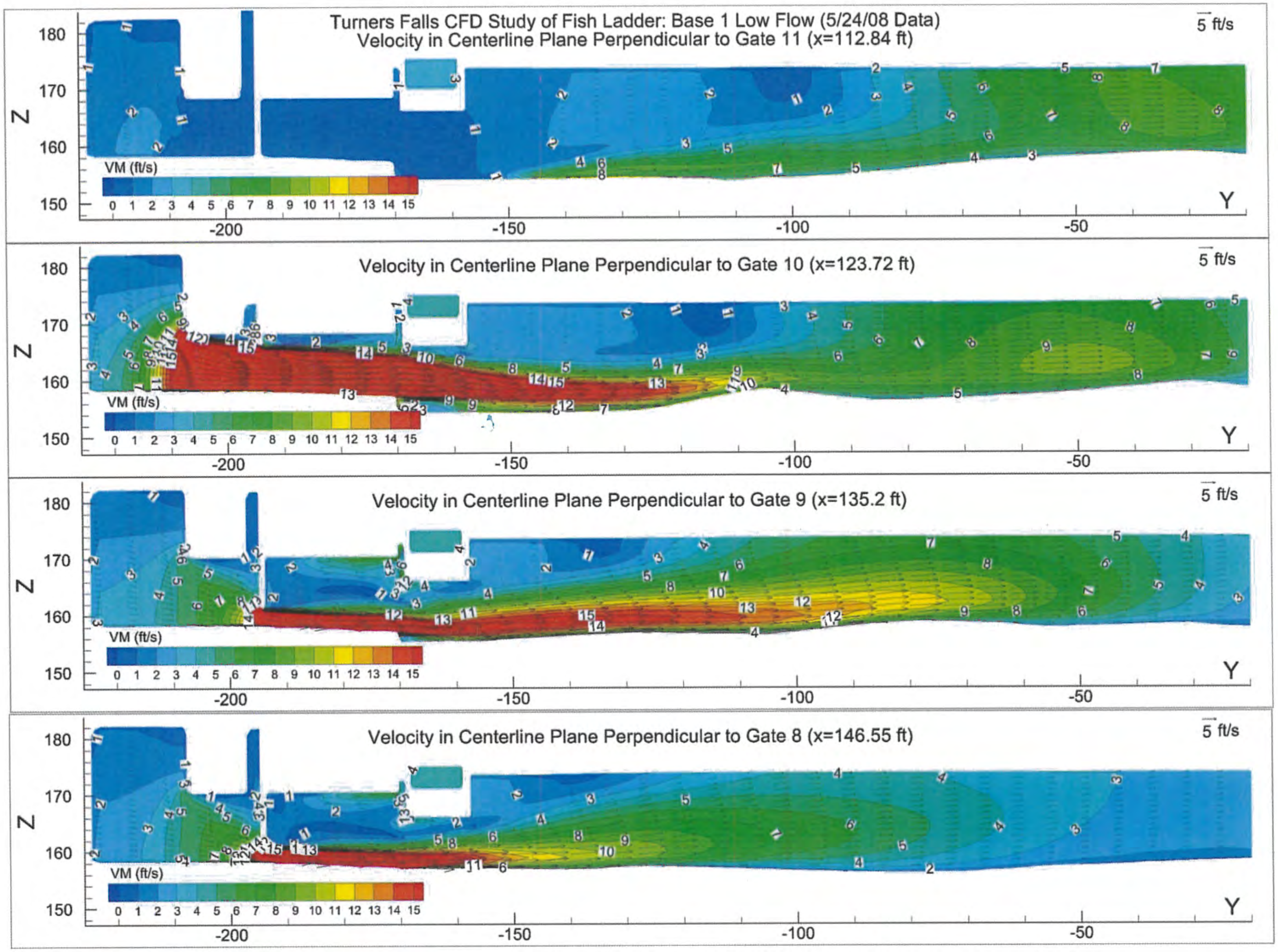


Figure 30 Base 1 Low Flow: Velocity in Centerline Planes of Gates 8 through 11

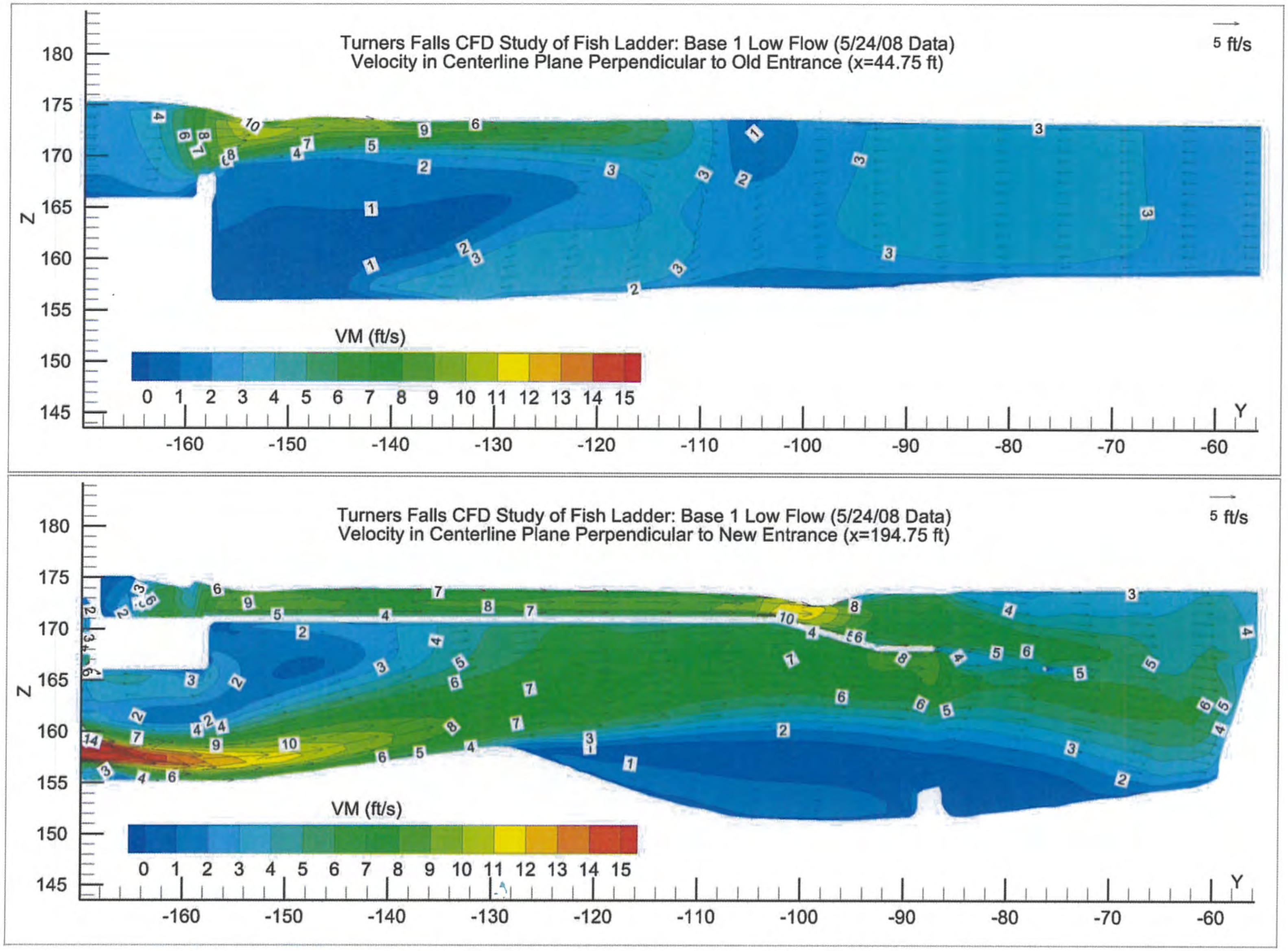


Figure 31 Base 1 Low Flow: Velocity in Centerline Planes of Old and New Entrance

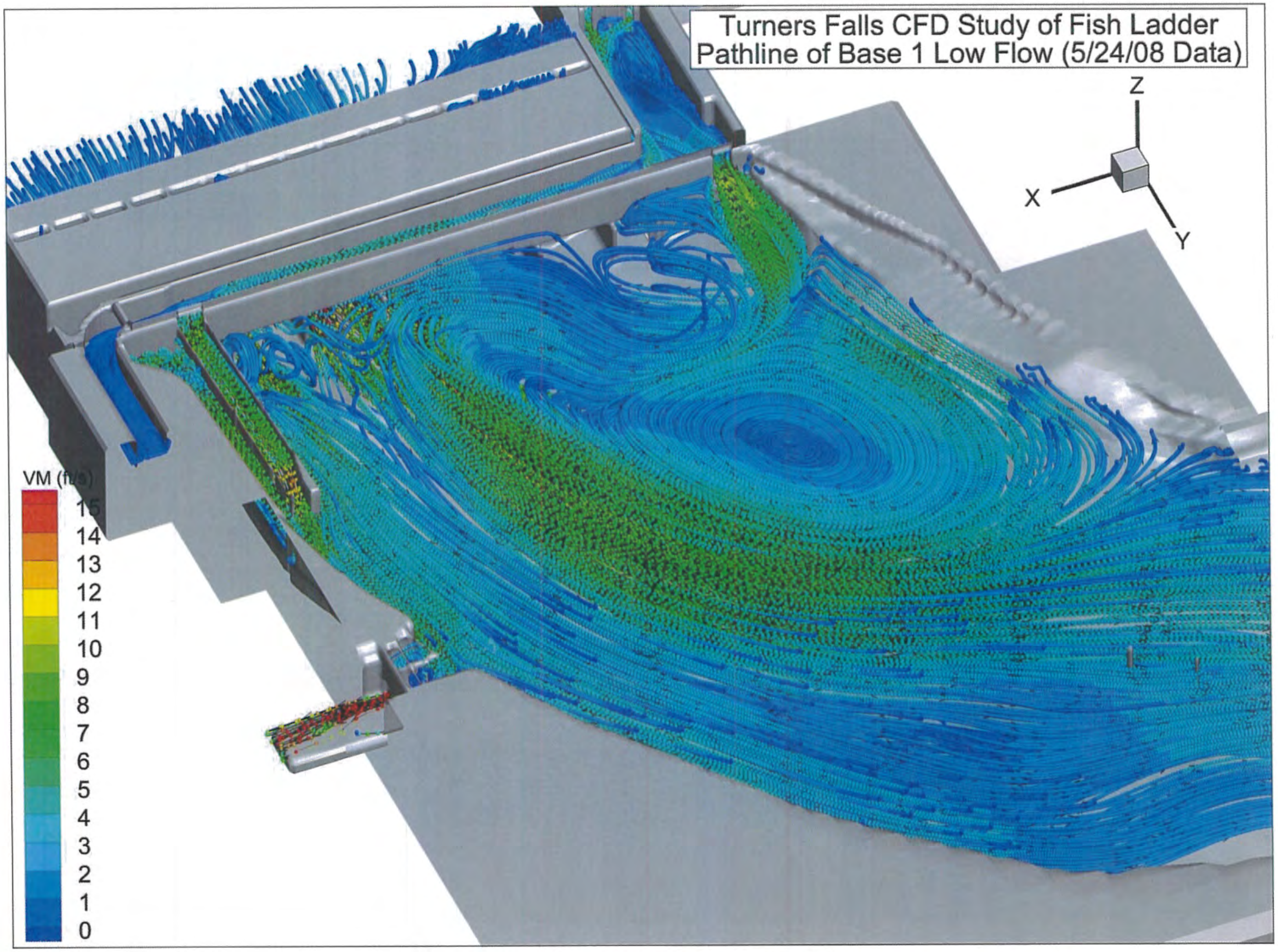


Figure 32 Base 1 Low Flow: 3D Pathlines

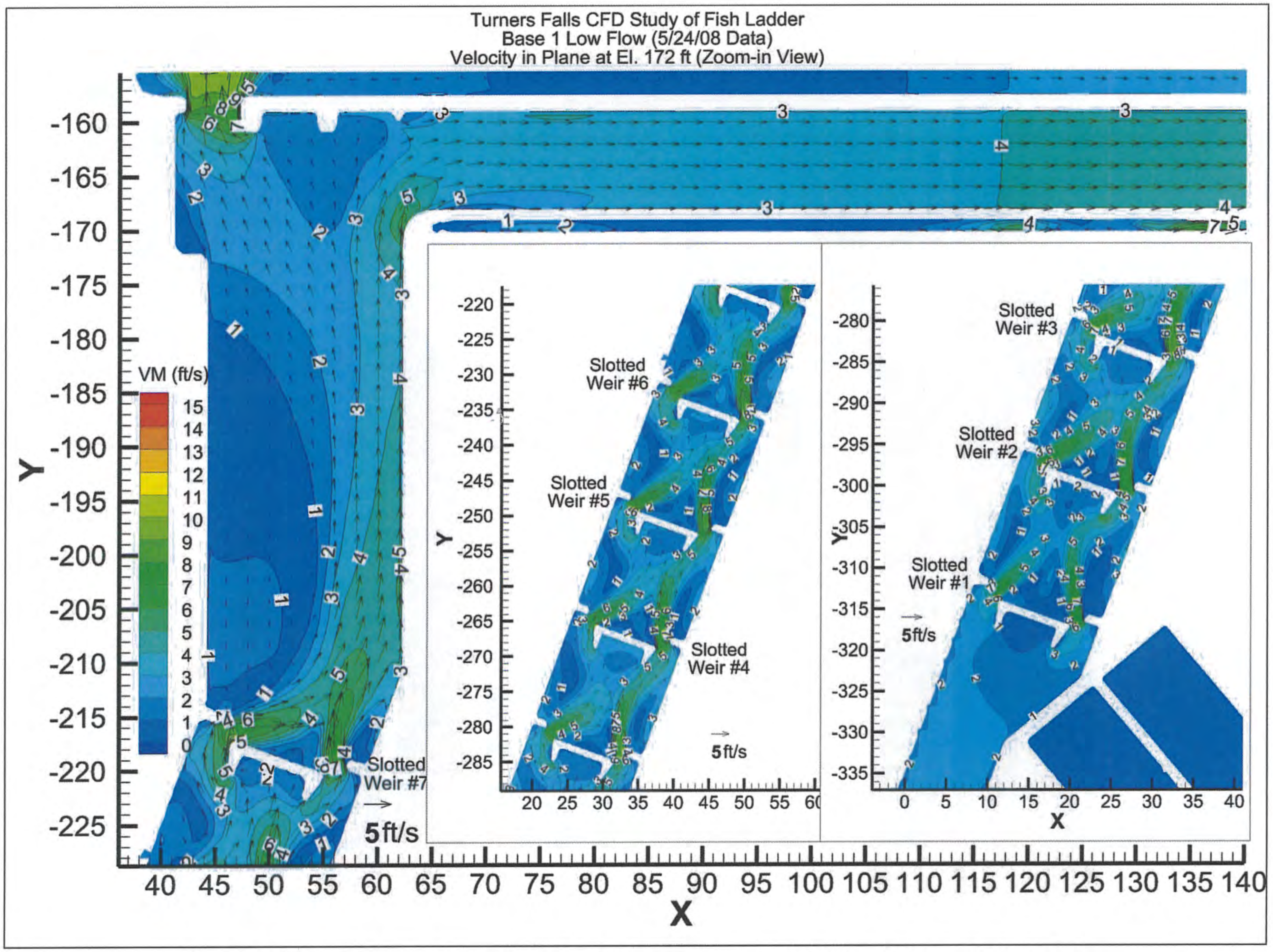


Figure 33 Base 1 Low Flow: Velocity in the Gallery and Slotted Weirs at El. 172 ft

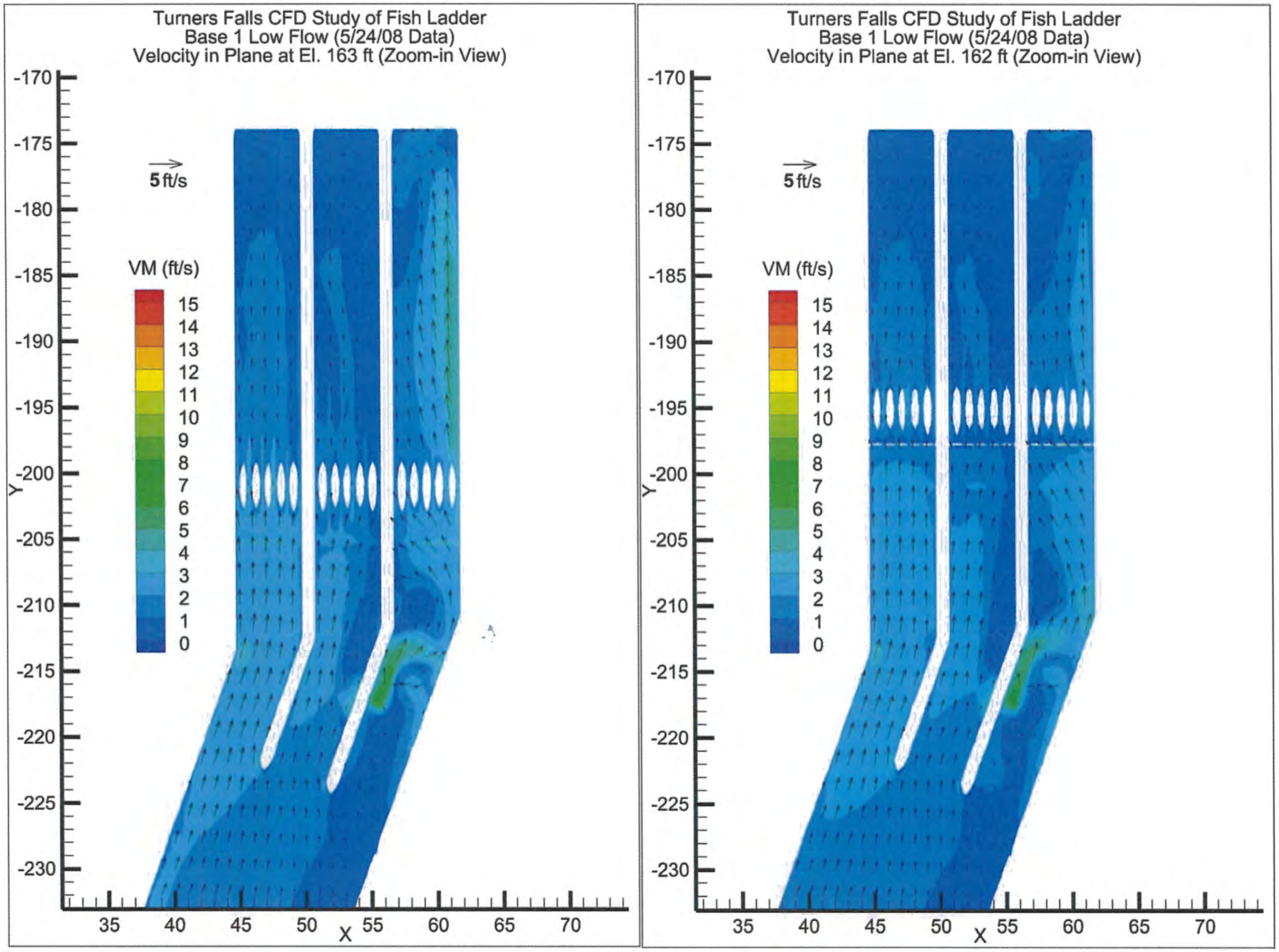


Figure 34 Base 1 Low Flow: Velocity in the Upstream Attraction Tunnel at El. 163 and El. 162 ft

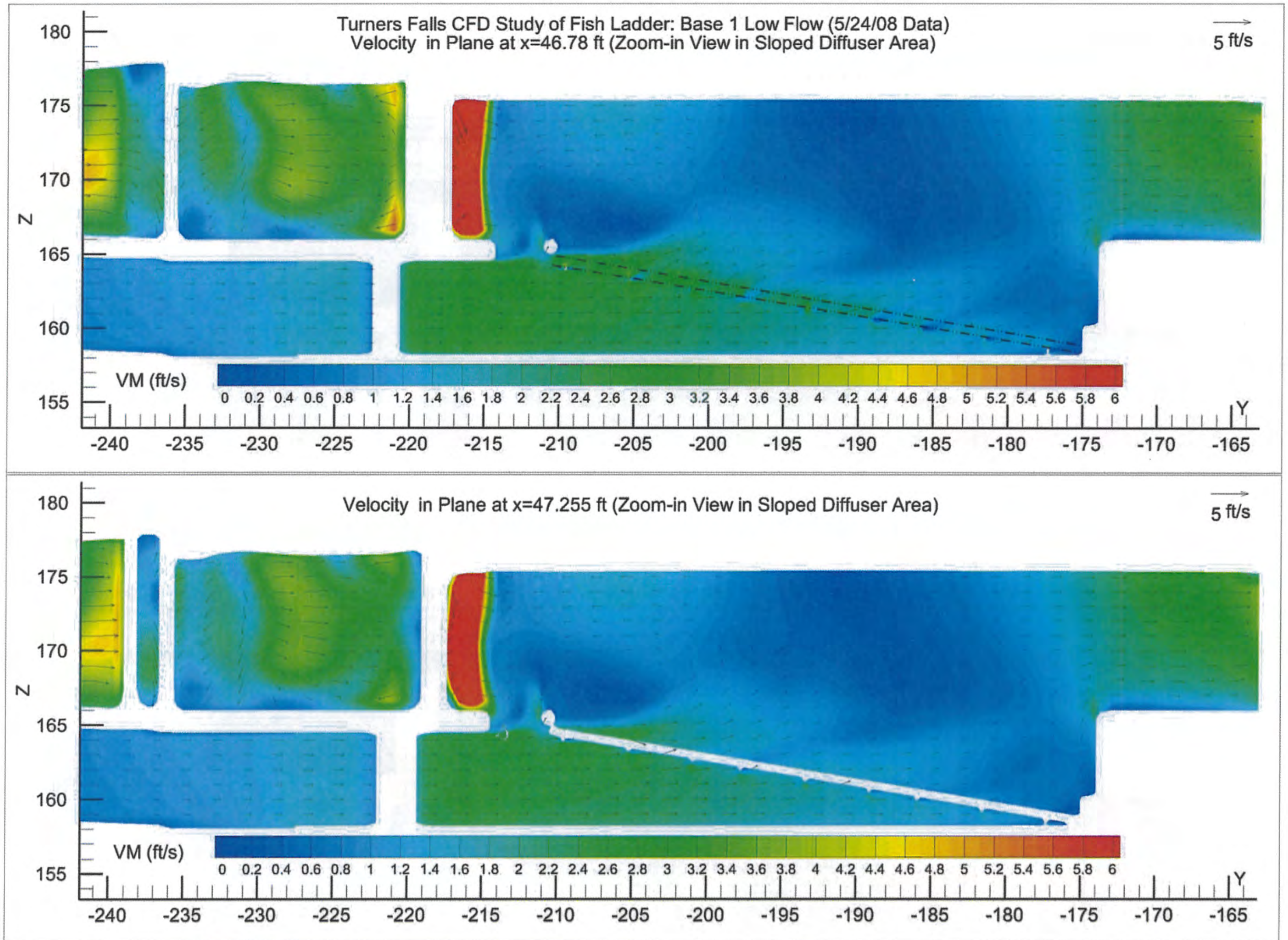


Figure 35 Base 1 Low Flow: Velocity in Vertical Planes of the Left Channel of Sloped Diffuser

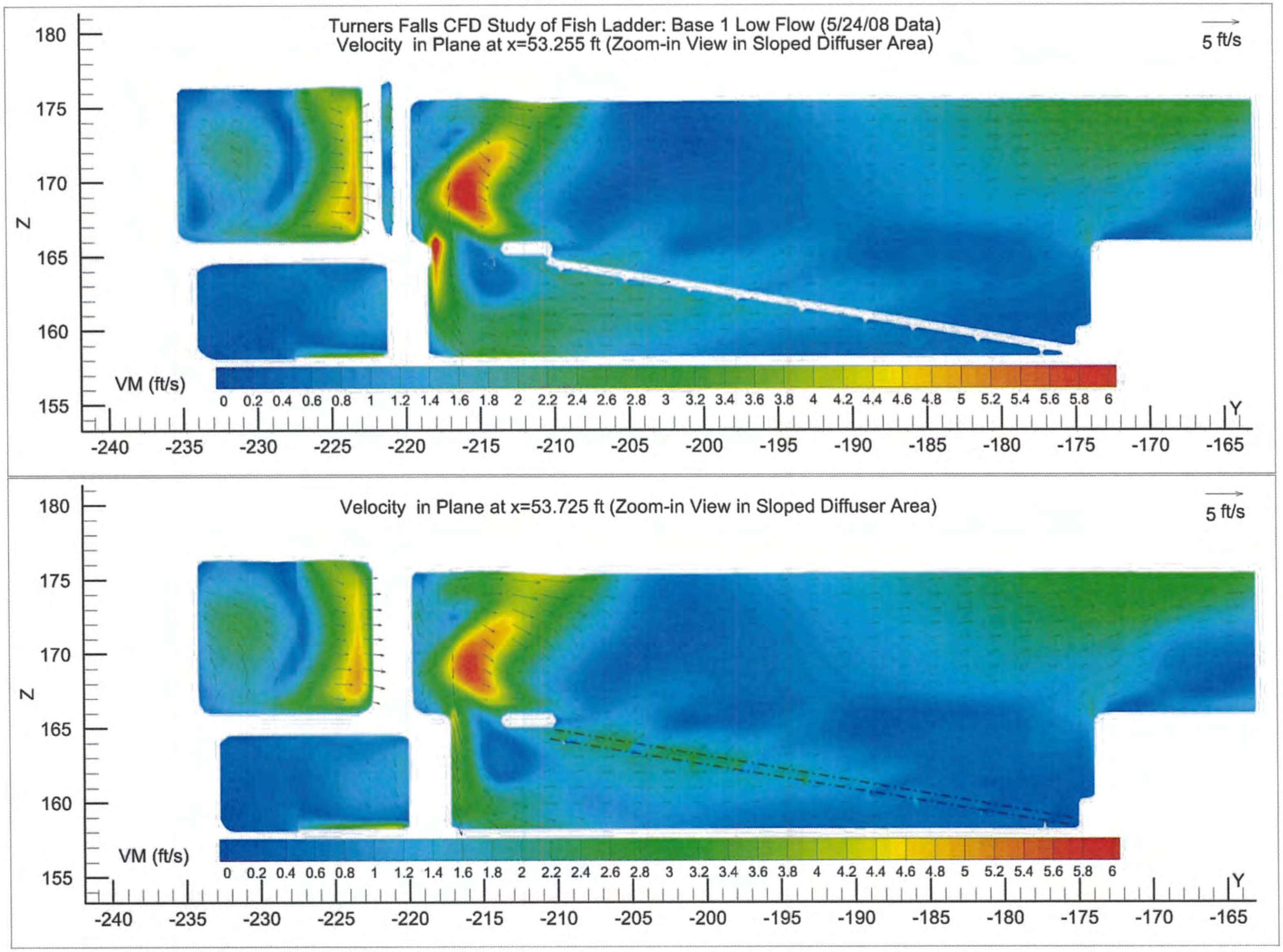


Figure 36 Base 1 Low Flow: Velocity in Vertical Planes of the Middle Channel of Sloped Diffuser

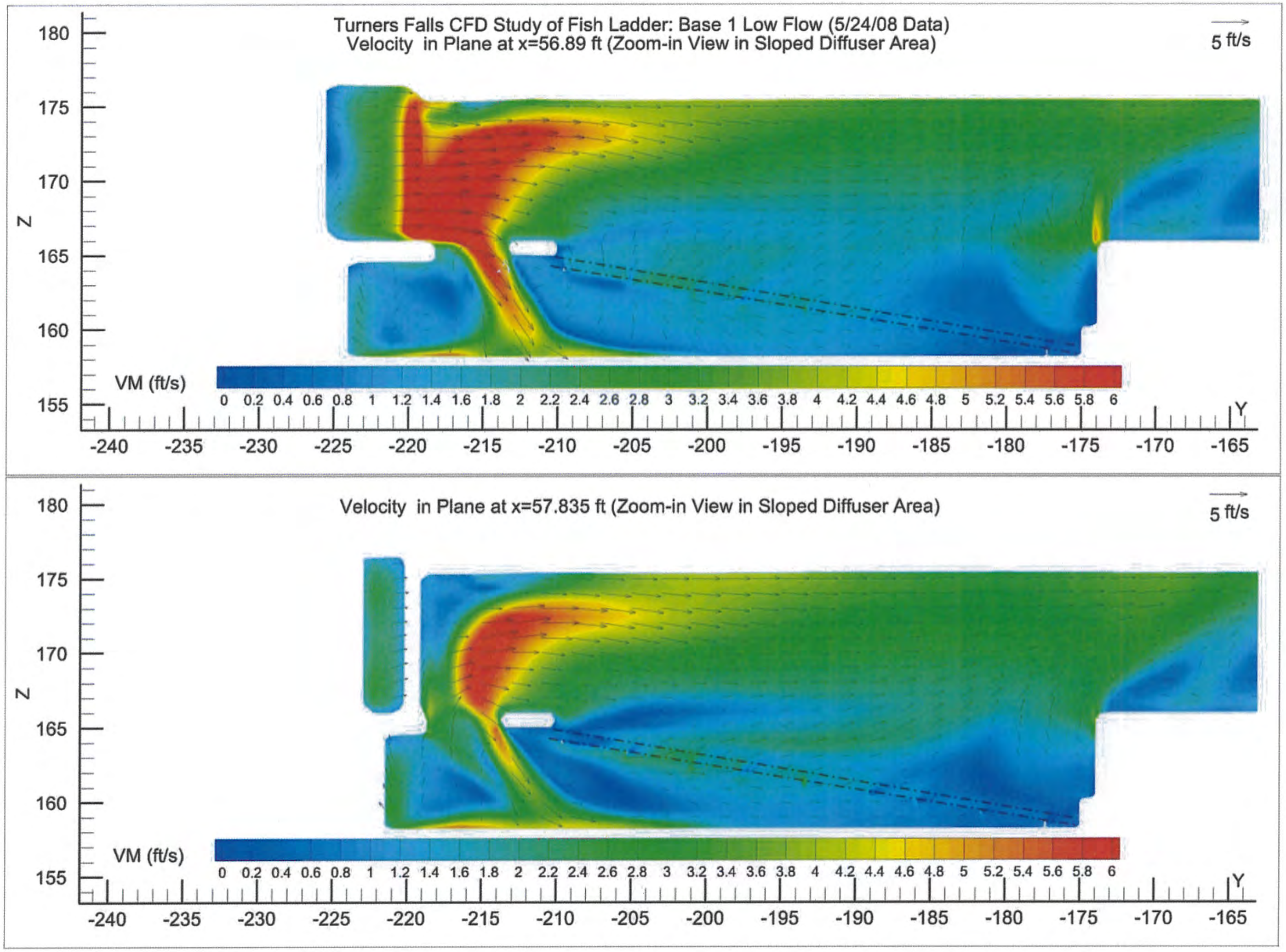


Figure 37 Base 1 Low Flow: Velocity in Vertical Planes in the Right Channel of Sloped Diffuser

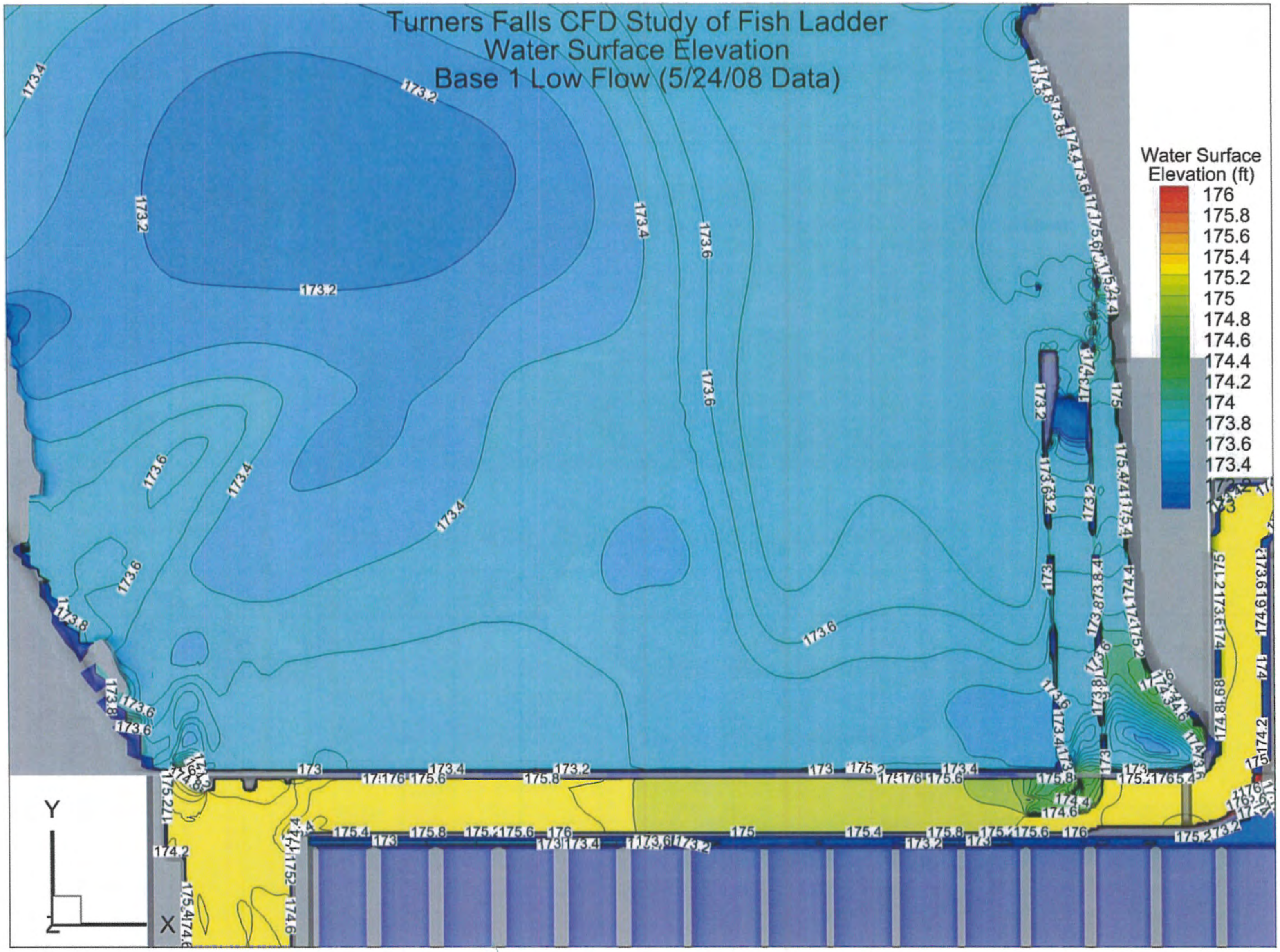


Figure 38 Base 1 Low Flow: Water Surface Elevation in the Vicinity of Old and New Entrances in the Canal

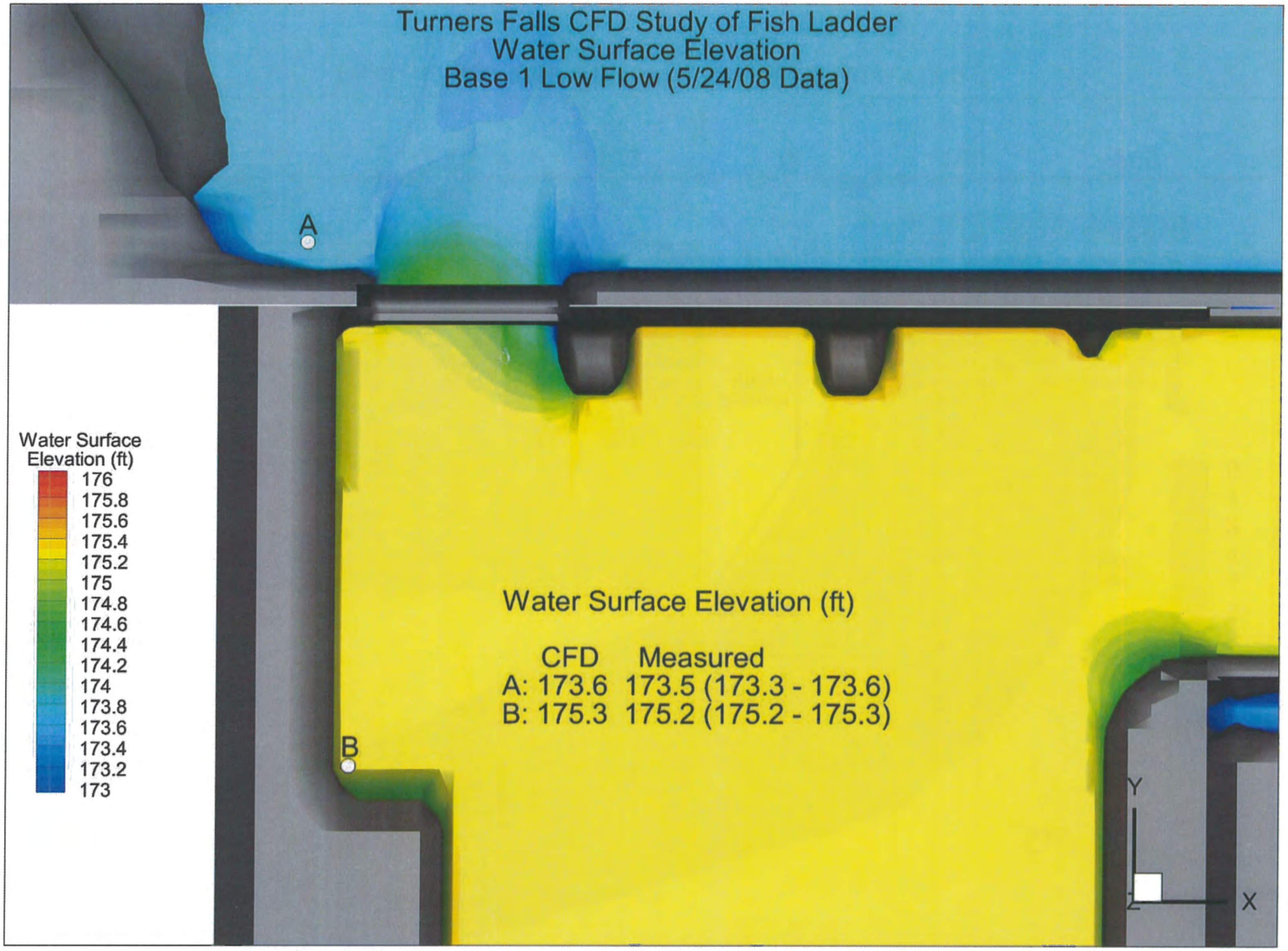


Figure 39 Base 1 Low Flow: Water Surface Elevation in the Vicinity of Old Entrance and Measurement Points Locations

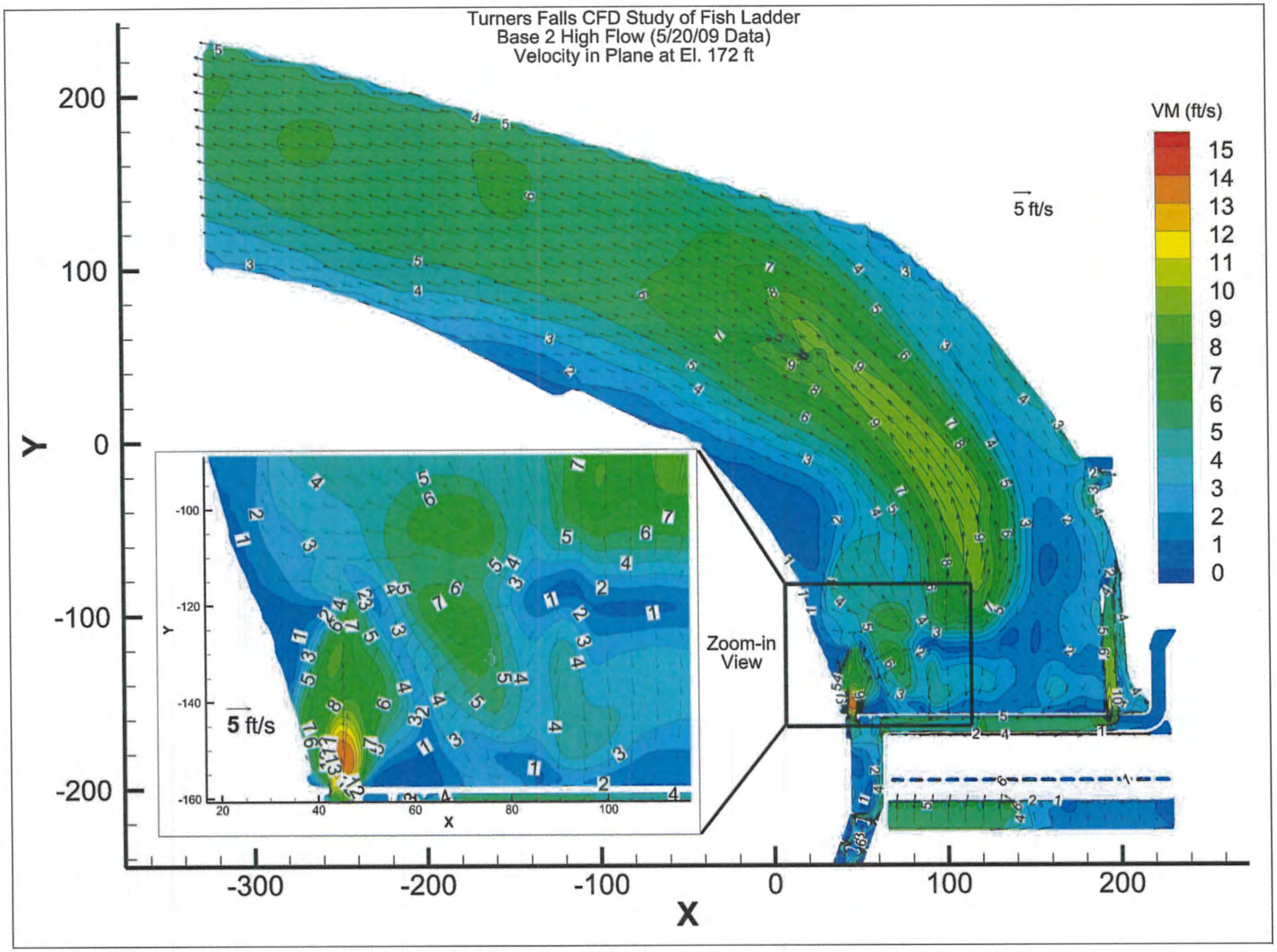


Figure 40 Base 2 High Flow: Velocity at Elevation 172 ft

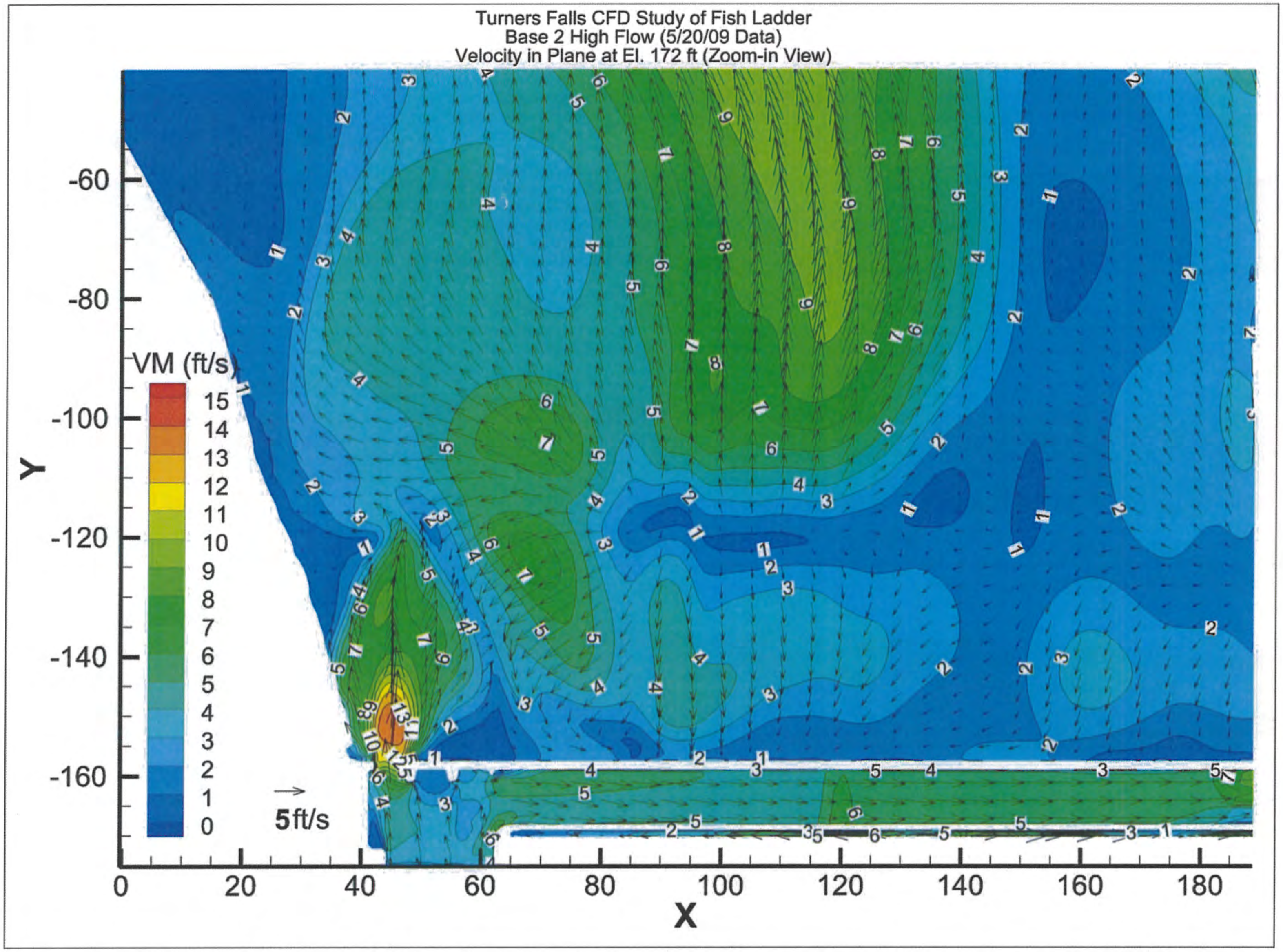


Figure 41 Base 2 High Flow: Velocity in the Vicinity of Old Entrance in the Canal at Elevation 172 ft

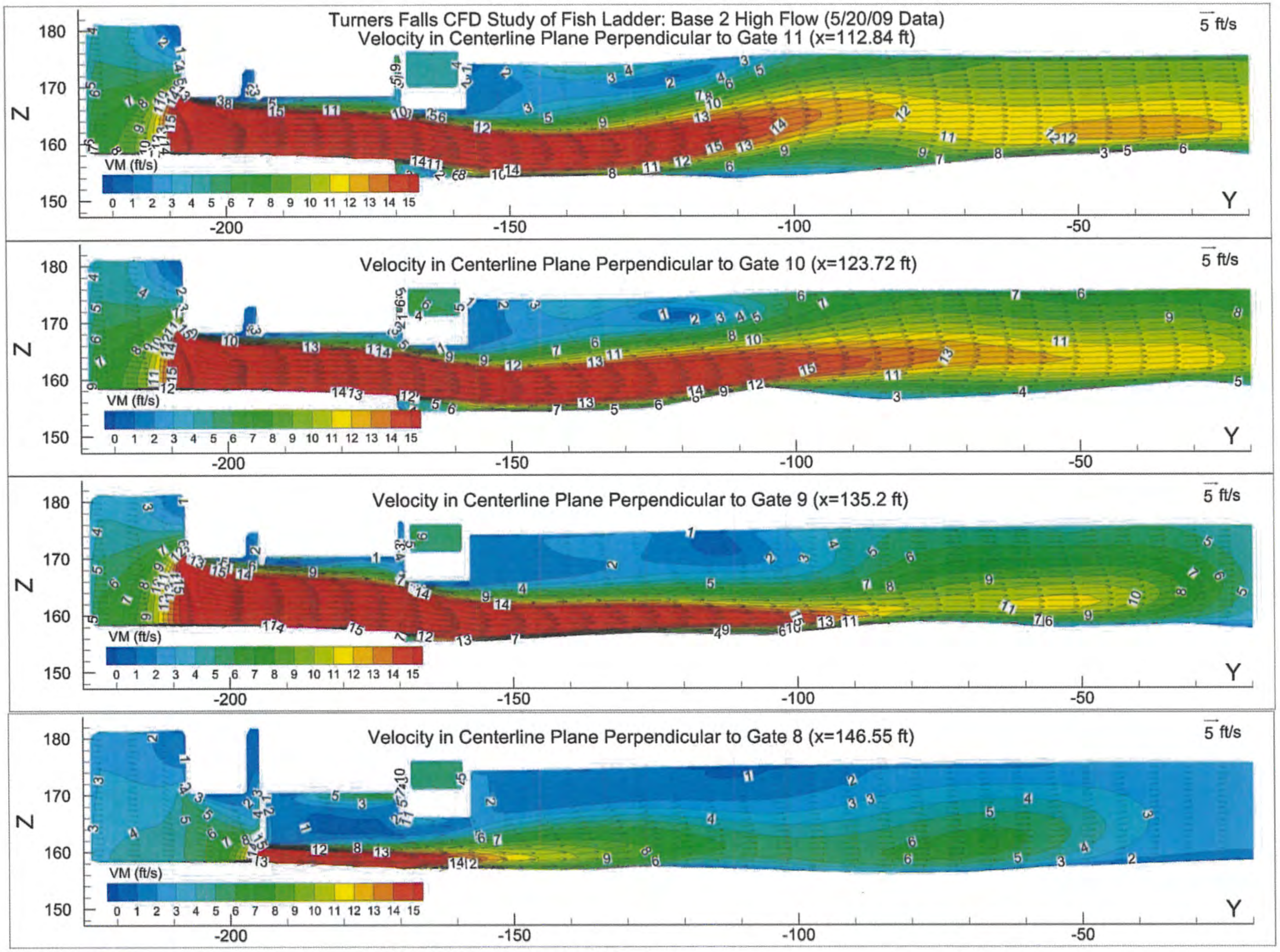


Figure 42 Base 2 High Flow: Velocity in Centerline Planes of Gates 8 through 11

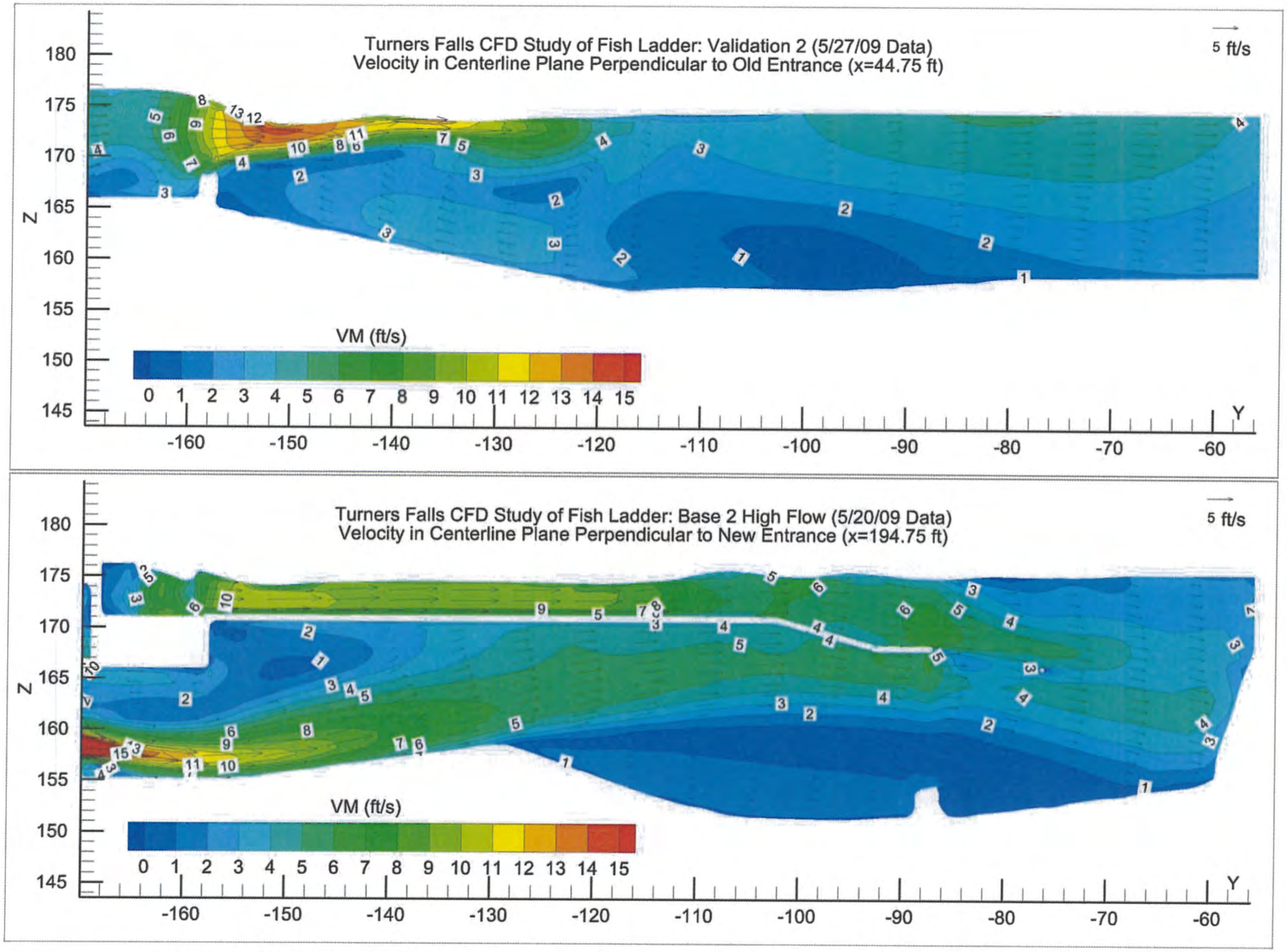


Figure 43 Base 2 High Flow: Velocity in the Centerline Planes of Old and New Entrances

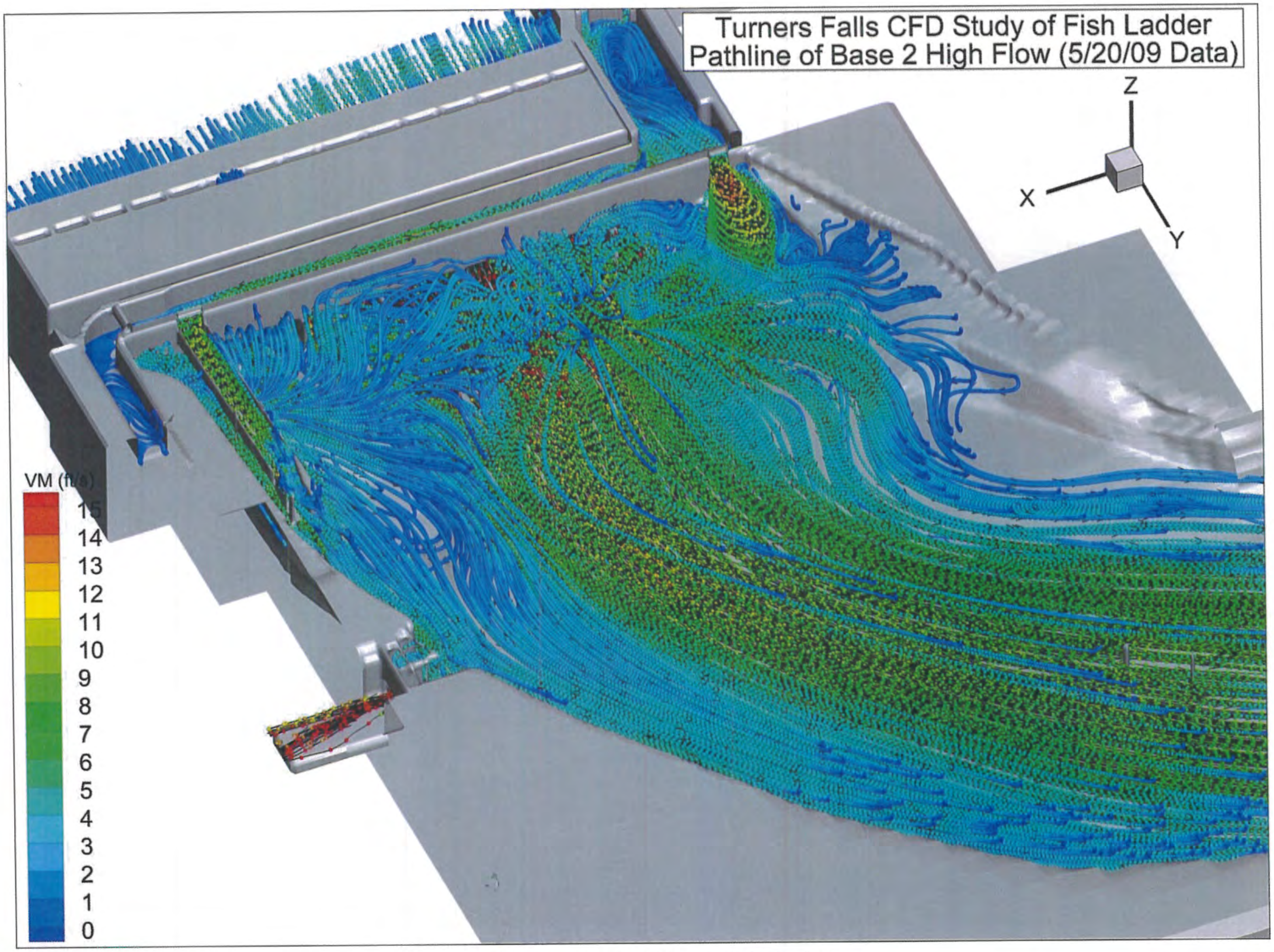


Figure 44 Base 2 High Flow: 3D Pathlines

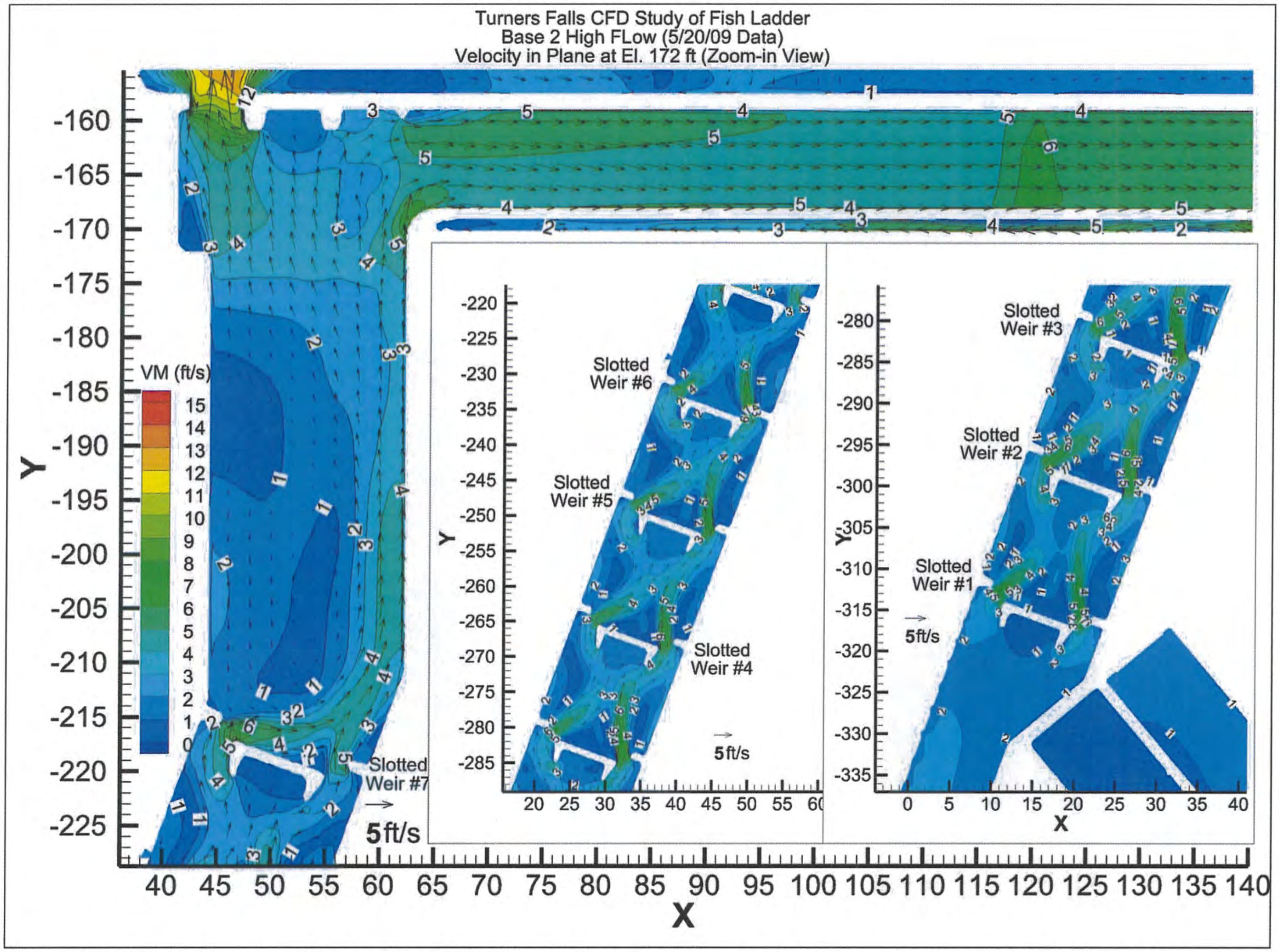
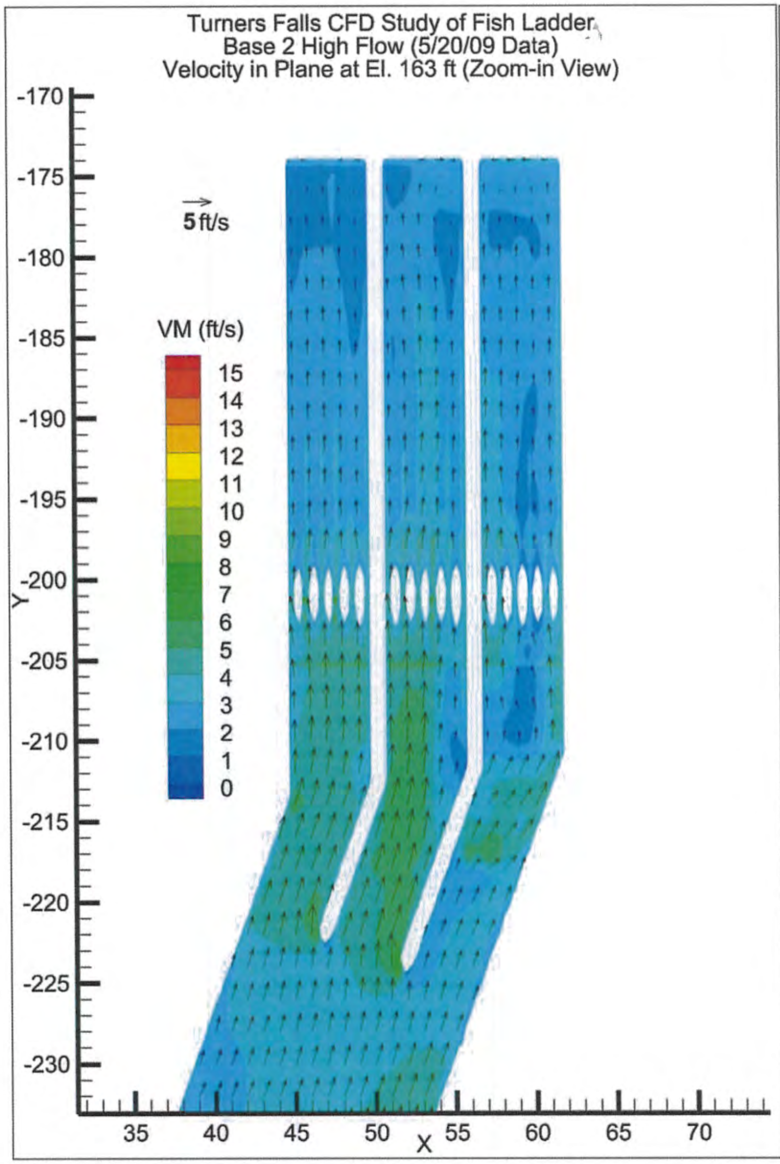


Figure 45 Base 2 High Flow: Velocity in the Upstream Slotted Weir and Gallery at Elevation 172 ft



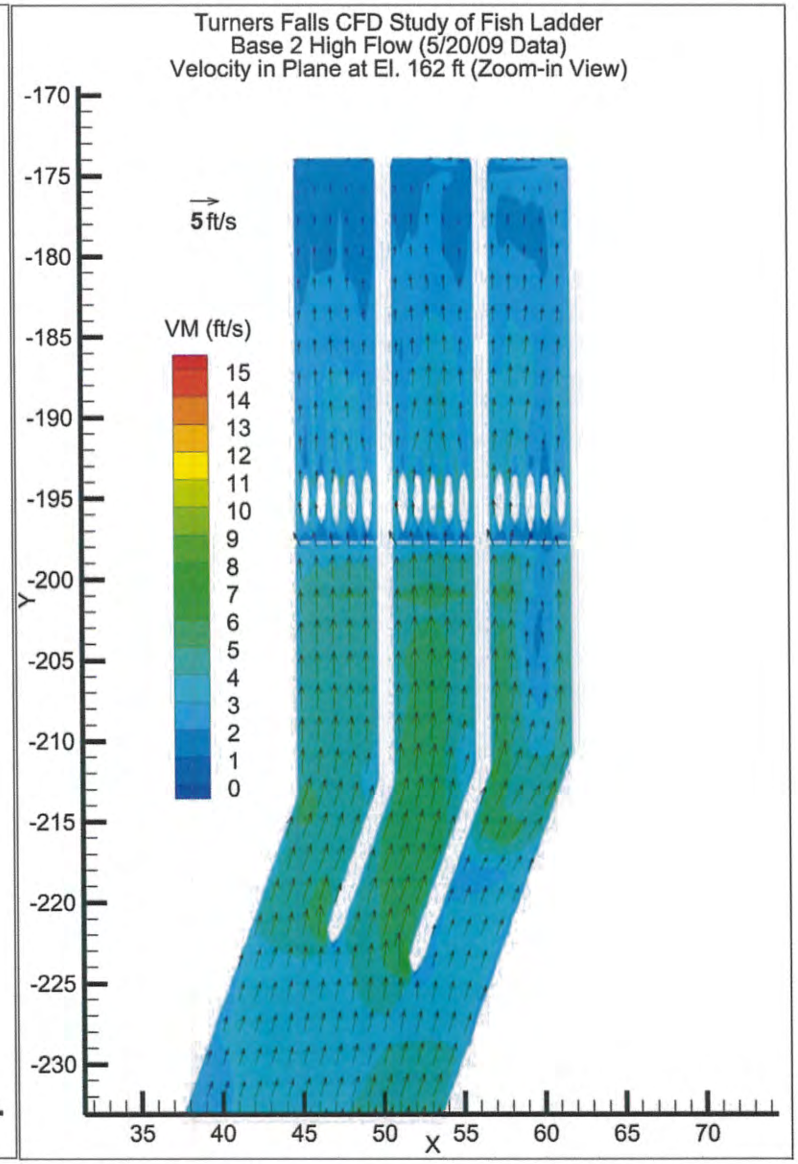


Figure 46 Base 2 High Flow: Velocity in the Upstream Attraction Channel at El. 163 ft and El. 162 ft

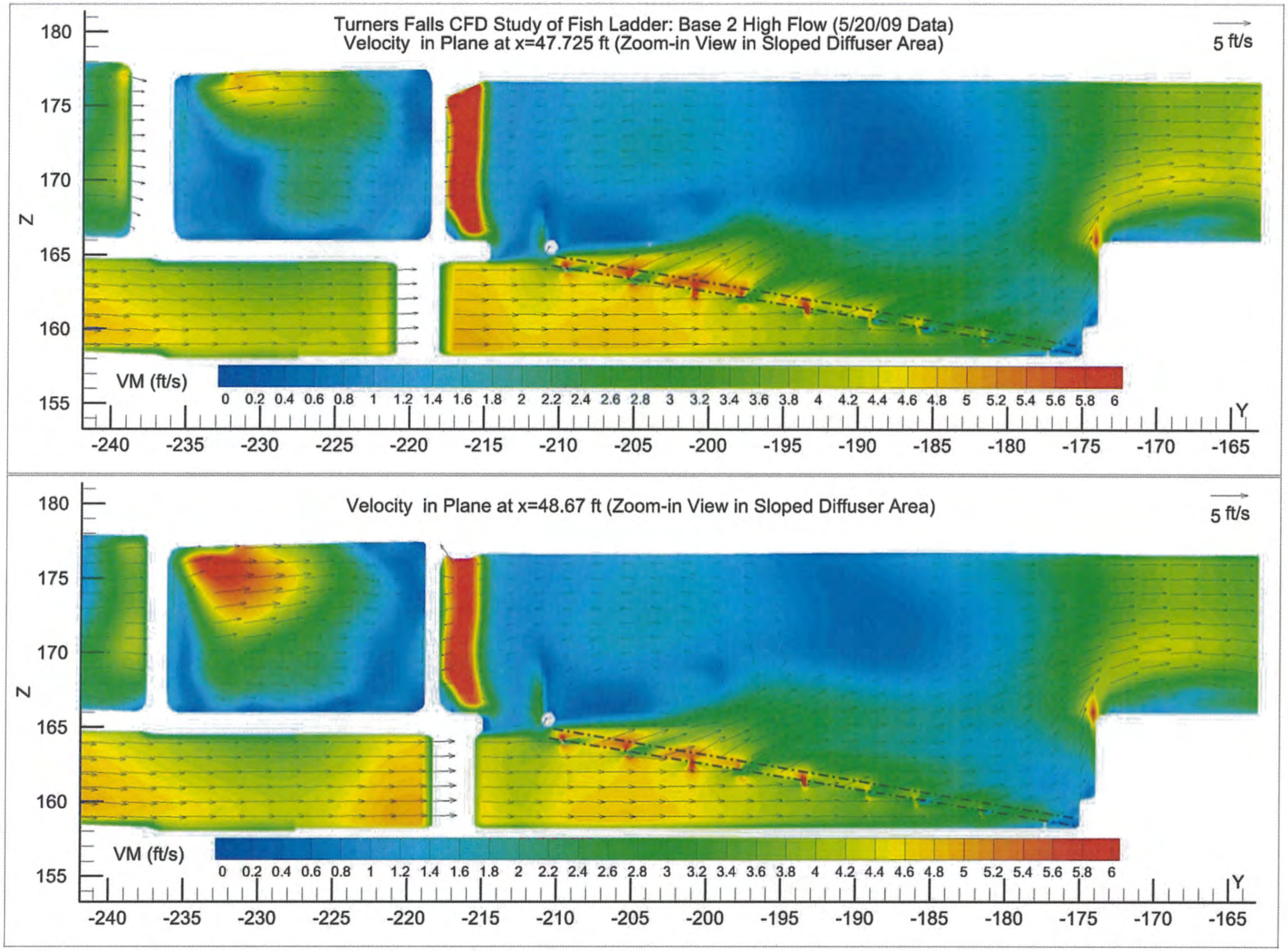


Figure 47 Base 2 High Flow: Velocity in Vertical Planes in the Left Channel of Sloped Diffuser

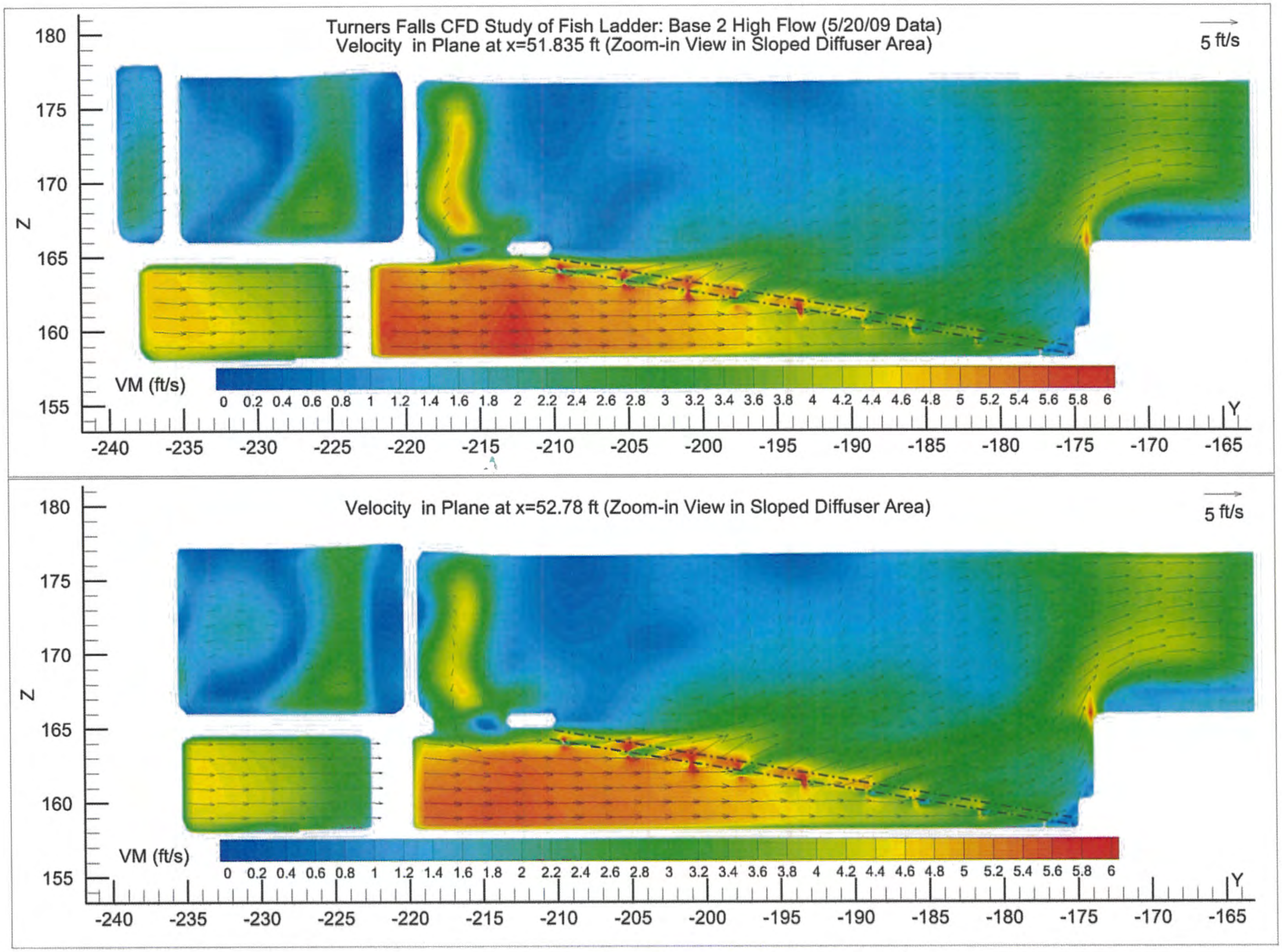


Figure 48 Base 2 High Flow: Velocity in Vertical Planes in the Middle Channel of Sloped Diffuser

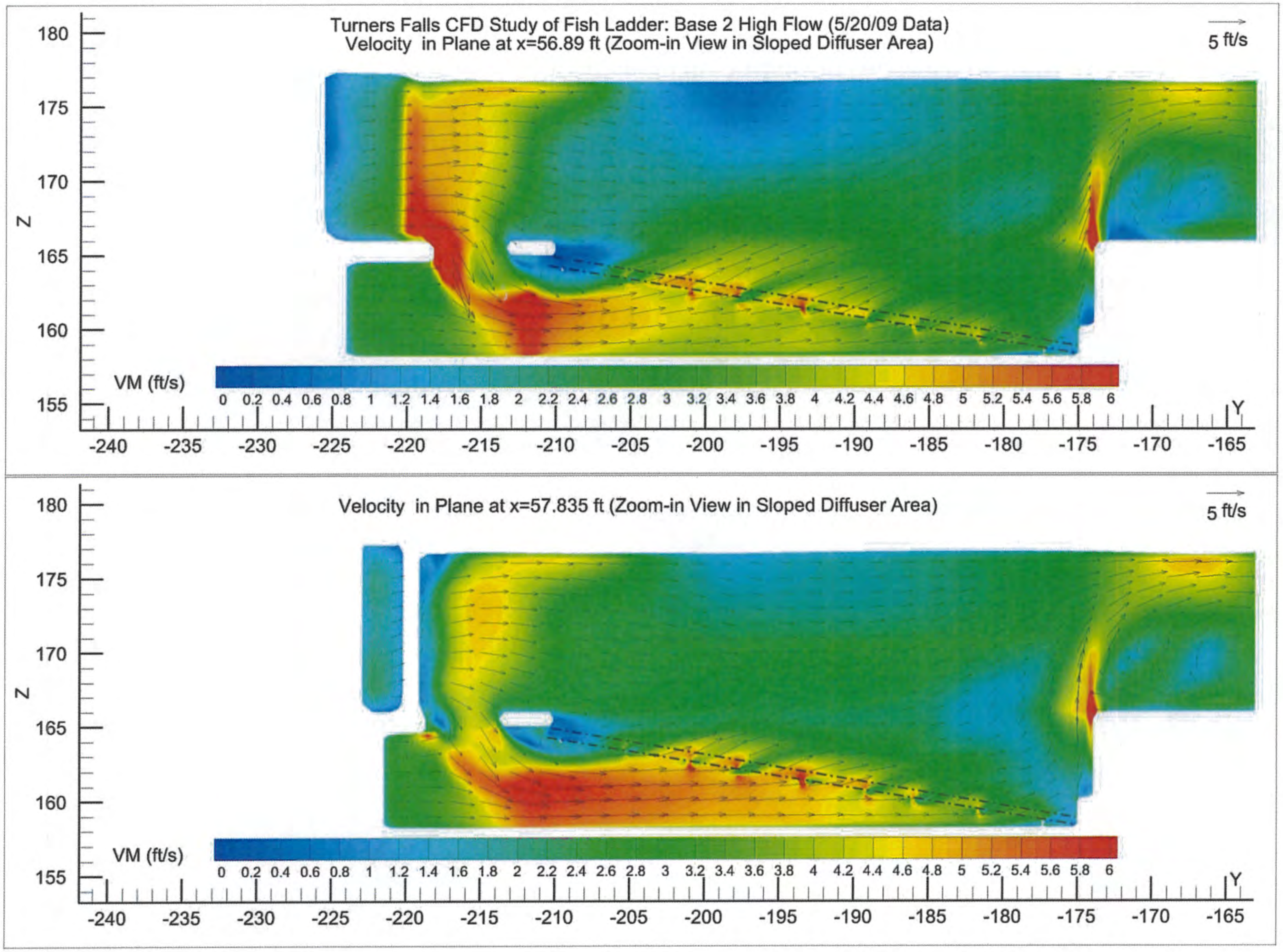


Figure 49 Base 2 High Flow: Velocity in Vertical Planes in the Right Channel of Sloped Diffuser

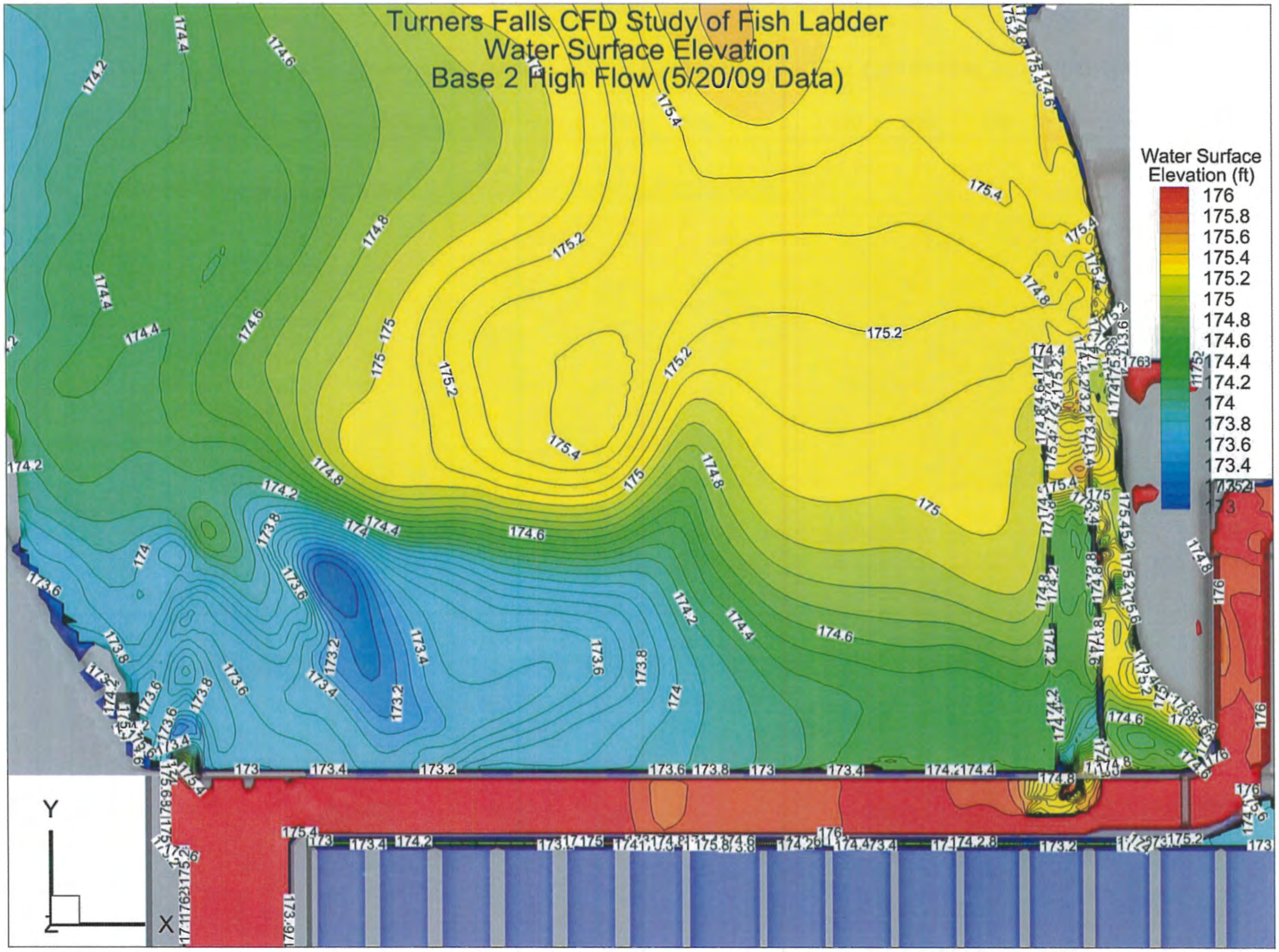


Figure 50 Base 2 High Flow: Water Surface Elevations in the Vicinity of Old and New Entrances in the Canal

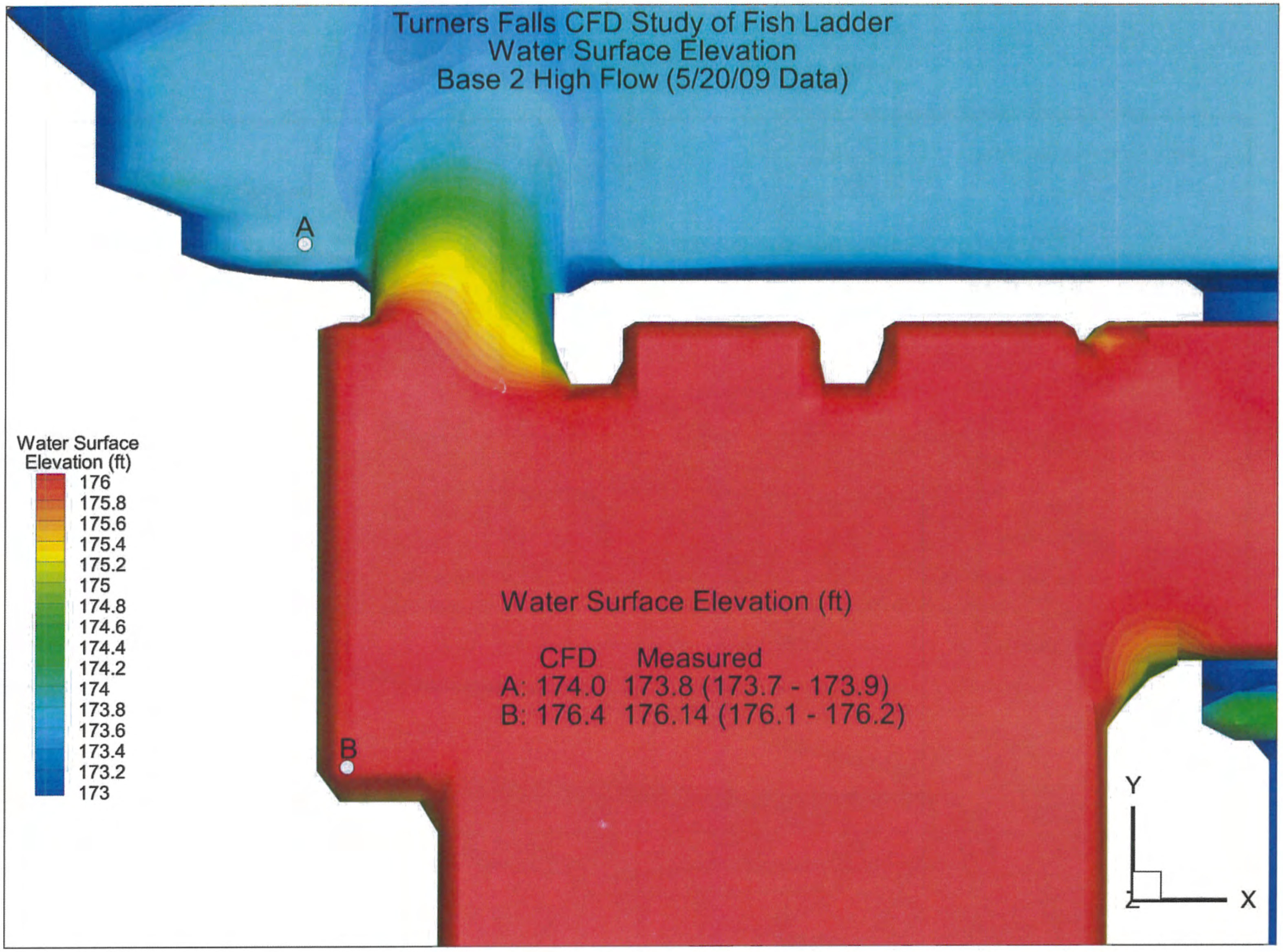


Figure 51 Base 2 High Flow: Water Surface Elevations in the Vicinity of Old Entrance and Measurement Points Locations

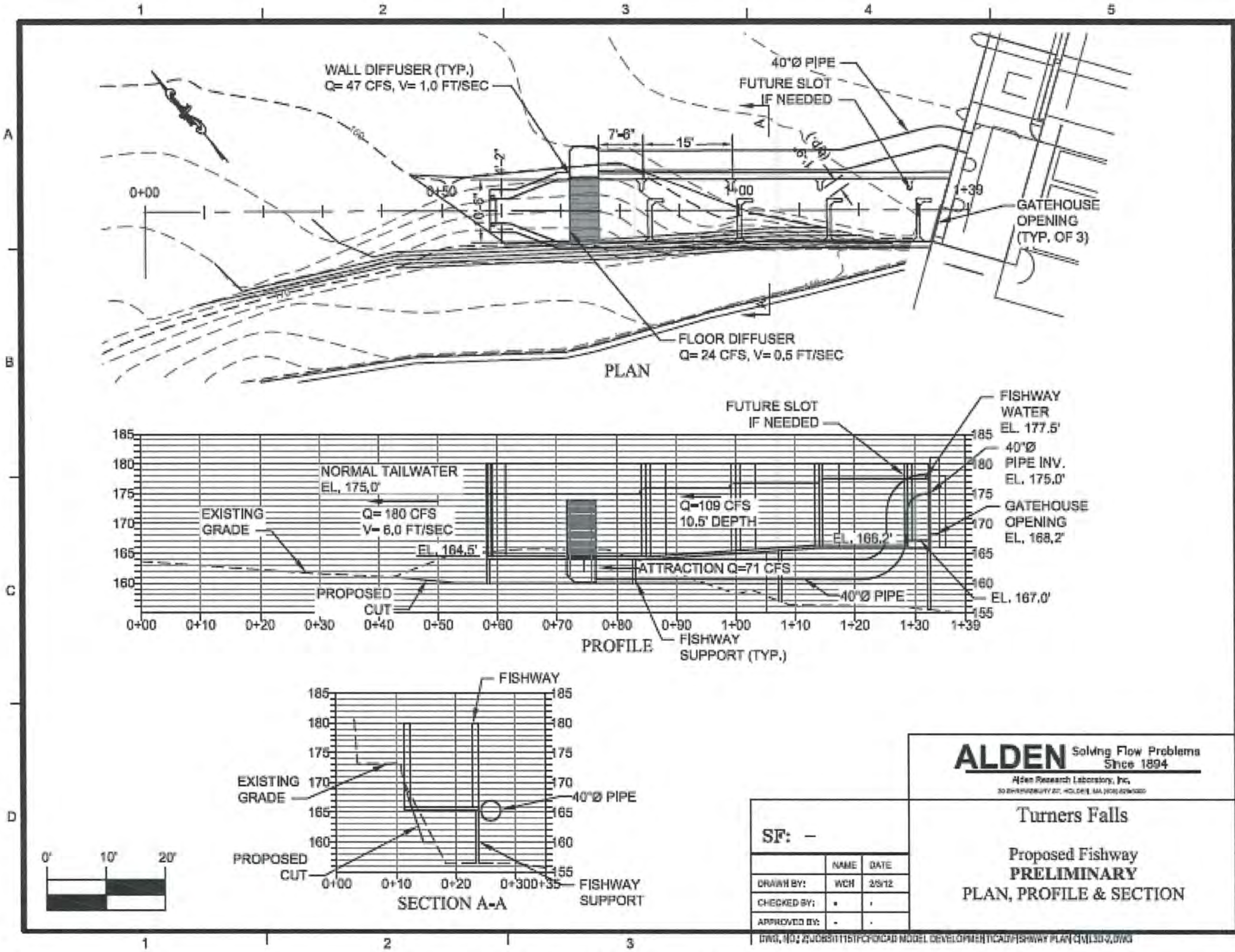


Figure 52 Plan and Vertical Views of Mod 0

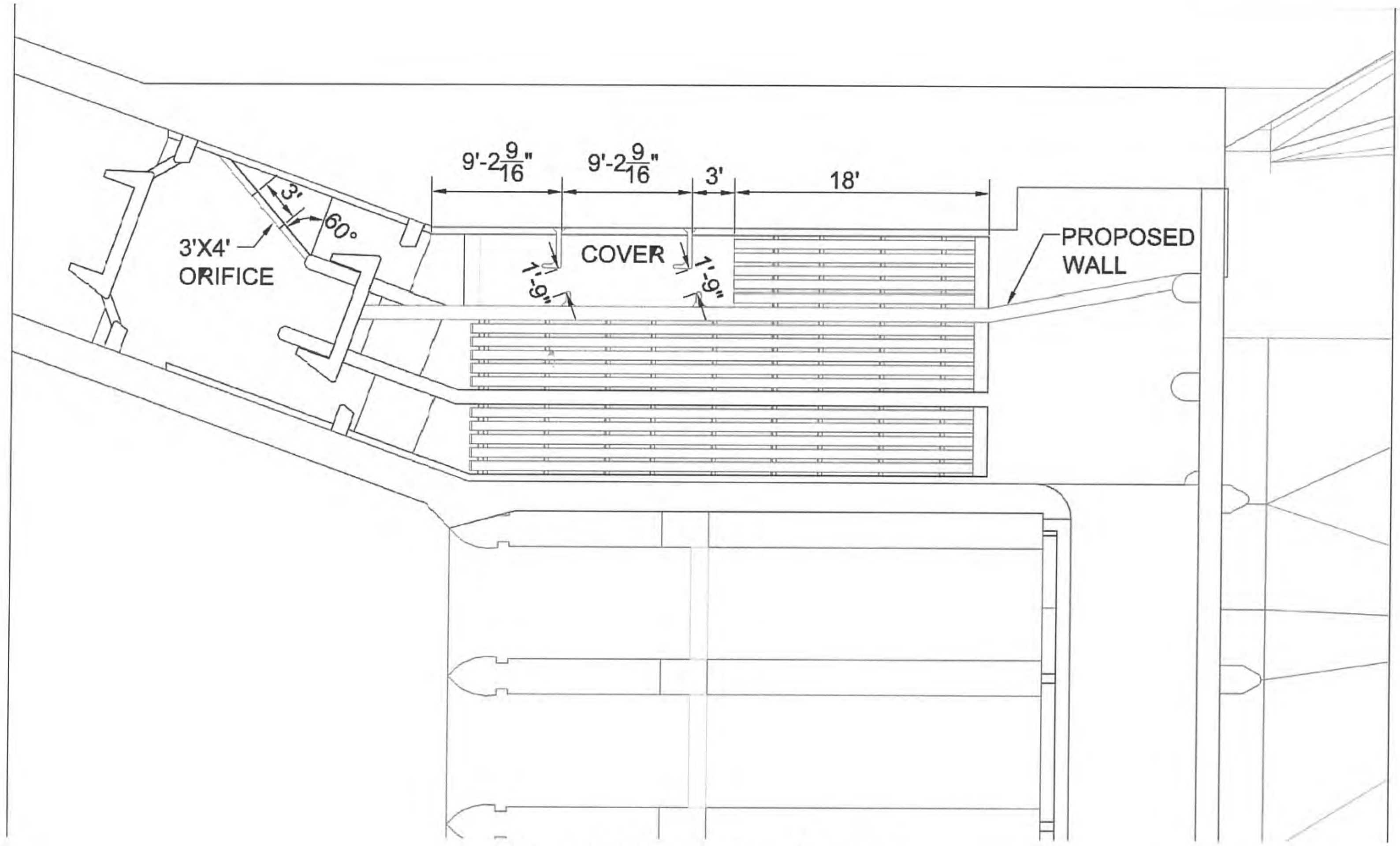


Figure 53 Description of Mod 1

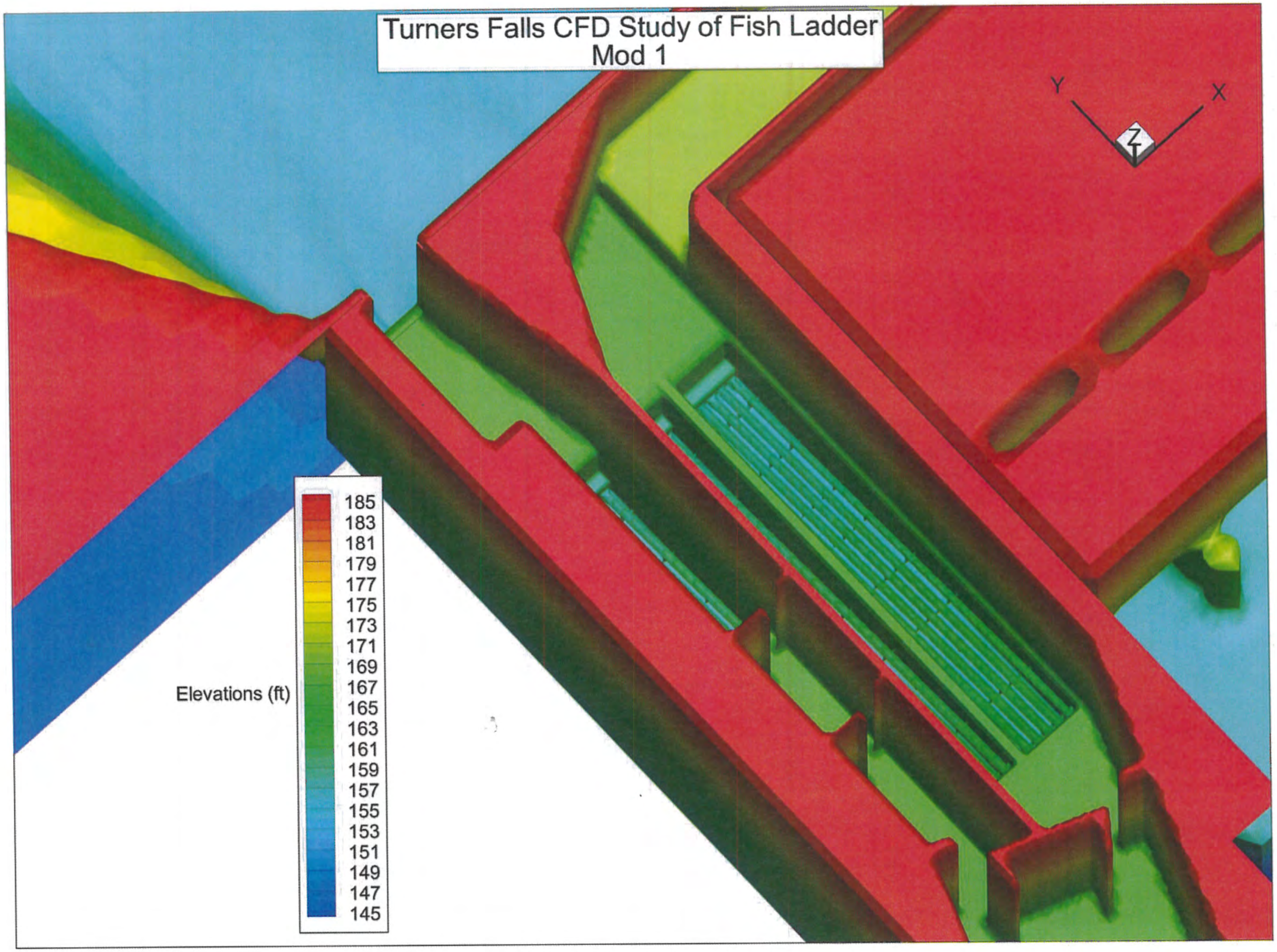


Figure 54 3D View of Mod 1 Concept

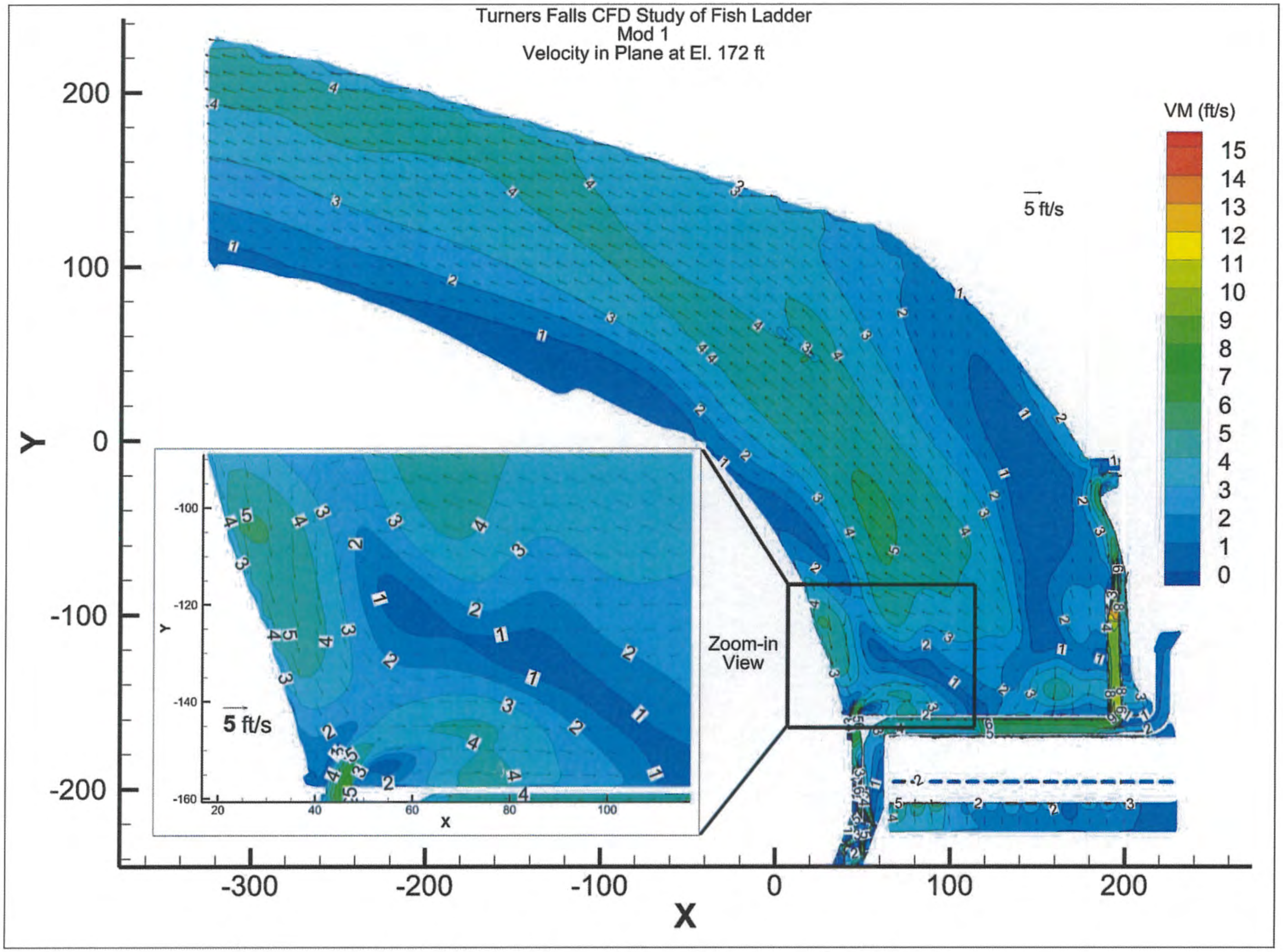


Figure 55 Mod 1: Velocity in Plane at El. 172 ft

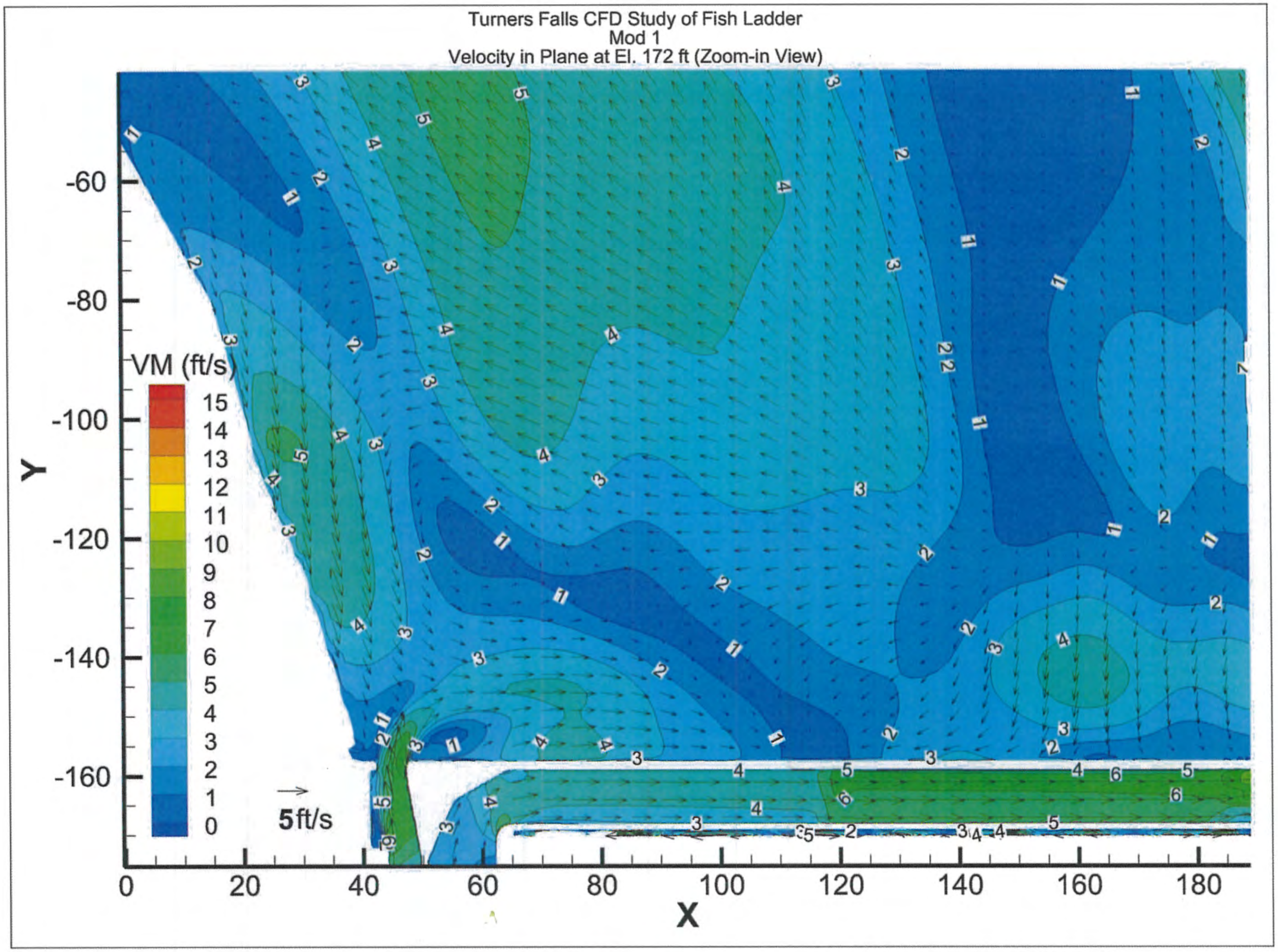


Figure 56 Mod 1: Velocity in the Vicinity of Old Entrance in the Canal at El. 172 ft

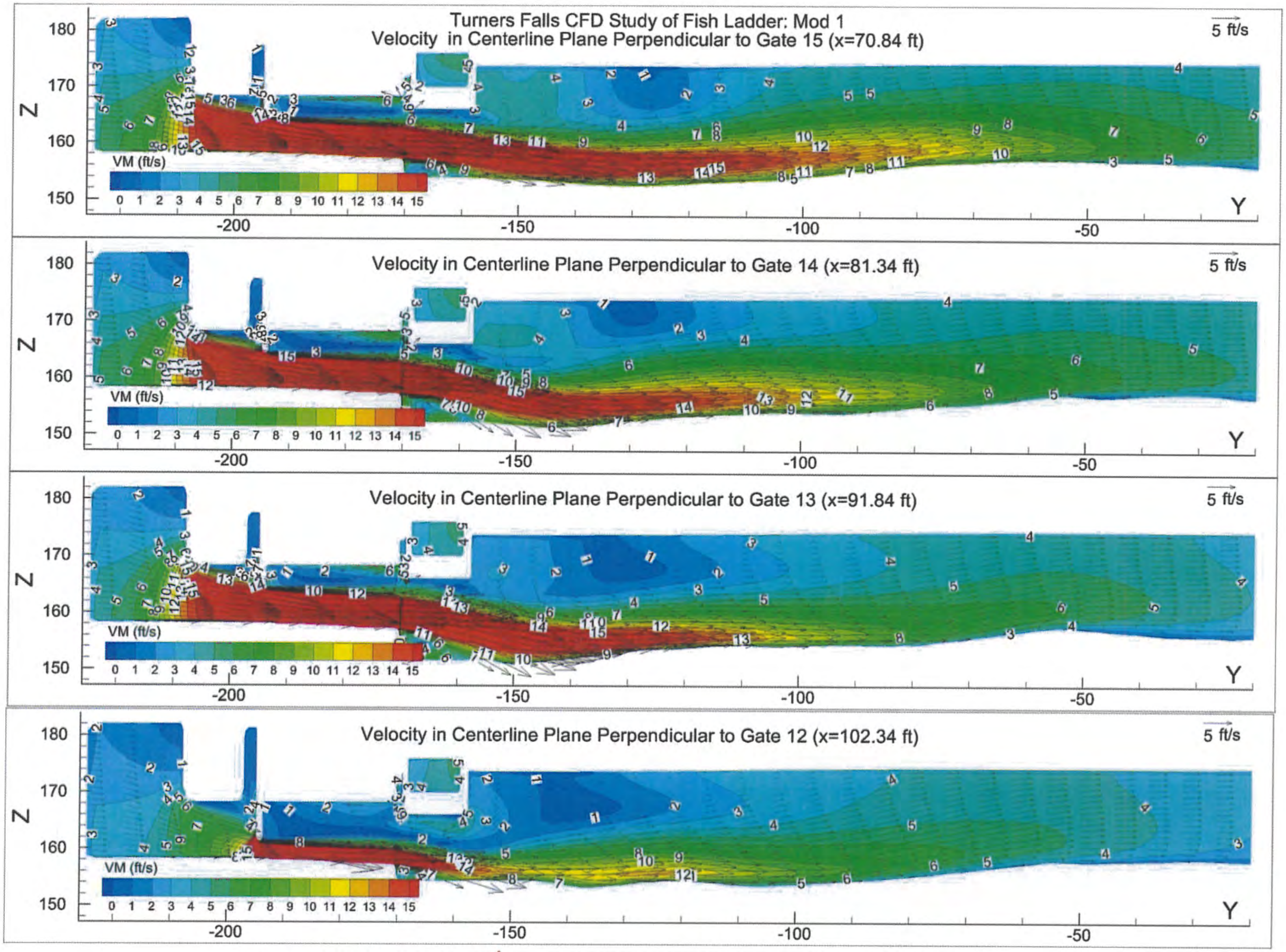


Figure 57 Mod 1: Velocity in Centerline Planes of Gates 12 through 15

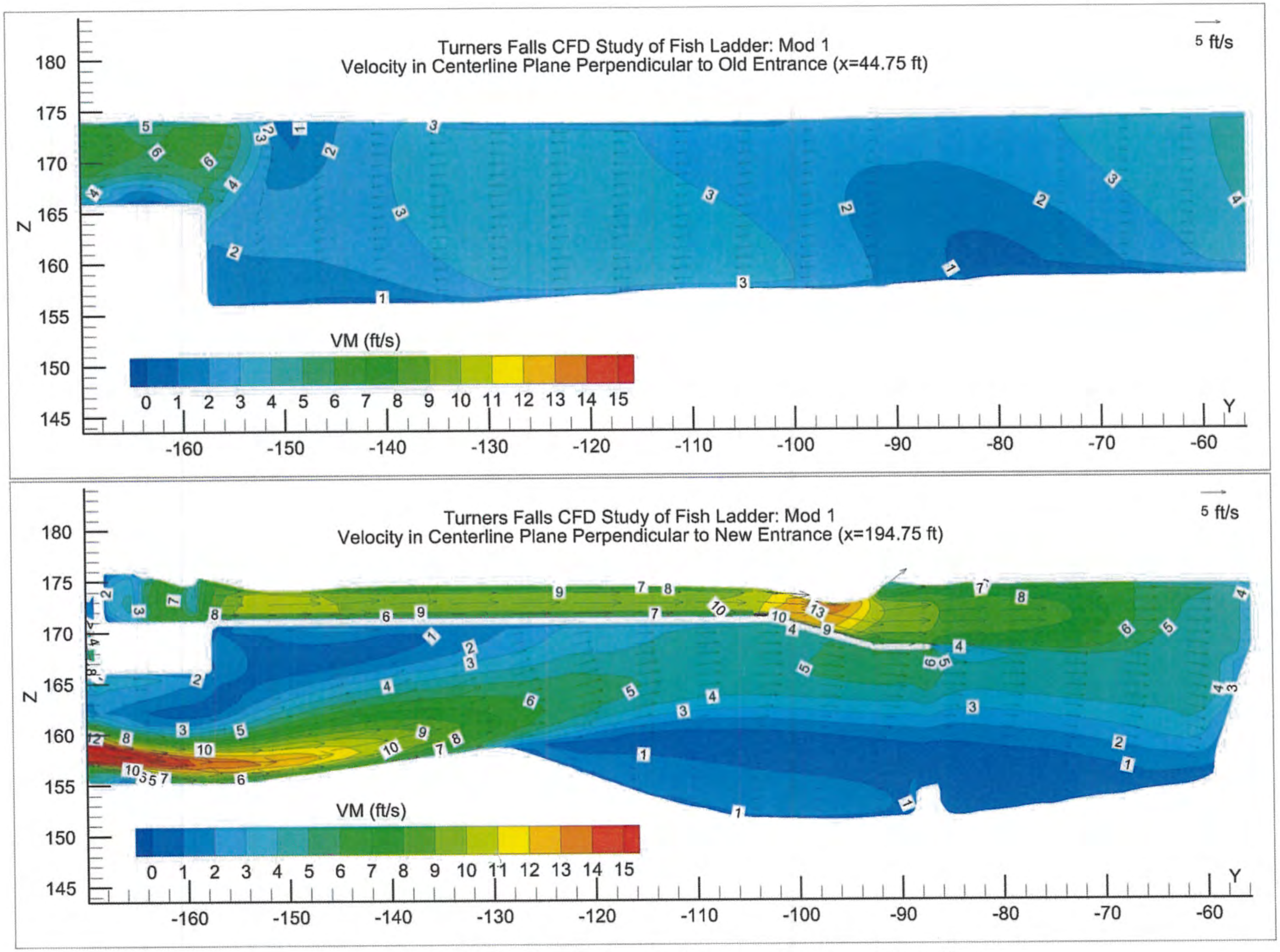


Figure 58 Mod 1: Velocity in Centerline Planes of Old and New Entrances

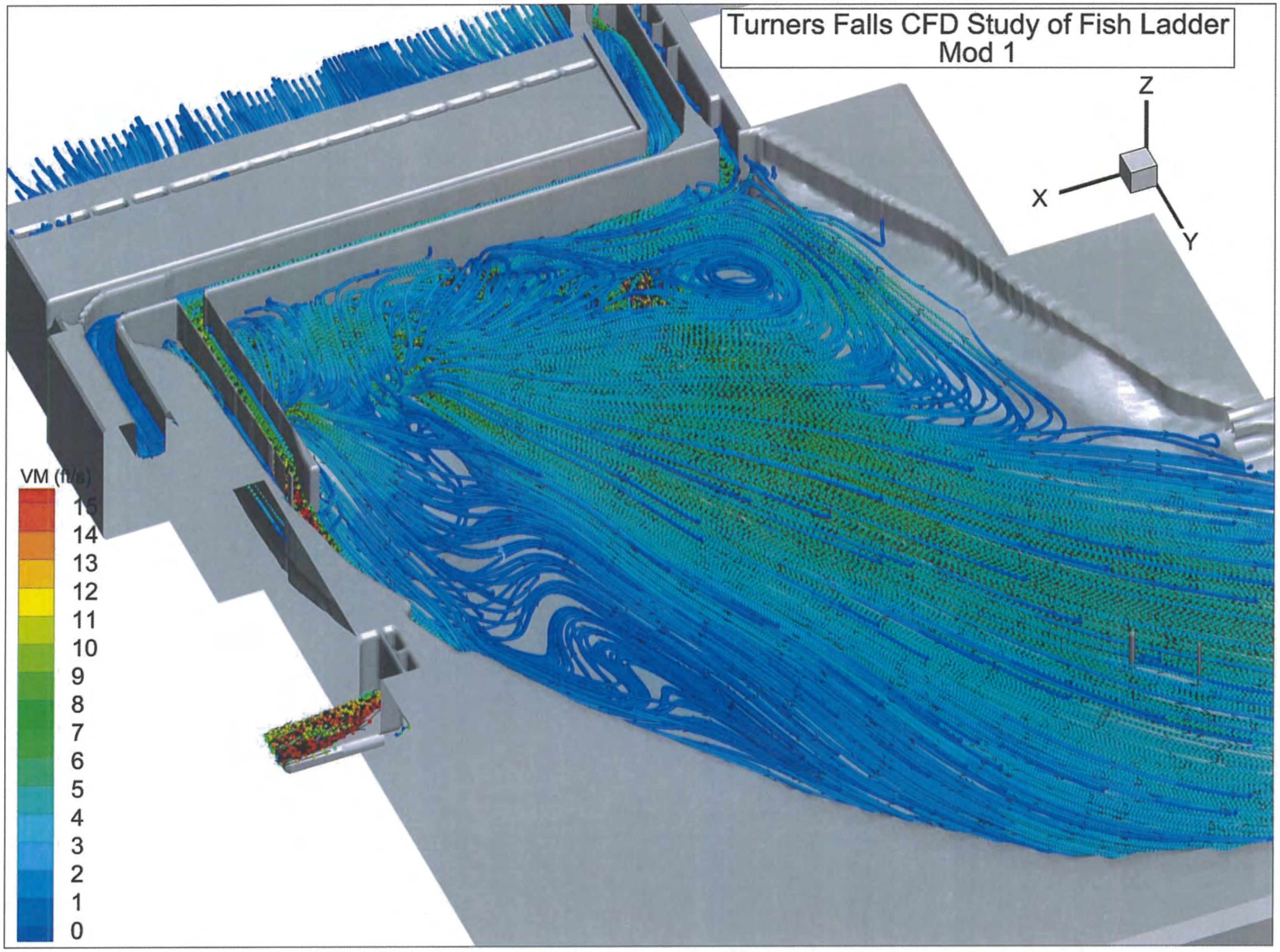


Figure 59 Mod 1: 3D Pathlines

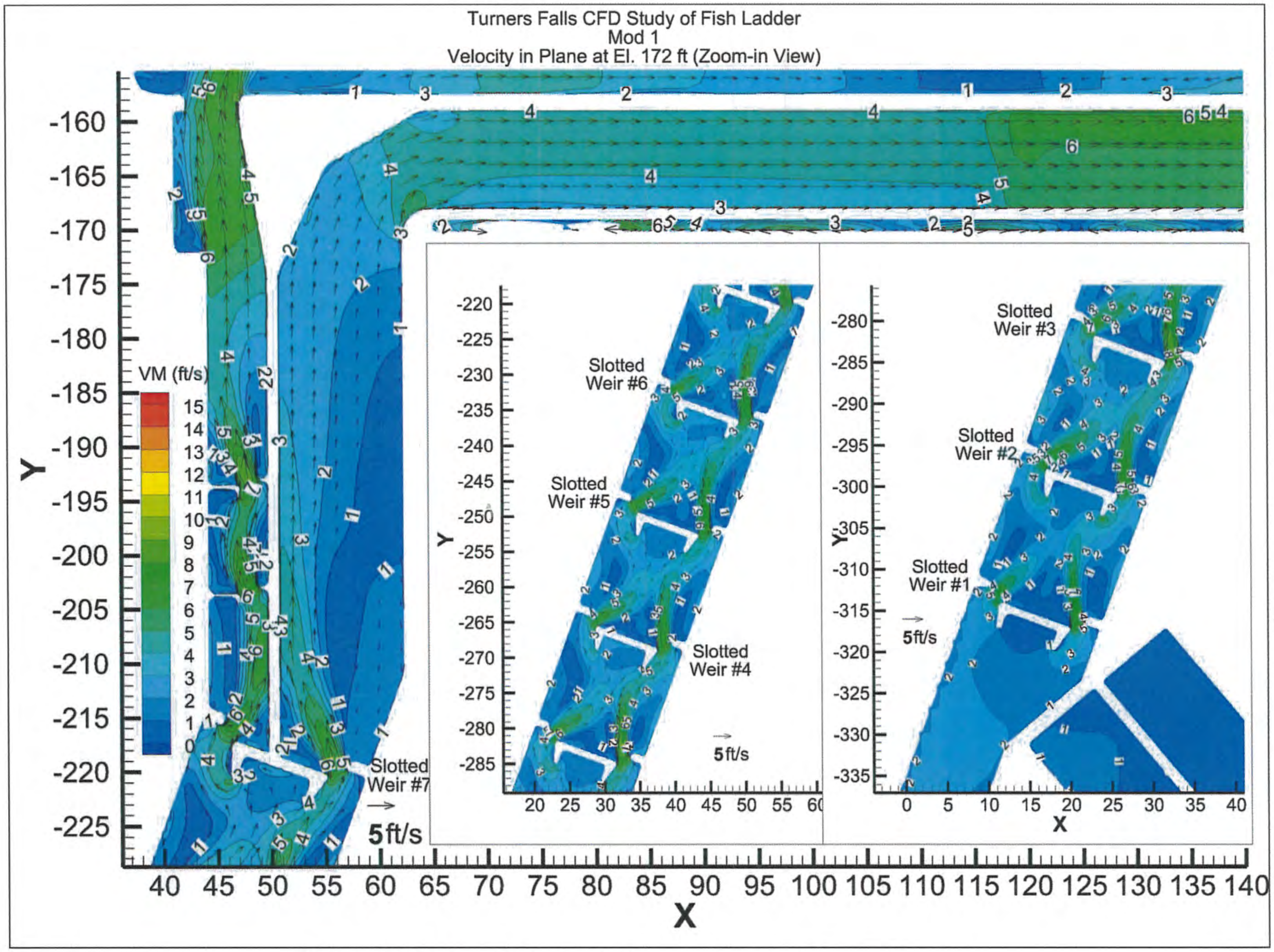


Figure 60 Mod 1: Velocity in Upstream Fish Way at El. 172 ft

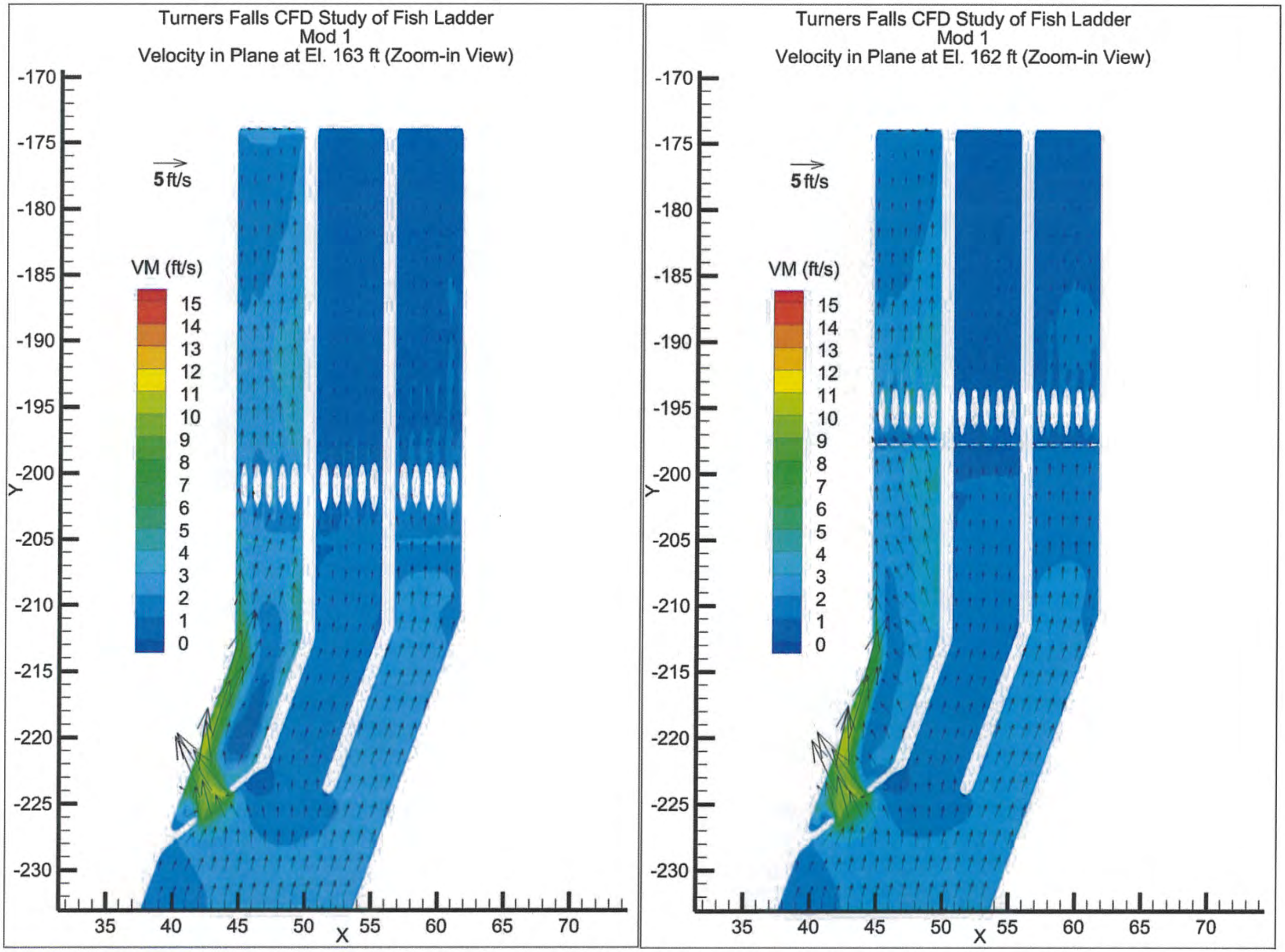


Figure 61 Mod 1: Velocity in Attraction Flow Channel at El. 163 and El. 162 ft

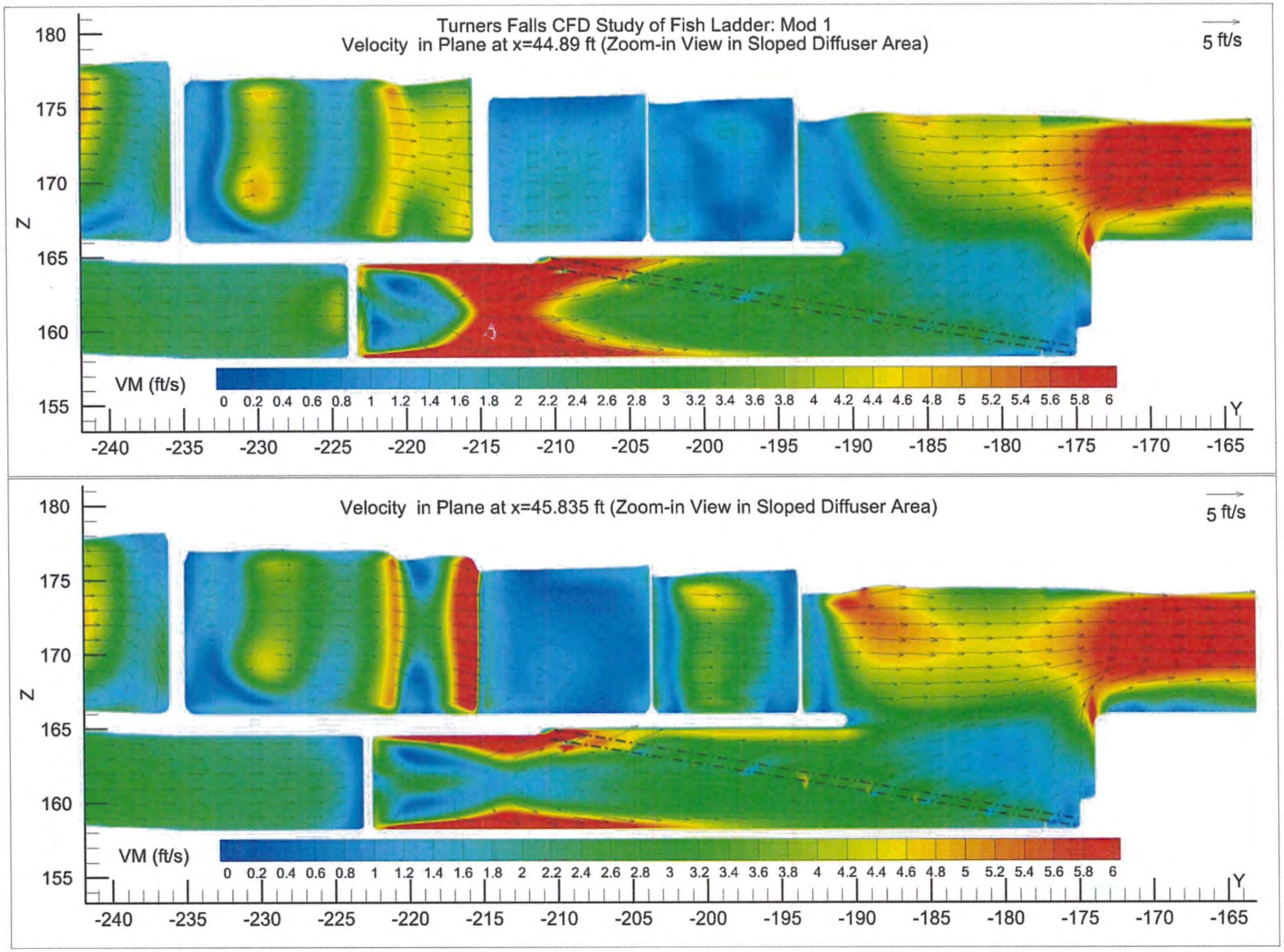


Figure 62 Mod 1: Velocity in Vertical Planes in the Left Sloped Diffuser Channel

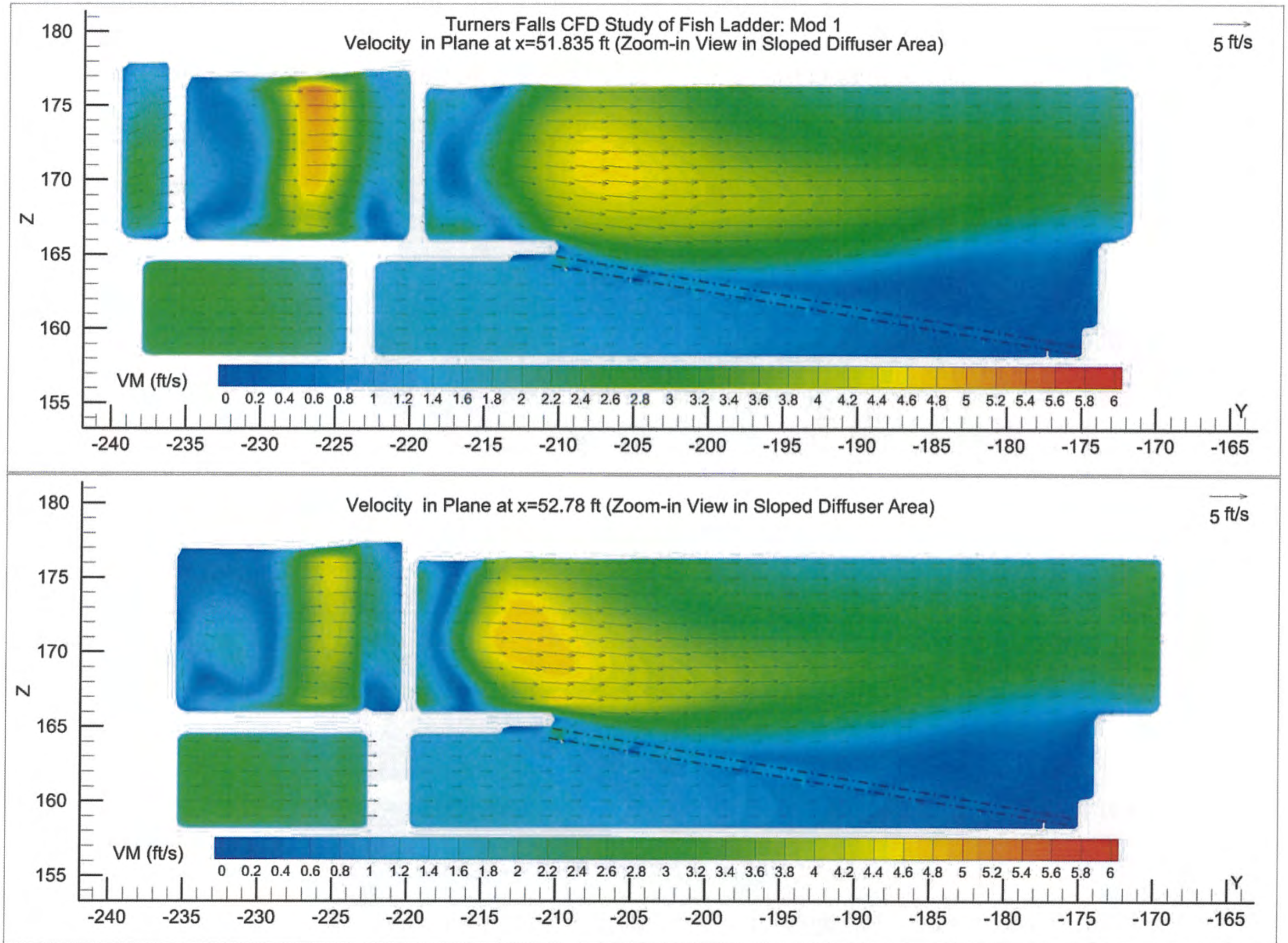


Figure 63 Mod 1: Velocity in Vertical Planes in the Middle Sloped Diffuser Channel

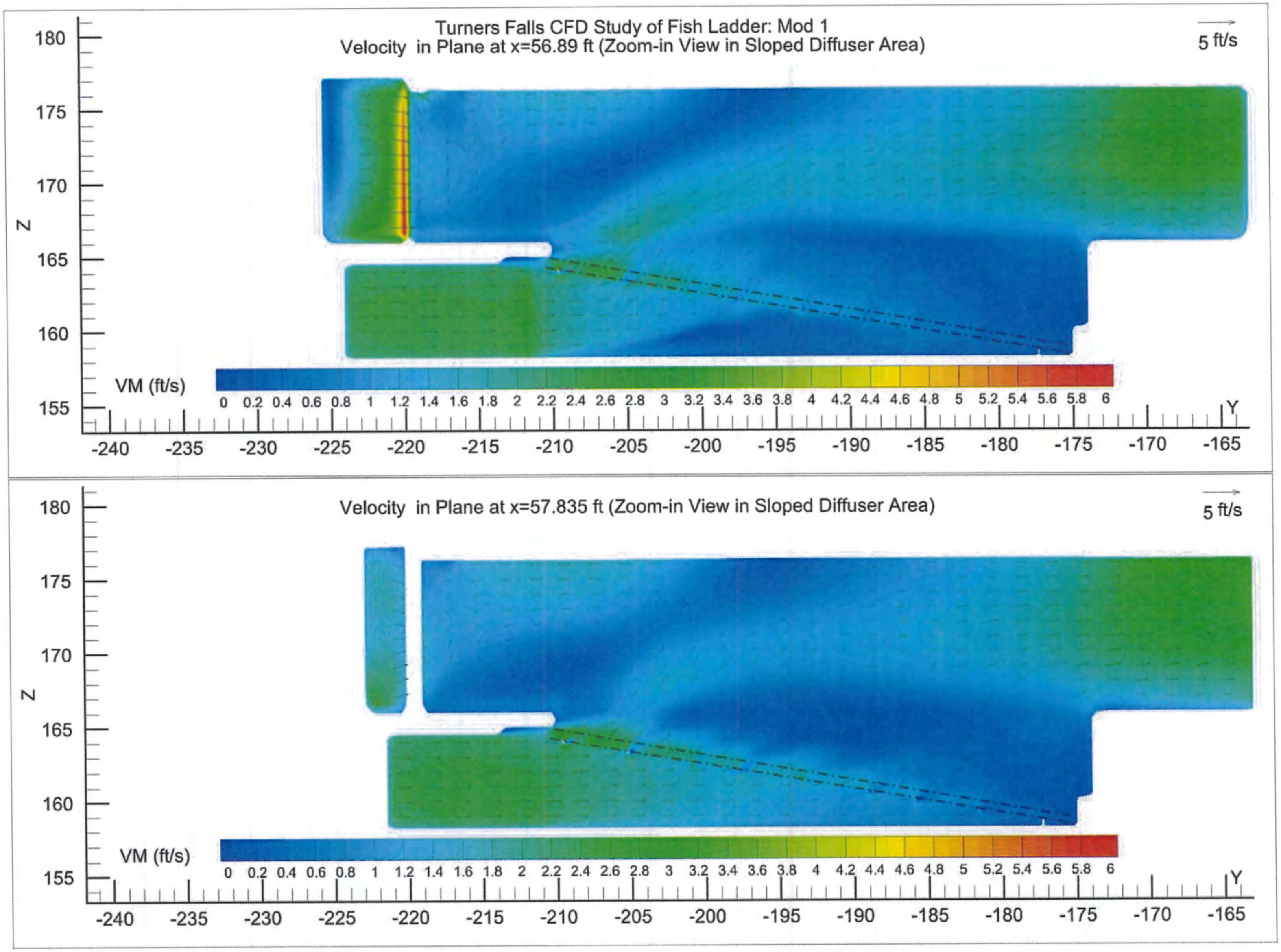


Figure 64 Mod 1: Velocity in Vertical Planes in the Right Sloped Diffuser Channel

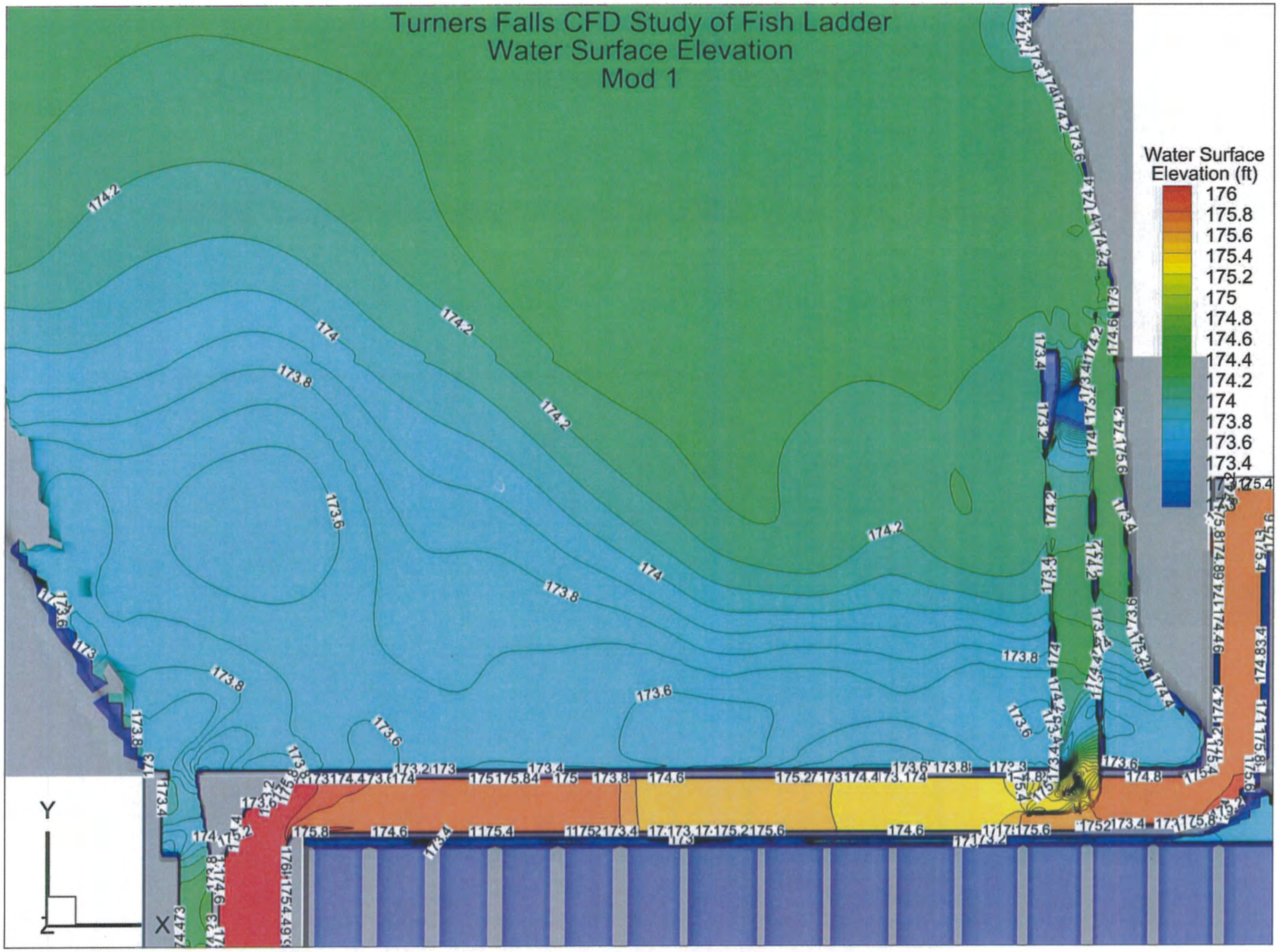


Figure 65 Mod 1: Water Surface Elevation in the Vicinity of Old and New Entrances in the Canal

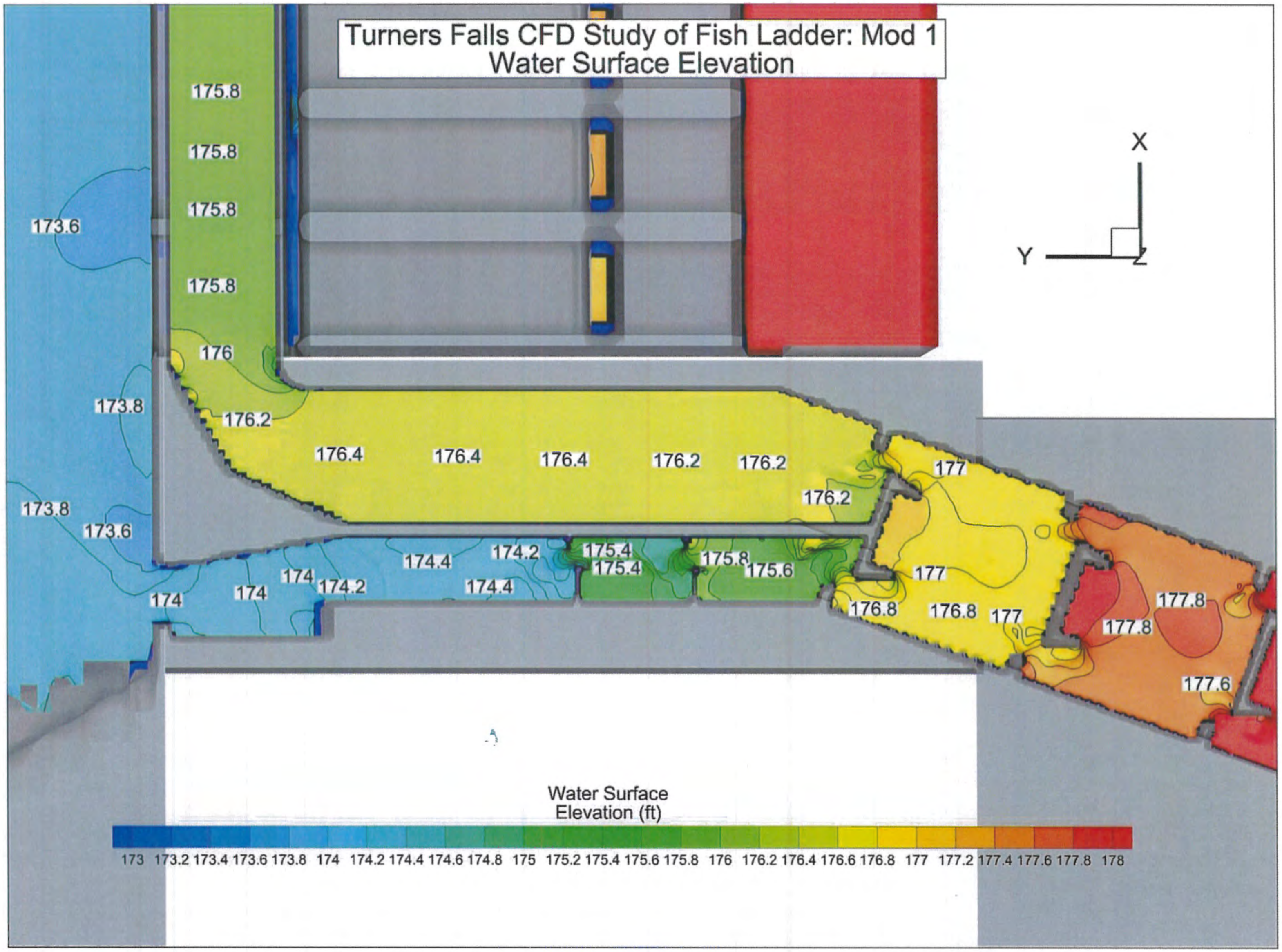


Figure 66 Mod 1: Water Surface Elevation in the Modified Area of Fish Way

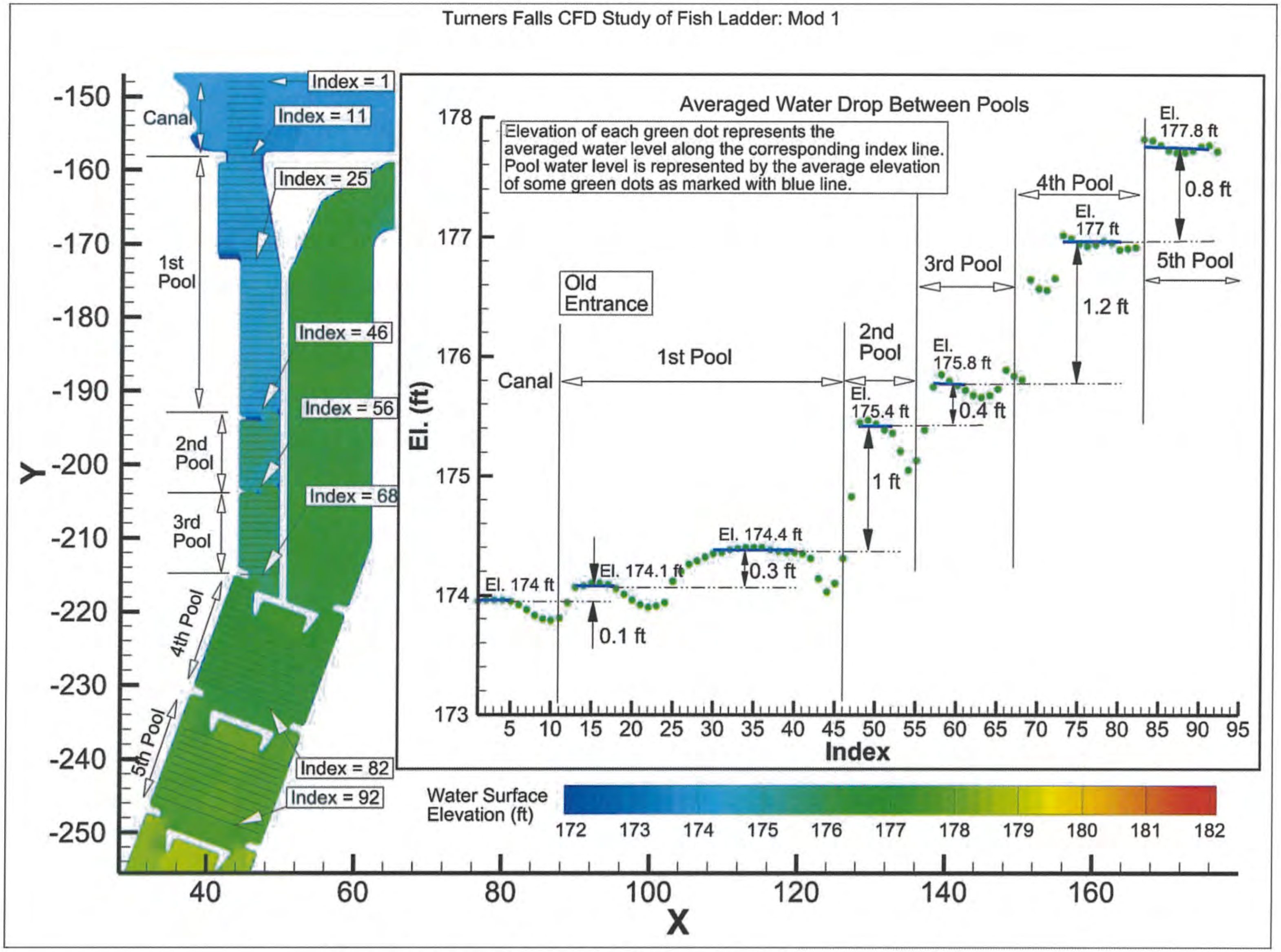


Figure 67 Mod 1: Averaged Water Drop between Pools

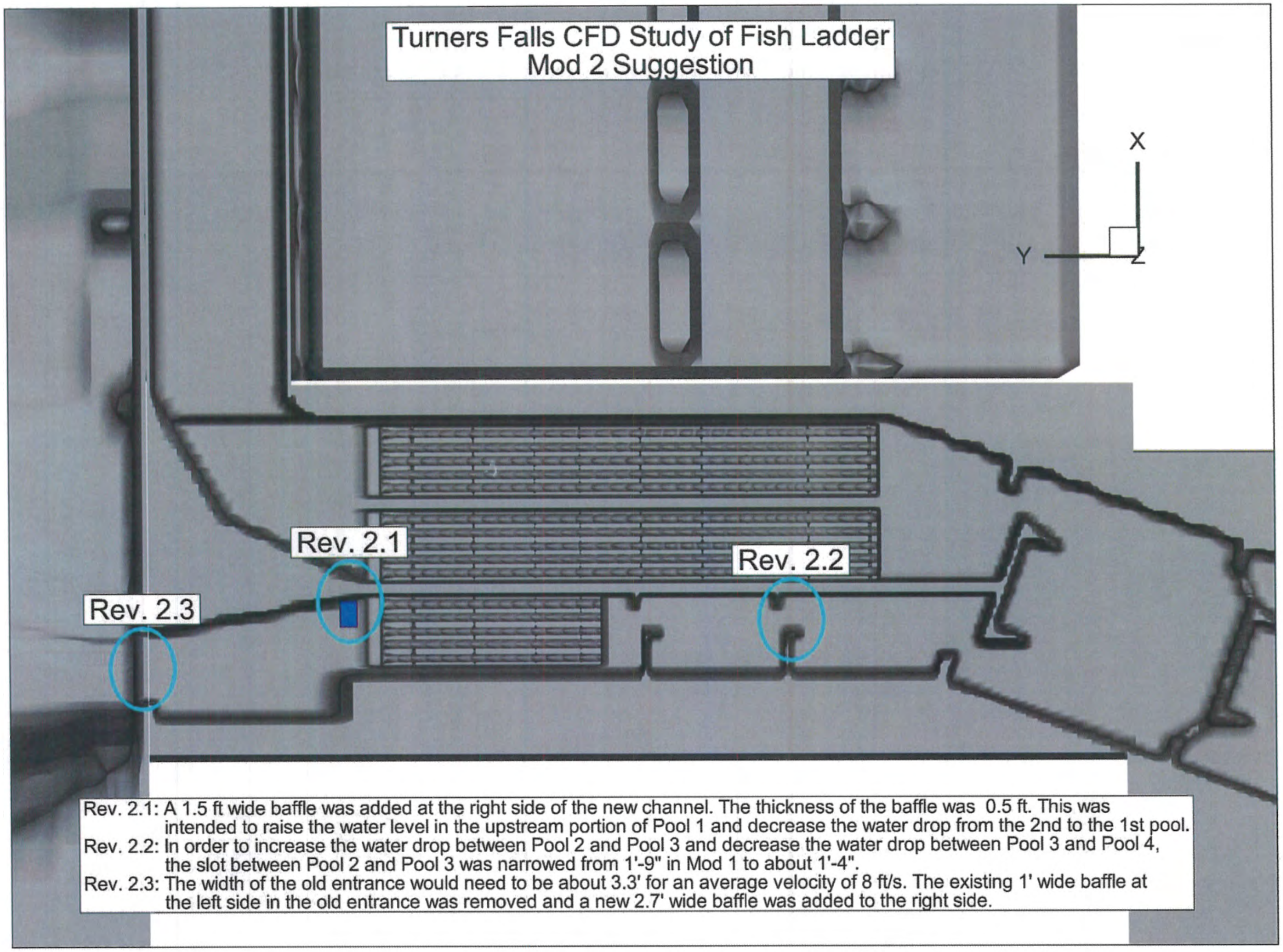


Figure 68 Schematic of Geometry Modification of Mod 2

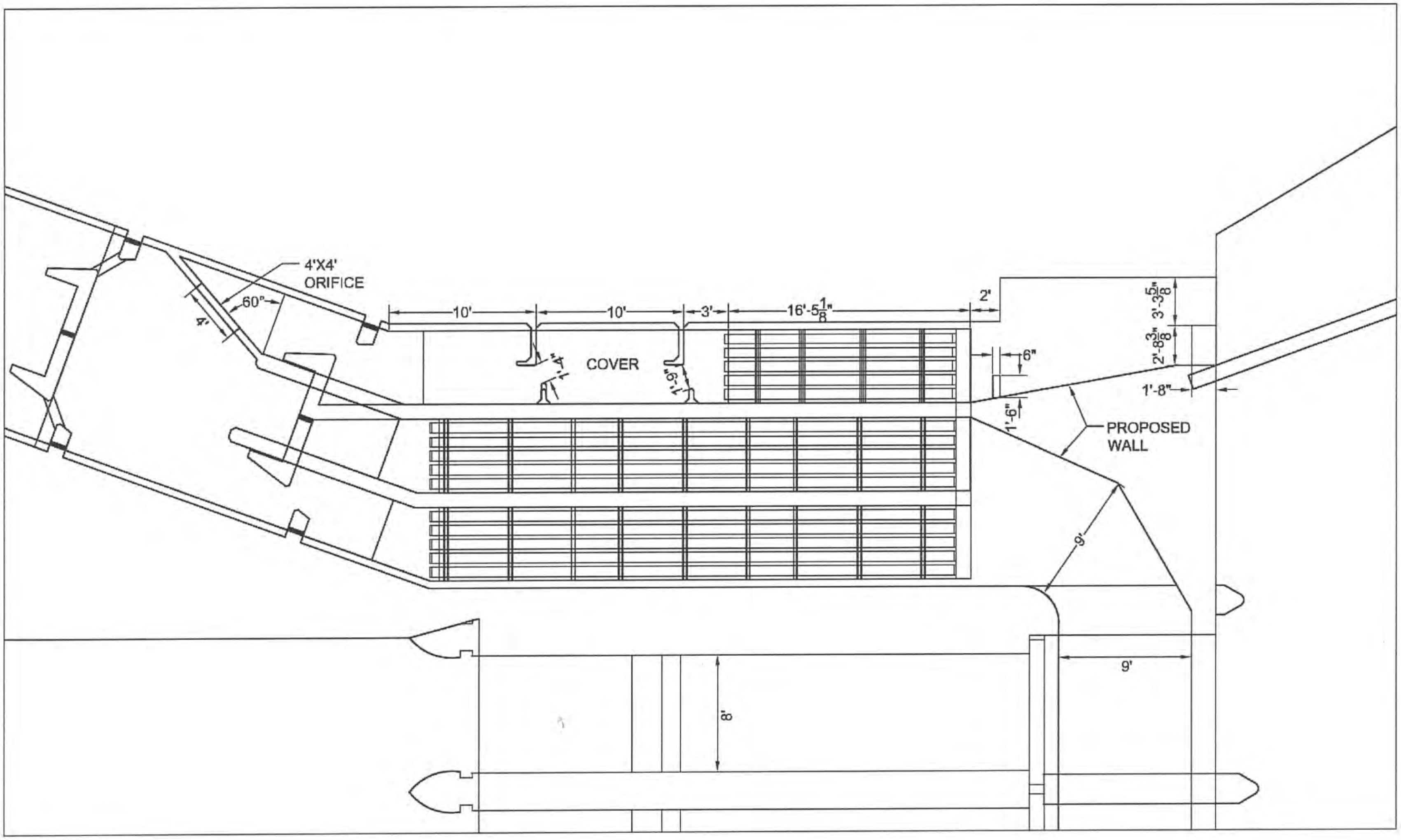


Figure 69 Plan View of Mod 2

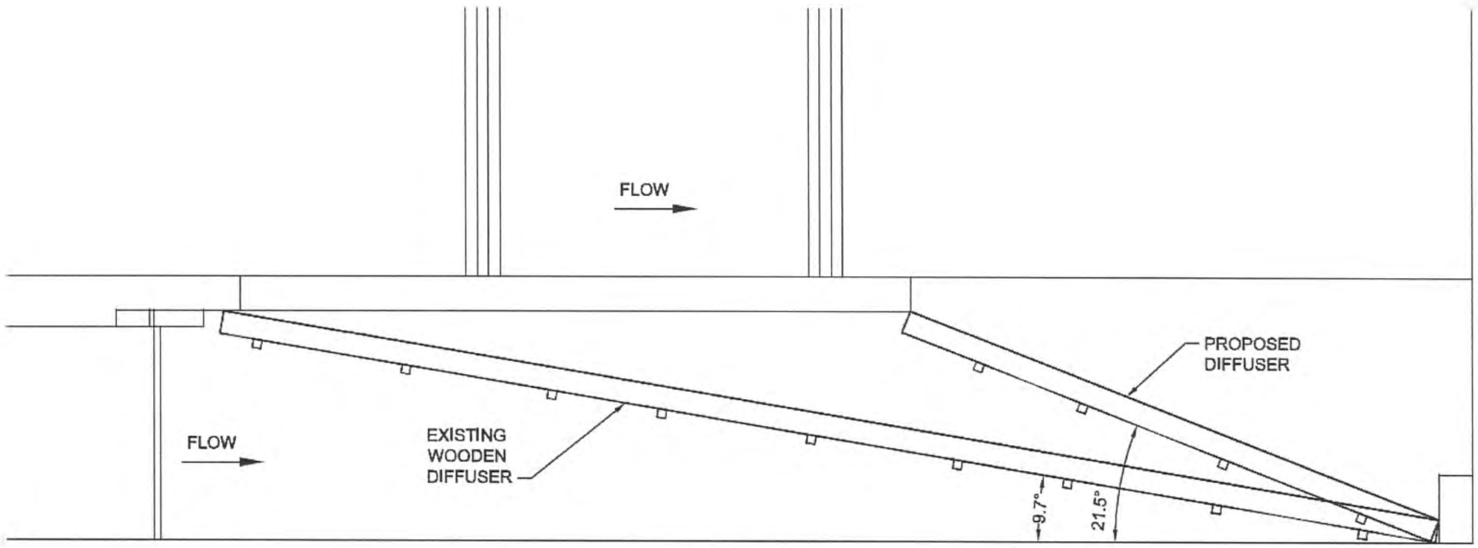


Figure 70 Schematic of Rev. 2.4 in Mod 2

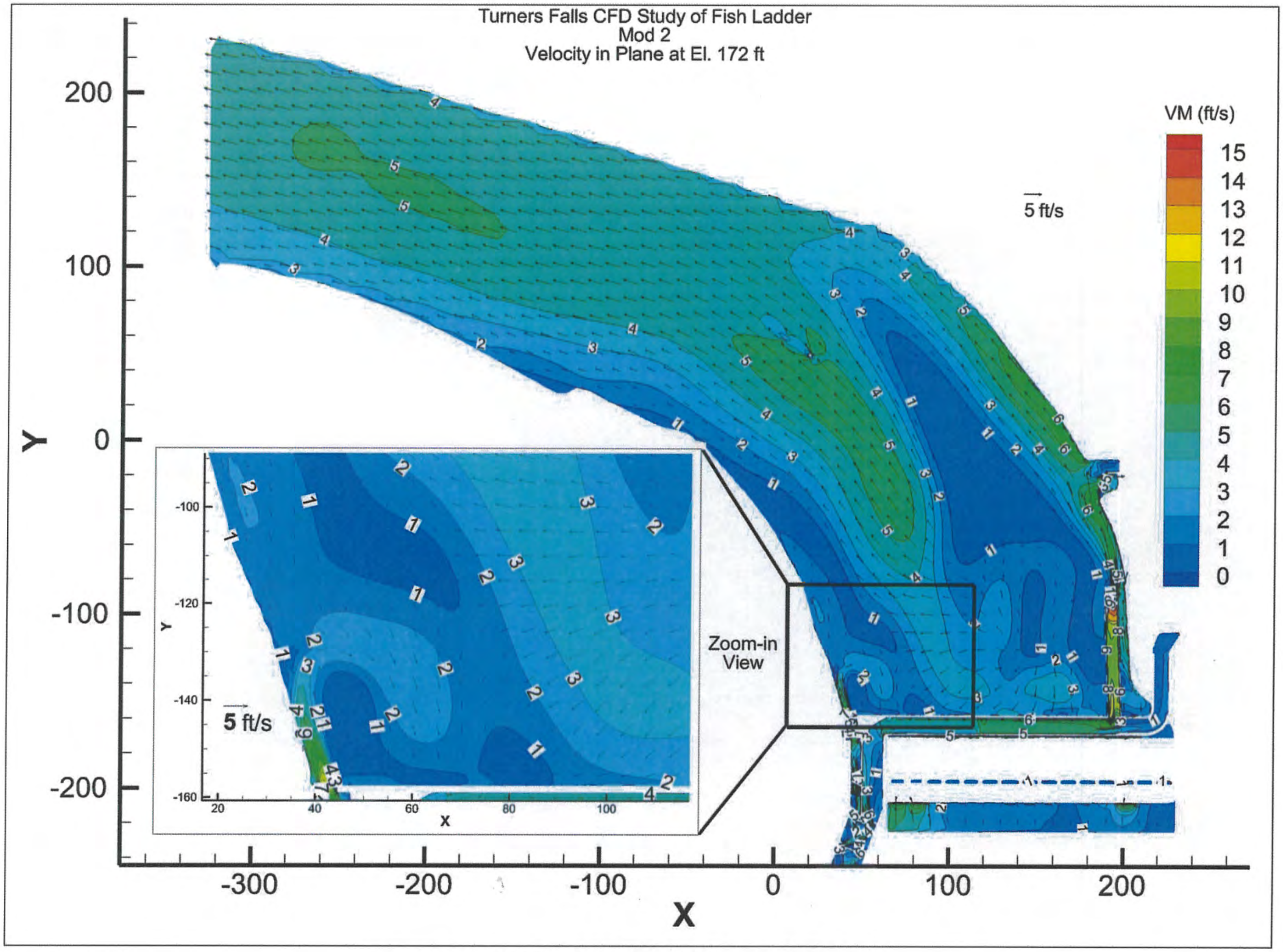


Figure 71 Mod 2: Velocity in Plane at El. 172 ft

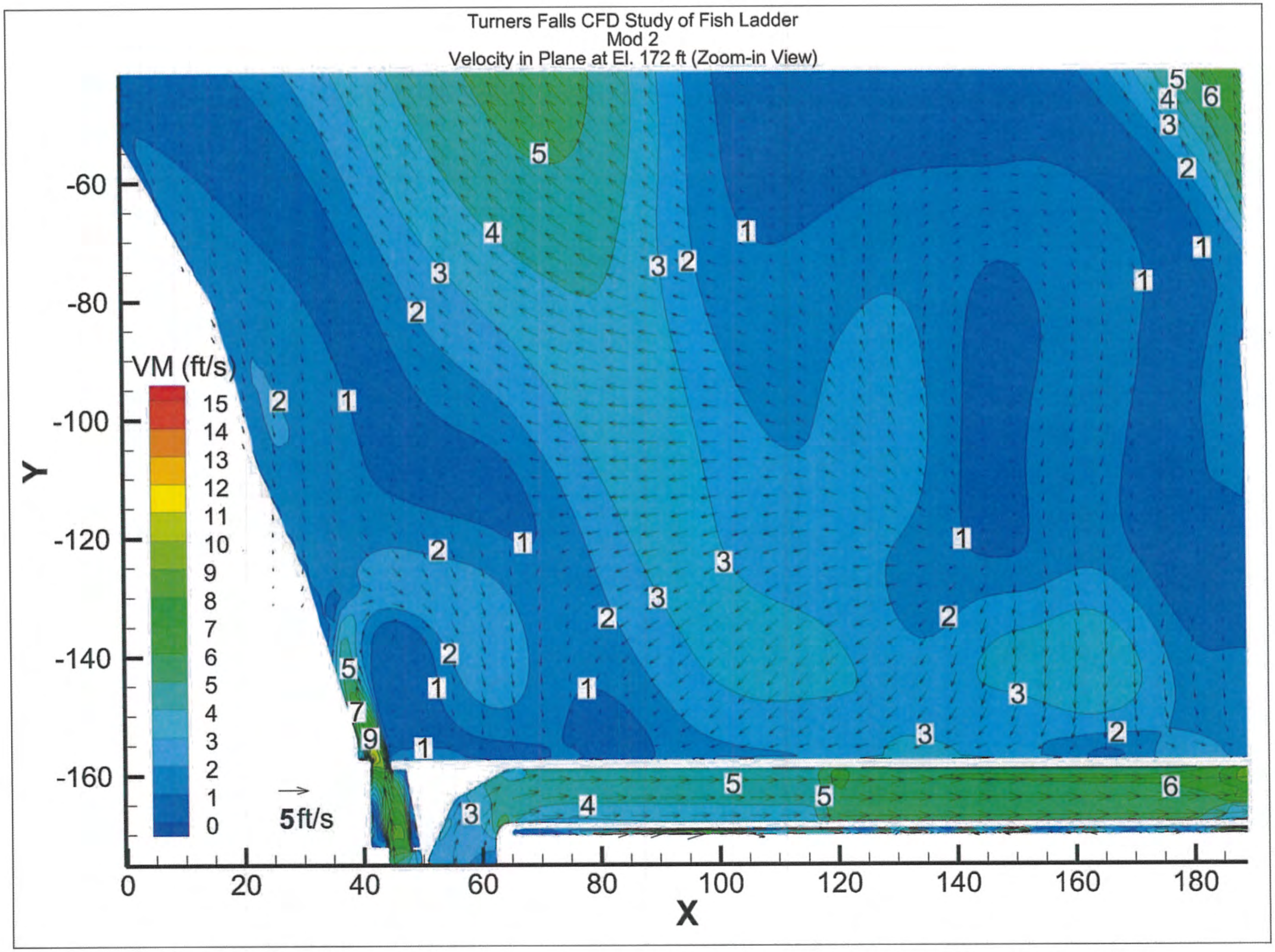


Figure 72 Mod 2: Velocity in the Vicinity of Old Entrance in the Canal in Plane at El. 172 ft

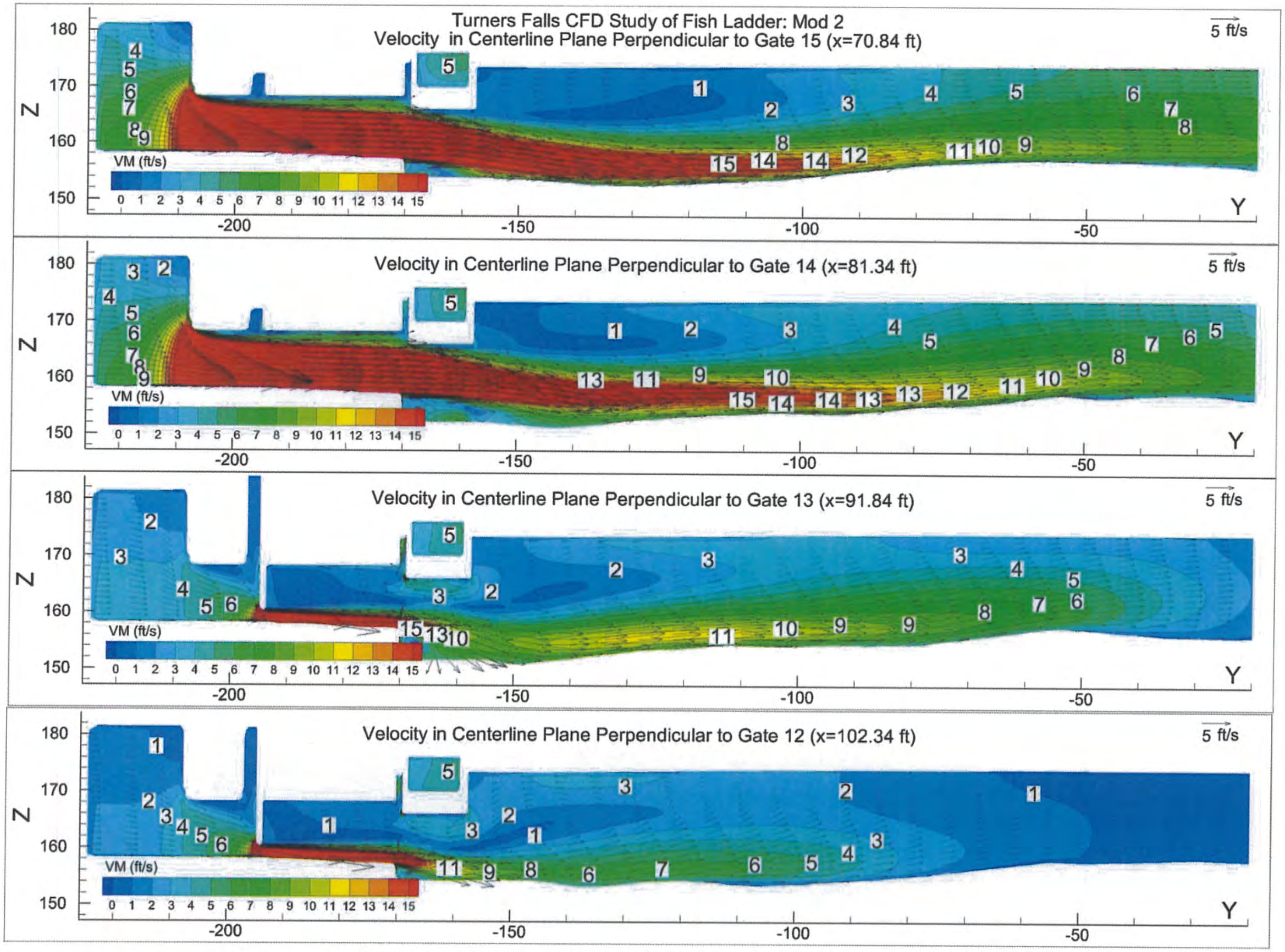


Figure 73 Mod 2: Velocity in Centerline Planes of Gates 12 through 15

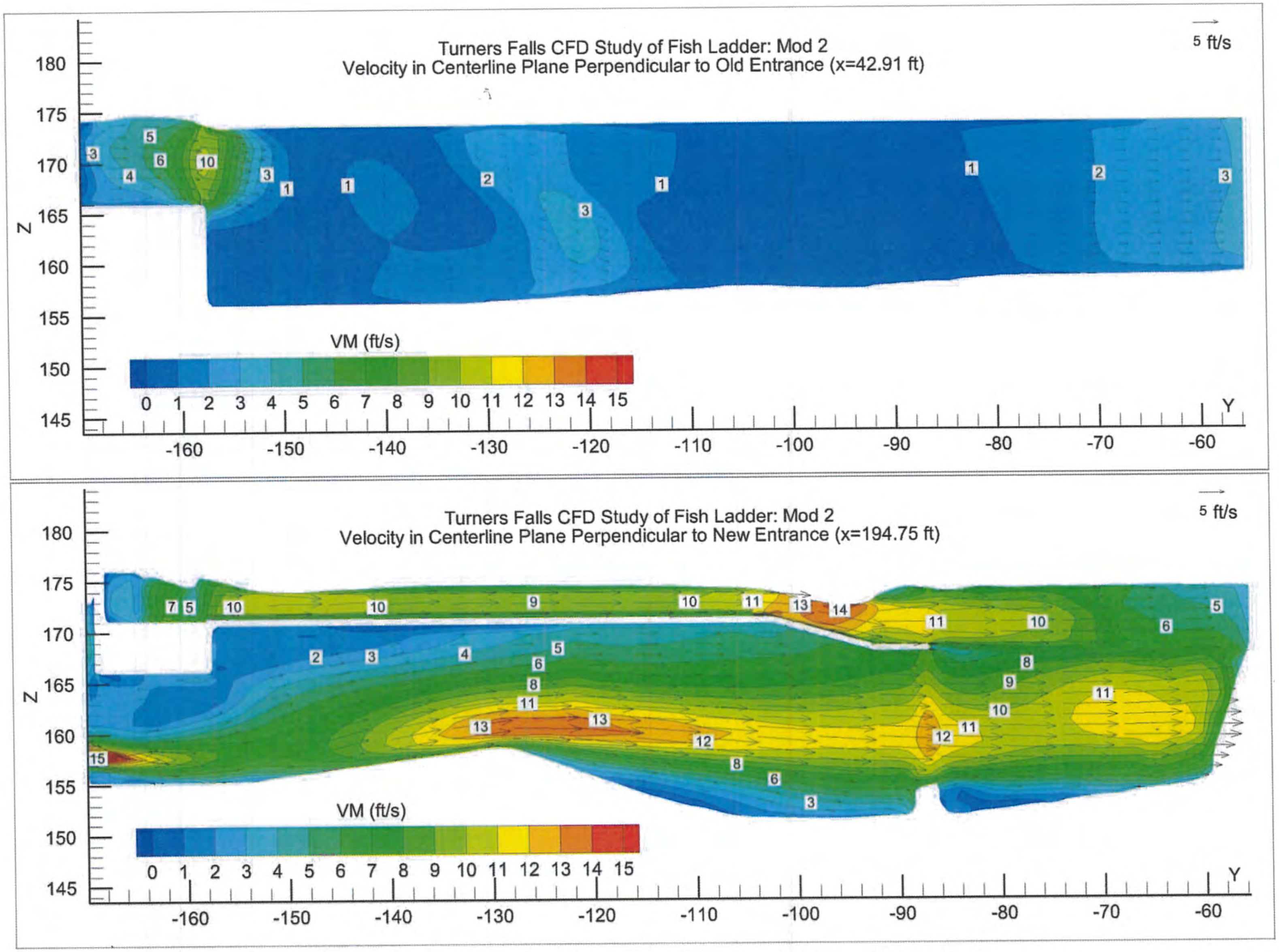


Figure 74 Mod 2: Velocity in Centerline Planes of Old and New Entrances

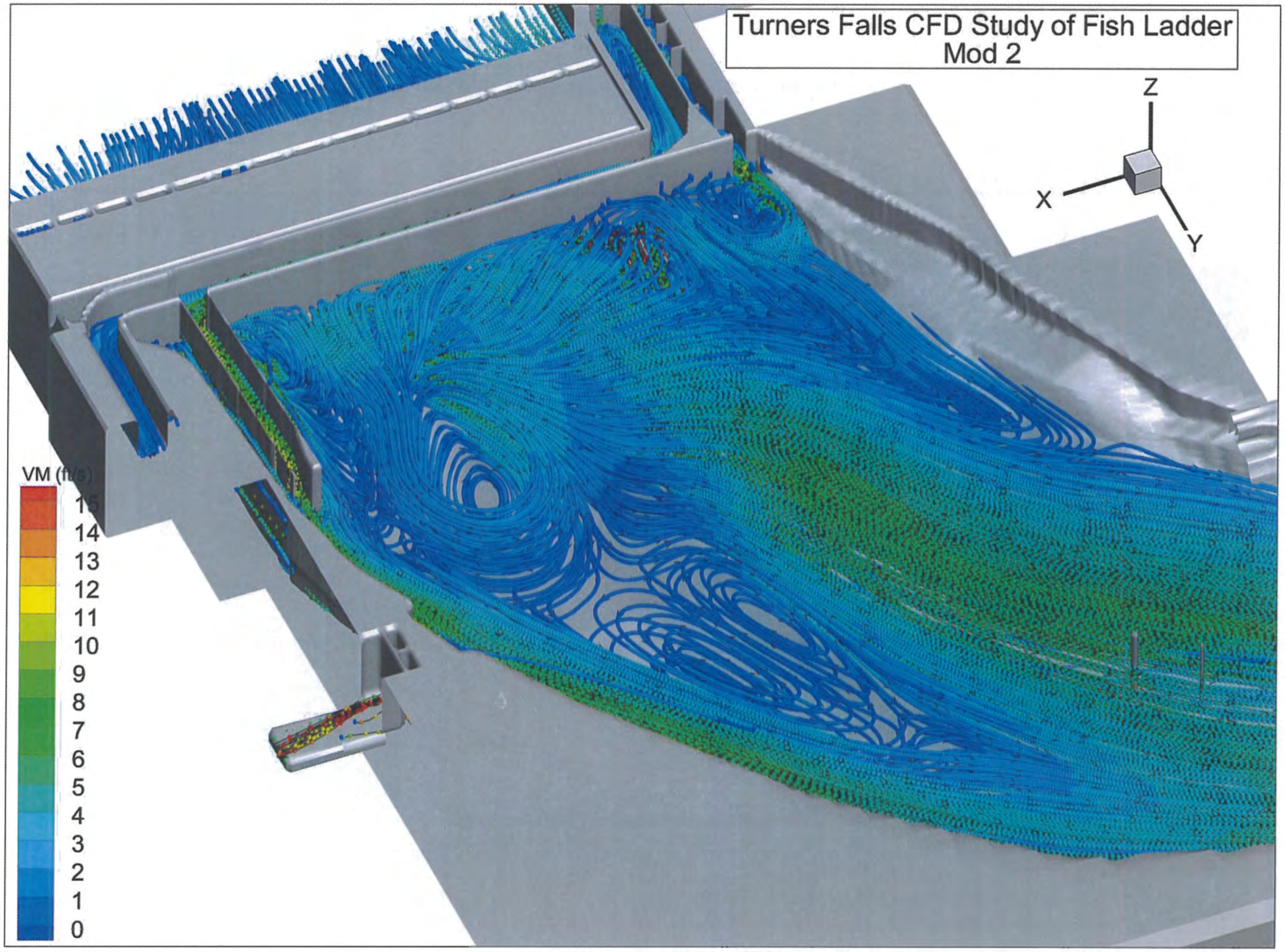


Figure 75 Mod 2: 3D Pathlines

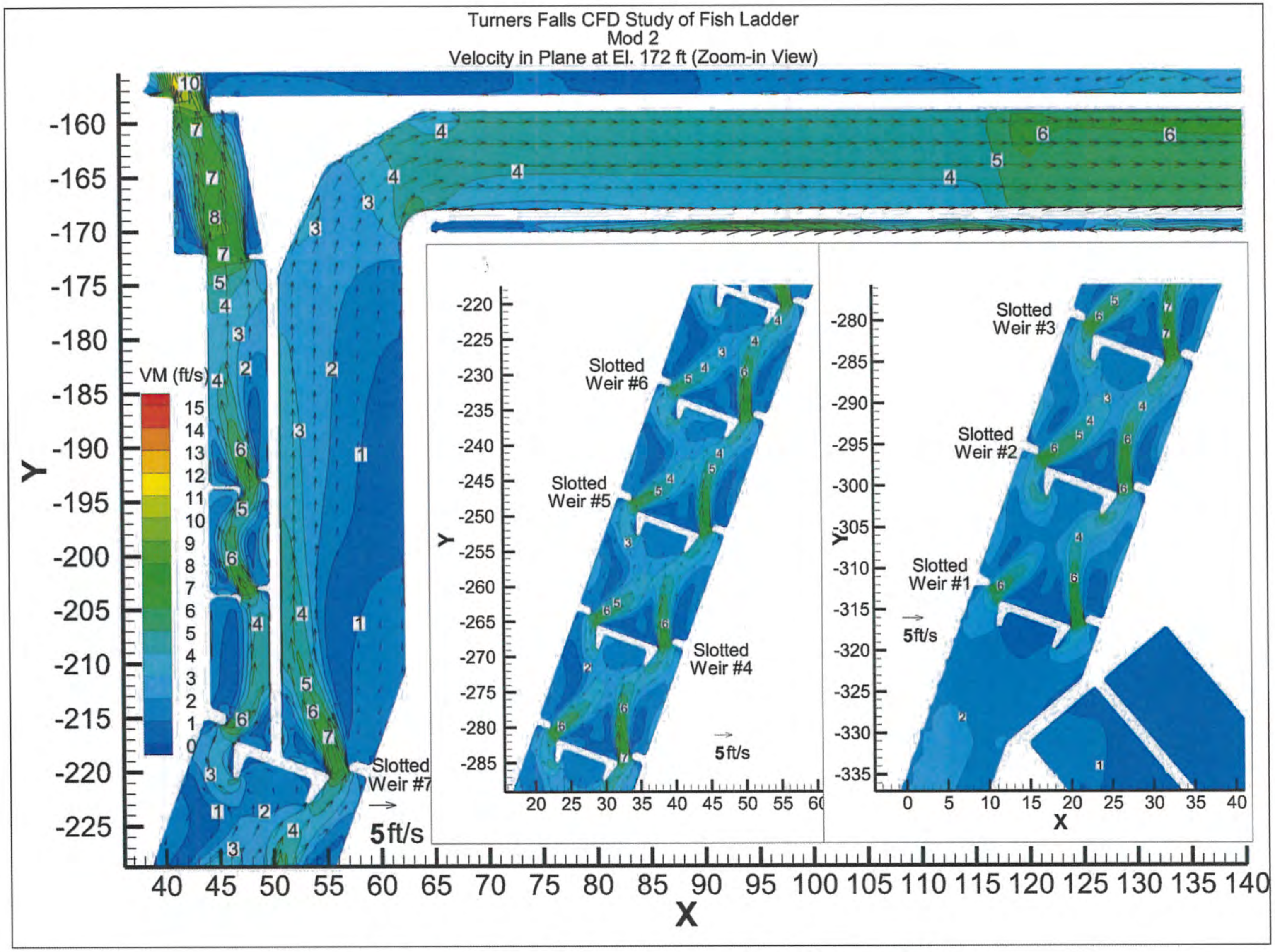


Figure 76 Mod 2: Velocity in Upstream Fish Way at El. 172 ft

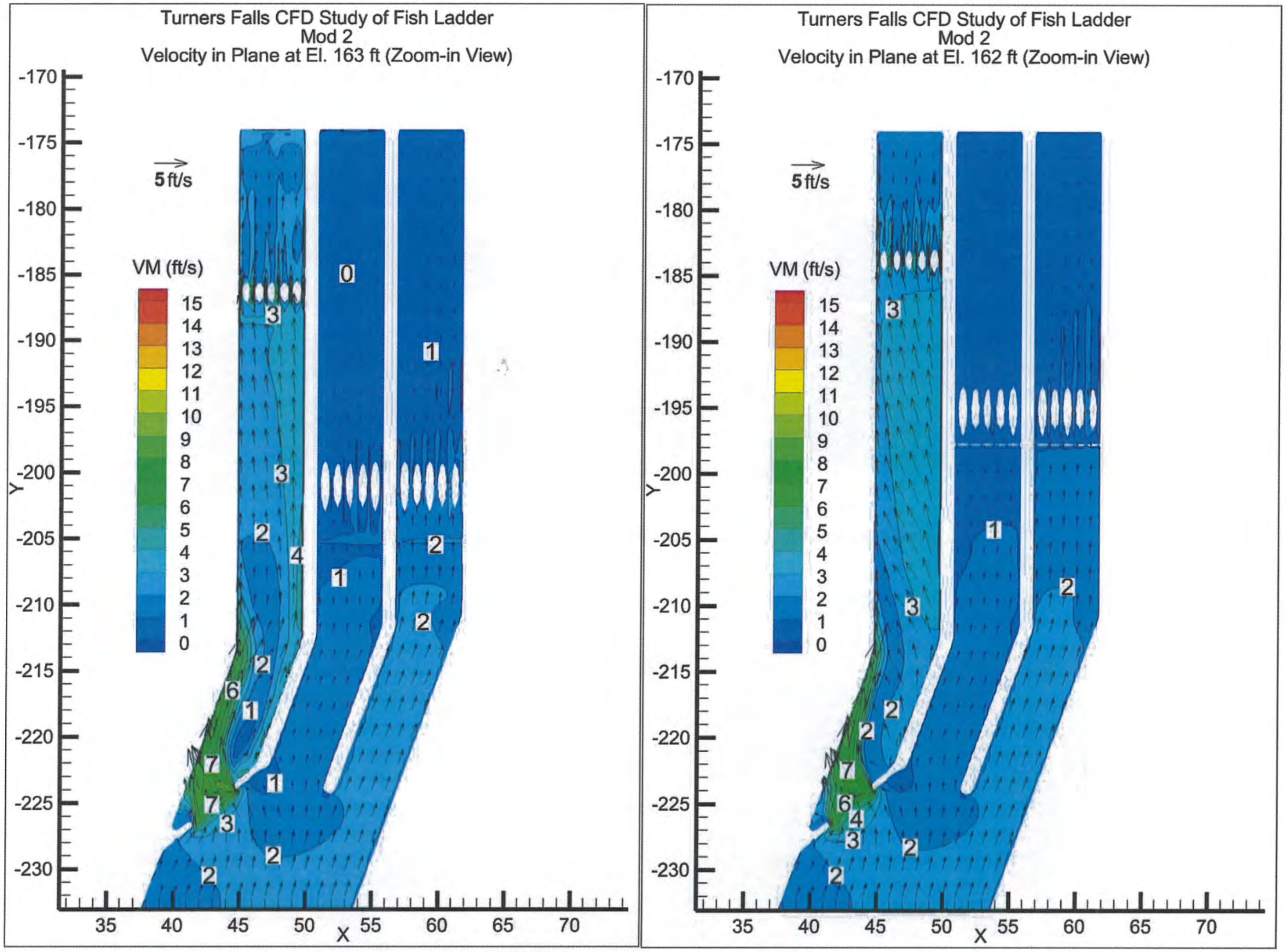


Figure 77 Mod 2: Velocity in Upstream Fishway at El. 163 ft and El. 162 ft

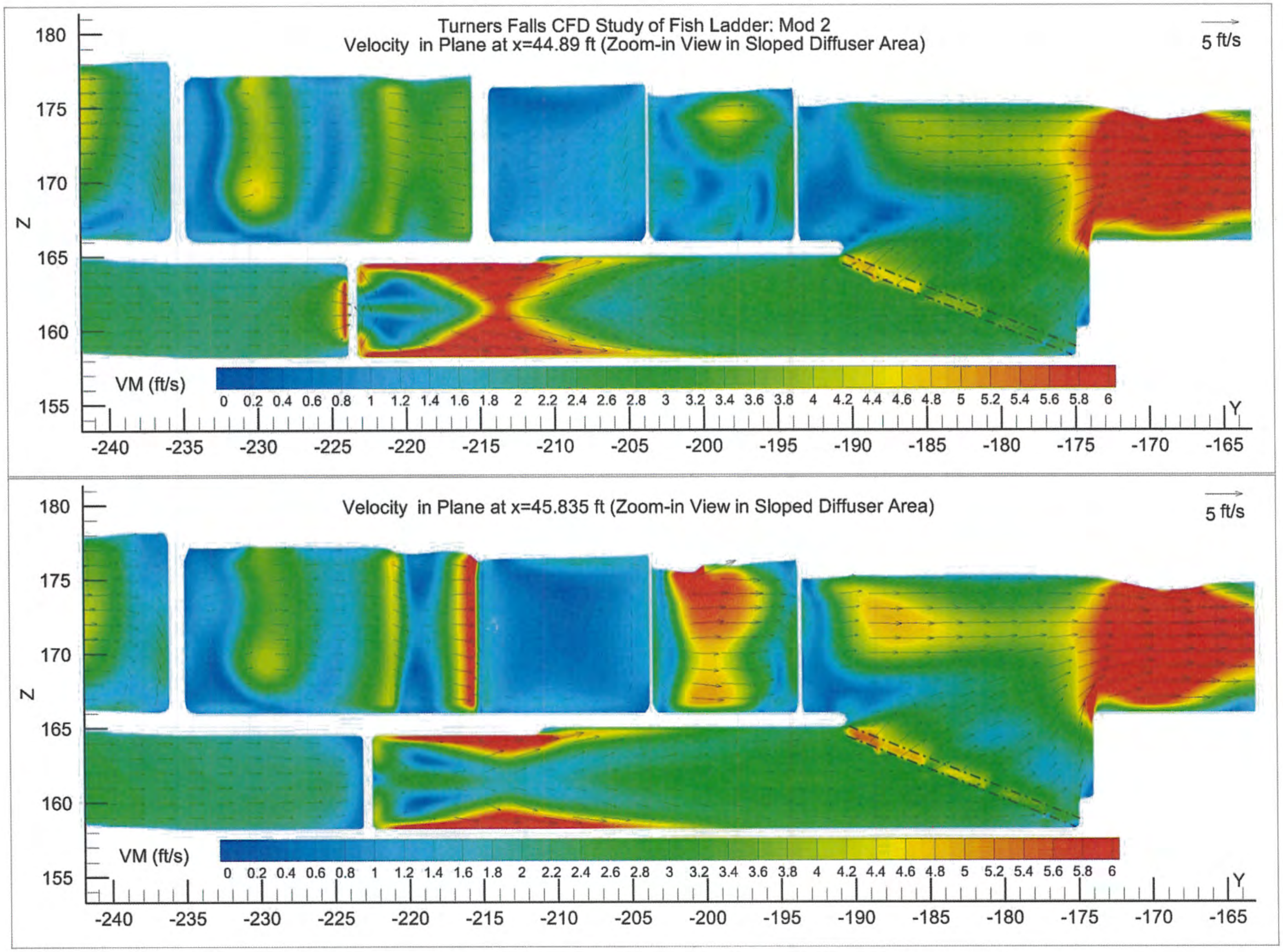
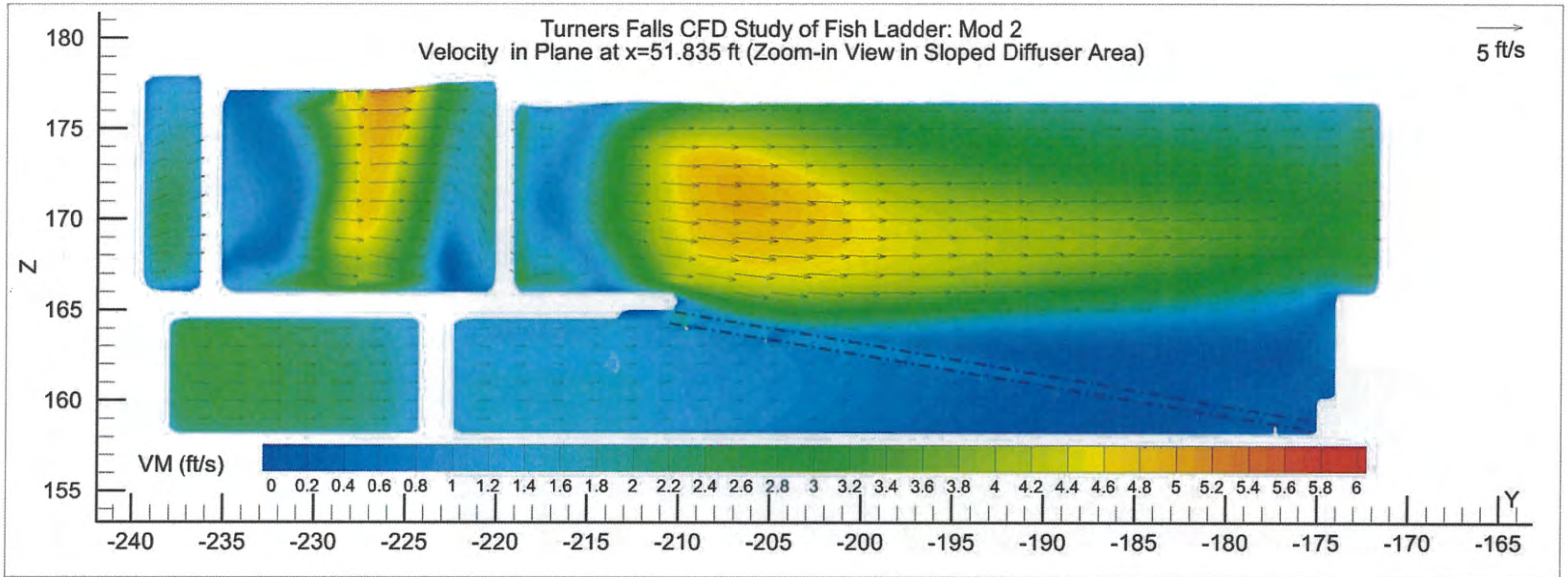


Figure 78 Mod 2: Velocity in Vertical Planes in the Left Sloped Diffuser Channel


Turners Falls CFD Study of Fish Ladder: Mod 2
Velocity in Plane at x=51.835 ft (Zoom-in View in Sloped Diffuser Area)
5 ft/s
VM (ft/s)
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4 4.2 4.4 4.6 4.8 5 5.2 5.4 5.6 5.8 6
Z
Y
180 175 170 165 160 155
-240 -235 -230 -225 -220 -215 -210 -205 -200 -195 -190 -185 -180 -175 -170 -165

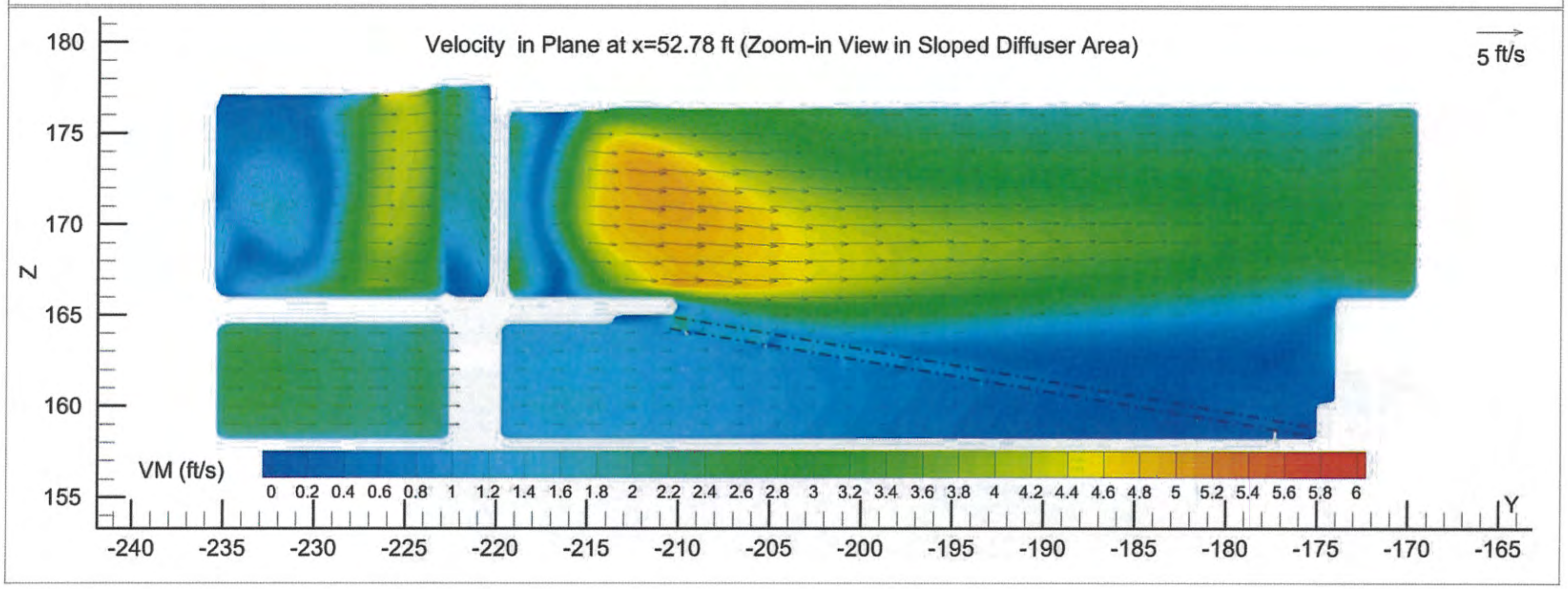
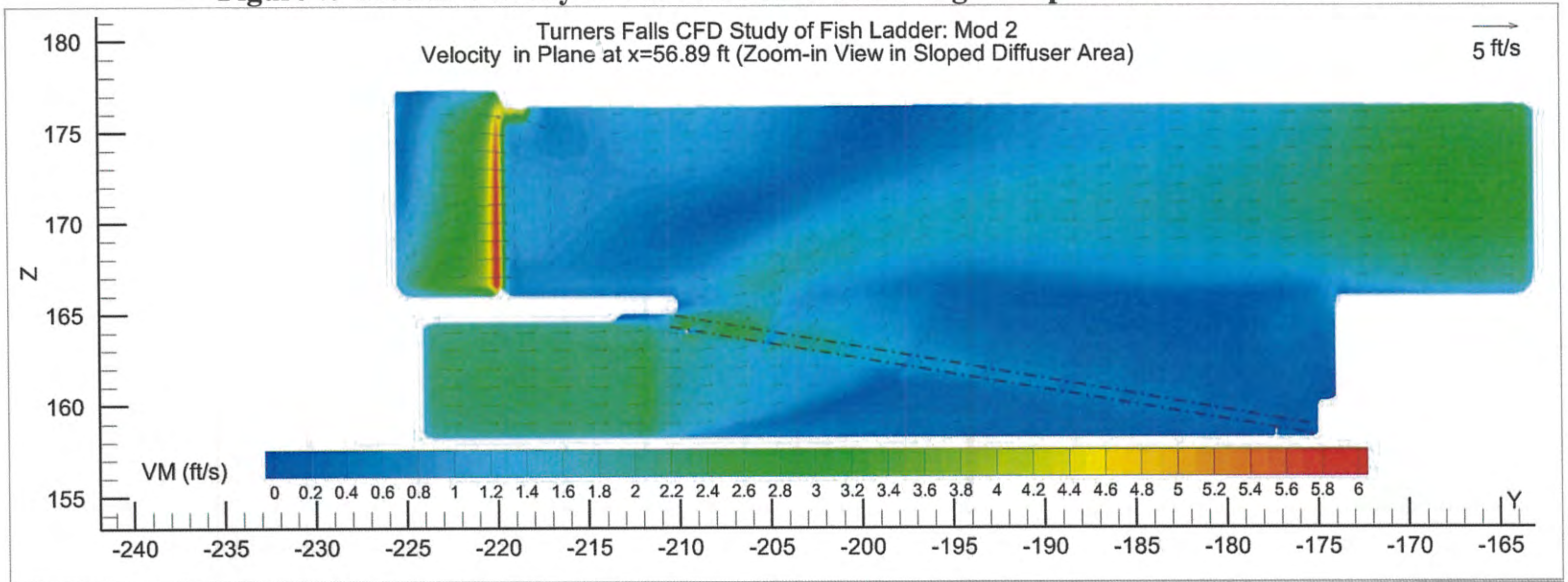

Velocity in Plane at x=52.78 ft (Zoom-in View in Sloped Diffuser Area)
5 ft/s
VM (ft/s)
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4 4.2 4.4 4.6 4.8 5 5.2 5.4 5.6 5.8 6
Z
Y
180 175 170 165 160 155
-240 -235 -230 -225 -220 -215 -210 -205 -200 -195 -190 -185 -180 -175 -170 -165

Figure 79 Mod 2: Velocity in Vertical Planes in the Right Sloped Diffuser Channel



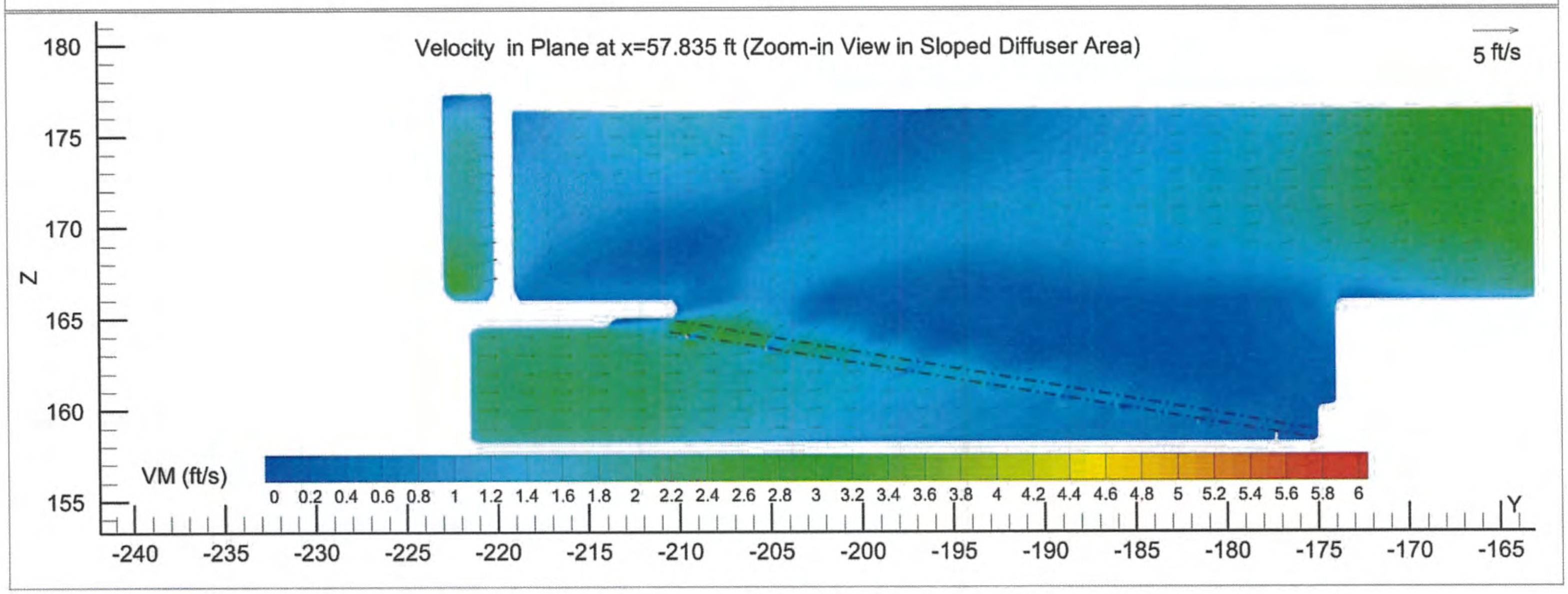


Figure 80 Mod 2: Velocity in Vertical Planes in the Right Sloped Diffuser Channel

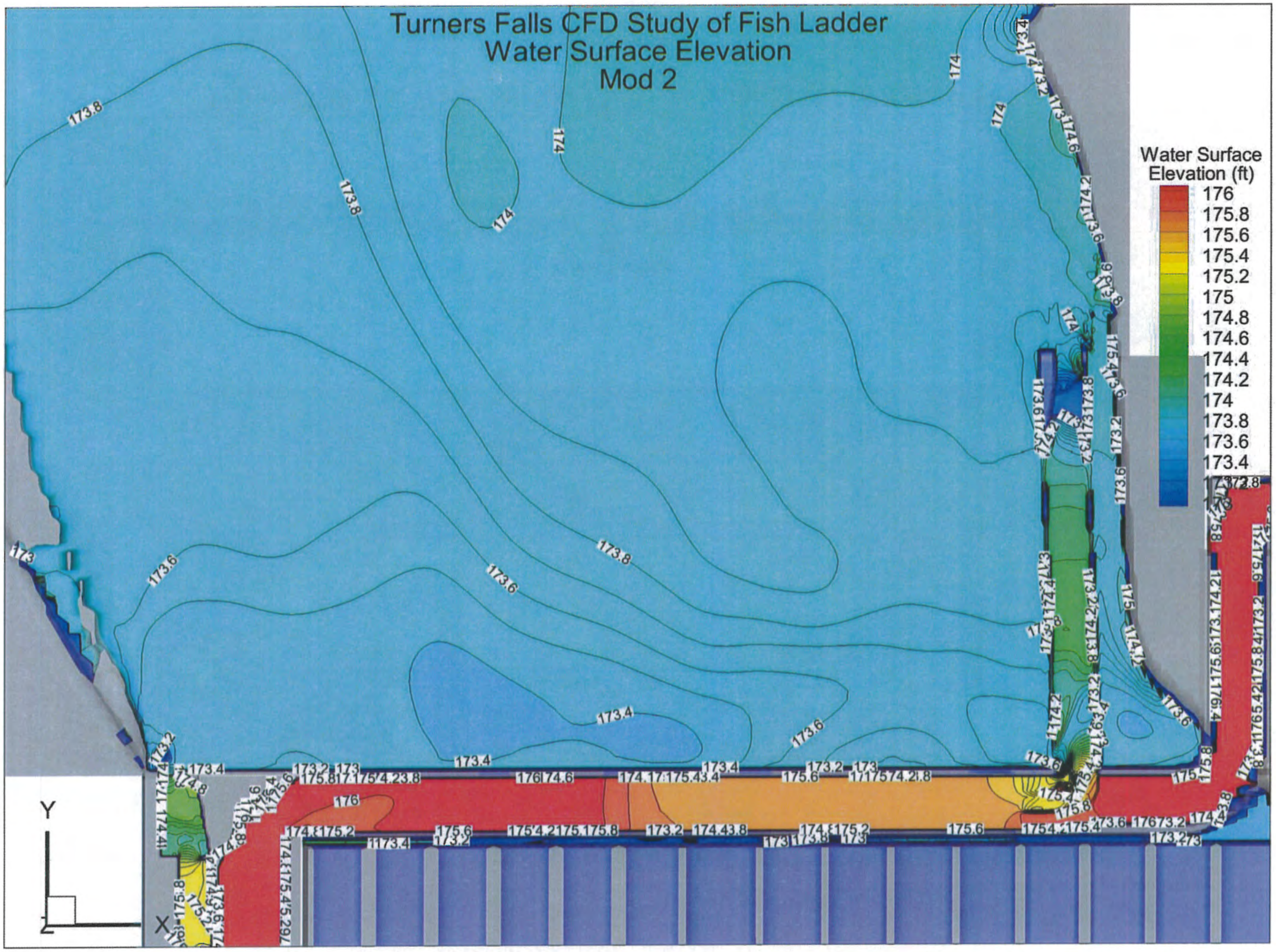


Figure 81 Mod 2: Water Surface Elevation in the Vicinity of Old and New Entrances in the Canal

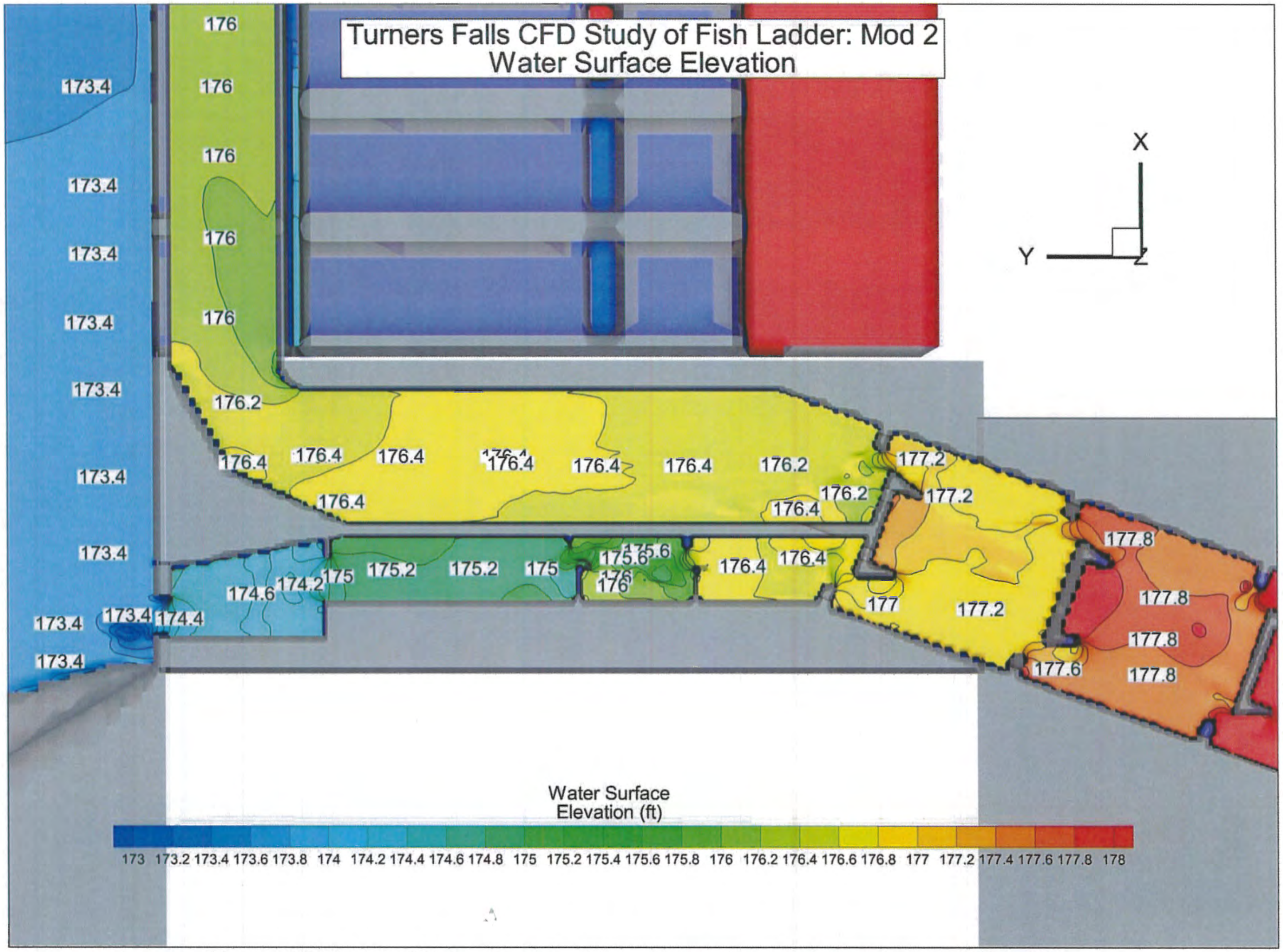


Figure 82 Mod 2: Water Surface Elevation in the Modified Area of Fish Way

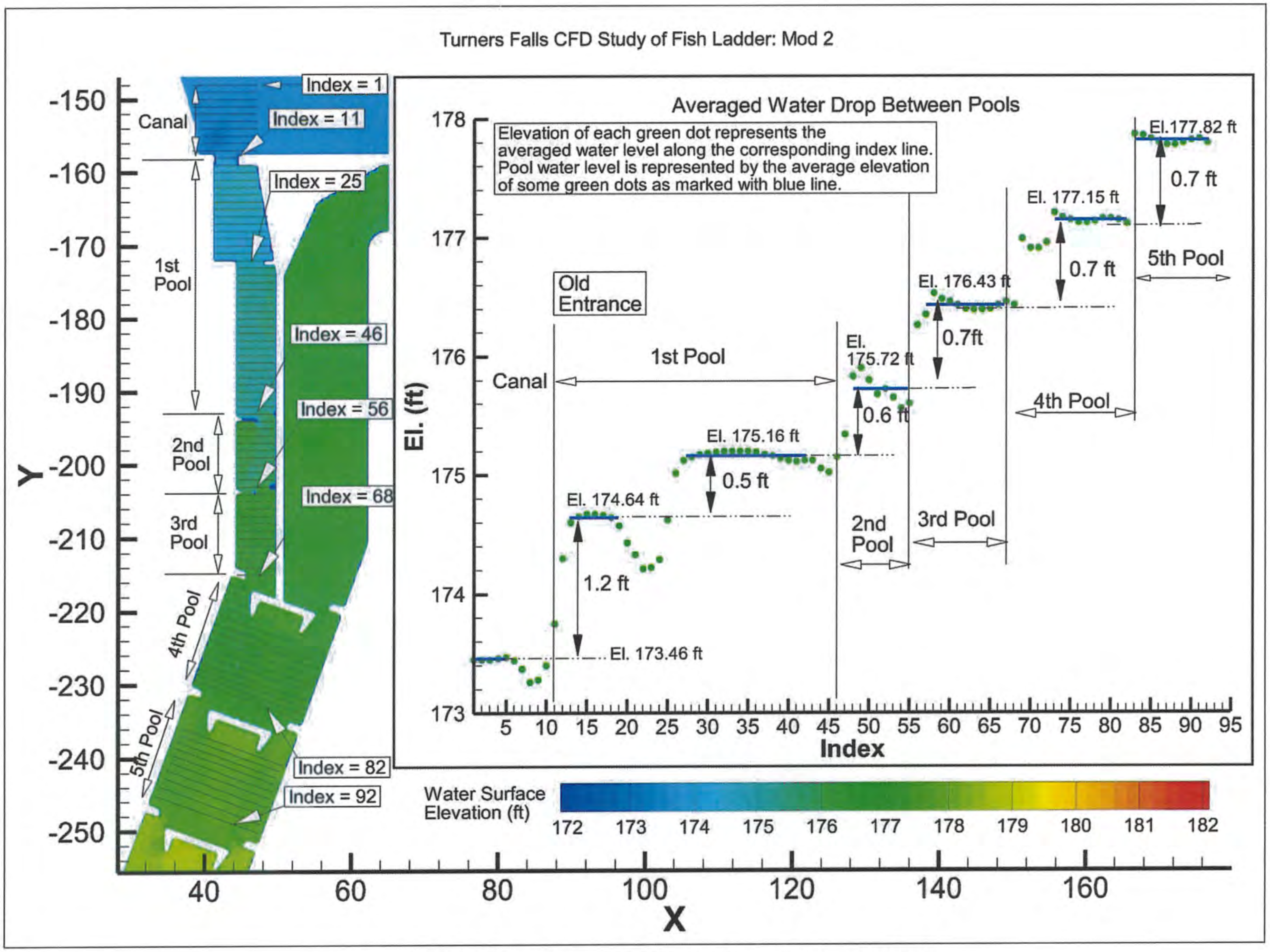
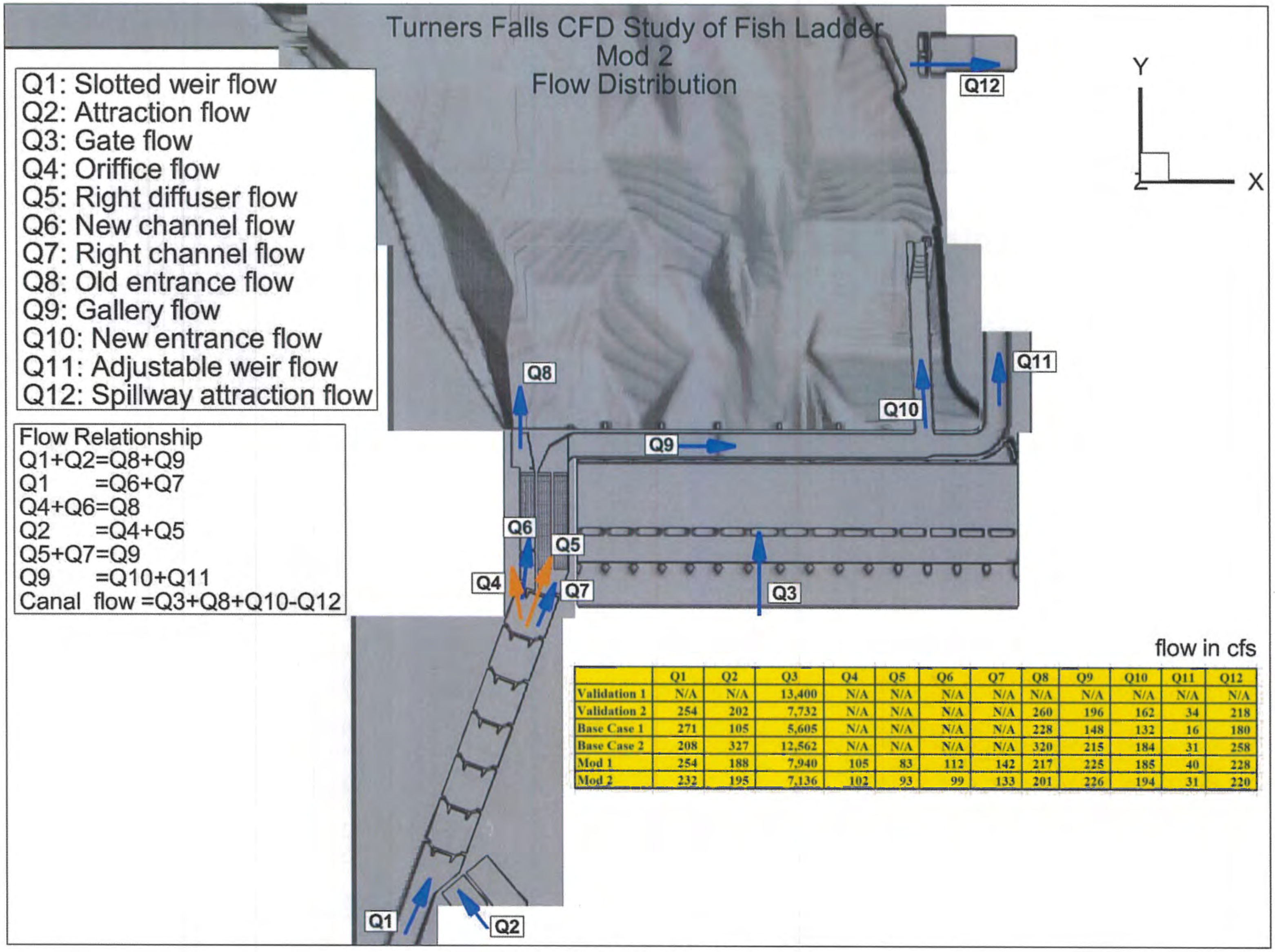


Figure 83 Mod 2: Averaged Water Drop between Pools



	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Validation 1	N/A	N/A	13,400	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Validation 2	254	202	7,732	N/A	N/A	N/A	N/A	260	196	162	34	218
Base Case 1	271	105	5,605	N/A	N/A	N/A	N/A	228	148	132	16	180
Base Case 2	208	327	12,562	N/A	N/A	N/A	N/A	320	215	184	31	258
Mod 1	254	188	7,940	105	83	112	142	217	225	185	40	228
Mod 2	232	195	7,136	102	93	99	133	201	226	194	31	220

Figure 84 Flow Distribution

Appendix G – 2011 Cabot Station Drawdown Juvenile American Shad Stranding Survey

MEMORANDUM

TO: FirstLight Power Resource Services, LLC

FROM: Chris Tomichek, Kleinschmidt Associates

DATE: September 16, 2011

RE: Cabot Station Drawdown Juvenile American Shad Stranding Survey

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INTRODUCTION

FirstLight Power Resource Services, LLC (FirstLight) conducted a drawdown of the Cabot Station power canal on Saturday September 10, 2011 to facilitate station maintenance. FirstLight contracted with Kleinschmidt Associates (Kleinschmidt) to conduct a visual survey of the dewatered power canal to document stranded juvenile American shad. The survey was conducted by a team of three biologists from Kleinschmidt and two biologists from the Conte Anadromous Fish Lab. The survey documented no juvenile shad within the power canal, stranded or otherwise.

METHODS

Kleinschmidt segmented the canal into seven distinct zones. Zones 1-6 each about 1,000-ft long were located in the section of the power canal closest to Cabot Station. The final segment, Zone 7, was substantially longer as few shad were expected in the segment of the canal that runs through the village of Turners Falls. The zones were delineated in the field by the crew using a handheld Garmin Vista GPS. A map of the GPS data is available in Attachment A.

Each zone was surveyed and visually inspected for juvenile shad by survey teams consisting of at least two biologists. In addition to shad, the field crews collected data on other stranded or observed fish species, as well as information on the location of pooled areas. The data generated by this survey are available in Attachment A. The abundance of non-shad species was estimated.

RESULTS/DISCUSSION

No juvenile American shad were observed in the Cabot Station power canal. Several riverine species, including, various centrarchid and cyprinid species, chain pickerel, channel catfish, and carp were observed in most zones. Additionally, two diadromous species were observed, American eel and sea lamprey. The majority of stranding occurred in Zones 1-4. Areas of pooled water within the power canal, representative photos and the observed species, as well as an estimate of their abundance are available in Attachment A.

The results presented herein and within Attachment A represent those fish and canal features that were readily observable by field crews. Though the majority of the canal was observable, observations in areas where pools were inaccessible, relatively deep or highly turbid were limited.

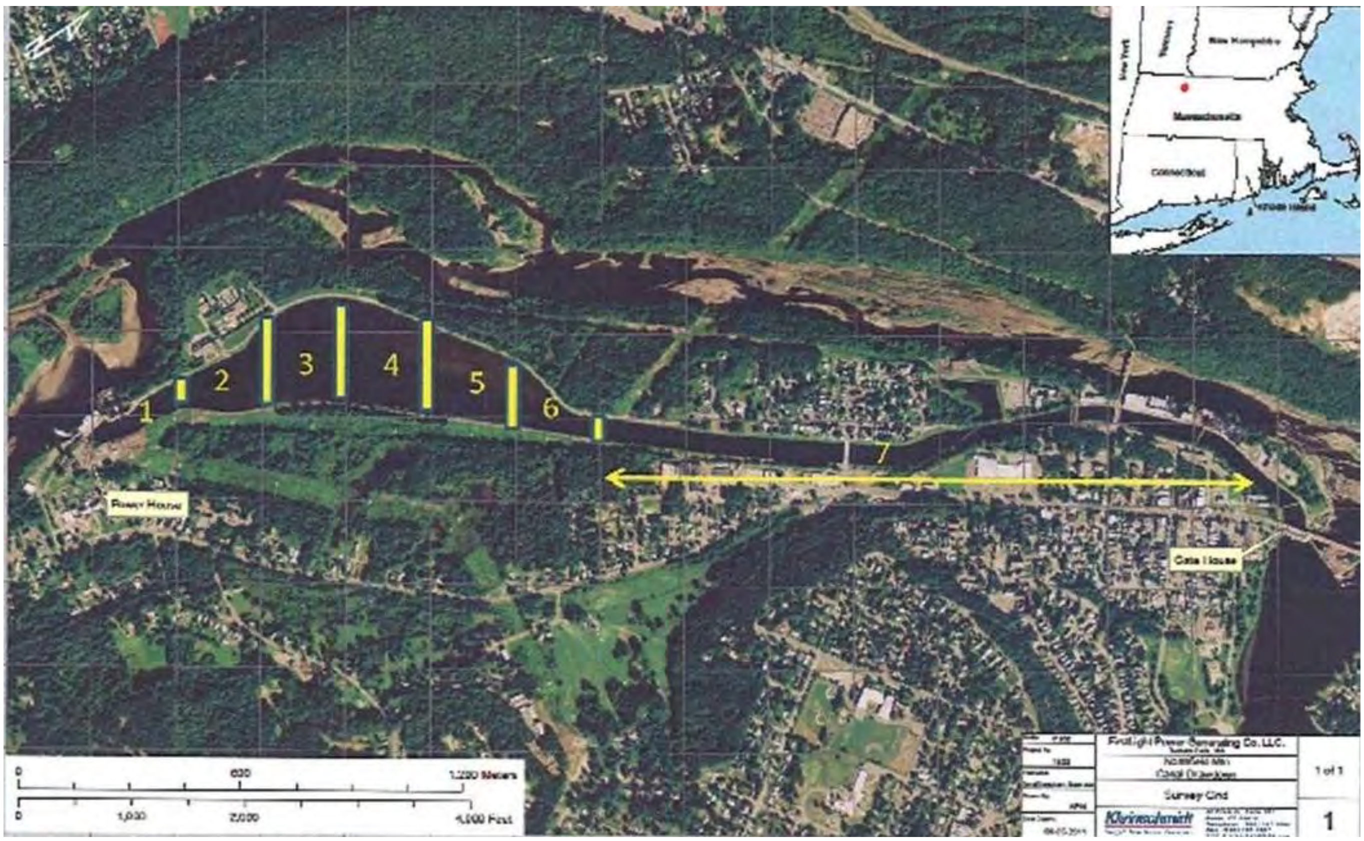
CONCLUSION

No juvenile American shad were observed in the dewatered Cabot Station power canal. Other riverine and diadromous species were observed especially in Zones 1-4. Kleinschmidt recommends reducing efforts in Zone 7 because leakage through the canal walls and gatehouse is apparently sufficient to maintain flow and depth through this section. The flow appears to be sufficient to support fish remaining in this section as it retains a relatively high proportion of water and will likely provide refugia for fish over the short term.

J:\1503\045\Docs\Report\001 Cabot Stranding Survey.9-16-11.docx

ATTACHMENT A

ID	Time	Coordinates
Zone 1	NA	N42 35 13.6 W72 34 42.2
Zone 2	9/10/2011 11:06	N42 35 23.2 W72 34 43.2
Zone 3	9/10/2011 11:25	N42 35 33.7 W72 34 43.5
Zone 4	9/10/2011 11:34	N42 35 40.8 W72 34 39.2
Zone 5	9/10/2011 11:41	N42 35 44.3 W72 34 32.8
Zone 6	9/10/2011 11:55	N42 35 48.7 W72 34 24.2
Zone 7	9/10/2011 12:03	N42 35 53.2 W72 34 11.3



Location of Zones sampled during the survey. Coordinates are located on the west bank of canal and mark the edges of each section.

Zone 1

Observers	BRA,TM, KPN	
Survey Date	9/10/2011	
Survey Time	15:00	15:30

No Shad Observed

Species List	Estimate of Abundance
Sea Lamprey	600
Carp	1
Black Crappie	1
Centrarchids	
Sunfish Species	6
Smallmouth Bass	4
Chain pickerel	1
Cyprinids	
Spottail Shiner	Several 100
fall fish	Several 100
chubsucker	several

(a) 

 (b)

 (c)

Location of Zone 1 (a) and typical views of Zone 1 during the drawdown (b and c).

Zone 2

Observers	KPN, Matt (Conte)
Survey Date	9/10/2011
Survey Time	morning

No Shad Observed

Other Observed Species

Species List	Estimate of Abundance
Sea Lamprey	Several 1,000
Mussel Species	Several 1,000
Yellow Perch	Less than 1,000
Carp	Less than 100
Chain pickerel	Less than 100
Centrarchids	
Sunfish Species	Less than 1,000
Smallmouth Bass	Less than 100
Cyprinids	
Spottail Shiner	Less than 1,000
Fallfish	Less than 1,000
Daters	Less than 1,000

Zone 2 views during drawdown, photos taken along the West side of canal.

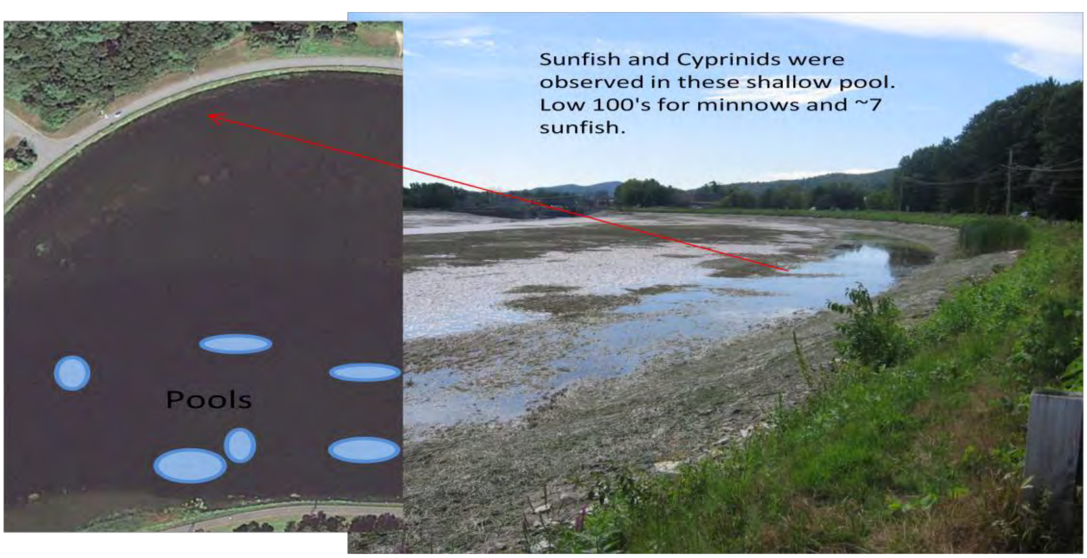
Zone 3

Observers	TM, Amy (Conte)	
Survey Date	9/10/2011	
Survey Time	11:30	12:10

No Shad Observed

Other Observed Species

Species List	Estimate of Abundance
Lamprey	Several 1,000
Mussel Species	Several 1,000
Yellow Perch	Less than 1,000
Carp	Less than 100
Chain pickerel	Less than 100
Centrarchids	
Sunfish Species	100's
blue gill and redbreast	
Smallmouth Bass	>50
Cyprinids	
Spottail Shiner	100's
Fallfish	100's
Daters	100's
common shiner	100's



Zone 4

Observers	TM, Amy (Conte)
Survey Date	9/10/2011
Survey Time	12:10

No Shad Observed

Other Observed Species

Species List	Estimate of Abundance
Sea Lamprey	Several 1,000
Mussel Species	Several 1,000
Yellow Perch	Less than 1,000
American eel	2
Chain pickerel	6
mud puppy	1
Crayfish	Less than 1,000
Centrarchids	
Sunfish Species	Less than 1,000
Smallmouth Bass	Less than 50
Cyprinids	
Spottail Shiner	Less than 1,000
Fallfish	Less than 1,000
Daters	Less than 1,000
common shiner	Less than 1,000

Typical view of pools in Zone 4.

Zone 5 and 6

Observers	TM, Amy (Conte)
Survey Date	9/10/2011
Survey Time	12:35

No Shad Observed

Species List	Estimate of Abundance
Sea Lamprey	Several 1,000
Crayfish	10
Centrarchids	
Sunfish Species	20
Smallmouth Bass	10
Cyprinids	30

Typical view of Zone 5 and 6

Zone 7

Observers	TM, BRA, KPN	
Survey Date	9/10/2011	
Survey Time	13:30	15:00

No Shad Observed

Typical view of Zone 7. One small school of fish (species unknown) observed in Zone 7.