**MEMORANDUM**
August 15, 2006

TO: Gary Petrewski, PPL

FROM: McLaughlin Whitewater Design Group

**RE: Whitewater Options - PPL Holtwood**

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# I. BACKGROUND

PPL is planning to increase its production capacity at Holtwood Dam from 107 MW to 234 MW by 2010. At present, discharge from the power plant goes into an excavated tailrace channel on the far river left (east) shore. With the addition of two new turbines (located in the smaller building closest to the shore, Figure 1), discharge capacity will increase from 31,500 cfs to 61,500 cfs.

Several excellent recreational whitewater features located within the natural river to the west of the plant run only when the dam is spilling. Increased plant capacity will reduce the amount of spill, thereby reducing the number of days available for whitewater boating at these features.

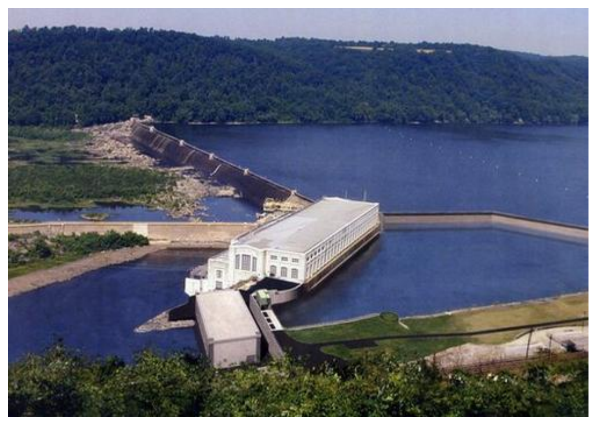


*Figure 1*
*Aerial View of Hydropower Facility*

## Impact on Existing Whitewater Recreation

While the existing tailrace below plant has little recreational value, the natural spill channel within the main river has a number of features that are highly valued by paddlers (See www.chasingrain.com for an excellent overview of these features). Under existing conditions, they only run when natural flow exceeds the capacity of the Holtwood dam (31,500 cfs). According to historical data, this occurs 45 days per year, on average. PPL forecasts that the increased capacity of the power plant will reduce the average number of spill days to 23.

Storm Hole, the crown jewel of surfing in the project area, will lose 22 days under the proposed conditions, as will other spots listed at chasingrain.com. Storm Hole begins to become an attractive recreational feature at 7,000 cfs and possesses excellent attributes up to about 15,000 cfs. Eddy service at low flow is marginal and is non-existent at higher flows.

The purpose of this study is to advise PPL on its options to improve whitewater recreation opportunities at the proposed flows. Improvements which include the construction of high quality breaking wave / hole (hydraulic) combinations would be constructed within the constraints of the expansion plans and project area.

## PPL Whitewater Recreational Outreach Efforts to Date

- Public input meeting at Willow Valley, in Lancaster PA on April 18, 2006
- Flow test and boater evaluation of 3,150cfs at Storm Hole, on May 11, 2006.
- Selected McLaughlin Whitewater Design Group to identify options for recreational whitewater enhancements, May 26, 2006
- Flow test of 7,000 cfs at Storm Hole, with MWDG on May 29, 2006

## Overview of PPL Proposed Expansion

The Holtwood expansion will double the capacity of the existing plant by adding two new turbines. These are to be located on the landward side of the dam and will discharge into the existing tailrace (far river left). Related environmental improvements related to fish passage are also planned for inclusion into the project. The main tailrace will be excavated (widened and deepened) to increase its capacity to 58,350 cfs with minimal head loss until it reaches the pool above Conowingo Dam, slightly more than a mile downstream. The remaining 3,150 cfs will be routed through Piney Channel, lying just to the west of the main tailrace and separated from it by a training wall and Piney Island. Subsequent refinements in the overall plan may alter these design flows somewhat.

### Main Tailrace and Primary Fish Passage

The existing tailrace will be widened and deepened considerably in order to convey the additional water without creating a backwater at the turbines. Extensive hydraulic modeling of the tailrace modifications has been performed by PPL consultants, Kleinschmidt USA and Alden Labs to support this excavation. Note that the existing tailrace is an engineered system, excavated during the original plant construction in 1910. A fish elevator is installed at the head of the tailrace that provides passage to for American Shad and other migratory species.

## Training Wall and Secondary Fish Passage

There is a divider wall to the west of the powerhouse that prevents spillway flow from entering the tailrace so as not to affect the plant's tailwater. A secondary fish elevator located on the westward side of the training wall provides passage for fish that swim up the main river channel during periods of spill. When seasonally high flows coincide with traditional shad migration each April through June, successful passage is critical. This project creates a unique opportunity to improve fish passage facilitation.

## Piney Channel Tailrace and Storm Hole

Unit #1, the outermost existing turbine (river right) will be re-plumbed to discharge into the Piney Channel, (Piney North) a natural river channel to the west of the main tailrace channel. This is the channel that feeds Storm Hole, Rumble Pit and Yesterday (again, described at www.chasingrain.com). Piney North bifurcates into two sub-channels, Piney East and Piney West. The flow from this Unit #1 is 1,200 to 3,150 cfs, a fraction of what is required for the formation of Storm Hole. In order to achieve the target water elevations at the tailrace, the Piney channels will need to be excavated to provide more favorable hydraulics for Unit #1. The hydraulic modeling to determine the extent of the excavation is underway by PPL consultant team. Preliminary discussions with PPL indicate that the excavations will be located in the Piney West Channel above Storm Hole.

## Proposed Fish Barrier Dam

Presently when the dam is being overtopped, American Shad have difficulty finding the fish elevator, located at the training wall west of the powerhouse. One possibility to enhance fish passage is to construct a new eight-foot tall fish barrier dam across the river downstream of the existing dam. The barrier dam, angled upstream, would respond to the fish's instinct to swim up and across currents in order to find a passable route. It would direct them towards Piney West, leading them to the fish elevator via a naturalized roughened channel fishway at its northeast end. The roughened fishway is referred to at the "Bypass Channel." The dam will be dry for most of the year, and will be fitted with stop logs near each abutment for seasonal deployment during the shad season.

# II. WHITEWATER ENHANCEMENTS

## Whitewater Basics

The quality and costs of man-made whitewater parks and features can vary substantially. Three "site" factors that impact the quality of specific whitewater features and costs are:

1. Flow / Hydrology - including flow amount, measured in cubic feet per second (cfs), the frequency of the flow, and the reliability of flows. Water quality can also be important.
2. Hydraulic Drop - available fall or drop in the water surface across a site (feet)
3. Access - for portage, access to the river, spectators, and parking.

The quality of these site factors determines the overall potential of the site, and the value of engineered whitewater facilities and their associated recreational experiences are made possible by solid, sustainable design and adequate funding. The site factors of available flow and hydraulic drop relate to the performance of the whitewater course, and access is a measure of the ability of its audience to use it.

### Hydrology

The functionality of a whitewater course located in a river relies upon the river's hydrologic conditions. Hydrologic factors impacting the usefulness of a whitewater course include the 1) amount of flow; 2) frequency of suitable flows; 3) reliability or predictability of the flow; and 4) quality of the water.

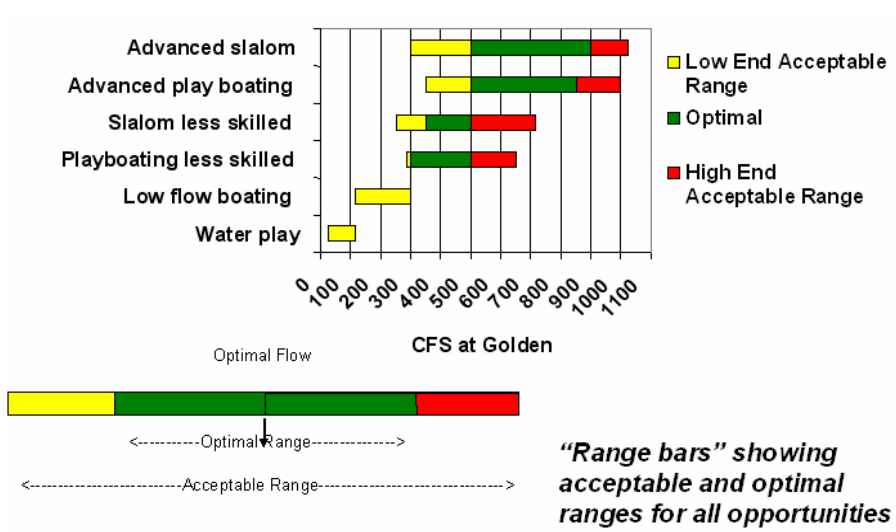



*Figure 2*
*Flow Needs for a small Course in Golden Colorado.*

Highly variable flows can limit the performance of a whitewater park due to the complexity involved in providing a course which performs well over a wide range of flows. Like most natural rapids, manmade rapids and whitewater courses tend to offer high quality performance within a limited range of flow.

Olympic caliber courses and national freestyle competitions have been held with as little as 350 cfs: some have required flows of 1,500 cfs and 3,000 cfs. Creation of whitewater features in this higher range can require extensive constriction of natural streambeds. The related impact on flow must be addressed to manage floodplains and river stability responsibly.

## Hydraulic Drop

The second site factor outlined in the approach described above is hydraulic drop. This is the difference in the elevation of the water surface downstream of a particular site subtracted from the elevation of the water surface at the upstream end, measured in feet. The hydraulic drop multiplied by the flow rate correlates to the power of the river and the potentially high quality experience of the course.

Constructing a whitewater course at a dam takes advantage of the drop created by the dam and its intended purpose. Without an existing low-head dam, a course would create adequate

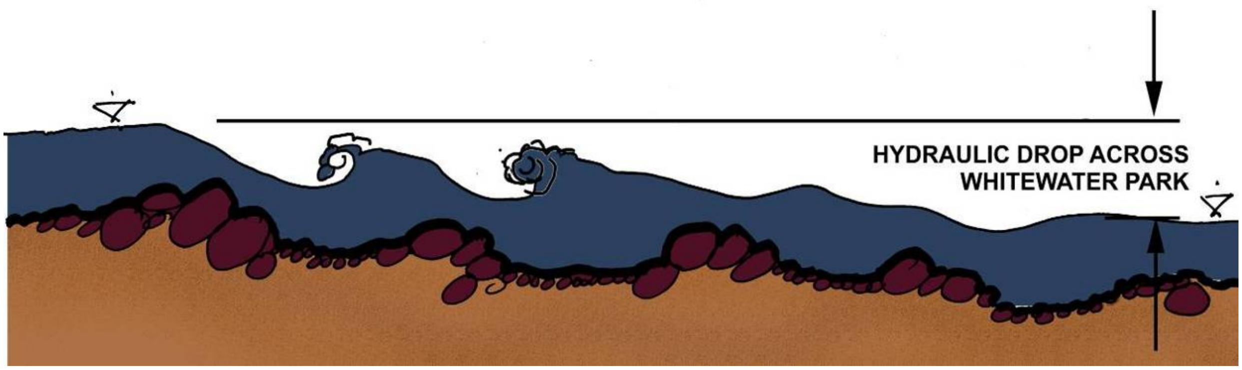



*Figure 3*
*Profile Illustrating the Hydraulic Drop at a Whitewater Park*

hydraulic drop by “backing up” the river. Such structures however, can increase the upstream floodplain elevations, which causes aggradation (raising) of the streambed. This aggradation can increase floodplain elevations and deposition in whitewater features, rendering them less effective. Given the difficulties in creating hydraulic drop at a site, locating a whitewater course at an existing dam has significant advantages.

The amount of vertical drop that has been used to create whitewater parks has varied dramatically, from a few feet on small rivers to 30 feet at the Ocoee Whitewater Course, used for the 1996 Olympics. Specific whitewater features have been created with as little as six inches and as much as four feet. The most common drop for freestyle features in engineered courses is around two feet.

## Access

The third site factor that is considered in this evaluation of whitewater improvements is access. There are a several components to the facilitation of access, including:

- Parking for boaters and spectators;
- “Put in” and “take out” locations that accommodate groups of paddlers;
- A portage route for users to 1) carry downstream around the course if they do not want to run it and 2) return to the upstream put in so that they can run the course again;
- Emergency access along one or both of the banks adjacent to the whitewater course for boaters to enter or exit the course;
- Accessible spaces for spectator viewing; and
- Construction access and staging

*Figure 4*
*Access at Confluence Park in Denver, Colorado is*

If other site factors such as hydraulic drop and flow are nearly equal, access and compatibility with surrounding land uses can be a deciding factor.

## Approach at Holtwood

Approaches to provide whitewater fall into several categories: A) Route higher flows to existing whitewater features; B) provide new play spots or “tune” existing features to run at lesser and more frequent flows; and C) create features that run at high (above 61,500 cfs) river flows. Approaches A and C would still depend on spills from the dam and would create “big water” features. Approach B would run on normal discharges from the plant and may be lesser quality in that they may not be as big. Discussions with stakeholders indicate that a trade of quality for reliability would be acceptable and experience indicates that this approach has merit.

*Figure 5*
*Large water, side-stream feature (Skookumchuck Wave in Coastal British Columbia) is formed by a rock ledge at the margin of a tidal rip channel. Under currently proposed conditions, the Holtwood site – primarily in the Piney Channels –provides sufficient flows and hydraulic drop to create this type of big water feature frequently. Banks of the features can be designed to provide slower currents and roughness elements to pass fish.*

## A. Route High Flows to the Piney Channel System

Train more "uncontrolled" spill water (normally going over the dam - above 61,500 cfs) into Piney West – possibly by using the fish barrier dam - to feed more water in that direction at flows. This may recoup some of the "lost" days at Storm Hole.

## B. Create More Reliable Whitewater Play Features

**Piney Channel System**

1. Modify Storm Hole to run at the proposed lower flows in Piney Channel (1,200 to 3,150 cfs) instead of the 7,000+ cfs.
2. Train more Unit #1 water to Storm Hole by feeding all of it all to the Piney West Channel. (Piney divides fairly evenly into an east and west channel, and the west channel feeds the hole.) Under this scenario 3,150 cfs would feel like closer to 7,000 cfs since all of the flow goes into the hole.
3. Create features downstream of Storm Hole that would run between 1,200 and 3,150 cfs.
4. Create features in the proposed Bypass Channel that is located at the river left side of the fish barrier dam and connecting into the Piney West Channel. This smaller feature would utilize approximately 1,200 cfs of the water from Unit #1 and thus be fairly reliable.

**Main Tailrace**

5. Create a feature in the Main Tailrace that utilizes outflow from the remaining turbines.

## C. Whitewater Play Features in the Main Spill Channel

Create feature(s) in the outlet of the Main Tailrace that capitalizes on the infrequent flows above 61,150 cfs that normally are conveyed over the dam.

*Figure 6*
*Large water, river wide feature (Ottawa River, Ontario). Focusing the flow using boulder constrictions at Holtwood could provide a unique (to the United States) expert surfing wave. The shoreline would be roughened to pass fish.*

## Safety Issues

Boater safety at the Fish Barrier Dam is a necessity. While the dam is “dry” and stop logs are not deployed then the notches in the dam may be made runnable or have value as a play feature in conjunction with various options described below. At a minimum, the dam should be made “survivable” through measures to reduce the danger of the hydraulic jump that typically occurs at low dams.

# III. PROJECT ISSUES AND CONSTRAINTS

## Fisheries Issues

The project is being reviewed by US Fish and Wildlife Service and the Pennsylvania Fish and Boat Commission (Agencies) for improvements to fish passage. Integration of recreational whitewater improvements and fish passage into a single channel has been shown to be advantageous to both fish and in-river recreational users.

Since preventing conflicts with recreational users is an important criterion for the whitewater improvements at Holtwood, recommendations combine recreational and fish flow paths with proven construction and design techniques. As result, a higher percentage of the river flow will attract fish to the mouth of the channel, thereby enhancing the effectiveness of the fish passage.

Integrated recreational whitewater and fish passage improvements have been developed by the authors over the past 15 years. From a fish passage perspective, the passage is known as a "roughened channel" passage. This type of passage simulates natural formations and provides upstream fish passage in a seamless way— the banks of the passage create good conditions for fish passage throughout the design range of flows. At lower flows the fish move along the lower portions of the roughened banks and irregular invert. At higher stages, the upper portions of the slopped banks, with their large boulders and lower velocities, promote fish migration.

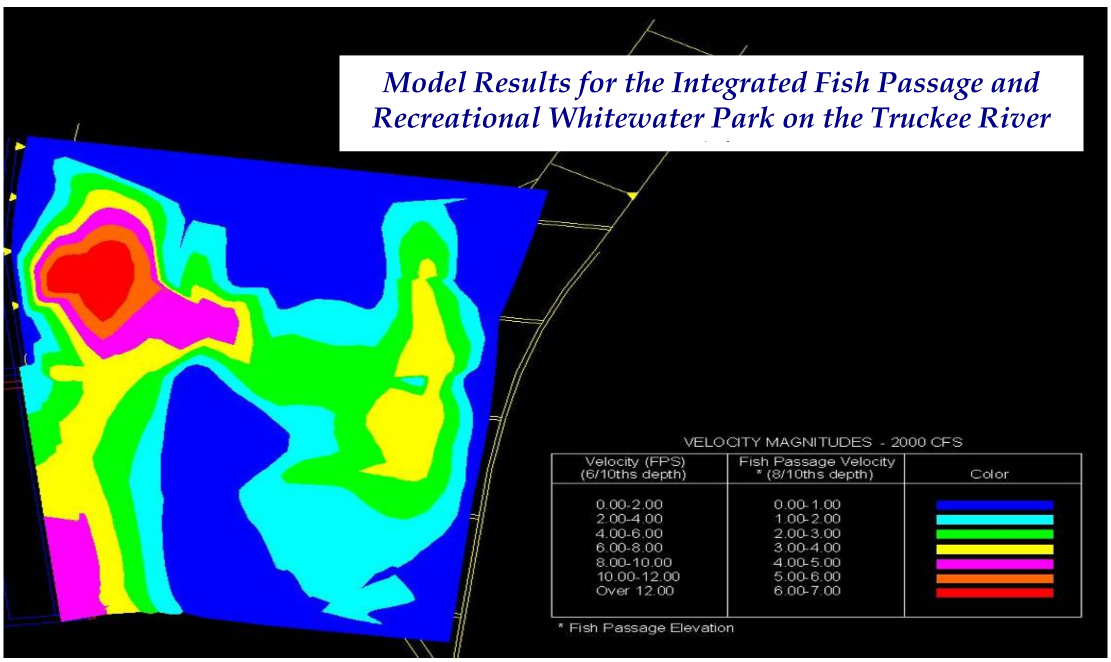



*Figure 7*
*Velocity from a Physical Model Study Used to Verify Passage for Federally Endangered Fish Species for an Integrated Whitewater and Fish Passage Feature*

Large boulders are used on the banks and constructed in a way that results in a high percentage of *interstitial* flow going around and through the boulder field. Design and construction of these areas requires special efforts to insure interstitial flow, reduce safety issues to in-river users, and create a bank that does not erode in flood flows.  Extensive computer and physical modeling has been conducted on various projects has demonstrated these objectives can be obtained for a wide range of species, and over a wide range of flows.

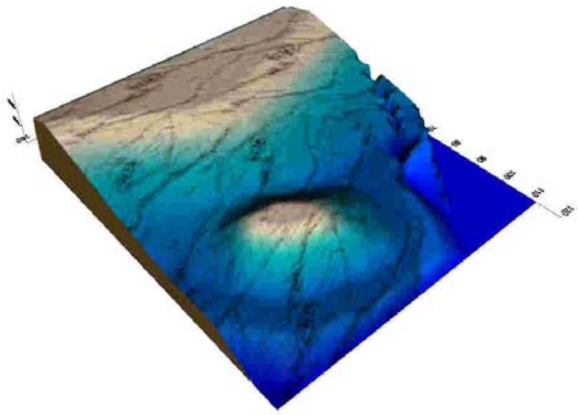
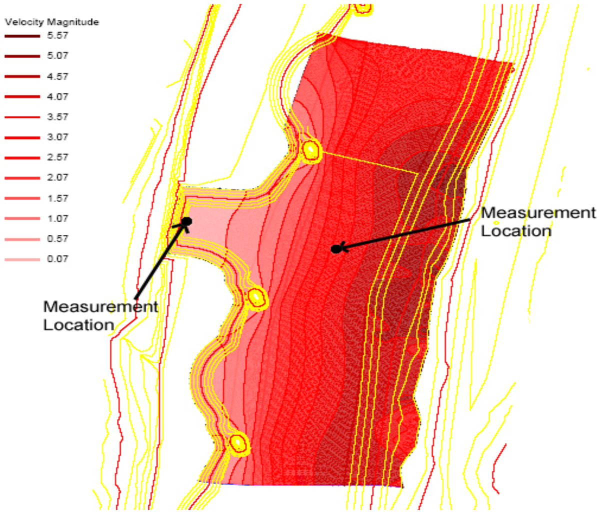



*Figure 8*
*MH Type Jetty Used to Create Resting Areas and Provide Low Bank Velocities for Fish Passage and Habitat.*

In addition, transverse stabilization features (jetties) have been used to create eddies and resting areas for fish.  Similar improvements have been modeled to demonstrate effectiveness in both lowering of bank velocities and reducing bank scour and erosion.  Figure 8 illustrates the results of a jetty developed by the authors – named the MH Jetty.  This hammer- shaped structure integrates a "V" notch and has three paths used for fish passage.




*Physical and two-dimensional computer modeling have been used to verify the effectiveness of specialized transverse bank modifications (jetties) in lowering bank velocities and scour. The lower figure illustrates the effectiveness of these features used on the river bank toward the bottom of the page.*

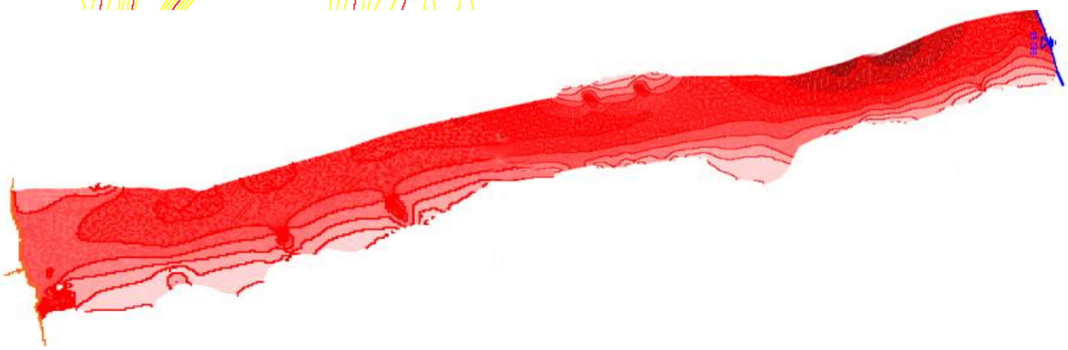


*Figure 9*
*Modeling of Transverse Bank Features on the Fox River, Illinois*

## Fish Passage Impacts on Options

Experienced gained in previous modeling and design of integrated fish and recreational feature design has been utilized in developing the proposed options. Maximum target velocities and drop heights for this project have been attained and substantiated using detailed physical modeling for endangered species at other sites. Given this past experience, future design efforts of the selected features or options should verify that fish passage criteria can be obtained at this site.

## Fish Barrier Dam Hazard Reduction

Presently an eight-foot high fish barrier dam is contemplated to exclude shad from the region below the main spillway. The currently proposed dam is to be gated at each end with manual stop logs so that it can be dewatered during the non-migration period (late June through March). At least four low-head dams have been designed in the U.S. to reduce boating hazards. These have included step dams, as shown below, that create a hydraulic jump that does not create "keeper" hydraulics. Velocity barriers for fish passage have also been contemplated at other sites and may be an effective, non-mechanical, and low maintenance alternative here.

*Figure 10*
*One of Four Dams Specifically Designed to Eliminate "Keeper" Hydraulics. This Dam has Operated for Eleven Years in Downtown Denver without Mishap or Maintenance.*

## Hydraulic Criteria of Plant Expansion

The whitewater improvements may not impact PPL's target water surface elevations with their tailraces. They are as follows:

Main Tailrace, 58,350 cfs: Water surface of 118.5(-) at the upstream end of the tailrace to elevation 108.5, the normal Conowingo Reservoir (no power generation).

Piney Channel, 3,150 cfs: Water surface of 118.5 at the plant discharge, 117.0 water surface just upstream of Storm Hole (station 3324.1) From Storm Hole to the Conowingo Reservoir there exists 8.5 feet of drop (117.0 to 108.5).

## Other Project Criteria

The area west of the training wall is subject to violent floods and is not easily served by electricity, plumbing, etc. Use of automated flashboards, gates and other devices to train or shape flow in the river will not be considered by PPL due to the difficulty of maintenance and providing services to them. Stop logs or other manually deployed flow regulators are the only acceptable methods.

For the type and magnitude of construction modifications, impacts to the 100 year flood plain are not an issue downstream of the Holtwood Dam.

# V. OPTIONS

Numerous options were identified by the design team to improve whitewater recreational opportunities for the proposed project. Seven options for recreational whitewater features are offered for further evaluation. The locations for these are shown on the following figure and are conceptually illustrated on the attached drawings. Following on-site meetings with PPL and Kleinschmidt, one-dimensional HEC-RAS modeling was used to verify the identified whitewater options. Modeling was based on the HEC-RAS model (version 4) of future conditions, provided by Kleinschmidt.

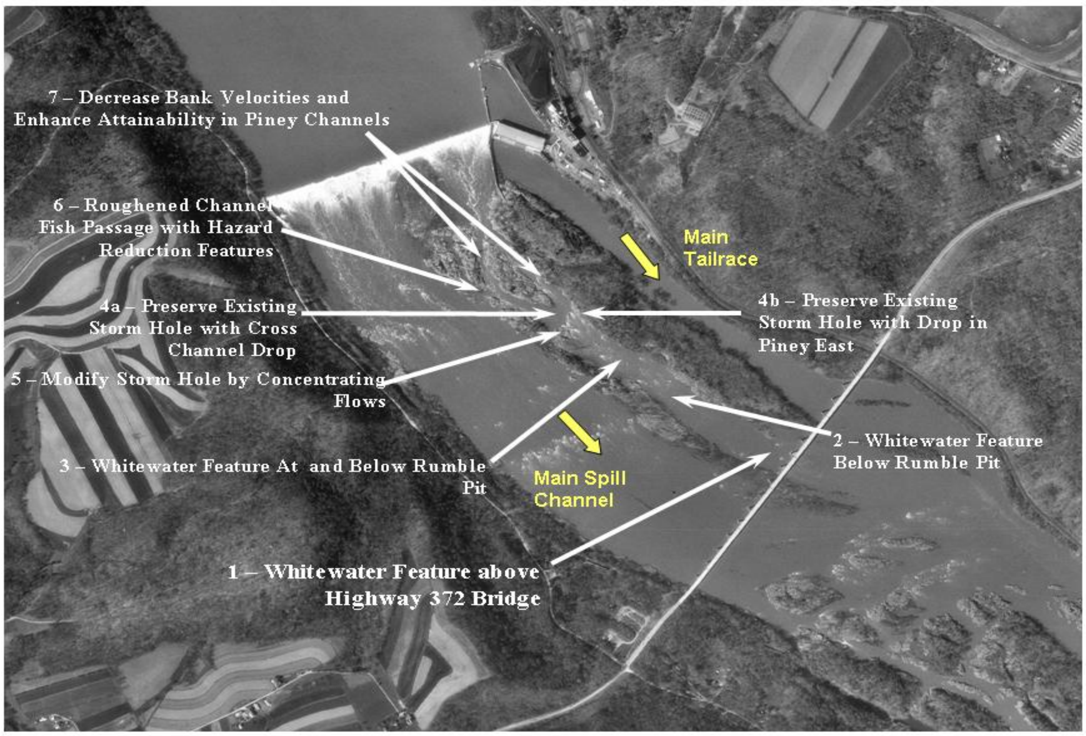



*Figure 11*
*Identified Whitewater Options in the Piney Channels*

## Approaches dropped from further consideration

A "big water" feature (30,000 cfs or greater) within the main tailrace has been discussed and rejected. Under the proposed scenario, the two feet of hydraulic drop required for such a feature will not be available.

Improvements in the Main Spill Channel were reviewed but not considered further due to obvious disadvantages of changes planned for the Piney Channel system. These disadvantages include the infrequency of water availability, the size of improvements needed, and the severe hydraulic conditions found in the channel during flooding. Improvements and excavation of a low-flow path for fish passage and attraction in the Main Spill Channel may be needed. If needed, it is suggested that these improvements be designed and constructed to reduce hazards to in-river recreational users.

## Fish Passage Modeling

Flow rates for the fish passages illustrated in the banks of the features are based on initial and approximate geometries at each whitewater feature. Ultimately, fish passage and bank configurations will be refined based upon final design efforts and modeling. The initial one-dimensional HEC-RAS modeling used to determine the initial width, drop and impacts of whitewater constrictions is adequate for preliminary layout of fish passages; however, refinement of passages in order to meet fisheries and whitewater performance criteria over the full range of passable flows required (up to 100,000 cfs river flow) will require further design efforts and multi-dimensional computer or physical modeling.

## Diverting More Spill Flows into Storm Hole

All of the identified options could be enhanced by routing excess flows – those that exceed 61,000 cfs - into the Piney Channel system. This could be accomplished by:

- Using the fish barrier dam to divert more spill flows into the Piney West channel with a cut upstream of the east dam abutment. This will cause water impounded by the barrier dam to flow east and then in greater quantities to Piney West.
- Creation of another feature structure to divert these higher flows to the Piney Channels.
- Operation and modifications of the proposed automated flash boards (tube dam) to divert a higher percentage of these flows from the Spill Channel to the Piney Channels.

## Presented Options

Based on review and elimination of alternatives, our work has been focused on the Piney system of channels (predominantly Piney South). These options (including plan views and profiles) are represented on the attached Drawings. It should be noted that for all options investigated, we assumed that Unit #1 would be running first on (i.e. providing flow to the Piney channels). The options explored and our findings are as follow:

### Option 1 – Whitewater Feature above Highway 372 Bridge

A wide constriction just above Highway 372 bridge, coupled with downstream channel excavation, provides the opportunity for a 1.2' to 3.5'+ hydraulic drop at low flows. The hydraulic drop for the feature varies significantly based on plant output with the highest levels of drop occurring when the power plant is at lower production rates. This option includes a mid-channel constriction and a provision for roughened fish passage channels in both banks. In terms of very wide, powerful waves with significant drop and good eddy service on both sides of the hydraulic, this is the best option for the site.

#### Fish Passage in Banks

Fish passage for this option is located adjacent of the main hydraulic and will consist of a pair of roughened channels with large confined boulders in both banks. The banks will be designed to create velocities below 5-feet per second, provide approximately 20 percent of the active-passage cross-sectional area of interstitial flow, and have no single drop greater than one-foot.

Locations and lengths are shown schematically. More detailed layout of the roughened channel should be completed prior to computer modeling if this option is selected.

### Option 2 – Whitewater Feature below Rumble Pit

Existing rock outcrops below Rumble Pit can be reconfigured to allow a combination with a mid-channel constriction and roughened fish passages within both of the banks. Under low flow conditions, a drop at this location can generate a 2' hydraulic wave or hole, angled to the main river flow with good eddy service on one side. The combination of flow from the fish passage and main hydraulic should create a seam that is suitable for squirt boating. Fish passage improvements within the banks are as described in Option 1.

### Option 3 – Whitewater Features at and below Rumble Pit

Option 3 uses the natural rock outcrops below Rumble Pit in combination with using natural outcrops at Rumble Pit to create a series of two smaller drops in Piney South. The lower drop will maintain similar geometry as Option 2, but the hydraulic drop is reduced to 1.1' at low flow. The work at Rumble Pit will result in a drop of 1' at low flow. The reconfiguration of Rumble Pit will result in a single constriction for the whitewater hydraulic and roughened fish passage on both banks. Fish passage improvements within the banks are as described in Option 1.

### Option 4a – Preserve Existing Storm Hole with Cross Channel Drop

Option 4a preserves the existing approach velocities to Storm Hole by utilizing a drop from Piney West to Piney East Channel. Excavation at the lower end of Piney East in order to reduce velocities for fish passage results in a deep pool with a head differential of 2.0' at low flow. A constriction at this location could generate a 2.0' deep hole or 2.0' tall wave, angled toward the main river flow. The deep pool in Piney East would serve twofold: as a resting area for upstream traveling fish as well as a deep recovery area for kayakers. This option was not modeled with HEC-RAS as it requires evaluation of lateral flow. If selected as an option, multi-dimensional modeling will provide the necessary results to better determine effects on fish passage up both the Piney East and Piney West Channels. One main benefit of this option is that Storm Hole would remain physically unchanged, but would only become active at higher dam spills. Fish passage improvements within the banks are as described in Option 1.

### Option 4b – Preserve Existing Storm Hole with Drop in Lower Piney East

Reconfiguration of the Piney East Channel - immediately east of Storm Hole, would result in a hydraulic drop of 1.2' at low flows. This drop – in combination with the rock sill, would maintain the approach velocities to Storm Hole by maintaining the upstream water surface in the Piney East Channel. Work would include excavation below the constriction for a kayaker recovery pool and improvement of eddy service. Similarly to Option 4a, Storm Hole would not be physically modified under this scenario. Fish passage improvements within the banks adjacent to the sill as described in Option 1. Excavation into the bedrock for the fish passage areas may be necessary.

### Option 5 – Modify Storm Hole by Concentrating Flows

Under proposed conditions, the number of spills to the Piney Channels will be significantly reduced from existing conditions. In addition, some water will be driven into the main spillway channel in an effort to attract fish in the Spillway Channel to Piney West and ultimately the fish elevator at the dam. Modification of Storm Hole to a constricted width of perhaps 30-40' would allow storm hole to come in during normal power plant production with discharges from Unit #1. As a compliment to increased velocities and hydraulic power at Storm Hole, work would include deep pool excavation and an improvement in eddy service at the hole. Improvements could also include adjustments to improve the form of the wave at Storm Hole and tuning of the feature during the construction phase. This option would also include separation of Piney West from Piney East flows through the installation of a boulder sill to focus flow to Storm Hole and prevent cross-flow conditions at higher flows. In addition to the sill, proposed excavation of Piney East will result in lower velocities for roughened fish passage. Fish passage improvements within the banks are as described in Option 1.

### Option 6 – Roughened Channel Fish Passage with Hazard Reduction Features

Under proposed normal operating conditions, flows from Piney West will spill to the Spillway Channel at the rate of 1,200 cfs +/-. This flow has been planned to pass fish upstream to Piney West and ultimately to the fish elevator. In addition, it could provide attraction flows in the Spillway Channel if the barrier dam is constructed. The channel is proposed to be constructed as a single, gradually sloped roughened fish passage channel with relatively flat banks. Recreational boating improvements within this channel are envisioned to primarily relate to safety- as the primary purpose of this feature is fish passage. It should be noted that the development of a hydraulic feature and roughened fish passage at this location rely on developing a driving head of 2 to 2.5 feet from Piney West to the Spillway Channel. The configuration at this location is not easily analyzed in 1 dimensional (HEC-RAS) modeling due to lateral flow. As a result, multi-dimensional modeling in this area will be required to determine the actual spill conditions, development of required hydraulic grade and ability to meet fish passage criteria at this location. Based on existing mapping, this roughened passage channel and possibly the channel downstream in the Spillway Channel will require excavation of bedrock to develop the hydraulic grade to convey the proposed 1,200 cfs.

### Option 7 – Decrease Bank Velocities and Enhance Attainability in Piney Channels

The provided two-dimensional modeling of the proposed channel conditions in both Piney East and Piney West Channels illustrates potential regions of high (>5 ft/sec) bank velocities. If future modeling using updated conditions and/or mapping verifies this, and if recreational whitewater improvements are desired in these areas, creation of bank outcroppings or jetties is proposed. In addition to providing enhanced fish passage, the features would create recreational whitewater features that would promote attainability (upward passage of boats) and conditions suitable for basic moves.

## VI. DISCUSSION

Conceptual layout and hydraulic modeling of Options 1-7 for whitewater recreation at the site (distributed separately) demonstrate the ability to achieve high quality and variable whitewater at a number of locations. These options would provide high quality large wave and wave/hole features during normal releases into the Piney Channels.

Most of the options can be selected independently and in some cases, combined. In addition, flows are sufficient to be divided to provide both fish passage (in lower velocity channels) and high quality whitewater (at higher velocity constrictions). One dimensional whitewater options modeling demonstrates no appreciable impact to the tail water conditions (compared to the

Kleinschmidt model) at Unit #1 of the low Conowingo Dam at base operating conditions of 25%, 50%, 75% and 100% power plant production, as well as 100% power plant production combined with 7,000 cfs and 15,000 cfs spill to the Piney Channels. This is represented on the attached water surface profiles for the options.

## Diverting More Spill Flows into Storm Hole

It is recommended that this option be investigated in future design efforts. The evaluation should take into account the options selected, and impacts on fish passage. Impacts on fish passage could be beneficial in certain flow ranges due to attraction velocities in both Piney South and the Bypass Channel (shown in Option 6).

## Options 1, 2 & 3 - Play Features Downstream of Storm Hole

These options use the normal discharge from Unit #1 and create recreational features in the region downstream of Storm Hole. Because of the wide channel in this area, the structures would need to be massive in order to concentrate the 1,200 to 3,150 cfs into a useable feature. For comparison at 7,000 cfs, Storm Hole is only marginal for recreation. The shoulders needed to concentrate the flow, however could create surfing spots at higher water.

Pros:

- Could run nearly all the time on the normal discharges from Unit #1
- Could operate in a wide range of flows, utilizing the shoulders as high water features
- Would greatly improve existing features both in form and frequency of use

Cons:

- Construction costs may be significant
- Would alter Rumble Pit and Yesterday Rapids at currently functional flows
- Would require detailed analysis and modeling of bank velocities to verify fish passage

## Option 4a and 4b – Preserve Approach Conditions to Storm Hole

The Piney West channel will be excavated in order to convey most of the flow from Unit #1 with minimal head losses. The Piney East Channel will receive a smaller percentage of the flow. Option 4a entails a cross-channel drop constructed at the downstream end of Holly Island to the large midstream rock abreast of Storm Hole. This keeps the flow segregated until it reaches the play spot.

Pros:

- The new drop could run nearly all the time on the normal discharges from Unit #1 (1,200 to 3,150 cfs)
- Enhances the Piney East Channel to pass fish
- Would maintain the approach velocities to Storm Hole during the current range of operational flows
- Would prevent more flow from being routed around Storm Hole.

Cons:

- Option 4b would require analysis and documentation to demonstrate fish passage and may possibly require excavation of bedrock along the banks.
- Does not create a feature at Storm Hole during normal flows.
- Does not capitalize on existing drop and flow for recreational uses during normal flows.

## Option 5 - Modify Storm Hole

In this option, rock features are constructed to focus the flow through Storm Hole and create a large wave that would operate during normal releases. An upstream rock sill located between the downstream end of Holly Island and the large midstream rock abreast of Storm Hole would rout more flow to Storm Hole and could reduce velocities in the Piney East Channel. The rock formation that shapes the Storm Hole is excavated to enhance the form and size of the wave so that it functions at the normal discharges from Unit #1 (1,200 to 3,150 cfs).

Pros:

- Could run nearly all the time on the normal plant discharges from Unit #1
- Does not “waste” (from a recreational standpoint) the limited hydraulic drop available in the Piney Channels
- Could be designed to operate over a wide range of flows.

Cons:

- Would require changes to the river bottom
- Small uncertainty in the new feature performance, but modeling during design and “tuning” during construction would greatly reduce this uncertainty.

## Option 6 Bypass Channel

Development and inclusion of recreational improvements must support the functionality of fish passage. Inclusion of safety and some recreational features are suggested.

## Option 7 Bypass Channel

Like Option 6, development and inclusion of recreational improvements must support the functionality of fish passage in the Piney East and Piney West Channels. Inclusion of safety and some recreational features are suggested. Furthermore, if excavation to create a continuous low flow channel in the Main Spill Channel is needed for fish passage, inclusion of safety related features are suggested.

## END OF MEMORANDUM