LONG LAKE DAM
TDG ABATEMENT FEASIBILITY PHASE III
PHYSICAL MODEL STUDY
2011 INTERIM REPORT

Prepared for: Avista Utilities

February 2012

Prepared by: Northwest Hydraulic Consultants

nhc

Long Lake Dam TDG Abatement Feasibility Phase III

Physical Model Study

2011 Interim Report

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TABLE OF CONTENTS

1 Introduction 1

1.1 System Description 1

1.1.1 Long Lake Hydroelectric Development 1

1.1.2 TDG Abatement Implementation 2

1.2 Study Objectives 3

1.3 Acknowledgements 4

2 TDG abatement Alternatives 5

2.1 Alternative 1 – Spill Bay 7-8 Deflectors 5

2.2 Alternative 6 – Stepped Spillway Structure 7

2.3 Alternative 7 – Noxon Spillway Concept 7

3 Physical Model Description 10

3.1 Similitude and Scale 10

3.2 Model Description 11

3.2.1 Model Construction 11

3.2.2 Model Measurements and Instrumentation 12

4 Model Calibration and Baseline Testing 16

4.1 Calibration Testing 16

4.2 Baseline Test Plan 17

4.3 Baseline Test Results 18

4.3.1 Baseline Test 1: 32,000 cfs 18

4.3.2 Baseline Test 2: 15,300 cfs 19

4.3.3 Baseline Test 3: 50,000 cfs 19

5 Alternative 1 – Spillway Deflector 21

5.1 Test Plan 21

5.1.1 Developmental Test Plan 21

5.1.2 Final Documentation Test Plan 22

5.2 Developmental Testing Results 22

5.2.1 Configuration 1 – Deflector Elevation 1358 ft 22

5.2.2 Configuration 2 – Deflector Elevation 1363 ft 23

5.2.3 Configuration 3 – Deflector Elevation 1368 ft 24

5.2.4 Configuration 4 – Deflector Elevations 1368 ft and 1373 ft 24

5.2.5 General Flow Classification Observation Unique to Long Lake 26

5.2.6 Plunge Pool Sensitivity 27

5.3 Final Documentation 28

5.3.1 Alternative 1 Final Test 1: 32,300 cfs 29

5.3.2 Alternative 1 Final Test 2: 15,300 cfs 30

5.3.3 Alternative 1 Final Test 3: 50,000 cfs 30

6 Alternative 6 – Stepped Weir Structure 32

7 Alternative 7 – Noxon Spillway Concept 33
8 Summary 34
9 References 35

Appendix A: Consultation

List of Tables

Table 3-1 Model Scale Relationships
Table 3-2 Model Construction Accuracy

Table 4-1 Calibration Test Operating Conditions
Table 4-2 Baseline Test Plan
Table 4-3 Calibration Test Data
Table 4-4 Baseline Test 1 Data
Table 4-5 Baseline Test 2 Data
Table 4-6 Baseline Test 3 Data

Table 5-1 Alternative 1 – Spillway Deflector – Developmental Test Plan
Table 5-2 Alternative 1 – Spillway Deflector – Final Documentation Test Plan
Table 5-3 Alternative 1 Spillway Deflector Configuration 4 Flow Performance
Table 5-4 Alternative 1 Final Test 1 Data
Table 5-5 Alternative 1 Final Test 2 Data
Table 5-6 Alternative 1 Final Test 3 Data

List of Figures

Figure 1-1 Aerial View of Long Lake Hydroelectric Dam
Figure 1-2 Graph of Tailwater Surface Elevation below Long Lake Dam

Figure 2-1 Noxon Rapids Hydroelectric Dam

Figure 3-1 Model Layout – General Arrangement
Figure 3-2 Model Layout – Spillway Gates and Piers
Figure 3-3 Model Layout – Spillway Sections
Figure 3-4 Model Layout – Pier Sections
Figure 3-5 Model Layout – Powerhouse Intake and Draft Tube – Sections
Figure 3-6 ERDC Flow Classifications

Figure 5-1 Model Layout – Alternative 1 – Spill Bay 7 & 8 Deflectors

Figure 6-1 Model Layout – Alternative 6 – Stepped Spillway – Plan
Figure 6-2 Model Layout – Alternative 6 – Stepped Spillway – Typical Section and Elevation

List of Reference Figures

Reference Figure 100 Alternative 1 – Spill Bay 7- 8 Deflectors – Overall Plan
Reference Figure 101 Alternative 1 – Spill Bay 7- 8 Deflectors – Sections 1
Reference Figure 102 Alternative 1 – Spill Bay 7- 8 Deflectors – Sections 2
Reference Figure 103 Alternative 1 – Spill Bay 7-8 Deflectors – Deflector Area Plan
Reference Figure 104 Alternative 1 – Spill Bay 7-8 Deflectors – Deflector Area Sections
Reference Figure 105 Alternative 1 – Construction Sequence Plan
Reference Figure 600 Alternative 6 – Stepped Spillway Plan
Reference Figure 601 Alternative 6 – Stepped Spillway Plan – Sections and Details
Reference Figure 602 Alternative 6 – Stepped Spillway Plan – Sections 1
Reference Figure 603 Alternative 6 – Stepped Spillway Plan – Sections 2

Reference Figure 604 Alternative 6 – Stepped Spillway Plan – Sections 3

List of Photo Plates

Photo Plate 3-1 Model Overview
Photo Plate 3-2 Model Details
Photo Plate 3-3 Model Controls and Instrumentation
Photo Plate 4-1 Calibration Testing – Total River Discharge: 26,500 cfs
Photo Plate 4-2 Baseline Test 1 – Total River Discharge: 32,300 cfs
Photo Plate 4-3 Baseline Test 2 – Total River Discharge: 15,300 cfs
Photo Plate 4-4 Baseline Test 3 – Total River Discharge: 50,000 cfs
Photo Plate 5-1 Configuration 1 – Deflector Elevation 1358 ft
Photo Plate 5-2 Configuration 2 – Deflector Elevation 1363 ft
Photo Plate 5-3 Configuration 3 – Deflector Elevation 1368 ft
Photo Plate 5-4 Configuration 4 – Deflector Elevations 1368 ft and 1373 ft
Photo Plate 5-5 Plunge Pool Fixed Bed Sensitivity Tests
Photo Plate 5-6 Plunge Pool Mobile Bed Stability Tests
Photo Plate 5-7 Plunge Pool Mobile Bed Test – 12.5 ft Diameter Material
Photo Plate 5-8 Plunge Pool Mobile Bed Test – 10.0 ft Diameter Material
Photo Plate 5-9 Plunge Pool Mobile Bed Test – 7.5 ft Diameter Material
Photo Plate 5-10 Alternative 1 – Final Configuration
Photo Plate 5-11 Alternative 1 – Final Test 1 – Total River Discharge: 32,300 cfs
Photo Plate 5-12 Alternative 1 – Final Test 2 – Total River Discharge: 15,300 cfs
Photo Plate 5-13 Alternative 1 – Final Test 3 – Total River Discharge: 50,000 cfs

1 Introduction

Northwest Hydraulic Consultants (NHC) was retained by Avista Utilities (Avista) to construct and test a hydraulic physical model of Long Lake Dam.

1.1 System Description

1.1.1 Long Lake Hydroelectric Development

The Long Lake Hydroelectric Development (Long Lake) is located at river mile 34, approximately 5 miles upstream of Little Falls Hydrolectric Project, and is the most downstream project of Avista's FERC licensed Spokane River Project. Figure 1-1 shows an aerial photograph of the Long Lake facility.

Figure 1-1 Aerial view of Long Lake Dam

The facility was designed and constructed between 1910 and 1915 and includes a concrete gravity dam with a gated spillway section, a horizontal curving non-overflow gravity arch dam, referred to as the ‘cut-off’ dam, and a non-overflow powerhouse intake section. The ogee shaped spillway crest is 353 ft long and set at El. 1508 ft. There are eight spillway bays, numbered sequentially from Bay 1 at the east (right) end of the spillway to Bay 8 at the west (left) end of the spillway (adjacent to the powerhouse intakes). Each spillway bay is controlled by a 29 ft high by 25 ft wide vertical lift gate. Spill Bays 3 through 6 discharge into a deep plunge pool, while Spill Bays 1, 2, 7 and 8 discharge onto rock outcrops adjacent to the plunge pool area. The hydraulic capacity of each spillway bay is approximately 14,000 cfs at the normal pool elevation of 1536.0 ft. The tailwater level below the dam varies with flow, ranging between El. 1361.0 ft and El. 1378.0 ft. Approximately 300 ft downstream from the spillway plunge pool, flow from the spillway passes through two sharp bends before meeting with powerhouse flows in the downstream river channel.

The cut-off dam is located in a saddle along the left bank of the reservoir, approximately 600 ft upstream of the intake dam. The crest of the cut-off dam is at El. 1537.0 ft, and the total crest length is approximately 247 ft with a constant radius of 170 ft.

The non-overflow powerhouse intake section has a length of 148 ft as measured along the face of the headgate section. There is an additional 100 ft of length that connects the intake dam to the spillway and to the west abutment. The intake to the powerhouse is comprised of four steel penstocks that penetrate through the intake dam at El. 1499.0 ft. Vertical slide gates, 18 ft square, are located on the upstream face of the dam at the inlet to the penstocks. The penstocks extend along the downstream face of the dam and an exposed rock surface to the powerhouse, which contains four 17.9 MW double-runner horizontal Francis turbines and has a hydraulic capacity of 6,800 cfs.

1.1.2 TDG Abatement Implementation

During spill operations, elevated levels of TDG can be generated by the exposure of heavily aerated flow to high hydrostatic pressure within deep stilling basins or plunge pools. The hydrostatic pressure causes the absorption of atmospheric gases to concentrations above equilibrium at the local atmospheric pressure. Water will absorb (or desorb) gases until the pressure of the dissolved gas equilibrates with atmospheric pressure, at which point it is considered “saturated.” In reality, water is rarely at equilibrium – rather it is either over-saturated (supersaturated) or under-saturated. When spilling, the flow can become supersaturated, often exceeding State and Federal water quality standards.

Current state standards mandate that the TDG downstream of projects must not exceed 110% for flows less than the 7Q10 discharge at the project (where “7Q10” is the highest average seven consecutive day discharge with an average recurrence probability of 10 percent in any given year). The 7Q10 discharge for the Long Lake project corresponds to a total river discharge of 32,000 cfs, according to the Washington State Department of Ecology estimate. With the powerhouse operating at its maximum capacity of 6,800 cfs, the resulting 7Q10 for the spillway is 25,200 cfs. The tailwater level at the spillway for the 7Q10 total discharge of 32,000 cfs is approximately El. 1373.0 ft as shown on Figure 1-2.

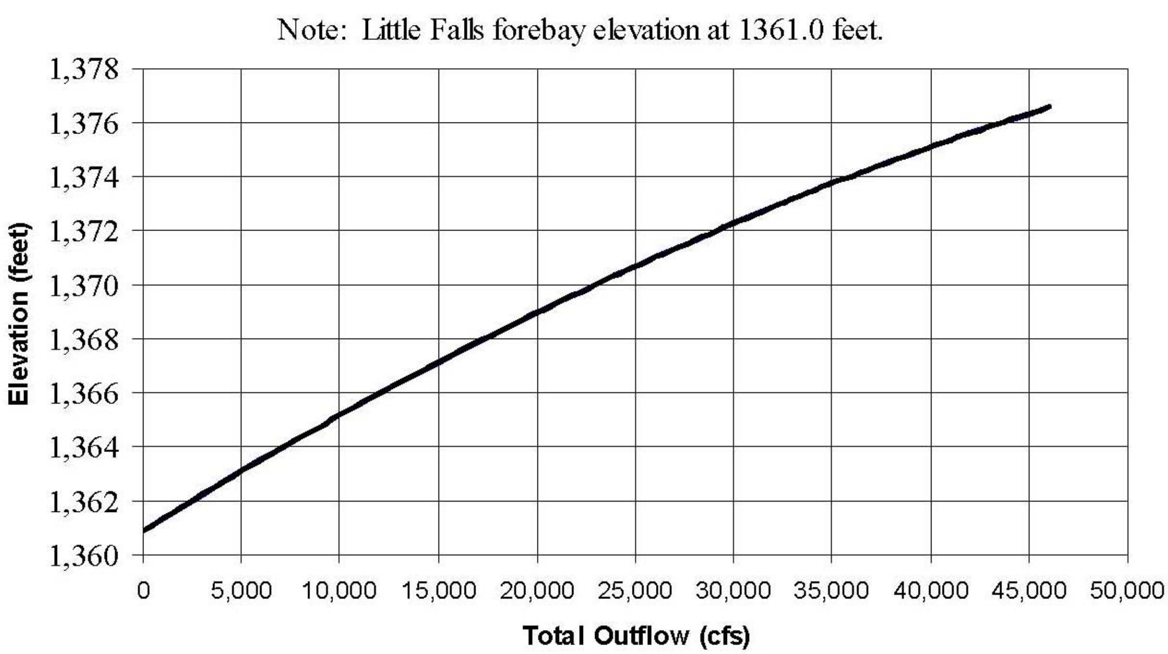


Figure 1-2 Graph of Tailwater Surface Elevation below Long Lake Dam

1.2 Study Objectives

The objectives of the Phase III TDG study include:

- Develop a physical model to test Alternatives 1 and 6
- Refine the TDG abatement designs to provide optimum performance of the alternatives

- Evaluate a new alternative, Alternative 7, Noxon Design
- Demonstrate the model to Avista and stakeholders
- Assist in the selection of a preferred alternative

1.3 Acknowledgements

The following individuals have contributed to the Long Lake Hydroelectric Development TDG Abatement Phase III Feasibility Study. Hank Nelson is Avista's project manager and Ryan Bean is Avista's project engineer. Speed Fitzhugh is the project manager for the implementation of Avista's Spokane River Project license articles and directed the project in relation to the overall license. Guy Paul, Steve Fry, and John Hamill provided engineering input and project information on behalf of Avista. Dr. John Gulliver served as an independent technical reviewer for Avista and provided input on the TDG abatement alternatives and physical modeling.

Lisa Larson was Northwest Hydraulic Consultants' (NHC) project manager and principal in charge. Jim Lencioni provided internal technical review for NHC; Andre Ball provided NHC's hydraulic engineering support; Noah Carlson was the lead model construction technician; Rob Lohr was the lead testing technician. Dr. Steve Wilhelms served as NHC's TDG expert and provided review throughout the project.

2 TDG abatement Alternatives

In 2006, as part of the Federal Energy Regulation Commission (FERC) relicensing studies, Avista conducted an initial TDG Feasibility Study for the Long Lake HED (EES Consulting, 2006) which resulted in a recommendation of five TDG abatement alternatives for the project. As part of the license implementation for this project, Avista completed the Phase II TDG Feasibility Study in 2010 (NHC, 2010). The Phase II study included more detailed evaluation and preliminary engineering for the five TDG abatement alternatives that were recommended for further evaluation in the 2006 study plus one additional alternative identified during the Phase II study. These alternatives are listed below:

- Alternative 1 – Spill Bay 7-8 Deflectors
- Alternative 2 – Spill Bay 7-8 Super-elevated Spillway Extension
- Alternative 3 – Spill Bay 1-2 Toe Modifications and Downstream Deflector
- Alternative 4 – Cut-off Dam Chute Spillway with Deflector
- Alternative 5 – New Second Powerhouse
- Alternative 6 - Stepped Spillway Structure

The Phase II study was reviewed and commented on by the Spokane Tribe and the Washington State Department of Ecology (DOE). At the conclusion of the Phase II study, Avista selected two alternatives to carry forward to the physical modeling phase (Phase III). Based on the conceptual designs of the alternatives and the estimated TDG reduction potential, the two alternatives selected for further investigation included Alternative 1 (Spillway Bay 7-8 Deflectors) and Alternative 6 (Stepped Spillway Structure). As Phase III progressed, the application of the Noxon Rapids Hydroelectric Dam (Noxon) spillway design to Long Lake Dam was discussed; and, a cursory review was conducted to determine how the Noxon design could be applied to Long Lake. As discussed in Section 2.3, additional conceptual design work will be conducted on the Noxon concept.

2.1 Alternative 1 – Spill Bay 7-8 Deflectors

Alternative 1 included the addition of a continuous deflector on the downstream face of the spillway ogee below Spill Bays 7-8. Reference Figures 100 through 105 provide preliminary plan and section views of Alternative 1. The initial deflector lip elevation was set at El. 1358 ft, and a

5 ft radius curve was used to form the transition from the spillway face to the deflector. The deflector is 12.5 ft long from the point of intersection (PI) of the horizontal deflector elevation and the face of the spillway chute. The existing rock outcropping downstream of Bays 7 and 8 would be excavated down to El. 1353 ft (5 ft below the deflector lip elevation), and the area between the deflector and the excavated rock shelf would be filled and capped with concrete (described further in Section 4.1.4).

The 7Q10 discharge for the Long Lake spillway is estimated at 25,200 cfs, and the 7Q10 tailwater level is estimated at El. 1373. With this flow passed through only two spillway bays, the resulting unit discharge would be between 300 and 500 cfs/ft, depending on how the jet expands downstream of the piers and onto the deflector. The deflector submergence required to produce acceptable TDG abatement for unit discharges in this range exceeds the typical maximum value of 15 ft that is often used in deflector designs based on research by the U.S. Army Corps of Engineers; therefore, the feasibility of developing a fully effective deflector utilizing only Bays 7 and 8 for the 7Q10 design flow was considered questionable in the Phase II study. The option to improve the deflector performance would be to expand the deflector to additional bays. A preliminary submergence value of 15 ft was used to set the elevation at El. 1358 ft for the initial deflector design.

The rock outcrop modifications downstream of Bays 7 and 8 would provide a relatively shallow tailrace downstream of the deflector. With a shallow basin and tailrace, aerated flow cannot plunge to depth, thereby limiting TDG absorption (Schneider and Wilhelms 1996). However, by filling in the plunge pool area downstream of Bays 7 and 8, the hydraulic conditions in the tailrace channel will be impacted to some degree and could affect the spillway's ability to safely pass the PMF discharge. With the existing plunge pool configuration, a significant amount of energy is dissipated in the plunge pool area between the toe of the spillway and the rock outcrop. By comparison, with the proposed design, the spillway flow will be re-directed across the new filled area and the excavated rock shelf, resulting in much less energy dissipation.

A physical model was recommended in the Phase II Study to evaluate a deflector's potential impact in the spillway tailrace area and develop an acceptable design. Additional design information related to this concept as well as cost estimates are provided in the Phase II report (NHC, 2010).

2.2 ALTERNATIVE 6 – STEPPED SPILLWAY STRUCTURE

Alternative 6 consists of a concrete stepped chute structure with the upstream end located just downstream of the existing spillway plunge pool and the downstream end located directly upstream of the powerhouse tailrace. Reference Figures 600 through 604 show preliminary plan and section views of this concept. The stepped spillway chute would reduce the high TDG concentrations resulting from the deep plunge downstream of the spillway by re-aerating the flow as it passes over the steps before being released back into the river upstream of the powerhouse. Although Alternative 6 does not require modifications to the existing dam and spillway and is considered to be a stand-alone alternative, it would form a permanent pool with a minimum pool elevation of 1,400 ft that would back up to the main dam structure. The depth of the pool would be nearly 90 ft at the lowest point in the plunge pool.

The conceptual design of the stepped spillway structure included a 200 ft wide spillway crest that was designed to limit the unit discharge to approximately 125 cfs/ft at the TDG design discharge of 25,200 cfs. A 1V:2H chute slope with a 5-ft high step height was selected for the preliminary design based on the results of a previous stepped spillway physical model study conducted for TDG abatement (NHC, 1998). A minimum of five steps above the TDG design discharge tailwater elevation is considered necessary to optimize the TDG reduction based on the re-aeration characteristics observed in the stepped chute physical model as well as desired flow characteristics observed with spillway flow deflectors. With a minimum of five, 5-ft high steps above the tailwater elevation, the structure crest elevation is 1400 ft.

Additional design information related to this concept as well as cost estimates are provided in the Phase II report (NHC, 2010).

2.3 ALTERNATIVE 7 – NOXON SPILLWAY CONCEPT

As mentioned previously, a new alternative was considered during the Phase III model study evaluations. Alternative 7, Noxon Spillway Concept, would include the application of the spillway design at Noxon Rapids Hydroelectric Development (Noxon) to the spillway at Long Lake Dam. Noxon is located on the Clark Fork River in Montana and is owned and operated by Avista. The spillway includes a stilling basin with baffles for energy dissipation and nappe deflectors on the interior five spillway bays. Figure 2-1 shows the top of the baffles, which are above the water surface elevation in this photo, and the nappe deflector for one of the bays. The outer bays of the spillway include three flip bucket type spillways for passing high discharges.

The application of this design to Long Lake would focus on the interior bay nappe deflectors, stilling basin, and baffles. Each of the interior bays includes a dentated sill structure consisting of baffles designed to dissipate energy and minimize erosion downstream. The nappe deflectors were added to reduce the negative pressures on the baffles that resulted in severe cavitation after the first year of operation. Based on TDG data collected by Avista, the TDG levels at the compliance point downstream of the project are typically within the 110% TDG limit.

Figure 2-1 Noxon Rapids Hydroelectric Dam

For the initial review of the Noxon spillway concept, the physical characteristics of the Noxon and Long Lake facilities were compared. The hydraulic head at Noxon is on the order of 130 ft (assuming tailwater elevation of about 2200 ft), which is about 20 percent less compared to Long Lake (165 ft). Although there is a difference in head, both projects are considered relatively high head facilities. The Noxon stilling basin is an 80 ft long concrete apron with baffles, and Long Lake utilizes a plunge pool instead of a stilling basin for energy dissipation. One significant difference is the downstream site characteristics of the tailrace channel. At Long Lake, the sharp bend (approximately 135 degree) immediately downstream of the plunge pool provides additional site challenges; whereas, the river at Noxon does not have any major bends immediately downstream of the project. There are also some differences with the locations of the permanent TDG measurement sites that need to be considered when evaluating the TDG field data.

From a theoretical perspective, the Noxon design concept could be applied to Long Lake; and, it might be capable of preventing high TDG levels if the nappes generated by the spillway face deflectors and the stilling basin baffles disintegrate to such a high degree that they do not retain sufficient energy and momentum to penetrate deep into the receiving tailrace or stilling basin. Conversely, if the nappes retain sufficient integrity prior to impacting in the tailrace, they could potentially create deep scour and plunge downstream from the stilling basin, particularly if they should impact outside of the basin. Based solely on a brief comparison of the site characteristics at the two projects, a stilling basin length in excess of 100 ft might be required at Long Lake to contain the deflected nappes from spillway deflectors similar to those at Noxon. The prediction of the disintegration of the nappes is difficult to estimate and will provide some uncertainty in the application of this concept to Long Lake for TDG abatement.

The Avista TDG team has decided to move this option forward to the conceptual design stage, and this work will proceed concurrently with the physical modeling of the stepped spillway alternative. The preliminary design of Alternative 7 will provide a basis for a construction cost estimate comparable to that used for the other alternatives considered in the initial alternatives report. Depending on the outcome of the conceptual design of the Noxon concept, the alternative may be tested in the existing comprehensive physical model after the stepped spillway model testing is completed. Due to the negative pressure and cavitation issues associated with the design of the original Noxon baffles, a larger scale sectional model would also likely be necessary to collect pressures on the baffles and refine the design. This model would include two of the modified bays and the new stilling basin and would be at a sufficient scale to monitor pressures in the stilling basin, specifically at multiple locations on the baffles.
Depending on the initial test results, modifications to the nappe deflector or other design features would be designed and tested to prevent cavitation damage.

3 Physical Model Description

The Long Lake model is a 'comprehensive' model that integrates all key features of the facility. The extent of the model (200 ft upstream of spillway and 1800 ft downstream of spillway) ensures that the boundaries do not adversely impact the correct simulation of flows under consideration. The model scale is sufficiently large to evaluate the overall flow patterns in the channel and downstream of the spillway.

3.1 Similitude and Scale

Scale hydraulic modeling requires that the force relationships in the model and prototype are dynamically similar. To achieve this similarity, the ratios of the inertial to the gravity, pressure, viscous, and surface tension forces must be the same between model and prototype. Only a 1:1 scale model can achieve these criteria simultaneously. Modeling at reduced scale in any dimension involves identifying the primary force relationship to accurately simulate prototype conditions, then selecting a model scale to minimize any scale effects. For free-surface flow conditions of the type being examined in the current study, the inertial and gravitational forces are the dominant forces that define the hydrodynamic flow conditions. As a result, the Froude number, as defined below, is the key force ratio that must be equal in the model and prototype.

$$F_r = \frac{F_M}{F_P} = 1$$

$$F_M = Froude\ number\ in\ the\ model = \frac{U_M}{\sqrt{g\,L_M}} = \frac{Inertial\ Force}{Gravitational\ Force}$$

where,

$$F_P = Froude\ number\ in\ the\ prototype = \frac{U_P}{\sqrt{g\,L_P}}$$

and,

U = characteristic flow velocity	P = prototype values
M = model values	M = model values
g = gravitational acceleration	L = characteristic length

Based on the study objectives, the dimensions of the structures and the project discharges, a geometric scale of 1:30 was used for the Long Lake model. At this scale, adherence to Froude criterion for similitude resulted in the scale relationships shown in Table 3-1.

Table 3-1 Model Scale Relationships

Parameter	Relationship	Value
Length	L	1:30
Velocity	$L^{1/2}$	1:5.47
Discharge	$L^{5/2}$	1:4930

3.2 Model Description

Figures 3-1 through 3-5 and Photo Plates 3-1 and 3-2 illustrate the configuration of the physical model and model structures. The model structure drawings were developed from drawings provided by Avista, and the bathymetry for the model was developed from the survey information also provided by the Avista.

3.2.1 Model Construction

The model bathymetry was placed within a model basin constructed using dimensional framing lumber and waterproofed using spray-on urethane foam. The bathymetry downstream of the spillway was constructed as a fixed bed surface in accordance with prototype survey data by placing a layer of concrete over compacted sand placed between vertical templates spaced every 60 to 120 ft (prototype). Bathymetry upstream of the dam was simulated using plywood panels.

The model bathymetry reproduced the full depth of the forebay and tailrace channels, extending up to El. 1390 ft and 1450 ft in the tailrace and 1540 ft in the forebay. The channel downstream of the spillway was roughened to simulate the surface texture of the prototype bathymetry. These roughness values were achieved by using a combination of chiseling, raking and brushing the concrete surfaces. The steep areas of the model, including the rock outcrop along the left bank of the spillway and the steep rock hillside on the right bank of the spillway, were constructed by using an underlying mesh with a concrete overlay. After the concrete was cured, it was roughened to simulate the prototype surfaces as described above.

The penstocks intakes were circular entrances approximating the prototype diameter of the penstocks. The turbine units were not modeled; however, butterfly valves and orifice plates were used to independently control and measure the discharge through the four units. Acrylic was used to construct draft tubes that matched the exit dimensions of the prototype draft tubes. The modeled draft tubes were extended upstream to facilitate flow expansion from the circular penstocks but the cross sectional area of the draft tubes remained consistent with the exit dimensions.

The dam and spillway were constructed using plywood templates and covered with a rigid laminate. The spillway piers were constructed out of acrylic and attached to the spillway and model framing. The spillway gates were constructed out of acrylic and were operated manually. The following construction tolerances were used during model construction.

Table 3-2 Model Construction Accuracy

Component	Prototype Tolerance	Model Scale Tolerance
Structural dimensions and elevations	± 2 inches	± 1/16 in
Bathymetric elevations	± 7.5 inches	± 1/4 in

The model construction tolerances where reviewed and checked by the project engineer on a regular basis through model construction. This included surveying all elevations during construction and measuring model components. The spillway crest was used as the benchmark for all model elevations, and the spillway crest was tied into a benchmark on the lab floor. In addition, a thorough QA/QC review was completed at the end of model construction.

3.2.2 Model Measurements and Instrumentation

Photo Plate 3-3 provides photos of the model controls and instrumentation. The following controls and instrumentation are being used for the study:

Flow Rates - The model flow is circulated with three centrifugal laboratory pumps supplying flow through 8-inch supply pipes. Discharges were measured using a combination of a Dynasonic flow meter and orifice plates. The precision of flow measurement is approximately ± 2% of the specified discharge. A standard equation was used to estimate the discharge based on the orifice plate head differentials. The orifice plates were installed in accordance with ASME test standards.

Water Levels - Measurements of the water surface elevations (WSEL's) at the spillway headwater and along the tailrace were collected by pressure tap readings. During detailed testing, a point gage was used to read the water surface elevations. The precision of the water level measurements was reported to the nearest 0.1 ft (prototype). Figures 3-1 shows the locations of the pressure taps in the model.

Point Velocities – Point velocity measurements along transects in the tailrace were taken with a Nixon propeller meter. The accuracy of the velocity measurements taken with the Nixon meter in the model are +/- 5% of prototype velocities.

TDG Flow Classification - In this study, the performance of the TDG abatement alternatives in the physical model was evaluated by qualitative analyses. The measurement of TDG in physical models is not practical due to the reduced magnitude of flow depths and scale effects of air bubbles. However, a significant amount of research has been conducted on the production of TDG levels in spillway/stilling basin flows. This work has shown that plunging aerated flow can cause significant TDG absorption in the immediate stilling basin. Since it is virtually impossible to prevent air entrainment, alternatives have been adopted to minimize the depth to which entrained air bubbles are transported.

In general, the most apropos retrofit TDG abatement structure has been a spillway deflector (NHC, 1996). Spillway deflectors are effective in eliminating, or at least minimizing, plunging flows by keeping the spillway jet near the top of the water column as it enters a receiving pool. Flow performance classifications, developed by U.S. Army Corps of Engineers Engineering Research and Development Center (USACE) for spillways, are shown in Figure 3-6 and have been used to estimate the effectiveness of spillway deflectors on several projects in the Northwest to develop and evaluate total dissolved gas abatement alternatives. Measurement of TDG levels at numerous projects where spillway deflectors have been constructed has shown that the hydraulic regime produced with the deflectors has been quite effective in reducing TDG levels with spillway operation. Research conducted on the production of TDG by the USACE, showed that hydraulic performance of a deflector was dictated by unit discharge and tailwater submergence (USACE).

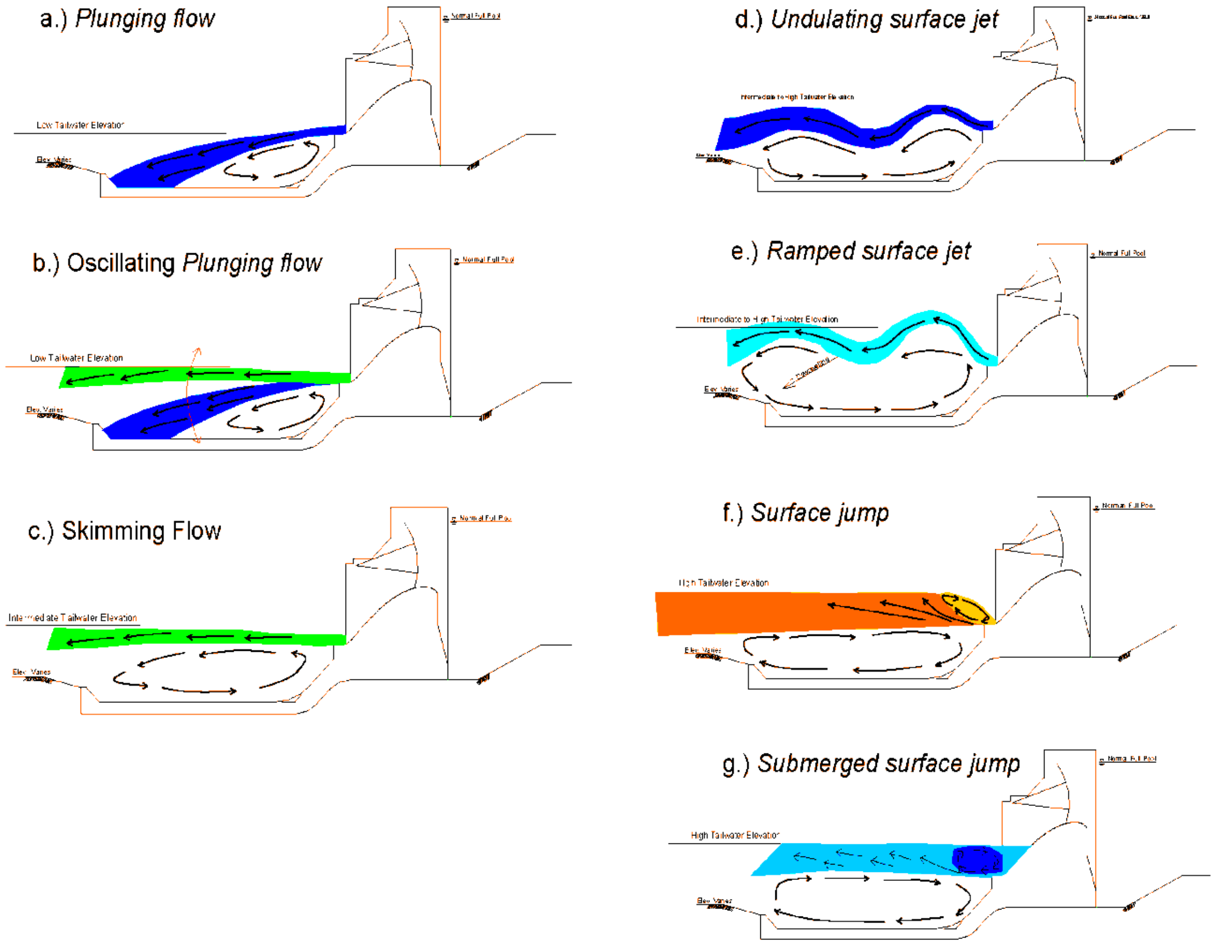


Figure 3-6 ERDC Flow Classifications

The “skimming” flow regime is the optimal flow regime for TDG reduction, and deflectors and other similar TDG abatement structures are typically designed to provide skimming flow at the 7Q10 flow. Since the performance of the deflectors and similar structures is sensitive to tailwater elevation and unit discharge, it is difficult, if not impossible, to design a stationary deflector that will produce a skimming flow regime over the full range of discharges up to the 7Q10 discharge. At lower discharges, the undulating surface jet regime has also been shown to produce favorable TDG reduction conditions. As a result, undulating surface jet conditions were also considered to be acceptable.

While these flow regime classifications have been shown to reduce TDG levels at other projects, it is not possible to accurately predict the magnitude of the TDG reduction that can be expected at Long Lake Dam. Based on past experimental and field experience with flow deflectors installed at more traditional spillway facilities, the prevention of plunging flow also leads to reduced TDG levels. Since this is the best prototype information available, the flow classification system was utilized for the evaluation of deflector alternatives for Long Lake.

4 Model Calibration and Baseline Testing

4.1 CALIBRATION TESTING

The purpose of the calibration testing was to compare the physical model hydraulic characteristics to prototype conditions for a given flow. NHC had the opportunity to visit the Long Lake site during spill conditions on June 14th, 2011. Photo and video data were collected during this field visit. Operating conditions collected during the field visit were also provided by the project staff, and these conditions are summarized below in Table 4-1.

Table 4-1
Calibration Test Operating Conditions

Test	Total River Discharge (cfs)	Powerhouse Discharge (cfs)	Spillway Discharge (cfs)	Tailwater El. (ft)	Forebay El. (ft)	Spillway Gate Openings (ft)							
						1	2	3	4	5	6	7	8
Calibration	25,600	6,700	18,900	1,370.9	1,534.7	X	X	8.0	8.0	4.0	8.0	X	X

Note: 'X' indicates gate is closed, 'O' indicates gate is full open

The model was operated under the same field conditions (modeled gate openings were adjusted as necessary to provide the same bay discharge that existed in the prototype) that were observed on June 14th, 2011 for comparison with the photo and video data collected in the field. This comparison was used to verify that the model was correctly simulating the modeled reach of the tailrace. Observations in the model included a qualitative evaluation of the flow conditions in the plunge pool and tailrace and a comparison of model observations with field conditions. In general, the plunge pool characteristics including the jet impact, turning flow, and extent of air bubbles downstream of the spillway in the model were very similar to those existing in the prototype. Photo Plate 4-1 provides a comparison between photos taken at the Long Lake site and of the physical model operating under similar conditions.

During the calibration testing, two intermediate hydraulic control locations were observed in the model including a control located several hundred feet downstream of the powerhouse and one located about midway between the spillway plunge pool and the powerhouse. The prototype tailwater elevation is measured at the powerhouse and, unfortunately, prototype tailwater elevation data does not exist at the spillway. Since the spillway tailwater elevation is of primary interest in development of TDG abatement structures, it was very important that the spillway tailwater elevation in the model was a true simulation of the prototype and not a model induced condition.

The most downstream control location in the model was about 400 feet downstream of the powerhouse and occurred at lower discharges when the model tailgate (typically used to control tailwater elevation at the powerhouse) was lowered sufficiently to shift control to the model transect at the tailgate location. This control was typically submerged by about 1 ft when the tailgate was operated to meet the prototype tailwater curve at the powerhouse (see Figure 2-1); therefore, this control did not impact tailwater elevations at the spillway or the model study results. Figure 2-1 notes that the tailwater rating curve is based on a Little Falls forebay elevation of 1361 ft. Lower forebay elevations at Little Falls could impact the powerhouse tailwater elevation. The other observed channel control in the model was located between the powerhouse and plunge pool near the original coffer dam location.

During the initial witness test on September 14th, 2011, the two downstream hydraulic control locations were observed by Avista employees which led to discussions regarding the existence of those hydraulic controls in the prototype, especially in the location between the spillway plunge pool and the powerhouse. Bill Maltby, Chief Operator for Long Lake HED, noted that he has observed rapids in that area suggesting the presence of a hydraulic control in the prototype. The model transects at these two locations were subsequently verified by surveying the model and comparing the elevations to the digital topography. In both cases, the survey points were within the model construction tolerances and were considered acceptable. In addition to the survey verification, this anecdotal information was considered to verify that the model tailwater elevations at the spillway reasonably simulate the field conditions.

4.2 Baseline Test Plan

The Baseline Test Plan consisted of three discharges to document the flow conditions with the existing infrastructure and operating procedures. The operating conditions for the Baseline 1 and Baseline 2 tests were identical to two of the CFD model simulations that were conducted as part of the Phase II Feasibility Study mentioned previously. The operating conditions for Baseline Test 1 were based on field conditions that existed on June 2nd, 2008, which was a discharge condition essentially representing the 7Q10 discharge. Baseline Test 2 operating conditions were based on field conditions that occurred on June 29, 2008; and, the discharge represented a lower flow condition that would be more commonly experienced at the project versus the 7Q10. Baseline 3 represented a high flow condition with a total river discharge of 50,000 cfs. This flow was selected to evaluate a higher discharge for dam safety purposes. The PMF at the project is on the order of 260,000 cfs; however, the maximum prototype spillway discharge to prevent dam overtopping is on the order of 100,000 cfs. The 50,000 cfs model discharge was selected based on what was reasonably feasible due to model pumping capacity for a 1:30 model scale. The operating conditions for the three tests are shown in Table 4-2.

Table 4-2
Baseline Test Plan

Test	Total River Discharge (cfs)	Powerhouse Discharge (cfs)	Spillway Discharge (cfs)	Tailwater El. (ft)	Forebay El. (ft)	Spillway Gate Openings (ft)							
						1	2	3	4	5	6	7	8
Baseline 1	32,300	6,400	25,900	1,373.2	1,533.1	X	X	10.5	10.0	10.0	11.0	X	X
Baseline 2	15,300	6,900	8,400	1,368.1	1,535.5	X	X	X	X	6.0	6.0	X	X
Baseline 3	50,000	6,900	43,100	1,377.0	1,532.5	X	X	O	O	O	O	X	X

Note: 'X' indicates gate is closed, 'O' indicates gate is fully open

Data collection for Baseline testing consisted of flow classifications downstream of the spillway, water surface elevation measurements (pressure taps), operating conditions, spillway gate settings, and velocities along the shoreline between the spillway and powerhouse, as well as photo and video documentation.

4.3 BASELINE TEST RESULTS

4.3.1 Baseline Test 1: 32,000 cfs

The first baseline model test (Baseline Test 1) was conducted for the project's 7Q10 discharge, which occurred on June 2, 2008 during the TDG monitoring program. The powerhouse was operating at less than peak capacity; therefore, the spillway discharge was about 750 cfs greater than the anticipated 7Q10 spillway discharge. Despite this minor discharge difference, this test scenario was considered to be a very good field representation of the 7Q10 spillway flow.

The most dramatic flow characteristic observed in the model was that the spillway discharges consisted of deep plunging flows; and, the flow was extremely aerated, which promotes gas absorption and accounts for the elevated TDG concentrations in the field measurements taken in the tailrace. The deep plunge pool does offer excellent energy dissipation characteristics as the energy associated with the high velocity spillway flow is dissipated in the deep pool. Due to this reduction in velocities and energy, the discharge is better able to turn the 135 degree bend without significant superelevation. The highly turbulent 'white water' conditions did not extend to the far shoreline. Velocities collected in the channel between the spillway and plunge pool ranged between 10 to 15 ft/s on the right bank and ranged between 15 to 18 ft/s on the left bank. Photo documentation for Baseline Test 1 is provided in Photo Plate 4-2

4.3.2 Baseline Test 2: 15,300 cfs

Since the spillway will generally operate at flows below the 7Q10 discharge, the second model test considered a more common operating condition. Baseline Test 2 consisted of a spillway discharge of around 8,000 cfs. Due to the lower discharge, the plunge pool energy dissipation and the amount of aeration were not as dramatic as with the Baseline Test 1; however, there was still a significant amount of energy dissipated in the plunge pool due to the high head of the spillway and total energy at the base of the spillway. The flow conditions would still result in gas absorption and account for elevated TDG concentrations in the field measurements taken in the tailrace.

Recirculation of the flow was observed on the right side of the plunge pool. This could contribute to higher TDG levels as a portion of the flow is re-entrained into the spill discharge. As mentioned previously in Section 4.3.1, the plunge pool functions well under this scenario for energy dissipation. As expected, the velocities along the shoreline were lower for this scenario compared to Baseline Test 1. The velocities were also more uniform than in Baseline 1. The near bank velocities were roughly 5 ft/s, and near the middle of the channel they were 10 to 12 ft/s. Photo documentation for Baseline Test 2 is provided in Photo Plate 4-3

4.3.3 Baseline Test 3: 50,000 cfs

The baseline 50,000 cfs test was conducted as a high flow test for comparison with TDG abatement modifications to ensure that potential modifications to the project would not have an adverse impact on the operation of the facility at higher discharges. During these tests, the following observations were made:

- Extent of jet in the plunge pool
- Velocities and turbulence along the shoreline across from the spillway
- Characteristics of the turning flow
- Extent of observed aeration downstream in the model

As expected, the flow conditions were very turbulent in the plunge pool for this high flow. A very compact and well defined hydraulic jump/boil reflecting significant energy dissipation occurred in the deep plunge pool. The highly aerated and turbulent flow made it difficult to obtain accurate velocities along the shoreline; however, velocities on the order of 16 ft/s on the right bank and 20 ft/s on the left bank were measured downstream of the plunge pool. There was very minimal recirculation in the plunge pool at this high discharge. Photo documentation for Baseline Test 3 is provided in Photo Plate 4-4

5 Alternative 1 – Spillway Deflector

The first TDG abatement alternative tested in the physical model included a spillway deflector on Bays 7 and 8 and modifications to the rock outcrop located on the left bank of the plunge pool channel just downstream of Bays 7 and 8. As discussed in Sections 1.0 and 2.0, deflectors have been proven to provide satisfactory gas abatement for numerous prototype installations on the Lower Snake and Columbia River projects and are designed to redirect spillway discharges into a horizontal trajectory (skimming type flow regime) and prevent flow from plunging to depth where gas bubbles can be forced into solution by higher hydrostatic pressures. The most proven method to evaluate deflector performance, other than in prototype, is through physical model testing. Deflector performance is impacted by submergence (Tailwater Elevation – Deflector Elevation), unit discharge, and to some degree, the depth of water downstream of the deflector. As a result, the physical model was used to evaluate the initial deflector configuration and to optimize the deflector design.

5.1 Test Plan

5.1.1 Developmental Test Plan

The developmental test plan for Alternative 1 consisted of optimizing the deflector configuration. Multiple deflector configurations were tested for a range of spillway discharges in order to document the performance. The deflector performance was evaluated based on the USACE classifications shown in Figure 2-1. Developmental testing is an iterative process and becomes more detailed as the design advances. Table 5-1 provides the range of operating conditions that were utilized in the final stages of the developmental testing.

Table 5-1 Alternative 1 – Spillway Deflector – Developmental Test Plan

Total River Discharge	Powerhouse Discharge	Spillway Discharge	Tailwater at Powerhouse (P11)	Spill Bays Open	Spillway Unit Discharge**
cfs	cfs	cfs	ft		cfs/ft
7,900	*6,900*	1,000	1364.4	8	40
11,900	*6,900*	5,000	1366.0	7, 8	100
16,900	*6,900*	10,000	1368.0	7, 8	200
16,900	*6,900*	10,000	1368.0	5, 6, 7, 8	100
22,900	*6,900*	16,000	1370.1	5, 6, 7, 8	160
26,900	*6,900*	20,000	1371.4	3, 4, 5, 6, 7, 8	133
31,900	*6,900*	25,000	1372.9	3, 4, 5, 6, 7, 8	167

**Based on 25' wide spillway gate openings

During this phase of testing, the tailwater elevation was set according to the total river discharge assuming that the powerhouse was operating at 6,900 cfs; however, the powerhouse was not operated for the developmental testing. The reason for only operating the spillway is that any errors contributed to the flow split between the spillway and powerhouse were eliminated as the powerhouse didn't have to be re-calibrated for every test, and this also facilitated the number of tests that could be conducted for the number of modifications tested. Based on sensitivity analyses, the powerhouse discharge flow characteristics had no impact on the deflector performance; therefore, this approach was considered acceptable and preferable for this stage of testing.

5.1.2 Final Documentation Test Plan

Once the configuration of the spillway deflector alternative was optimized, three final documentation tests were completed. These three tests consisted of operating the model under the same operating conditions as the Baseline Tests 1, 2, and 3. During these tests, the powerhouse was operated for formal documentation purposes. Table 5-2 summarizes the operating conditions for the final documentation of the spillway deflector alternative.

Table 5-2 Alternative 1 – Spillway Deflector – Final Documentation Test Plan

Test	Total River Discharge	Powerhouse Discharge	Spillway Discharge	Tailwater El. (ft)	Forebay El. (ft)	Spillway Gate Openings (ft)							
						1	2	3	4	5	6	7	8
Alt 1 - 1	32,300	6,400	25,900	1,373.2	1,533.1	X	X	10.5	10.0	10.0	11.0	X	X
Alt 1 - 2	15,300	6,900	8,400	1,368.1	1,535.5	X	X	X	X	6.0	6.0	X	X
Alt 1 - 3	50,000	6,900	43,100	1,377.0	1,532.5	X	X	O	O	O	O	X	X

Note: 'X' indicates gate is closed, 'O' indicates gate is fully open

5.2 Developmental Testing Results

5.2.1 Configuration 1 – Deflector Elevation 1358 ft

The first deflector configuration tested in the model was placed below Spill Bays (Bays) 7 and 8 and consisted of a 15 ft long deflector at elevation 1358 ft. The existing rock outcrop immediately downstream of Bays 7 and 8 was lowered to elevation 1353 ft. This initial configuration was originally presented in Avista's 2006 Phase I TDG feasibility Study (EES Consulting, 2006). During the Phase II TDG Feasibility Study (NHC, 2010), the deflectors were evaluated in more detail; and, the high unit discharge (up to 500 cfs/ft) of a two bay deflector was noted as a potential problem. Previous evaluation of deflectors on the Lower Snake and

Columbia River projects suggest that the maximum unit discharge should be limited to around 200 cfs/ft for TDG abatement. However, testing with deflectors on only two bays and then expanding the deflector as needed was considered to be a logical approach to the deflector model testing process.

Due to the high unit discharge and the elevation of the deflector, unacceptable (for TDG purposes) surface jumps and submerged surface jumps were the primary flow classifications that existed for all spillway discharges tested between 1,000 cfs and 25,000 cfs (Photo Plate 5-1). These flow regimes were due to a combination of the deflector elevation being too low and the high unit discharge. Additionally, the high residual energy downstream of Bays 7 and 8 resulted in high velocities and wave conditions downstream that were unacceptable. As a result, the next modification included testing a higher deflector elevation and extending the deflector across additional bays to reduce the unit discharge.

5.2.2 Configuration 2 – Deflector Elevation 1363 ft

The second deflector configuration consisted of raising the deflector elevation by 5 feet to elevation 1363 ft and extending the deflector across Bays 3 through 6 in addition to Bays 7 and 8. This extension allowed the flexibility to test the deflector at a higher elevation (lower submergence) and at lower unit discharges. Brief testing of this configuration showed the deflector performance improved and flow was classified as a ramped surface jet. This was considered an improvement since the flow regime was brought closer to the desired skimming flow classification.

At the 7Q10 spillway discharge, 4–bay and 6-bay operating variations were tested (Photo Plate 5-2). The 4-bay test included operating Bays 3 through 6. The effective tailwater was higher on the outer bays (Bays 3 and 6) than on Bays 4 and 5. This had the effect of producing submerged surface jump regimes on the outer edges and surface jumps to a ramped surface jump condition in the center between Bays 4 and 5. Bays 3 through 8 were used in the 6-bay operating condition. This resulted in a gradual transition from ramped surface jet downstream of Bay 8 to a submerged surface jump downstream of Bay 3. Bay 8 had the benefit of the shallow tailrace resulting from the lowered rock outcrop, and it also had the sloped retaining wall that was located parallel to the spillway discharge and acted as a guide wall along the flow path. In contrast, Bay 3 had the deep plunge pool downstream and was adjacent to two non-operating bays, Bays 1 and 2. As a result, a portion of the flow from the deflectors recirculated upstream and intersected the discharge from Bay 3, which resulted in a higher effective tailwater and resulted in a submerged surface jump regime.

Performance with Configuration 2 indicated that the deflector needed to be raised further.

5.2.3 Configuration 3 – Deflector Elevation 1368 ft

For Configuration 3, the deflector elevation across Bays 3 through 8 was raised an additional 5 feet to elevation 1368 ft. For the 1,000 cfs condition, the flow was discharged through Bay 8 and was classified as a slightly plunging flow. Despite the plunging flow regime, Bay 8 discharges into the shallow stilling basin and the discharge is very low, which both limit the potential for increased air entrainment and high TDG levels. For the 5,000 cfs spillway discharge, Bays 7 and 8 were operated; and, the flow regime was classified as skimming flow (Photo Plate 5-3). For the 20,000 and 25,000 cfs discharges, Bays 5 through 8 were operated; and, the flow was classified as ramped surface jet. The right side of Bay 5 was a borderline surface jump or submerged surface jump due to the recirculation along the right bank.

Based on Configurations 1 through 3 testing, a deflector elevation of 1368 ft was considered to be acceptable for spillway discharges below 5,000 cfs; however, a higher deflector elevation was considered necessary to develop acceptable skimming flow conditions at higher spillway discharges. As a result, a two-step deflector design was determined to be a solution that would potentially allow for an acceptable flow regime under a wider range of flow conditions; and, this scenario is discussed in Section 5.2.4.

5.2.4 Configuration 4 – Deflector Elevations 1368 ft and 1373 ft

Configuration 4 consisted of a two step deflector with a higher elevation across Bays 3 through 6. The deflector below Bays 7 and 8 was left at elevation 1368 ft, and the deflector below Bays 3 through 6 was raised 5 feet to elevation 1373 ft (Photo Plate 5-4).

The design tested in Configuration 3 indicated that a deflector elevation of 1368 ft across Bays 7 and 8 was optimum to provide acceptable flow conditions for a spillway discharge of 1,000 cfs through Bay 8 (unit discharge 40 cfs/ft) and for a discharge of 5,000 cfs equally distributed through Bays 7 and 8 (unit discharge 100 cfs/ft). With a spillway discharge of 10,000 cfs and only Bays 7 and 8 operating (unit discharge approximately 200 cfs/ft), the flow regime downstream of Bays 7 and 8 bordered between a skimming and ramped surface jet (~10 degrees) flow. There was very little energy dissipation, and the high velocity jet leaving the deflector extended beyond the extent of the flat basin formed by the removal of the rock outcrop. Those results indicated that the deflector design spillway discharges in excess of 5,000 cfs would require use of more than only Bays 7 and 8. Therefore, Configuration 4 consisted of a deflector elevation of 1368 ft on Bays 7 and 8; and, a deflector elevation of 1373 ft on Bays 3 through 6. Bays 3 through 6 would be operated in conjunction with Bays 7 and 8 when spillway discharges exceed 5,000 cfs.

With a spillway discharge of 10,000 cfs equally distributed through Bays 5 through 8 (unit discharge 100 cfs/ft), Bays 7 and 8 exhibited skimming flow. A slightly plunging flow regime existed on Bays 5 and 6; however, the jet did not appear to plunge to a significant depth (based on under water video footage) and was considered acceptable for TDG abatement purposes. With a spillway discharge of 16,000 cfs equally distributed through Bays 5 through 8 (unit discharge 140 cfs/ft), the tailwater submergence was high enough to produce skimming flow from Bays 5 and 6 and a slightly ramped surface jet (~10 degrees) from Bays 7 and 8. With a spillway discharge of 20,000 cfs equally distributed across Bays 3 through 8 (unit discharge 135 cfs/ft), Bays 7 and 8 exhibited a slight ramped surface jet (~10 degrees), and Bays 3 through 6 showed ideal skimming flow. With a spillway discharge of 25,000 cfs equally distributed across Bays 3 through 8 (unit discharge 165 cfs/ft), Bays 7 and 8 exhibited a ramped surface jet (15 degrees), and Bays 3 and 6 had a slight ramped surface jet (~5 degrees) that was very near skimming flow. Photo documentation of the various flow conditions tested is shown in Photo Plate 5-4, and the abbreviated water surface elevations and flow regimes are summarized below in Table 5-3.

Table 5-3 Alternative 1 Spillway Deflector Configuration 4 Flow Performance

			Deflector El. 1373 ft		Deflector El. 1368 ft
Spillway Discharge	Spillway Tailwater (P4)	Project Tailwater (P11)	Flow Regime	Flow Regime	Flow Regime
cfs	ft	ft	Bays 3 and 4	Bays 5 and 6	Bays 7 and 8
1,000	1364.1	1364.4	–	–	plunging (Bay 8 only)
5,000	1367.9	1366.0	–	–	skimming
10,000	1369.9	1368.0	–	–	ramped surface jet (~10°)
10,000	1369.9	1368.0	–	plunging	skimming
16,000	1372.4	1370.1	–	skimming	ramped surface jet (~10°)
20,000	1374.1	1371.4	skimming	skimming	ramped surface jet (~10°)
25,000	1375.3	1372.9	ramped surface jet (~5°)	ramped surface jet (~5°)	ramped surface jet (~15°)

Underwater video footage was taken for the tests described in this section. The video and a brief summary memorandum of the results with Configuration 4 were submitted to Avista (NHC, 10/24/2011). The video verified that flow exiting the deflector with spillway discharges up to 25,000 cfs did not plunge to depth in the existing deep plunge pool downstream of Bays 3 through 6.

Based on the test results and acceptable performance associated with Configuration 4, this alternative was selected for final testing. The operating conditions summarized in Table 5-3 would be an acceptable starting point for field operations. However the model was only tested with uniform flow distribution from all deflector bays for a given discharge. Additional field optimization may be possible by varying the gate openings between bays. The deflector design tested in the model included an abrupt step transition between the higher and lower deflector elevations between Bays 6 and 7. Strong flow separation existed at that interface when Bays 6 and 7 were operating suggesing a high potential for cavitation conditions to exist in the prototype. If this alternative is selected for final design, this area needs further evaluation to prevent cavitation damage in the prototype. Some design considerations include steel lining of the deflector surface at the interface or shaping of the transition to provide a more streamlined flow surface.

5.2.5 General Flow Classification Observation Unique to Long Lake

During testing of the deflector alternative, it was noted that the flow regimes appeared to transition directly between skimming flow and a ramped surface jet. The USACE flow classification system (Figure 3-6) shows an intermediate flow regime, “undular surface jet.” This flow regime was not observed during testing in the Long Lake model. Flow regimes are qualitative and somewhat subjective as a result; but, the absence of an observed undular surface jet could be a result of the tailrace configuration and the sharp left turn immediately downstream of the spillway. The USACE flow classifications were developed for standard hydraulic jump stilling basins on the Lower Columbia and Snake Rivers versus a plunge pool type of energy dissipation method. Skimming flow was still easily identified in the model; however, as the tailwater elevation increased, the flow regime was then classified as a ramped surface jet. To help describe the flow classification in more detail, a rough estimation of the trajectory of the jet was included in degrees (relative to horizontal). As shown previously, Table 5-3 summarizes the results from the last iteration of testing in the developmental testing phase.

5.2.6 Plunge Pool Sensitivity

Filling in the plunge pool downstream of Bays 3 through 6 with the rock excavated from the rock outcrop downstream of Bays 7 and 8 was considered as a potential option to limit the tailwater depth and the hydrostatic pressure that forces gas into solution. Disposing of that material in the plunge pool was included in the Phase II construction costs for the Bays 7 and 8 deflector alternative. The volume of excavated rock (13,000 cubic yards) would only fill the plunge pool to an elevation of 1340 ft, which still leaves the plunge pool 13 feet deeper than the elevation 1353 ft stilling basin below Bays 7 and 8. Testing of the Configuration 4 deflector design with the plunge pool filled was accomplished to ensure that the shallower depth downstream of Bays 3 through 6 did not adversely impact flow conditions downstream of those bays.

Both ‘fixed bed’ and ‘mobile bed’ model tests were conducted with the plunge pool filled. For the ‘fixed bed’ test, the plunge pool was filled to El. 1340 ft with small sized gravel; and, then it was capped with a thin concrete crust to prevent any of the fill material from eroding or shifting. The model was then operated through the entire series of flows outlined in Table 5-1 to verify whether or not the raised bed would have any impact to the flow regimes. Based on these tests, there were no observed changes in the flow regime classifications (Photo Plate 5-5).

The ‘mobile bed’ test was used to estimate the size class of material required to remain stable at high flows exceeding the 7Q10 spillway discharge. For this test, the spillway was operated at 50,000 cfs with the discharge evenly distributed between Bays 3 through 8. Three different size classifications of materials were tested simulating 12.5 ft, 10 ft, and 7.5 ft diameter prototype material. The individual rocks were also painted white, red, and blue to represent the 12.5, 10 ft, and 7.5 ft material, respectively, for easier identification (Photo Plate 5-6). The model discharge was gradually increased up to the 50,000 cfs (note: all discharge passed over the spillway for this test) to raise the tailwater to simulate a discharge of 50,000 cfs; and, then the flow was continuously maintained for the equivalent of 5.5 hours in the prototype.

The 12.5 ft diameter material did not show any movement (Photo Plate 5-7). The 10 ft material showed a slight amount of movement at the downstream extent of the fill material; however, no material near the spillway toe moved. In addition, none of the mobilized material from the downstream area migrated upstream where it could cause an erosion risk by recirulating along the spillway toe (Photo Plate 5-8). The 7.5 ft material showed a significant amount of displacement at the downstream end of the plunge pool at the impact point of the jet (Photo Plate 5-9). Based on the mobile plunge pool testing, it was concluded that the a minimum rock size of 10 ft diameter would be required to withstand spillway discharges up to 50,000 cfs. This size may be larger than can be feasibly fractured from the outcrop and maneuvered at the project site during the rock outcrop excavation. If filling in the plunge pool is pursued, civil design and construction feasibility will need to be conducted to determine if this size of rock, or manufacturing of other material of similar mass, is possible.

5.3 Final Documentation

The final documentation phase for Alternative 1 consisted of operating the model with the powerhouse operating at maximum hydraulic capacity with the selected deflector design under the same operating conditions as the baseline tests (project discharges of 32,300; 15,300 cfs and 50,000 cfs). During the deflector developmental testing phase of the study, subsequent deflector designs were installed without removing the previous deflector for model construction expediency. This procedure resulted in a stepped configuration that limited the tailwater depth immediately downstream from the deflector itself. The final documentation provided an opportunity to test the final recommended design with all remnants of other deflector geometries and structures removed from the model to ensure that the tailwater depth immediately downstream of the deflector did not affect the deflector performance previously observed. This documentation also provided the opportunity to evaluate how the deflectors may impact operations and dam safety issues at the site.

Configuration 4, the two-step elevation deflector (deflector elevations 1373 ft on Bays 3-6 and 1368 ft on Bays 7 and 8) and 15 ft in length, was selected as the optimum design from the developmental testing. This deflector design was reconstructed in the model after removing remnants of Configurations 1 through 3 that had accumulated during the iterative design process. For the final tests, the plunge pool was filled to elevation 1340 ft with the 10 ft diameter material. Photo Plate 5-10 shows the model in the dry state prior to testing.

Testing confirmed that the acceptable deflector performance previously observed with Configuration 4 development testing was not impacted by removal of the remnants of the old deflectors.

5.3.1 Alternative 1 Final Test 1: 32,300 cfs

The first test repeated the field 7Q10 flow scenario that was conducted for Baseline Test 1 (spillway discharge 25,900 cfs and powerhouse discharge 6,400 cfs). The middle four bays (Bays 3 through 6) were operated to reflect the same spillway discharge distribution used in Baseline Test 1. The flow regime downstream of the deflector was a ramped surface jet (~5 degrees). Photos of Final Test 1 are provided in Photo Plate 5-11. This test conducted for comparison purposes with Baseline Test 1. Under ideal future operating conditions, Bays 7 and 8 would have also been operating to lower the unit discharge over the entire deflector. Water surface elevation data and operating conditions are provided in Table 5-4.

The major change that was observed between Baseline Test 1 and Alternative 1 Final Test 1 included the flow regime change from a plunging flow with the existing condition to shallow ramped surface jet with the deflector. Since Alternative 1 deflects the flow in a near skimming flow regime, the discharge is deflected across the plunge pool to the far shoreline. There could be erosion concerns along the bank due to this change in flow regime; and, these concerns should be evaluated by a geotechnical engineer should this alternative proceed to a more detailed design phase. The velocities were too turbulent for accurate velocity readings in the plunge pool. Downstream of the plunge pool, velocities were taken in the same locations as recorded in the Baseline 1 Test. With the deflector installed, the velocities increased on the right side of the channel and decreased on the left side compared to the Baseline 1 Test. Velocities on the right side of the channel were near 20 ft/s; and, on the left side of the channel, they were near 15 ft/s. This supports the observation that the flow was impacting the far bank (right bank) downstream of the spillway before slowing and turning the bend.

5.3.2 Alternative 1 Final Test 2: 15,300 cfs

This test represented a spill flow that would occur more readily at the site than the 7Q10 flow scenario. These intermediate spill flows are important as they will occur for a longer period of time than higher flows. This test scenario included a spillway flow of 8,400 cfs passing through Bays 5 and 6 and 6,900 cfs through the powerhouse. This spillway discharge falls in between two of the developmental testing spillway flows of 5,000 cfs and 10,000 cfs. As discussed in Section 5.2, only Bays 7 and 8 were operated for these low spillway flows during the design development testing. For comparison purposes with Baseline Test 2, the Final Test 2 operations included only Bays 5 and 6 operating. Water surface elevation data and operating conditions are provided in Table 5-5 and photos are provided in Photo Plate 5-12.

Similar to the results discussed for Final Test 1, the most apparent change in the flow conditions was the change from a plunging flow regime in Baseline Test 2 to a skimming and ramped surface jet flow regime for Final Test 2. Although the flow was deflected across the plunge pool to a noticeable degree compared to the baseline condition, the impact on the far shoreline was much less significant than what was observed for Final Test 1 at the higher discharge. The velocity measurements taken in the channel after the bend were more consistent with the Baseline 2 data, 5 ft/s near the banks and 10 to 12 ft/s velocities in the middle of the channel.

5.3.3 Alternative 1 Final Test 3: 50,000 cfs

The 50,000 cfs baseline test scenario, Baseline Test 3, was repeated with the Alternative 1 deflector. For Final Test 3, the entire 50,000 cfs discharge was passed through Bays 3 through 6 so that the results could be directly compared to the Baseline; however, the recommended flow regime for Configuration 4 would be to spread the flow across Bays 3 through 8 for spillway discharges greater than 20,000 cfs. Water surface elevation data and operating conditions are provided in Table 5-6 and photos are provided in Photo Plate 5-13.

Similar to the observations in Final Tests 1 and 2, the jet is deflected further across the plunge pool to the far shoreline. The potential to increase erosion along the shoreline should be investigated should this alternative advance to subsequent design phases. In addition, a strong recirculation eddy was observed downstream of Bays 7 and 8 where the rock outcrop was removed; however, operation of Bays 7 and 8 would likely impact the eddy condition observed in the model. Although this flow is well above the 7Q10 and re-entraining flow into the highly aerated discharge isn't a concern from a TDG perspective, the higher velocities in this area should be considered in the design of the rock outcrop excavation downstream of Bays 7 and 8 and along the left bank sloped retaining wall. The velocities measured in the channel downstream of the bend after the plunge pool were near 22 ft/s on the right side of the channel and 18 ft/s on the left side. Relative to Baseline 3, there was a shift to higher velocities on the right side of the channel. This relative change is consistent with what was observed comparing the Baseline Test 1 to the Final Test 1.

6 Alternative 6 – Stepped Weir Structure

This section will be completed after the stepped weir structure is installed and tested in the physical model in early 2012. Figures 6-1 and 6-2 are included with this report to show the initial stepped weir structure that will be tested in the physical model.

7 Alternative 7 – Noxon Spillway Concept

This section will be completed in early 2012 and will include the conceptual design, constructability, and cost estimating of Alternative 7.

8 Summary

This section will be completed after all of the alternatives have been tested in the physical model.

9 References

EES Consulting. Long Lake Hydroelectric Development Total Dissolved Gas Abatement Initial Feasibility Study Report. Avista Utilities. September 2006.Northwest Hydraulic Consultants, Inc. Dissolved Gas Abatement Study, Assessment of Gas Abatement Alternatives. USACE. August 1996.

Northwest Hydraulic Consultants, Inc. “Long Lake HED TDG Abatment – Spillway Deflector alternative – Underwater Video” Memorandum to Avista, October 24th, 2011.

Northwest Hydraulic Consultants, Inc. Long Lake HED TDG Abatement Phase II Feasibility Study, Final Report. December 9, 2010.

Northwest Hydraulic Consultants, Inc. Dissolved Gas Abatement Study Stepped Spillway Model. USACE April 1998.

TABLES

Table 4-3
Calibration Test Data

Supply Pump Settings			
Pump	Deflection (in.)	Flow Meter (model, cfs)	Flow (cfs)
A	19.5		8600
B	60.5		17000
C	–		
Total River Discharge (cfs)			25600
Total Powerhouse Discharge (cfs)			6700
Total River Discharge (cfs)			18900

Powerhouse Unit Settings		
Powerhouse Unit	Deflection (in.)	Flow (cfs)
1	2.0	1675
2	2.0	1675
3	2.0	1675
4	2.0	1675

Spillway Gate Openings (Proto Ft.)							
1	2	3	4	5	6	7	8
X	X	8.0	8.0	4.0	8.0	X	X

Pressure Taps							
Forebay Pressure Taps		Tailrace Pressure Taps					
P1 (FB)	1535.5	P4	1370.8	P9	1370.8	P14	1370.9
P2	1535.5	P5	1373.0	P10	1370.8	P15	1369.5
P3	1535.5	P6	1375.5	P11 (TW)	1370.9	P16	1369.9
		P7	1373.6	P12	1371.0	P17	1370.0
		P8	1370.9	P13	1371.0		

Table 4-4
Baseline Test 1 Data

Supply Pump Settings			
Pump	Deflection (in.)	Flow Meter (model, cfs)	Flow (cfs)
A	62.5		15300
B	60.5		17000
C	–		
Total River Discharge (cfs)			32300
Total Powerhouse Discharge (cfs)			6400
Total River Discharge (cfs)			25900

Powerhouse Unit Settings		
Powerhouse Unit	Deflection (in.)	Flow (cfs)
1	1.8	1600
2	1.8	1600
3	1.8	1600
4	1.8	1600

Spillway Gate Openings (Proto Ft.)							
1	2	3	4	5	6	7	8
X	X	10.9	10.4	10.4	11.5	X	X

Pressure Taps							
Forebay Pressure Taps		Tailrace Pressure Taps					
P1 (FB)	1533.1	P4	1370.8	P9	1372.8	P14	1373.2
P2	1533.1	P5	1374.8	P10	1372.9	P15	1371.4
P3	1533.1	P6	1378.3	P11 (TW)	1373.2	P16	1372.3
		P7	1375.5	P12	1373.3	P17	1372.5
		P8	1372.5	P13	1373.3		

Table 4-5
Baseline Test 2 Data

Supply Pump Settings			
Pump	Deflection (in.)	Flow Meter (model, cfs)	Flow (cfs)
A	62.2		15300
B	–		
C	–		
Total River Discharge (cfs)			15300
Total Powerhouse Discharge (cfs)			6900
Total River Discharge (cfs)			8400

Powerhouse Unit Settings		
Powerhouse Unit	Deflection (in.)	Flow (cfs)
1	2.1	1725
2	2.1	1725
3	2.1	1725
4	2.1	1725

Spillway Gate Openings (Proto Ft.)							
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
X	X	X	X	6.0	6.0	X	X

Pressure Taps							
Forebay Pressure Taps		Tailrace Pressure Taps					
P1 (FB)	1534.4	**P4**	1366.1	**P9**	1368.0	**P14**	1368.1
P2	1535.4	**P5**	1363.5	**P10**	1368.1	**P15**	1367.3
P3	1535.4	**P6**	1369.5	**P11 (TW)**	1368.1	**P16**	1367.3
		P7	1369.3	**P12**	1368.0	**P17**	1367.3
		P8	1367.9	**P13**	1368.3		

Table 4-6
Baseline Test 3 Data

Supply Pump Settings			
Pump	Deflection (in.)	Flow Meter (model, cfs)	Flow (cfs)
A	76.5		17000
B	60.5		17000
C	53.5		16000
Total River Discharge (cfs)			50000
Total Powerhouse Discharge (cfs)			6900
Total River Discharge (cfs)			43100

Powerhouse Unit Settings		
Powerhouse Unit	Deflection (in.)	Flow (cfs)
1	2.1	1725
2	2.1	1725
3	2.1	1725
4	2.1	1725

Spillway Gate Openings (Proto Ft.)							
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
X	X	open	open	open	open	1.0	X

Pressure Taps							
Forebay Pressure Taps		Tailrace Pressure Taps					
P1 (FB)	1532.5	**P4**	1366.0	**P9**	1376.4	**P14**	1377.0
P2	1532.5	**P5**	1380.3	**P10**	1376.8	**P15**	1374.0
P3	1532.5	**P6**	1383.5	**P11 (TW)**	1377.0	**P16**	1375.0
		P7	1379.8	**P12**	1377.3	**P17**	1375.8
		P8	1376.0	**P13**	1377.1		

Table 5-4
Alternative 1 Final Test 1 Data

Supply Pump Settings			
Pump	Deflection (in.)	Flow Meter (model, cfs)	Flow (cfs)
A	62.5		15300
B	60.5		17000
C	–		
Total River Discharge (cfs)			32300
Total Powerhouse Discharge (cfs)			6400
Total River Discharge (cfs)			25900

Powerhouse Unit Settings		
Powerhouse Unit	Deflection (in.)	Flow (cfs)
1	1.8	1600
2	1.8	1600
3	1.8	1600
4	1.8	1600

Spillway Gate Openings (Proto Ft.)							
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
X	X	10.9	10.4	10.4	11.5	X	X

Pressure Taps							
Forebay Pressure Taps		**Tailrace Pressure Taps**					
P1 (FB)	1533.3	**P4**	1365.5	**P9**	1373.0	**P14**	1373.3
P2	1533.3	**P5**	1365.1	**P10**	1373.0	**P15**	1371.3
P3	1533.3	**P6**	1373.6	**P11 (TW)**	1373.2	**P16**	1372.1
		P7	1374.8	**P12**	1373.3	**P17**	1372.5
		P8	1372.5	**P13**	1373.3		

Table 5-5
Alternative 1 Final Test 2 Data

Supply Pump Settings			
Pump	**Deflection (in.)**	**Flow Meter (model, cfs)**	**Flow (cfs)**
A	62.5		15300
B	–		
C	–		
Total River Discharge (cfs)			15300
Total Powerhouse Discharge (cfs)			6900
Total River Discharge (cfs)			8400

Powerhouse Unit Settings		
Powerhouse Unit	**Deflection (in.)**	**Flow (cfs)**
1	2.1	1725
2	2.1	1725
3	2.1	1725
4	2.1	1725

Spillway Gate Openings (Proto Ft.)							
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
X	X	X	X	6.0	6.0	X	X

Pressure Taps							
Forebay Pressure Taps		**Tailrace Pressure Taps**					
P1 (FB)	1534.5	**P4**	1365.0	**P9**	1367.9	**P14**	1368.0
P2	1534.5	**P5**	1364.8	**P10**	1368.0	**P15**	1367.0
P3	1534.5	**P6**	1367.9	**P11 (TW)**	1368.0	**P16**	1367.0
		P7	1369.4	**P12**	1368.0	**P17**	1367.0
		P8	1367.8	**P13**	1368.1		

Table 5-6
Alternative 1 Final Test 3 Data

Supply Pump Settings			
Pump	Deflection (in.)	Flow Meter (model, cfs)	Flow (cfs)
A	76		17000
B	60.5		17000
C	53.5		16000
Total River Discharge (cfs)			50000
Total Powerhouse Discharge (cfs)			6900
Total River Discharge (cfs)			43100

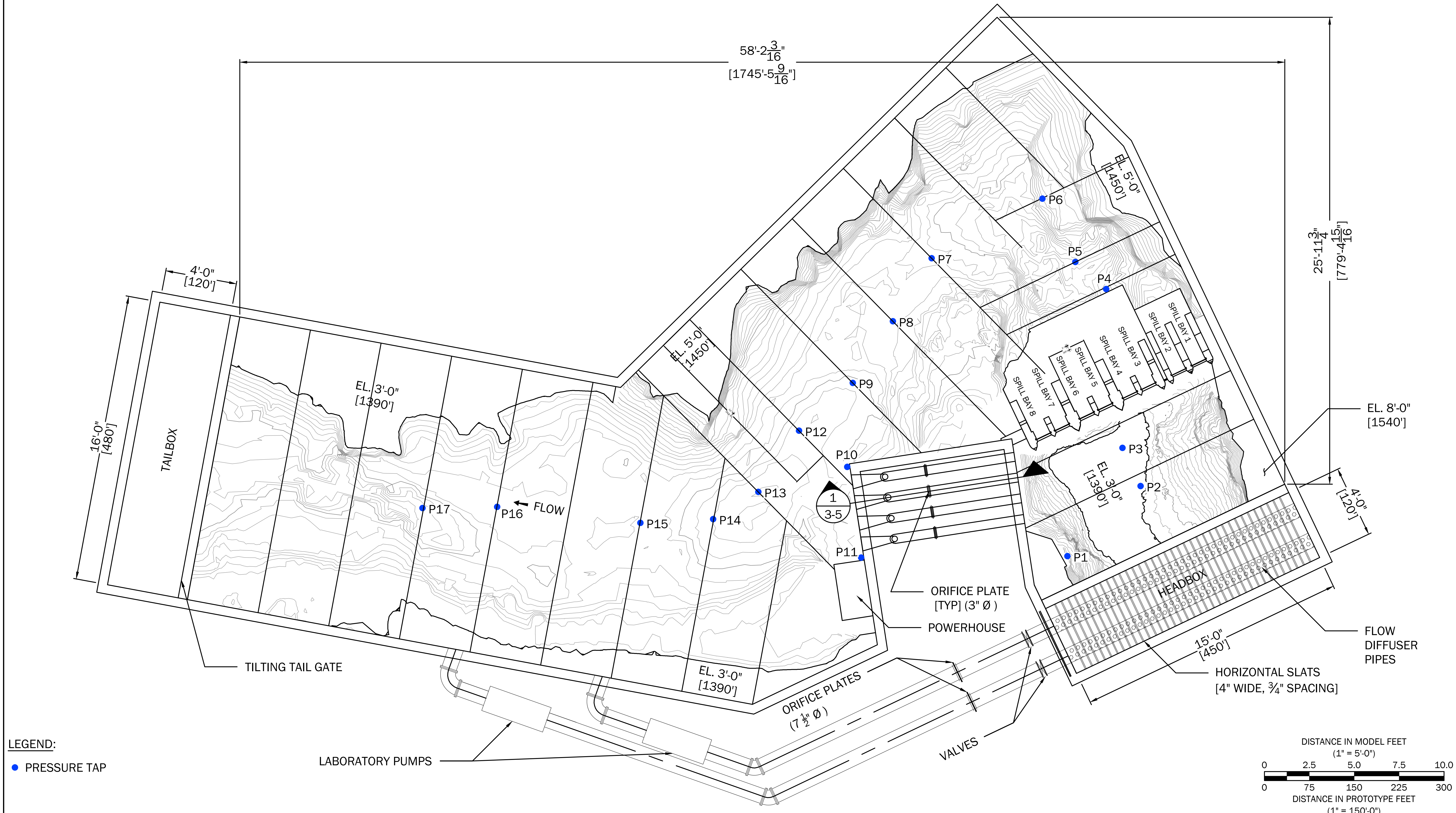
Powerhouse Unit Settings		
Powerhouse Unit	Deflection (in.)	Flow (cfs)
1	2.1	1725
2	2.1	1725
3	2.1	1725
4	2.1	1725

Spillway Gate Openings (Proto Ft.)							
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
X	X	open	open	open	open	1.0	X

Pressure Taps							
Forebay Pressure Taps		Tailrace Pressure Taps					
P1 (FB)	1532.5	**P4**	1365.0*	**P9**	1376.9	**P14**	1377.1
P2	1532.5	**P5**	1360.5*	**P10**	1376.9	**P15**	1373.9
P3	1532.5	**P6**	1376.8*	**P11 (TW)**	1377.0	**P16**	1375.3
		P7	1378.9	**P12**	1377.3	**P17**	1376.0
		P8	1376.0	**P13**	1377.3		

*Flow was too turbulent and aerated to get accurate reading

FIGURES



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NOTES:

1. PRIMARY DIMENSIONS ARE GIVEN IN MODEL FEET.
2. SECONDARY [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET.
3. CONSTRUCTION TOLERANCE = ±1/8".
4. MODEL SCALE: 1 MODEL = 30 PROTOTYPE.

SCALE:	1" - 150'
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DRAWN BY:	KEH
DATE:	APR 2011
DRAWING NO:	21885

AVISTA Utilities

LONG LAKE DAM TDG ABATEMENT FEASIBILITY PHASE III PHYSICAL MODEL STUDY

MODEL LAYOUT GENERAL ARRANGEMENT

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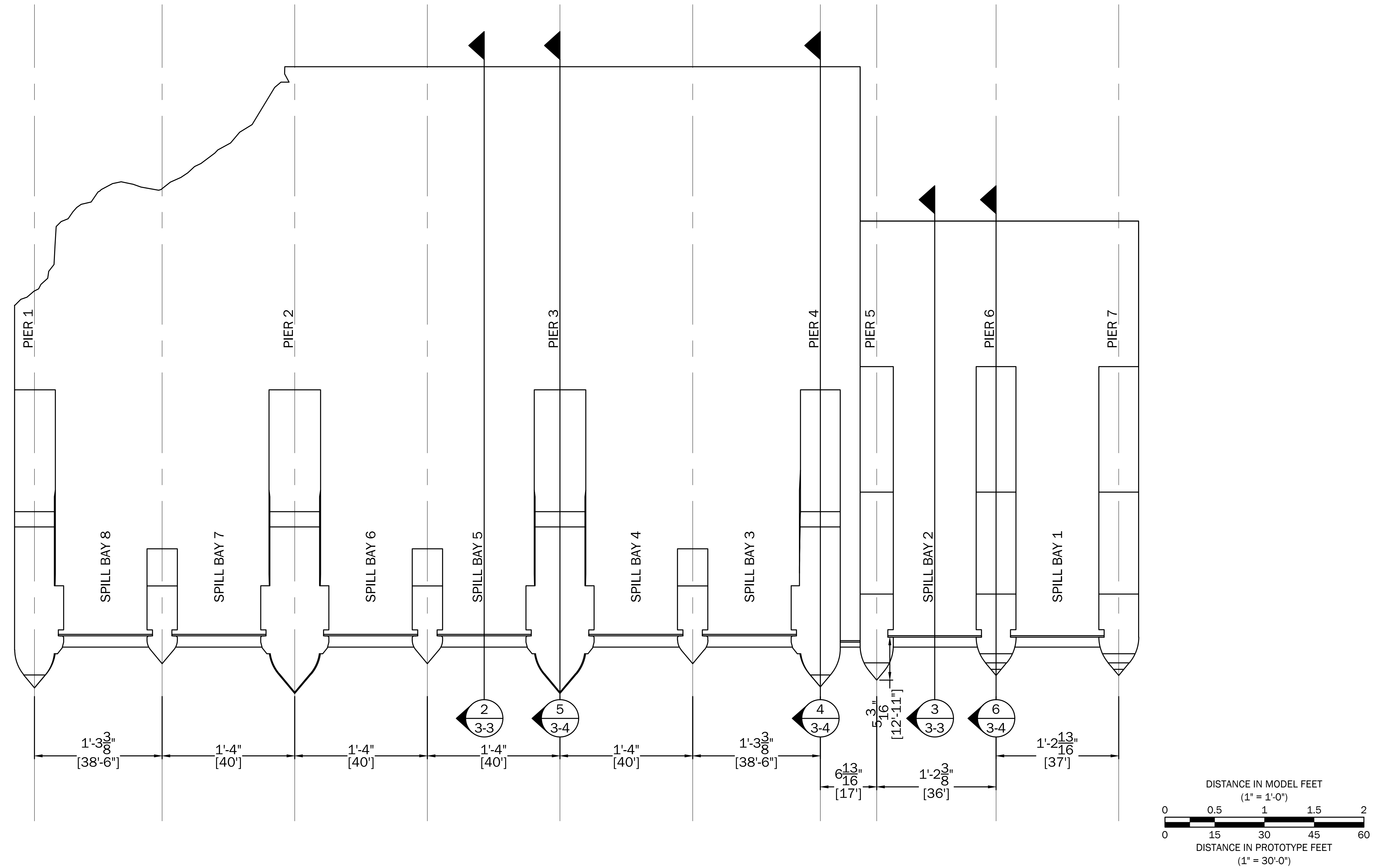
FIGURE 3-1



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NOTES:

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SCALE:	1" - 30'
REVISION NO:	
DRAWN BY:	KEH
DATE:	APR 2011
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LONG LAKE DAM TDG ABATEMENT FEASIBILITY PHASE III PHYSICAL MODEL STUDY

MODEL LAYOUT SPILLWAY GATES AND PIERS

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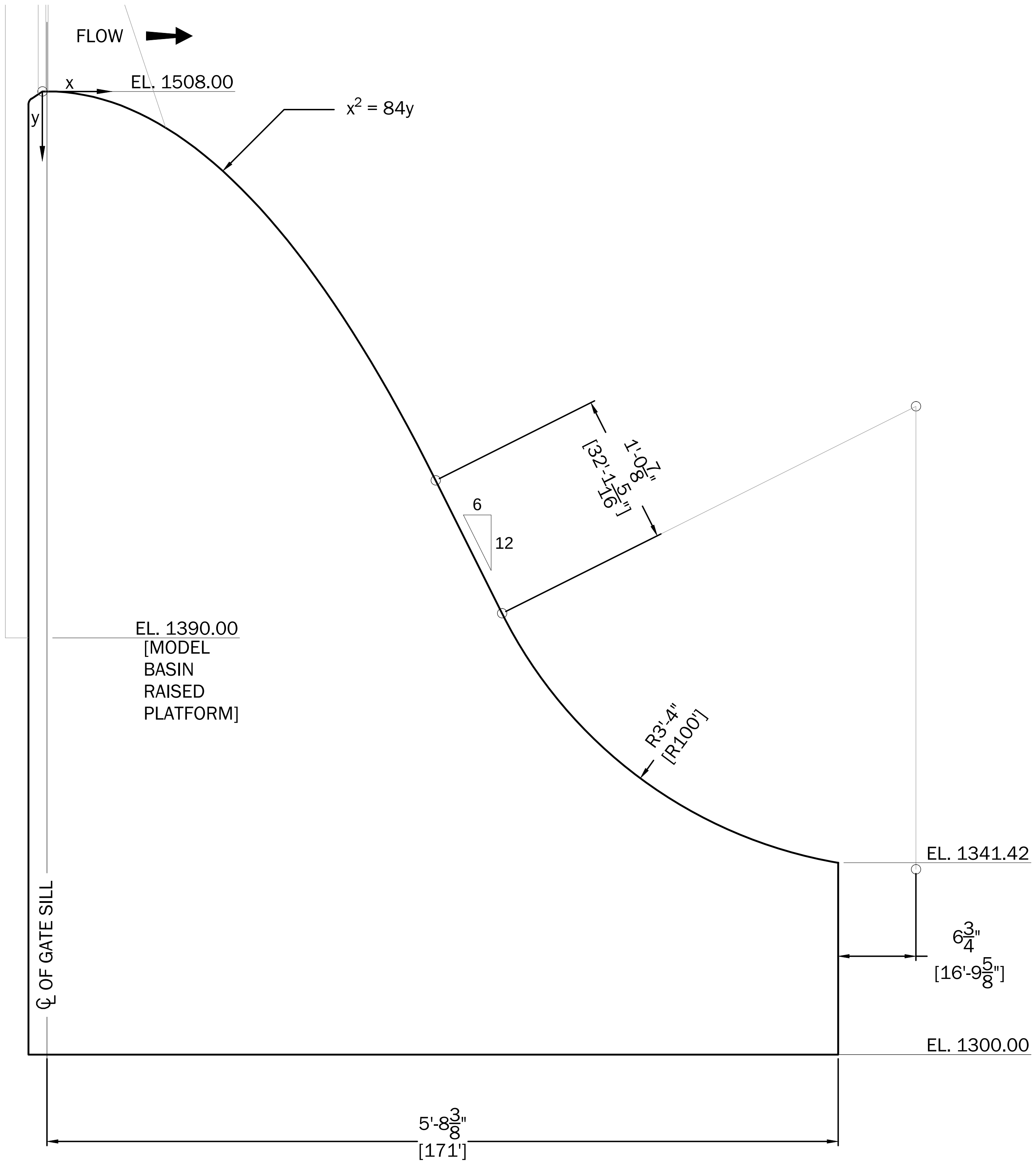
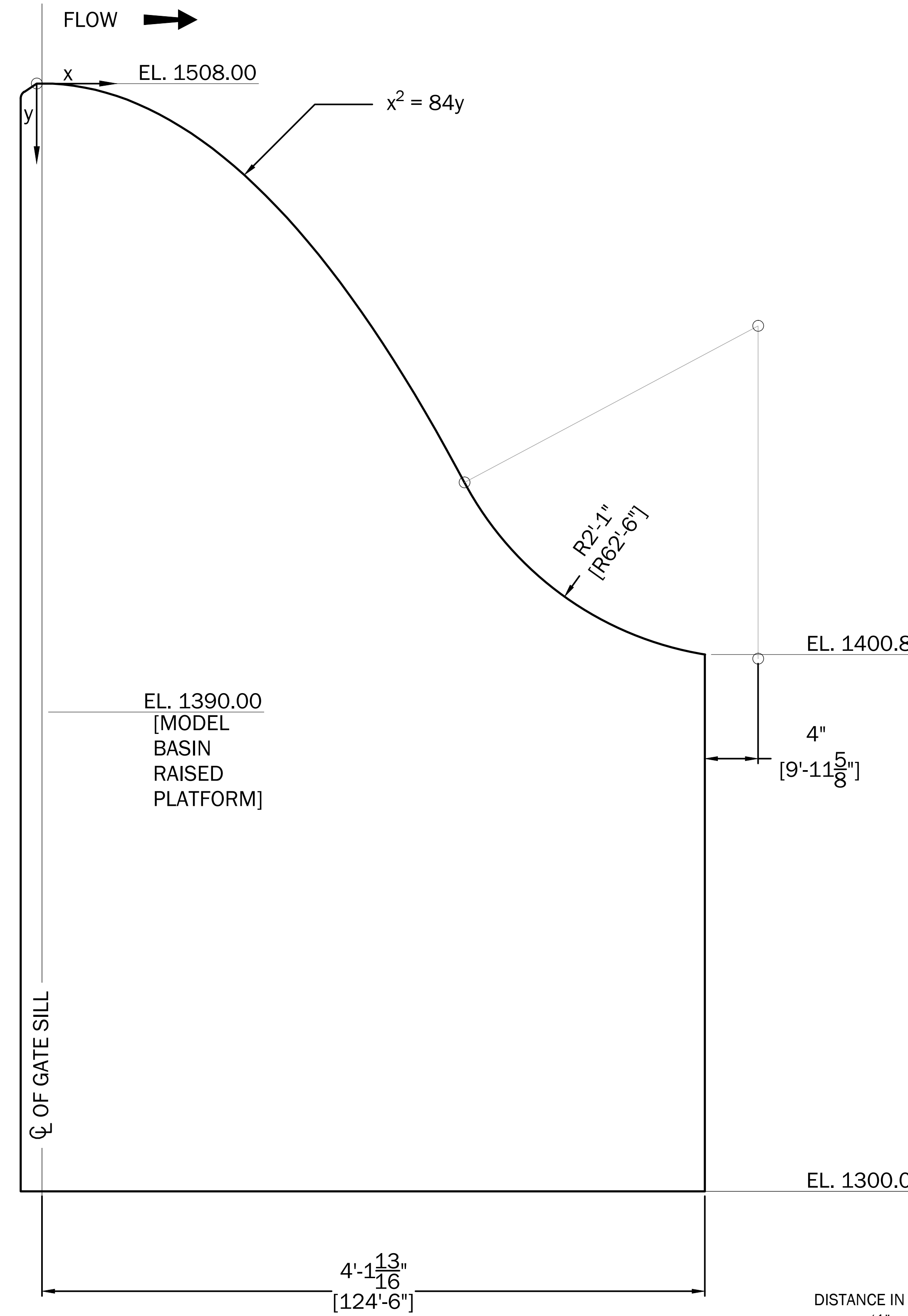
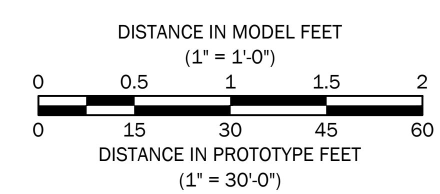
FIGURE 3-2



2 / 3-2 TYPICAL SECTION - SPILLWAY: GATES 3, 4, 5, 6, 7 & 8



3 / 3-2 TYPICAL SECTION - SPILLWAY: GATES 1 & 2



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NOTES:

1. PRIMARY DIMENSIONS ARE GIVEN IN MODEL FEET.
2. SECONDARY [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET.
3. CONSTRUCTION TOLERANCE = ±1/8".
4. MODEL SCALE: 1 MODEL = 30 PROTOTYPE.

SCALE:	1" - 30'
REVISION NO:	
DRAWN BY:	KEH
DATE:	APR 2011
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LONG LAKE DAM TDG ABATEMENT FEASIBILITY PHASE III PHYSICAL MODEL STUDY

MODEL LAYOUT SPILLWAY SECTIONS

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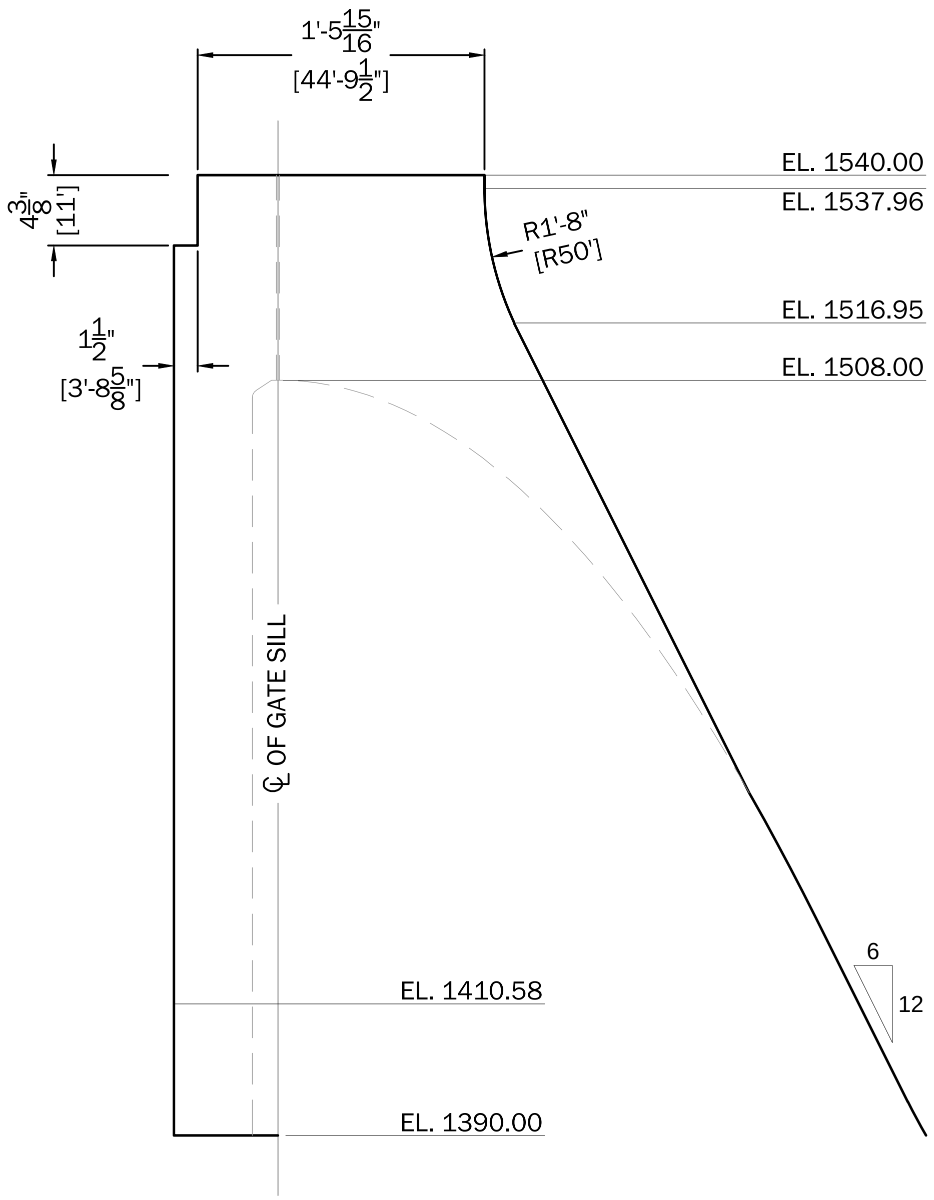
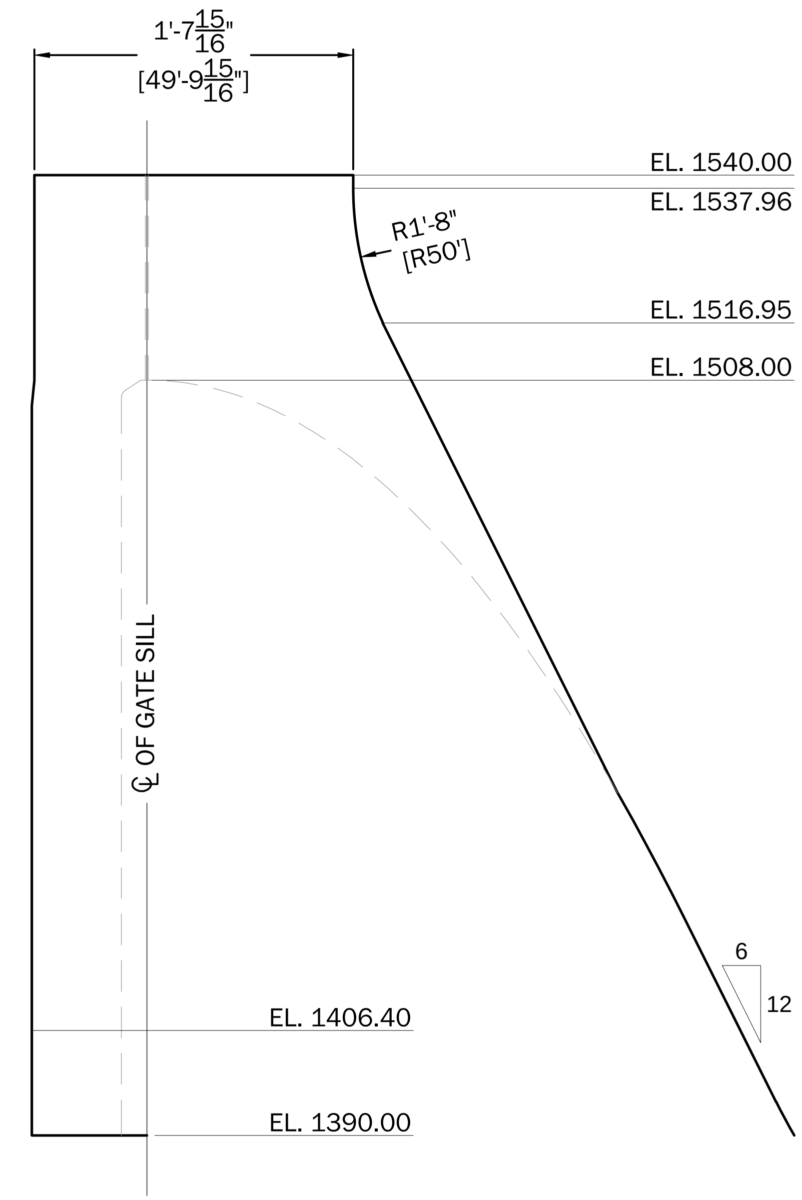
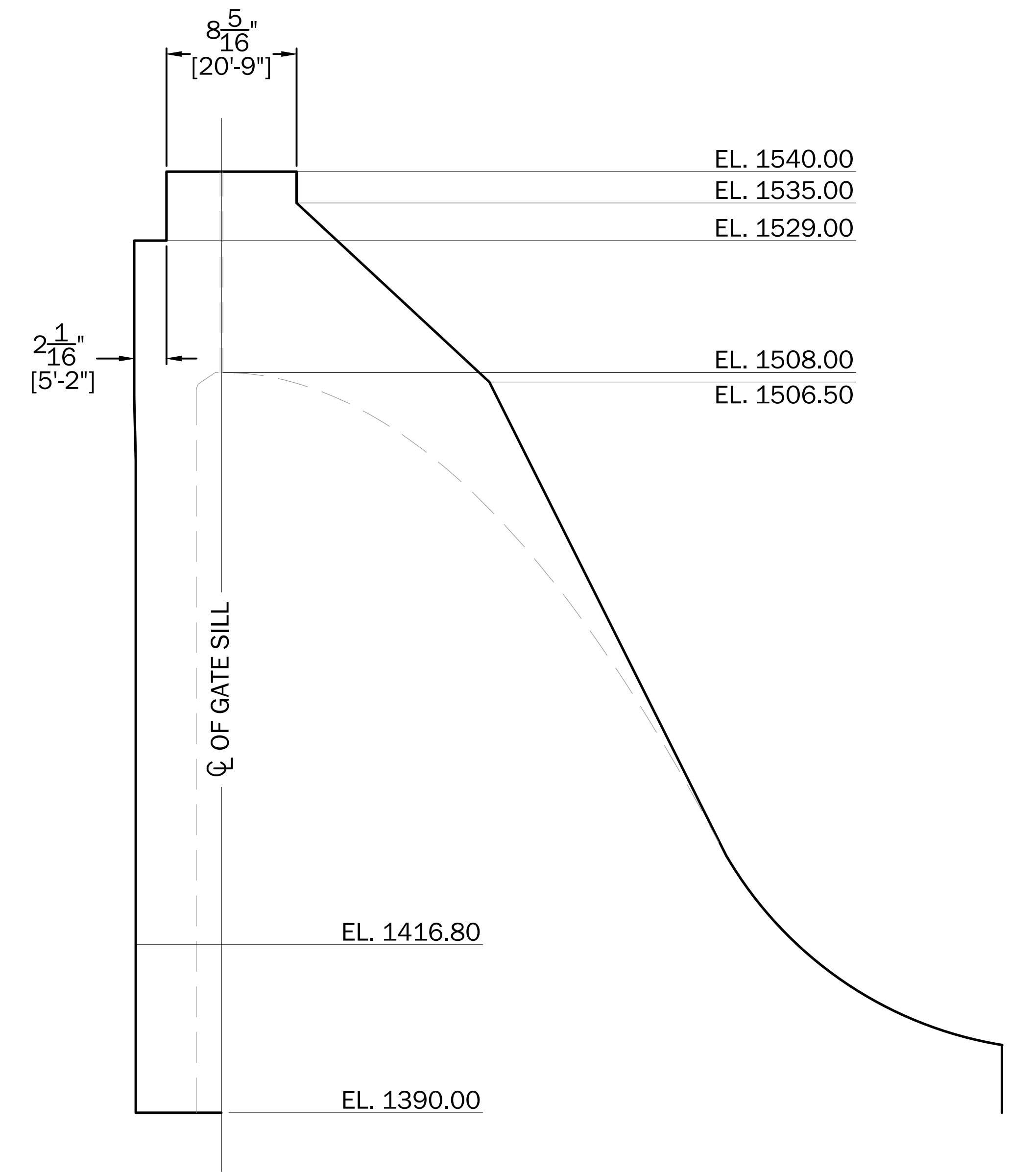
FIGURE 3-3



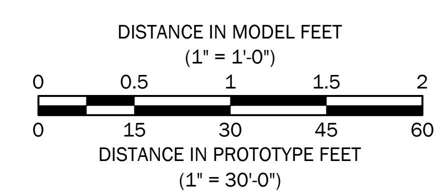
4
3-2
TYPICAL SECTION - PIERS 1 & 4



5
3-2
TYPICAL SECTION - PIERS 2 & 3



6
3-2
TYPICAL SECTION - PIERS 5, 6, & 7



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NOTES:

1. PRIMARY DIMENSIONS ARE GIVEN IN MODEL FEET.
2. SECONDARY [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET.
3. CONSTRUCTION TOLERANCE = ±1/8".
4. MODEL SCALE: 1 MODEL = 30 PROTOTYPE.

SCALE:	1" - 30'
REVISION NO:	
DRAWN BY:	KEH
DATE:	APR 2011
DRAWING NO:	21885

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LONG LAKE DAM TDG ABATEMENT FEASIBILITY PHASE III PHYSICAL MODEL STUDY

MODEL LAYOUT PIER SECTIONS

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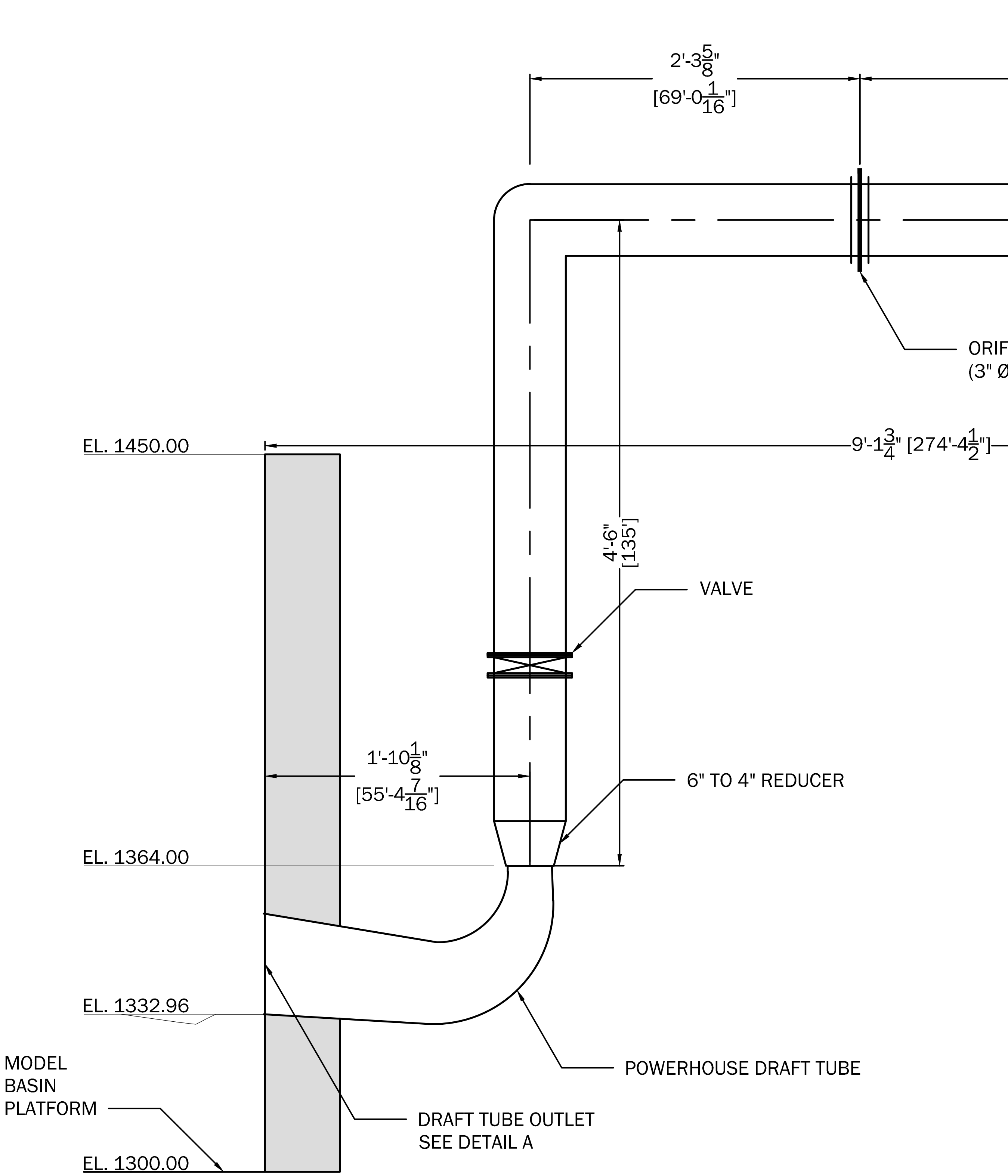
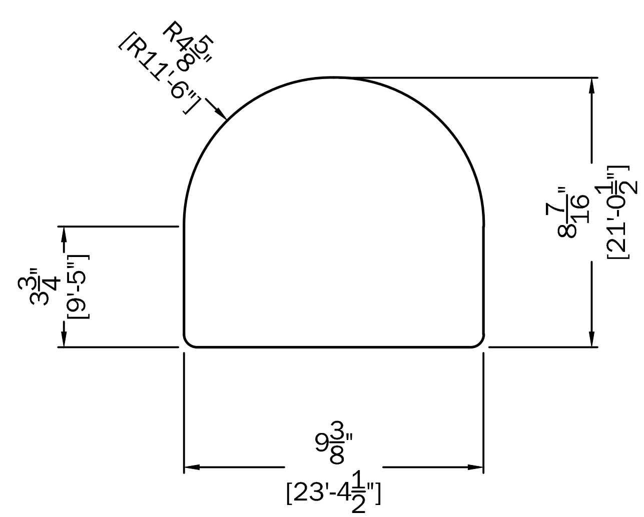
FIGURE 3-4



1 3-1 **TYPICAL SECTION - POWERHOUSE INLET AND DRAFT TUBE**



A - **DETAIL - DRAFT TUBE OUTLET**

DISTANCE IN MODEL FEET
(1" = 1'-0")
0 0.5 1 1.5 2
0 15 30 45 60
DISTANCE IN PROTOTYPE FEET
(1" = 30'-0")

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NOTES:

1. PRIMARY DIMENSIONS ARE GIVEN IN MODEL FEET.
2. SECONDARY [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET.
3. CONSTRUCTION TOLERANCE = ±1/8".
4. MODEL SCALE: 1 MODEL = 30 PROTOTYPE.

SCALE:	1" - 30'
REVISION NO:	
DRAWN BY:	KEH
DATE:	APR 2011
DRAWING NO:	21885

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LONG LAKE DAM TDG ABATEMENT FEASIBILITY PHASE III
PHYSICAL MODEL STUDY

MODEL LAYOUT
POWERHOUSE INTAKE AND DRAFT TUBE
SECTIONS

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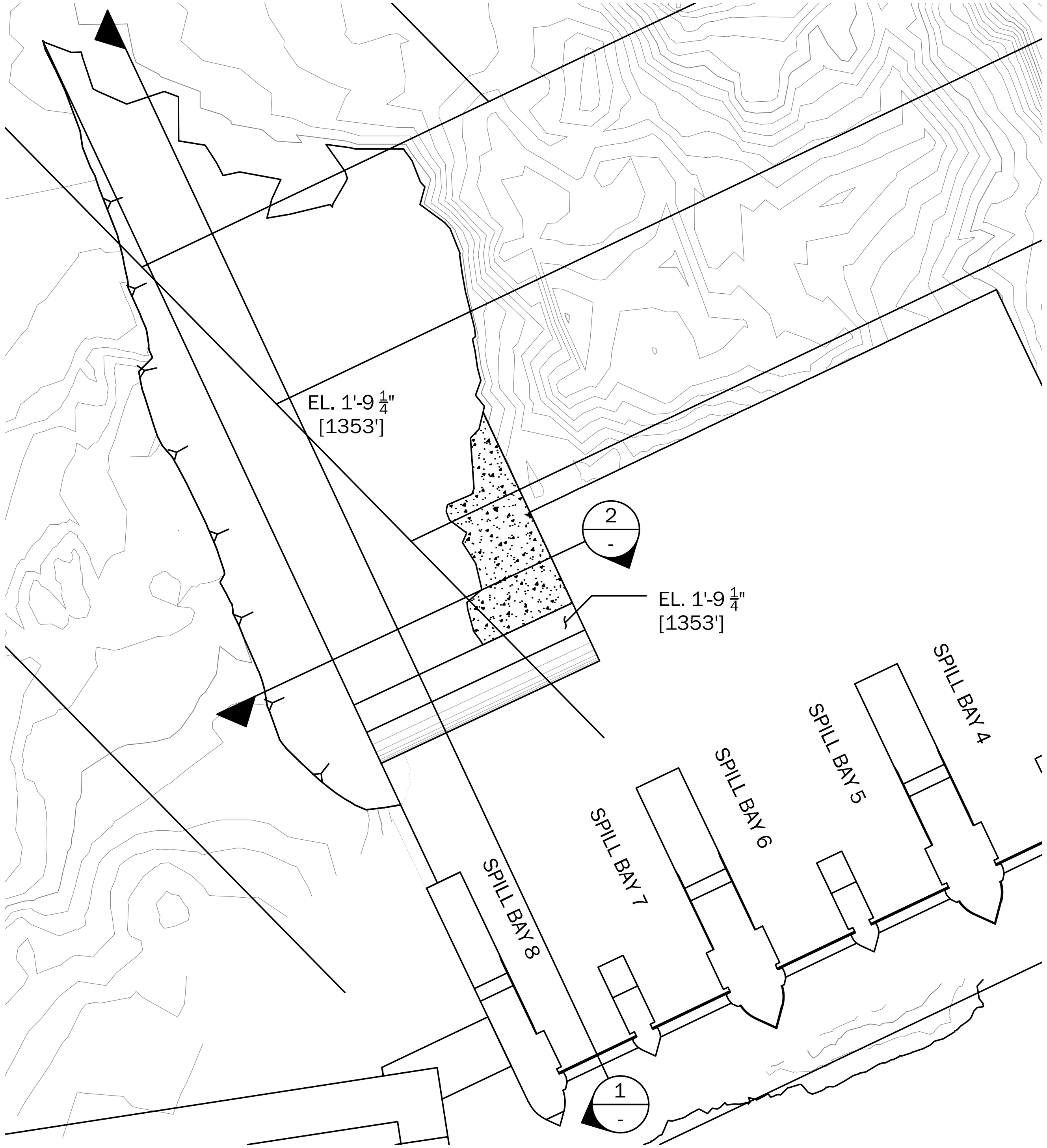
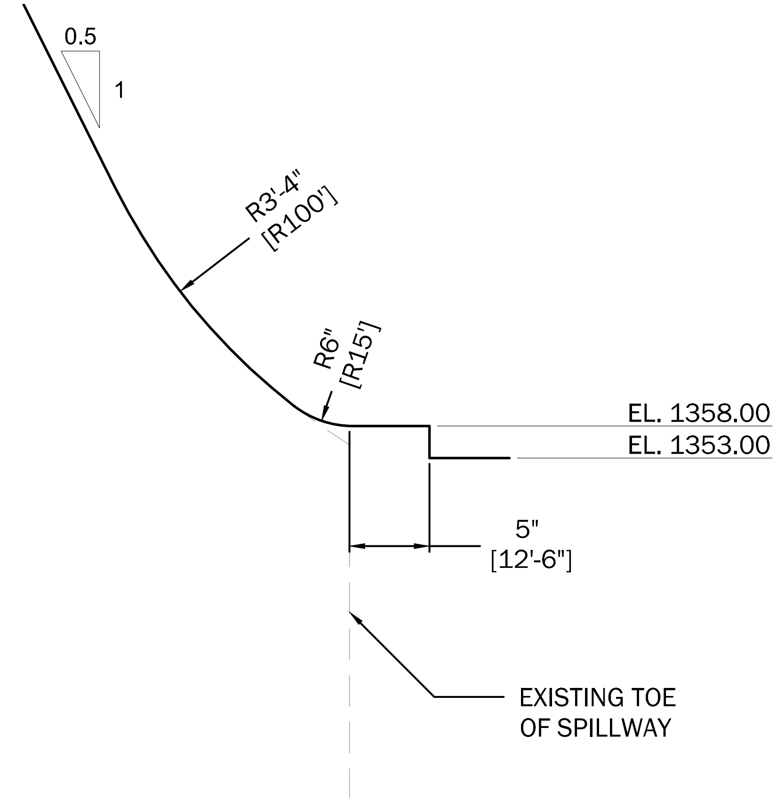
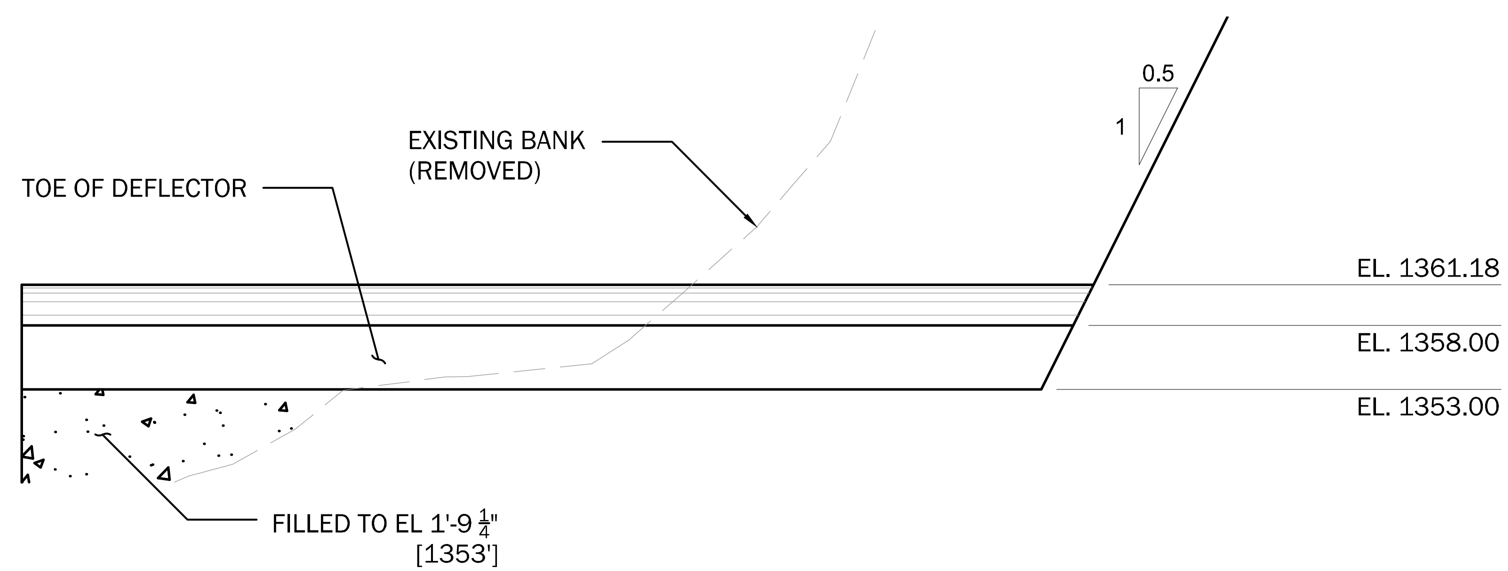
FIGURE 3-5





1 TYPICAL SECTION - SPILL BAY 7 & 8 DEFLECTORS
SCALE: 1" = 1'-0" (1" = 30'-0")



2 TYPICAL ELEVATION - SPILL BAY 7 & 8 DEFLECTORS
SCALE: 1" = 6" (1" = 15'-0")

DISTANCE IN MODEL FEET
(1" = 1'-0")
0 0.5 1 1.5 2
0 15 30 45 60
DISTANCE IN PROTOTYPE FEET
(1" = 30'-0")

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NOTES:

1. PRIMARY DIMENSIONS ARE GIVEN IN MODEL FEET.
2. SECONDARY [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET.
3. CONSTRUCTION TOLERANCE = ±1/8".
4. MODEL SCALE: 1 MODEL = 30 PROTOTYPE.

SCALE:	AS SHOWN
REVISION NO:	
DRAWN BY:	KEH
DATE:	APR 2011
DRAWING NO:	21885

AVISTA Utilities

**LONG LAKE DAM TDG ABATEMENT FEASIBILITY PHASE III
PHYSICAL MODEL STUDY**

**MODEL LAYOUT
ALTERNATIVE 1 - SPILL BAY 7 & 8 DEFLECTORS**

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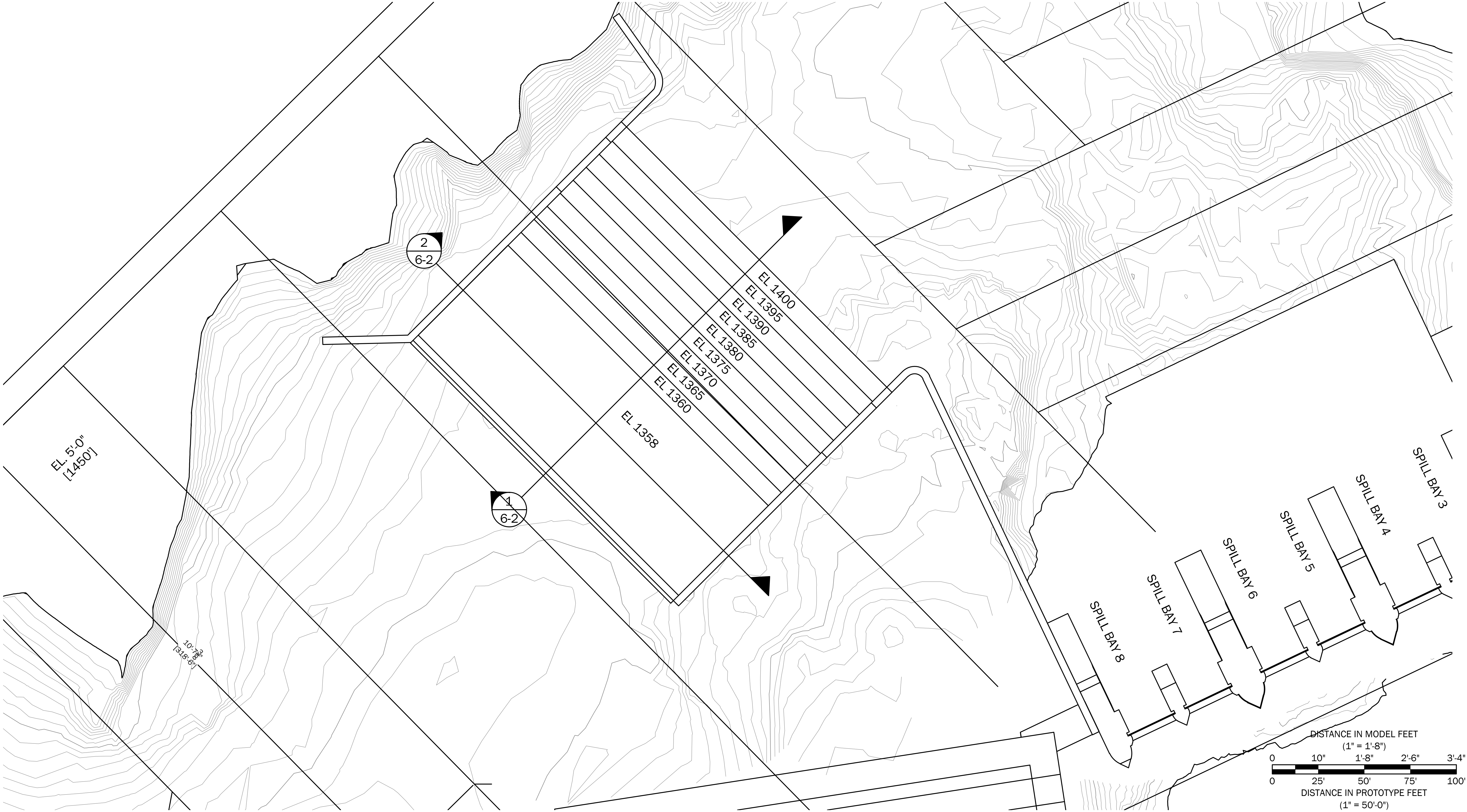
FIGURE 5-1



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NOTES:

1. PRIMARY DIMENSIONS ARE GIVEN IN MODEL FEET.
2. SECONDARY [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET.
3. CONSTRUCTION TOLERANCE = ±1/8".
4. MODEL SCALE: 1 MODEL = 30 PROTOTYPE.

SCALE:	AS SHOWN
REVISION NO:	
DRAWN BY:	KEH
DATE:	APR 2011
DRAWING NO:	21885

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LONG LAKE DAM TDG ABATEMENT FEASIBILITY PHASE III
PHYSICAL MODEL STUDY

MODEL LAYOUT
ALTERNATIVE 6 - STEPPED SPILLWAY
PLAN

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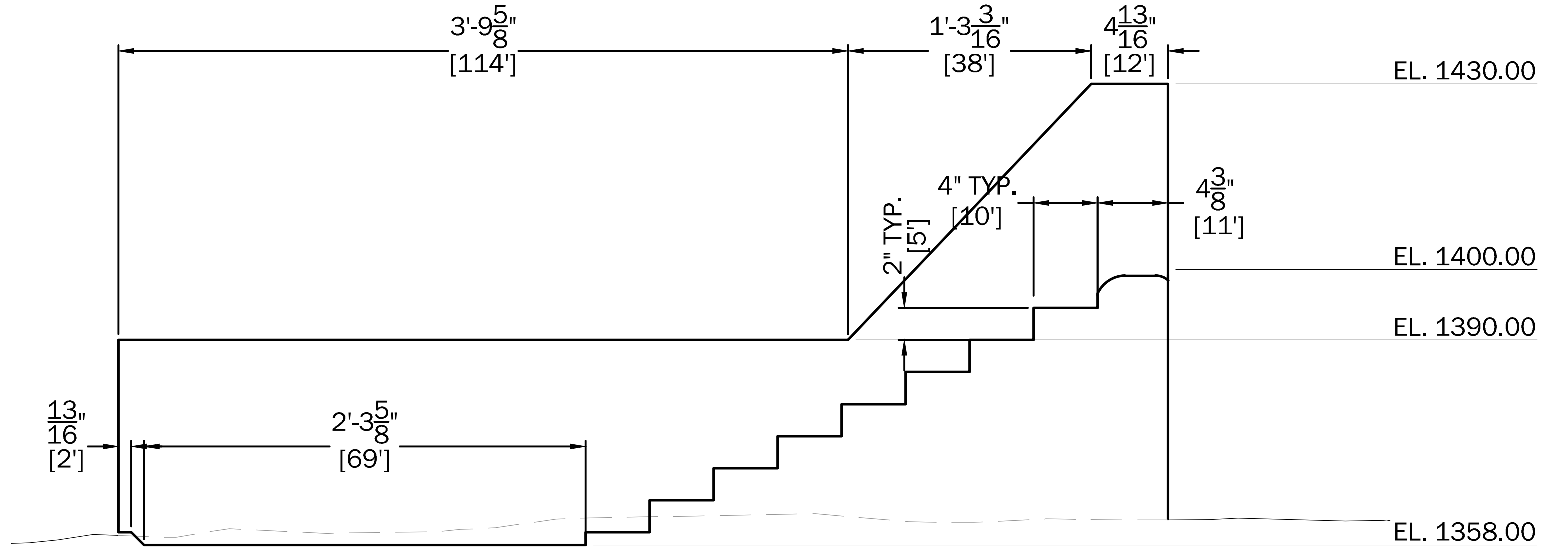
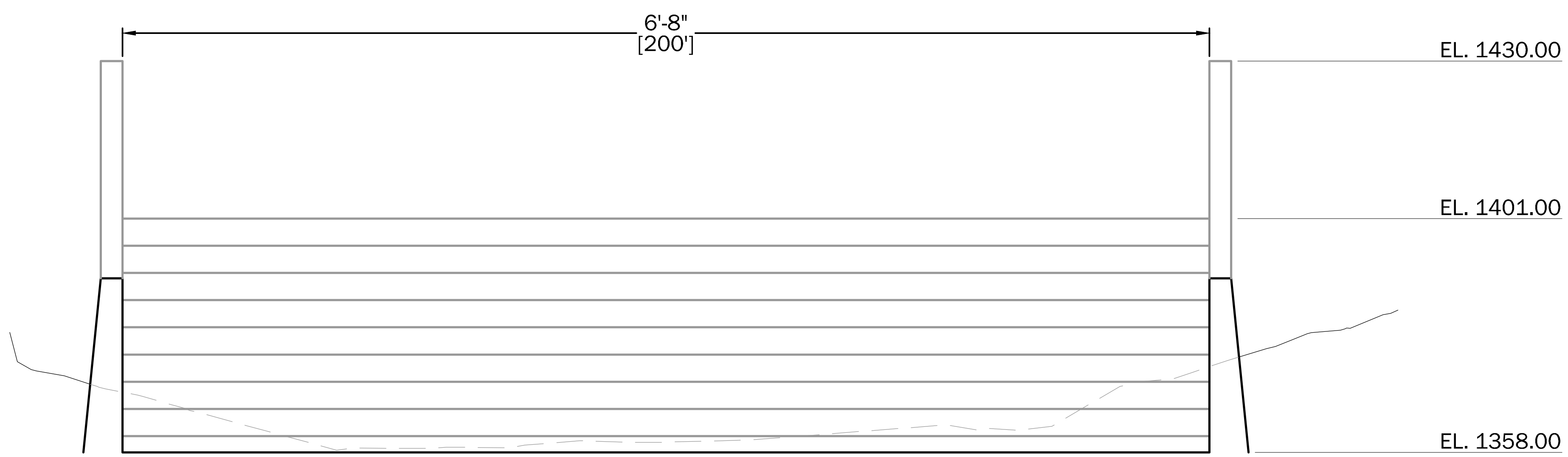
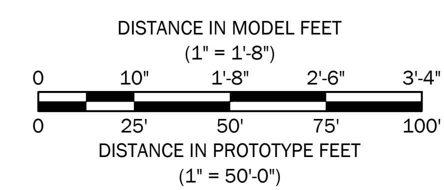
FIGURE 6-1



1 (6-1) TYPICAL SECTION - STEPPED SPILLWAY



2 (6-1) TYPICAL ELEVATION - STEPPED SPILLWAY



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NOTES:

1. PRIMARY DIMENSIONS ARE GIVEN IN MODEL FEET.
2. SECONDARY [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET.
3. CONSTRUCTION TOLERANCE = ±1/8".
4. MODEL SCALE: 1 MODEL = 30 PROTOTYPE.

SCALE:	AS SHOWN
REVISION NO:	
DRAWN BY:	KEH
DATE:	APR 2011
DRAWING NO:	21885

AVISTA Utilities

LONG LAKE DAM TDG ABATEMENT FEASIBILITY PHASE III
PHYSICAL MODEL STUDY

MODEL LAYOUT
ALTERNATIVE 6 - STEPPED SPILLWAY
TYPICAL SECTION AND ELEVATION

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FIGURE 6-2

REFERENCE FIGURES

PLAN

SCALE: 1"=50'

0' 50' 100'

N

GENERAL NOTES:

1. TOPOGRAPHIC SURVEY DATA PROVIDED BY AVISTA FOR THE AREAS ABOVE THE RESERVOIR AND STREAM WATER LEVEL.
2. BATHYMETRY IN THE TAILRACE AREA BASED ON 1990 DATA AS PROVIDED BY AVISTA. THE TOPOGRAPHIC AND BATHYMETRY MAPPING WERE TIED TOGETHER TO SERVE AS THE BASE MAP FOR THIS STUDY. THE TOE OF THE EXISTING SPILLWAY WAS ESTIMATED FROM THE AVAILABLE BATHYMETRY AND 1990 INSPECTION PHOTO'S.

SHEET NOTES:

1. CONSTRUCT NEW DEFLECTOR AT THE TOE OF SPILLWAY BAYS 7 AND 8. EXTEND THE DEFLECTOR ACROSS THE ENTIRE WIDTH OF THE SPILLWAY BAY.
2. REMOVE ROCK AND SLOPE AT 2V:1H SLOPE.
3. REMOVE ROCK KNOB TO ELEVATION 1353.0 FT. REMOVE ALL LOOSE ROCK AND MATERIAL TO PROVIDE A UNIFORM ROCK SURFACE.
4. FILL THE VOID BETWEEN THE ROCK SURFACE AND THE NEW SPILLWAY FLOW DEFLECTOR WITH CONCRETE. FORM A VERTICAL WALL ON THE EAST. INSTALL ROCK ANCHORS TO TIE CONCRETE TO ROCK SURFACE.

AVISTA UTILITIES

LONG LAKE HYDROELECTRIC DEVELOPMENT
TOTAL DISSOLVED GAS ABATEMENT –
PHASE 2 FEASIBILITY STUDY

ALTERNATIVE 1
SPILL BAY 7 - 8 DEFLECTORS
OVERALL PLAN

21758-002	REV. NO.: 0	DRN. BY: RWW	JUNE 2010

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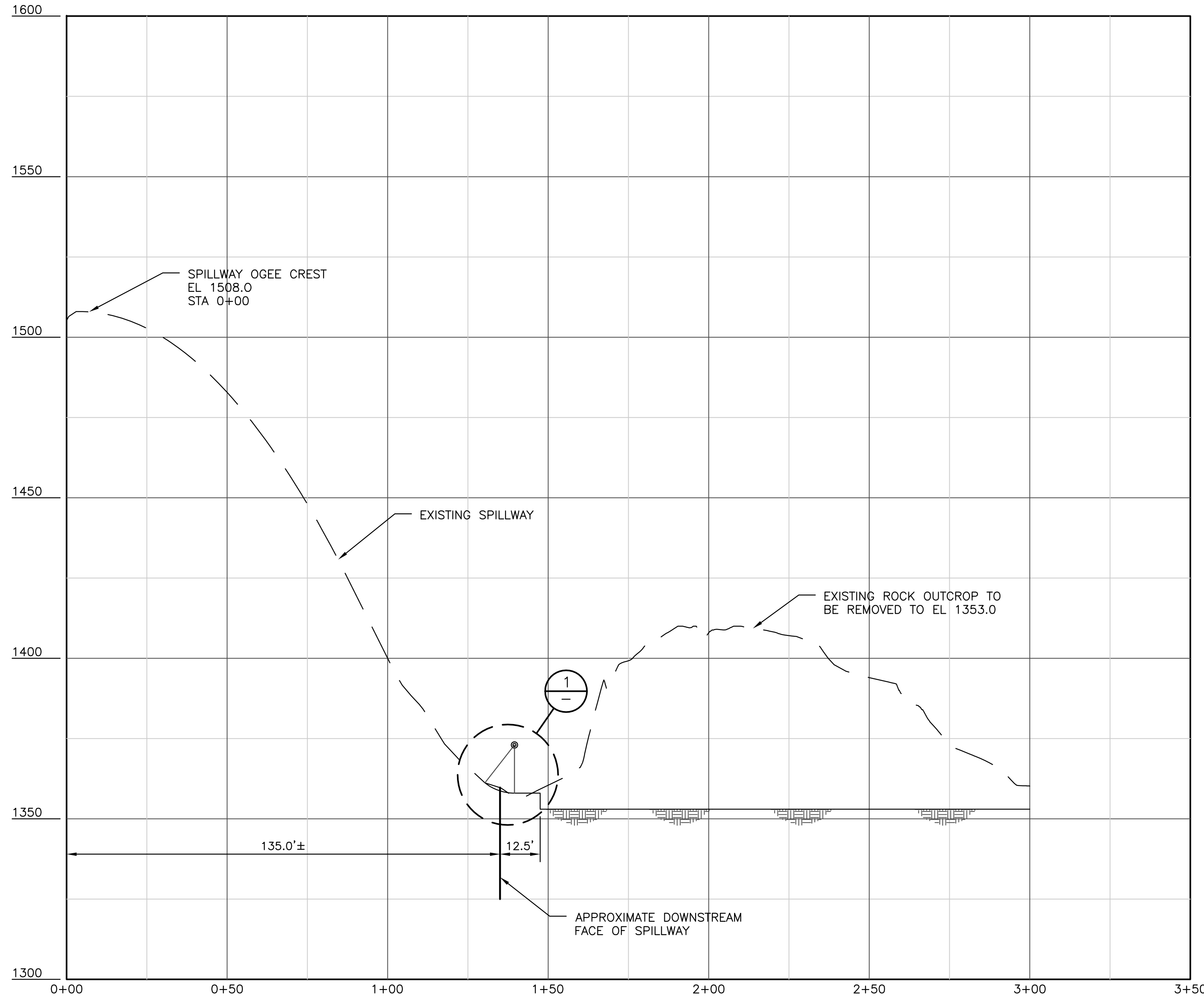
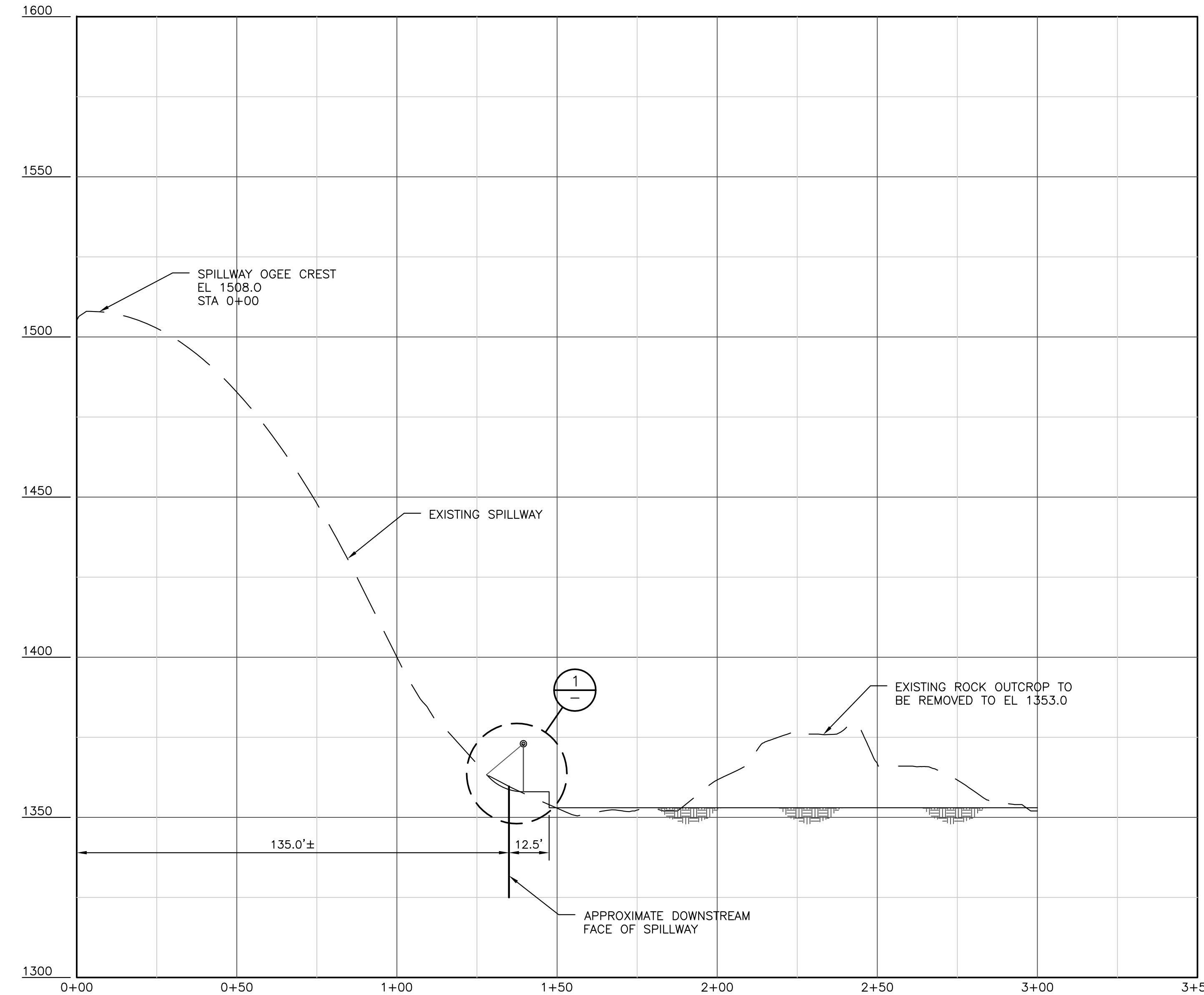
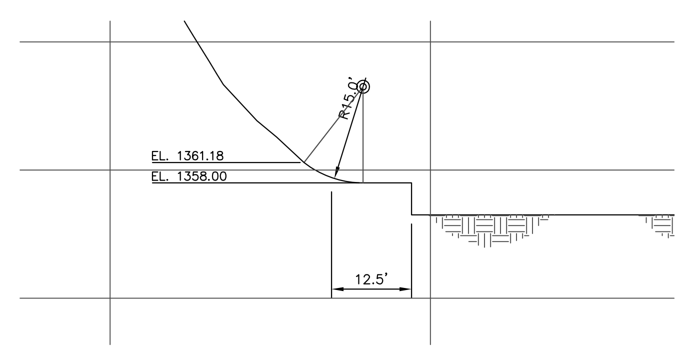
Drawing 100



SECTION A/100
SCALE: 1"= 50'



SECTION B/100
SCALE: 1"= 50'



DETAIL 1
SCALE: NTS

AVISTA UTILITIES

LONG LAKE HYDROELECTRIC DEVELOPMENT
TOTAL DISSOLVED GAS ABATEMENT –
PHASE 2 FEASIBILITY STUDY

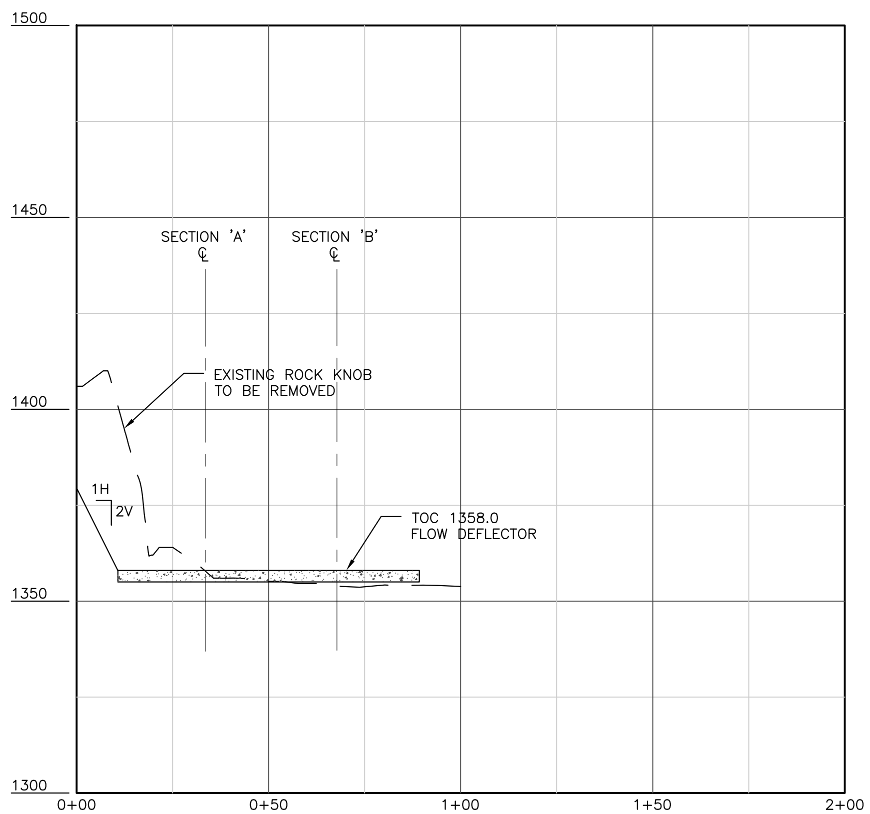
ALTERNATIVE 1
SPILL BAY 7 AND 8 DEFLECTORS
SECTIONS 1

21758–002	REV. NO.: 0	DRN. BY: RWW	JUNE 2010

nhc MCMILLEN, LLC

Drawing 101

Plot Date: Dec 08, 2010 – 11:49am Drawing File: P:\Avista\Long Lake (NHC)\7.0 Design\CAD_101-104.dwg



SECTION STA 1+47.0 C/100

SCALE: 1"= 50'

AVISTA UTILITIES

LONG LAKE HYDROELECTRIC DEVELOPMENT
TOTAL DISSOLVED GAS ABATEMENT –
PHASE 2 FEASIBILITY STUDY

ALTERNATIVE 1
SPILL BAY 7 AND 8 DEFLECTORS
SECTIONS 2

21758-002	REV. NO.: 0	DRN. BY: RWW	JUNE 2010

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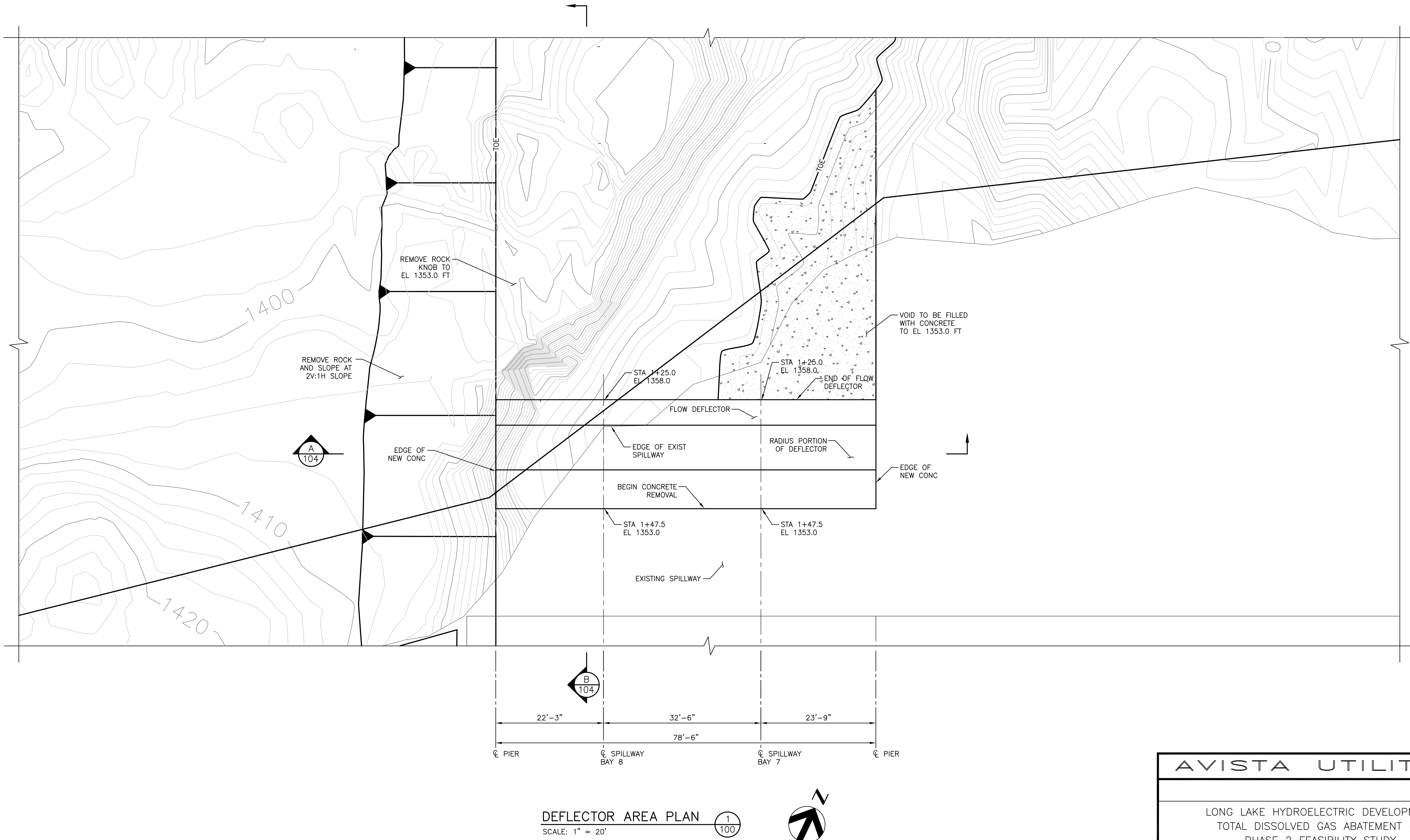
Drawing 102

Plot Date: Dec 08, 2010 – 11:49am Drawing File: P:\Avista\Long Lake (NHC)\7.0 Design\CAD_101-104.dwg



DEFLECTOR AREA PLAN 1/100
SCALE: 1" = 20'

AVISTA UTILITIES

LONG LAKE HYDROELECTRIC DEVELOPMENT
TOTAL DISSOLVED GAS ABATEMENT –
PHASE 2 FEASIBILITY STUDY

ALTERNATIVE 1
SPILL BAY 7-8 DEFLECTORS
DEFLECTOR AREA PLAN

21758–002	REV. NO.: 0	DRN. BY: RWW	JUNE 2010

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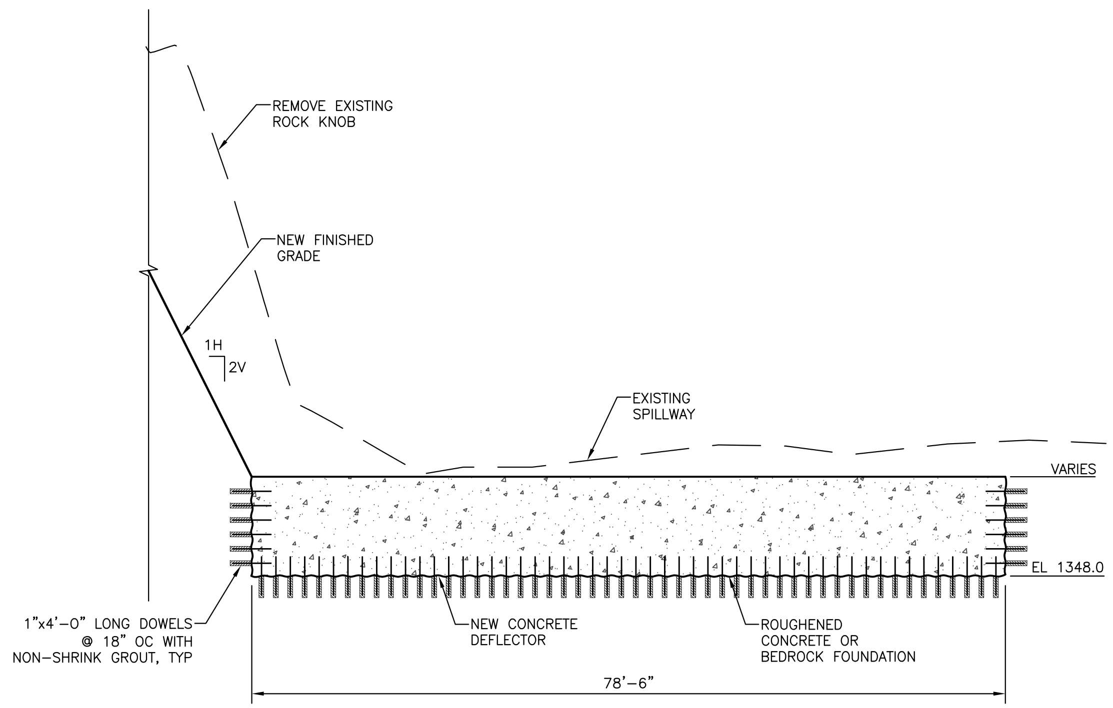
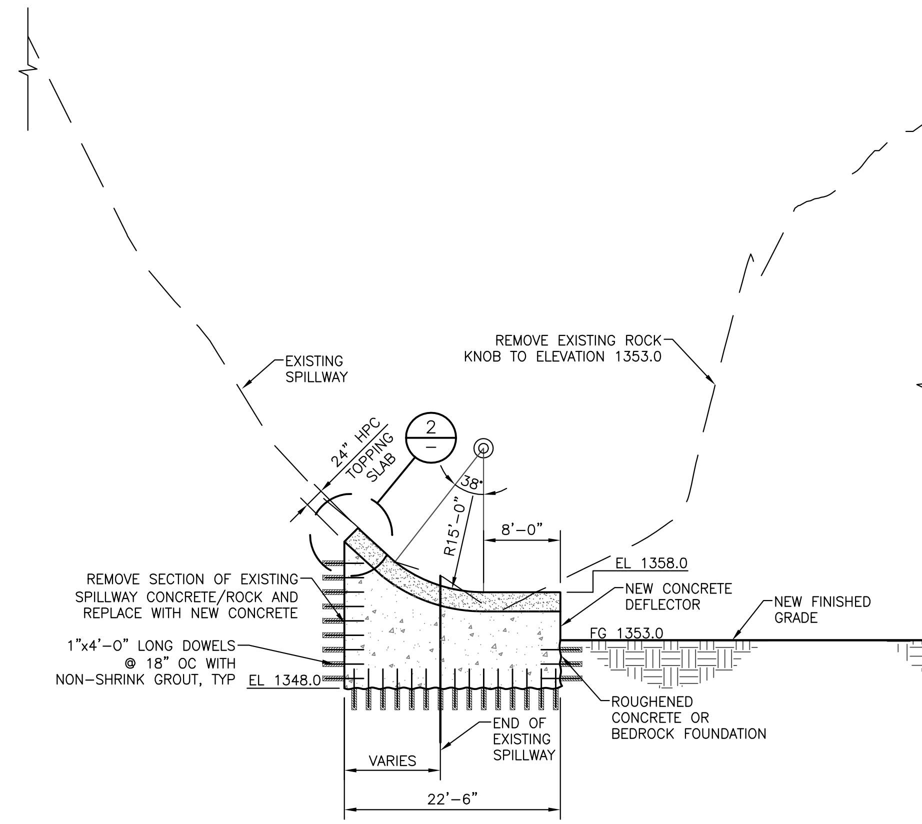
Plot Date: Dec 08, 2010 – 11:49am   Drawing File: P:\Avista\Long Lake (NHC)\7.0 Design\CAD_101-104.dwg

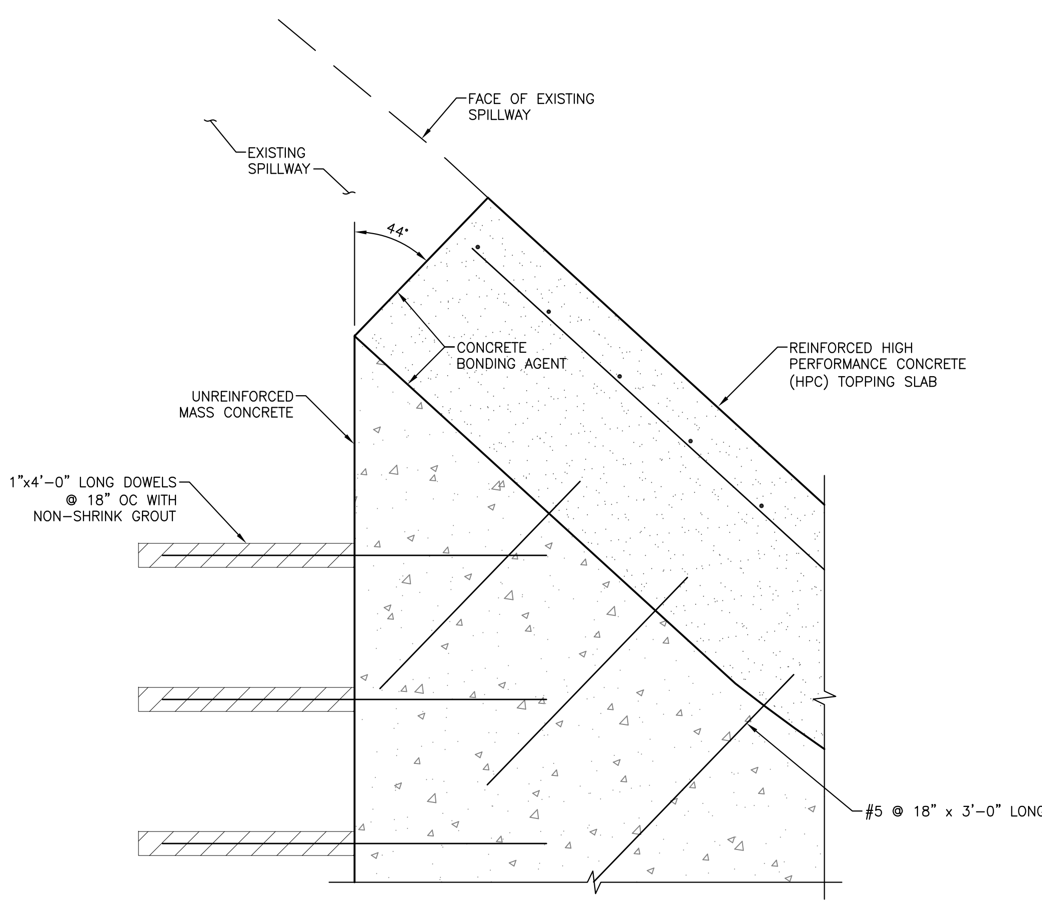
Drawing 103



SECTION A/103
SCALE: 1"=20'



SECTION B/103
SCALE: 1"=20'



DETAIL 2/–
SCALE: 1"=2'

AVISTA UTILITIES

LONG LAKE HYDROELECTRIC DEVELOPMENT
TOTAL DISSOLVED GAS ABATEMENT –
PHASE 2 FEASIBILITY STUDY

ALTERNATIVE 1
SPILL BAY 7-8 DEFLECTORS
DEFLECTOR AREA SECTIONS

21758–002	REV. NO.: 0	DRN. BY: RWW	JUNE 2010

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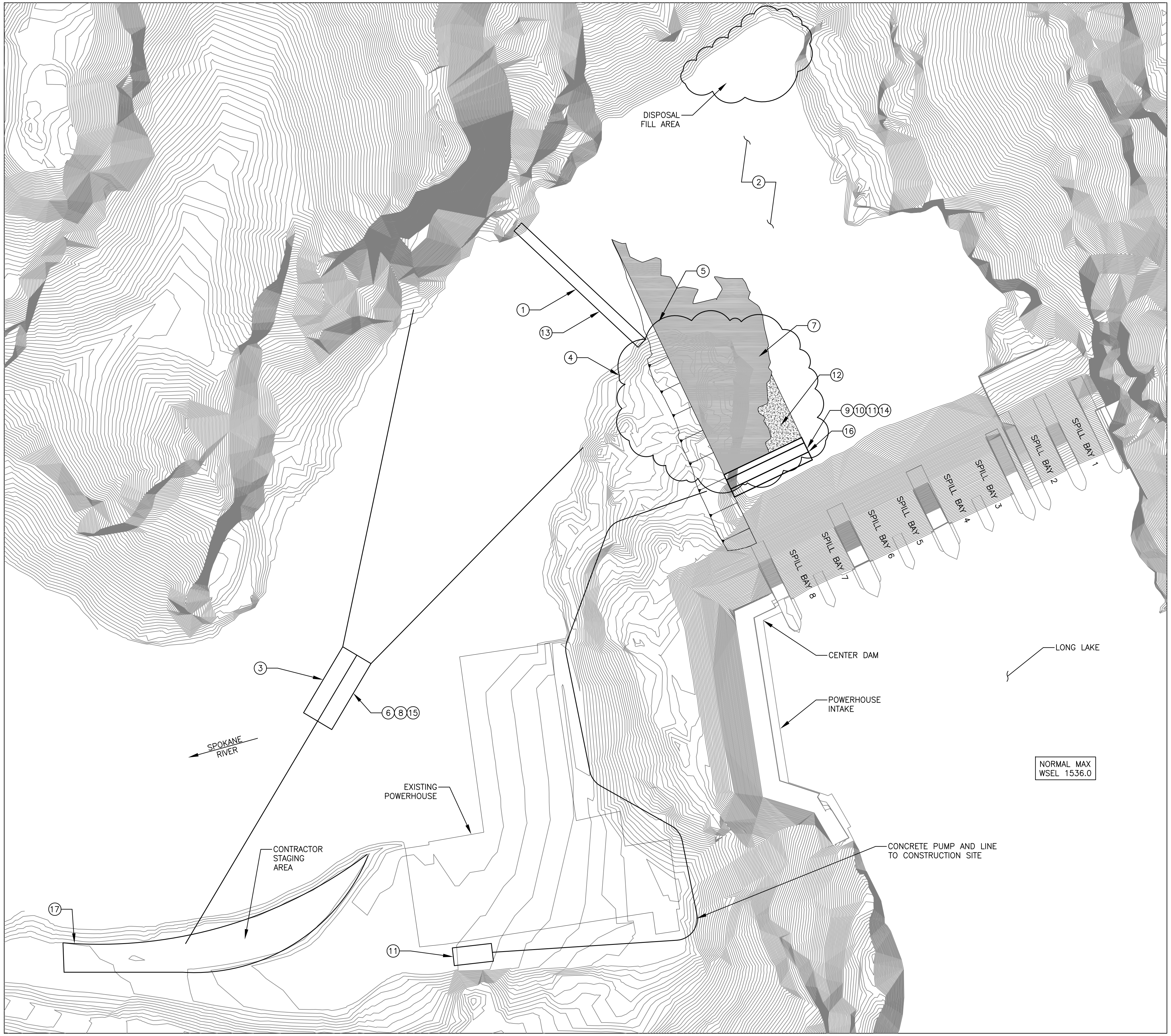
Plot Date: Dec 08, 2010 – 11:49am Drawing File: P:\Avista\Long Lake (NHC)\7.0 Design\CAD_101–104.dwg

Drawing 104



PLAN
SCALE: 1"=100'
0" 100' 200'

N

ANTICIPATED CONSTRUCTION SEQUENCE:

1. INSTALL COFFERDAM AT EXISTING CONCRETE SILL AND STOPLOG STRUCTURE LOCATION.
2. DEWATER TAILRACE AREA FROM TOE OF SPILLWAY TO COFFERDAM.
3. ASSEMBLE AND LAUNCH MODULAR BARGE WITH BANK MOUNTED DRIVE WINCHES.
4. SURVEY AND SET CONSTRUCTION STAKING.
5. HAND BLAST A WORK PLATFORM ON THE EXISTING ROCK ISLAND AS WELL AS ACCESS ROAD.
6. TRANSPORT EXCAVATOR AND DRILL RIG TO ROCK JETTY ON BARGE
7. DRILL, SHOOT, AND EXCAVATE ROCK. TRANSPORT TO DISPOSAL FILL AREA.
8. TRANSPORT DRILLING MACHINE AND MAN BASKET ON BARGE TO WORK AREA.
9. LINE DRILL AND BLAST SPILLWAY FACE. EXCAVATE AND HAUL MATERIALS ON BARGE FOR OFFSITE DISPOSAL.
10. DRILL AND DOWEL INTO EXISTING CONCRETE SPILLWAY.
11. MOBILIZE PUMP TRUCK AND FORM AND POUR FIRST LIFT ON SPILLWAY.
12. ERECT TEMPORARY COFFERDAM AROUND SPILLWAY DEFLECTOR CONSTRUCTION.
13. REMOVE MAIN COFFERDAM IN PROJECT TAILRACE.
14. FORM AND PLACE CONCRETE IN LIFTS ON SPILLWAY FACE.
15. BARGE REMAINING MATERIALS OUT OF CONSTRUCTION SITE.
16. REMOVE TEMPORARY COFFERDAM AROUND CONCRETE FLOW DEFLECTOR.
17. DEMOBILIZE FROM SITE.

AVISTA UTILITIES

LONG LAKE HYDROELECTRIC DEVELOPMENT
TOTAL DISSOLVED GAS ABATEMENT –
PHASE 2 FEASIBILITY STUDY

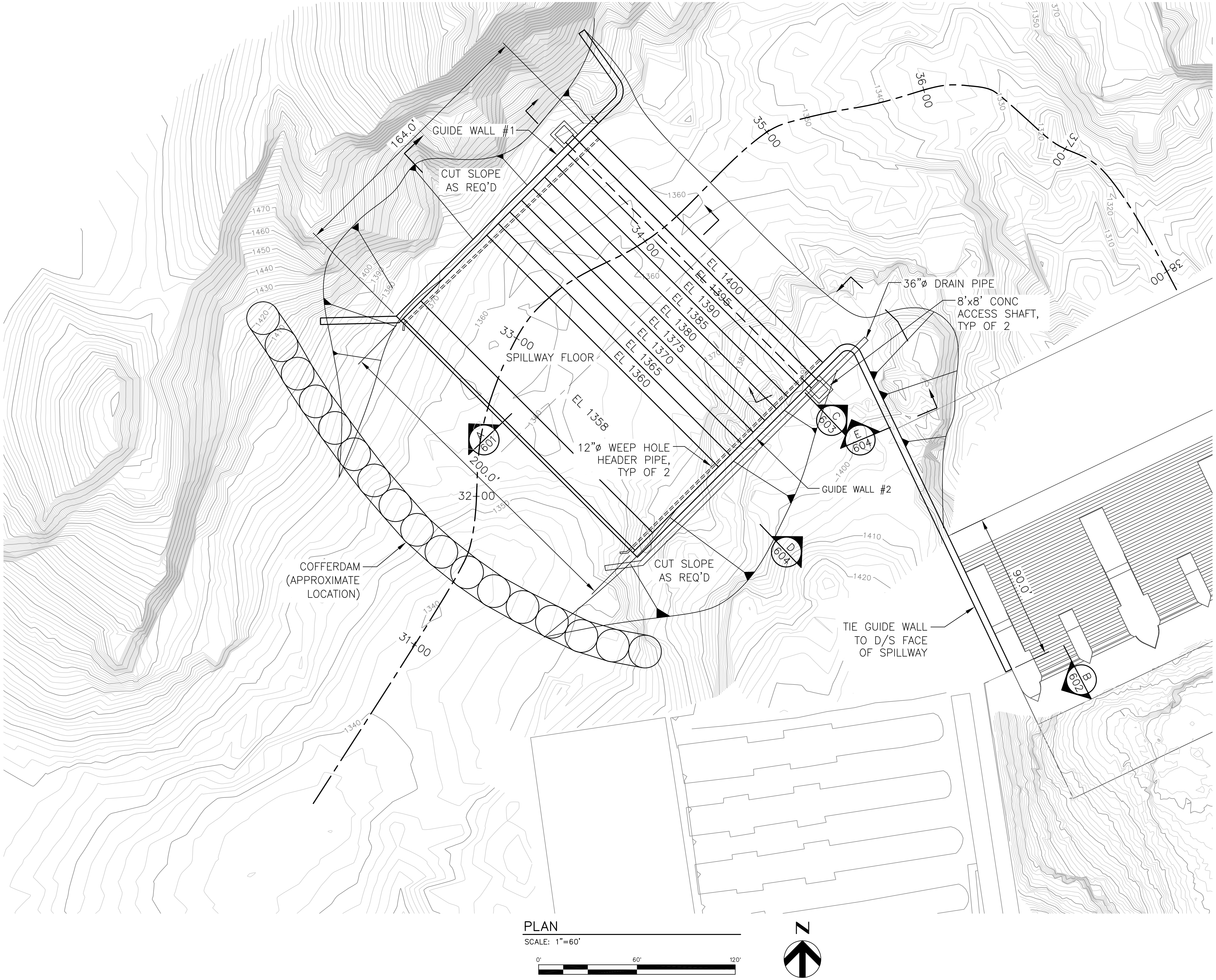
ALTERNATIVE 1
CONSTRUCTION SEQUENCE PLAN

21758-002	REV. NO.: 0	DRN. BY: RLG	JUNE 2010

nhc
McMILLEN, LLC

Plot Date: Dec 08, 2010 – 11:49am Drawing File: P:\Avista\Long Lake (NHC)\7.0 Design\CAD_105.dwg

Drawing 105



Plot Date: Dec 08, 2010 – 11:51am Drawing File: P:\Avista\Long Lake (NHC)\7.0 Design\CAD_600.dwg

AVISTA UTILITIES

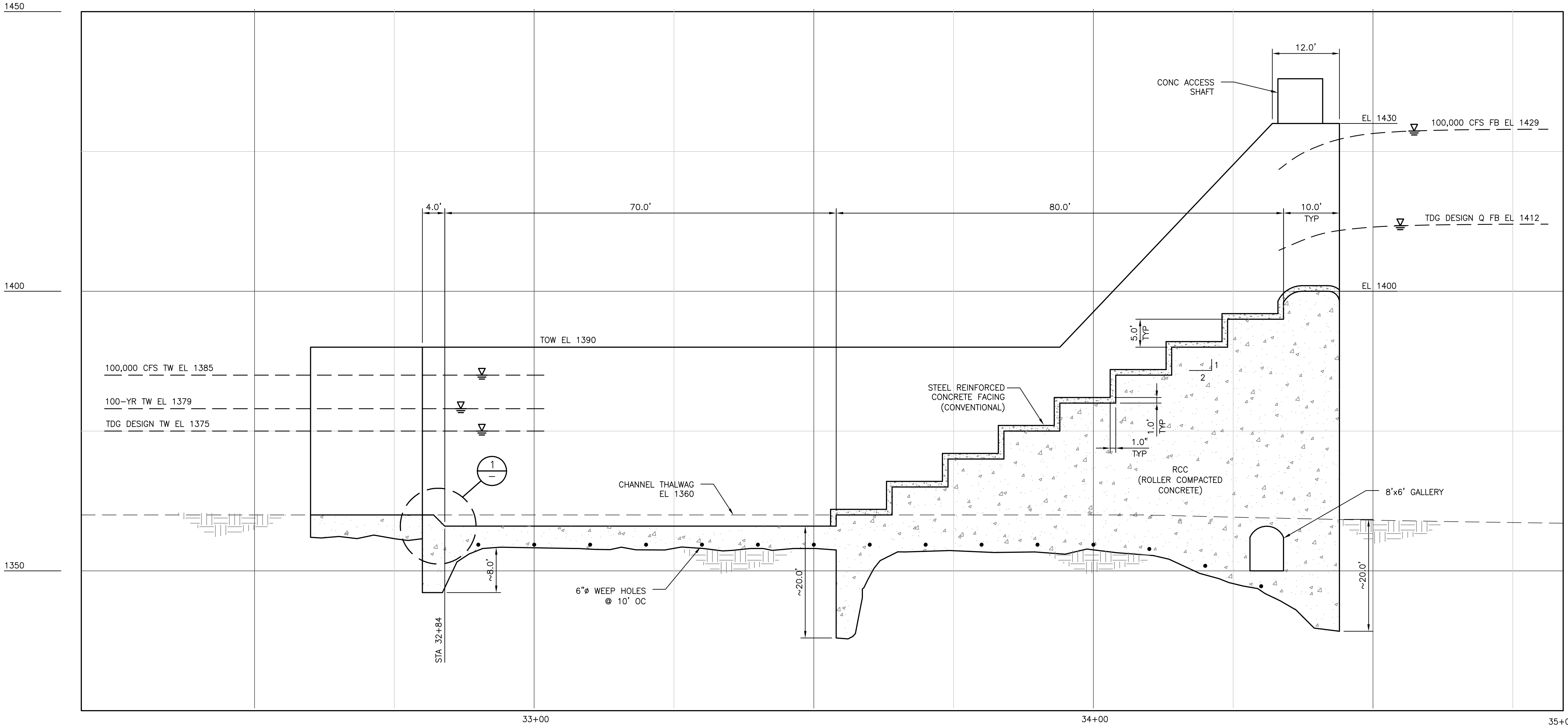
LONG LAKE HYDROELECTRIC DEVELOPMENT
TOTAL DISSOLVED GAS ABATEMENT –
PHASE 2 FEASIBILITY STUDY

ALTERNATIVE 6
STEPPED SPILLWAY PLAN

21758–002	REV. NO.: 0	DRN. BY: RWW	JUNE 2010

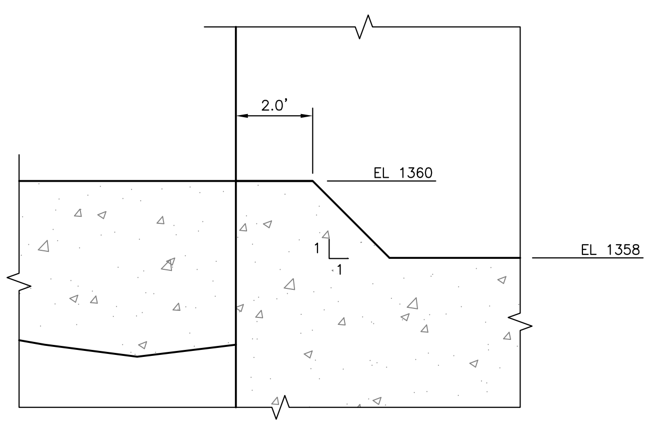
nhc McMILLEN, LLC

Drawing 600



SECTION A/600
SCALE: 1" = 20'

NOTE:
CUTOFF WALL(S) DEPTH TBD BASED ON FOUNDATION INVESTIGATION.



DETAIL 1
SCALE: NTS

Plot Date: Dec 08, 2010 – 11:51am Drawing File: P:\Avista\Long Lake (NHC)\7.0 Design\CAD_601-604.dwg

AVISTA UTILITIES

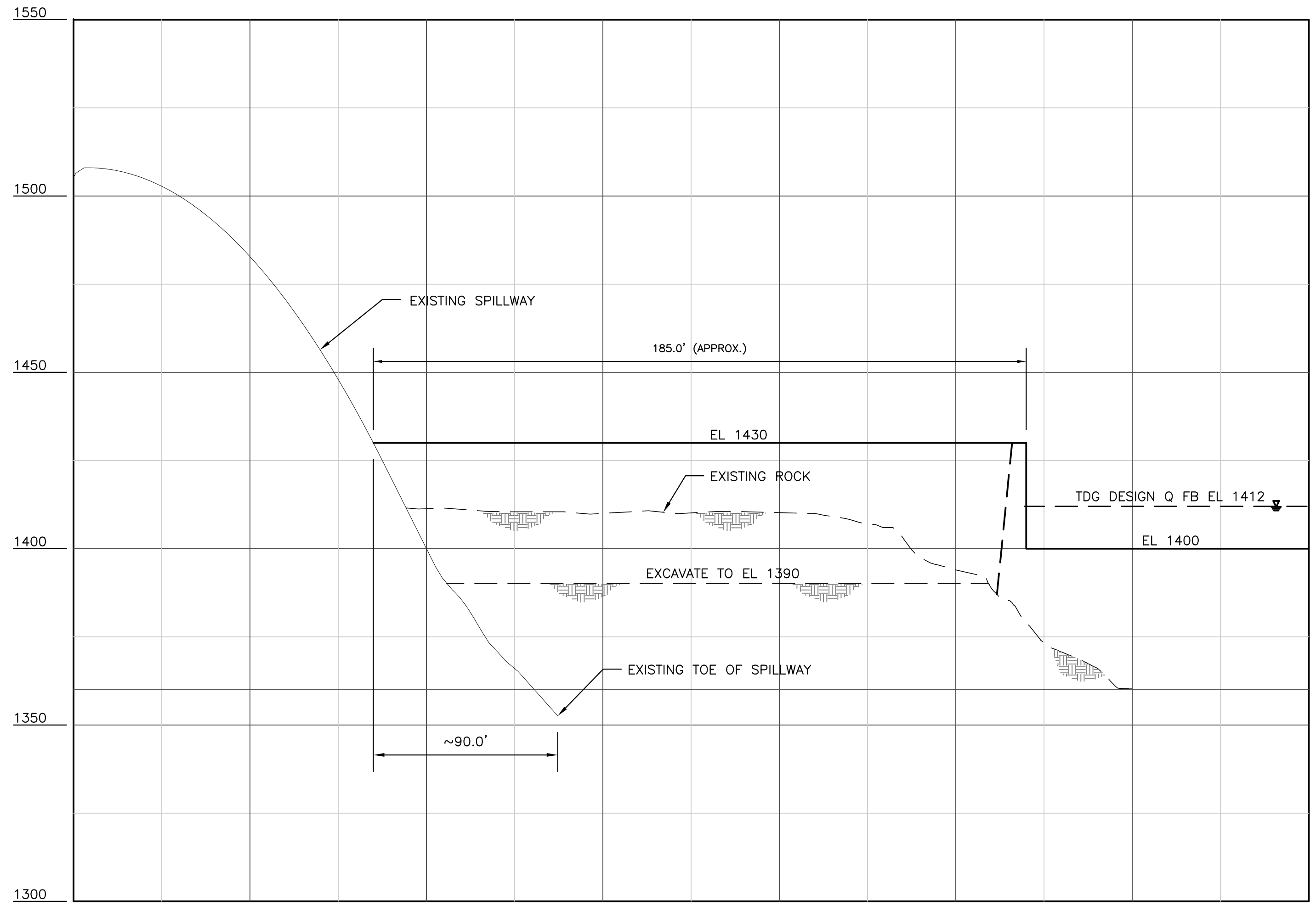
LONG LAKE HYDROELECTRIC DEVELOPMENT
TOTAL DISSOLVED GAS ABATEMENT –
PHASE 2 FEASIBILITY STUDY

ALTERNATIVE 6
STEPPED SPILLWAY PLAN
SECTIONS AND DETAILS

21758-002	REV. NO.: 0	DRN. BY: RLG	JUNE 2010

nhc MCMILLEN, LLC

Drawing 601



SECTION B/600
SCALE: 1"= 50'

0' 50' 100'

AVISTA UTILITIES

LONG LAKE HYDROELECTRIC DEVELOPMENT
TOTAL DISSOLVED GAS ABATEMENT –
PHASE 2 FEASIBILITY STUDY

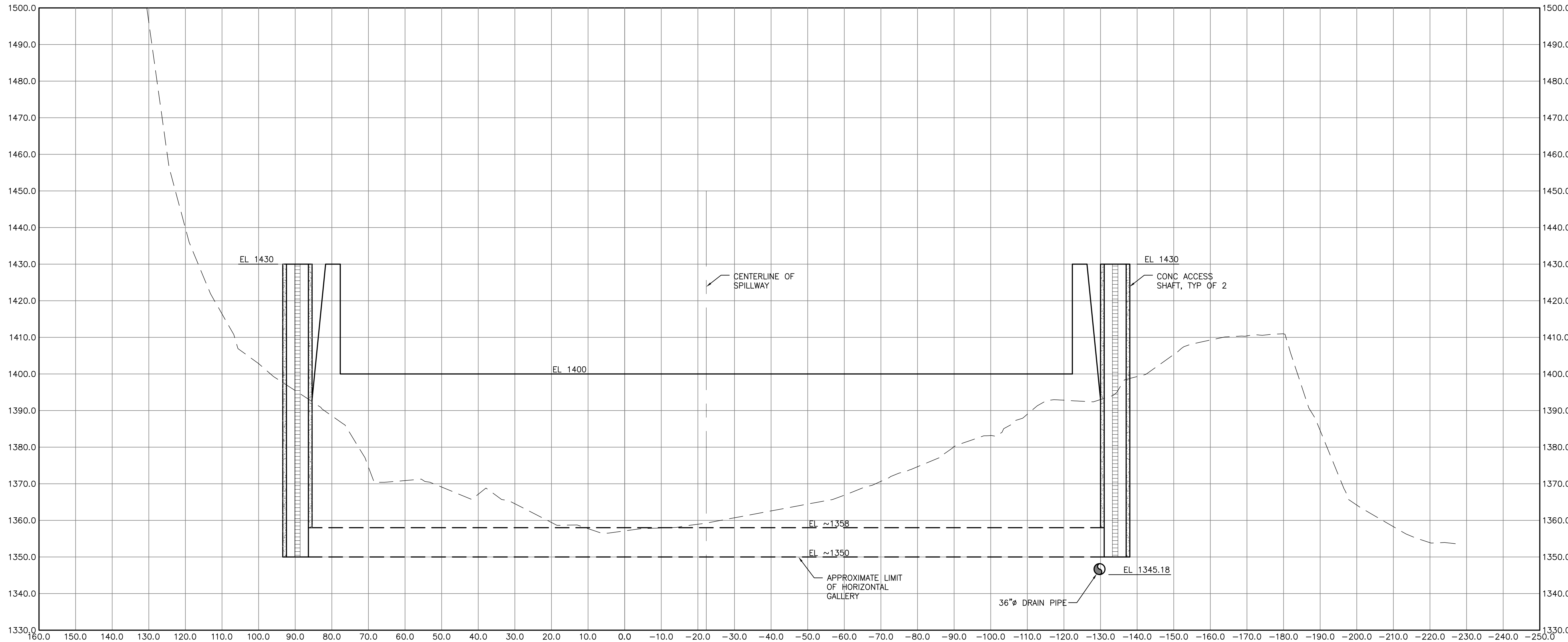
ALTERNATIVE 6
STEPPED SPILLWAY PLAN
SECTIONS 1

21758–002	REV. NO.: 0	DRN. BY: RLG	JUNE 2010

nhc MCMILLEN, LLC

Drawing 602

Plot Date: Dec 08, 2010 – 11:51am Drawing File: P:\Avista\Long Lake (NHC)\7.0 Design\CAD_601-604.dwg



SECTION C

SCALE: 1" = 30'

0' 30' 60'

AVISTA UTILITIES

LONG LAKE HYDROELECTRIC DEVELOPMENT
TOTAL DISSOLVED GAS ABATEMENT –
PHASE 2 FEASIBILITY STUDY

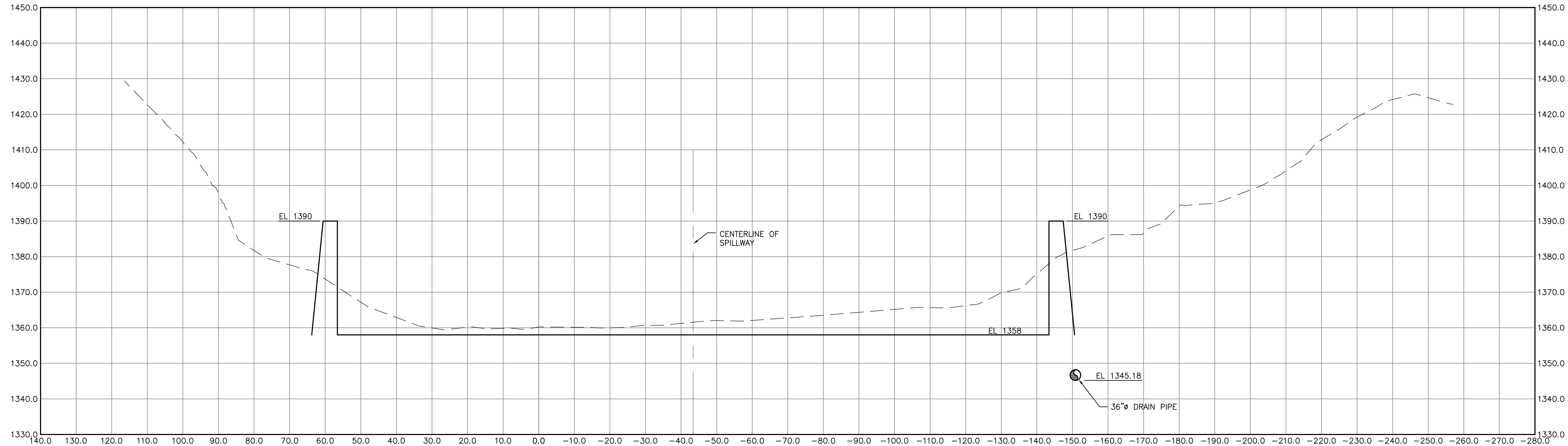
ALTERNATIVE 6
STEPPED SPILLWAY PLAN
SECTIONS 2

21758–002	REV. NO.: 0	DRN. BY: RLG	JUNE 2010

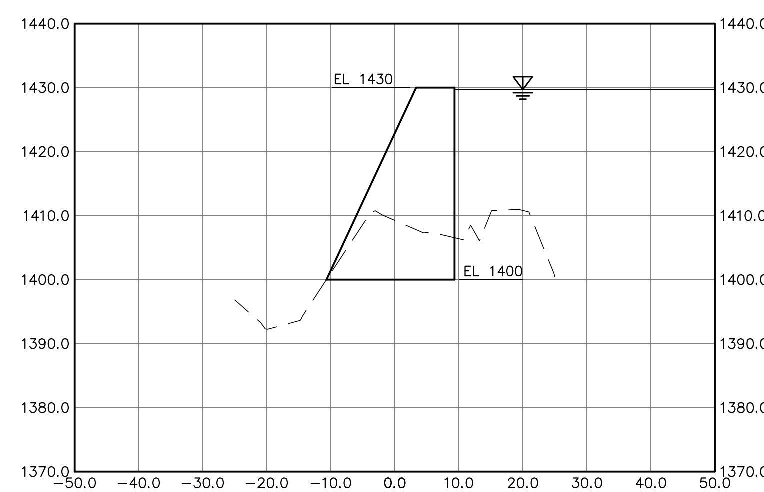
nhc McMILLEN, LLC

Drawing 603

Plot Date: Dec 08, 2010 – 11:51am Drawing File: P:\Avista\Long Lake (NHC)\7.0 Design\CAD_601–604.dwg



SECTION D
SCALE: 1" = 30'



SECTION E
SCALE: 1" = 30'

AVISTA UTILITIES

LONG LAKE HYDROELECTRIC DEVELOPMENT
TOTAL DISSOLVED GAS ABATEMENT –
PHASE 2 FEASIBILITY STUDY

ALTERNATIVE 6
STEPPED SPILLWAY PLAN
SECTIONS 3

21758–002	REV. NO.: 0	DRN. BY: RLG	JUNE 2010

nhc MCMILLEN, LLC

Drawing 604

PHOTO PLATES

Photo 1: Overview of the Long Lake Physical Model, looking upstream.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Model Overview
PHOTO PLATE 3-1

***Photo 1**:* Upstream view of the spillway, plunge pool, and rock outcrop.
(Construction Photo: Prior to installation of pier structures and gates)

***Photo 2**:* Downstream view of the plunge pool and spillway toe.
(Construction Photo)

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Model Details
PHOTO PLATE 3-2

Photo 3: Upstream view of the powerhouse.
(Construction Photo: Diffuser screen and penstocks not installed yet.)

Photo 4: Acrylic draft tubes.
(Construction Photo: Prior to valve and penstock installation

Model Details
PHOTO PLATE 3-2

***Photo 1**: Two of the Three* Laboratory pumps supplying water to the model.

Photo 2: Manometer boards used to measure deflection and measure flow.

Photo 3: tilling wells used to measure pressure tap readings from the model.

Photo 4: Dynasonic transit time flow meter for measuring flows.

Photo 5*: Values used to control the individual discharge for each powerhouse unit.*

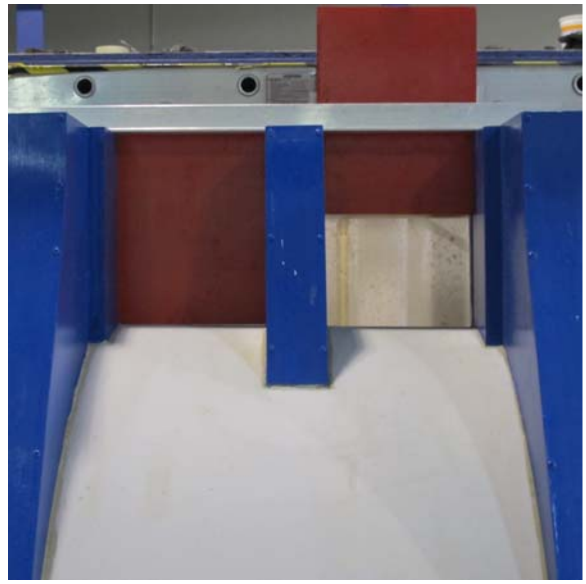


Photo 6: Individual slide gates used to control spillway discharges.

Photo 7: Tailgate which is used to control the tailwater condition.

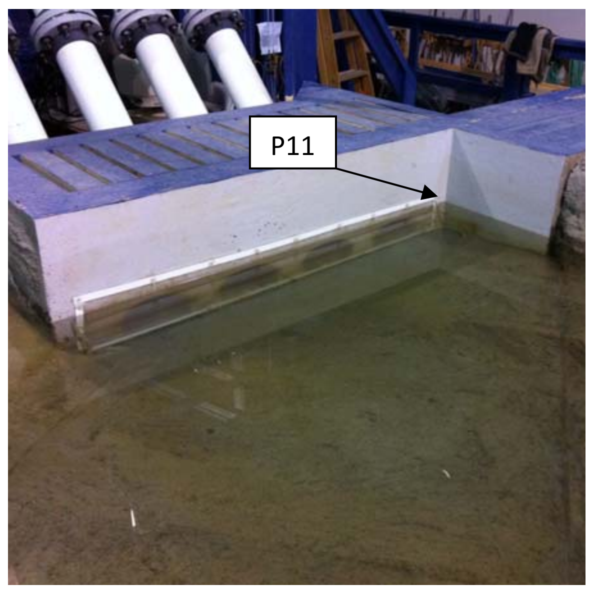


***Photo 8*:** The model tailwater was measured at P11 near the powerhouse.

Model Controls and Instrumentation
PHOTO PLATE 3-3

Photo 1: Long Lake Hydroelectric Project, 26,500 cfs River Discharge, June 15th, 2011, observed from viewpoint off HWY-291

Photo 2: Long Lake physical model from comparable perspective to HWY-291 viewpoint.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Calibration Testing
Total River Discharge: 26,500 cfs
PHOTO PLATE 4-1

Photo 3: Long Lake Hydroelectric Project, 26,500 cfs River Discharge, June 15th, 2011, observed from powerhouse access road on the left bank.

Photo 4: Long Lake physical model from comparable perspective on left bank.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Calibration Testing
Total River Discharge: 26,500 cfs
PHOTO PLATE 4-1

Photo 1: Looking upstream at spillway and plunge pool.

Photo 2: Looking downstream from the spillway crest at the plunge pool.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Baseline Test 1
Total River Discharge: 32,300 cfs
PHOTO PLATE 4-2

Photo 3: Looking upstream from the left bank towards the powerhouse.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Baseline Test 1
Total River Discharge: 32,300 cfs
PHOTO PLATE 4-2

Photo 1: Looking upstream at spillway and plunge pool.

Photo 2: Looking downstream from the spillway crest at the plunge pool.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Baseline Test 2
Total River Discharge: 15,300 cfs
PHOTO PLATE 4-3

Photo 3: Looking upstream towards the powerhouse.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Baseline Test 2
Total River Discharge: 15,300 cfs
PHOTO PLATE 4-3

Photo 1: Looking upstream at spillway and plunge pool.

Photo 2: Looking downstream from the spillway crest at the plunge pool.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Baseline Test 3
Total River Discharge: 50,000 cfs
PHOTO PLATE 4-4

Photo 3: Looking upstream towards the powerhouse.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Baseline Test 3
Total River Discharge: 50,000 cfs
PHOTO PLATE 4-4

Photo 1: 1000 cfs Spillway Discharge – Bay 8 – submerged surface jump flow regime*.*

Photo 2: 25,000 cfs Spillway Discharge – Bays 7-8 – submerged surface jump flow regime

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Configuration 1
Deflector Elevation 1358 ft
PHOTO PLATE 5-1

Photo 1: 10,000 cfs Spillway Discharge – Bays 5-8 – ramped surface jet flow regime.

Photo 2: 25,000 cfs Spillway Discharge – Bays 3-8 – ramped surface jet flow and surface jump.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Configuration 2
Deflector Elevation 1363 ft
PHOTO PLATE 5-2

Photo 1: 5,000 cfs Spillway Discharge – Bays 7-8 – skimming flow regime.

Photo 2: 25,000 cfs Spillway Discharge – Bays 5-8 – ramped surface jet flow regime.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Configuration 3
Deflector Elevation 1368 ft
PHOTO PLATE 5-3

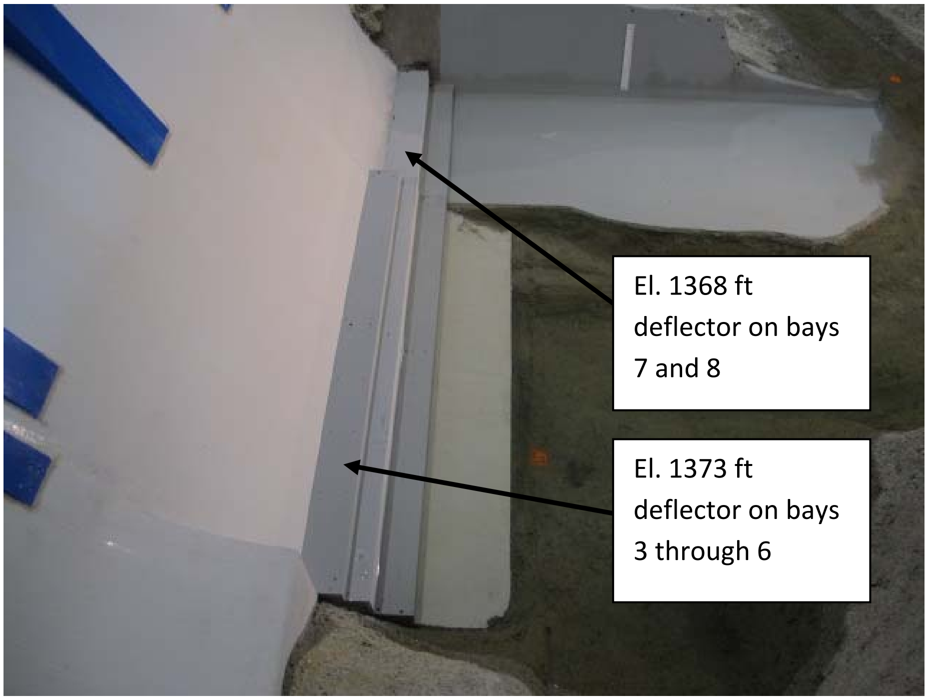


Photo 1: Elevation 1368 ft and 1373 ft deflectors, model not running.

Photo 2: 1,000 cfs Spillway Discharge – Bay 8 – plunging flow.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Configuration 4
Deflector Elevations 1368 ft and 1373 ft
PHOTO PLATE 5-4

Photo 3: 5,000 cfs Spillway Discharge – Bays 7-8 – skimming flow regime.

Photo 4: 10,000 cfs Spillway Discharge – Bays 7-8 – skimming to ramped surface jet.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Configuration 4
Deflector Elevations 1368 ft and 1373 ft
PHOTO PLATE 5-4

Photo 5: 10,000 cfs Spillway Discharge – Bays 5-8 – skimming (Bay 7&8), plunging (Bays 5&6)

Photo 6: 16,000 cfs Spillway Discharge – Bays 5-8 – skimming to ramped surface jet.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Configuration 4
Deflector Elevations 1368 ft and 1373 ft
PHOTO PLATE 5-4

Photo 7: 20,000 cfs Spillway Discharge – Bays 3-8 – skimming (Bays 3-6), ramped surface jet (Bays 7 & 8)

Photo 8: 25,000 cfs Spillway Discharge – Bays 3-8 – ramped surface jet (degrees varies).

Configuration 4
Deflector Elevations 1368 ft and 1373 ft
PHOTO PLATE 5-4

Photo 1: 5,000 cfs Spillway Discharge – Bays 7-8 – skimming flow
Plunge pool filled to elevation 1340 ft with fixed bed material

Photo 2: 25,000 cfs Spillway Discharge – Bays 3-8 – skimming and ramped surface jet flow
Plunge pool filled to elevation 1340 ft with fixed bed material

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Plunge Pool Fixed Bed Sensitivity Tests
PHOTO PLATE 5-5

Photo 1: Different size classes of material used to test the stability of plunge pool fill material.
From Left to Right: 12.5 ft (5 in), 10 ft (4 in), 7.5 ft (3 in)

Photo 1: Mobile bed prior to 50,000 cfs discharge.

Photo 2: Mobile bed following 5.5 hours (prototype) of 50,000 cfs spillway discharge.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Plunge Pool Mobile Bed Test
12.5 ft Diameter Material
PHOTO PLATE 5-7

Photo 1: Mobile bed prior to 50,000 cfs discharge.

Photo 2: Mobile bed following 5.5 hours (prototype) of 50,000 cfs spillway discharge

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Plunge Pool Mobile Bed Test
10.0 ft Diameter Material
PHOTO PLATE 5-8

Photo 1: Mobile bed prior to 50,000 cfs discharge.

Photo 2: Mobile bed following 5.5 hours (prototype) of 50,000 cfs spillway discharge.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Plunge Pool Mobile Bed Test
7.5 ft Diameter Material
PHOTO PLATE 5-9

Photo 1: Alternative 1 spillway deflector final configuration with filled plunge pool.

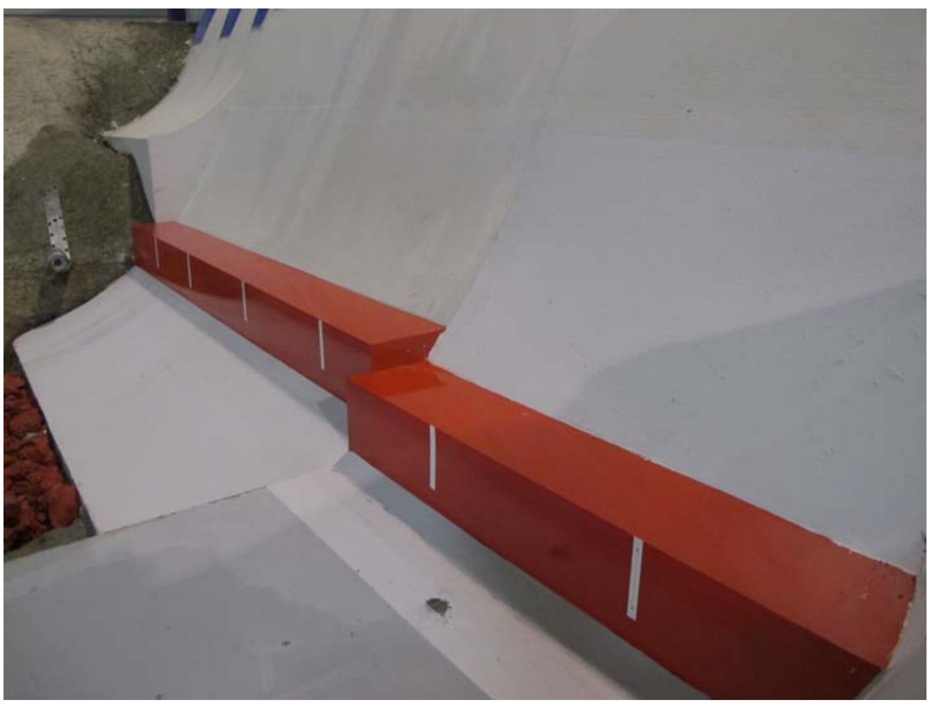


Photo 2: The final configuration consisted of an elevation 1368 ft deflector on Bays 7 & 8 and an elevation 1373 ft deflector on Bays 3 through 6.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Alternative 1 Final Configuration
PHOTO PLATE 5-10

Photo 1: Looking upstream at the spillway and plunge pool.

Photo 2: Looking downstream for the spillway crest at the plunge pool.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Alternative 1 Final Test 1
Total River Discharge: 32,300 cfs
PHOTO PLATE 5-11

Photo 3: Looking upstream at towards the powerhouse.

Photo 4: Overhead view of the powerhouse floe (Green) mixing with the spillway discharge (Red)

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Alternative 1 Final Test 1
Total River Discharge: 32,300 cfs
PHOTO PLATE 5-11

Photo 1: Looking upstream at the spillway and plunge pool.

Photo 2: Looking downstream for the spillway crest at the plunge pool.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Alternative 1 Final Test 2
Total River Discharge: 15,300 cfs
PHOTO PLATE 5-12

Photo 3: Looking upstream at towards the powerhouse.

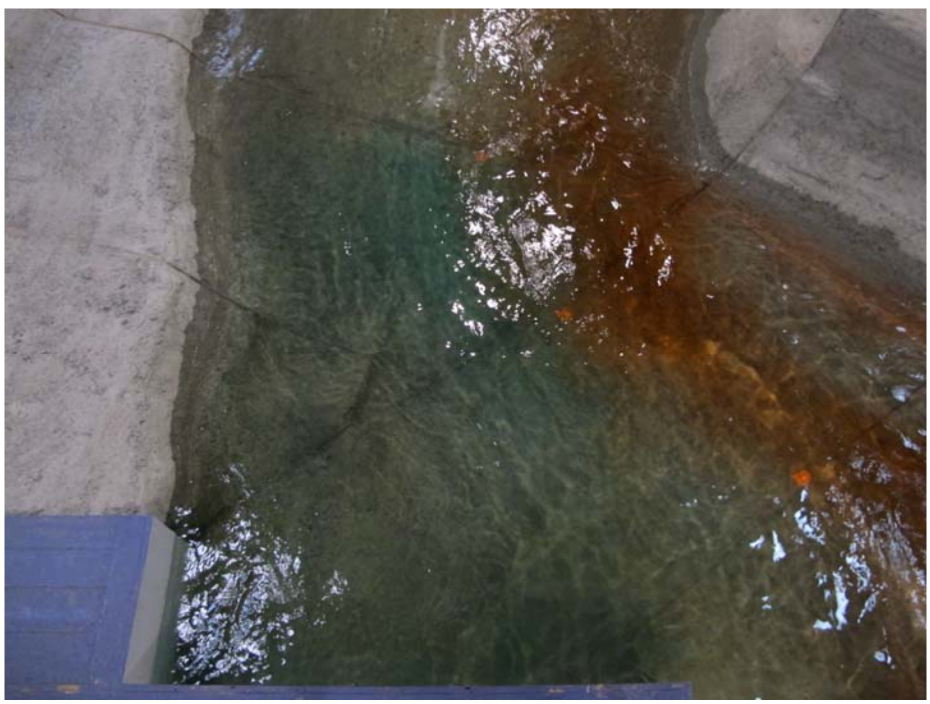


Photo 4: Overhead view of the powerhouse floe (Green) mixing with the spillway discharge (Red)
.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Alternative 1 Final Test 2
Total River Discharge: 15,300 cfs
PHOTO PLATE 5-12

Photo 1: Looking upstream at the spillway and plunge pool.

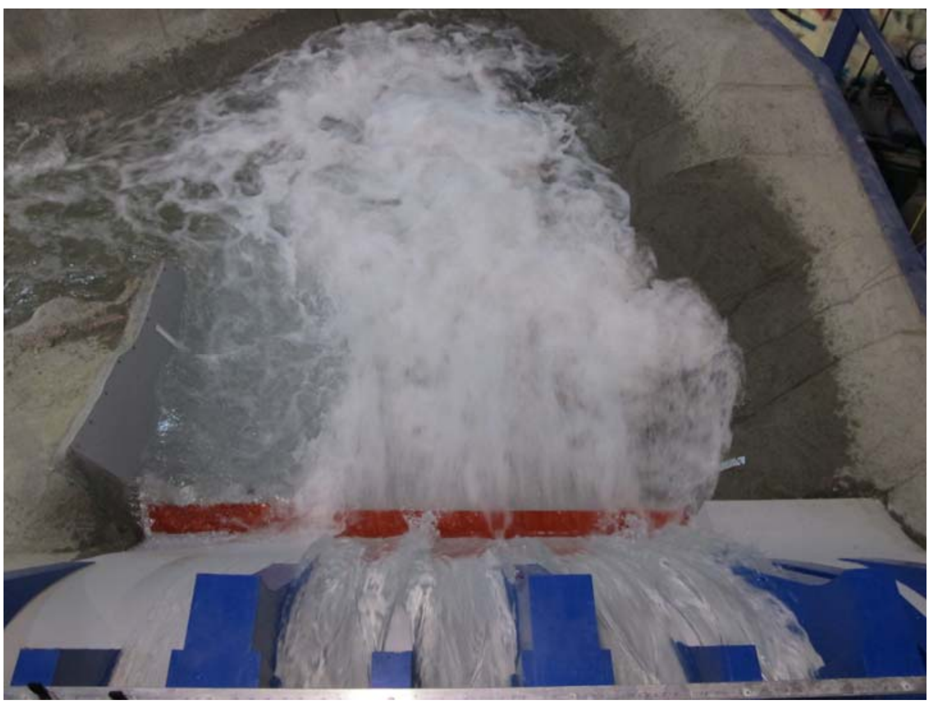


Photo 2: Looking downstream for the spillway crest at the plunge pool.

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Alternative 1 Final Test 3
Total River Discharge: 50,000 cfs
PHOTO PLATE 5-13

Photo 3: Looking upstream at towards the powerhouse.

Photo 4: Overhead view of the powerhouse floe (Green) mixing with the spillway discharge (Red)

Long Lake Dam
TDG Abatement Feasibility Phase III
Physical Model Study

Alternative 1 Final Test 3
Total River Discharge: 50,000 cfs
PHOTO PLATE 5-13

Appendix A - Consultation

Long Lake Phase III - Record of Consultations:

<u>December 20, 2011: Spokane Tribe – Model Demonstration</u>

The Spokane Tribe visited NHC's laboratory on December 20th, 2011 to view the Long Lake physical model. The model demonstration included a presentation that covered an overview of the model, baseline testing, and Alternative 1 (Deflector on Bays 3 through 8) testing. Alternative 1 was operable in the model during the visit and was shown to the representatives from the Spokane Tribe.

<u>January 9th, 2012: Dr. John Gulliver – Independent Technical Review Model Demonstration</u>

Dr. Gulliver from the University of Minnesota is working directly for Avista as a consultant on the Long Lake TDG Phase III project. He was also involved in the Phase II work. Dr. Gulliver visited NHC's laboratory on January 9th, 2011 to view the physical model. He observed several different flows in the model including the 7Q10. After the visit, Dr. Gulliver provided a letter to Avista that documented his visit. He agreed with the deflector flow classifications developed by NHC for Alternative 1 (Deflectors on Bays 3 through 8).

2/17/2012

Marcie Mangold
Department of Ecology
4601 N Monroe Street
Spokane, WA 99205

In accordance with Avista's Federal Energy Regulatory Commission (FERC) June 18, 2009 Spokane River Project (FERC No. 2545) License Avista is submitting the following reports for your review and comment.

Annual Total Dissolved Gas Attainment and Monitoring Report for the Long Lake Development. There are two related components to this report.

A. *Annual Total Dissolved Gas Monitoring Report for 2011, Golder Associates, Dec. 2011.* As required by the Total Dissolved Gas (TDG) Water Quality Attainment Plan (WQAP) and the Washington TDG Monitoring Plan, this report provides the results of monitoring TDG at Long Lake HED and Nine Mile HED during 2011. Avista proposes to continue implementing the same monitoring plan at Long Lake HED in 2012. However, during 2011 the Nine Mile HED was plagued with numerous equipment issues which resulted in lost generation and increased spill. As a result, Avista proposed to delay monitoring until operations at the plant return to normal. Ecology agreed with this proposal and in their correspondence dated February 17, 2012 suspended TDG monitoring until the first season following completion of the Unit 1 and 2 turbine/generator replacement project and the sediment by-pass tube is again fully operational. This correspondence is attached.
B. *Long Lake Dam TDG Abatement Feasibility Phase III, Physical Model Study, 2011 Interim Report. Northwest Hydraulic Consultants, Jan. 2012.* This report documents the progress of building the physical model and hydraulic testing deflectors on the modeled Long Lake Dam spillway. Avista proposes to continue the modeling of the stepped weir alternative identified in the Phase II study during 2012. In addition, a third alternative termed the Noxon Concept (dentated spillway) will be developed including preliminary hydraulic design calculations, civil engineering, drawings, and cost estimates. Once these items are completed, Avista will be able to determine if the design should be modeled. Avista believes this effort could also be completed in 2012.

Annual Long Lake Tailrace Dissolved Oxygen Monitoring Report. This is the first annual report required under the FERC approved Dissolved Oxygen (DO) Feasibility and Implementation Plan. Monitoring DO took place from July 1st through October 31, 2011. The report illustrates the seasonal changes in DO just downstream of the dam during the low flow period of the year. In order to boost DO levels in the river, Avista installed manual aeration equipment on turbine Units 3 and 4. The results of aerating the turbine discharge water with the aeration equipment during generation are included in this report. This was Avista's first effort to implement the system, which had been tested in 2010. The results were encouraging. Avista proposes to automate the components of the system in 2012, which will allow for a more thorough, and effective aeration effort and assessment.

Avista would appreciate your review of the attached reports by March 21, 2012. This 30 day review period should allow Avista enough time to address your comments prior to submitting the reports to

FERC for their review and approval. Please feel free to call me anytime if you have questions or concerns.

Sincerely,

Hank Nelson

Hank Nelson
Environmental Coordinator

Enclosures

CC: Brian Crossley, Spokane Tribe

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
4601 N Monroe Street • Spokane, Washington 99205-1295 • (509)329-3400

March 21, 2011

Mr. Elvin "Speed" Fitzhugh
Spokane River License Manager
Avista Corporation
1411 East Mission Ave., MSC-1
Spokane, WA 99220-3727

RE: Request for Comments – Spokane River Hydroelectric Project No. 2545 2011 Long Lake Dam Total Dissolved Gas Monitoring Report and Long Lake Dam TDG Abatement Feasibility Phase III Physical Model Study 2011 Interim Report – Washington 401 Certification, Section 5.4(D)

Dear Mr. Fitzhugh:

The Department of Ecology (Ecology) has reviewed the following documents mailed to us on February 22, 2012, and would like to provide the comments below:

<u>2011 Long Lake Dam Total Dissolved Gas Monitoring Report</u>

We currently do not have any comments on monitoring protocol or collection methods.

Although the data showed that often total dissolved gas (TDG) exceeded the 110% water quality standard in the tailrace, Ecology acknowledges that while you are actively working on your compliance schedule identified in your TDG abatement plan, you are in compliance with your 401 water quality certification.

<u>Long Lake Dam TDG Abatement Feasibility Phase III Physical Model Study 2011</u>

We would like to thank Avista for offering us the opportunity to visit the physical model on several occasions, but unfortunately our schedules did not allow the time to visit.

The study outlined and thoroughly discussed each alternative in great detail. It would be helpful if the introduction section included a recap of the TDG attainment plan as well as the compliance schedule.

According to your approved compliance schedule, Phase III was to be completed in 2012. This included hydraulic modeling for Alternative 1 (spillway deflectors) and Alternative 6 (stepped weir). Ecology understands that the modeling for the spillway deflectors has been completed, though the modeling for Alternative 6 is still ongoing, and that an additional Alternative 7 (Noxon design concept) is being developed. As such, it appears

that Phase III work will continue into 2012, which will put Avista one year behind in their compliance schedule.
We fully understand that this lapse in schedule is due to the complex challenges, including but not limited to physical constraints associated with the tailrace, of reducing TDG at Long Lake HED and agree that the additional modeling and/or assessment efforts are appropriate. Further exploration of the stepped weir and the Noxon design alternatives, as well as completion of Phase IV-Formulate Design, Plans, and Specs, should still allow Avista to meet the final deadline for TDG abatement in 2018.

We thank you for the opportunity to comment and look forward to working with you in the future. Please contact me by phone at (509) 329-3450 or by email at dman461@ecy.wa.gov if you have any further questions.

Sincerely,

D. Marcie Mangold

D. Marcie Mangold
Water Quality Program

DMM:dw
cc: Brian Crossley, Spokane Tribe of Indians
Hank Nelson, Avista
David Moore, Ecology/WQP