Lower Granite Lock and Dam

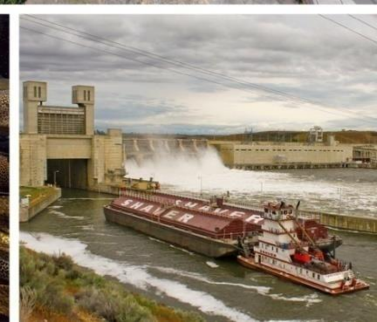
Juvenile Bypass System (JBS) Primary & Secondary Dewatering Testing

2019 Pacific NW Fish Screening and Passage Workshop

September 19, 2016

Mark Morris

Hydraulic Engineer



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Outline

- Post Construction Testing
  - ▶ Hydraulic Testing
    - PDS - Primary Dewatering Structure
      - ▷ ADP
      - ▷ ADV
    - SDS - Secondary
      - ▷ ADV

    Reference: Lower Granite JFF Commissioning Dewatering Screen Velocity Measurement Report
  - ▶ Biological Testing

    References: PNNL 28331 or 29052, 28461 (2018)

NOAA Fisheries Criteria

1.1 NOAA Fisheries Dewatering Screen Design Guidance

1.1.1 Horizontal screen/Incline Screen (floor screen in this case) sweep velocity > 2.5 ft/s for horizontal screens and less than 3 ft/s for incline screens.
PDS – Since the primary dewatering floor screen has a slope of -6%, it is closer to a horizontal screen than an inclined screen, therefore coordination with NOAA-Fisheries resulted in a sweeping velocity criteria of greater than 2.5 ft/s and less than 6 ft/s with a goal not to decelerate along the screen.
SDS – The secondary dewatering floor screen is truly horizontal and therefore is only required to be greater than 2.5 ft/s. Sweeping velocity exceed this by at least at least 3 times and is not reported in this document.

1.1.2 Vertical screen sweep velocity: optimally between 0.8 ft/s and 3 ft/s, and must not decrease along screen. Negotiation with NOAA Fisheries changed the 3 ft/s maximum magnitude at the wall screens where the PDS constricts up to 5 ft/s.

1.1.3 Approach (through screen) velocity < 0.4 ft/s.

Approach (through screen) velocity < 0.4 ft/s.

No deceleration.

Minimize holding.

1.2 Post-construction Evaluation

1.2.1 Confirm approach and sweep velocities across entire screen face.

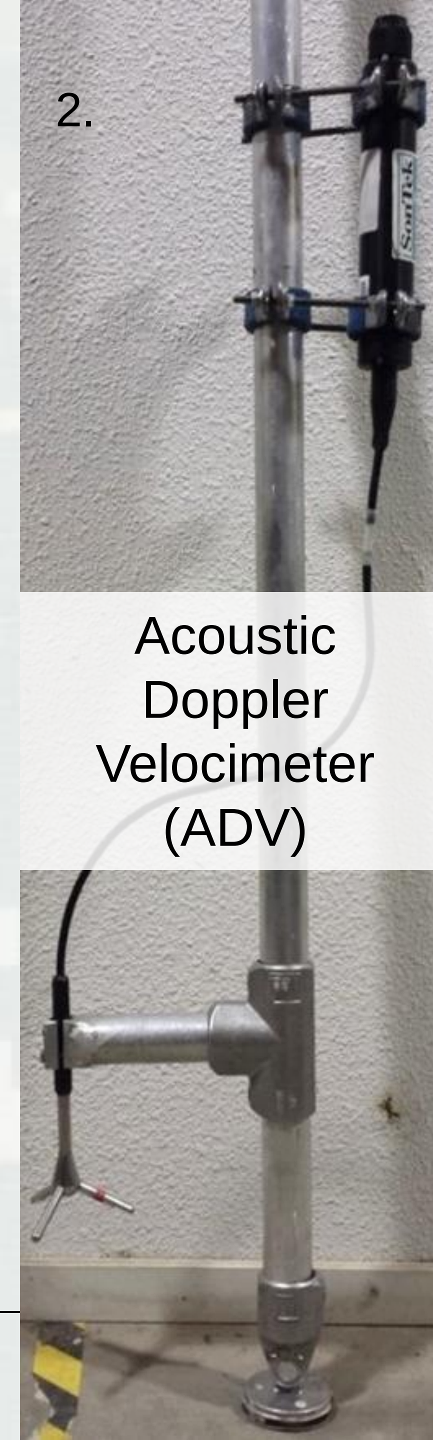
1.2.2 Each measurement must represent < 0.05 of total through-screen discharge, and be located at the center point of each grid section, as close as possible to screen face.

1.2.3 No individual approach velocity > 0.44 ft/s.

Flow Quantifiers

1\.

Acoustic Doppler Profiler (ADP)



2\.

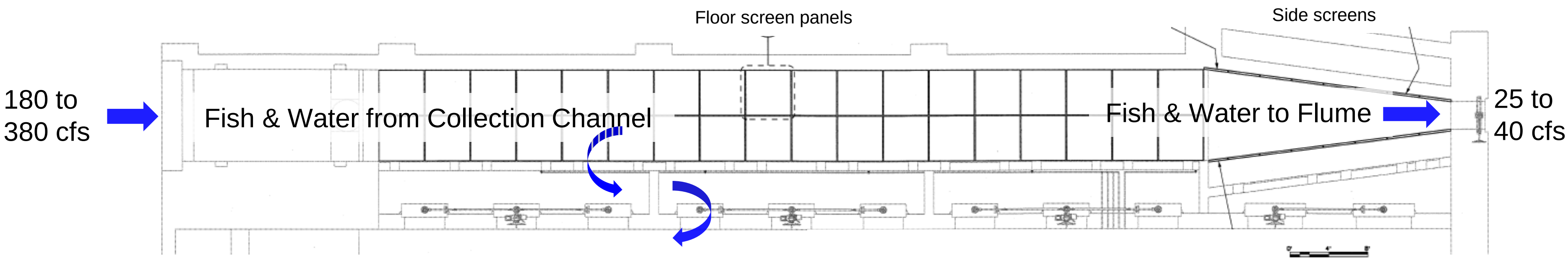
Acoustic Doppler Velocimeter (ADV)

3\. Weirs

Primary Dewatering Structure (PDS) Conditions

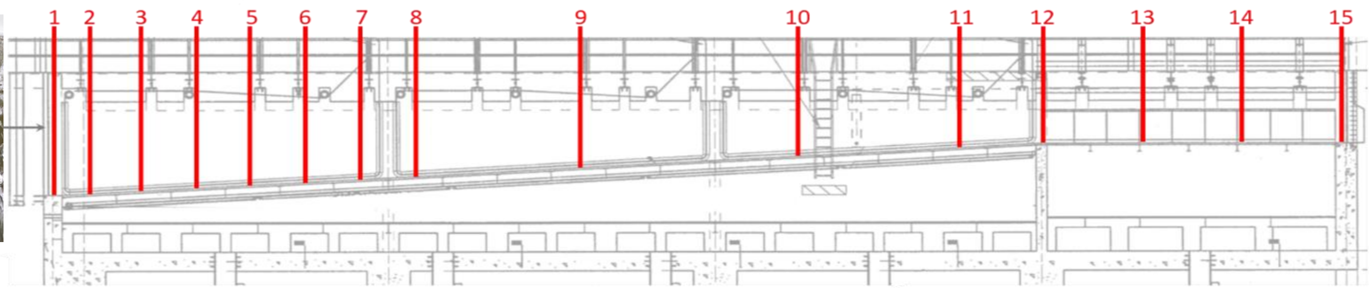
	Norm	Max	Max	Norm	High
	Test Conditions				
	#1	#2	#3	#4	#5
Date	3/30/18	4/4/18	10/23/18	11/2/18	11/9/18
Estimated Inflow (cfs)	280	350	330	303	308
Forebay Avg. (fmsl)	734.9	735.3	736.6	736.6	735.7
Forebay Min. (fmsl)	734.8	735.1	736.5	736.5	735.6
Forebay Max. (fmsl)	735.0	735.4	736.8	736.7	735.7
Units Running Avg.	3	2	2	2	1.6
Powerhouse Flow Avg. (kcfs)	54	30	26	26	23
14” orifices open	18	18	17	15	17
10” orifices open	0	7	4	3	3
Water Supply ON/OFF	ON	ON	ON	OFF	OFF
PDS Exit Flow Setpoint (cfs)	30	25	35	35	35
Weir Position (relative)	Level	Level	B low	Level	B low D high
Dewatered Q (cfs)	250	325	295	268	273

PDS Velocimetry Overview
Water Budget Approach

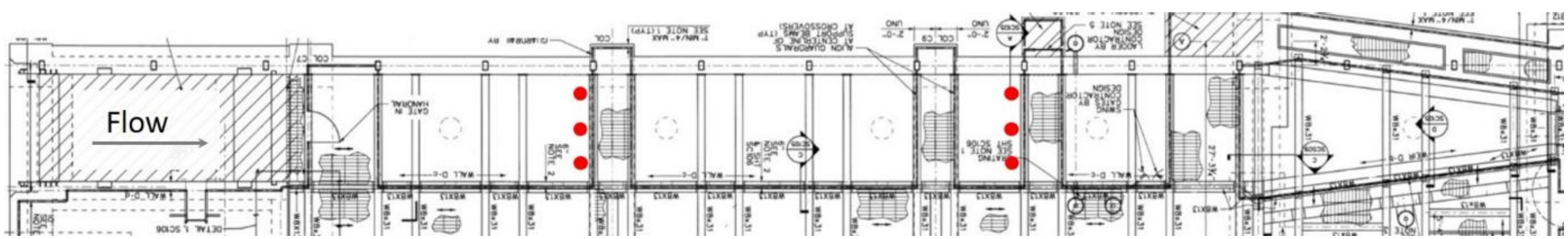


PDS Plan View

ADP

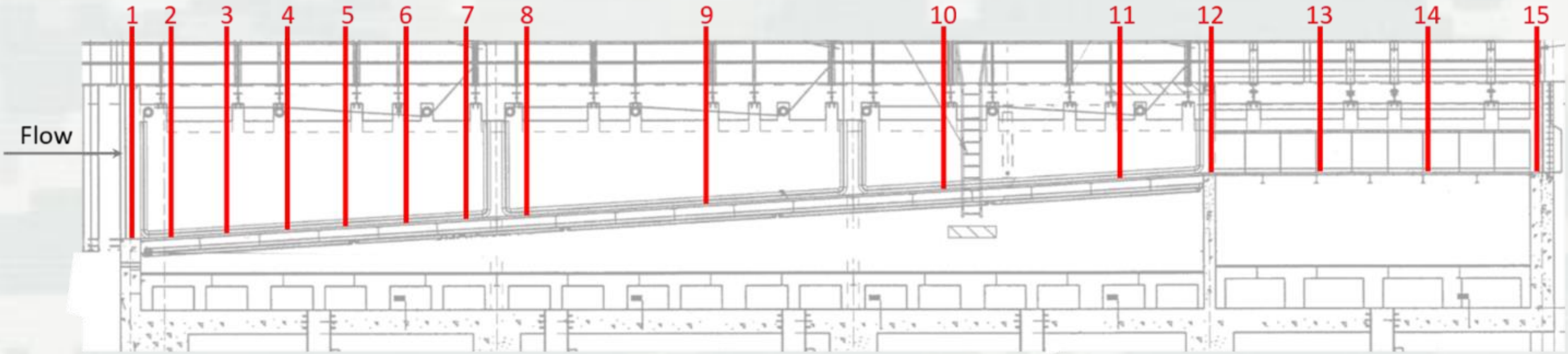


ADV



ADP Results

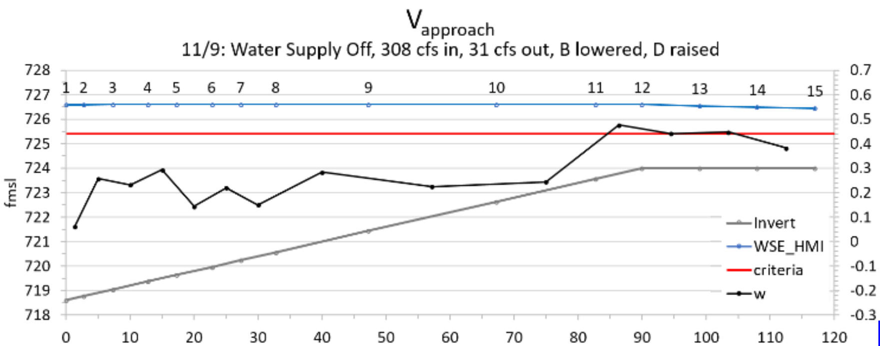
		Vapproach (ft/s)											
Date	Condition	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11	11 - 12	12 - 15
3/30	Norm w/ WS	-0.24	0.53	0.22	0.28	0.15	0.23	0.20	0.23	0.19	0.22	0.37	0.39
4/4	Max w/ WS	0.34	0.28	0.30	0.12	0.31	0.44	0.24	0.28	0.27	0.28	0.48	0.51
10/23	Max w/ WS, B dwn	0.04	0.09	0.26	0.33	0.25	0.29	0.28	0.25	0.24	0.28	0.65	0.37
11/2	Norm no WS	0.06	0.07	0.47	0.19	0.19	0.20	0.33	0.22	0.20	0.24	0.42	0.40
11/9	High no WS, B dwn D up	0.06	0.26	0.23	0.29	0.14	0.22	0.15	0.28	0.22	0.24	0.48	0.39

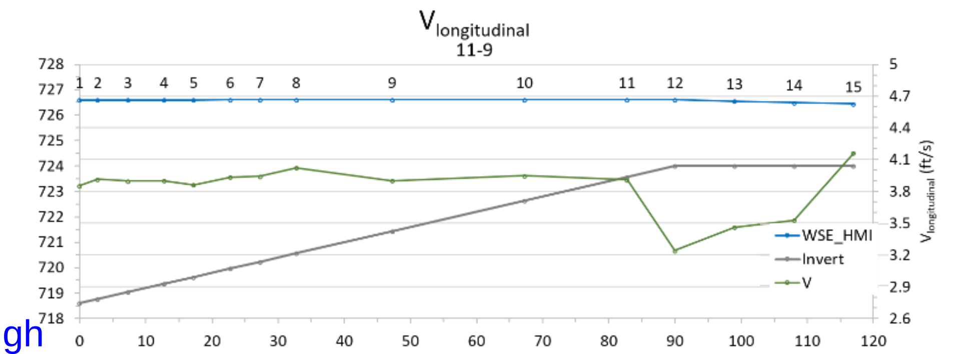


ADP cross section measurement locations.

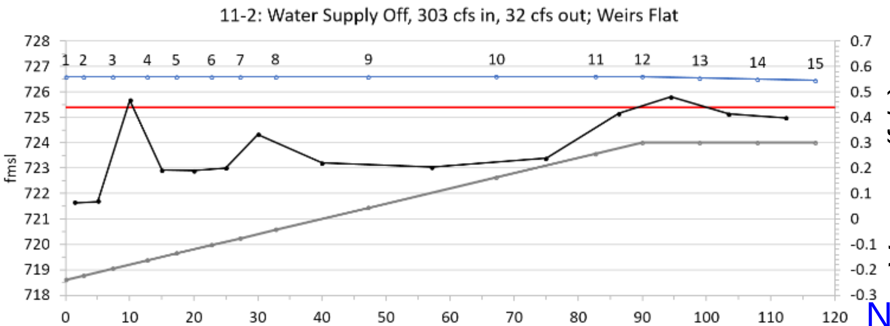
NOAA Fisheries target $V_{approach}$: 0.4 ft/s

ADP Velocity Longitudinal Profiles

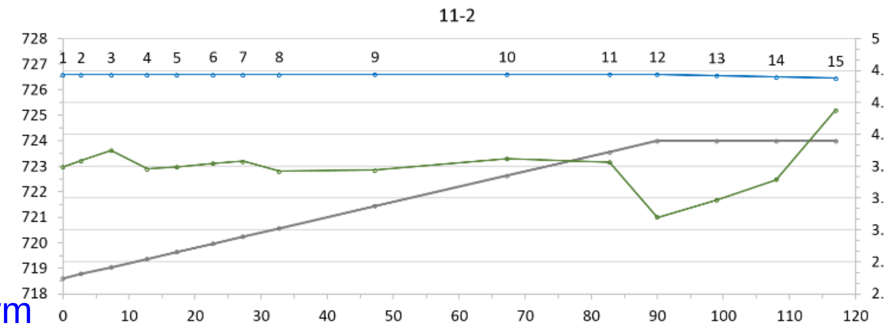




High

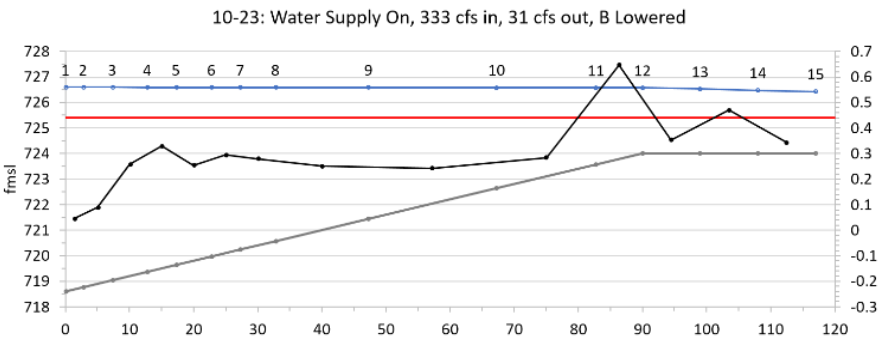


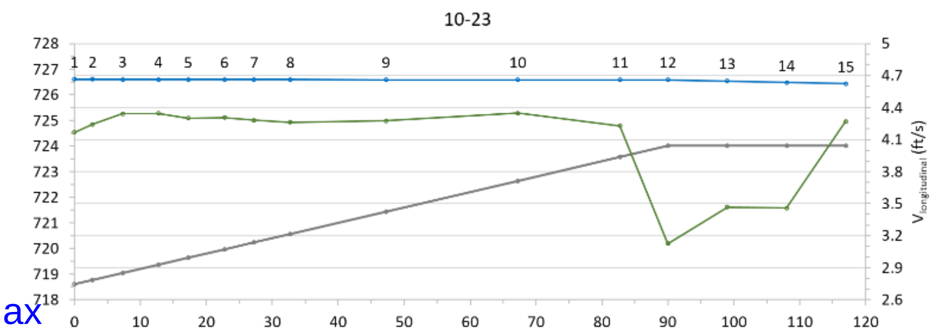
$V_{approach}$ (ft/s)



$V_{longitudinal}$ (ft/s)

Norm



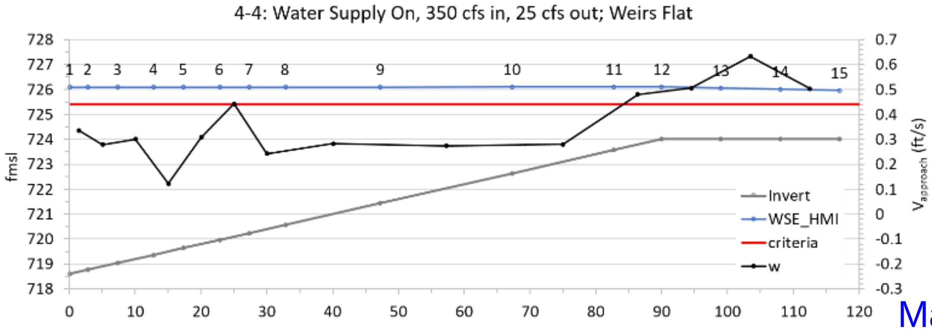


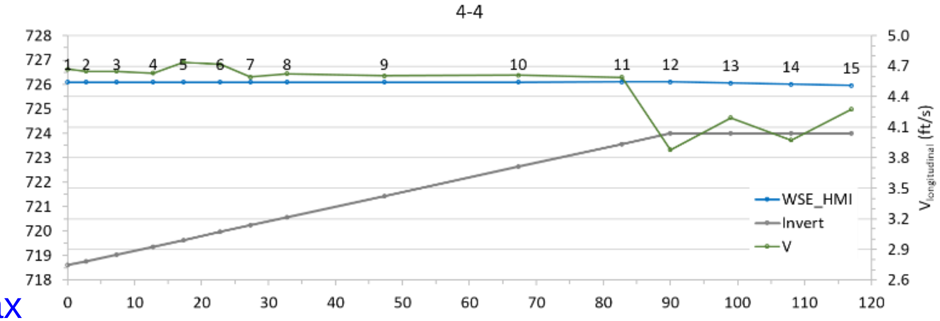
Max

ADP Velocity Longitudinal Profiles

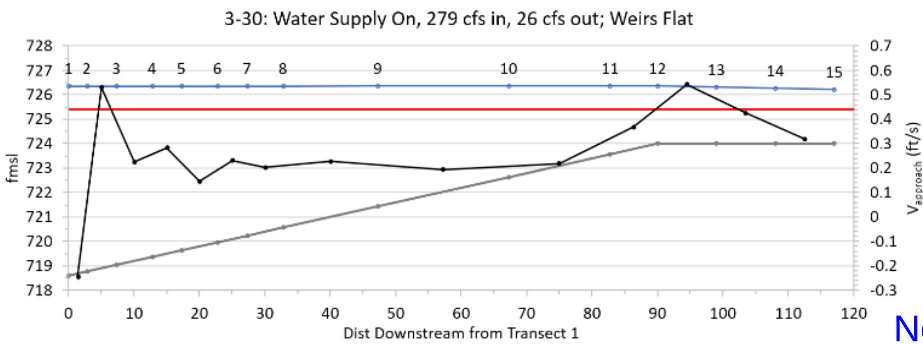
$V_{approach}$

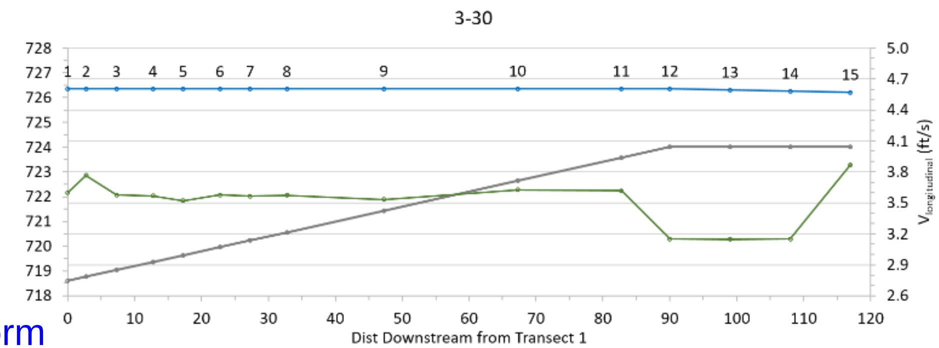
$V_{longitudinal}$





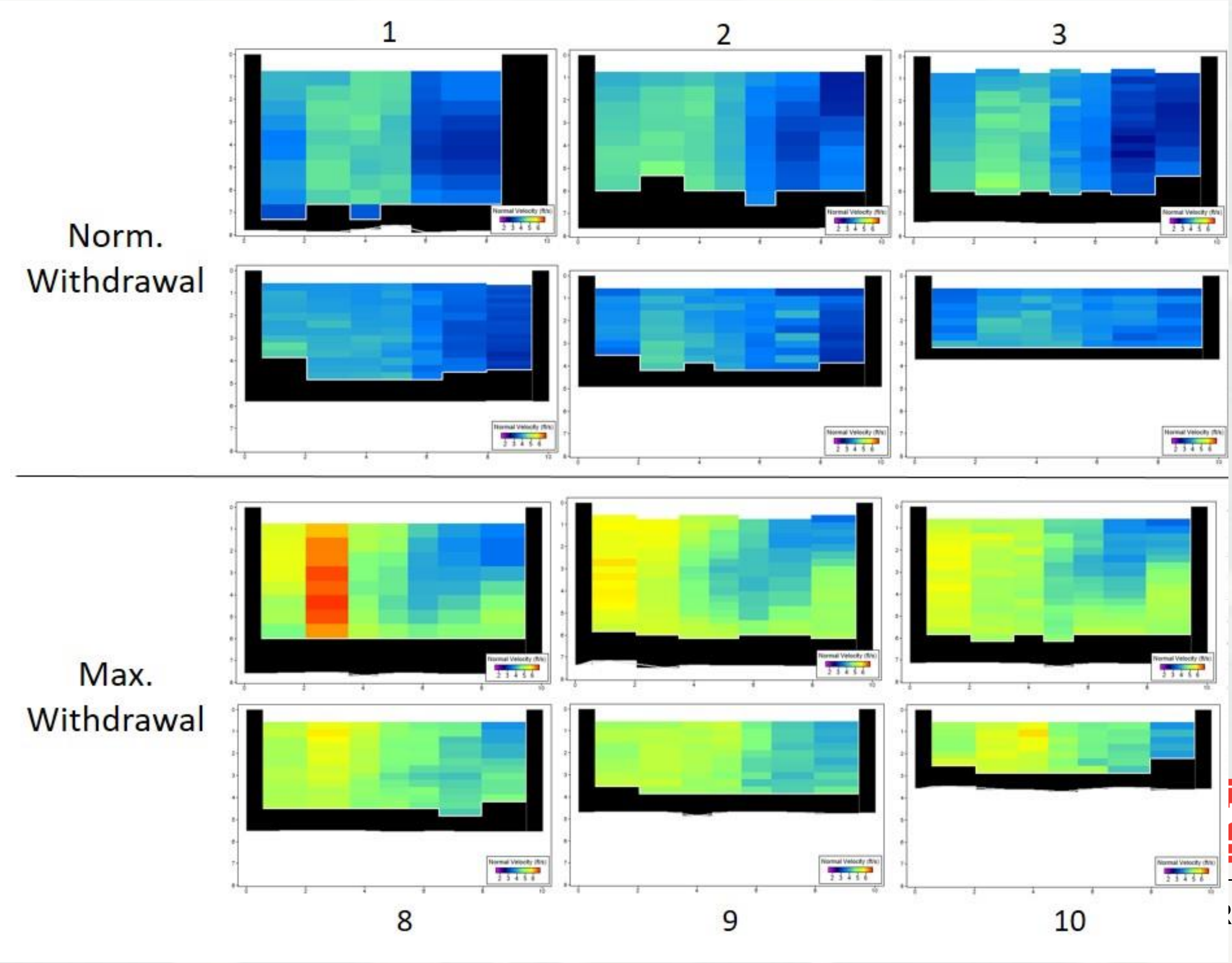
Max



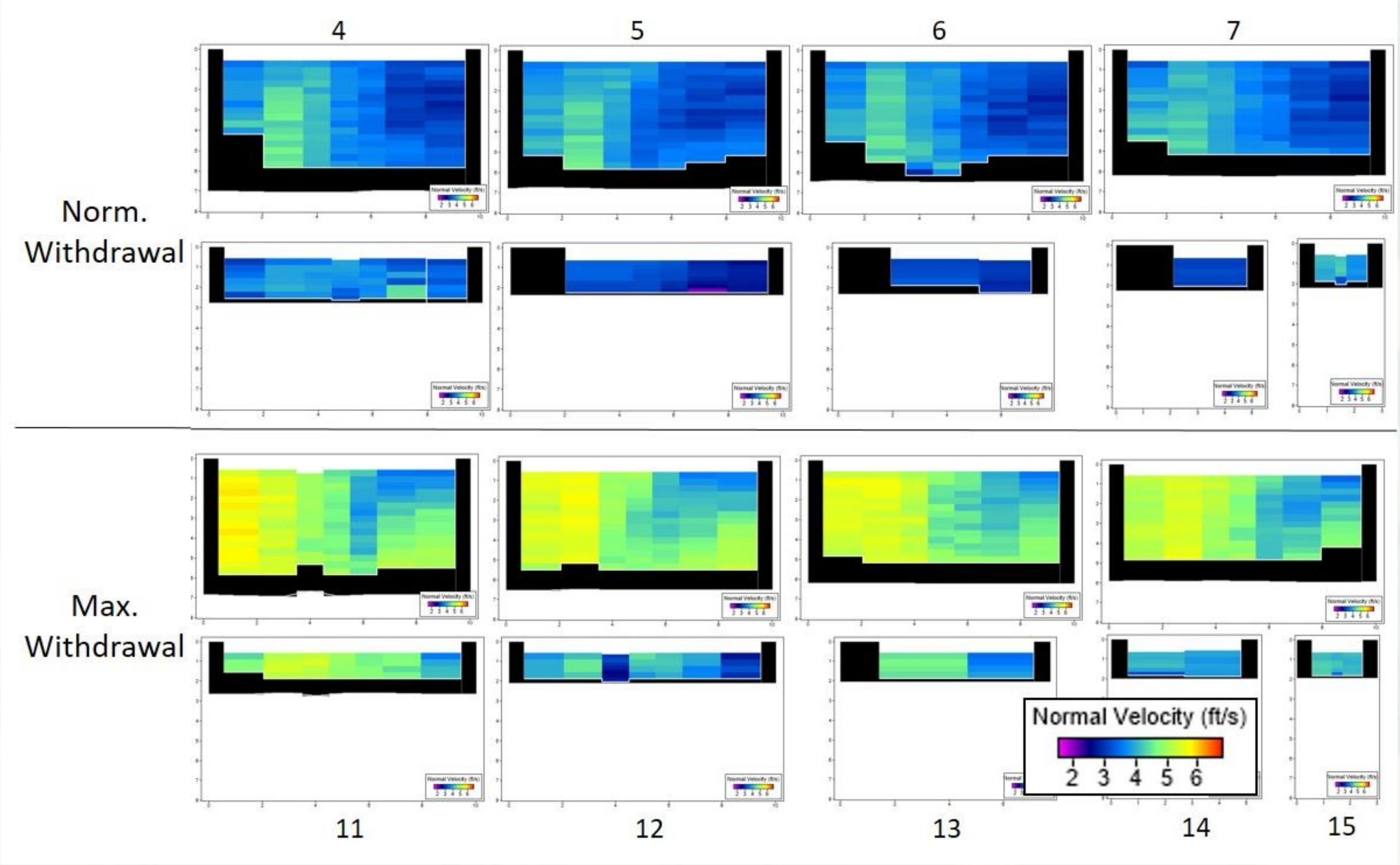


Norm

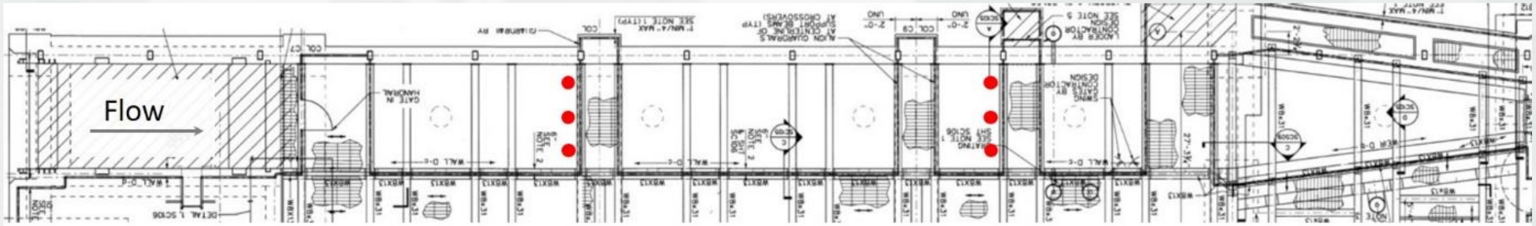
ADP Velocity Cross Section Plots

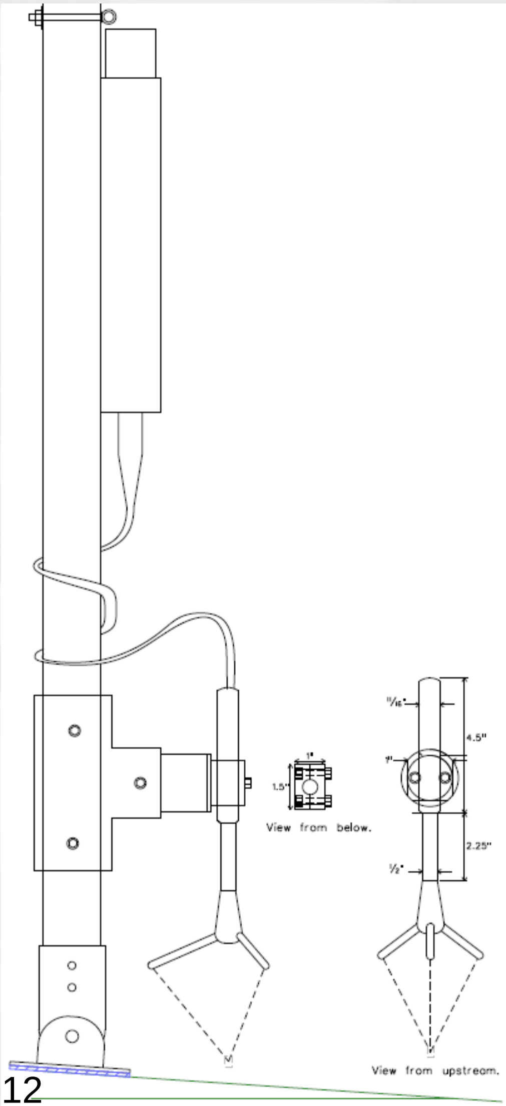


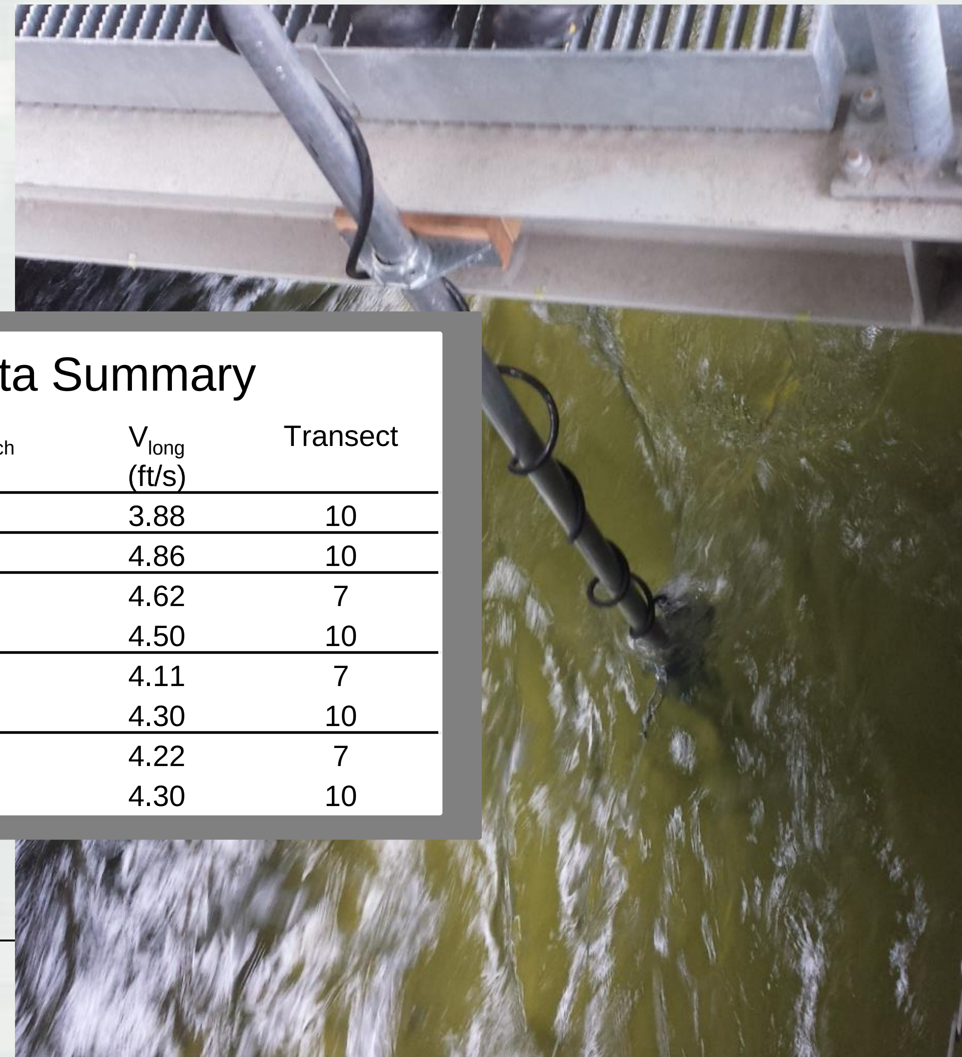
ADP Velocity Cross Section Plots



Acoustic Doppler Velocimeter (ADV)







ADV Data Summary

2018 Date	$V_{approach}$ (ft/s)	V_{long} (ft/s)	Transect
3/30	-0.17	3.88	10
4/4	-0.28	4.86	10
10/23	-0.23	4.62	7
	-0.11	4.50	10
11/2	-0.06	4.11	7
	-0.04	4.30	10
11/9	-0.05	4.22	7
	0.12	4.30	10

Weir Double Check

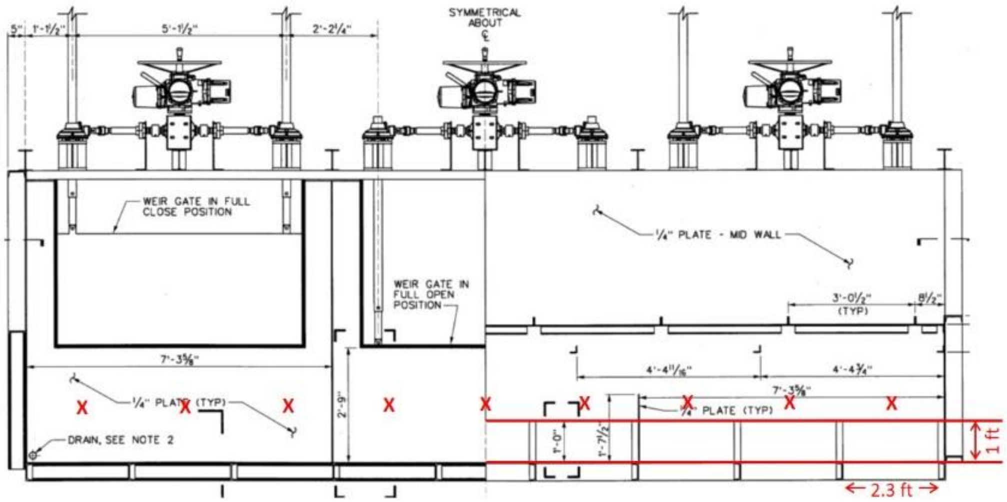
PDS Q_{ADP} vs Q_{weir} Withdrawal; Water Supplied to JFF

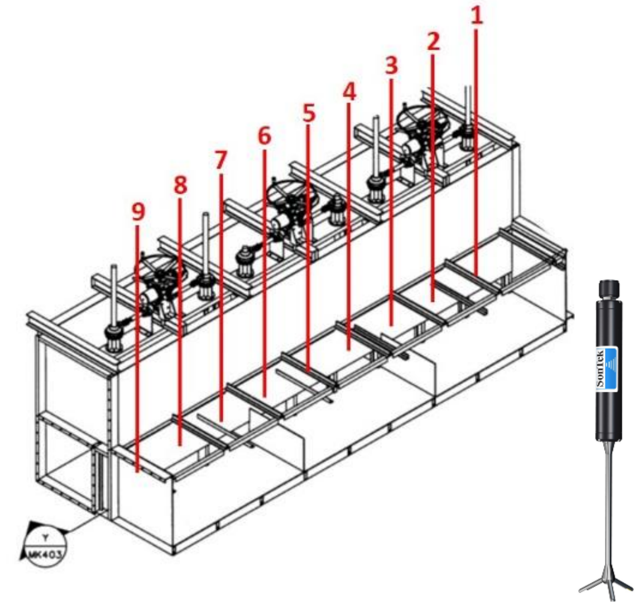
		Water Supply On			Water Supply Off	
		Norm	Max	Max. B lowered	Norm	Norm. B Raised, D Lowered
Date		3/30	4/4	10/23	11/2	11/9
Q_{weir}	a.m.	187	283	246	275	278
	p.m.	196	284	238	265	293
Q_{ADP}		253	325	302	271	278
Water Supplied to JFF	a.m.	66	42	56	-4	0
	p.m.	57	41	64	6	-15

$$Q_{weir} = \frac{2}{3} C (b - 0.2H) H^{3/2} \sqrt{2g}$$

$$C = 0.602 + 0.083 \frac{H}{W}$$

Secondary Dewatering Structure (SDS)



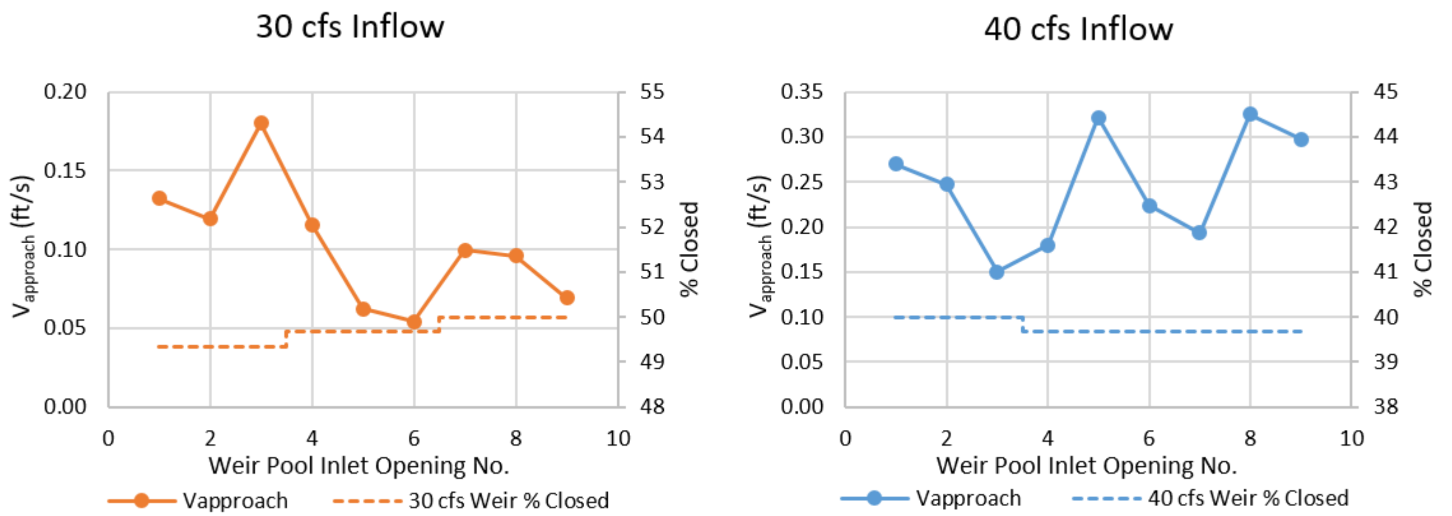


- SDS weirs adjusted so downstream hydraulic conditions (mostly the location of the hydraulic jump) deemed acceptable by project biologist
- Then ADV measurements

Q_{ADV} (cfs; velocity x cross section area of opening) Through Each Weir Pool Inlet Opening

QADV (cfs)	9	8	7	6	5	4	3	2	1
30 cfs Inflow	0.48	0.66	0.69	0.37	0.43	0.80	1.24	0.82	0.91
40 cfs Inflow	2.06	2.24	1.33	1.55	2.22	1.24	1.04	1.71	1.86

SDW Q_{ADV} vs Q_{weir}



SDW weir opening velocity magnitude and weir % closure.

Q_{ADV} vs Q_{weir}

Inflow (cfs)	**30**
Weir No.	Q_{weir} (cfs)
1	3.8
2	2.4
3	0.5
Q_{ADV}	6.4
Total Q_{weir}	6.7

Biological Testing

Travel Time
Max Flow: 3:19 (min:s) to PDS endgate
Norm Q: 4:6 to PDS endgate

Endgate to Separator at JFF: 2:46

JBS Descaling for Yearling Chinook (hatchery)

Year	%
2013	14.4
2014	9.2
2018	5.6

PNNL-28461 Post-Construction Evaluation of the Upgraded Juvenile Bypass System at Lower Granite Dam; Final Technical Report; July 2019

2018 Survival Compared to Past Studies

Year	% Increase in Survival	Class
2005	1	Yearling
2006	5	Yearling
2007	15	Subyearling

PNNL-29052 or 28331 Survival and passage of Yearling and Subyearling Chinook Salmon and Juvenile Steelhead at Lower Granite Dam; Aug 2019

Photo (right) showing a dead tagged fish attached to the deep-water release mechanism prior to release into the outflow from Turbine Unit 1 at Lower Granite Dam. (PNNL-28325)

Summary

Worked:

- ADP water budget approach for an estimated $V_{approach}$

Did not work quite as well:

- ADV point measurements in PDS
- ADP reflection (<2 ft depth) flat stainless steel channel bed

Questions?

Survival and Passage of Yearling and Subyearling Chinook Salmon and Juvenile Steelhead at Lower Granite Dam, 2018

Final Technical Report

August 2019

Pacific Northwest National Laboratory

(also known as PNNL-28331 – a different number is assigned to the different drafts. This report has not been officially finalized yet.)

Table E.5. Survival Estimates by Route for CH1 at Lower Granite Dam During Spill

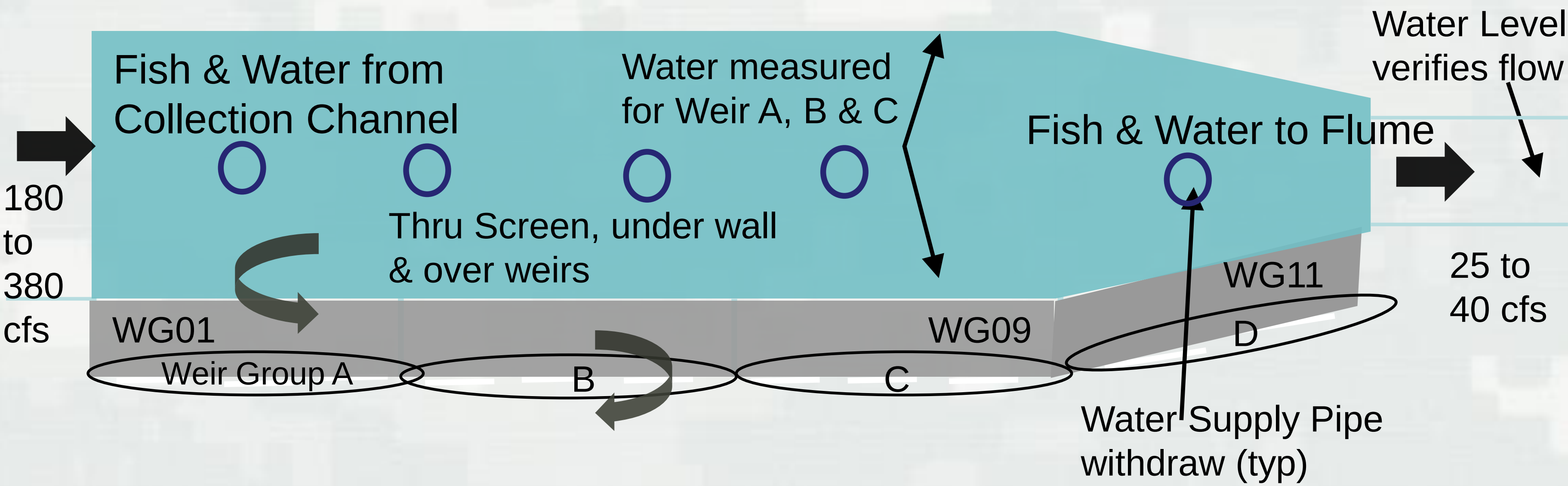
Year	Spill Operation	Spillway	RSW	JBS	Turbine	Source
2003	24-hr Spill RSW+12 kcfs	-	0.980 (0.023)	-	-	Plumb et al. 2004
2005	Involuntary Spill	0.905 (0.057)	0.982 (0.016)	0.097 (0.018)	1.011 (0.169)	Perry et al. 2007
2006	24-hr Spill RSW+12 kcfs	0.970 (0.018)	0.985 (0.016)	0.987 (0.014)	0.815 (0.086)	Beeman et al. 2008
2018	**Court-Ordered Gas Cap Spill**	**0.9521 (0.0244)**	**0.9855 (0.0172)**	**0.9961 (0.0158)**	**0.8779 (0.0599)**	**This Study (VIPRE)**
		0.9898 (0.0102)	**1.0016 (0.0360)**	**1.0001 (0.0264)**	**0.8697 (0.0604)**	**This Study (ViRDCt)**

Table E.6. Survival Estimates by Route for STH at Lower Granite Dam During Spill

Year	Spill Operation	Spillway	RSW	JBS	Turbine	Source
2006	24-hr Spill RSW+12 kcfs	0.985 (0.013)	0.952 (0.022)	0.955 (0.017)	0.879 (0.082)	Beeman et al. 2008
2018	**Court-Ordered Gas Cap Spill**	**1.0003 (0.0119)**	**0.9843 (0.0141)**	**1.0111 (0.0087)**	**0.8804 (0.0715)**	**This Study (VIPRE)**
		1.0002 (0.0153)	**0.9937 (0.0063)**	**1.0000 (0.0124)**	**0.9076 (0.0626)**	**This Study (ViRDCt)**

Table E.7. Survival Estimates by Route for CH0 at Lower Granite Dam During Spill

Year	Spill Operation	Spillway	RSW	JBS	Turbine	Source
2007	24-hr Spill RSW+12 kcfs	0.811 (0.044)	0.922 (0.023)	0.853 (0.042)	0.872 (0.067)	Puls et al. 2008
2018	**Court-Ordered Gas Cap Spill**	**0.8456 (0.0321)**	**0.9655 (0.0230)**	**1.0023 (0.0277)**	**0.9949 (0.0306)**	**This Study (VIPRE)**
		0.8450 (0.0323)	**0.9654 (0.0234)**	**1.0022 (0.0280)**	**0.9949 (0.0309)**	**This Study (ViRDCt)**



Fish & Water from Collection Channel
Water measured for Weir A, B & C
Water Level verifies flow
Fish & Water to Flume
180 to 380 cfs
Thru Screen, under wall & over weirs
25 to 40 cfs
WG01
WG09
WG11
Weir Group A
B
C
D
Water Supply Pipe withdraw (typ)

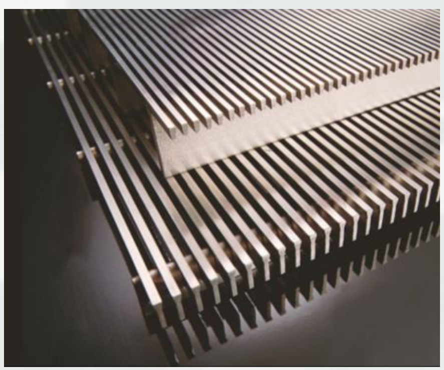


Table 13 Q_{ADV} through each opening separately for 30 cfs.

Opening (No.)	V Mag (ft/s)	Q (cfs)	Area (ft²)	$V_{approach}$ (ft/s)	Weir Opening %
1	0.40	0.91		0.13	
2	0.36	0.82		0.12	50.67
3	0.54	1.24		0.18	
4	0.35	0.80		0.12	
5	0.19	0.43	6.91	0.06	50.33
6	0.16	0.37		0.05	
7	0.30	0.69		0.10	
8	0.29	0.66		0.10	50.00
9	0.21	0.48		0.07	

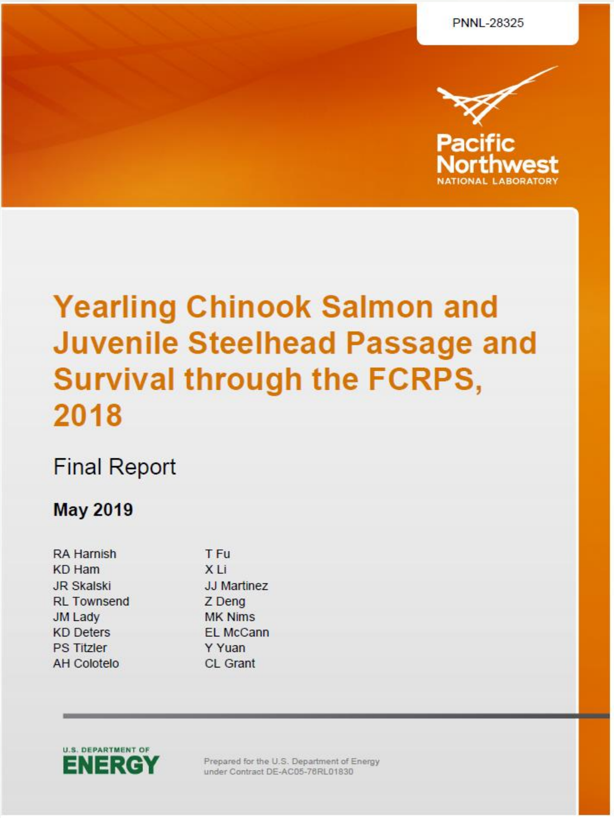
ADV Data @ SDS

Table 15 Q_{ADV} through each opening separately for 40 cfs.

Opening (No.)	V Mag (ft/s)	Q (cfs)	Area (ft²)	$V_{approach}$ (ft/s)	Weir Opening %
1	0.81	1.86		0.27	
2	0.75	1.71		0.25	60.00
3	0.45	1.04		0.15	
4	0.54	1.24		0.18	
5	0.97	2.22	6.91	0.32	60.33
6	0.68	1.55		0.22	
7	0.58	1.33		0.19	
8	0.98	2.24		0.32	60.33
9	0.90	2.06		0.30	

	$V_{approach}$ (ft/s)												
Date	Condition	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11	11 - 12	12 - 15
3/30	Norm w/ WS	-0.24	0.53	0.22	0.28	0.15	0.23	0.20	0.23	0.19	0.22	0.37	0.39
4/4	Max w/ WS	0.34	0.28	0.30	0.12	0.31	0.44	0.24	0.28	0.27	0.28	0.48	0.51
10/23	Max w/ WS, B dwn	0.04	0.09	0.26	0.33	0.25	0.29	0.28	0.25	0.24	0.28	0.65	0.37
11/2	Norm no WS	0.06	0.07	0.47	0.19	0.19	0.20	0.33	0.22	0.20	0.24	0.42	0.40
11/9	High no WS, B dwn, D raised	0.06	0.26	0.23	0.29	0.14	0.22	0.15	0.28	0.22	0.24	0.48	0.39


DETOUR



PNNL-28325

Pacific Northwest NATIONAL LABORATORY

Yearling Chinook Salmon and Juvenile Steelhead Passage and Survival through the FCRPS, 2018

Final Report

May 2019

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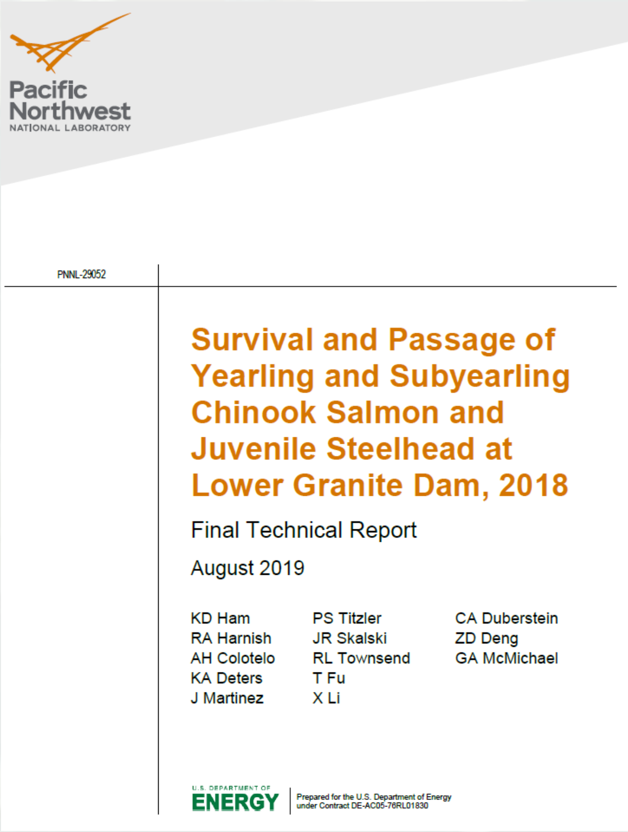
Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830



Pacific Northwest NATIONAL LABORATORY

PNNL-29052

Survival and Passage of Yearling and Subyearling Chinook Salmon and Juvenile Steelhead at Lower Granite Dam, 2018

Final Technical Report

August 2019

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J Martinez	X Li	

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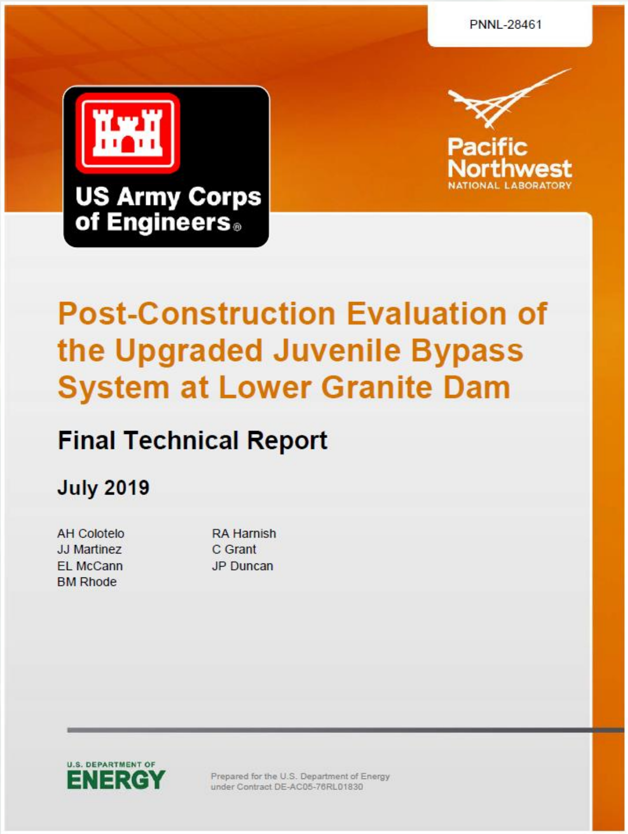

PNNL-28461

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Pacific Northwest NATIONAL LABORATORY

Post-Construction Evaluation of the Upgraded Juvenile Bypass System at Lower Granite Dam

Final Technical Report

July 2019

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Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830

Relevant PNNL Reports

Copied from Peter Christensen (R2 Consultants), FSOC 2016, Ellensburg, WA

Approach Velocity Measurement Issue

Traditional Method:

- Approach Velocity Measured with ADV Meter a Few Inches from Screen Face
- Can Work Well in Low-Velocity Channel Flow Environments

Issue:

- Many Recent Designs Use High-Velocity Channel Flow to Trap Fish
- This Can Compromise Ability to Accurately Measure Approach Velocity

Solution:

- Alternate Method to Reasonably Calculate Estimates of Approach Velocities

Concerns with traditional approach

Location:

- If Perpendicular Velocity is High then Screen Flow is NOT at Meter Location
- Example: Meter 3 Inches From Screen

Approach Velocity = 0.40 ft/s

Perpendicular Channel Velocity = 4.0 ft/s (10 Times Approach)

Approach Flow Travels Downstream 30 Inches before Reaching Screen

At Trapping Velocity of 7 to 8 ft/s Problem Even Worse

Meter Positioning:

- Accurate Meter Positioning Becomes Nearly Impossible

Sensitivity Analysis of Measured Velocity vs. ADV Probe Orientation

Meter Positioning Accuracy

(Courtesy of Alden Laboratories)

Scenario 1 - Input Parmeters

Assumed Vx	6 fps
Assumed Vy	5.5 fps
Resultant Velocity (Vr)	8.14 fps
Resultant X-Y Vector Angle (α)	42.51 deg
Va - Actual	0.35 fps
Vs - Actual	8.13 fps

Analysis 1

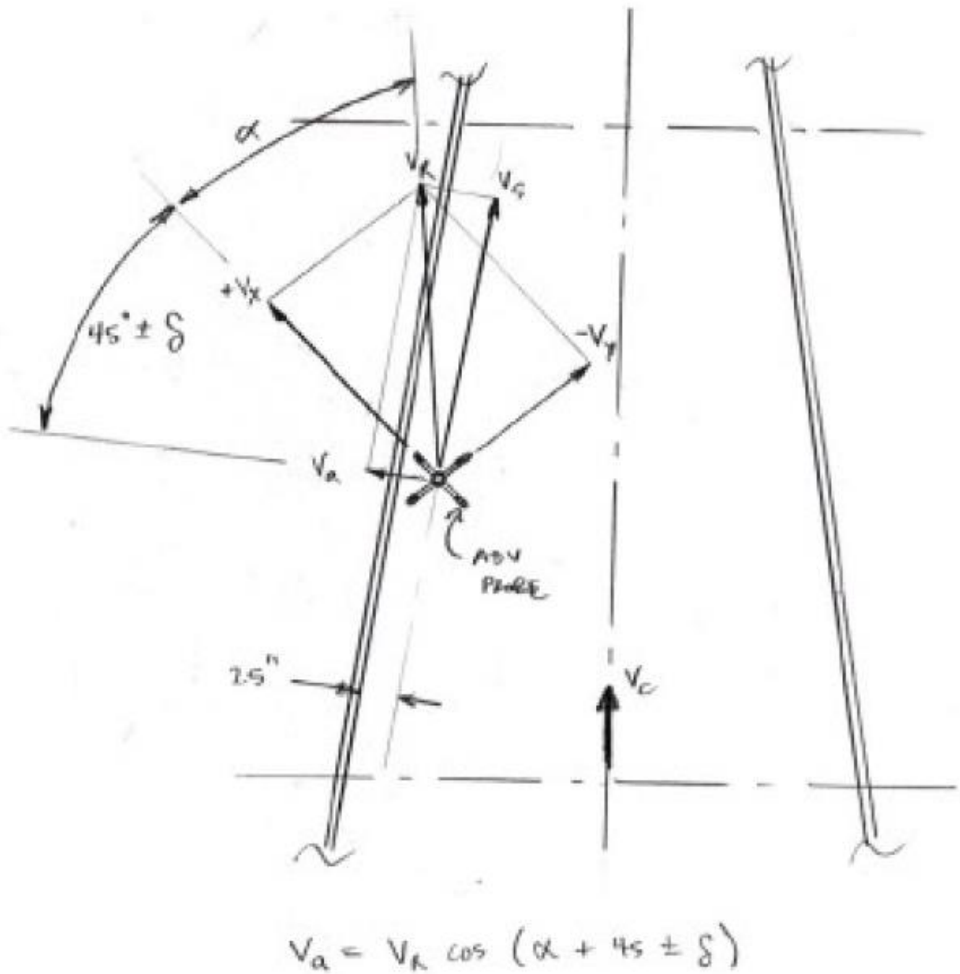
Probe Alignment (δ) (deg from true)	Va - Meas (fps)	Vs - Meas (fps)	% Error Va	% Error Vs
-5	1.06	8.07	200%	-0.8%
-2	0.64	8.11	80%	-0.2%
-1	0.50	8.12	40%	-0.1%
-0.25	0.39	8.13	10%	0.0%
0	0.35	8.13	0%	0.0%
0.25	0.32	8.13	-10%	0.0%
1	0.21	8.14	-40%	0.1%
2	0.07	8.14	-80%	0.1%
5	-0.36	8.13	-201%	0.0%

Scenario 2 - Input Parmeters

Assumed Vx	2 fps
Assumed Vy	1.5 fps
Resultant Velocity (Vr)	2.50 fps
Resultant X-Y Vector Angle (α)	36.87 deg
Va - Actual	0.35 fps
Vs - Actual	2.47 fps

Analysis 2

Probe Alignment (δ) (deg from true)	Va - Meas (fps)	Vs - Meas (fps)	% Error Va	% Error Vs
-5	0.57	2.43	61%	-1.6%
-2	0.44	2.46	24%	-0.6%
-1	0.40	2.47	12%	-0.3%
-0.8	0.39	2.47	10%	-0.2%
0	0.35	2.47	0%	0.0%
0.80	0.32	2.48	-10%	0.2%
1	0.31	2.48	-12%	0.2%
2	0.27	2.49	-24%	0.4%
5	0.14	2.50	-61%	0.9%



Method for Calculating Approach Velocity Estimates

- Requirements:
  - Screen Divided into Independently Controlled Sections
  - Control Baffles Provide Evenly Distributed Flow over Screen Area
- Approach:
  - Preset Baffles to Design Conditions (if possible)
  - Measure Channel Flow at Discrete Locations along Channel
  - Adjust Overall Flow to Meet (or approximate) Targets
  - Difference in Flow Measurements is Screen Flow Leaving Channel
  - Measure Head Difference Across Individual Screen Panels
  - Calculate Approach Velocity Estimates Based on Heads

Calculation of Approach Flow Estimates

Flow Through a Screen Section is Defined by Following Governing Equation:

$Q_P = C * A_P * P * (2G)^{0.5} * H^{0.5}$

Where: Q_P = Screen Panel Flow

C = Screen Orifice Flow Coefficient

A_P = Submerged Area of Screen Panel

P = Open Area Porosity of Screen Material

G = Gravity Acceleration

H = Hydraulic Headloss across the Screen Panel

Given Identical Screen Material, and Near Constant Channel Environment Conditions:

The Flow Coefficients, Screen Porosities, and Gravity are Essentially Constants

Therefore: $Q_P = Z * A_P * H^{0.5}$ where the Correction Factor $Z = C * P * (2G)^{0.5}$

So the Total Screen Flow Out of the Channel Section :

$$Q_T = Z * (A_1 * H_1^{0.5} + A_2 * H_2^{0.5} + A_3 * H_3^{0.5} + A_4 * H_4^{0.5} + A_5 * H_5^{0.5} + A_6 * H_6^{0.5} + A_7 * H_7^{0.5} + A_8 * H_8^{0.5})$$

Calculation of Approach Flow Estimates

Channel Section P-2 (Between Transects 2 and 3)

Primary Section P-2 Individual Screen Panel Approach Velocity Estimates	Starboard				Port				Total
	Screen Panel P5-A	Screen Panel P5-B	Screen Panel P7-A	Screen Panel P7-B	Screen Panel P6-A	Screen Panel P6-B	Screen Panel P8-A	Screen Panel P8-B	Screen Flow (cfs) **198.86**
Screen Area (ft^2):	67.95	67.98	67.95	68.02	67.85	67.93	67.95	67.98	Correction
Measured Screen Headloss (in):	0.20	0.30	0.30	0.30	0.20	0.25	0.30	0.25	Factor
Screen Headloss (ft):	0.02	0.03	0.03	0.03	0.02	0.02	0.03	0.02	2.48
Square Root of Headloss ($ft^{1/2}$)	0.13	0.16	0.16	0.16	0.13	0.14	0.16	0.14	Totals
Area*Square Root of Headloss ($ft^{2.5}$):	8.77	10.75	10.74	10.75	8.76	9.81	10.74	9.81	80.14
Screen Panel Flow (cfs)	21.77	26.67	26.66	26.69	21.73	24.33	26.66	24.35	198.86
Screen Panel Approach Velocity (ft/s):	**0.32**	**0.39**	**0.39**	**0.39**	**0.32**	**0.36**	**0.39**	**0.36**	

The Sum of the Screen Areas times the Square-roots of the Heads = 80.14

Multiplying 80.14 times 2.48 Results in the Measured Flow of 199 cfs

As a Check: $Z/(2G)^{0.5}/P = C$ $2.48/64.4^{0.5}/0.43 = 0.70$

Which is a Reasonable Screen Flow Coefficient for These Conditions

Approach Velocity Measurement Issue

Traditional Method:

- Approach Velocity Measured with ADV Meter a Few Inches from Screen Face
- Can Work Well in Low-Velocity Channel Flow Environments

Issue:

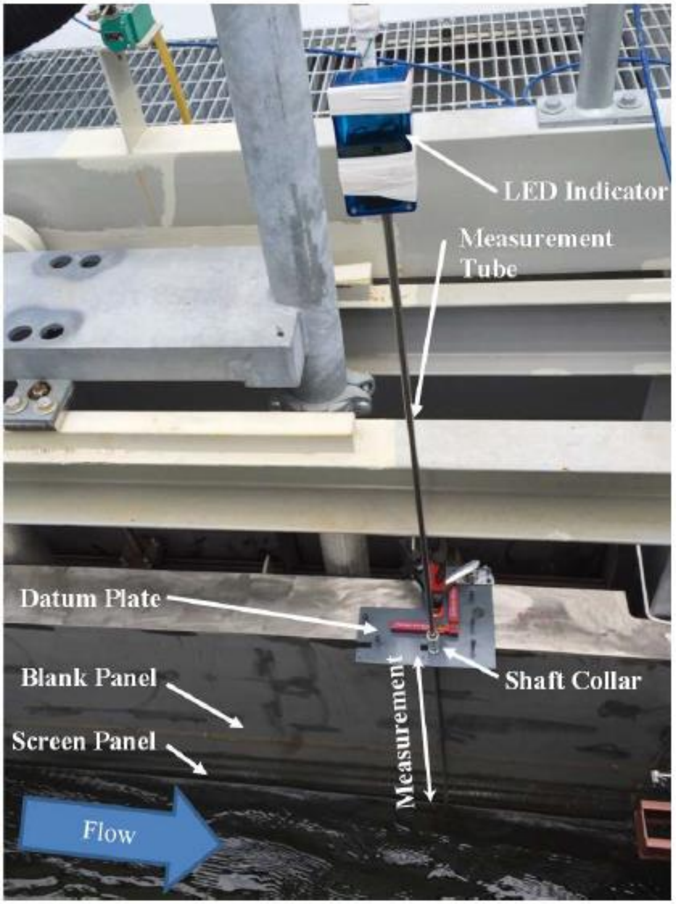
- Many Recent Designs Use High-Velocity Channel Flow to Trap Fish
- This Can Compromise Ability to Accurately Measure Approach Velocity

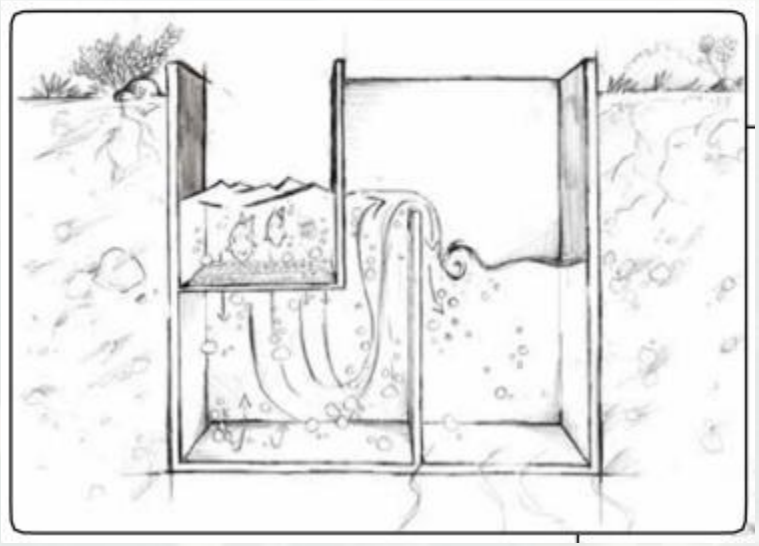
Solution:

- Alternate Method to Reasonably Calculate Estimates of Approach Velocities

Methods for Screen Head Measurements

LED Water Surface Indicator Measurement Tool
Used at North Fork FSC





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