Saccarappa Fish Passage
Selection of Final Fish Passage Design
October 12, 2015

1.0 Background

On March 14, 2014, S.D. Warren Company (Warren), dba as Sappi North America, entered into an agreement (Agreement) with the U.S. Department of the Interior and U.S. Fish and Wildlife Service (USFWS), the Maine Department of Inland Fisheries and Wildlife (DIFW), the Maine Department of Marine Resources (MDMR), the City of Westbrook, the Friends of the Presumpscot River (FOPR), and the Conservation Law Foundation (CLF) (collectively, the "Parties") to request from the Federal Energy Regulatory Commission (FERC) an extension of the fish passage deadline for the Saccarappa Project and a stay of the license surrender application filed by Warren on December 31, 2015. The purpose of the Agreement was to allow the Parties time to engage in a collaborative, open, and joint process to evaluate two fish passage design alternatives at the Saccarappa Dam site.

The Agreement was approved by FERC on July 30, 2014 and became final on September 2, 2014.

The Agreement includes the following provision:

> *"**2.2.2.1** Unless the Parties agree that it is not necessary, Warren will prepare a written summary of its evaluation of both design alternatives, based on the Information. In its evaluation, Warren will provide its determination, made in its sole discretion but in consultation with the other Parties, of whether it will proceed with the Denil Alternative, the Two-Channel Alternative, or some combination of those designs."*

This document is the written summary of Warren's evaluation of the design alternatives, and provides Warren's determination of the design it will propose in its revised FERC surrender application and related regulatory approval applications. Warren's determination was made following an extensive and careful evaluation of all the factors related to the two designs that were developed and considered during the extension period. Both designs that were considered are different from the original design submitted with the December 2013 FERC Surrender Application, and, as a result of this collaborative effort, the final recommended design is an improvement over the original submission.

During the extension period a series of technical meetings were held. These meetings were attended by the Parties and their respective technical consultants for the purpose of carefully exploring several alternatives for fish passage at the Saccarappa Dam site, post surrender. Warren's consultants, as well as the consultant selected by FOPR and CLF, developed alternative designs that came to be referred to as the Western Channel Design and the Two Channel Design. On September 21, 2015 and September 22, 2015 respectively, the USFWS and MDMR provided written feedback based on the two designs. In addition to the numerous technical meetings held by the Parties to develop and discuss these two designs, Warren also held two public meetings in Westbrook during the extension period to solicit comments on the designs, and received voluminous written comments. In making its decision, Warren carefully considered the features of the two designs, the agency feedback, the comments and suggestions of those who attended the public meetings, the submitted written comments, and the likelihood of a successful and predictable outcome.

Warren would like to thank all of the Parties to the Agreement for their hard work and involvement in this process.

1.1 Summary of the Two Designs

The Saccarappa site consists of two falls, the upper falls and the lower falls. Both final designs propose solutions for fish passage over both falls, but the two proposals differ in their approach to elevation changes, as follows:

Proposal Designation	Upper Falls Design	Lower Falls Design
Western Channel Design	Provide fish passage in the western channel only, while retaining the original bedrock and elevations of the upper impoundment to what existed prior to original hydro construction.	Provide a 180' double Denil fish ladder within the existing hydro tailrace, with a counting station at the outlet.
Two Channel Design	Provide fish passage in both the western and eastern channels by reshaping the original bedrock of the eastern channel and lowering the impoundment above the falls to below the pre-hydro elevation level.	Provide a 500' riffle/pool fishway within the existing hydro tailrace. In order to obtain the required length and slope, this design includes a 180° "switchback" within the tailrace. Fish counting is not included.

2.0 Lowering the Hydraulic Control Elevation and Water Levels Upstream of Saccarappa

The Two Channel Design calls for lowering the water level in the river upstream of Saccarappa by removal of bedrock in the upper eastern channel to elevation 62 in the eastern channel and relying on the existing hydraulic control in the western channel at elevation 60. The Western Channel Design leaves the existing bedrock in the eastern channel at elevation 64 and the fill in the western channel at elevation 64, and leaves the river impoundment above the site closer to pre-dam conditions.

The Two Channel Design would cause the water levels in the river upstream of Saccarappa, post dam removal, to be approximately 1.7 feet lower at average flow rates (900 cfs) and up to 3 feet lower at low flow rates than the Western Channel Design. Any potential impacts to environmental, cultural, fisheries, soils, embankments, wetlands, and man-made resources related to lowering of water levels in the river will be exacerbated by the Two Channel Design. With the Western Channel Design, the water level in the river upstream of Saccarappa will be returned to the levels that existed prior to construction of the first Warren hydroelectric facility at the site. All of the impact studies that have been done based on a control elevation of 64 would need to be re-done to reflect the lower control elevation in the proposed Two Channel Design, causing delays and potential complications in the permitting process. Examples of studies that would have to be redone include the following: (1) wetlands assessment, (2) erosion and sedimentation, (3) water quality (mostly related to potential erosion), (4) archeological resources, (5) historic structures, (6) irrigation system intakes, and (7) docks and retaining walls.

In addition to the potential impacts upstream, excavation of bedrock in the eastern channel will alter the aesthetics of water flow over the upper eastern falls. The appearance of the water flow over the falls will be altered by flattening the falls. Additionally, several landowners on the river commented during the public meetings that they preferred that Warren try to minimize the drop in impoundment water levels.

Warren's conclusion is that the impacts associated with lowering water levels in the river upstream of the Saccarappa site required by the Two Channel Design would be significantly greater than the impacts associated with the Western Channel Design, and not necessary to accomplish the objectives of timely and effective fish passage.

3.0 Recreational Considerations

The final two designs considered by Warren differ substantially in their consideration of recreation, specifically water craft recreation. Over the past several years, the City of Westbrook has expressed an interest in enhancing recreational opportunities for boaters. The potential enhancements could include substantive structural modifications at the site, as long as those enhancements do not impede or interfere with fish passage at the site. The City's recreational consultant has indicated that the opportunities for enhancements in the eastern channel are only limited by one’s imagination. Warren believes that the expressed interests of the City are better served by allocating the western channel for fish passage and leaving the eastern channel available for other non-conflicting interests.

The Two Channel Design includes substantive modification to both the eastern and western channels for fish passage. In addition, with the Two Channel Design, Warren would need to install barriers to watercraft upstream of the western channel to exclude boats from entering the western channel because watercraft could be drawn into the riffle / pool fishway in the tailrace. The riffle / pool fishway area is not appropriate or safe for recreational boating activities, especially in the area of the 180° switchback and during times of heavy river flow. The 20-foot wide opening to the riffle / pool fishway area could encourage boaters to try to navigate the fishway. An option might be to install a boating barrier at the entrance to the tailrace area, but such a barrier at that location poses complications and challenges. Therefore, Warren is very concerned about the safety risks of this design.

The Western Channel Design concentrates the modifications to enhance fish passage in the western channel. The Western Channel Design does not necessitate any restrictions to boating activities in either channel. Both channels are available for recreational boaters (predominantly kayaks). It will not be practical, however, to implement structural modifications in the western channel because any structural enhancements could adversely impact the success of fish passage in the western channel. Warren’s modeling in the western channel shows that it will provide safe and effective fish passage, so modifications in the eastern channel to promote or enhance fish passage are not necessary and are not being proposed; hence the eastern channel is available for structural enhancements for recreational boating without adversely impacting fish passage.

On the other hand, the Two Channel Design does include substantive modification to both the eastern and western channels. Therefore, any structural modifications in either channel solely for the purpose of enhancing recreational boating could negatively impact the modifications proposed for fish passage.

Warren’s conclusion is that the Western Channel Design is preferred because it does not limit in any way potential future opportunities for recreational enhancements in the eastern channel, and the Western Channel Design allows boats to use both the eastern and western channels for recreational boating.

4.0 Cost Comparison

An opinion of potential construction and post-construction costs was prepared for both options. The summary of the cost opinions is presented below.

Item Description	***Western Channel Design***	***Two Channel Design***
Construction Cost	$4,500,000	$5,300,000
Post Construction Capital Cost	$70,000	$225,000
Post Construction Annual O&M Cost	$85,000	$150,000

Warren's conclusion from the cost comparison of the two options is that it will cost substantially more to build and operate the Two Channel Design than the Western Channel Design.

5.0 Provisions to Count Fish

The ability to count fish at the Saccarappa site is important because the licenses for Mallison Falls and Little Falls, the next two stations upstream from Saccarappa, include triggers for fish passage that are tied to fish counts at Saccarappa. The Western Channel Design includes provisions to view and count fish at the exit of the Denil fishway. Viewing and counting are important because the triggers are species specific. Warren has not been able to devise a reliable and proven method of counting and identifying fish species with the Two Channel Design.

Warren's conclusion is that the Western Channel Design is preferable to the Two Channel Design because the Western Channel Design includes provisions for counting fish at Saccarappa as required by the FERC licenses for Mallison Falls and Little Falls.

6.0 Performance Evaluation

6.1 Performance Evaluation by Alden Labs

<u>Tailrace Switchback Channel (Two Channel Design) versus Denil Fishway (Western Channel Design)</u>

The lower roughened channel in the Two Channel Design is approximately 580 feet long, at a 2% slope. The lower 280 feet of the channel occupies the full tailrace width at approximately 30 feet and then transitions to a variable 10 to 20 foot wide switchback section for the remainder 300 feet to the middle pool. The channel includes 13 boulder sills, creating a step pool channel. The normal tailwater elevation ranges between 41 to 42 feet and the middle pool elevation ranges between 53.5 to 56.5 feet. The total head from the tailwater to the middle pool ranges between 12 to 15 feet. The lower two boulder sills are submerged, thereby providing a total of

11 boulder sills for the full head, creating 14 to 18 inch drops between pools. The flow through the channel ranges from 152 cfs to 557 cfs for corresponding river flow of 300 cfs and 3,000 cfs, respectively. HEC-RAS model results of the proposed design provided by FOPR predict velocities of 2 to 6.7 ft/sec, as shown below.

Switchback Channel Velocities

Total River Flow (cfs)	Switchback Channel Flow (cfs)	Max Channel Velocity (ft/sec)
300	152	4.9
1500	379	6.0
2250	476	6.4
3000	557	6.7

The Two Channel Design switchback channel fishway proposed for the lower falls is a one-of-a-kind design without known precedent. The expected hydraulic conditions within the irregular channel are complex and not easily predicted without sophisticated analysis, and there is insufficient information to predict the ability of fish to pass up this channel. One dimensional modeling has been completed, which is appropriate and useful to predict water levels through the channel and can provide an approximation of average velocity, but it does not provide adequate information to assess fish passage.

The following considerations are important relative to fish passage success for the lower falls:

- The switchback channel is over 500 feet long, at a 2% slope with velocities ranging from 2 to 7 ft/sec. Shad passage effectiveness decreases as the length of fishways increase. The Denil ladder is about 1/3 the length of the switchback channel and can provide more timely passage than the switchback channel due to its shorter length.

- There are significant uncertainties and risks with the hydraulic design of the switchback channel. The average velocities predicted by HEC-RAS approach and exceed fish passage design threshold recommendations of 6 ft/sec. The one-dimensional modeling is not adequate to understand the three dimensional irregularity of the proposed channel. In particular, the proposed 180 degree switchback pool has potential to create adverse flow conditions such as eddies, which are known to delay fish and hinder passage. By contrast, the hydraulics of the Denil ladder are well understood and effective. The Denil ladder configuration has been carefully designed to optimize internal hydraulics (no 180 degree turning pools) to eliminate the potential for adverse conditions (such as eddies) that may delay or hinder passage.

- The switchback channel includes 10 pools with a hydraulic drop of 14 to 18 inches between pools. Typically, step pool fishways for shad and herring are designed with drops of less than 6 inches (a drop that produces a plunging flow of about 6 ft/sec). The Two Channel Design will create plunging flow velocity of up to 10 ft/sec.

- Average velocity predicted by HEC-RAS modeling is greater than 6 ft/sec for river flows greater than 1,500 cfs. Maximum channel velocity will be considerably higher than 6 ft/sec and fish passage will be challenging for river flows greater than 1,500 cfs.

- The switchback channel lacks a means to limit flow into the channel. As the river flow increases, the switchback channel flow also increases. Flood flows are of particular concern, which could damage and move grade control features such as the boulder sills and also deposit large debris within the channel (especially in the switchback area, where the flow changes 180°). Debris and trees have potential to become trapped within the tight turns of the channel, and there are no means of accessing the channel with heavy equipment to remove large debris. The channel is constructed of fill material that will require periodic inspection and adjustment to maintain proper sill elevations and hydraulic conditions.

- The as-built conditions of the switchback channel are very important to the ultimate success of the design. Considerable uncertainties exist with the design, which are compounded by the challenges associated with constructing irregular rock structures at the design elevations and widths. Great care will be needed to document as-built conditions and final hydraulics. Adaptive management and additional channel modifications will likely be required after initial construction.

- Hydraulic conditions at the entrance of the switch-back fishway will be substantially altered by the cascade of water over the lower falls. Currently, a 10 foot deep plunge pool exists where the water flows over the lower falls. The plans call for the depth of water to be approximately 1 to 1.5 feet deep. This cascade of water into this shallow area may cause confusing hydraulic conditions which may delay or hinder the ability of fish to find the entrance to the switch-back channel.

Upper Western Channel

The upper western channel in the Two Channel Design is approximately 520 feet long, at a 2.5% slope with velocities ranging from 3 to 8 ft/sec.

- The upper western channel in the Two Channel Design is similar to the Western Channel Design, but the Two Channel Design includes pools and riffles to assist in dissipating energy. The Western Channel Design includes sculpted bedrock features to dissipate energy. Relative to fish passage, the two designs in this location are expected to be similarly effective.

6.2 Performance Evaluation by MDMR and USFWS

On August 26, 2015, Brett Towler from the USFWS provided all parties to the Agreement a copy of a model intended to evaluate and compare three performance parameters for the Western Channel Design and the Two Channel Design. The three parameters are:

- *Survivorship Analysis*: The proportion of fish successfully passing a velocity barrier.
- *Fatigue Analysis*: Fatigue and distance relationships.
- *Work-Energy Analysis:* Estimate of the energy that it takes a fish to move through a fishway.

Warren compared the results of the model outputs for both of the designs. The results of the comparison clearly indicate that the Western Channel Design fared better than the Two Channel Design. Warren also concluded that if some resting pools could be added into the western channel upstream of the Denil exit, then the model results for the Western Channel Design would be even better, so Warren asked its consultants to modify the Western Channel Design to add some resting pools. The site plan for the modified design is attached to this document along with the results of the performance passage model developed to reflect the modified design of the western channel.

Warren's assessment of this information is that with relatively minor modifications to the design submitted to the agencies at the July 14, 2015 technical meeting in Hadley, Massachusetts and the August 26, 2015 public meeting in Westbrook, Maine, the predicted effectiveness and efficiency of the Western Channel Design's nature like passage in the upper western channel can be improved. The passage model results for the revised Western Channel Design are dramatically better than the passage model results for the Two Channel Design.

Therefore, based on the independent evaluation of potential fish passage performance by the agencies and the modifications proposed by Warren to the Western Channel Design, Warren believes the Western Channel Design will provide safe, timely, and effective passage over the lower and upper falls at Saccarappa.

7.0 Formal Comments by MDMR and USFWS

On September 22, 2015, Warren received written comments from both MDMR and USFWS on the Western Channel and Two Channel designs. Both of the letters from the resource agencies included an extensive summary as well as recommendations. The following are the recommendations copied from each letter. Each of the letters and the recommendations were discussed and reviewed extensively during the September 22, 2015 technical meeting in Westbrook.

*"**MDMR RECOMMENDATIONS***

1. *To pass upstream migrants over the lower falls, MDMR recommends that Sappi change the Denil fishway design to a double Denil. This design consists of two side-by-side Denil fishways. The additional flow of the second fishway will allow Sappi to eliminate the attraction water supply system.*

2. *Retain the fish counting facility that was included in the Denil design. With the double Denil, the two fishways should be designed to exit into a common pool with a counting window and a removable crowder.*

3. *Provide passage on both the east and west channel using the nature-like fishways proposed by FOPR. MDMR believes that for this project to be successful both channels must be passable."*

"SERVICE RECOMMENDATIONS

1. *To pass upstream migrants over the lower falls, the Service recommends that Sappi change the Denil fishway design to a double Denil. This design consists of two side-by-side Denil fishways. The additional flow of the second fishway will allow Sappi to eliminate the auxiliary water supply system.*

2. *Retain the fish counting facility that was included in the Denil design. This facility is needed in order to determine when triggers are met for fish passage construction at upstream sites. With the double Denil, the two fishways should be designed to exit into a common pool with a counting window and a removable crowder. (Note: The Service is willing to discuss a date certain for construction of fish passage at the next upstream Projects in lieu of constructing counting facilities at the Denil fishway. This letter does not address the jurisdictional difficulties that may arise from the current structure, which triggers fish passage at upstream projects based on counts at Saccarappa, when Saccarappa is no longer a FERC-licensed Project.)*

3. *Construct a nature-like fishway in the west spillway channel to provide passage over the upper falls. As the design progresses, incorporate appurtenant in-stream structures (e.g., retain suitable ledge features, construct rock vanes, or place boulder clusters) to further improve passage effectiveness.*

4. *Modify ledges in the east channel spillway section to improve passage over the upper falls and reduce the potential for false attraction and stranding."*

Warren has carefully considered the input received during the meeting and the written material provided by the agencies. Representatives from both agencies are very familiar with the site, and their comments and recommendations were based on a careful and thorough evaluation of all the information provided by Warren and others.

Following a detailed review of the comments and recommendations from the agencies, Warren decided to modify the Western Channel Design to include a double Denil fishway in the tailrace, as recommended by the agencies. Both of the letters include the same recommendation for a double Denil fishway instead of the single 4-foot wide fishway. Warren understands the agencies' rationale for the double Denil fishway and believes that the second fishway can be added without adding significantly to the cost of the project.

The letter from MDMR includes a recommendation that Warren provide passage on both the east and west channels using the nature-like fishways proposed by FOPR. The USFWS letter included a recommendation that Warren modify the ledges in the east channel spillway section to improve passage over the upper falls and reduce the potential for false attraction and stranding. It is unclear precisely what the USFWS recommendation would involve, but the recommendation by MDMR is clear because 30% design drawings of the proposed modifications in the eastern channel were provided by Princeton Hydro.

8.0 Conclusion

The Two Channel Design for the modifications in the eastern channel call for removing bedrock to reduce the elevation of the hydraulic control from elevation 64 to elevation 62 +/-. The elevation of the hydraulic control in both the eastern and western channels was at or near elevation 64 prior to hydroelectric development at the site. Water levels in the river segment upstream of the falls were controlled by the bedrock at the falls at elevation 64. The Western Channel Design calls for removal of the spillways and replacement of excavated material in the upper western channel, allowing the river above Saccarappa to return to conditions that existed prior to hydroelectric development at the site. The available evidence indicates that the wooden crib and masonry dams that preceded Warren's activities did not involve structural modifications to the bedrock that created the hydraulic control of river water levels upstream.

Warren has studied the potential environmental, recreational, and social impacts related to removing the spillway but leaving the hydraulic control at elevation 64 feet and has determined that the impacts associated with returning river water levels to pre-hydro development levels are minimal. Warren has not studied the potential impact of lowering water levels below the pre-development levels, but Warren is concerned that potential impacts related to wetlands, soil erosion, embankment stability, and cultural and historic resources could be greater – and potentially significantly greater than with the Western Channel Design.

Additionally, Warren estimates that the cost associated with modifying the eastern falls as proposed by in the Two Channel Design will add a minimum of $600,000, or 25%, to the cost of fish passage at Saccarappa.

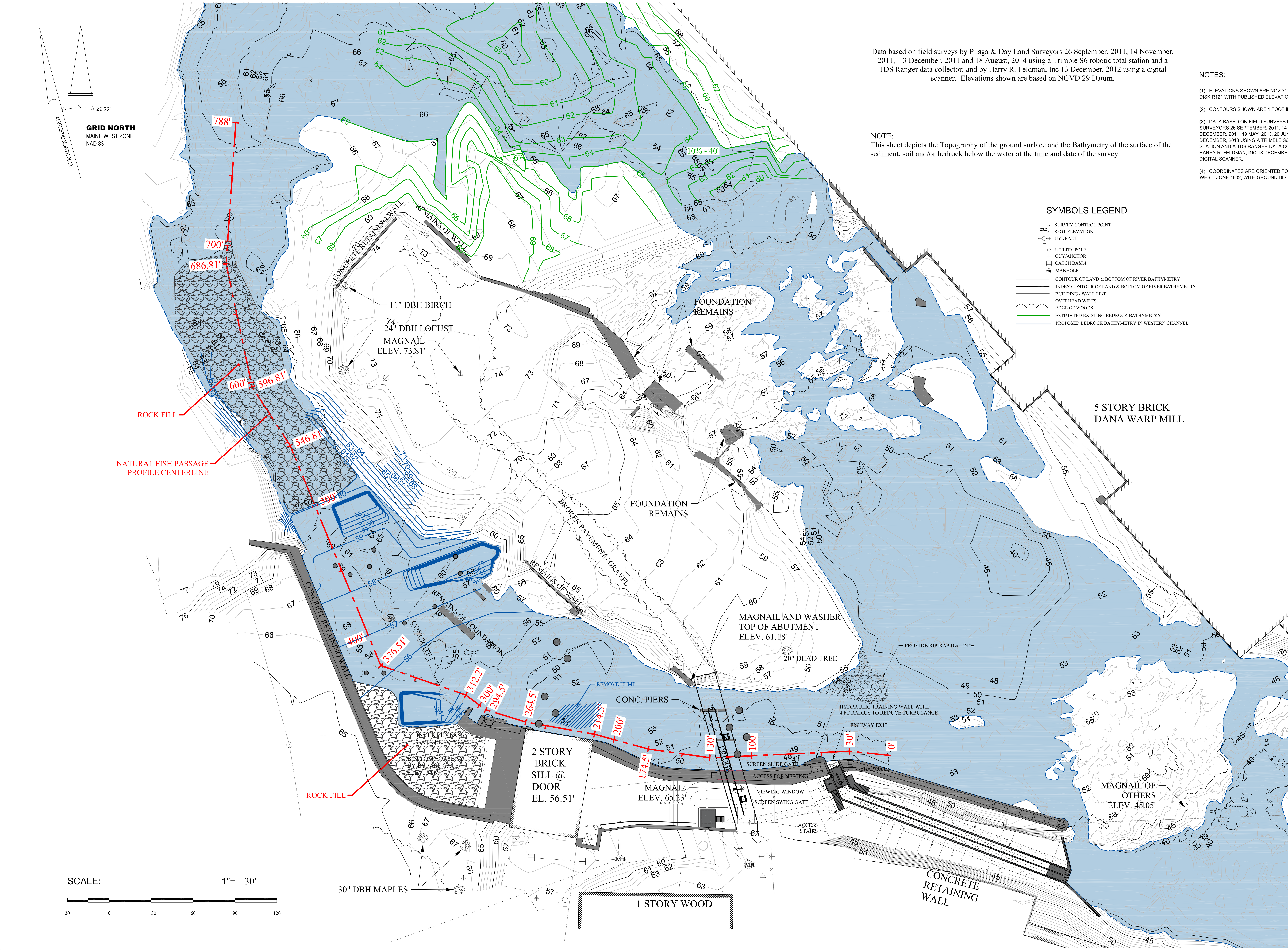
Warren's conclusion from its evaluation of all the available data, facts, and opinions is that the potential negative impacts to environmental, recreational, cultural, and social resources upstream of and at the site, as well as the cost of construction, associated with the Two Channel Design are not worth the potential negligible or *de minimis* benefits to fish passage at the Saccarappa site. Warren concluded that its efforts and resources should be directed toward making safe, timely, and effective fish passage in the western channel as successful as possible.

Warren agrees with the No. 3 recommendation from the USFWS related to modifications to the passage in the upper western channel and has incorporated changes into the design, as attached to this document and described in Section 5.

Based on Warren's careful consideration of all of the facts, data, and opinions described above, Warren has determined that the Western Channel Design, as modified following the September 22, 2015 technical meeting, is its preferred design, and Warren will therefore proceed with the process of implementing the surrender of its FERC license based on that design. The Surrender Application will include Warren's proposal to implement fish passage at the Saccarappa site based on the Western Channel Design depicted in the attached site plan.

Attachments:

Passage Model for American Shad - Fatigue Analysis
Double Denil Site Plan



Data based on field surveys by Plisga & Day Land Surveyors 26 September, 2011, 14 November, 2011, 13 December, 2011 and 18 August, 2014 using a Trimble S6 robotic total station and a TDS Ranger data collector; and by Harry R. Feldman, Inc 13 December, 2012 using a digital scanner. Elevations shown are based on NGVD 29 Datum.

NOTE:
This sheet depicts the Topography of the ground surface and the Bathymetry of the surface of the sediment, soil and/or bedrock below the water at the time and date of the survey.

NOTES:

(1) ELEVATIONS SHOWN ARE NGVD 29 BASED UPON NGS DISK R121 WITH PUBLISHED ELEVATION OF 54.14'.

(2) CONTOURS SHOWN ARE 1 FOOT INTERVALS.

(3) DATA BASED ON FIELD SURVEYS BY PLISGA & DAY LAND SURVEYORS 26 SEPTEMBER, 2011, 14 NOVEMBER, 2011,13 DECEMBER, 2011, 19 MAY, 2013, 20 JUNE, 2013, AND 4 DECEMBER, 2013 USING A TRIMBLE S6 ROBOTIC TOTAL STATION AND A TDS RANGER DATA COLLECTOR; AND BY HARRY R. FELDMAN, INC 13 DECEMBER, 2011 USING A DIGITAL SCANNER.

(4) COORDINATES ARE ORIENTED TO STATE PLANE, MAINE WEST, ZONE 1802, WITH GROUND DISTANCES.

No.	Revision Description	Drwn	Chk'd	Date
-	-	-	-	-

Drwn By: BPG / P&D
Desg By: -
Chkd By: -
Aprvd By: WBB
Date: -

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Saccarappa Falls Fish Passage Project

Denil Option B-1 Eastern Falls
Existing Bedrock Control at 64.0'

Sappi / Warren Release Papers
Saccarappa Falls
Westbrook, Maine

Job Number: 49268

Drawing No: C-

Sheet 1 of 5

Passage Model for American shad
Sappi (Acheron) Design
Fatigue Analysis 8/27/2015

K. Ball (Acheron)

Alternative	ZOP/Path	Section	Fish swim mode	Fish size	River flow condition	Passage model	Model Inputs Vf (ft/s)	Vw (ft/s)	TL (in)	S0 (ft/ft)	T (C)	D (ft)	Model Outputs t (s)	D (ft)	E (cal)	S (%)	Evaluation D to pass	Pass ?	Comments
Sappi (Acheron)	Western channel	Upper Ramp Segment A (Station 300 - 376)	Prolonged	small	Avg @ 300 cfs	Work - Energy	9.1	3.16	15.2	0.0500		76			86				
				average			11.5	3.16	19.1	0.0500		76			168				
				large			13.3	3.16	22.1	0.0500		76			261				
				small	Avg @ 600 cfs		9.1	3.53	15.2	0.0500		76			93				
				average			11.5	3.53	19.1	0.0500		76			180				
				large			13.3	3.53	22.1	0.0500		76			278				
				small	Avg @ 900 cfs		9.1	3.69	15.2	0.0500		76			96				
				average			11.5	3.69	19.1	0.0500		76			185				
				large			13.3	3.69	22.1	0.0500		76			285				
				small	Avg @ 1200 cfs		9.1	3.84	15.2	0.0500		76			99				
				average			11.5	3.84	19.1	0.0500		76			191				
				large			13.3	3.84	22.1	0.0500		76			292				
				small	Avg @1500 cfs		9.1	3.98	15.2	0.0500		76			102				
				average			11.5	3.98	19.1	0.0500		76			195				
				large			13.3	3.98	22.1	0.0500		76			299				
		Upper Ramp Segment B (Station 376 - 490)		small	Avg @ 300 cfs		9.1	2.83	15.2	0.0317		114			118				
				average			11.5	2.83	19.1	0.0317		114			234				
				large			13.3	2.83	22.1	0.0317		114			367				
				small	Avg @ 600 cfs		9.1	3.52	15.2	0.0317		114			137				
				average			11.5	3.52	19.1	0.0317		114			267				
				large			13.3	3.52	22.1	0.0317		114			412				
				small	Avg @ 900 cfs		9.1	4.03	15.2	0.0317		114			153				
				average			11.5	4.03	19.1	0.0317		114			293				
				large			13.3	4.03	22.1	0.0317		114			447				
				small	Avg @ 1200 cfs		9.1	4.42	15.2	0.0317		114			166				
				average			11.5	4.42	19.1	0.0317		114			314				
				large			13.3	4.42	22.1	0.0317		114			476				
				small	Avg @1500 cfs		9.1	4.86	15.2	0.0317		114			182				
				average			11.5	4.86	19.1	0.0317		114			338				
				large			13.3	4.86	22.1	0.0317		114			509				
		Upper Ramp Segment C (Station 490 - 650)		small	Avg @ 300 cfs		9.1	3.00	15.2	0.0269		160			171				
				average			11.5	3.00	19.1	0.0269		160			339				
				large			13.3	3.00	22.1	0.0269		160			528				
				small	Avg @ 600 cfs		9.1	3.91	15.2	0.0269		160			209				
				average			11.5	3.91	19.1	0.0269		160			401				
				large			13.3	3.91	22.1	0.0269		160			614				
				small	Avg @ 900 cfs		9.1	4.51	15.2	0.0269		160			237				
				average			11.5	4.51	19.1	0.0269		160			446				
				large			13.3	4.51	22.1	0.0269		160			676				
				small	Avg @ 1200 cfs		9.1	4.97	15.2	0.0269		160			260				
				average			11.5	4.97	19.1	0.0269		160			483				
				large			13.3	4.97	22.1	0.0269		160			725				
				small	Avg @1500 cfs		9.1	5.39	15.2	0.0269		160			282				
				average			11.5	5.39	19.1	0.0269		160			518				
				large			13.3	5.39	22.1	0.0269		160			773				

Passage Model for American shad
Sappi (Acheron) Design
Fatigue Analysis 8/27/2015

K. Ball (Acheron)

Alternative	ZOP/Path	Section	Fish swim mode	Fish size	River flow condition	Passage model	Model Inputs Vf (ft/s)	Vw (ft/s)	TL (in)	S0 (ft/ft)	T (C)	D (ft)	Model Outputs t (s)	D (ft)	E (cal)	S (%)	Evaluation D to pass	Pass ?	Comments
Sappi (Acheron)	Western channel	Upper Ramp Segment A (Station 300 - 376)	Prolonged	small	Avg @ 300 cfs	Survivorship		3.16	15.2		18	76				96%			
				average				3.16	19.1		18	76				97%			
				large				3.16	22.1		18	76				98%			
				small	Avg @ 600 cfs			3.53	15.2		18	76				95%			
				average				3.53	19.1		18	76				97%			
				large				3.53	22.1		18	76				97%			
				small	Avg @ 900 cfs			3.69	15.2		18	76				95%			
				average				3.69	19.1		18	76				96%			
				large				3.69	22.1		18	76				97%			
				small	Avg @ 1200 cfs			3.84	15.2		18	76				95%			
				average				3.84	19.1		18	76				96%			
				large				3.84	22.1		18	76				97%			
				small	Avg @1500 cfs			3.98	15.2		18	76				94%			
				average				3.98	19.1		18	76				96%			
				large				3.98	22.1		18	76				97%			
		Upper Ramp Segment B (Station 376 - 490)		small	Avg @ 300 cfs			2.83	15.2		18	114				94%			
				average				2.83	19.1		18	114				95%			
				large				2.83	22.1		18	114				96%			
				small	Avg @ 600 cfs			3.52	15.2		18	114				91%			
				average				3.52	19.1		18	114				94%			
				large				3.52	22.1		18	114				95%			
				small	Avg @ 900 cfs			4.03	15.2		18	114				89%			
				average				4.03	19.1		18	114				92%			
				large				4.03	22.1		18	114				94%			
				small	Avg @ 1200 cfs			4.42	15.2		18	114				87%			
				average				4.42	19.1		18	114				90%			
				large				4.42	22.1		18	114				93%			
				small	Avg @1500 cfs			4.86	15.2		18	114				84%			
				average				4.86	19.1		18	114				88%			
				large				4.86	22.1		18	114				91%			
		Upper Ramp Segment C (Station 490 - 650)		small	Avg @ 300 cfs			3.00	15.2		18	160				88%			
				average				3.00	19.1		18	160				92%			
				large				3.00	22.1		18	160				94%			
				small	Avg @ 600 cfs			3.91	15.2		18	160				82%			
				average				3.91	19.1		18	160				87%			
				large				3.91	22.1		18	160				90%			
				small	Avg @ 900 cfs			4.51	15.2		18	160				77%			
				average				4.51	19.1		18	160				83%			
				large				4.51	22.1		18	160				87%			
				small	Avg @ 1200 cfs			4.97	15.2		18	160				71%			
				average				4.97	19.1		18	160				79%			
				large				4.97	22.1		18	160				84%			
				small	Avg @1500 cfs			5.39	15.2		18	160				65%			
				average				5.39	19.1		18	160				75%			
				large				5.39	22.1		18	160				81%			

Passage Model for American shad
Sappi (Acheron) Design
Fatigue Analysis 8/27/2015

K. Ball (Acheron)

Alternative	ZOP/Path	Section	Fish swim mode	Fish size	River flow condition	Passage model	Model Inputs Vf (ft/s)	Vw (ft/s)	TL (in)	S0 (ft/ft)	T (C)	D (ft)	Model Outputs t (s)	D (ft)	E (cal)	S (%)	Evaluation D to pass	Pass ?	Comments
Sappi (Acheron)	Western channel	Upper Ramp Segment A (Station 300 - 376)	Prolonged	small	Avg @ 300 cfs	Fatigue	9.1	3.16	15.2				33.6	200			76.0	Y	
				average			11.5	3.16	19.1				43.6	364			76.0	Y	
				large			13.3	3.16	22.1				43.7	443			76.0	Y	
				small	Avg @ 600 cfs		9.1	3.53	15.2				33.6	187			76.0	Y	
				average			11.5	3.53	19.1				43.6	348			76.0	Y	
				large			13.3	3.53	22.1				43.7	427			76.0	Y	
				small	Avg @ 900 cfs		9.1	3.69	15.2				33.6	182			76.0	Y	
				average			11.5	3.69	19.1				43.6	341			76.0	Y	
				large			13.3	3.69	22.1				43.7	420			76.0	Y	
				small	Avg @ 1200 cfs		9.1	3.84	15.2				33.6	177			76.0	Y	
				average			11.5	3.84	19.1				43.6	334			76.0	Y	
				large			13.3	3.84	22.1				43.7	413			76.0	Y	
				small	Avg @1500 cfs		9.1	3.98	15.2				33.6	172			76.0	Y	
				average			11.5	3.98	19.1				43.6	328			76.0	Y	
				large			13.3	3.98	22.1				43.7	407			76.0	Y	
		Upper Ramp Segment B (Station 376 - 490)		small	Avg @ 300 cfs		9.1	2.83	15.2				33.6	211			114	Y	
				average			11.5	2.83	19.1				43.6	378			114	Y	
				large			13.3	2.83	22.1				43.7	457			114	Y	
				small	Avg @ 600 cfs		9.1	3.52	15.2				33.6	188			114	Y	
				average			11.5	3.52	19.1				43.6	348			114	Y	
				large			13.3	3.52	22.1				43.7	427			114	Y	
				small	Avg @ 900 cfs		9.1	4.03	15.2				33.6	171			114	Y	
				average			11.5	4.03	19.1				43.6	326			114	Y	
				large			13.3	4.03	22.1				43.7	405			114	Y	
				small	Avg @ 1200 cfs		9.1	4.42	15.2				33.6	157			114	Y	
				average			11.5	4.42	19.1				43.6	309			114	Y	
				large			13.3	4.42	22.1				43.7	388			114	Y	
				small	Avg @1500 cfs		9.1	4.86	15.2				33.6	143			114	Y	
				average			11.5	4.86	19.1				43.6	290			114	Y	
				large			13.3	4.86	22.1				43.7	369			114	Y	
		Upper Ramp Segment C (Station 490 - 650)		small	Avg @ 300 cfs		9.1	3.00	15.2				33.6	205			160	Y	
				average			11.5	3.00	19.1				43.6	371			160	Y	
				large			13.3	3.00	22.1				43.7	450			160	Y	
				small	Avg @ 600 cfs		9.1	3.91	15.2				33.6	175			160	Y	
				average			11.5	3.91	19.1				43.6	331			160	Y	
				large			13.3	3.91	22.1				43.7	410			160	Y	
				small	Avg @ 900 cfs		9.1	4.51	15.2				33.6	154			160	N	
				average			11.5	4.51	19.1				43.6	305			160	Y	
				large			13.3	4.51	22.1				43.7	384			160	Y	
				small	Avg @ 1200 cfs		9.1	4.97	15.2				33.6	139			160	N	
				average			11.5	4.97	19.1				43.6	285			160	Y	
				large			13.3	4.97	22.1				43.7	364			160	Y	
				small	Avg @1500 cfs		9.1	5.39	15.2				33.6	125			160	N	
				average			11.5	5.39	19.1				43.6	267			160	Y	
				large			13.3	5.39	22.1				43.7	345			160	Y	