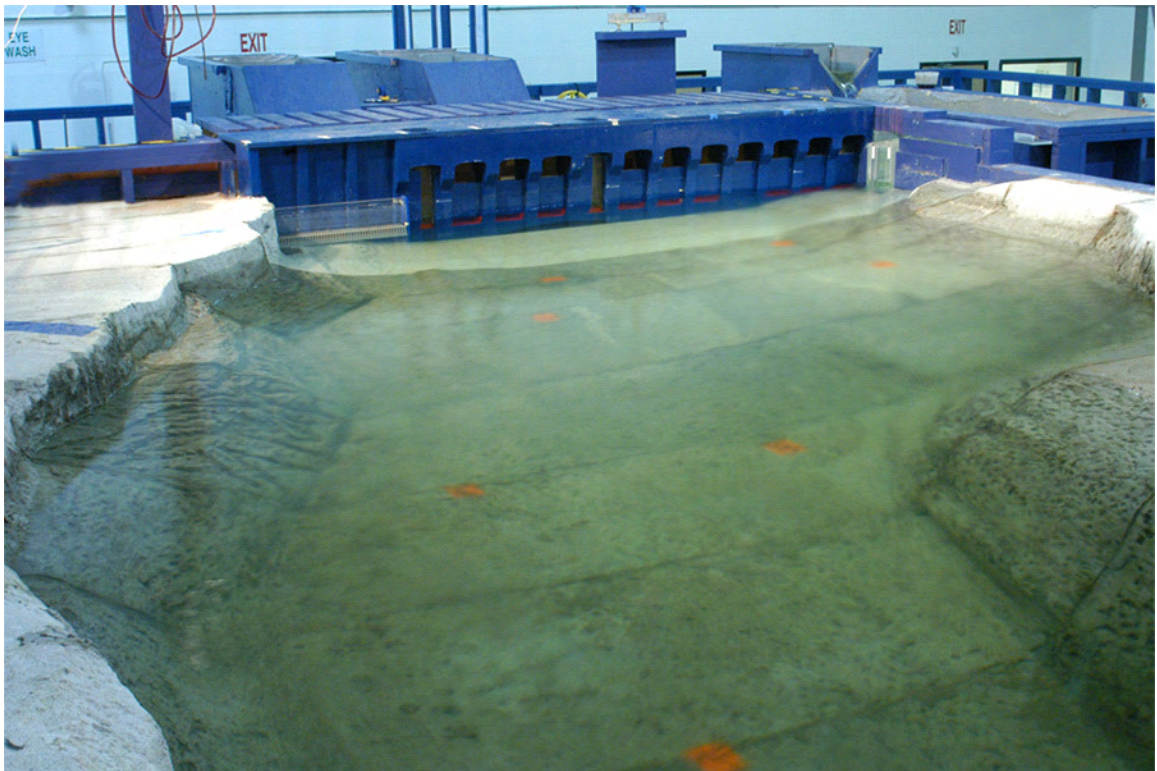


LEWIS RIVER FISH PASSAGE MERWIN ADULT FISH TRAP TAILRACE PHYSICAL HYDRAULIC MODEL STUDY FINAL REPORT

Prepared for:  **PACIFICORP ENERGY**
A DIVISION OF PACIFICORP



July 2008

Prepared by: Northwest Hydraulic Consultants

nhc

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FINAL REPORT**

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Black & Veatch Corporation

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July 16, 2008

EXECUTIVE SUMMARY

northwest hydraulic consultants (nhc) was retained as a subconsultant to Black & Veatch Corporation (B&V) under a prime contract with PacifiCorp Energy (PacifiCorp) to conduct a tailrace physical hydraulic model study for a new adult fish trap at Merwin Dam. Additional design team members involved in this model study included R2 Resource Consultants, Inc. (R2), and KozmoBates. The modeling study was a collaborative process and witness tests were conducted with members of the Lewis River Aquatics Coordination Committee (ACC) Engineering Subgroup to demonstrate the modeling progress and to gain input from the group.

Merwin Dam is the most downstream project on the Lewis River, and it is owned and operated by PacifiCorp. As a part of the relicensing of the Lewis River Projects, improvements to adult fish passage facilities will be constructed at Merwin Dam. The objectives of the modeling study were to evaluate and aid design of the current proposed fish trap entrance and future phased trap entrances for Merwin Dam. The physical model provided a tool to assist in the selection of an entrance location, to confirm the entrance weir design, and to assist with the pump intake design associated with the adult fish trap facility. In addition, the model was used to document general tailrace flow patterns for future use to assist with understanding observed fish behavior associated with the trap improvements.

Baseline testing was performed to document existing conditions for comparison with the proposed fish entrances. The initial fish trap entrance tested in the model was the corner entrance, which will be the first entrance constructed at the corner between Unit 1 and the left bank. Through the modeling process, it was concluded that the corner entrance provided optimal attraction flow along the left bank and powerhouse face when the entrance angle was 70 degrees. Two weir designs, a 4-ft and 6-ft wide option, with crests at El. 38.0 ft provided good attraction flow and 1.5-ft of head drop when operated at 400 and 600 cfs, respectively. Extensive testing was documented at different operational conditions with these two corner entrance options.

The attraction flow for the entrance will be provided by a pump station located in the skeleton turbine unit bay that is adjacent to Unit 3. Modeling of the pump intake showed that this location was acceptable; however, the flow distribution to the three pumps may be influenced by the large circulating eddy in the tailrace, which sweeps flow across the pump intake screen face.

Testing was also conducted to document alternative entrance locations and general tailrace flow patterns. Two alternative fish trap locations include the pump bay entrance locations (Pump Bay No. 2 & Pump Bay No. 3) located along the powerhouse face. If an additional entrance is needed in the future, the hydraulic documentation of these entrances provided by this modeling study, in conjunction with fish behavior information, is expected to be of considerable value in deciding which of the two pump bays to use for a future second entrance. Other model documentation information that may be used in the future includes the tailrace flow pattern mapping. This mapping information combined with results of future fish tracking studies, may provide useful fish behavior information.

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* Information in Appendix B, although not a part of **nhc**'s modeling work, is included for convenient reference in the context of the subject matter of this report

1 INTRODUCTION

northwest hydraulic consultants (nhc) was contracted by Black & Veatch Corporation (B&V) in September 2007 to develop and perform physical modeling related to planning and design of adult fish trap improvements at Merwin Dam. This work was conducted under the prime Contract Agreement No. P024447 (Release No. 3000028924) between PacifiCorp Energy (PacifiCorp) and B&V and the professional services agreement between B&V and **nhc** dated June 7, 2006.

1.1 SYSTEM DESCRIPTION

1.1.1 MERWIN DAM

Merwin Dam is located on the Lewis River approximately 19 miles upstream of the confluence with the Columbia River, and about 12 miles upstream from the town of Woodland, Washington. There are four hydroelectric facilities located on the Lewis River including (from upstream to downstream): Swift No. 1 Dam, Swift No. 2 Dam, Yale Dam, and Merwin Dam. The Merwin project consists of a concrete arch dam with a single spillway and a 3-unit powerhouse (Photo 1.1).

1.1.2 MERWIN ADULT FISH TRAP

The purpose of the Merwin adult fish trap is to attract and collect adult fish migrating upstream. The fish are then sorted on site and transported off-site per fisheries plan. An existing single entrance fish trap is currently operating at Merwin Dam but an improved fish trap is being designed and will be constructed in the future.

1.2 STUDY OBJECTIVES

The present investigation was conducted to evaluate the proposed corner entrance configuration that will be constructed initially. Future improvement phases contemplate the possible implementation of a second entrance along the downstream face of the powerhouse. The physical model testing program provided design input regarding the following:

- Corner entrance: weir configuration, orientation, and attraction flow amounts
- Pump bay entrance: at pump bay No. 2 or No. 3, weir configuration, orientation, and attraction flow amounts
- Pump station intake rack design
- General tailrace flow patterns for future reference

1.3 ACKNOWLEDGEMENTS

Several individuals worked with **nhc** and contributed to the successful completion of this study. **nhc** would like to thank Monty Nigus and Dennis Anderson from B&V; Dana Postlewait from R2 Resource Consultants, Inc. (R2); and KozmoBates for their involvement in the physical model test program. **nhc** would also like to thank Arnold Adams and Frank Shrier, both from PacifiCorp, as well as members of the Lewis River Aquatics Coordination Committee (ACC) Engineering Subgroup for their involvement and contributions to the study. The model study was led by Lisa Larson of **nhc**. Andre Ball was the modeling engineer and Brian Hughes provided technical review for the study.

2 PHYSICAL MODEL DESCRIPTION

2.1 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. Modeling at reduced scale 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. That is,

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

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

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

and, $U = \text{characteristic flow velocity}$

$M = \text{model values}$

$g = \text{gravitational acceleration}$

$P = \text{prototype values}$

$L = \text{characteristic length}$

Based on the study objectives, project configuration, and project discharges a geometric scale of 1:24 was selected for the Merwin tailrace physical hydraulic model. At this scale, adherence to Froude criterion for similitude resulted in the following scale relationships.

Model Scale Relationships

Parameter	Relation	Ratio
Length	L_m/L_p	1 : 24
Velocity	$(L_m/L_p)^{1/2}$	1 : 4.9
Discharge	$(L_m/L_p)^{5/2}$	1 : 2822

Note: m = model, p = prototype

2.2 MODEL DESCRIPTION

Figures 2.1 through 2.5 and Photos 2.1 through 2.6 illustrate the configuration of the physical model and model structures. B&V and R2 provided prototype drawings, discharge information, and the tailwater rating curve for use in the model development. The Merwin Dam tailwater rating curve is shown in Figure 2.6.

The model represented the draft tube configurations and discharges for Units 1, 2, and 3, the proposed pump intake, and three possible entrances to the adult fish trap. The model encompassed the full width of the tailrace channel extending approximately 550 ft downstream of the powerhouse. The spillway descending on the right bank, downstream of the powerhouse, was not included in the model as spillway flows were not required for this study. The model limits were sufficient to provide adequate tailwater control and establishment of stable tailrace flow patterns downstream of the powerhouse and fish trap entrances.

The model featured independent flow control for the individual powerhouse units, proposed fish entrances, and the pump intake. The tailwater level, measured at the powerhouse face, was controlled by an adjustable tailgate at the downstream end of the model. The operating conditions simulated during the testing program ranged between high and low flow conditions with different combinations of powerhouse units operating. At the high end of the operating conditions, the tailwater elevation was 53.2 feet and all three powerhouse units were operating with a combined discharge of 11,470 cfs. At the low end of the operating conditions, the tailwater elevation was 46.7 feet with a single powerhouse unit operating at 1,200 cfs.

2.3 MODEL MEASUREMENTS AND INSTRUMENTATION

The following controls and instrumentation were provided for the study:

Flow Rates – To accommodate the multiple powerhouse units and alternative fish trap entrance locations as described in Section 2.2, the model flow was circulated using a centrifugal laboratory pump supplying flow to a manifold of six separate pipes, each fitted with an independent control valve. Three of the pipes supplied flow to separate head boxes leading to three turbine unit draft tubes. The flow in these pipes was measured using 4.67-inch diameter orifice plates with air-water manometers used to measure the pressure differential across the orifice plates. The orifice plate and pressure taps were installed in accordance with American Society of Mechanical Engineers (ASME) Standards (2004).

The three remaining pipes supplied flow to the three adult fish trap entrances. Independent v-notch weir boxes were used to measure the flow to each entrance.

The simulated pump intake flow, which matched the fish trap attraction flow, was gravity fed from the tailrace. The three individual bays flowed to a common tailbox. The outlet from the tailbox was controlled by an independent valve and measured using a v-notch weir box.

Based on experience with these measurement systems, the precision of flow measurement is estimated to be within 2% of the actual discharge. This represents approximately ± 78 cfs for a single unit turbine flow (3,890 cfs) and ± 12 cfs for the target fish attraction flow and pump intake (600 cfs).

Water Levels - Measurement of the water levels in the tailrace channel and upstream of each fish entrance opening was achieved by using flush-mounted piezometric pressure

taps. The location of the pressure taps are shown in Figure 2.1. The precision of the water level measurements was approximately ± 0.1 ft (prototype).

Velocities - Velocity measurements were recorded using a Nortek Vectrino high-resolution Acoustic Doppler Velocimeter (ADV) and a Nixon propeller meter depending on the test application. At the proposed scale of 1:24, the ADV instrument was capable of measuring 3-dimensional velocities ranging from 0.1 ft/s to 64 ft/s with a published accuracy of ± 0.1 ft/s (prototype). The Nixon probe was capable of measuring one-dimensional velocities ranging from 2 ft/s to 20 ft/s with a published accuracy of ± 0.2 ft/s (prototype). Turbulent and pulsing conditions in the model may result in slightly diminished accuracy levels relative to the published values for the probes.

3 TEST PROGRAM

The test program included baseline tests without any adult fish trap entrances in place and tests with the alternative adult fish trap entrances in operation. In addition, tests were conducted to document the general tailrace flow patterns and the local flow patterns near the pump intake.

3.1 BASELINE TEST PROGRAM

The baseline test program was conducted without any fish trap entrances in operation. This testing documented the flow patterns and velocities in the tailrace area for comparison with tests conducted with the corner entrance, pump bay entrance, and pump intake operating. Video footage was taken to document dye injections in the tailrace near the powerhouse face and proposed corner entrance location. Velocity measurements were taken with the ADV to quantify differences in the flow patterns between baseline conditions and conditions with the corner entrance operating.

3.2 DEVELOPMENTAL TEST PROGRAM

The developmental test program included testing the corner entrance, pump bay entrances, and pump intake in operation. Initial testing focused on details regarding the layout of the fish entrance and the pump intake screen. The different design variables for the corner entrance included attraction flow quantity, entrance weir width and crest elevation, as well as the entrance orientation and projection into the tailrace. The pump bay entrance design variables included attraction flow quantity, entrance weir width and crest elevation, and the selection of an entrance location of either between powerhouse Units 2 and 3 (referred to as Pump Bay No. 2) or between powerhouse Unit 3 and the pump intake (referred to as Pump Bay No. 3). Different intake configurations were evaluated for the pump intake structure, and the flow was varied to match the total fish trap entrance flow.

Initial testing involved many iterative, hands-on tests and documentation was limited to visual observations, notes, and photos/video. The entire design team (**nhc**, B&V, R2, and KozmoBates), as well as several ACC Engineering Subgroup members, were involved in this

initial phase of the test program. Subsequent testing then utilized the entrance configurations developed during initial tests and involved documenting their performance over a range of operational and attraction flow scenarios. Due to the qualitative nature of the evaluation of the entrances and pump intake flow patterns, video footage of dye tracers was used extensively to document the tests. Velocity readings were taken using an ADV and Nixon propeller meter for selected tests, and hand sketches of predominant flow patterns in the tailrace were collected to document flow patterns for potential future use if adjustments or modifications to the entrances are needed based on biological evaluations. Appendix A consists of two data discs which include a spreadsheet documenting the model scenarios, including links to the associated video footage, velocity plots, and sketches.

4 TEST RESULTS

Table 4.1 provides an index of test numbers that document the majority of tests run during the study. This table summarizes test numbers, dates, operating conditions, entrance configurations, and the collected data types. The digital form of this table is included as a spreadsheet in the data discs included in Appendix A, and includes hyperlinks to the video footage, velocity plots, and sketches available for individual tests. The test run numbers indicate the sequential order in which they were run, and the table is organized with certain runs grouped together by topic and modeling goals for comparison.

Preliminary tests, not summarized in Table 4.1, were completed during initial model demonstrations with B&V, R2, KozmoBates, and also with members of the ACC Engineering Subgroup; however, these tests were preliminary in nature and documentation was limited to visual observations and some hand sketches. The observations and insight from these initial tests influenced the corner entrance configuration and are described below in Section 4.2.

The following sections provide an overview of the tests performed and general observations.

*(For convenient reference, a memorandum summarizing observations and decisions made by representatives of PacifiCorp, PacifiCorp's Engineer, and members of the ACC Engineering Subgroup, largely utilizing results of this modeling effort, is included in Appendix B. Although not part of **nhc**'s modeling work, this information is included for convenient reference in the context of the subject matter of this report.)*

4.1 BASELINE CONDITIONS

Test 3 documents the baseline condition with the powerhouse operating at full generation, 11,470 cfs, a tailwater elevation of 53.2 ft, and without the fish entrances or pump intake operating. ADV data were collected at 5-ft and 12-ft depths for this run, and the results are provided in Tables 4.2 and 4.3 and Figures 4.1 and 4.2. The ADV data were collected along arcs at three radii from the proposed corner entrance weir. The centerlines of Unit 1 – Bay 2, Unit 1 –

Bay 3, and Unit 2 – Bay 1 were tangent to the three radii. The arcs were located 17'-7", 32'-7", and 62'-7" feet from the corner entrance, respectively.

The velocity data showed that the near-surface velocities (recorded at 5-ft depth) in the vicinity of the proposed corner entrance location typically ranged between 1.5 to 4.5 ft/s. Velocities were found to be higher along the steep rock slope along the left descending bank. Velocities at the 12-ft depth were aligned with the roof of draft tube exits and were in the 3.5 to 8 ft/s range with the direction of flow more consistently pointed downstream.

During the baseline run, some distinct general flow patterns were noted in the tailrace area as shown in Photo 4.1. A large clockwise circulating eddy formed along the right side of the tailrace. The eddy extended nearly 250 ft downstream of the powerhouse and traveled upstream along the right bank. Flow traveled upstream along the right bank from as far downstream as 250 feet. Near the proposed pump intake location, the eddy turned toward the left bank across the powerhouse face. The eddy turns downstream in front of Unit 2 before beginning another cycle. Another prominent feature was an intermittent boil (or upwelling) that was visible on the water surface between Units 2 and 3, located approximately 40 feet downstream of the powerhouse face. This boil coincides with field observations by PacifiCorp personnel.

4.2 CORNER ENTRANCE

4.2.1 ENTRANCE ORIENTATION AND PROJECTION

Initial testing of the corner entrance focused on the orientation and projection of the entrance weir. The angle of the corner entrance relative to the flow exiting the powerhouse was one of the first design details investigated. The entrance angle (see Figure 2.5 and Photo 2.4) was varied between 90 degrees (perpendicular to powerhouse) and 45 degrees. Several factors were considered when evaluating the performance of alternative designs and the resulting flow patterns in the tailrace. The main factor was that in order to attract fish to the entrance, a jet issuing from the entrance that would potentially attract fish from either the powerhouse or the

rock wall along the left bank was considered to be optimum. Dye was injected in the entrance channel and the jet and flow patterns downstream of the fish trap were qualitatively evaluated.

At the January 30th, 2008 witness tests (PacifiCorp Energy, January 2008), after several tests with dye injected in the channel upstream of the entrance weir, the ACC Engineering Subgroup members concluded that the optimal angle appeared to be 70 degrees. When the entrance was orientated at 90 degrees, the dye released from the entrance dissipated quickly and did not extend very far downstream. Similarly, when the entrance was orientated at 45 degrees, the dye plume was less distinct and the flow impacted the protruding rock wall just downstream of the entrance.

One of the initial entrance designs evaluated in the model included a fillet to smooth the transition between the downstream face of the powerhouse and the corner entrance, as shown in Photo 4.2. The intent of the fillet was to help guide flow around the protruding entrance. After observing the model with and without a fillet, it was decided that the “without fillet” option was preferable, Photo 4.3. The obstruction provided by the protruding entrance configuration dissipated some of the energy associated with the turbine flow near Unit 1, which allowed the near-surface attraction flow to travel farther across the face of the powerhouse.

4.2.2 WEIR DESIGN

The potential weir designs for the corner entrance focused on addressing several objectives involving both fish passage criteria as well as space constraints within the existing buildings. National Marine Fisheries Service (NMFS) recommends a maximum head drop of 1.0 to 1.5 ft for weirs at upstream passage facilities (NMFS, 2008). The physical model provided a tool to observe several weir discharges with different width and crest elevation combinations that met this guideline. The site constraints include both the interaction between the entrance and powerhouse flows, and space availability for incorporation of the entrance into the existing facilities.

The interaction between the entrance and powerhouse flows was observed during the initial phase of testing. During these tests, it became apparent that when the weir crest was lower than approximately El. 40.0 ft (coincides with the upper elevation of the draft tube exit openings) the magnitude of the powerhouse flow overpowered the portion of attraction flow from the corner entrance that was lower than El. 40.0. Therefore, the design team and ACC Engineering Subgroup decided to set the minimum weir crest elevation at El. 38.0 ft, which would overlap the powerhouse flow slightly, but would provide good attraction flow in the remaining upper portion of the water column. Site constraints also impacted the overall design criteria of the entrance. Due to space limitations within the existing powerhouse facility, the fishway approach channel width was limited to 8 ft. It was assumed that an optimum entrance condition would include at least a slight contraction so some fish resting area would be present just inside the entrance. By visual observation with dye, the jet from the entrance with the slight contraction appeared to penetrate the tailrace further than the one without contraction. To accommodate this flow contraction, the maximum width of the weir was limited to 6-ft.

The corner entrance configurations that met the above objectives, with the powerhouse operating at full generation capacity, and that were pursued for additional testing included:

- 6-ft wide weir: 1.5 ft of head drop; weir crest at El. 38.0 ft; weir discharge 600 cfs.
- 4-ft wide weir: 1.5 ft of head drop; weir crest at El. 38.0 ft; weir discharge 400 cfs.

Figures 4.3 and 4.4 depict the hydraulic characteristics of the 4-ft and 6-ft weirs, respectively. These figures demonstrate how the entrance weir discharges can be varied to maintain a constant head drop across the weir for different powerhouse operating conditions. The Merwin tailrace tailwater rating curve is also provided at the bottom of these figures. Tests 4 and 5 documented the operation of the 4-ft and 6-ft weirs, respectively, in comparison to the baseline conditions. Figures 4.5 and 4.6 and Tables 4.4 and 4.5 display the ADV data collected for Test 4, and Figures 4.7 and 4.8 and Tables 4.6 and 4.7 display the ADV data collected for Test 5.

From these data, it is evident that at the 5-ft depth, the attraction flow extends across the powerhouse face from the corner entrance for both Tests 4 and 5 in comparison to the baseline conditions (Test 3). For the arc closest to the entrance, the ADV data suggests that the 6-ft weir operating at 600 cfs provides more prominent attraction flow based on velocities; however, farther from the entrance, the 4-ft weir operating at 400 cfs has about the same impact. At the 12-ft depth (coincides with El. 41.2 ft), the ADV data shows that the powerhouse flow discharging from the draft tubes was more prominent than the attraction flow jet; however, the attraction flow near the entrance was still distinguishable from the powerhouse flow.

4.2.3 LEFT BANK LOCAL EDDY

During the initial working meetings, including the January 30th witness test (PacifiCorp Energy, January 30th), it was noted that the protrusion of the corner entrance resulted in a localized eddy along the left bank immediately downstream of the entrance (Photo 4.4). Initially, this presented some concern to the members of the ACC Engineering Subgroup representatives due to the potential for the eddy to cause fish to become disoriented and possibly miss the entrance or delay. Later, after evaluating the eddy more closely, these concerns were eliminated based on biological needs; however, efforts were still made to explore solutions to minimize or eliminate the eddy.

The first attempt at reducing the localized eddy was to modify the entrance design by raising the exterior bottom elevation, which initially extended to El. 29.4 ft. The goal of this design was to provide more flow area for the Unit 1 discharge to impact the eddy and potentially dissipate its strength. The revised design for the entrance raised the exterior bottom elevation to El. 34.0 ft (interior to El. 36.0 ft). This modification provided an area for the turbine flow from the left bay of Unit 1 to pass under the entrance with the goal of dissipating the eddy. However, testing demonstrated that the eddy was not reduced significantly for this configuration. Appendix A contains video footage of dye releases near the corner entrance with both the original entrance invert at El. 29.4 ft (Test 6) and the entrance invert raised to El. 34.0 ft (Test 7). Velocity data were collected for Test 6 and are provided in Tables 4.8 and 4.9 and Figures 4.9 and 4.10.

Tests 8 through 12 were run to further investigate the eddy and the interaction between entrance operation and the localized eddy. Tests 8 and 9 were similar to Tests 4 and 5 and simulated the powerhouse operating at full generation with the corner entrance operating at 400 and 600 cfs. With the entrance operating there was a well-defined flow transition between the eddy and the left edge of the attraction flow. Tests 10 through 12 evaluated the flow patterns with the three powerhouse units being run separately at 2,700 cfs and the corner entrance operating at 260 cfs. During these tests it was noted that the eddy was less pronounced for lower powerhouse flows, and its existence was more dependent on whether or not Unit 1 was operating. Video documentation of Tests 8 through 12 is provided in Appendix A.

The second modification involved eliminating the area where the eddy formed by filling in the area between the left bank and the entrance as shown in Photo 4.5. Test 35 included taking one-dimensional velocity measurements at three locations along the left bank at 5-ft and 12-ft depths (Figures 4.11 and 4.12) to document the eddy. The flow measurement locations along the bank were at the same approximate locations as the ADV measurements taken along the bank in Tests 3 through 5. Note that Test 36, which had the same operating conditions as Test 8, was run as a complement to Test 35 to collect velocities at the same locations with no fill in place (Figures 4.13 and 4.14). The addition of the fill and elimination of the eddy appeared to increase velocities along the left descending bank at the 5-ft depth. The near-shore velocities increased from 2.0, 3.5, and 9.0 ft/s (Test 36) to 2.7, 4.2, and 9.2 ft/s (Test 35). Video documentation is provided for both tests in Appendix A. Results from this set of tests show that the left bank local eddy could be eliminated using fill should the need arise.

Members of the design team and ACC Engineering Subgroup decided that the local eddy could be a beneficial feature to fish approaching the corner entrance. The eddy provides potential resting area before the fish enter the corner entrance. Eliminating the eddy may increase the near shore velocities approaching the corner entrance and could result in another obstacle for the fish to overcome.

4.2.4 CORNER ENTRANCE WITH LOW TURBINE FLOW

Tests 14 through 16 included operating individual powerhouse units at 1,200 cfs with the minimum operating tailwater at El. 46.7 ft. Video documentation of dye released upstream of the weir and along the downstream face of the powerhouse was taken and is provided in Appendix A. All three tests were run with the corner entrance in operation with the 4-ft wide weir and 230 cfs of attraction flow. In general, it was found that with the powerhouse operating at minimum capacity, the attraction flow represented a larger percentage of total flow and was much more evident in the tailrace area. However, when only Unit 1 was operating (Test 14), the attraction flow was intercepted, re-directed downstream, and therefore, it did not extend as far across the tailrace channel. By comparison, when only Unit 3 was operating (Test 16), the attraction flow extended almost across the entire tailrace channel to the right bank.

4.2.5 CORNER ENTRANCE WEIR WITH VARIOUS POWERHOUSE OPERATIONS

Tests 17 through 26 were run to provide additional dye video documentation of the 4-ft and 6-ft weirs at the corner entrance for intermediate powerhouse operating conditions between full generation and low generation. Combinations of 3 unit and 2 unit operations were simulated. The operation of Unit 1 had the most impact on the flow jet from the corner entrance but in all cases the attraction flow was still present.

4.2.6 CORNER ENTRANCE – 1 FT HEAD DROP TESTS

The majority of tests for the corner entrance simulated a 1.5 ft head drop at the weir; however, tests were also conducted for a 1 ft head drop. Tests 37 and 38 simulated the 4-ft and 6-ft corner entrance weirs, respectively, with 1 ft of head drop. These tests were similar to conditions simulated in Tests 4 and 5. The weir crests elevations were fixed at El. 38.0 ft, but the flow rates were reduced to facilitate the lower head drop. For Test 37 with the 4-ft weir, the flow rate was reduced to 330 cfs from 400 cfs in Test 4; and, for Tests 38 with the 6-ft weir, the flow rate was reduced to 500 cfs from 600 cfs in Test 5. Video footage was used to document dye released through the corner entrance. In both Tests 37 and 38, the attraction jet appeared to be less

pronounced along the left bank than in the 1.5 ft head drop tests. The attraction flow along the powerhouse face was similar.

4.3 PUMP BAY ENTRANCE

In addition to the corner entrance, a potential second entrance was also investigated. The second entrance would be located at one of two possible locations along the powerhouse: (1) between Units 2 and 3 (referred to as Pump Bay No. 2); or (2) between Unit 3 and the pump station intake (referred to as Pump Bay No. 3). Figure 2.3 and Photo 2.5 illustrate these alternative locations.

The weir designs evaluated in the model at both potential pump bay entrances were as follows:

- 170 cfs, 3-ft wide weir, crest El. 43.7 ft
- 170 cfs, 4-ft wide weir, crest El. 46.2 ft
- 330 cfs, 3-ft wide weir, crest El. 37.2 ft
- 330 cfs, 4-ft wide weir, crest El. 40.7 ft

The flows associated with these weir geometries resulted in 1.5 ft of head drop across the weir when the powerhouse was operating at full generation. A weir width of 4-ft was considered the maximum due to space constraints at the respective pump bays. This was based on preliminary layouts that indicated a maximum fishway approach channel width of 6-ft. As with the corner entrance, to provide at least a slight contraction the maximum width of the weir for either pump bay entrance was limited to 4-ft.

Tests 13.1 through 13.8 tested the four weir designs listed above in both the Pump Bay No. 2 and Pump Bay No. 3 locations. The hydraulic characteristics of the attraction flow from the weirs were assessed using dye injections at 5 ft depth and upstream of the weirs. These dye tests were recorded on video and are included in Appendix A.

The attraction flow from the Pump Bay No. 2 entrance tended to travel farther downstream in the tailrace before it was dissipated. The jet was carried around the left side of the upwelling that typically occurred between Units 2 and 3. After passing the upwelling area, the dye plume was

still fairly distinct and accelerated downstream as it merged with the large circulating eddy in the tailrace. By comparison, during runs where the Pump Bay No. 3 entrance was operating, the dye plume was almost immediately swept toward the left, across the face of the powerhouse, by the large eddy. In addition, it was noted that the attraction flow from the 3-ft wide weirs with lower crest elevation tended to dissipate more quickly, while flow from the 4-ft wide weirs with a higher crest elevation extended farther downstream in the tailrace and remained more distinct.

4.4 COMBINED CORNER AND PUMP BAY ENTRANCE OPERATIONS

After the corner and alternative pump bay entrance locations were evaluated separately, their combined operations were also evaluated. Simultaneous dye releases from the corner and pump bay entrances showed the interaction between the attraction flows. Operating conditions for Tests 27, 29, 31, and 33 included the following:

- full powerhouse capacity generation (11,700 cfs)
- corner entrance operating with the 4-ft weir and 400 cfs
- pump bay entrance operating at 330 cfs
- varied pump bay entrance location (Pump Bay No. 2 or Pump Bay No. 3) and weir width (3-ft or 4-ft).

Overall, the results were similar to those obtained for the individual pump bay entrance tests. For Tests 27 and 29, the flow from Pump Bay No. 2 traveled downstream in the tailrace while the flow from the corner entrance traveled along the left bank. Dye released from the corner entrance and the Pump Bay No. 2 entrance merged with the large circulating eddy about 150 to 200 ft downstream. After merging, some dye was carried back upstream along the right bank with the eddy while some dye continued downstream with the main river flow. When the Pump Bay No. 3 entrance was operating in combination with the corner entrance (Tests 31 and 33), the dye release from Pump Bay No. 3 was initially swept to the left and subsequently merged with the dye released from the corner entrance at a downstream location similar to that where Pump Bay No. 2 and the corner entrance flows had merged.

A set of tests with moderate powerhouse generation flows were run in addition to the full-capacity tests. Operating conditions for Tests 28, 30, 32, and 34 included the following:

- moderate powerhouse generation (Units 1 and 2 at 2,700 cfs each; Unit 3 off)
- corner entrance operating with the 4-ft weir and 320 cfs attraction flow
- pump bay entrance operating at 240 cfs
- varied pump bay entrance locations (Pump Bay No. 2 or 3) and weir width (3-ft or 4-ft).

For these powerhouse operating conditions, the large tailrace eddy was less pronounced, which had a significant impact on the attraction flows coming from the Pump Bay No. 2 and Pump Bay No. 3 entrances. Tests 28 and 30 were run with the Pump Bay No. 2 entrance operating in combination with the corner entrance. The dye from Pump Bay No. 2 flowed directly downstream and appeared to merge with the dye released from the corner entrance closer to the powerhouse than observed in Tests 27 and 29. Beyond this point most of the dye continued downstream, as the large eddy was weaker and did not draw as much flow back upstream along the right bank. Tests 32 and 34 were run with the Pump Bay No. 3 entrance operating in combination with the corner entrance. These results were notably different than those obtained for the full powerhouse capacity tests (Tests 31 and 33). During Tests 32 and 34, the dye released from the Pump Bay No. 3 entrance was not swept towards the left bank by the eddy, as observed previously; instead, it traveled primarily downstream before it merged with the dye released from the corner entrance.

Tests 39 and 40 simulated the Pump Bay No. 2 and Pump Bay No. 3 entrances, respectively, operating with 1 ft of head drop over the 4-ft wide pump bay entrance weirs. The discharge over the weirs was 260 cfs, relative to 330 cfs for 1.5 ft of head drop. The reduced flow rate seemed to result in weaker attraction conditions in the tailrace. In both Test 39 and 40, the dye released upstream of the pump bay weirs was immediately swept towards the left bank, along the downstream face of the powerhouse, by the large circulation eddy. Video footage is provided in Appendix A.

4.5 TAILRACE FLOW PATTERN MAPPING RUNS

The Merwin physical model was also used to document flow patterns throughout the entire tailrace, not exclusively near the fish trap entrances, for the range of proposed operating conditions. The purpose of this documentation was to provide a comprehensive mapping of flow patterns that may be used in the future to interpret fish behavior studies in the Merwin tailrace area. Visualizing the flow at discrete locations was accomplished by using dye injections and fine string attached to a rod at specific depths. The flow patterns were sketched at three depths: near surface (5-ft depth), turbine draft tube level (El. 35.0 ft), and near the bottom (~5 ft above river bed). Spot velocity measurements were taken using the one-dimensional propeller meter along the shore, near the pump intake, and along the powerhouse face. Six different powerhouse operating conditions were evaluated in these tests (Tests 41 through 46). The tests included combinations of three unit, two unit, and single unit operations. Individual sketches of the flow pattern mapping are presented in Figures 4.15 through 4.32. An interactive pdf file is included in Appendix A that allows the user to quickly move between the different flow pattern maps using the layers feature.

4.6 PUMP INTAKE

The attraction flow for the corner entrance and potential future pump bay entrance will be supplied by pumping from the tailrace. Three pumps are planned for installation in the skeleton unit to the north of Unit 3. The three existing draft tube openings associated with the skeleton unit will be used for the pump intakes. At the face of the powerhouse, an intake rack will be installed to prevent large debris and fish from entering the pump intakes. Design options considered for the intake rack included the following:

- Intake rack located 7.5 ft from the powerhouse face
- Angled intake rack located 7.5 ft (left side) / 15 ft (right side) from the powerhouse face
- Intake rack located 15 ft from the powerhouse face

After observing the initial intake rack design (offset 7.5 ft from powerhouse face, Photo 2.6) and the tailrace flow patterns, the design team ruled out the angled intake screen because it was not

anticipated to provide added benefit and would likely present additional maintenance difficulties. The larger intake rack design, located 15 ft from the powerhouse face, had been considered to provide additional separation between the right draft tube of Unit 3; however, flow was not drawn into the pump intake bays from Unit 3, so this design was also eliminated from further consideration. The intake rack located 7.5 ft from the powerhouse was the most promising design considered and was used for the pump intake tests.

The intake rack design included a vertical rack face, a solid divider along the left side wall, a solid roof at El. 44.8 ft and a solid floor at El. 29.4 ft. The rock wall along the right bank formed the right wall, thus all flow entering the pump intake passed through the vertical trash rack (Photo 2.6). The intake screen provided for 3/8" x 3" vertical flat bars with 7/8" maximum clear spacing between bars and had a gross screen area of 670 square feet, resulting in average intake velocities of less than 1 ft/s for a pump intake flow of 600 ft/s. In the prototype, it is our understanding the gross area of the intake rack may be reduced by approximately 10 percent to account for the large structural framing needed to support the intake screen, which still results in an average intake velocity of less than 1 ft/s. There are no divider walls within the trash rack. In the model, the total pump intake flow is simulated, but the distribution of individual flows into the three pump intake bays was not controlled.

Tests 47 through 50 were conducted specifically to examine flow conditions in the vicinity of the pump intakes and intake rack. The specific concerns that were investigated included whether any of the aerated flow from Unit 3 could be immediately drawn into the pump intakes, which could lead to pump operation and maintenance problems, and how the large eddy impacted the pump intake. For all four tests, the corner entrance with the 6-ft weir was operating with 1.5 ft of head drop. The weir discharge was varied, based on the tailwater elevation, to provide the 1.5 ft of head drop, and the pump intake discharge was adjusted to match the corner entrance discharge.

Video footage of dye traces and velocity data were collected to document the local flow patterns in front of the intake rack to investigate how they may impact the intake performance. For all

tests, dye was injected in the right bay of Unit 3 (closest to the pump intake) and the flow path was documented. Video footage is available in Appendix A.

Test 47 represented full generation operation and the corner entrance operating at 600 cfs with a 6-ft weir. The dye plume, released from the right bay of Unit 3, had a distinct right edge but diffused to the left. At approximately 150 to 200 ft downstream of the powerhouse, some of the dye began traveling back upstream in the large eddy observed along the right bank. Test 49, with Unit 3 operating at 2,700 cfs, showed that the dye plume traveled mainly downstream with the exception of a recirculating eddy along the right bank that began drawing dye upstream after it had traveled 75 to 100 ft downstream of the draft tube exit. Test 50 represented a similar test with only Unit 3 operating at a lower discharge of 1,200 cfs. In this case, the dye plume exiting the right bay of Unit 3 traveled approximately 50 ft before some of the dye recirculated back towards the intake rack. However, because of slower velocities in the flow exiting the unit and within the eddy at the reduced unit discharge, the travel time for the dye to reach the intake did not change significantly for these tests. The travel times for the dye to recirculate in the model ranged between 15 seconds (model scale), for Tests 49 and 50, and 20 seconds (model scale) for Test 47.

The other issue of interest near the pump intake was the impact of the large tailrace eddy on the flow distribution at the pump intakes. As described previously, the large circulating eddy rotates in the clockwise direction and extends laterally between Unit 2 and the right bank, and in the streamwise direction from the powerhouse to a point about 200 ft downstream, when the powerhouse is operating at full generation. Near the pump intakes, the eddy is flowing upstream along the right bank and turns 90 degrees toward the left bank as it approaches the intake rack and powerhouse face. The ADV data collected for Test 47 (Table 4.10) suggests that when the powerhouse is operating and the eddy is present, that it will induce a bias with more flow entering the left bay of the pump intakes. Test 48 (Table 4.11) was a hypothetical simulation in which there was no powerhouse flow, and hence no eddy, to determine how the eddy impacted the flow distribution at the pump intakes. For this test, the tailwater was set at the full

powerhouse generation level (El. 53.2 ft), and the pump intake was operating at 600 cfs. Without the large tailrace eddy, the velocities in front of the pump intake bays still varied, but the data showed a more uniform distribution of flow into the pump intakes. Again it should be noted that the model did not control the individual pump intake flows, only the total combined pump intake flow. Hyperlinks to sketches of the intake velocity measurements for Tests 47 and 48 are provided in Appendix A.

5 SUMMARY

The purpose of this study was to provide a tool to evaluate initial design concepts of proposed new entrances and structures for the Merwin adult fish trap improvements, help to refined these concepts, as well as provide documentation of the tailrace flow patterns for use in future studies.

Baseline testing was conducted to document existing tailrace flow patterns for comparison with subsequent testing of proposed features. The main hydraulic feature documented in the baseline testing was the presence of a large clockwise eddy along the right side of the tailrace. Baseline testing also included documenting the extent of the turbine draft tube jets for various powerhouse discharge and tailwater levels. Velocity measurements were also recorded in the vicinity of the proposed corner entrance.

The initial fish trap tests focused on the corner entrance located adjacent to Unit 1. Testing demonstrated that the optimal angle of the entrance channel and weir appeared to be 70 degrees, clockwise, relative to the downstream direction (i.e. 20 degrees counter-clockwise relative to the downstream face of the powerhouse). This angle provided an attraction jet that extended downstream along the left bank as well as along the downstream face of the powerhouse. The corner entrance was shown to provide good attraction flow conditions for entrance discharges between 400 and 600 cfs, in combination with full powerhouse generation flows (11,700 cfs). Two additional entrances, located at Pump Bay No. 2 and 3, were also evaluated in the physical model. The documentation of tailrace flow patterns with the pump bay entrances operating may be used in the future, along with fish behavior studies, to assist in selecting which of these to implement as a second entrance if deemed necessary. In general, test results indicated that wider and shallower pump bay entrance configurations provided better attraction flow patterns.

The final phase of testing focused on documenting the flow patterns in the vicinity of the pump intake and the general tailrace area. The pump intake is required to provide the attraction flow at the entrance(s) and will be located at the skeleton unit adjacent to Unit 3. There were two concerns with the pump intake: 1) the potential for the intake to draw flow directly from Unit 3,

and; 2) the impact of the large eddy on the intake flow distribution. Modeling showed that the pump intake did not directly draw in flow from Unit 3; however, it was noted that the large eddy along the right side of the tailrace area generated sweeping flow across the intake rack, which may influence the flow uniformity entering the individual pump bays. The model also provided a good opportunity to collect tailrace data for future use. Tailrace flow patterns were mapped during this study to offer insight into interpreting fish behavior associated with future fish tracking studies proposed in the Merwin tailrace.

The modeling effort was a collaborative process involving the Lewis River ACC Engineering Subgroup, and it provided a significant amount of data for use in the future. The modeling efforts provided the design team and stakeholders with a tool to determine the optimum entrance configuration based on documented flow patterns and observations.

*(For convenient reference, a memorandum summarizing observations and decisions made by representatives of PacifiCorp, PacifiCorp's Engineer, and members of the ACC Engineering Subgroup, largely utilizing results of this modeling effort, is included in Appendix B. Although not part of **nhc**'s modeling work, this information is included for convenient reference in the context of the subject matter of this report.)*

6 REFERENCES

NMFS. Anadromous Salmonid Passage Facility Design. Northwest Region. 2008.

PacifiCorp Energy, Lewis River Engineering Subgroup Meeting Minutes. January 30th 2008.

PacifiCorp Energy, Lewis River Engineering Subgroup Meeting Minutes. April 8th, 2008.

Table 4.1 Merwin Test Run Index

Test No.	Notes	Data File: ADV Data, Video Links, or Sketch*	Test Date	Operating Conditions					Pump Intake	Corner Entrance Configuration						Pump Bay Entrance								Data Collected		
				Tailwater El.	Total PH Flow	Unit 1 Flow	Unit 2 Flow	Unit 3 Flow		Weir Box	Angle	Flow	Weir Width	Weir El.	Delta H over Weir	PB-2 Flow	Weir Width	Weir El.	Delta H over Weir	PB-3 Flow	Weir Width	Weir El.	Delta H over Weir			
				ft	cfs	cfs	cfs	cfs		--	deg	cfs	ft	ft	ft	cfs	ft	ft	ft	cfs	ft	ft	ft			
Data Disc 1 (DVD)	ADV Method Validation, Preliminary Data																									
	Runs conducted to test method of using ADV probe along an arc to compare flow patterns with 400 vs. 600 cfs. These runs were repeated with Test 4 and 5 after ES agreed that the method was appropriate.																									
	1	Corner Eval Method Validation			A			1/31/2008	53.2	11,470	3,790	3,790	3,890	400	Ext. Bot. 29.4'	70	400	4	38.0	1.5	--	--	--	--	--	ADV**
	2	Corner Eval Method Validation			A			2/6/2008	53.2	11,470	3,790	3,790	3,890	600	Ext. Bot. 29.4'	70	600	6	38.0	1.5	--	--	--	--	--	ADV**
	** Preliminary Trials, data not needed as runs duplicated in Tests 4 and 5.																									
	Baseline Runs with no Corner Fishway compared to 400 and 600 cfs entrance (4' and 6' wide weirs)																									
	Runs conducted to document affects of protruding corner fishway entrance relative to existing conditions, and of corner entrance flow.																									
	3	Baseline A Retracted, Existing Cond.	V1		A			2/22/2008	53.2	11,470	3,790	3,790	3,890	--	Retracted	--	--	--	--	--	--	--	--	--	--	ADV
	6	Baseline B1 Projected, 29.4	V1	E	A			3/25/2008	53.2	11,470	3,790	3,790	3,890	--	Ext. Bot. 29.4'	70	0	--	--	--	--	--	--	--	--	ADV, Dye Vid.
4	Corner Eval ADV 400 FG	V1	E	A			2/21/2008	53.2	11,470	3,790	3,790	3,890	400	Ext. Bot. 29.4'	70	400	4	38.0	1.5	--	--	--	--	--	ADV, Nixon, Dye	
5	Corner Eval ADV 600 FG	V1	E	A			2/20/2008	53.2	11,470	3,790	3,790	3,890	600	Ext. Bot. 29.4'	70	600	6	38.0	1.5	--	--	--	--	--	Video, Hand	
Baseline Runs with no Corner Fishway Flow, and raised bottom of fishway entrance pool to exterior EI 34.0.																										
Runs conducted to see if raising bottom of fishway allowed flow to reduce eddy along left bank immediately downstream of entrance. Did not eliminate eddy.																										
7	Baseline B2 Projected, 34.0	V1	E1	E2			4/2/2008	53.2	11,470	3,790	3,790	3,890	--	Ext. Bot. 34.0'	70	0	--	--	--	--	--	--	--	--	Dye Vid, Nixon	
Data Disc 1 of 2 (DVD)	Runs to examine eddy immediately downstream of corner entrance.																									
	Prepared for and discussed at interim 4/8/08 ES meeting. Eddy issue is observed to be less than originally anticipated.																									
	8	Corner Eddy Dye 400cfs FG (sim T4)	V1	E	I			4/2/2008	53.2	11,470	3,790	3,790	3,890	400	Ext. Bot. 34.0'	70	400	4	38.0	1.5	--	--	--	--	--	Dye Vid, Nixon
	9	Corner Eddy Dye 600cfs FG (sim T5)	V1	E	I			4/2/2008	53.2	11,470	3,790	3,790	3,890	600	Ext. Bot. 34.0'	70	600	6	38.0	1.5	--	--	--	--	--	Dye Vid, Nixon
	10	Corner Eddy Dye 260cfs U1	V1	E	I			4/2/2008	48.0	2,700	2,700	0	0	260	Ext. Bot. 34.0'	70	260	4	38.0	1.5	--	--	--	--	--	Dye Video
	11	Corner Eddy Dye 260cfs U2	V1	E	I			4/2/2008	48.0	2,700	0	2,700	0	260	Ext. Bot. 34.0'	70	260	4	38.0	1.5	--	--	--	--	--	Dye Video
	12	Corner Eddy Dye 260cfs U3	V1	E	I			4/2/2008	48.0	2,700	0	0	2,700	260	Ext. Bot. 34.0'	70	260	4	38.0	1.5	--	--	--	--	--	Dye Video
	Runs to examine Fill to Eliminate Eddy immediately downstream of corner entrance.																									
	Discussed at 4/28/08 ES Meeting, Brute force method to eliminate the eddy space with fill.																									
35	Cor Eddy Dye 400cfs w/ Fillet	E	S				4/25/2008	53.2	11,470	3,790	3,790	3,890	400	Ext. Bot. 34.0'	70	400	4	38.0	1.5	--	--	--	--	--	Dye Video	
36	Cor Eddy Dye 400cfs (=T8)	E	S				4/25/2008	53.2	11,470	3,790	3,790	3,890	400	Ext. Bot. 34.0'	70	400	4	38.0	1.5	--	--	--	--	--	Dye Video	
Runs to examine Corner Entrance with Low Turbine Flows for Each Unit																										
Discussed at 4/28/08 ES Meeting																										
14	Corner Dye 230 U1 Only Low 4'	V1	I				4/3/2008	46.7	1,200	1,200	0	0	230	Ext. Bot. 34.0'	70	230	4	38.0	1.5	--	--	--	--	--	Dye Video	
15	Corner Dye 230 U2 Only Low 4'	V1	I				4/3/2008	46.7	1,200	0	1,200	0	230	Ext. Bot. 34.0'	70	230	4	38.0	1.5	--	--	--	--	--	Dye Video	
16	Corner Dye 230 U3 Only Low 4'	V1	I				4/3/2008	46.7	1,200	0	0	1,200	230	Ext. Bot. 34.0'	70	230	4	38.0	1.5	--	--	--	--	--	Dye Video	

Table 4.1 Merwin Test Run Index

Test No.	Notes	Data File: ADV Data, Video Links, or Sketch*	Test Date	Operating Conditions					Pump Intake	Corner Entrance Configuration						Pump Bay Entrance								Data Collected				
				Tailwater El.	Total PH Flow	Unit 1 Flow	Unit 2 Flow	Unit 3 Flow		Weir Box	Angle	Flow	Weir Width	Weir El.	Delta H over Weir	PB-2 Flow	Weir Width	Weir El.	Delta H over Weir	PB-3 Flow	Weir Width	Weir El.	Delta H over Weir					
				ft	cfs	cfs	cfs	cfs		--	deg	cfs	ft	ft	ft	cfs	ft	ft	ft	cfs	ft	ft	ft					
Data Disc 1 of 2 (DVD)	Runs to examine Corner Entrance with Various Unit Configurations. 4' weir alternatives. Discussed at 4/28/08 ES Meeting																											
	4	Corner Eval ADV 400 FG	V1 E					2/21/2008	53.2	11,470	3,790	3,790	3,890	400	Ext. Bot. 29.4'	70	400	4	38.0	1.5	--	--	--	--	--	--	ADV, Nix, D, V	
	18	Corner Dye U1 Med U2&3 High 4'	V1					4/14/2008	52.6	10,380	2,700	3,790	3,890	375	Ext. Bot. 34.0'	70	375	4	38.0	1.5	--	--	--	--	--	--	Dye Video	
	17	Corner Dye U1 Low U2&3 High 4'	V1					4/14/2008	51.9	8,880	1,200	3,790	3,890	350	Ext. Bot. 34.0'	70	350	4	38.0	1.5	--	--	--	--	--	--	Dye Video	
	23	Corner Dye U2&3 Med U1 Off 4'	V1					4/15/2008	50.0	5,400	0	2,700	2,700	320	Ext. Bot. 34.0'	70	320	4	38.0	1.5	--	--	--	--	--	--	Dye Video	
	21	Corner Dye U1&2 Med U3 Off 4'	V1					4/15/2008	50.0	5,400	2,700	2,700	0	320	Ext. Bot. 34.0'	70	320	4	38.0	1.5	--	--	--	--	--	--	Dye Video	
	22	Corner Dye U1&3 Med U2 Off 4'	V1					4/15/2008	50.0	5,400	2,700	0	2,700	320	Ext. Bot. 34.0'	70	320	4	38.0	1.5	--	--	--	--	--	--	Dye Video	
	Runs to examine Corner Entrance with Various Unit Configurations. 6' weir alternatives. Discussed at 4/28/08 ES Meeting																											
	5	Corner Eval ADV 600 FG	V1 E					2/20/2008	53.2	11,470	3,790	3,790	3,890	600	Ext. Bot. 29.4'	70	600	6	38.0	1.5	--	--	--	--	--	--	--	ADV, Nix, D, V
20	Corner Dye U1 Med U2&3 High 6'	V1					4/14/2008	52.6	10,380	2,700	3,790	3,890	560	Ext. Bot. 34.0'	70	560	6	38.0	1.5	--	--	--	--	--	--	--	Dye Video	
19	Corner Dye U1 Low U2&3 High 6'	V1					4/14/2008	51.9	8,880	1,200	3,790	3,890	530	Ext. Bot. 34.0'	70	530	6	38.0	1.5	--	--	--	--	--	--	--	Dye Video	
26	Corner Dye U2&3 Med U1 Off 6'	V1					4/15/2008	50.0	5,400	0	2,700	2,700	475	Ext. Bot. 34.0'	70	475	6	38.0	1.5	--	--	--	--	--	--	--	Dye Video	
25	Corner Dye U1&3 Med U2 Off 6'	V1					4/15/2008	50.0	5,400	2,700	0	2,700	475	Ext. Bot. 34.0'	70	475	6	38.0	1.5	--	--	--	--	--	--	--	Dye Video	
24	Corner Dye U1&2 Med U3 Off 6'	V1					4/15/2008	50.0	5,400	2,700	2,700	0	475	Ext. Bot. 34.0'	70	475	6	38.0	1.5	--	--	--	--	--	--	--	Dye Video	
Data Disc 1 of 2 (DVD)	Runs to examine PB2 and PB3 Entrance Flows at 170 cfs. Prepared for and discussed at interim 4/8/08 ES meeting.																											
	13.1	PB-2 Dye 3' 170cfs FG	V1 V2 I					4/2/2008	53.2	11,470	3,790	3,790	3,890	170	Ext. Bot. 34.0'	70	0	--	--	--	170	3	43.7	1.5	--	--	--	Dye Video
	13.2	PB-2 Dye 4' 170cfs FG	V1					4/2/2008	53.2	11,470	3,790	3,790	3,890	170	Ext. Bot. 34.0'	70	0	--	--	--	170	4	46.2	1.5	--	--	--	Dye Video
	13.3	PB-3 Dye 3' 170cfs FG	V1 V2 I					4/2/2008	53.2	11,470	3,790	3,790	3,890	170	Ext. Bot. 34.0'	70	0	--	--	--	--	--	170	3	43.7	1.5	Dye Video	
	13.4	PB-3 Dye 4' 170cfs FG	V1					4/2/2008	53.2	11,470	3,790	3,790	3,890	170	Ext. Bot. 34.0'	70	0	--	--	--	--	--	170	4	46.2	1.5	Dye Video	
	Runs to examine PB2 and PB3 Entrance Flows at 330 cfs. Prepared for and discussed at interim 4/8/08 ES meeting.																											
	13.5	PB-2 Dye 3' 330cfs FG	V1 V2					3/13/2008	53.2	11,470	3,790	3,790	3,890	330	Ext. Bot. 34.0'	70	0	--	--	--	330	3	37.2	1.5	--	--	--	Dye Video
	13.6	PB-2 Dye 4' 330cfs FG	V1					3/13/2008	53.2	11,470	3,790	3,790	3,890	330	Ext. Bot. 34.0'	70	0	--	--	--	330	4	40.7	1.5	--	--	--	Dye Video
	13.7	PB-3 Dye 3' 330cfs FG	V1 V2					3/13/2008	53.2	11,470	3,790	3,790	3,890	330	Ext. Bot. 34.0'	70	0	--	--	--	--	--	330	3	37.2	1.5	Dye Video	
13.8	PB-3 Dye 4' 330cfs FG	V1					3/13/2008	53.2	11,470	3,790	3,790	3,890	330	Ext. Bot. 34.0'	70	0	--	--	--	--	--	330	4	40.7	1.5	Dye Video		

Table 4.1 Merwin Test Run Index

Test No.	Notes	Data File: ADV Data, Video Links, or Sketch*	Test Date	Operating Conditions					Pump Intake	Corner Entrance Configuration						Pump Bay Entrance								Data Collected					
				Tailwater El.	Total PH Flow	Unit 1 Flow	Unit 2 Flow	Unit 3 Flow		Weir Box	Angle	Flow	Weir Width	Weir El.	Delta H over Weir	PB-2 Flow	Weir Width	Weir El.	Delta H over Weir	PB-3 Flow	Weir Width	Weir El.	Delta H over Weir						
				ft	cfs	cfs	cfs	cfs		--	deg	cfs	ft	ft	ft	cfs	ft	ft	ft	cfs	ft	ft	ft						
Data Disc 1 of 2 (DVD)	Runs to examine Corner Entrance 4' Weir with PB2 and PB3 at Higher and Medium Turbine Flows Discussed at 4/28/08 ES Meeting																												
	Full Gen, PB2 and PB3 at 3' and 4' weir width																												
	27	Corner 4' & PB-2 3'	V1	V2				4/15/2008	53.2	11,470	3,790	3,790	3,890	730	Ext. Bot. 34.0'	70	400	4	38.0	1.5	330	3	37.2	1.5	--	--	--	--	Dye Video
	31	Corner 4' & PB-3 3'	V1	V2				4/15/2008	53.2	11,470	3,790	3,790	3,890	730	Ext. Bot. 34.0'	70	400	4	38.0	1.5	--	--	--	--	330	3	37.2	1.5	Dye Video
	29	Corner 4' & PB-2 4'	V1	V2				4/15/2008	53.2	11,470	3,790	3,790	3,890	730	Ext. Bot. 34.0'	70	400	4	38.0	1.5	330	4	40.7	1.5	--	--	--	--	Dye Video
	33	Corner 4' & PB-3 4'	V1	V2				4/15/2008	53.2	11,470	3,790	3,790	3,890	730	Ext. Bot. 34.0'	70	400	4	38.0	1.5	--	--	--	--	330	4	40.7	1.5	Dye Video
	5,400 Gen Capacity, PB2 and PB3 at 3' and 4' weir width																												
	28	Corner 4' & PB-2 3' U3 Off	V1	V2				4/15/2008	50.0	5,400	2,700	2,700	0	560	Ext. Bot. 34.0'	70	320	4	38.0	1.5	240	3	37.2	1.5	--	--	--	--	Dye Video
	32	Corner 4' & PB-3 3' U3 Off	V1	V2				4/15/2008	50.0	5,400	2,700	2,700	0	560	Ext. Bot. 34.0'	70	320	4	38.0	1.5	--	--	--	--	240	3	37.2	1.5	Dye Video
	30	Corner 4' & PB-2 4' U3 Off	V1	V2				4/15/2008	50.0	5,400	2,700	2,700	0	560	Ext. Bot. 34.0'	70	320	4	38.0	1.5	240	4	40.7	1.5	--	--	--	--	Dye Video
	34	Corner 4' & PB-3 4' U3 Off	V1	V2				4/15/2008	50.0	5,400	2,700	2,700	0	560	Ext. Bot. 34.0'	70	320	4	38.0	1.5	--	--	--	--	240	4	40.7	1.5	Dye Video
Data Disc 1 of 2 (DVD)	Runs to examine Corner Entrance with 1.5' head vs. 1.0' head across 4' wide entrance weir. Follow up data from 4/28/08 ES Meeting																												
	4	Corner Eval ADV 400 FG	V1	E				2/21/2008	53.2	11,470	3,790	3,790	3,890	400	Ext. Bot. 29.4'	70	400	4	38.0	1.5	--	--	--	--	--	--	--	--	ADV, Nix, D, V
	8	Corner Eddy Dye 400cfs FG (sim T4)	V1	E	I			4/2/2008	53.2	11,470	3,790	3,790	3,890	400	Ext. Bot. 34.0'	70	400	4	38.0	1.5	--	--	--	--	--	--	--	--	Dye Vid, Nixon
	37	Corner Eddy Dye 400cfs FG (sim T4)	V1					4/30/2008	53.2	11,470	3,790	3,790	3,890	330	Ext. Bot. 34.0'	70	330	4	38.0	1.0	--	--	--	--	--	--	--	--	Dye Vid, Nixon
	Runs to examine Corner Entrance with 1.5' head vs. 1.0' head across 6' wide entrance weir. Follow up Data from 4/28/08 ES Meeting																												
	5	Corner Eval ADV 600 FG	V1	E				2/20/2008	53.2	11,470	3,790	3,790	3,890	600	Ext. Bot. 29.4'	70	600	6	38.0	1.5	--	--	--	--	--	--	--	--	ADV, Nix, D, V
	9	Corner Eddy Dye 600cfs FG (sim T5)	V1	E	I			4/2/2008	53.2	11,470	3,790	3,790	3,890	600	Ext. Bot. 34.0'	70	600	6	38.0	1.5	--	--	--	--	--	--	--	--	Dye Vid, Nixon
	38	Corner Eddy Dye 600cfs FG (sim T5)	V1					4/30/2008	53.2	11,470	3,790	3,790	3,890	500	Ext. Bot. 34.0'	70	500	6	38.0	1.0	--	--	--	--	--	--	--	--	Dye Vid, Nixon
	Runs to examine PB2 Entrance with 1.5' head vs. 1.0' head across 4' wide entrance weir. Follow up Data from 4/28/08 ES Meeting																												
	29	Corner 4' & PB-2 4'	V1	V2				4/15/2008	53.2	11,470	3,790	3,790	3,890	730	Ext. Bot. 34.0'	70	400	4	38.0	1.5	330	4	40.7	1.5	--	--	--	--	Dye Video
	39	Corner 4' & PB-2 4'	V1					4/30/2008	53.2	11,470	3,790	3,790	3,890	660	Ext. Bot. 34.0'	70	400	4	38.0	1.5	260	4	40.7	1.0	--	--	--	--	Dye Video
Runs to examine PB3 Entrance with 1.5' head vs. 1.0' head across 4' wide entrance weir. Follow up Data from 4/28/08 ES Meeting																													
33	Corner 4' & PB-3 4'	V1	V2				4/15/2008	53.2	11,470	3,790	3,790	3,890	730	Ext. Bot. 34.0'	70	400	4	38.0	1.5	--	--	--	--	330	4	40.7	1.5	Dye Video	
40	Corner 4' & PB-3 4'	V1					4/30/2008	53.2	11,470	3,790	3,790	3,890	660	Ext. Bot. 34.0'	70	400	4	38.0	1.5					260	4	40.7	1.0	Dye Video	

Table 4.1 Merwin Test Run Index

Test No.	Notes	Data File: ADV Data, Video Links, or Sketch*	Test Date	Operating Conditions					Pump Intake	Corner Entrance Configuration						Pump Bay Entrance								Data Collected						
				Tailwater El.	Total PH Flow	Unit 1 Flow	Unit 2 Flow	Unit 3 Flow		Weir Box	Angle	Flow	Weir Width	Weir El.	Delta H over Weir	PB-2 Flow	Weir Width	Weir El.	Delta H over Weir	PB-3 Flow	Weir Width	Weir El.	Delta H over Weir							
				ft	cfs	cfs	cfs	cfs		cfs	deg	cfs	ft	ft	ft	cfs	ft	ft	ft	cfs	ft	ft	ft							
Data Disc 1 of 2 (DVI)	Tailrace Flow Pattern Runs, for 3 Depth Sketches Layered interactive PDF File Provided to view these Runs																													
	41	TW Pattern, U1 U2 U3				S			4/21/2008	51.6	8,100	2,700	2,700	2,700	335	Ext. Bot. 34.0'	70	335	4	38.0	1.5	--	--	--	--	--	sketches @ 3d			
	42	TW Pattern, U1 (same as T10)	V1	E	T	S			5/1/2008	48.1	2,700	2,700	0	0	270	Ext. Bot. 34.0'	70	270	4	38.0	1.5	--	--	--	--	--	sketches @ 3d			
	43	TW Pattern, U2 (same as T11)	V1	E	T	S			5/2/2008	48.1	2,700	0	2,700	0	270	Ext. Bot. 34.0'	--	270	4	38.0	1.5	--	--	--	--	--	sketches @ 3d			
	44	TW Pattern, U3 (same as T12)	V1	E	T	S			5/5/2008	48.1	2,700	0	0	2,700	270	Ext. Bot. 34.0'	70	270	4	38.0	1.5	--	--	--	--	--	sketches @ 3d			
	45	TW Pattern, U1 U2 (same as T21)	V1			S			4/22/2008	50.0	5,400	2,700	2,700	0	320	Ext. Bot. 34.0'	70	320	4	38.0	1.5	--	--	--	--	--	sketches @ 3d			
	46	TW Pattern, U2 U3 (same as T23)	V1			S			4/23/2008	50.0	5,400	0	2,700	2,700	320	Ext. Bot. 34.0'	70	320	4	38.0	1.5	--	--	--	--	--	sketches @ 3d			
Data Disc 2 of 2 (CD)	Runs to examine AWS Intake Rack																													
	Test Set Up Diagrams (Fig I, II, III, IV) [Link]		Video, Fig I & II				ADV DATA Fig III & IV	TIMED DYE FIG I																						
			Dye E, F, G	Dye H	Dye J	Dye K																								
			V1	V2	V3	V4			S	D	5/13/2008	53.2	11,470	3,790	3,790	3,890	600	Ext. Bot. 34.0'	70	600	6	38.0	1.5	--	--	--	--	--	--	ADV, Dye Vid.
			V1	V2					S		5/12/2008	53.2	0	0	0	0	600	Ext. Bot. 34.0'	70	600	6	38.0	1.5	--	--	--	--	--	--	ADV, Dye Vid.
						V1					5/13/2008	53.2	2,700	0	0	2,700	400	Ext. Bot. 34.0'	70	400	6	38.0	1.5	--	--	--	--	--	--	Dye Video
	50	1,200 cfs Unit 3, Corner				V1			5/13/2008		53.2	1,200	0	0	1,200	350	Ext. Bot. 34.0'	70	350	6	38.0	1.5	--	--	--	--	--	--	Dye Video	

* Data File Type Key
V: General dye video
E: Eddy specific dye video, near corner entrance
T: Traverse with dye wand
A: ADV Data (PDF layered file)
S: Sketch (PDF layered file)
D: Timed Dye Tests

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Table 4.2 Tailrace Velocities at 5 ft Depth - Test 3A - Baseline

	Measurement Angle	Avg V _x	Avg V _y	Avg V _z	Magnitude of Resultant of Avg V _x , V _y , V _z	Average Magnitude		Avg V _{xy}	Model Plane Angle
	deg	ft/s	ft/s	ft/s	ft/s	ft/s		ft/s	deg
Radius 1: Unit 1 - Bay 2									
Sample 1: Parallel to PH Face	0	1.3	-1.2	0.4	1.8	2.7		1.7	-44.0
Sample 2:	15	2.1	-1.1	1.1	2.6	3.3		2.4	-13.5
Sample 3:	30	2.5	-1.1	2.6	3.7	4.3		2.7	7.0
Sample 4:	45	1.8	-0.7	2.1	2.9	3.6		2.0	23.6
Sample 5: Left Bank	55	1.4	-0.3	1.3	1.9	3.2		1.4	44.2
Radius 2: Unit 1 - Bay 3									
Sample 1: Parallel to PH Face	0	1.4	-1.5	-0.6	2.1	3.2		2.1	-47.2
Sample 2:	15	1.3	-1.8	-0.2	2.2	3.5		2.2	-38.0
Sample 3:	30	2.9	-0.9	0.5	3.1	4.0		3.1	12.3
Sample 4:	45	4.3	-0.3	1.9	4.7	5.2		4.3	41.5
Sample 5: Left Bank	55	3.6	0.7	1.8	4.1	4.7		3.7	65.8
Radius 3: Unit 2 - Bay 1									
Sample 1: Parallel to PH Face	0	1.0	0.1	-0.7	1.2	2.2		1.0	3.9
Sample 2:	15	2.2	-0.1	-0.4	2.2	2.9		2.2	12.4
Sample 3:	30	2.0	-0.7	0.2	2.1	3.0		2.1	10.9
Sample 4:	45	3.9	0.8	0.4	4.0	4.6		3.9	56.7
Sample 5: Left Bank	55	8.4	2.6	1.8	9.0	9.2		8.8	72.2

Notes:

- 1) Model Operating Conditions: Test 3A - Baseline: No Fishway Weir, Full Powerhouse Generation, 53.2' Tailwater
- 2) Figure 4.1 illustrates the resulting vector plot for this test condition
- 3) Data was collected with a Nortek Vectrino Acoustic Doppler Velocimeter (ADV)
- 4) All values are shown in prototype dimensions
- 5) Angles are measured in degrees, CCW from Powerhouse Face, e.g. the turbine drafttubes are aligned at 90°

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Table 4.3 Tailrace Velocities at 12 ft Depth - Test 3B - Baseline

	Measurement Angle	Avg V _x	Avg V _y	Avg V _z	Magnitude of Resultant of Avg V _x , V _y , V _z	Average Magnitude		Avg V _{xy}	Model Plane Angle
	deg	ft/s	ft/s	ft/s	ft/s	ft/s		ft/s	deg
Radius 1: Unit 1 - Bay 2									
Sample 1: Parallel to PH Face	0	-0.7	2.0	-0.3	2.1	3.0		2.1	109.6
Sample 2:	15	0.7	3.4	0.8	3.5	4.4		3.4	94.0
Sample 3:	30	3.2	3.3	3.1	5.5	6.2		4.6	75.8
Sample 4:	45	2.9	0.5	3.4	4.5	5.0		2.9	55.6
Sample 5: Left Bank	50	3.2	0.2	2.9	4.3	4.9		3.2	53.7
Radius 2: Unit 1 - Bay 3									
Sample 1: Parallel to PH Face	0	-0.8	5.6	-0.8	5.7	6.3		5.6	97.8
Sample 2:	15	0.1	6.8	-0.1	6.8	7.8		6.8	104.4
Sample 3:	30	2.1	4.9	0.8	5.4	6.1		5.3	97.0
Sample 4:	45	5.2	4.6	2.6	7.4	7.7		6.9	86.6
Sample 5: Left Bank	50	6.2	4.3	3.3	8.2	8.5		7.6	84.4
Radius 3: Unit 2 - Bay 1									
Sample 1: Parallel to PH Face	0	-0.7	3.0	-1.7	3.5	4.5		3.1	103.2
Sample 2:	15	-0.1	4.2	-1.1	4.4	5.1		4.2	105.9
Sample 3:	30	1.0	2.7	0.0	2.9	4.0		2.9	99.0
Sample 4:	45	2.6	2.4	1.0	3.7	4.6		3.5	88.3
Sample 5: Left Bank	50	6.2	3.9	1.3	7.4	7.8		7.3	82.5

Notes:

- 1) Model Operating Conditions: Test 3B - Baseline: Baseline, No Fishway Weir, Full Powerhouse Generation, 53.2' Tailwater
- 2) Figure 4.2 illustrates the resulting vector plot for this test condition
- 3) Data was collected with a Nortek Vectrino Acoustic Doppler Velocimeter (ADV)
- 4) All values are shown in prototype dimensions
- 5) Angles are measured in degrees, CCW from Powerhouse Face, e.g. the turbine drafttubes are aligned at 90°

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Table 4.4 Tailrace Velocities at 5 ft Depth - Test 4A

	Measurement Angle deg	Avg V _x ft/s	Avg V _y ft/s	Avg V _z ft/s	Magnitude of Resultant of Avg V _x , V _y , V _z ft/s	Average Magnitude ft/s		Avg V _{xy} ft/s	Model Plane Angle deg
Radius 1: Unit 1 - Bay 2									
Sample 1: Parallel to PH Face	0	5.4	-0.4	3.6	6.5	7.0		5.4	-4.0
Sample 2:	15	8.4	0.1	0.9	8.5	8.7		8.4	15.6
Sample 3: Jet C/L	25	3.9	0.0	-0.6	4.0	4.7		3.9	25.0
Sample 4:	30	1.3	-0.2	-1.2	1.8	3.0		1.3	20.9
Sample 5:	35	-0.5	-0.5	-1.0	1.3	2.2		0.7	-104.8
Sample 6:	45	-0.3	0.0	-0.4	0.5	1.6		0.3	-126.9
Sample 7: Left Bank	55	-0.5	0.0	0.4	0.7	1.9		0.5	-123.9
Radius 2: Unit 1 - Bay 3									
Sample 1: Parallel to PH Face	0	4.5	-1.9	0.1	4.9	5.6		4.9	-22.8
Sample 2:	15	5.1	-0.9	1.0	5.3	6.0		5.2	4.5
Sample 3: Jet C/L	25	5.3	1.2	1.3	5.6	6.2		5.4	37.9
Sample 4:	30	5.0	1.7	1.4	5.4	6.0		5.3	48.4
Sample 5:	35	3.8	1.7	1.1	4.3	5.1		4.1	58.9
Sample 6:	45	1.5	1.3	0.7	2.1	3.4		1.9	86.0
Sample 7: Left Bank	55	1.7	2.1	2.7	3.9	4.3		2.7	106.0
Radius 3: Unit 2 - Bay 1									
Sample 1: Parallel to PH Face	0	3.6	0.3	0.4	3.6	4.2		3.6	5.5
Sample 2:	15	3.5	0.1	-0.2	3.5	4.1		3.5	16.9
Sample 3: Jet C/L	25	3.5	-1.0	0.2	3.7	4.3		3.7	8.5
Sample 4:	30	2.8	-0.5	0.3	2.9	3.9		2.8	20.7
Sample 5:	35	3.1	-0.1	0.9	3.2	4.1		3.1	33.7
Sample 6:	45	6.1	1.9	0.8	6.5	6.9		6.4	62.1
Sample 7: Left Bank	55	8.4	2.2	1.6	8.8	8.9		8.7	69.4

Notes:

- 1) Model Operating Conditions: Test 4A: 4' Weir at 38.0', 400 cfs Attraction Flow, Full Powerhouse Generation, 53.2' Tailwater
- 2) Figure 4.5 illustrates the resulting vector plot for this test condition
- 3) Data was collected with a Nortek Vectrino Acoustic Doppler Velocimeter (ADV)
- 4) All values are shown in prototype dimensions
- 5) Angles are measured in degrees, CCW from Powerhouse Face, e.g. the turbine drafttubes are aligned at 90°

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Table 4.5 Tailrace Velocities at 12 ft Depth - Test 4B

	Measurement Angle deg	Avg V _x ft/s	Avg V _y ft/s	Avg V _z ft/s	Magnitude of Resultant of Avg V _x , V _y , V _z ft/s	Average Magnitude ft/s		Avg V _{xy} ft/s	Model Plane Angle deg
Radius 1: Unit 1 - Bay 2									
Sample 1: Parallel to PH Face	0	2.2	3.3	3.5	5.3	6.1		3.9	56.1
Sample 2:	15	4.6	2.9	2.3	5.9	6.4		5.4	47.4
Sample 3: Jet C/L	25	6.0	3.0	1.1	6.9	7.2		6.8	51.8
Sample 4:	30	3.8	1.4	0.0	4.0	4.6		4.0	50.8
Sample 5:	45	0.7	1.0	0.3	1.3	2.3		1.2	101.0
Sample 6: Left Bank	50	0.1	1.9	2.7	3.3	3.8		1.9	136.1
Radius 2: Unit 1 - Bay 3									
Sample 1: Parallel to PH Face	0	-1.0	5.4	0.4	5.5	6.1		5.5	100.8
Sample 2:	15	0.9	6.3	1.3	6.5	7.0		6.3	97.1
Sample 3: Jet C/L	25	3.5	5.7	2.5	7.1	7.5		6.7	83.6
Sample 4:	30	5.0	6.0	2.7	8.3	8.5		7.8	80.3
Sample 5:	45	6.2	4.5	2.6	8.1	8.4		7.7	80.7
Sample 6: Left Bank	50	4.6	3.2	3.5	6.5	6.8		5.6	85.1
Radius 3: Unit 2 - Bay 1									
Sample 1: Parallel to PH Face	0	0.7	2.6	-1.3	3.0	3.8		2.7	74.1
Sample 2:	15	0.2	1.7	-1.3	2.2	3.4		1.7	98.6
Sample 3: Jet C/L	25	0.7	2.3	-0.5	2.5	3.7		2.4	97.9
Sample 4:	30	1.3	2.6	1.0	3.1	4.2		2.9	93.6
Sample 5:	45	4.7	3.5	0.8	5.9	6.5		5.9	81.8
Sample 6: Left Bank	50	8.9	4.1	1.8	10.0	10.2		9.8	74.6

Notes:

- 1) Model Operating Conditions: Test 4B: 4' Weir at 38.0', 400 cfs Attraction Flow, Full Powerhouse Generation, 53.2' Tailwater
- 2) Figure 4.6 illustrates the resulting vector plot for this test condition
- 3) Data was collected with a Nortek Vectrino Acoustic Doppler Velocimeter (ADV)
- 4) All values are shown in prototype dimensions
- 5) Angles are measured in degrees, CCW from Powerhouse Face, e.g. the turbine drafttubes are aligned at 90°

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Tailrace Physical Hydraulic Model Study

Table 4.6 Tailrace Velocities at 5 ft Depth - Test 5A

	Measurement Angle deg	Avg V _x ft/s	Avg V _y ft/s	Avg V _z ft/s	Magnitude of Resultant of Avg V _x , V _y , V _z ft/s	Average Magnitude ft/s		Avg V _{xy} ft/s	Model Plane Angle deg
Radius 1: Unit 1 - Bay 2									
Sample 1: Parallel to PH Face	0	5.6	-1.4	2.7	6.4	6.7		5.8	-14.5
Sample 2:	15	8.7	-1.0	1.8	9.0	9.1		8.8	8.3
Sample 3: Jet C/L	25	8.4	-0.5	0.9	8.5	8.6		8.5	21.8
Sample 4:	30	7.1	-0.4	0.7	7.1	7.3		7.1	26.5
Sample 5:	35	3.3	-0.5	-0.2	3.3	4.0		3.3	26.1
Sample 6:	45	0.2	-0.1	-0.9	0.9	2.1		0.2	27.4
Sample 7: Left Bank	55	-0.2	0.0	-0.3	0.4	1.3		0.2	-114.1
Radius 2: Unit 1 - Bay 3									
Sample 1: Parallel to PH Face	0	3.8	-2.0	0.0	4.3	5.1		4.3	-28.1
Sample 2:	15	4.5	-1.7	0.3	4.8	5.7		4.8	-5.9
Sample 3: Jet C/L	25	6.0	0.2	1.2	6.1	6.6		6.0	27.4
Sample 4:	30	6.1	0.5	1.2	6.3	6.6		6.1	34.6
Sample 5:	35	5.4	1.1	1.2	5.7	6.1		5.5	46.5
Sample 6:	45	3.1	1.0	0.6	3.3	4.2		3.2	62.3
Sample 7: Left Bank	55	1.5	1.1	1.2	2.2	3.2		1.8	92.2
Radius 3: Unit 2 - Bay 1									
Sample 1: Parallel to PH Face	0	2.6	0.4	0.0	2.6	3.4		2.6	8.5
Sample 2:	15	3.4	0.0	-0.3	3.4	4.0		3.4	15.2
Sample 3: Jet C/L	25	3.8	-0.9	-0.1	3.9	4.6		3.9	11.1
Sample 4:	30	3.6	-0.5	0.3	3.6	4.6		3.6	22.6
Sample 5:	35	3.6	0.3	0.7	3.7	4.7		3.7	39.3
Sample 6:	45	4.9	1.2	0.4	5.1	5.6		5.0	59.0
Sample 7: Left Bank	55	8.3	2.5	1.6	8.8	9.0		8.7	71.4

Notes:

- 1) Model Operating Conditions: Test 5A: 6' Weir at 38.0', 600 cfs Attraction Flow, Full Powerhouse Generation, 53.2' Tailwater
- 2) Figure 4.7 illustrates the resulting vector plot for this test condition
- 3) Data was collected with a Nortek Vectrino Acoustic Doppler Velocimeter (ADV)
- 4) All values are shown in prototype dimensions
- 5) Angles are measured in degrees, CCW from Powerhouse Face, e.g. the turbine drafttubes are aligned at 90°

Merwin Adult Fish Trap
Tailrace Physical Hydraulic Model Study

Table 4.7 Tailrace Velocities at 12 ft Depth - Test 5B

	Measurement Angle deg	Avg V _x ft/s	Avg V _y ft/s	Avg V _z ft/s	Magnitude of Resultant of Avg V _x , V _y , V _z ft/s	Average Magnitude ft/s		Avg V _{xy} ft/s	Model Plane Angle deg
Radius 1: Unit 1 - Bay 2									
Sample 1: Parallel to PH Face	0	0.1	4.7	1.8	5.0	5.6		4.7	89.1
Sample 2:	15	3.2	5.9	2.8	7.2	7.7		6.7	76.6
Sample 3: Jet C/L	25	4.5	3.8	1.5	6.1	6.6		5.9	65.2
Sample 4:	30	5.0	3.1	0.9	5.9	6.4		5.9	62.2
Sample 5:	45	3.1	1.3	0.1	3.4	4.0		3.4	67.3
Sample 6: Left Bank	50	1.8	1.0	0.4	2.1	2.9		2.0	78.7
Radius 2: Unit 1 - Bay 3									
Sample 1: Parallel to PH Face	0	-0.8	7.2	-0.1	7.3	7.8		7.3	96.3
Sample 2:	15	0.9	9.1	0.7	9.1	9.5		9.1	99.1
Sample 3: Jet C/L	25	3.4	7.1	0.9	7.9	8.3		7.8	89.2
Sample 4:	30	4.8	5.7	1.7	7.6	8.0		7.5	80.3
Sample 5:	45	6.7	4.3	1.8	8.2	8.4		7.9	77.6
Sample 6: Left Bank	50	6.2	3.6	2.4	7.6	7.8		7.2	80.6
Radius 3: Unit 2 - Bay 1									
Sample 1: Parallel to PH Face	0	0.5	8.5	0.3	8.5	9.0		8.5	86.4
Sample 2:	15	1.8	5.9	-0.9	6.2	7.5		6.2	88.4
Sample 3: Jet C/L	25	1.0	2.9	-0.9	3.2	4.5		3.1	96.1
Sample 4:	30	1.4	4.0	0.0	4.2	5.2		4.2	101.2
Sample 5:	45	3.2	3.1	0.7	4.5	5.4		4.5	89.2
Sample 6: Left Bank	50	6.8	3.6	1.0	7.8	8.1		7.7	77.9

Notes:

- 1) Model Operating Conditions: Test 5B: 6' Weir at 38.0', 600 cfs Attraction Flow, Full Powerhouse Generation, 53.2' Tailwater
- 2) Figure 4.8 illustrates the resulting vector plot for this test condition
- 3) Data was collected with a Nortek Vectrino Acoustic Doppler Velocimeter (ADV)
- 4) All values are shown in prototype dimensions
- 5) Angles are measured in degrees, CCW from Powerhouse Face, e.g. the turbine drafttubes are aligned at 90°

Merwin Fishtrap
Tailrace Physical Hydraulic Model Study

Table 4.8 Tailrace Velocities at 5 ft Depth - Test 6A

	Measurement Angle	Avg V _x	Avg V _y	Avg V _z	Magnitude of Resultant of Avg V _x , V _y , V _z	Average Magnitude		Avg V _{xy}	Model Plane Angle
	deg	ft/s	ft/s	ft/s	ft/s	ft/s		ft/s	deg
Radius 1: Unit 1 - Bay 2									
Sample 1: Parallel to PH Face	0	3.2	0.1	2.6	4.1	4.8		3.2	2.5
Sample 2:	15	3.2	0.7	2.3	4.0	4.7		3.2	27.8
Sample 3:	30	0.5	0.0	0.5	0.7	2.9		0.5	30.5
Sample 4:	45	-1.6	-0.1	-0.5	1.7	2.8		1.6	-129.8
Sample 5: Left Bank	55	-1.3	0.5	0.9	1.6	2.8		1.4	214.9
Radius 2: Unit 1 - Bay 3									
Sample 1: Parallel to PH Face	0	1.3	-0.8	-0.3	1.6	2.7		1.5	-31.9
Sample 2:	15	1.8	-1.0	0.4	2.1	3.3		2.0	-15.8
Sample 3:	30	3.3	0.9	1.6	3.8	4.6		3.5	44.3
Sample 4:	45	3.1	2.0	1.6	4.1	4.6		3.7	77.6
Sample 5: Left Bank	55	2.0	2.5	3.4	4.7	5.2		3.2	105.9
Radius 3: Unit 2 - Bay 1									
Sample 1: Parallel to PH Face	0	1.4	0.2	-0.5	1.5	2.1		1.4	8.2
Sample 2:	15	1.0	-0.7	-0.7	1.4	2.2		1.2	-17.8
Sample 3:	30	1.6	-0.4	0.4	1.7	2.7		1.7	15.1
Sample 4:	45	4.2	1.6	0.6	4.5	5.2		4.5	66.2
Sample 5: Left Bank	55	0.0	0.0	0.0	0.0	0.1		0.0	39.8

Notes:

- 1) Model Operating Conditions: Test 6A: Fishway Weir Protruding, No Fishway Flow, Full Powerhouse Generation, 53.2' Tailwater
- 2) Figure 4.9 illustrates the resulting vector plot for this test condition
- 3) Data was collected with a Nortek Vectrino Acoustic Doppler Velocimeter (ADV)
- 4) All values are shown in prototype dimensions
- 5) Angles are measured in degrees, CCW from Powerhouse Face, e.g. the turbine drafttubes are aligned at 90°

Merwin Fishtrap
Tailrace Physical Hydraulic Model Study

Table 4.9 Tailrace Velocities at 12 ft Depth - Test 6B

	Measurement Angle	Avg V _x	Avg V _y	Avg V _z	Magnitude of Resultant of Avg V _x , V _y , V _z	Average Magnitude		Avg V _{xy}	Model Plane Angle
	deg	ft/s	ft/s	ft/s	ft/s	ft/s		ft/s	deg
Radius 1: Unit 1 - Bay 2									
Sample 1: Parallel to PH Face	0	1.2	3.6	3.5	5.2	6.0		3.8	71.0
Sample 2:	15	3.2	3.8	3.0	5.8	6.3		5.0	64.8
Sample 3:	30	3.5	2.5	1.0	4.4	5.2		4.3	65.8
Sample 4:	45	0.5	0.9	1.1	1.5	3.1		1.1	104.6
Sample 5: Left Bank	50	-0.6	1.4	2.6	3.0	3.7		1.5	162.2
Radius 2: Unit 1 - Bay 3									
Sample 1: Parallel to PH Face	0	-1.1	4.8	-0.8	4.9	5.6		4.9	102.8
Sample 2:	15	0.3	5.6	0.7	5.7	6.6		5.6	102.4
Sample 3:	30	2.8	5.2	2.1	6.2	6.7		5.9	91.8
Sample 4:	45	5.3	4.9	3.3	7.9	8.2		7.2	87.7
Sample 5: Left Bank	50	3.7	3.5	4.3	6.7	7.8		5.1	93.6
Radius 3: Unit 2 - Bay 1									
Sample 1: Parallel to PH Face	0	-0.7	3.7	-1.3	4.0	5.1		3.8	100.3
Sample 2:	15	-0.5	2.6	-0.9	2.8	4.1		2.7	115.4
Sample 3:	30	0.1	1.2	0.5	1.3	2.6		1.2	113.3
Sample 4:	45	3.7	3.2	1.0	5.0	5.7		4.9	85.7
Sample 5: Left Bank	50	8.6	4.9	2.0	10.1	10.4		9.9	79.8

Notes:

- 1) Model Operating Conditions: Test 6B: Fishway Weir Protruding, No Fishway Flow, Full Powerhouse Generation, 53.2' Tailwater
- 2) Figure 4.10 illustrates the resulting vector plot for this test condition
- 3) Data was collected with a Nortek Vectrino Acoustic Doppler Velocimeter (ADV)
- 4) All values are shown in prototype dimensions
- 5) Angles are measured in degrees, CCW from Powerhouse Face, e.g. the turbine drafttubes are aligned at 90°

Merwin Fishtrap
Tailrace Physical Hydraulic Model Study

Table 4.10 Pump Intake ADV Data - Test 47

Pump Intake Test 47: Tailwater: 53.2'
Powerhouse: Unit 1 - 3,790 cfs; Unit 2 - 3,790 cfs; Unit 3 - 3,890 cfs;
Fishtrap: Corner Entrance, 6' wide weir, 38.0' crest, 600 cfs
Pump Intake: 600 cfs

ADV Measurement Location	Avg Vx	Avg Vy	Avg Vz	Magnitude of Resultant of Avg Vx, Vy, Vz	Average Magnitude
	ft/s	ft/s	ft/s	ft/s	ft/s
V1A	0.0	-0.9	-0.4	1.0	1.4
V1B	-0.4	-0.4	0.4	0.7	1.4
V1C	-0.5	-1.2	0.4	1.4	1.7
V2A	-0.9	-0.1	-0.5	1.0	1.4
V2B	-1.2	-0.4	-0.4	1.3	1.6
V2C	-1.3	-0.3	0.1	1.3	1.7
V3A	-0.9	0.8	-0.9	1.5	1.6
V3B	-1.3	0.5	-0.8	1.6	1.7
V3C	-1.3	0.6	-0.2	1.4	1.7
V4A	-1.0	0.7	-0.7	1.4	1.6
V4B	-0.7	0.8	-0.4	1.1	1.3
V4C	-0.6	1.2	-0.6	1.5	1.7
V5	-0.6	1.7	-0.2	1.8	1.9
V6	-0.8	1.1	-0.9	1.6	1.7
Bay 1	-2.3	-0.1	-0.3	2.3	2.4
Bay 2	-1.8	-0.1	-0.2	1.8	1.9
Bay 3	-1.3	-0.1	0.2	1.3	1.4

Notes:

- 1) Positive X-direction is downstream, perpendicular to the powerhouse face, right hand rule applies
- 2) Data was collected with a Nortek Vectrino Acoustic Doppler Velocimeter (ADV)
- 3) Hand sketch of vectors available on data DVD

Merwin Fishtrap
Tailrace Physical Hydraulic Model Study

Table 4.11 Pump Intake ADV Data - Test 48

Pump Intake Test 48: Tailwater: 53.2'
Powerhouse: Unit 1 - 0 cfs; Unit 2 - 0 cfs; Unit 3 -0 cfs;
Fishtrap: Corner Entrance, 6' wide weir, 38.0' crest, 600 cfs
Pump Intake: 600 cfs

ADV Measurement Location	Avg V _x ft/s	Avg V _y ft/s	Avg V _z ft/s	Magnitude of Resultant of Avg V _x , V _y , V _z ft/s	Average Magnitude ft/s
V1A	-0.7	-0.2	-0.8	1.1	1.2
V1B	-1.4	0.0	-0.5	1.5	1.5
V1C	-1.2	0.2	-0.3	1.3	1.3
V2A	0.3	0.5	-0.8	1.0	1.5
V2B	-0.9	-1.0	0.0	1.4	1.4
V2C	-0.9	0.2	0.2	1.0	1.1
V3A	-0.2	-0.6	-0.6	0.9	1.0
V3B	-0.7	-0.7	0.0	0.9	1.0
V3C	-0.4	-0.1	1.0	1.0	1.3
V4A	-0.1	-0.9	-0.3	0.9	1.0
V4B	-0.5	-0.5	0.5	0.9	1.0
V4C	-0.2	-0.4	0.6	0.7	0.9
V5	-0.2	-0.8	-0.1	0.8	0.9
V6	0.1	0.2	0.0	0.2	0.4
Bay 1	-1.6	0.1	0.1	1.6	1.6
Bay 2	-1.5	0.0	0.0	1.5	1.6
Bay 3	-1.7	0.0	-0.4	1.8	1.8

Notes:

- 1) Positive X-direction is downstream, perpendicular to the powerhouse face, right hand rule applies
- 2) Data was collected with a Nortek Vectrino Acoustic Doppler Velocimeter (ADV)
- 3) Hand sketch of vectors available on data DVD

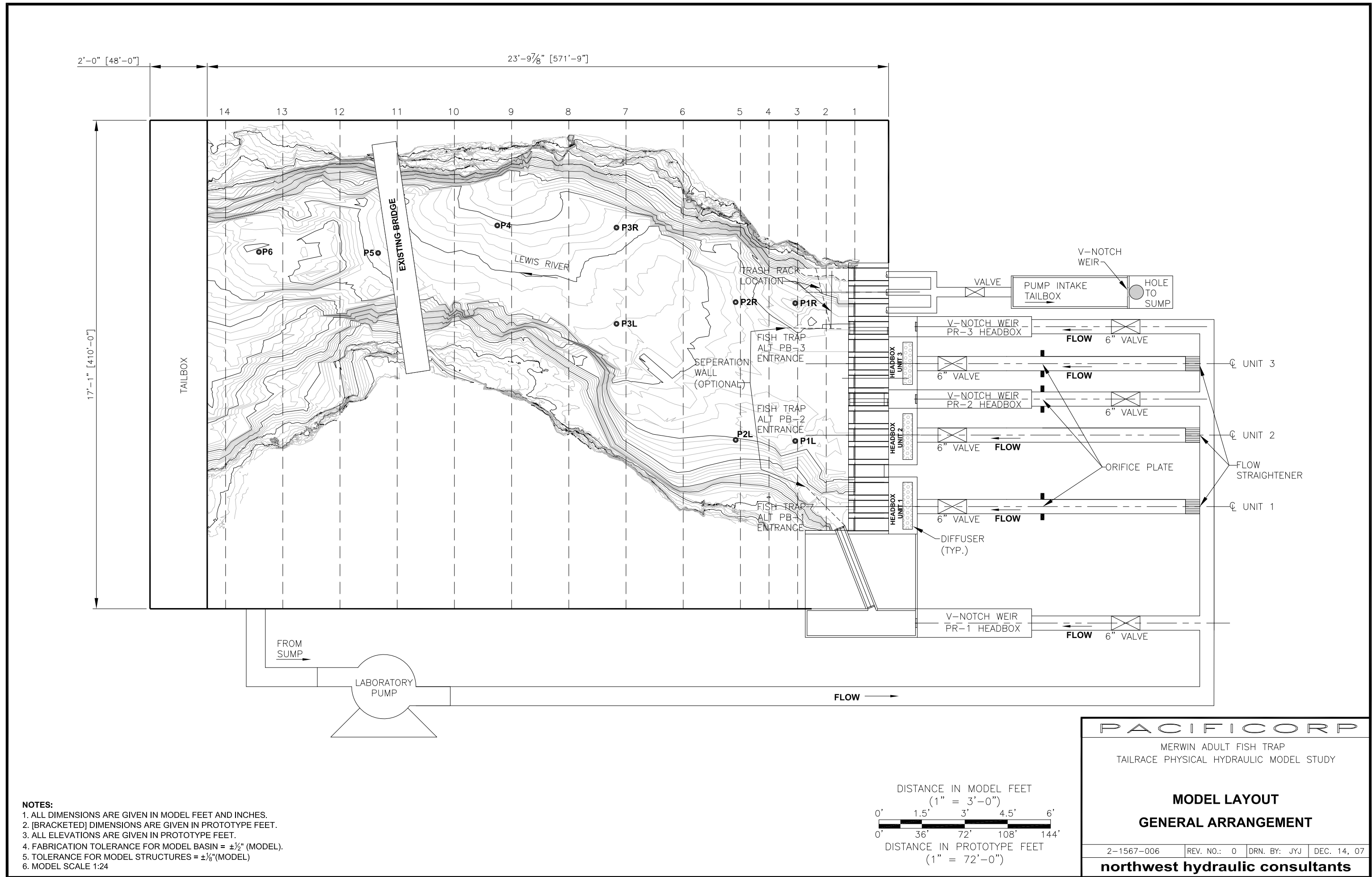


FIGURE 2.1

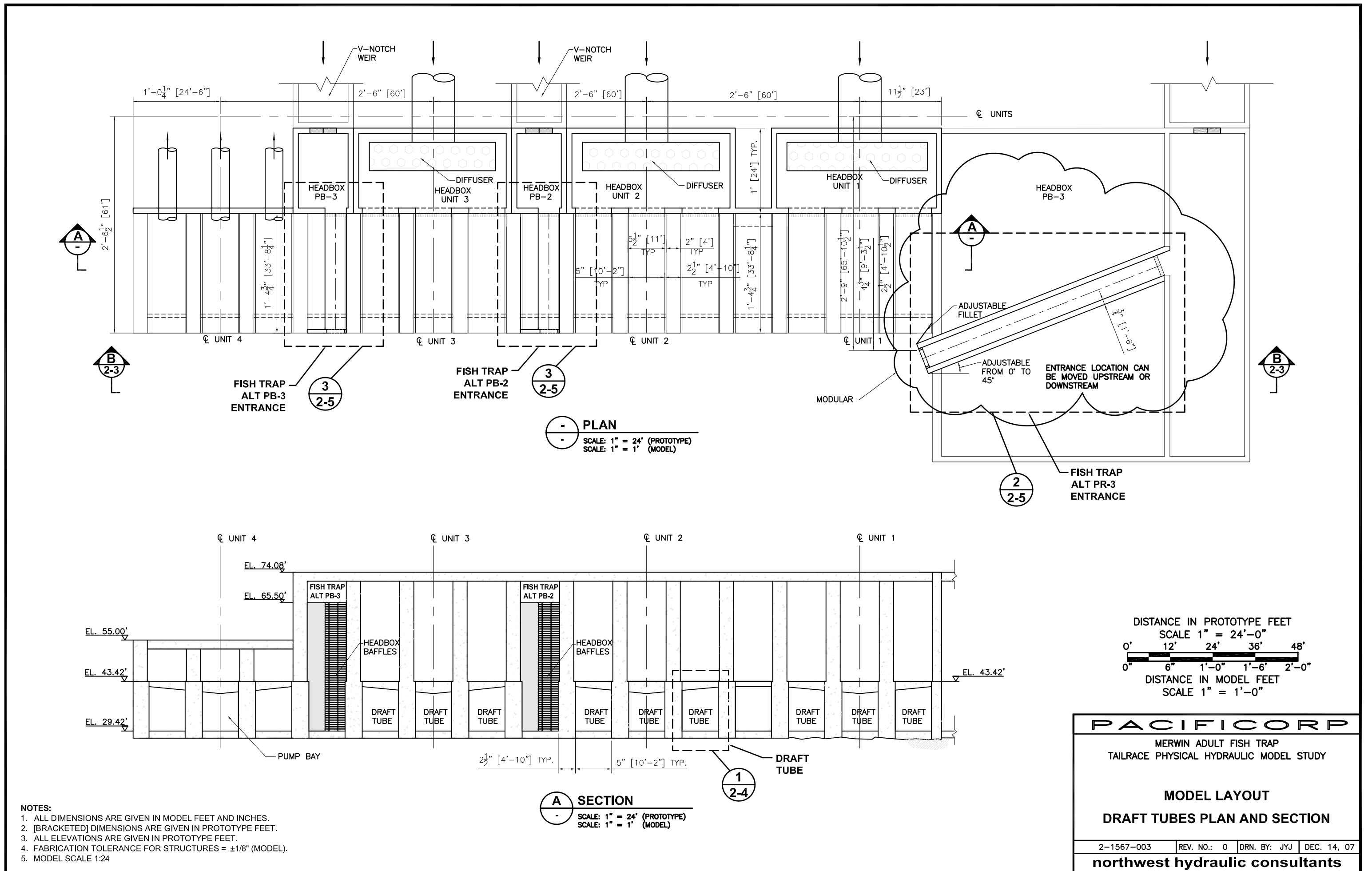
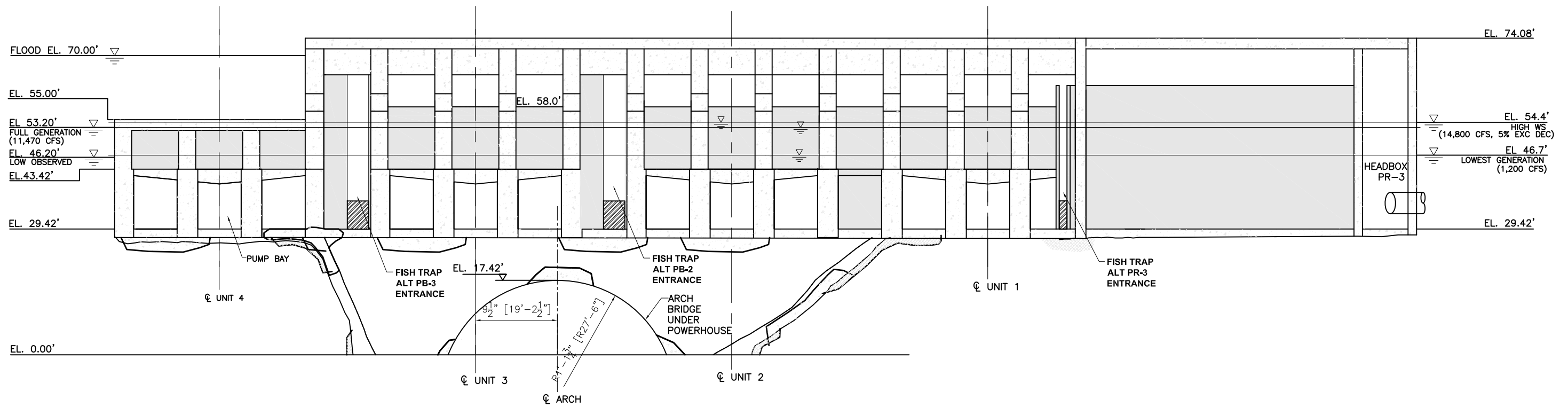
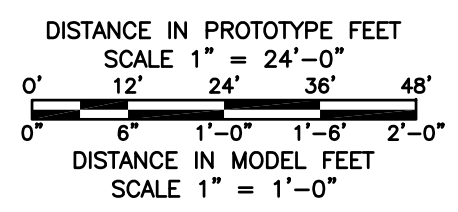


FIGURE 2.2



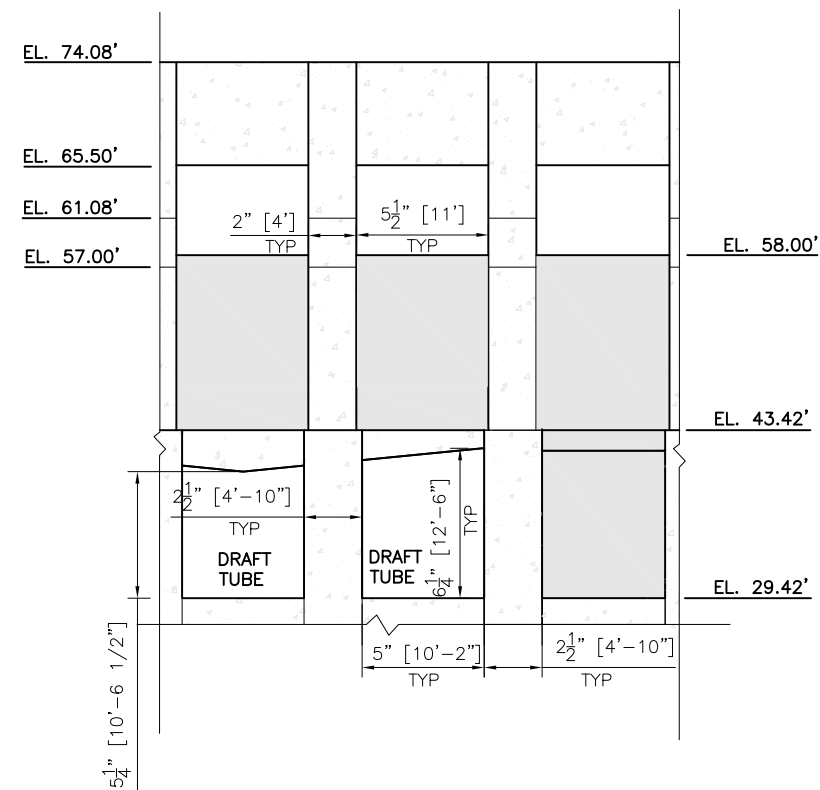
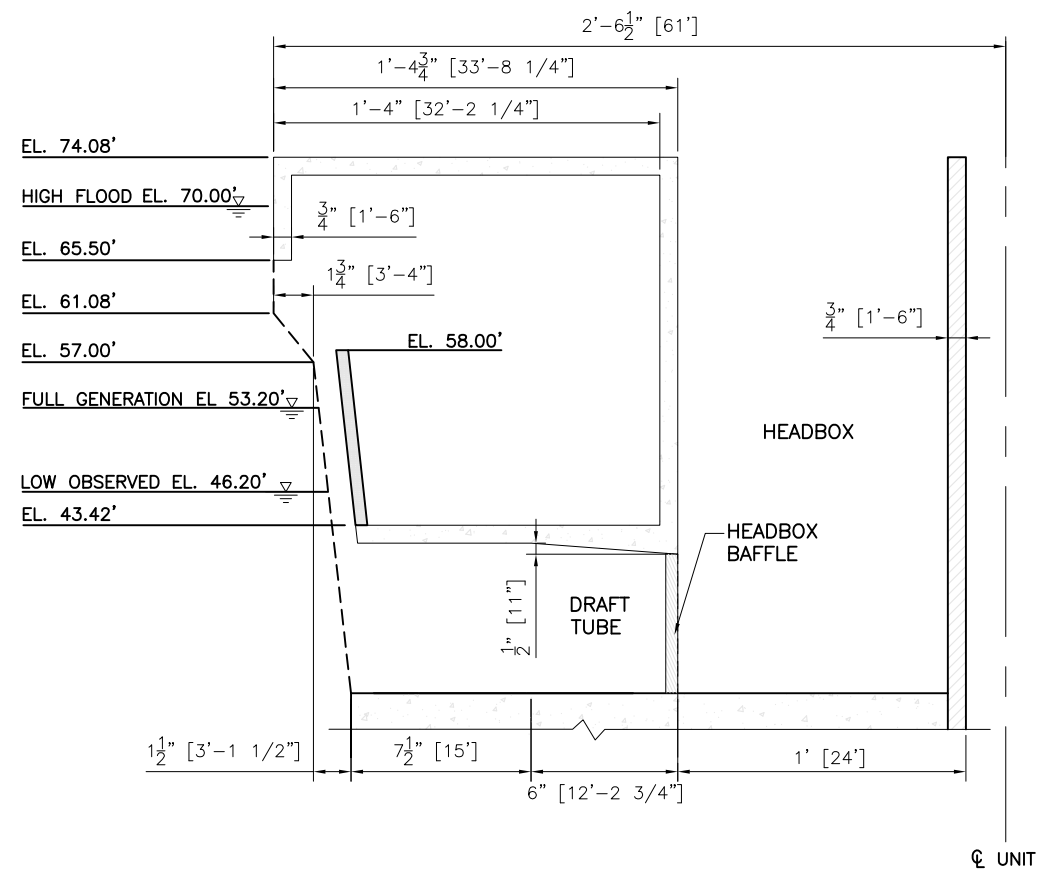
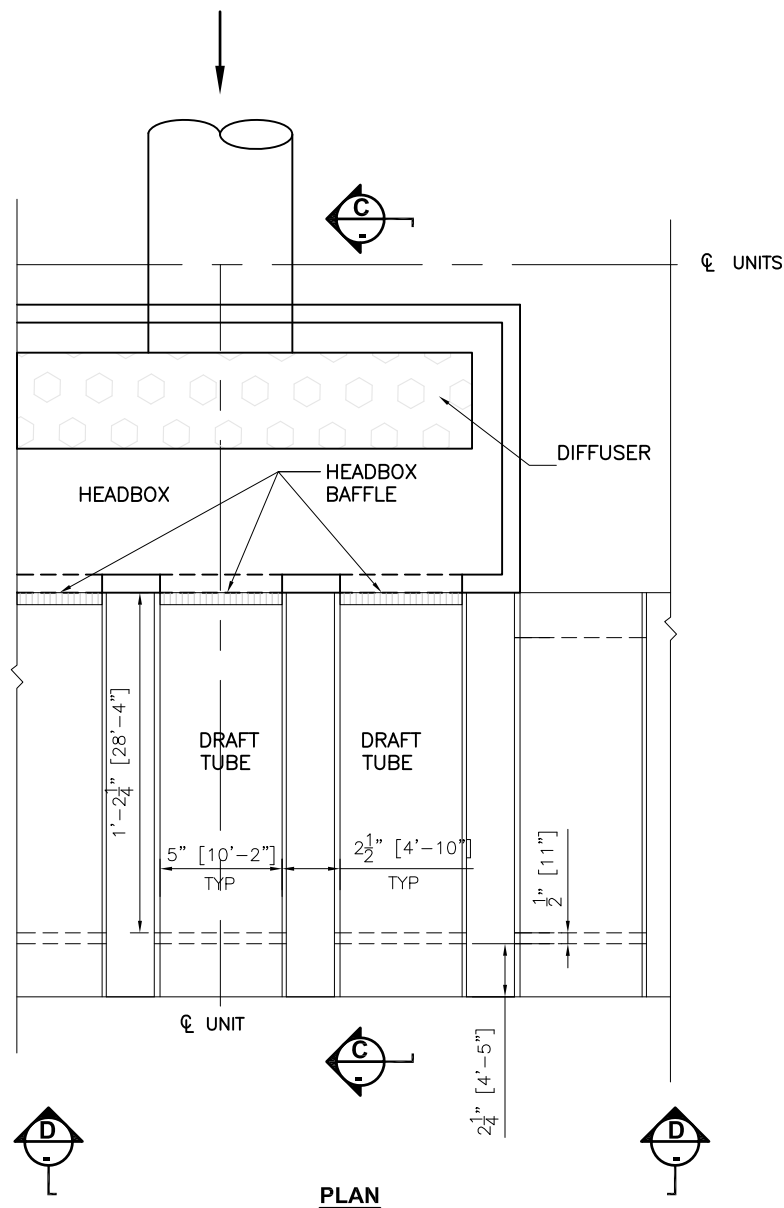
B
 2-2
ELEVATION - POWER HOUSE
 SCALE: 1" = 24' (PROTOTYPE)
 SCALE: 1" = 1' (MODEL)

- NOTES:**
1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET AND INCHES.
 2. [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET.
 3. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.
 4. FABRICATION TOLERANCE FOR MODEL STRUCTURES = ±1/8" (MODEL).
 5. MODEL SCALE 1:24



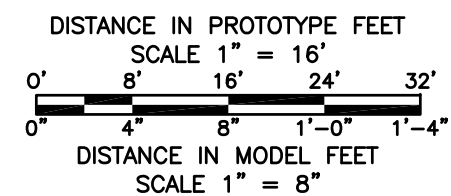
PACIFICORP			
MERWIN ADULT FISH TRAP TAILRACE PHYSICAL HYDRAULIC MODEL STUDY			
MODEL LAYOUT			
POWER HOUSE ELEVATION			
2-1567-003	REV. NO.: 0	DRN. BY: JYJ	DEC. 14, 07
northwest hydraulic consultants			

FIGURE 2.3



1 Detail - Draft Tubes
2-2

SCALE: 1" = 16' (PROTOTYPE)
SCALE: 1" = 8" (MODEL)



- NOTES:**
1. ALL DIMENSIONS ARE GIVEN IN MODEL FEET AND INCHES.
 2. [BRACKETED] DIMENSIONS ARE GIVEN IN PROTOTYPE FEET.
 3. ALL ELEVATIONS ARE GIVEN IN PROTOTYPE FEET.
 4. FABRICATION TOLERANCE FOR MODEL STRUCTURES = $\pm 1/8"$ (MODEL).
 5. MODEL SCALE 1:24

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MERWIN ADULT FISH TRAP
TAILRACE PHYSICAL HYDRAULIC MODEL STUDY

**MODEL LAYOUT
DRAFT TUBE DETAILS**

2-1567-003 | REV. NO.: 0 | DRN. BY: JYJ | DEC. 14, 07

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FIGURE 2.4

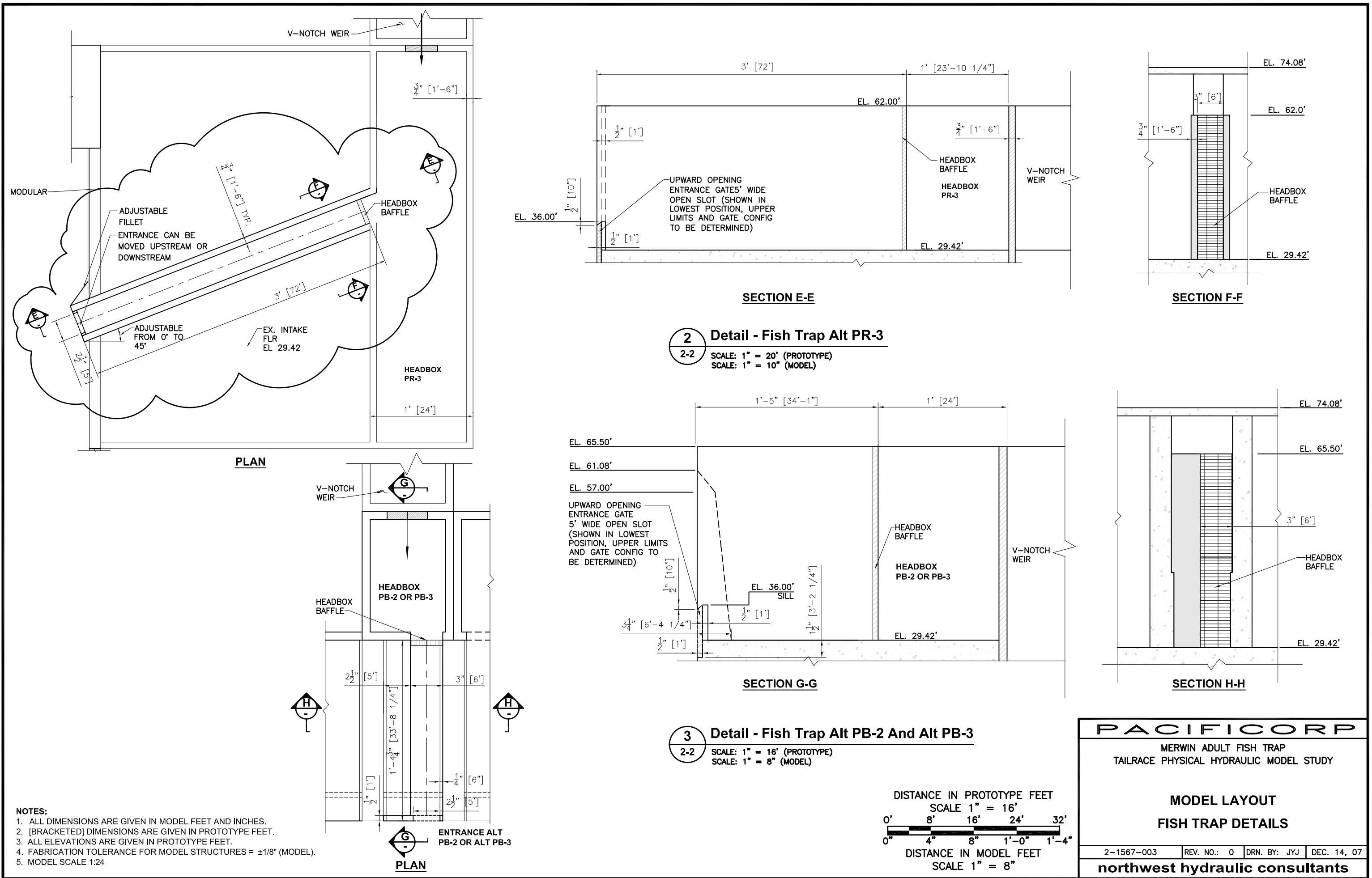


FIGURE 2.5

Merwin Adult Fish Trap
Tailrace Physical Hydraulic Model Study

**Tailwater Elevation vs. Powerhouse Flow
at Merwin Powerhouse**

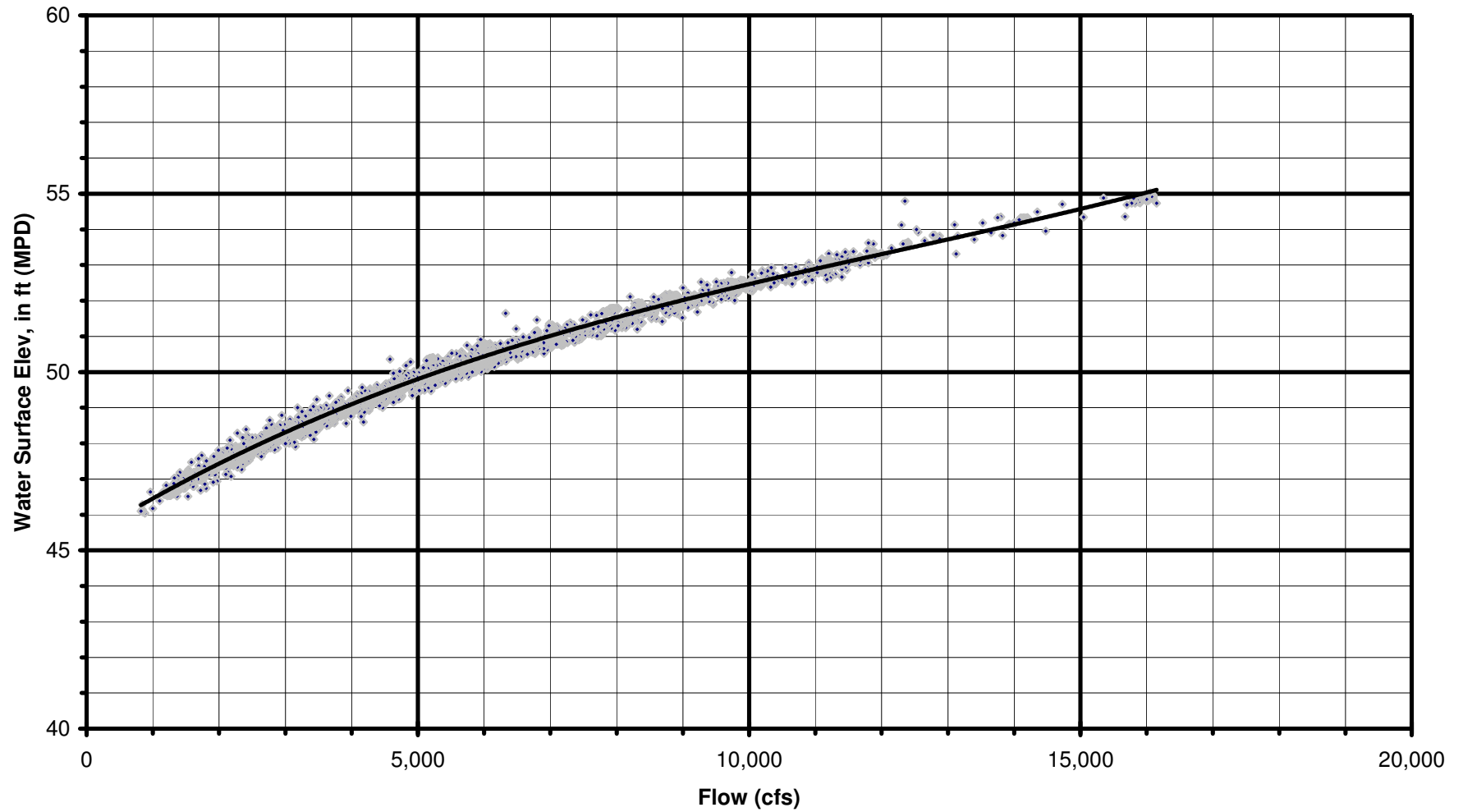


Figure 2.6

TEST 3A

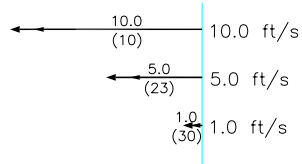
FISH TRAP CONFIGURATION

FISHTRAP ENTRANCE	CORNER TRAP
WEIR WIDTH	— ft
WEIR EL.	— ft

OPERATING CONDITIONS

POWERHOUSE DISCHARGE	11,400 cfs
FISHTRAP DISCHARGE	— cfs
TAILWATER EL.	53.2 ft

LEGEND:



1) LONGER ARROWS REPRESENT VELOCITY IN X, Y, Z PLANES.
SHORTER ARROWS REPRESENT VELOCITY IN X, Y PLANE.

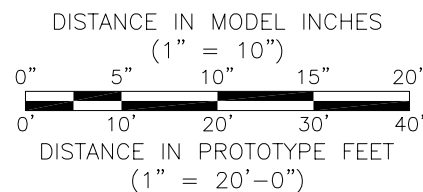
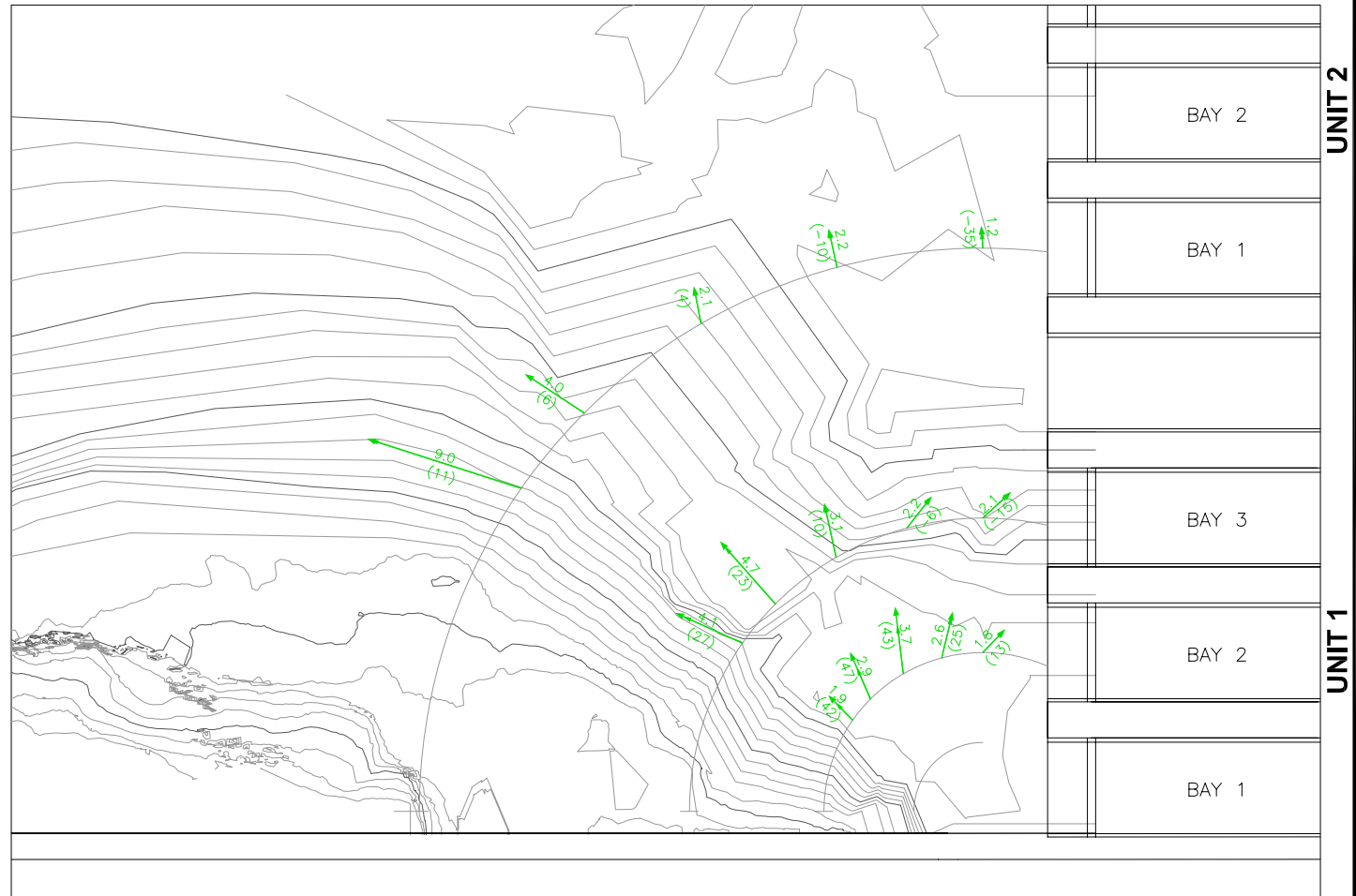
2) FIRST VALUE PROVIDES VELOCITY MAGNITUDE (IN PROTOTYPE FEET PER SECOND) IN THE X, Y, Z PLANES. SECOND VALUE (BRACKETED VALUE) PROVIDES VELOCITY ANGLE IN Z PLANE (POSITIVE ANGLE IS VERTICALLY UP).

Notes:

1) TABLE 4.2 DISPLAYS THE TABULATED DATA FOR THIS TEST CONDITION

2) DATA WAS COLLECTED WITH A NORTEK VECTRINO ACOUSTIC VELOCIMETER (ADV)

3) ALL VALUES ARE SHOWN IN PROTOTYPE DIMENSIONS



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MERWIN ADULT FISH TRAP
TAILRACE PHYSICAL HYDRAULIC MODEL STUDY

TAILRACE VELOCITIES AT 5 FT DEPTH TEST 3A - BASELINE

2-1567-100 REV. NO.: 0 DRN. BY: BH MAR 7-08

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FIGURE 4.1

TEST 3B

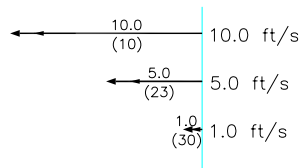
FISH TRAP CONFIGURATION

FISHTRAP ENTRANCE	CORNER TRAP
WEIR WIDTH	— ft
WEIR EL.	— ft

OPERATING CONDITIONS

POWERHOUSE DISCHARGE	11,400 cfs
FISHTRAP DISCHARGE	— cfs
TAILWATER EL.	53.2 ft

LEGEND:



1) LONGER ARROWS REPRESENT VELOCITY IN X, Y, Z PLANES. SHORTER ARROWS REPRESENT VELOCITY IN X, Y PLANE.

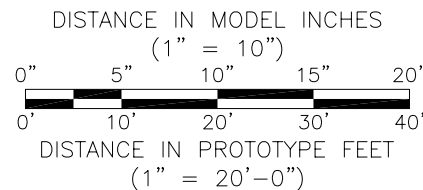
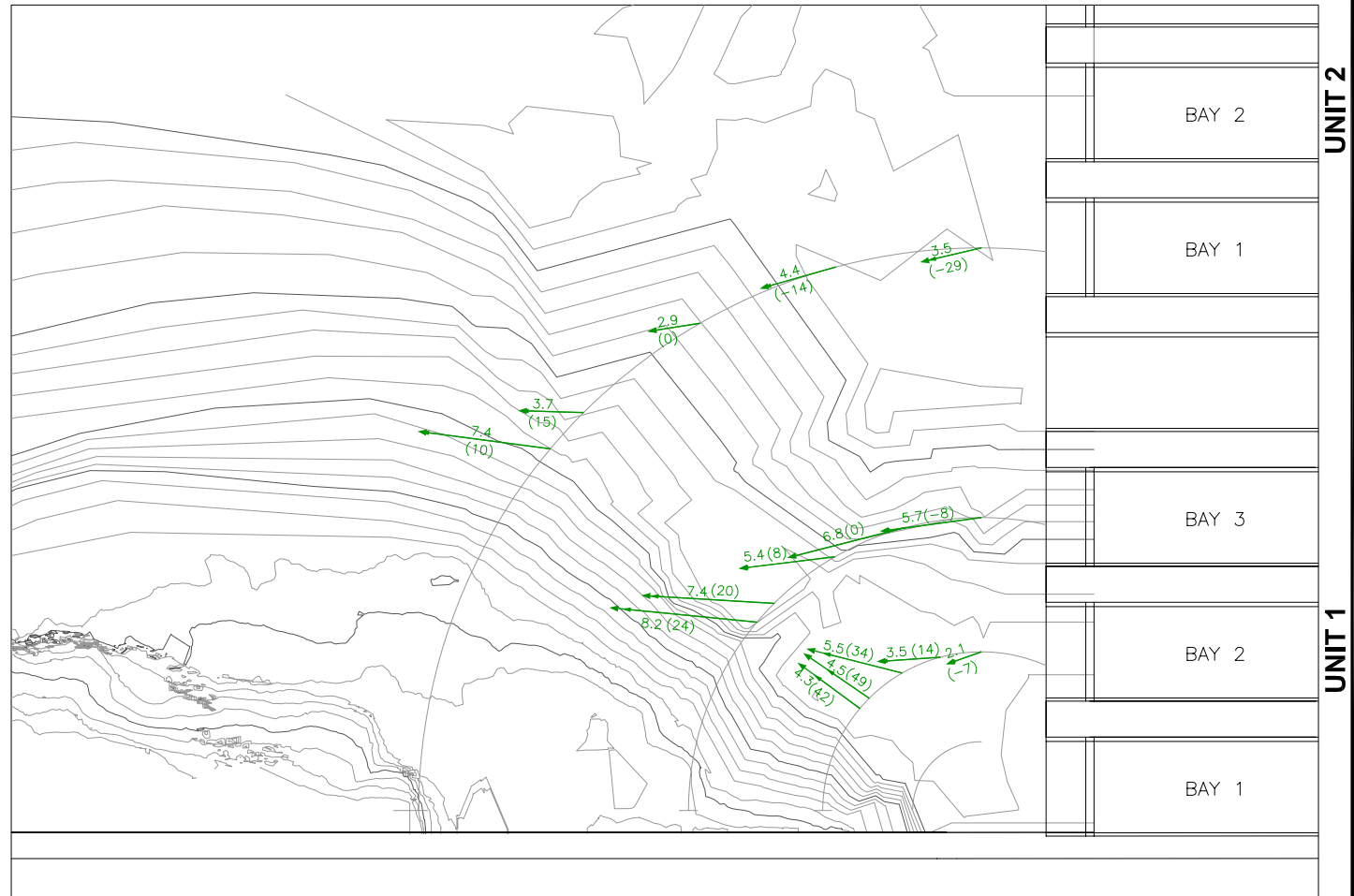
2) FIRST VALUE PROVIDES VELOCITY MAGNITUDE (IN PROTOTYPE FEET PER SECOND) IN THE X, Y, Z PLANES. SECOND VALUE (BRACKETED VALUE) PROVIDES VELOCITY ANGLE IN Z PLANE (POSITIVE ANGLE IS VERTICALLY UP).

Notes:

1) TABLE 4.3 DISPLAYS THE TABULATED DATA FOR THIS TEST CONDITION

2) DATA WAS COLLECTED WITH A NORTEK VECTRINO ACOUSTIC VELOCIMETER (ADV)

3) ALL VALUES ARE SHOWN IN PROTOTYPE DIMENSIONS



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MERWIN ADULT FISH TRAP
TAILRACE PHYSICAL HYDRAULIC MODEL STUDY

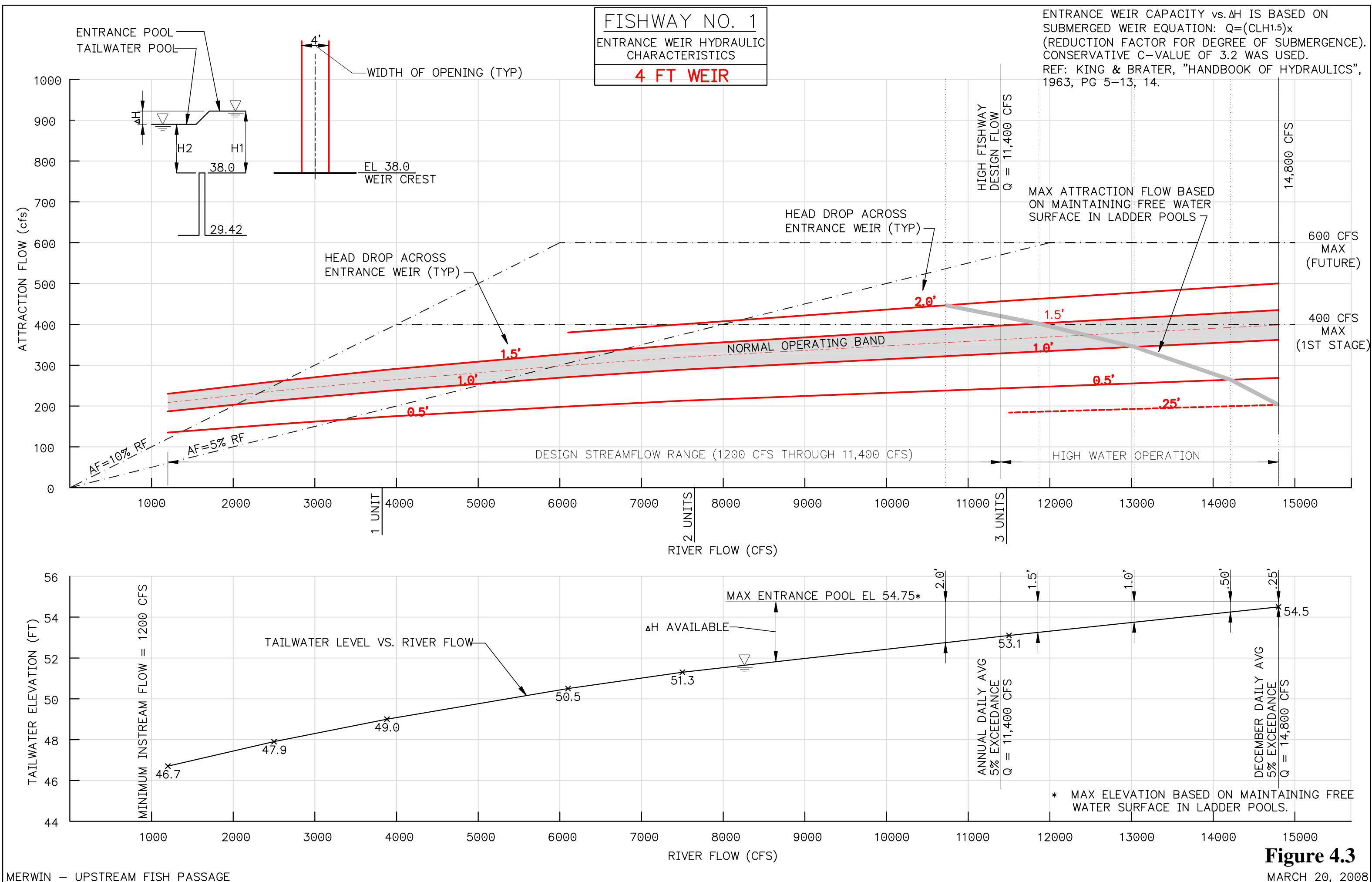
TAILRACE VELOCITIES AT 12 FT DEPTH

TEST 3B - BASELINE

2-1567-100 REV. NO.: 0 DRN. BY: BH MAR 7-08

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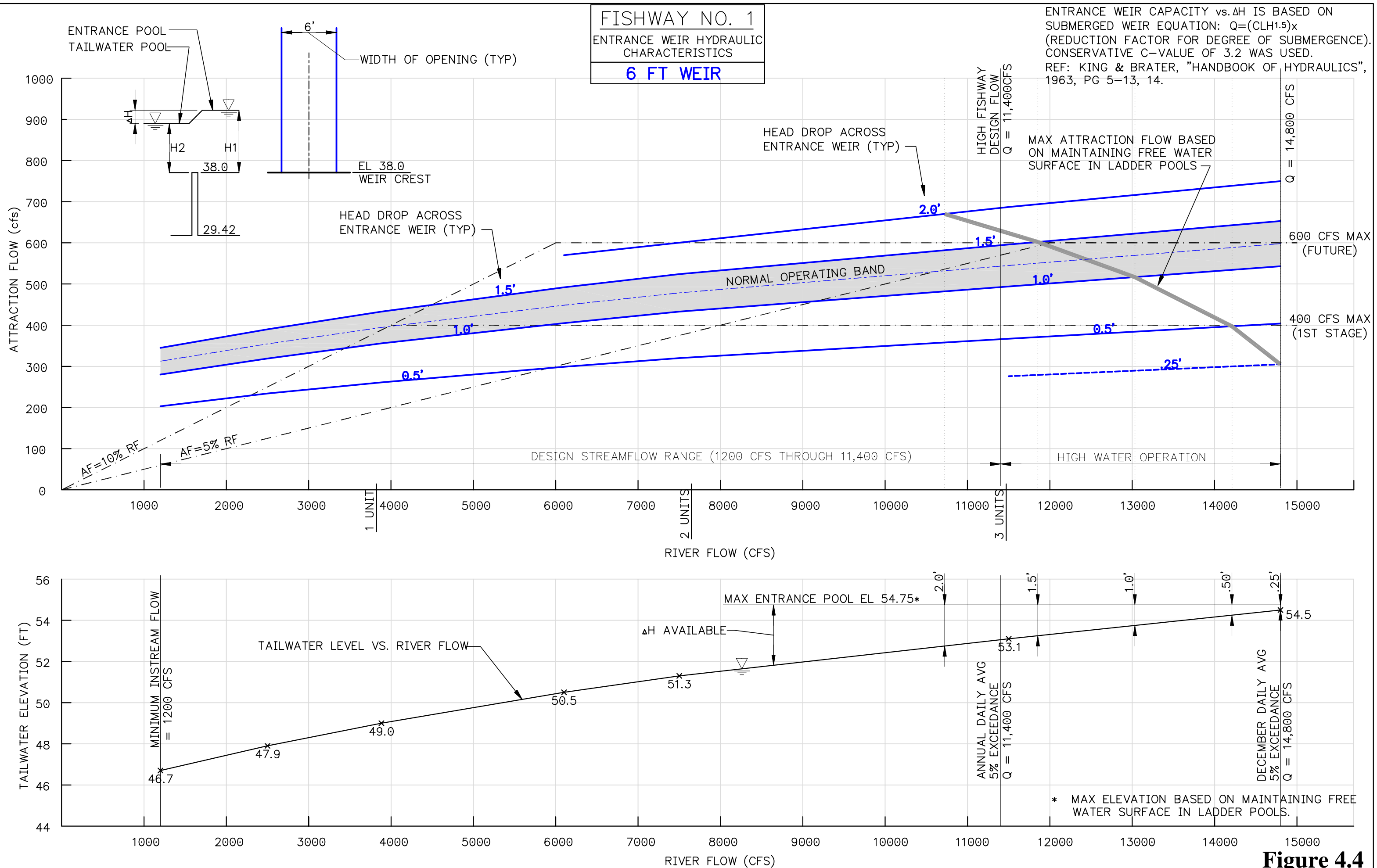
FIGURE 4.2



MERWIN — UPSTREAM FISH PASSAGE

Figure 4.3

MARCH 20, 2008



TEST 4A

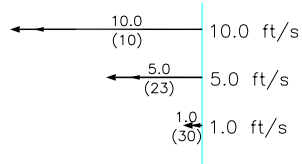
FISH TRAP CONFIGURATION

FISHTRAP ENTRANCE	CORNER TRAP
WEIR WIDTH	4.0 ft
WEIR EL.	38.0 ft

OPERATING CONDITIONS

POWERHOUSE DISCHARGE	11,400 cfs
FISHTRAP DISCHARGE	400 cfs
TAILWATER EL.	53.2 ft

LEGEND:



1) LONGER ARROWS REPRESENT VELOCITY IN X, Y, Z PLANES. SHORTER ARROWS REPRESENT VELOCITY IN X, Y PLANE.

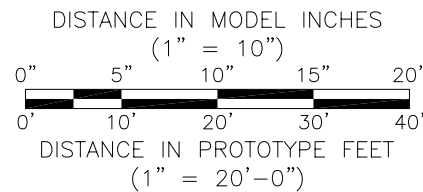
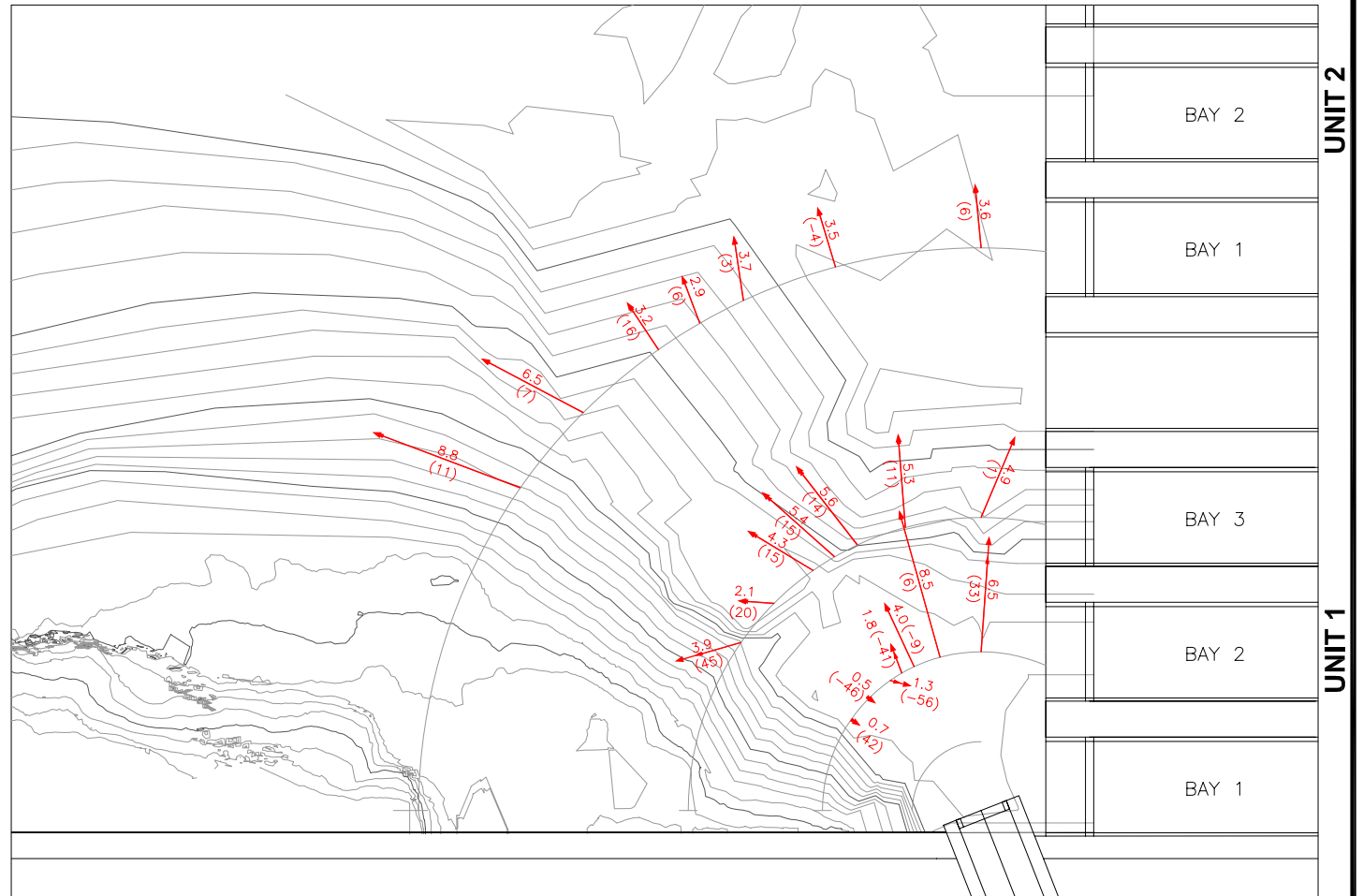
2) FIRST VALUE PROVIDES VELOCITY MAGNITUDE (IN PROTOTYPE FEET PER SECOND) IN THE X, Y, Z PLANES. SECOND VALUE (BRACKETED VALUE) PROVIDES VELOCITY ANGLE IN Z PLANE (POSITIVE ANGLE IS VERTICALLY UP).

Notes:

1) TABLE 4.4 DISPLAYS THE TABULATED DATA FOR THIS TEST CONDITION

2) DATA WAS COLLECTED WITH A NORTEK VECTRINO ACOUSTIC VELOCIMETER (ADV)

3) ALL VALUES ARE SHOWN IN PROTOTYPE DIMENSIONS



PACIFICORP

MERWIN ADULT FISH TRAP
TAILRACE PHYSICAL HYDRAULIC MODEL STUDY

TAILRACE VELOCITIES AT 5 FT DEPTH

TEST 4A

2-1567-100 REV. NO.: 0 DRN. BY: BH MAR 7-08

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FIGURE 4.5

TEST 4B

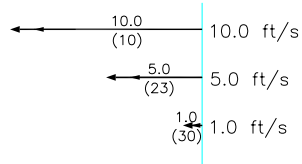
FISH TRAP CONFIGURATION

FISHTRAP ENTRANCE	CORNER TRAP
WEIR WIDTH	4.0 ft
WEIR EL.	38.0 ft

OPERATING CONDITIONS

POWERHOUSE DISCHARGE	11,400 cfs
FISHTRAP DISCHARGE	400 cfs
TAILWATER EL.	53.2 ft

LEGEND:



1) LONGER ARROWS REPRESENT VELOCITY IN X, Y, Z PLANES. SHORTER ARROWS REPRESENT VELOCITY IN X, Y PLANE.

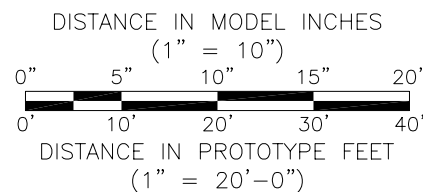
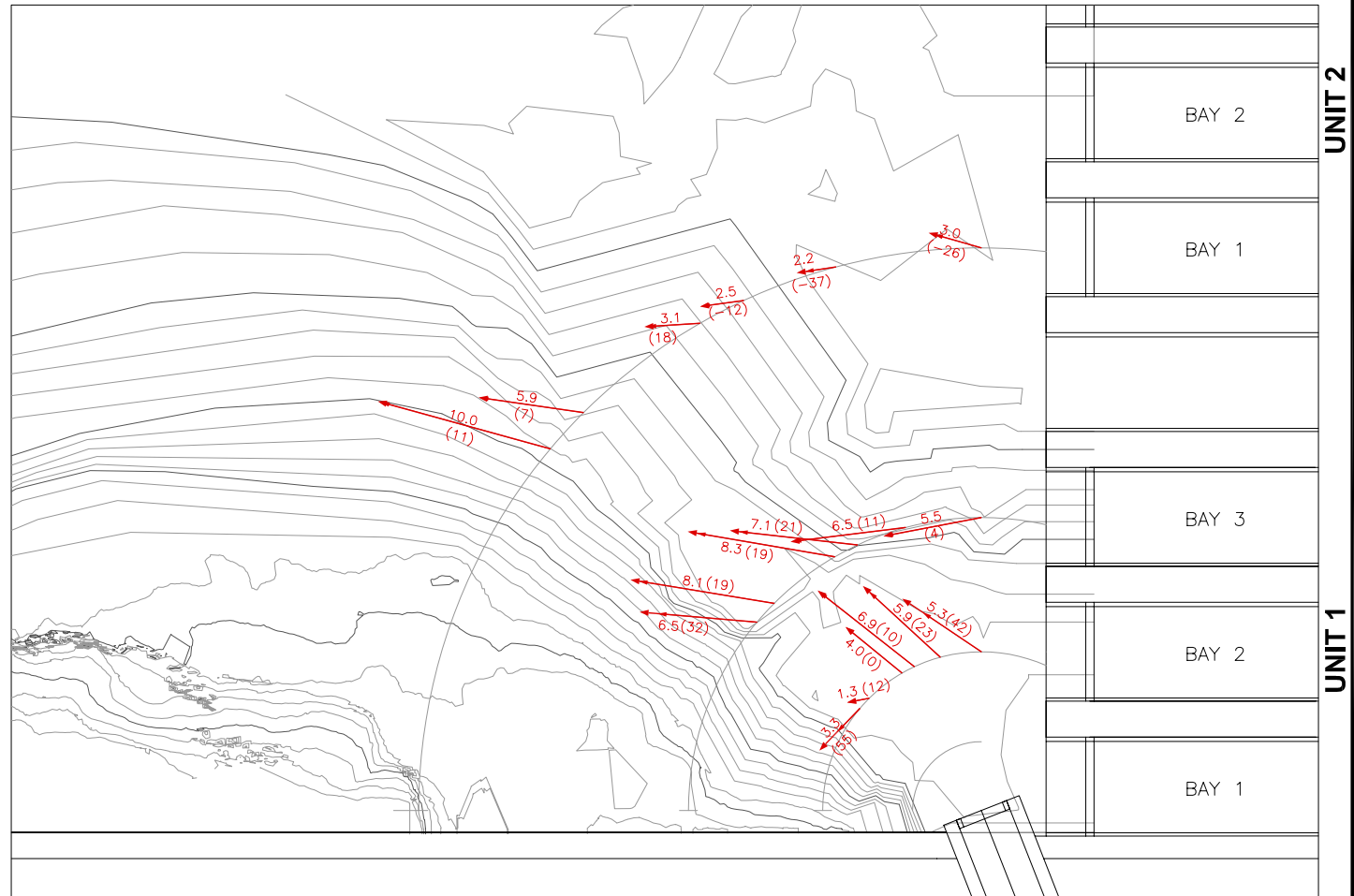
2) FIRST VALUE PROVIDES VELOCITY MAGNITUDE (IN PROTOTYPE FEET PER SECOND) IN THE X, Y, Z PLANES. SECOND VALUE (BRACKETED VALUE) PROVIDES VELOCITY ANGLE IN Z PLANE (POSITIVE ANGLE IS VERTICALLY UP).

Notes:

1) TABLE 4.5 DISPLAYS THE TABULATED DATA FOR THIS TEST CONDITION

2) DATA WAS COLLECTED WITH A NORTEK VECTRINO ACOUSTIC VELOCIMETER (ADV)

3) ALL VALUES ARE SHOWN IN PROTOTYPE DIMENSIONS



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MERWIN ADULT FISH TRAP
TAILRACE PHYSICAL HYDRAULIC MODEL STUDY

TAILRACE VELOCITIES AT 12 FT DEPTH

TEST 4B

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FIGURE 4.6

TEST 5A

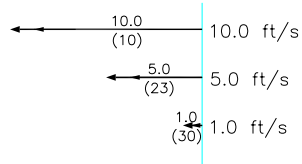
FISH TRAP CONFIGURATION

FISHTRAP ENTRANCE	CORNER TRAP
WEIR WIDTH	6.0 ft
WEIR EL.	38.0 ft

OPERATING CONDITIONS

POWERHOUSE DISCHARGE	11,400 cfs
FISHTRAP DISCHARGE	600 cfs
TAILWATER EL.	53.2 ft

LEGEND:



1) LONGER ARROWS REPRESENT VELOCITY IN X, Y, Z PLANES.
SHORTER ARROWS REPRESENT VELOCITY IN X, Y PLANE.

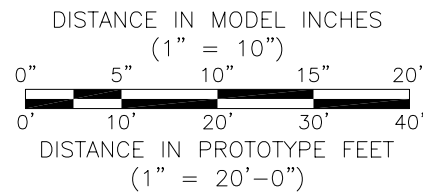
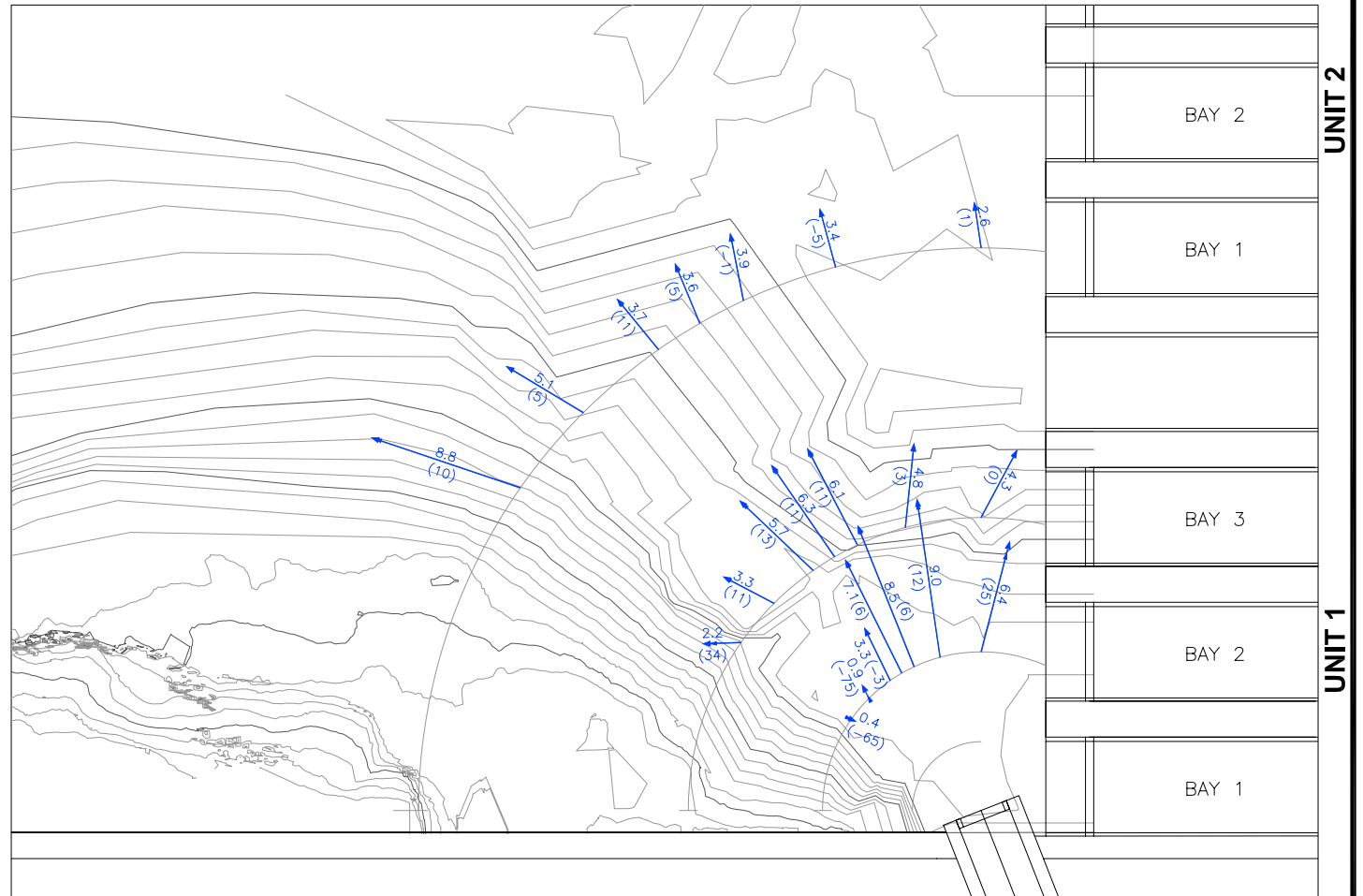
2) FIRST VALUE PROVIDES VELOCITY MAGNITUDE (IN PROTOTYPE FEET PER SECOND) IN THE X, Y, Z PLANES. SECOND VALUE (BRACKETED VALUE) PROVIDES VELOCITY ANGLE IN Z PLANE (POSITIVE ANGLE IS VERTICALLY UP).

Notes:

1) TABLE 4.6 DISPLAYS THE TABULATED DATA FOR THIS TEST CONDITION

2) DATA WAS COLLECTED WITH A NORTEK VECTRINO ACOUSTIC VELOCIMETER (ADV)

3) ALL VALUES ARE SHOWN IN PROTOTYPE DIMENSIONS



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MERWIN ADULT FISH TRAP
TAILRACE PHYSICAL HYDRAULIC MODEL STUDY

TAILRACE VELOCITIES AT 5 FT DEPTH

TEST 5A

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FIGURE 4.7

TEST 5B

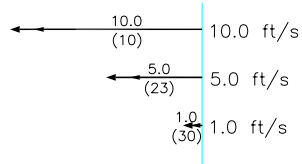
FISH TRAP CONFIGURATION

FISHTRAP ENTRANCE	CORNER TRAP
WEIR WIDTH	6.0 ft
WEIR EL.	38.0 ft

OPERATING CONDITIONS

POWERHOUSE DISCHARGE	11,400 cfs
FISHTRAP DISCHARGE	600 cfs
TAILWATER EL.	53.2 ft

LEGEND:



1) LONGER ARROWS REPRESENT VELOCITY IN X, Y, Z PLANES. SHORTER ARROWS REPRESENT VELOCITY IN X, Y PLANE.

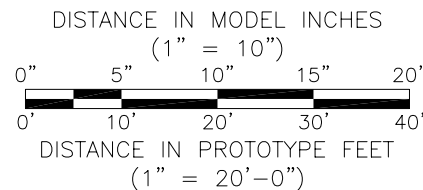
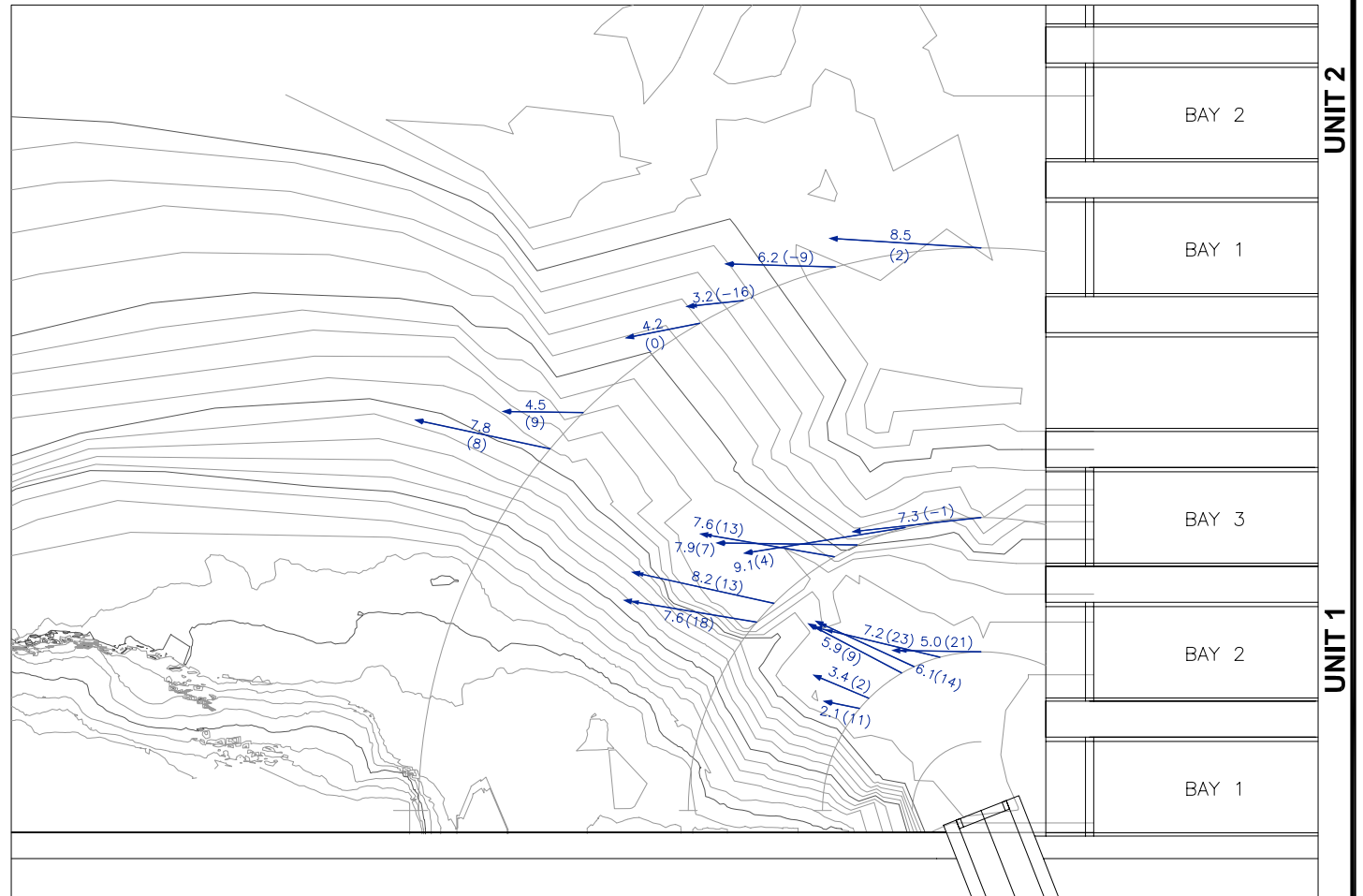
2) FIRST VALUE PROVIDES VELOCITY MAGNITUDE (IN PROTOTYPE FEET PER SECOND) IN THE X, Y, Z PLANES. SECOND VALUE (BRACKETED VALUE) PROVIDES VELOCITY ANGLE IN Z PLANE (POSITIVE ANGLE IS VERTICALLY UP).

Notes:

1) TABLE 4.7 DISPLAYS THE TABULATED DATA FOR THIS TEST CONDITION

2) DATA WAS COLLECTED WITH A NORTEK VECTRINO ACOUSTIC VELOCIMETER (ADV)

3) ALL VALUES ARE SHOWN IN PROTOTYPE DIMENSIONS



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MERWIN ADULT FISH TRAP
TAILRACE PHYSICAL HYDRAULIC MODEL STUDY

TAILRACE VELOCITIES AT 12 FT DEPTH

TEST 5B

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FIGURE 4.8

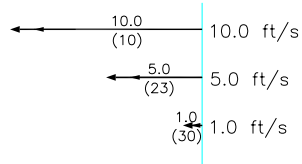
FISH TRAP CONFIGURATION

FISHTRAP ENTRANCE	CORNER TRAP
WEIR WIDTH	— ft
WEIR EL.	— ft

OPERATING CONDITIONS

POWERHOUSE DISCHARGE	11,400 cfs
FISHTRAP DISCHARGE	— cfs
TAILWATER EL.	53.2 ft

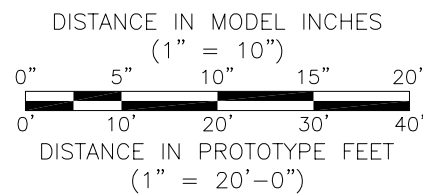
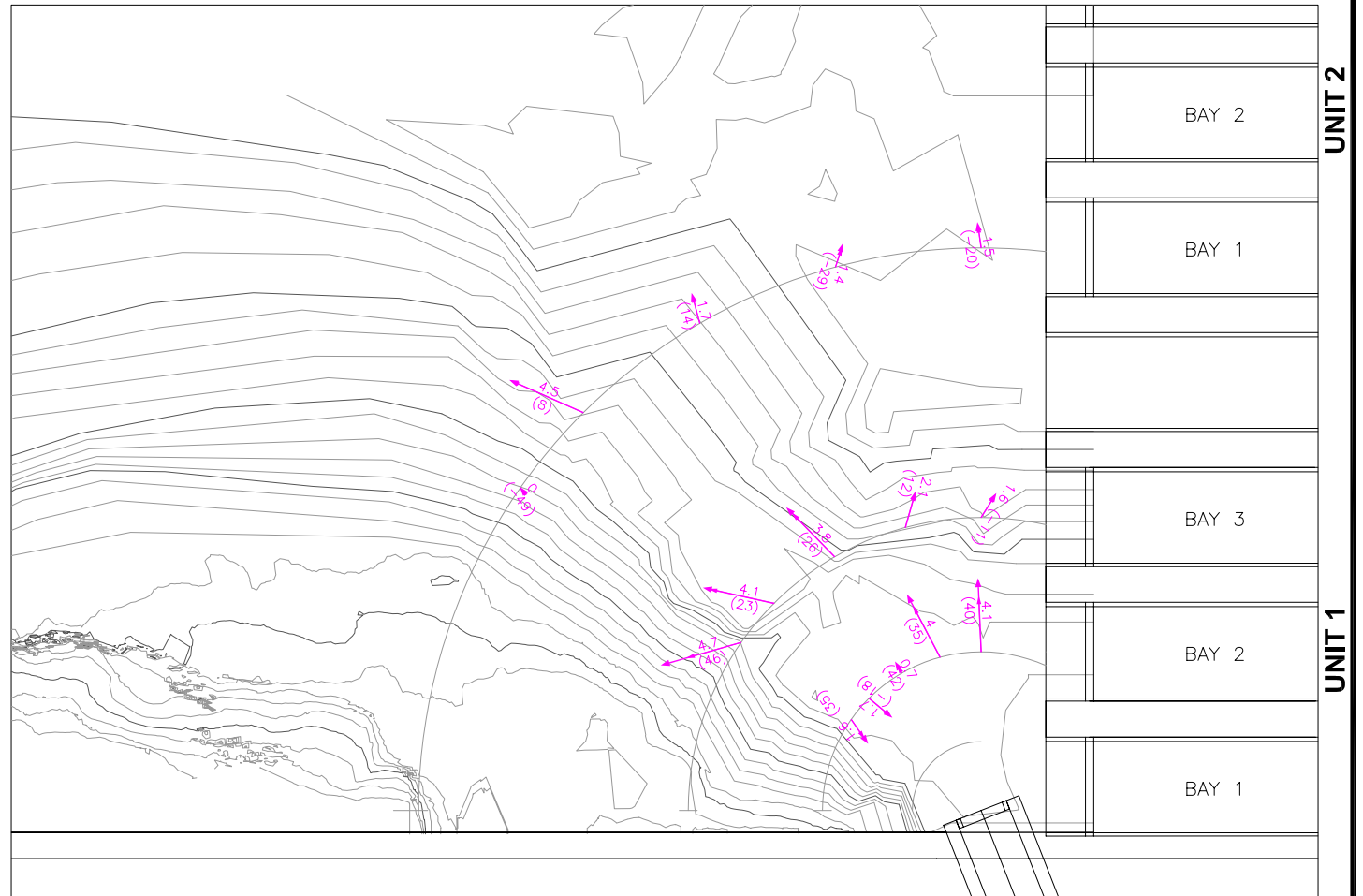
LEGEND:



- 1) LONGER ARROWS REPRESENT VELOCITY IN X, Y, Z PLANES. SHORTER ARROWS REPRESENT VELOCITY IN X, Y PLANE.
- 2) FIRST VALUE PROVIDES VELOCITY MAGNITUDE (IN PROTOTYPE FEET PER SECOND) IN THE X, Y, Z PLANES. SECOND VALUE (BRACKETED VALUE) PROVIDES VELOCITY ANGLE IN Z PLANE (POSITIVE ANGLE IS VERTICALLY UP).

Notes:

- 1) TABLE 4.8 DISPLAYS THE TABULATED DATA FOR THIS TEST CONDITION
- 2) DATA WAS COLLECTED WITH A NORTEK VECTRINO ACOUSTIC VELOCIMETER (ADV)
- 3) ALL VALUES ARE SHOWN IN PROTOTYPE DIMENSIONS



MERWIN ADULT FISH TRAP
TAILRACE PHYSICAL HYDRAULIC MODEL STUDY

TAILRACE VELOCITIES AT 5 FT DEPTH

TEST 6A

2-1567-100	REV. NO.: 0	DRN. BY: BH	MAR 7-08
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FIGURE 4.9

TEST 6B

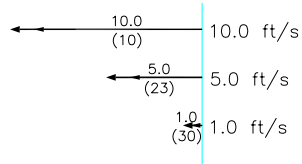
FISH TRAP CONFIGURATION

FISHTRAP ENTRANCE	CORNER TRAP
WEIR WIDTH	— ft
WEIR EL.	— ft

OPERATING CONDITIONS

POWERHOUSE DISCHARGE	11,400 cfs
FISHTRAP DISCHARGE	— cfs
TAILWATER EL.	53.2 ft

LEGEND:



1) LONGER ARROWS REPRESENT VELOCITY IN X, Y, Z PLANES. SHORTER ARROWS REPRESENT VELOCITY IN X, Y PLANE.

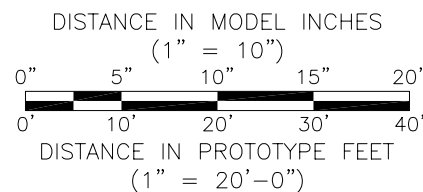
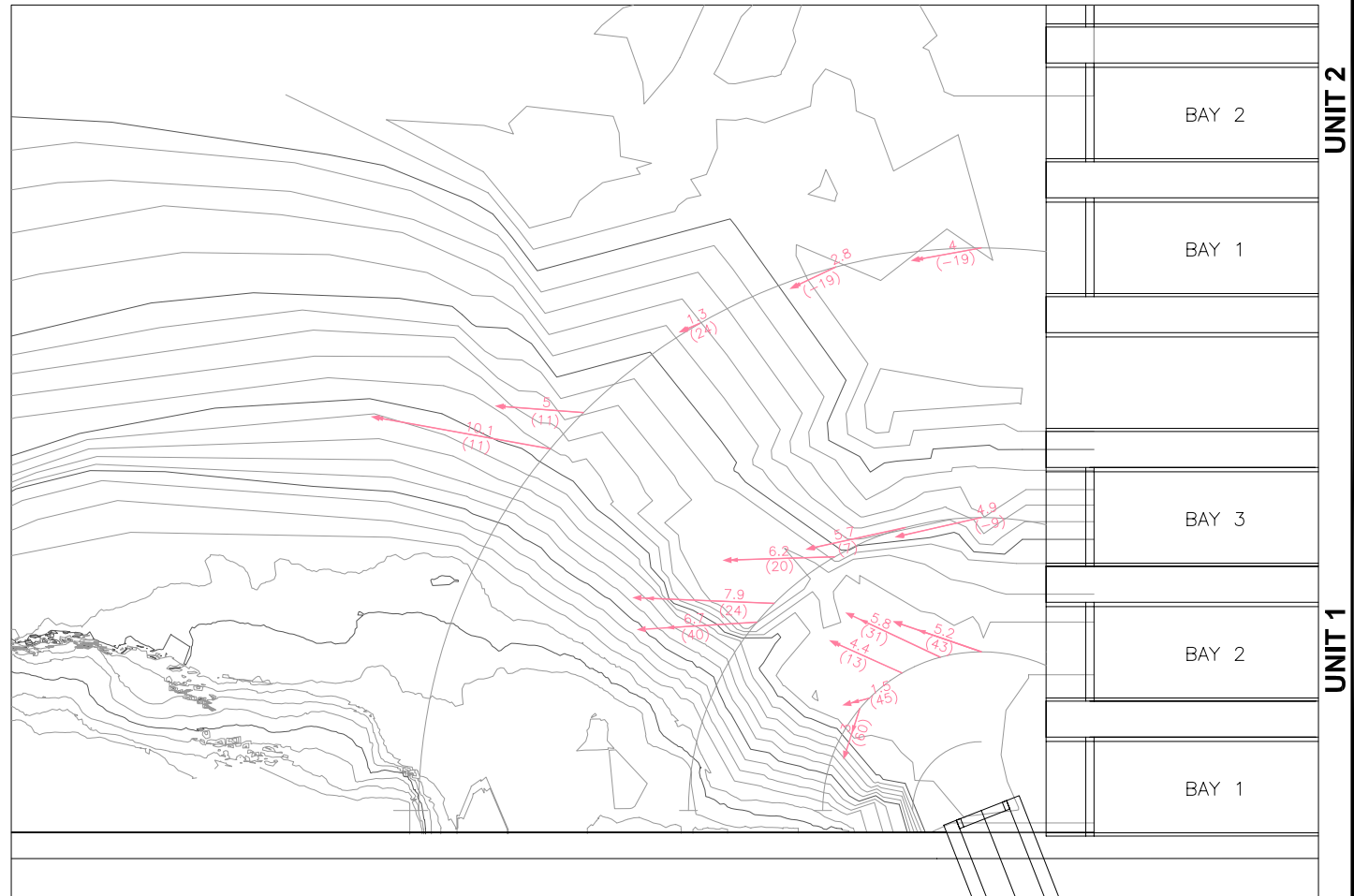
2) FIRST VALUE PROVIDES VELOCITY MAGNITUDE (IN PROTOTYPE FEET PER SECOND) IN THE X, Y, Z PLANES. SECOND VALUE (BRACKETED VALUE) PROVIDES VELOCITY ANGLE IN Z PLANE (POSITIVE ANGLE IS VERTICALLY UP).

Notes:

1) TABLE 4.9 DISPLAYS THE TABULATED DATA FOR THIS TEST CONDITION

2) DATA WAS COLLECTED WITH A NORTEK VECTRINO ACOUSTIC VELOCIMETER (ADV)

3) ALL VALUES ARE SHOWN IN PROTOTYPE DIMENSIONS



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MERWIN ADULT FISH TRAP
TAILRACE PHYSICAL HYDRAULIC MODEL STUDY

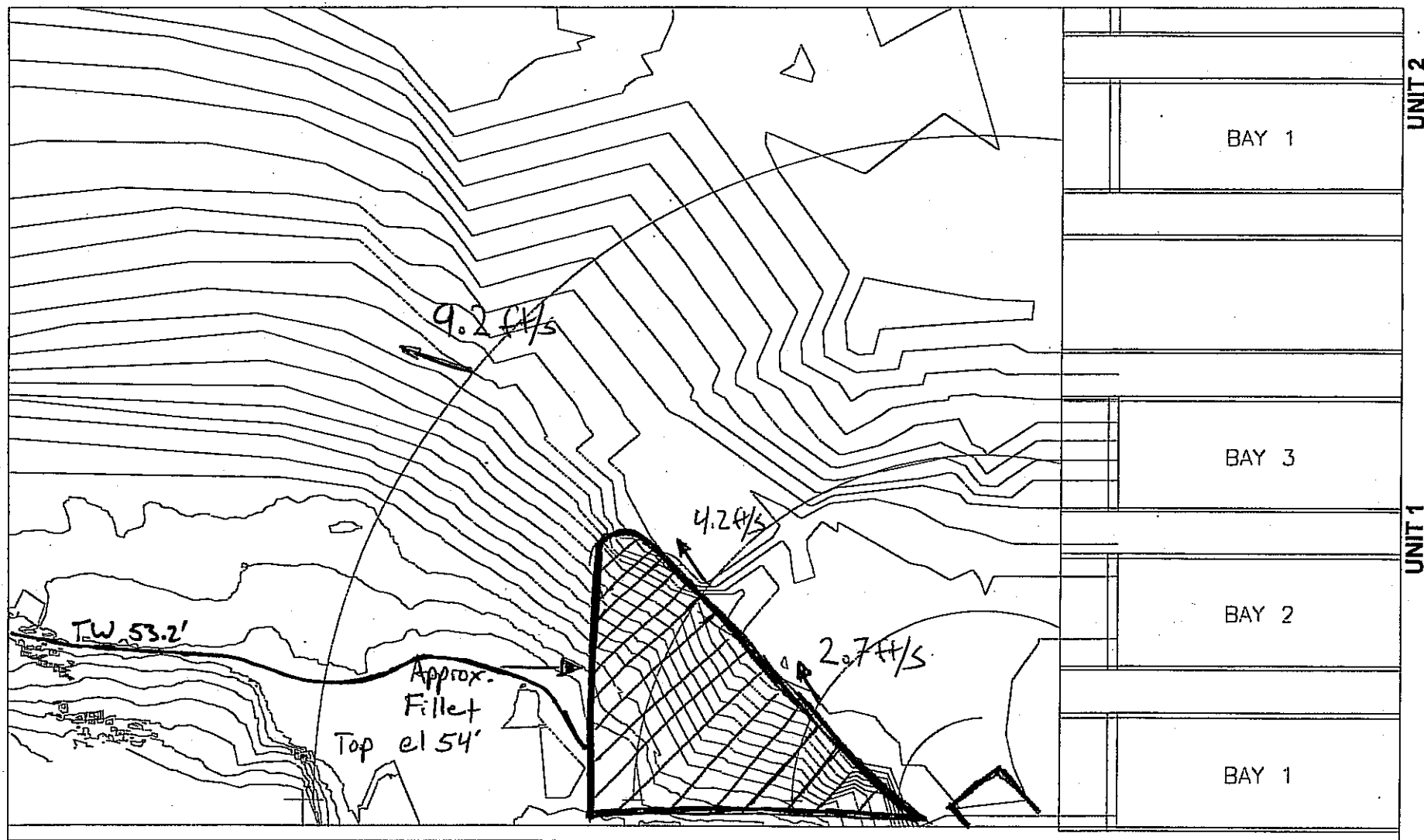
TAILRACE VELOCITIES AT 12 FT DEPTH

TEST 6B

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FIGURE 4.10



Test 35 Corner Eddy with Fillet

TW: 53.2'

PH: Full Gate

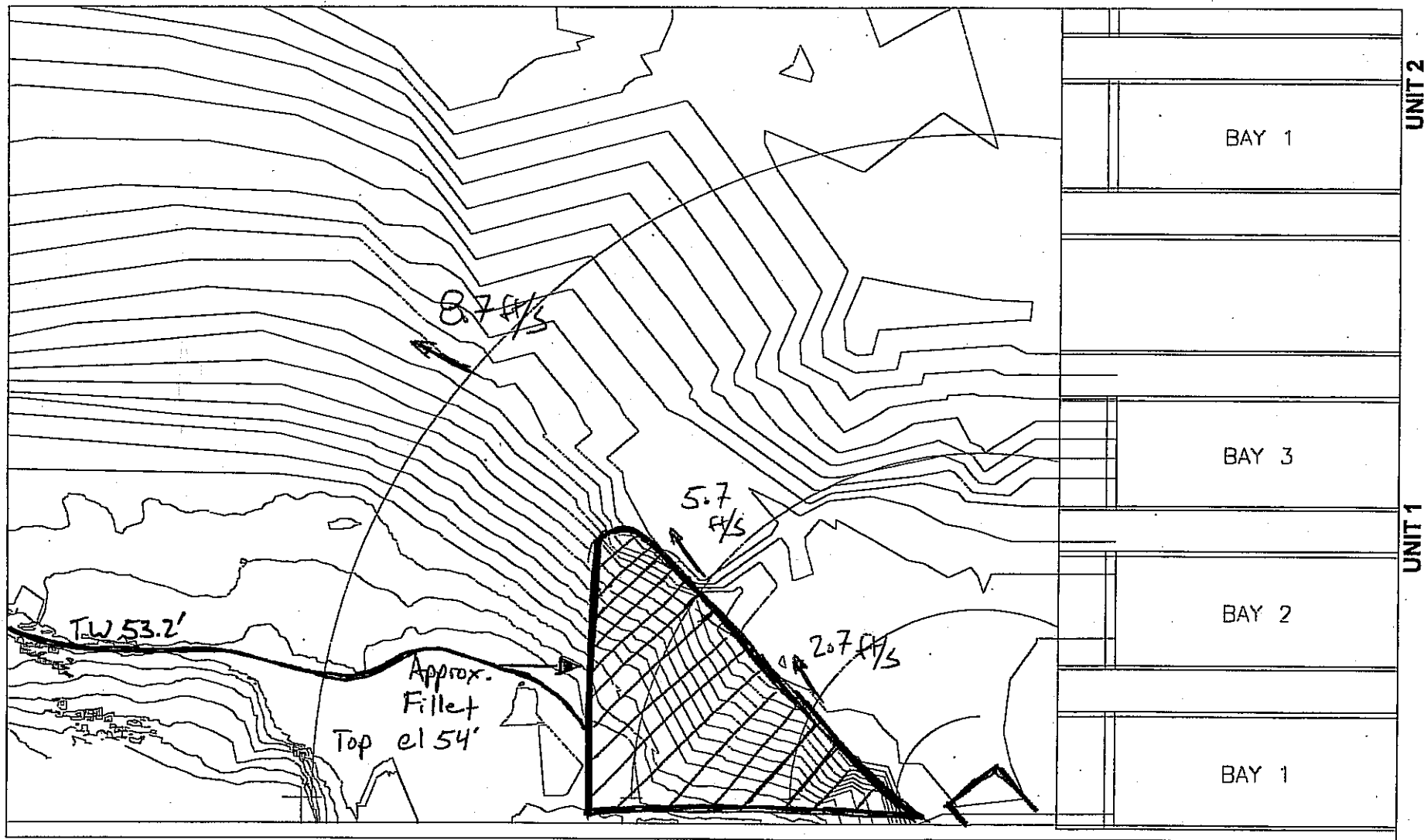
Corner Trap: 4' weir @ 38.0, 400 cfs

5/7/00 JAB

Nixon Meter Velocities

5 ft depth

Figure 4.11



Test 35 Corner Eddy with Fillet

TW: 53.2'

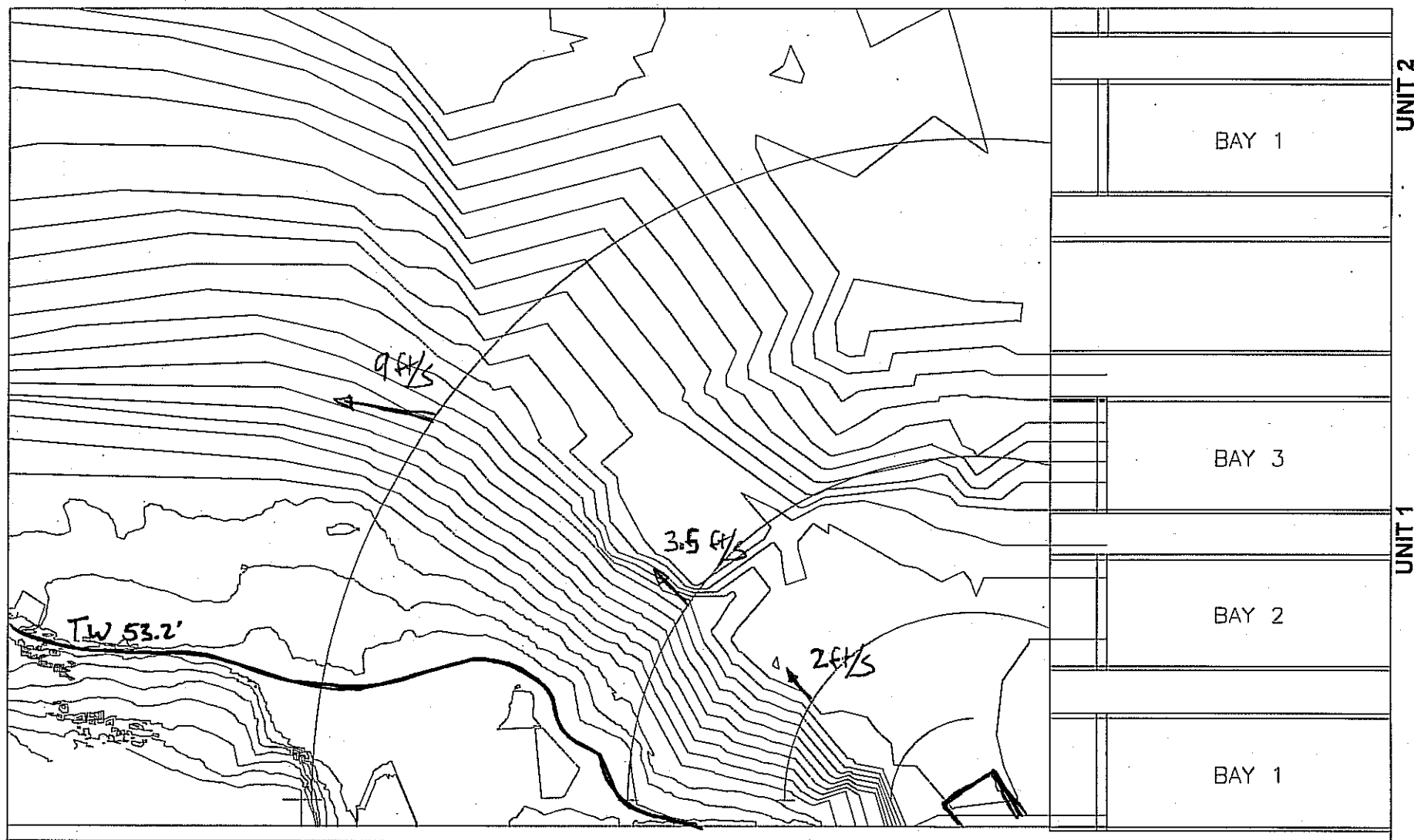
PH: Full Gen

Corner Trap: 4' weir @ 38.0, 400 cfs

5/7/00 JAB

Nixon Meter Velocities
12' depth

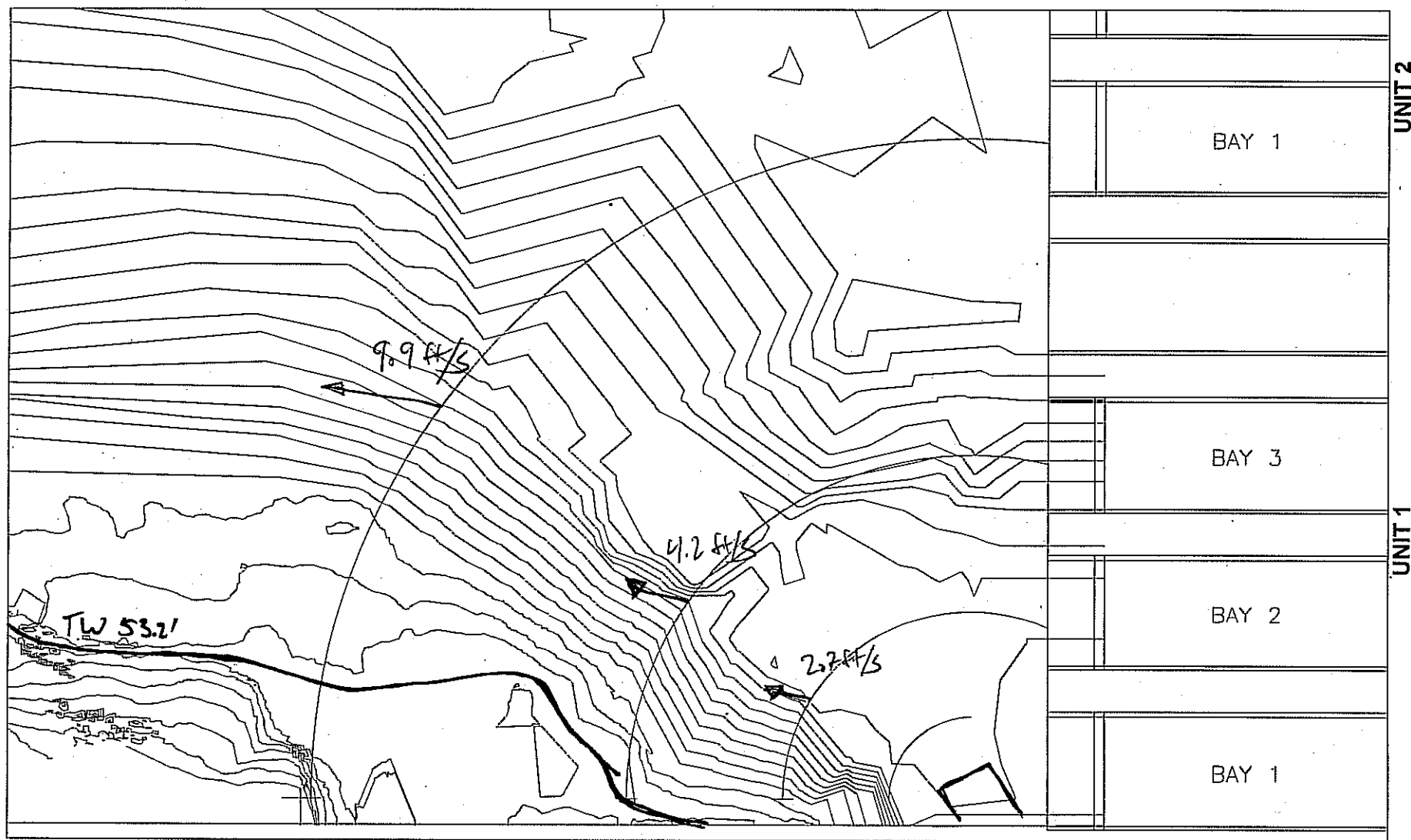
Figure 4.12



Test 36 Corner Eddy without fillet
 TW: 53.2'
 PH: Full Gen
 Corner Trap: 4' weir @ 38.0', 400 cfs
 5/7/08 JAB

Nixon Meter Velocities
 5 ft depth

Figure 4.13



Test 36 Corner Eddy without fillet

TW: 53.2'

PH: Full Gen

Corner Trap: 4' weir @ 38.0', 400 cfs

5/7/08 JAB

Nixon Meter Velocities

12 ft depth

Figure 4.14

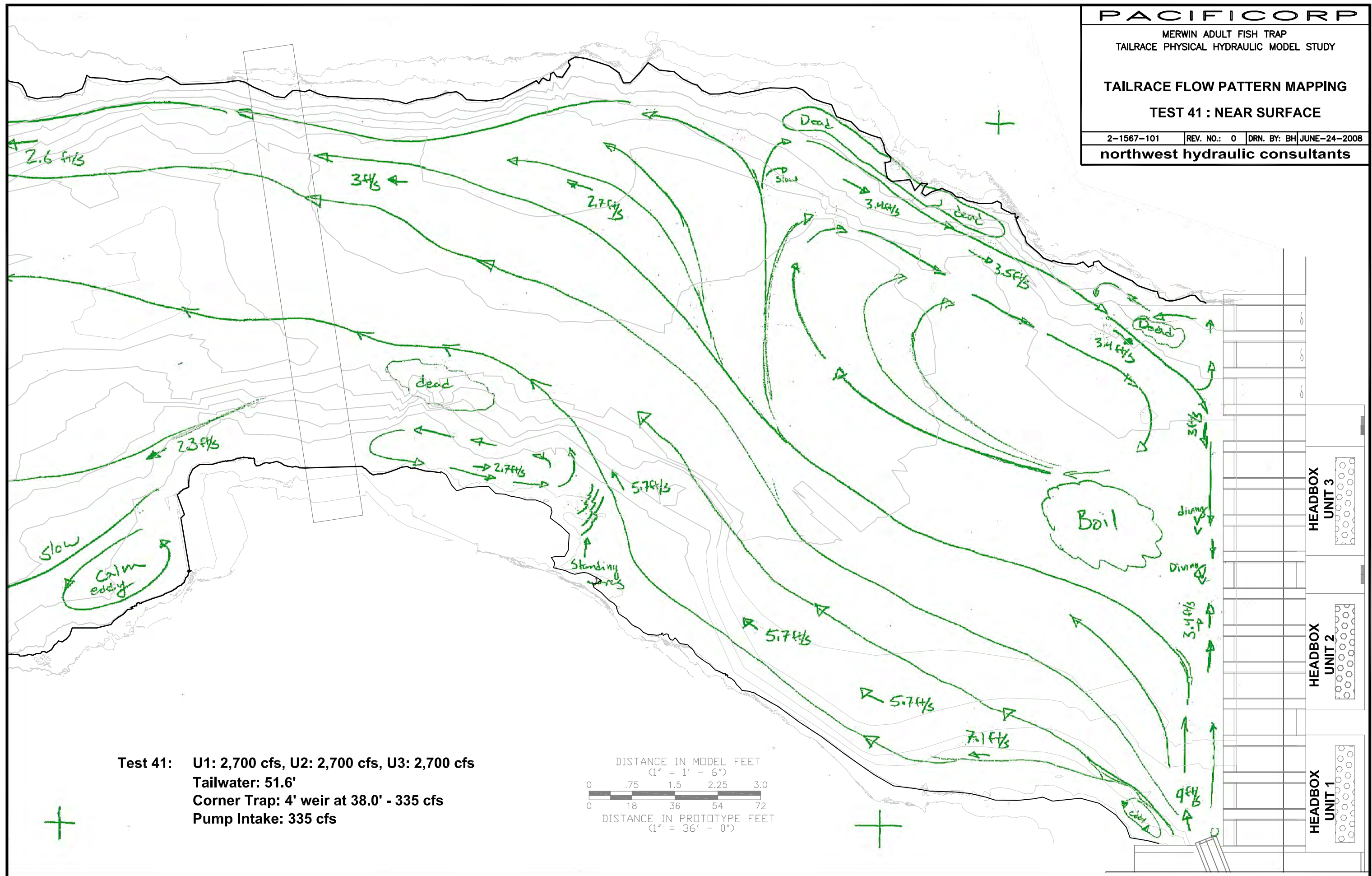


FIGURE 4.15

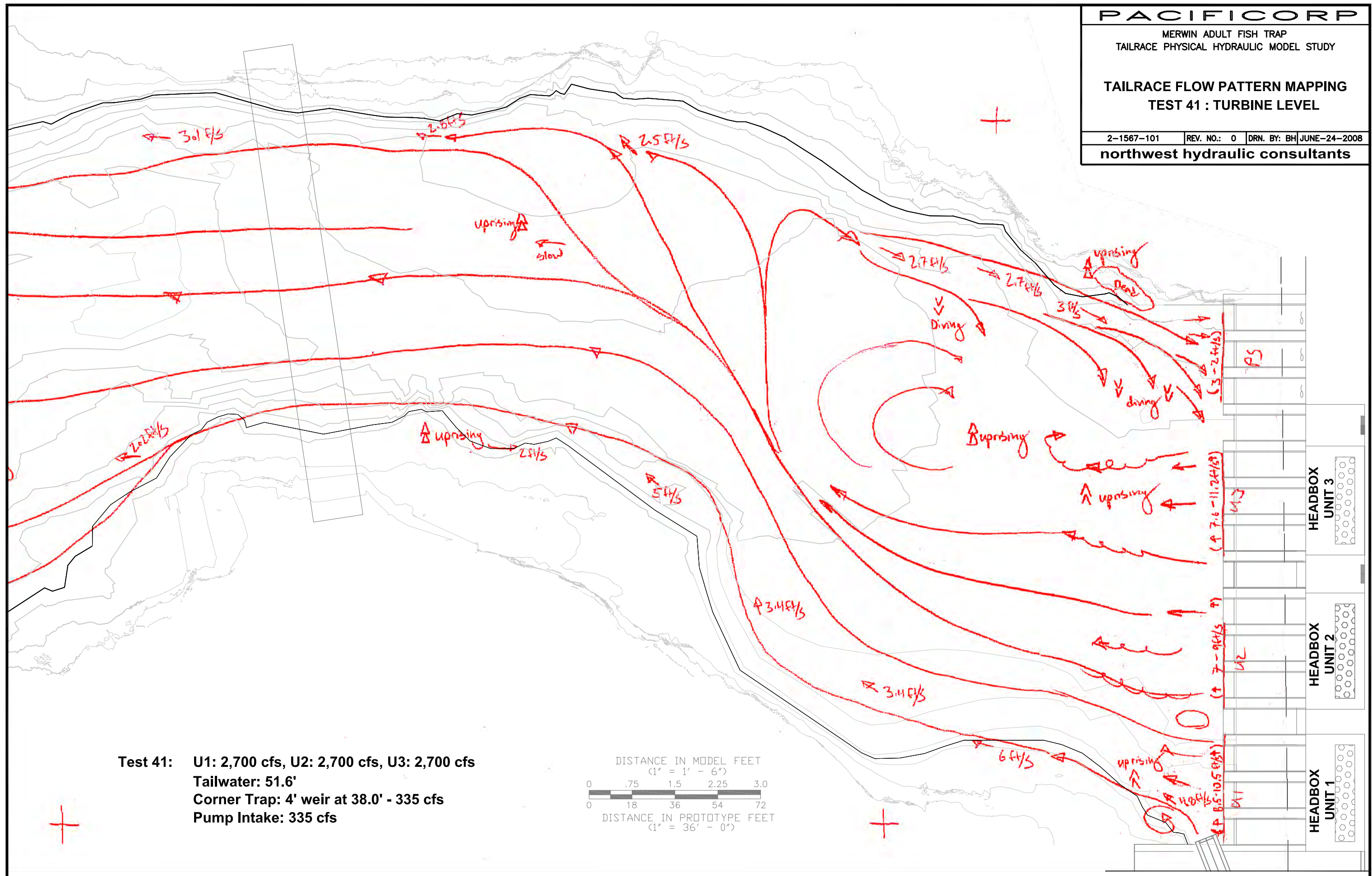


FIGURE 4.16

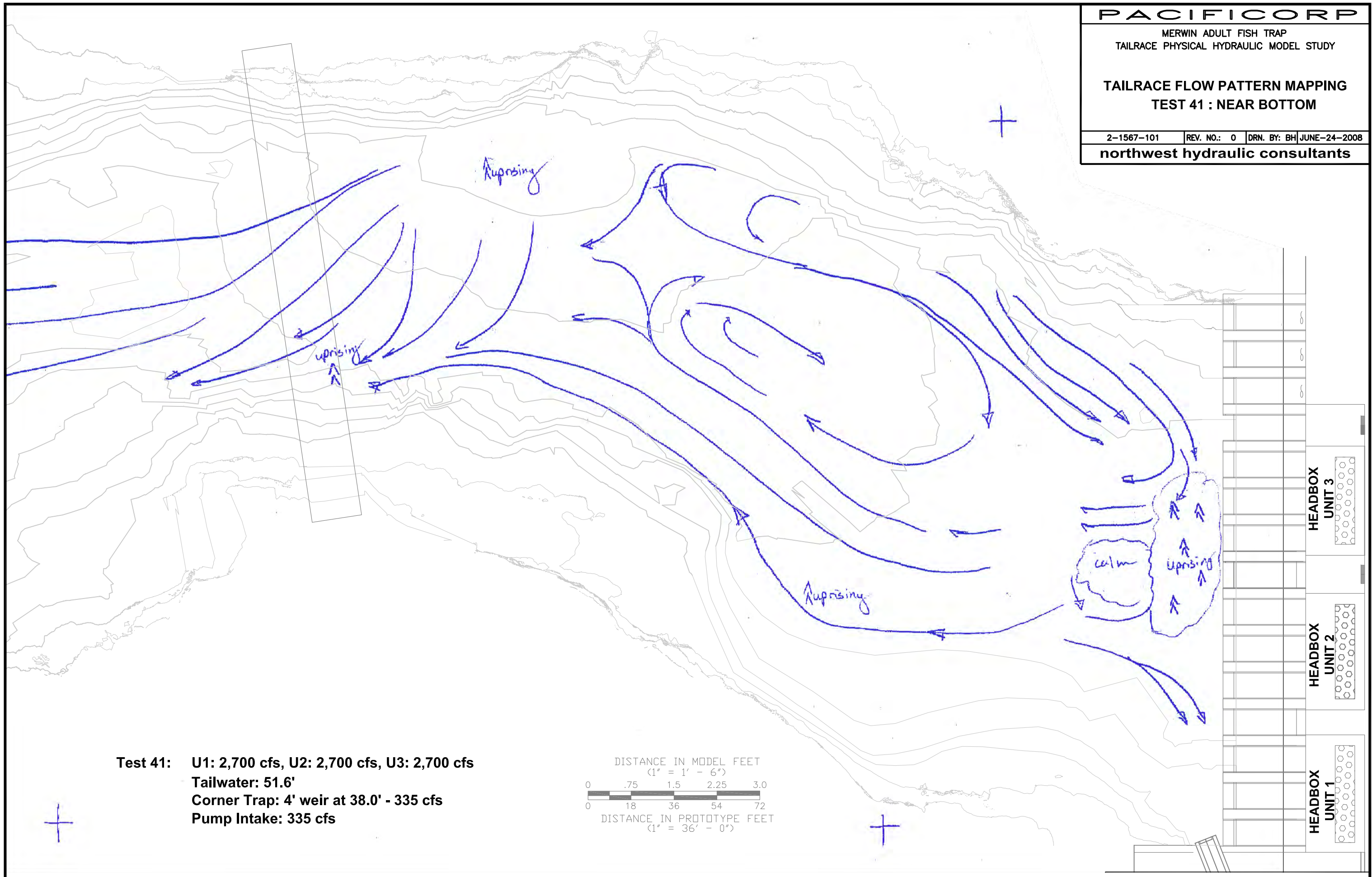


FIGURE 4.17

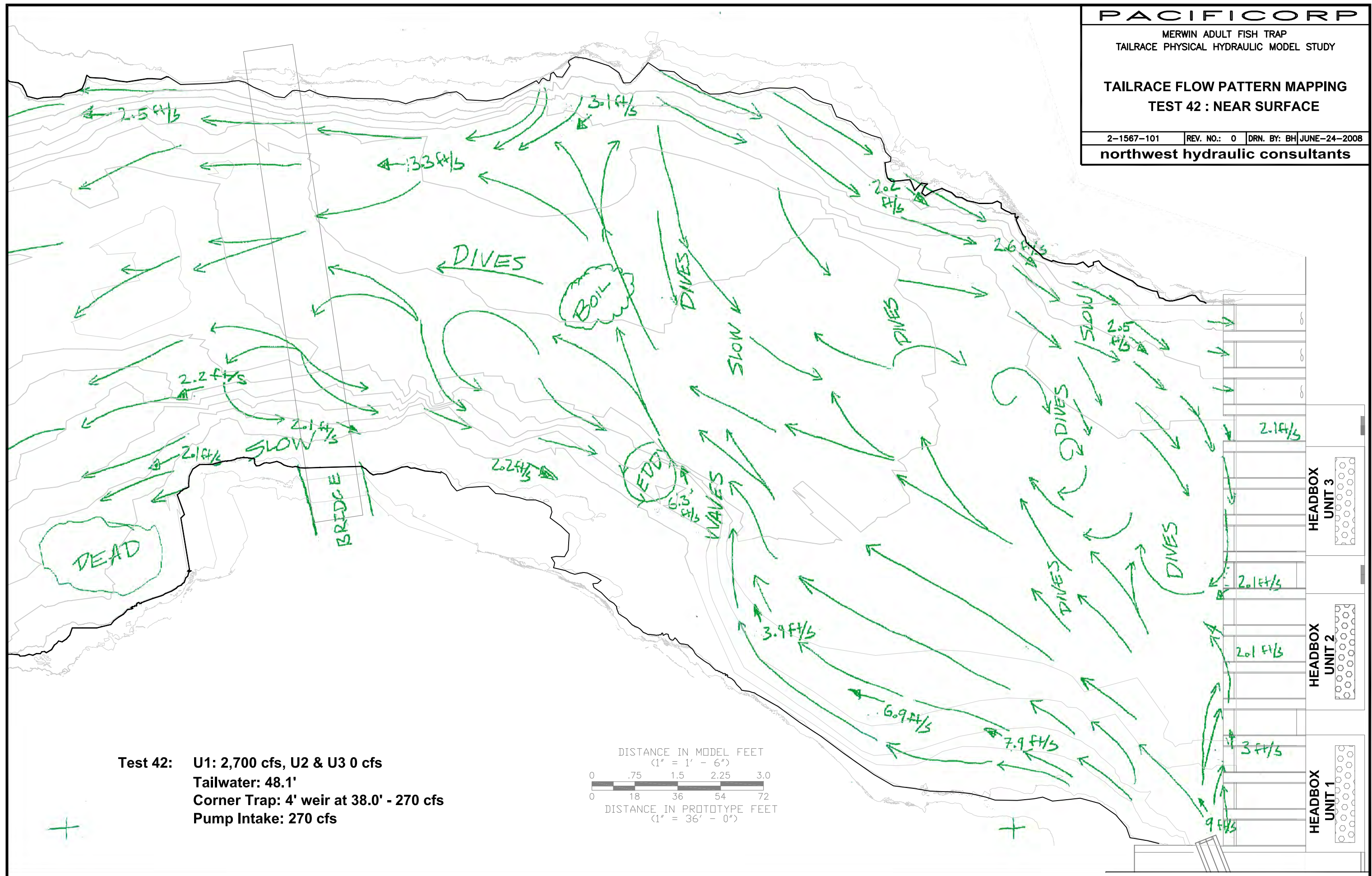


FIGURE 4.18

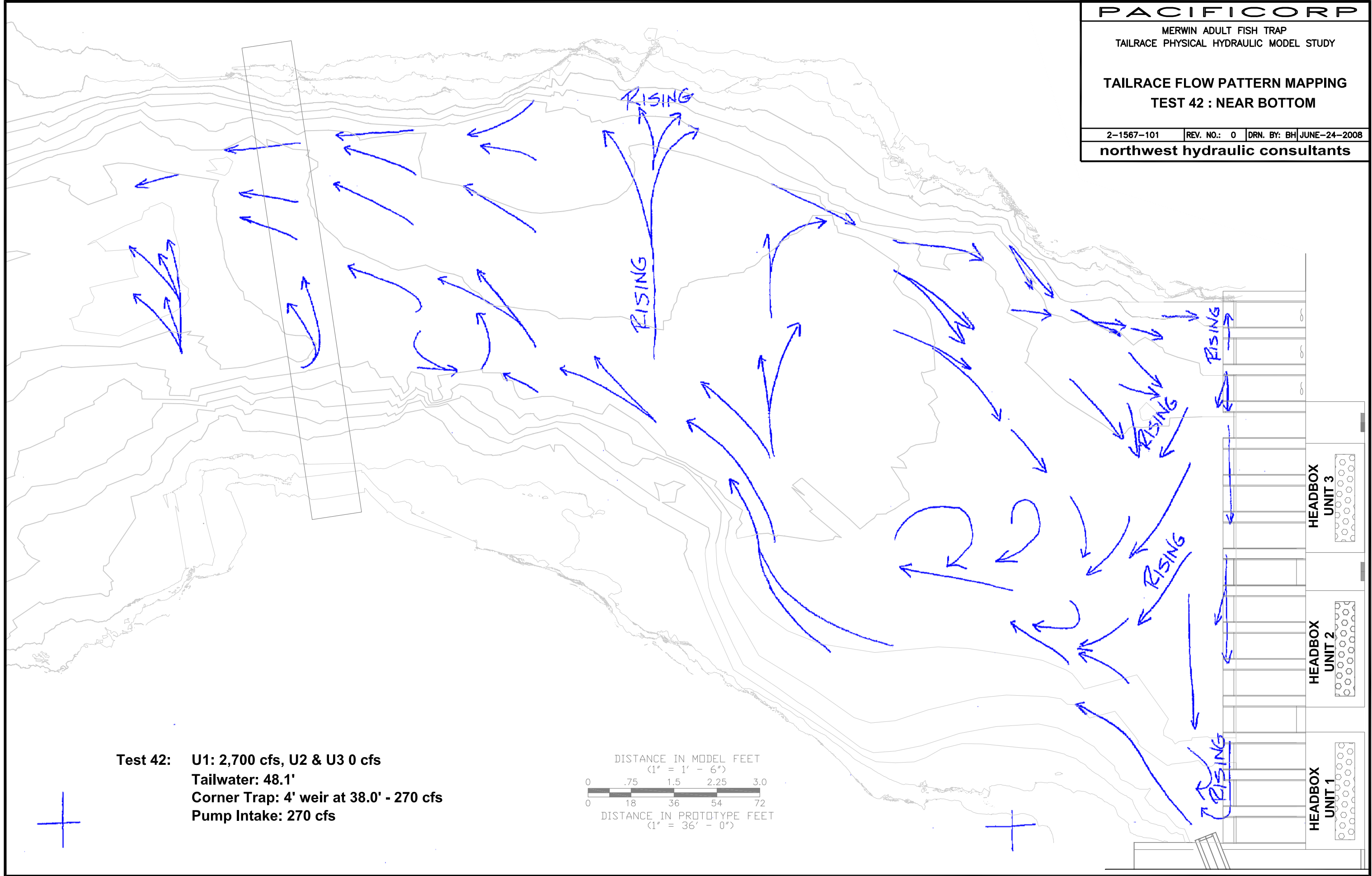


FIGURE 4.20

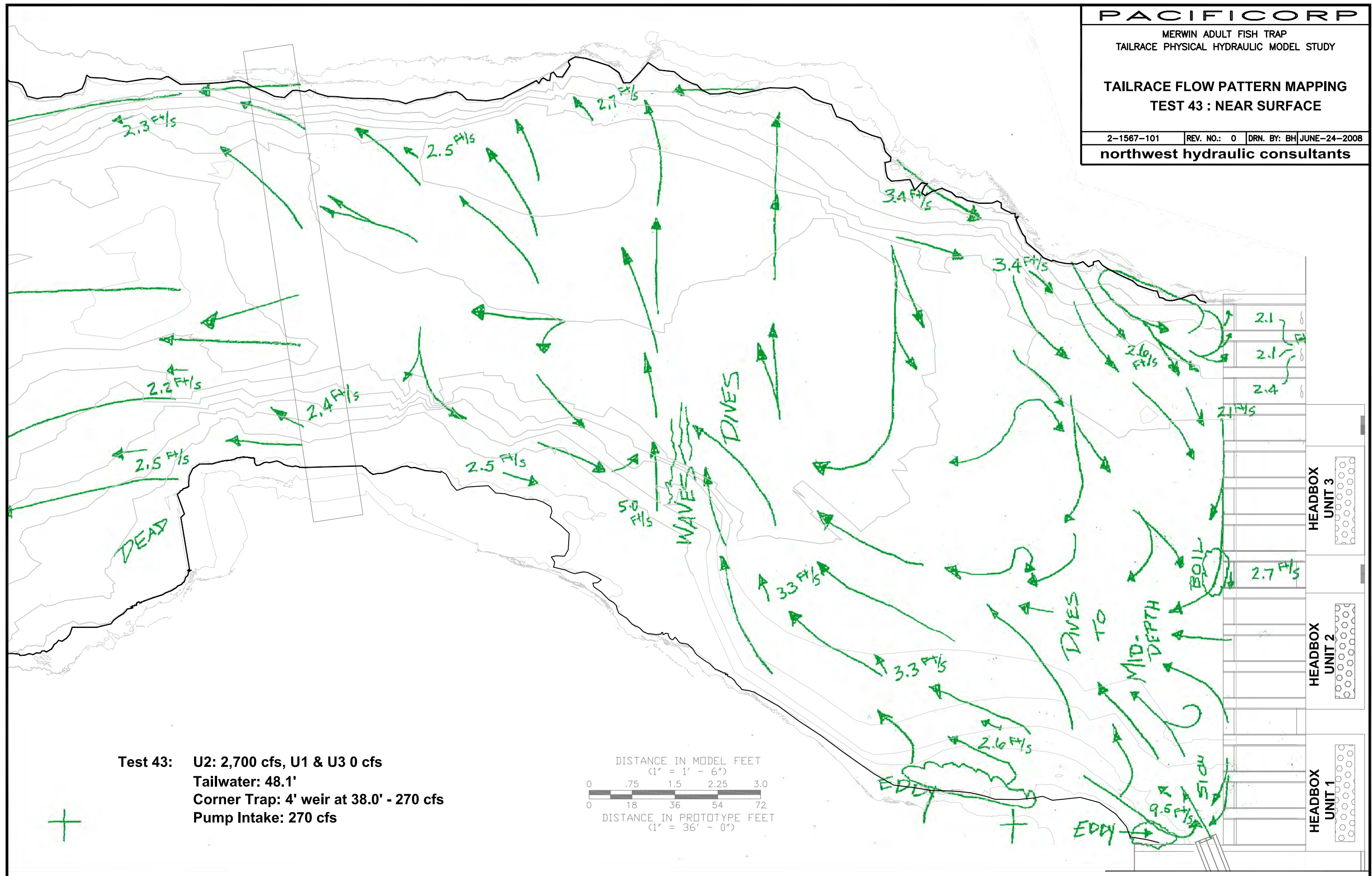


FIGURE 4.21

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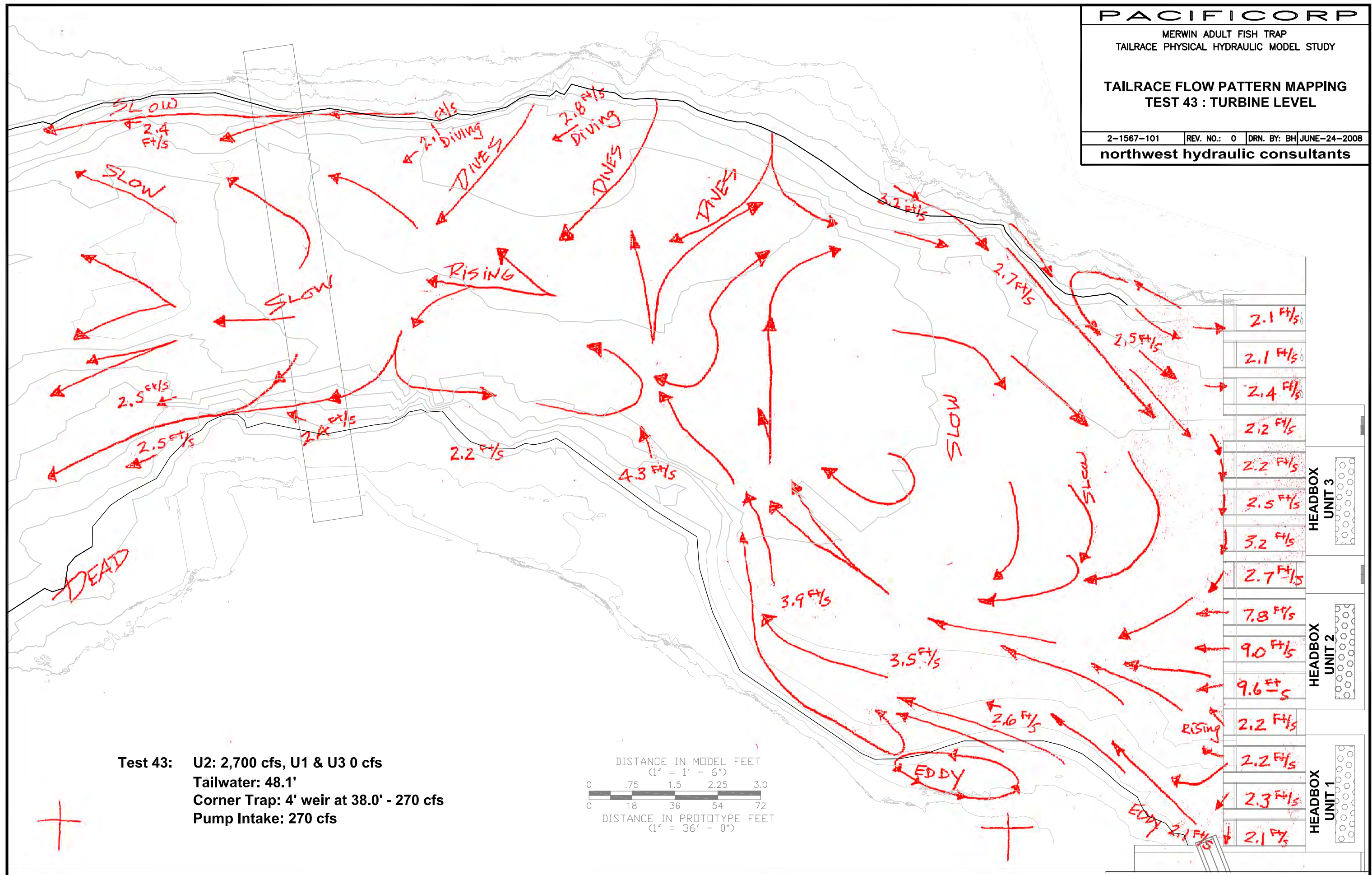


FIGURE 4.22

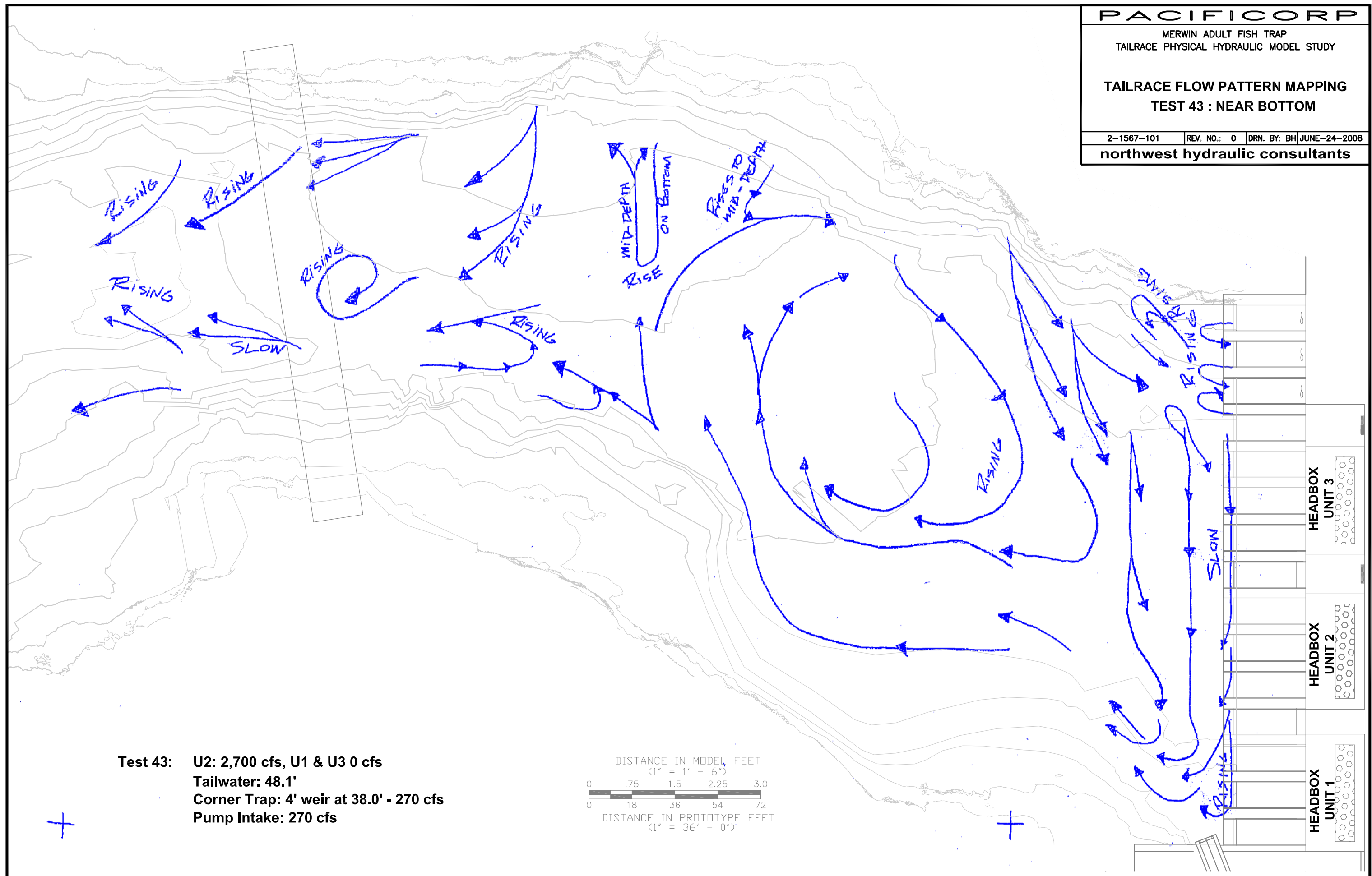


FIGURE 4.23

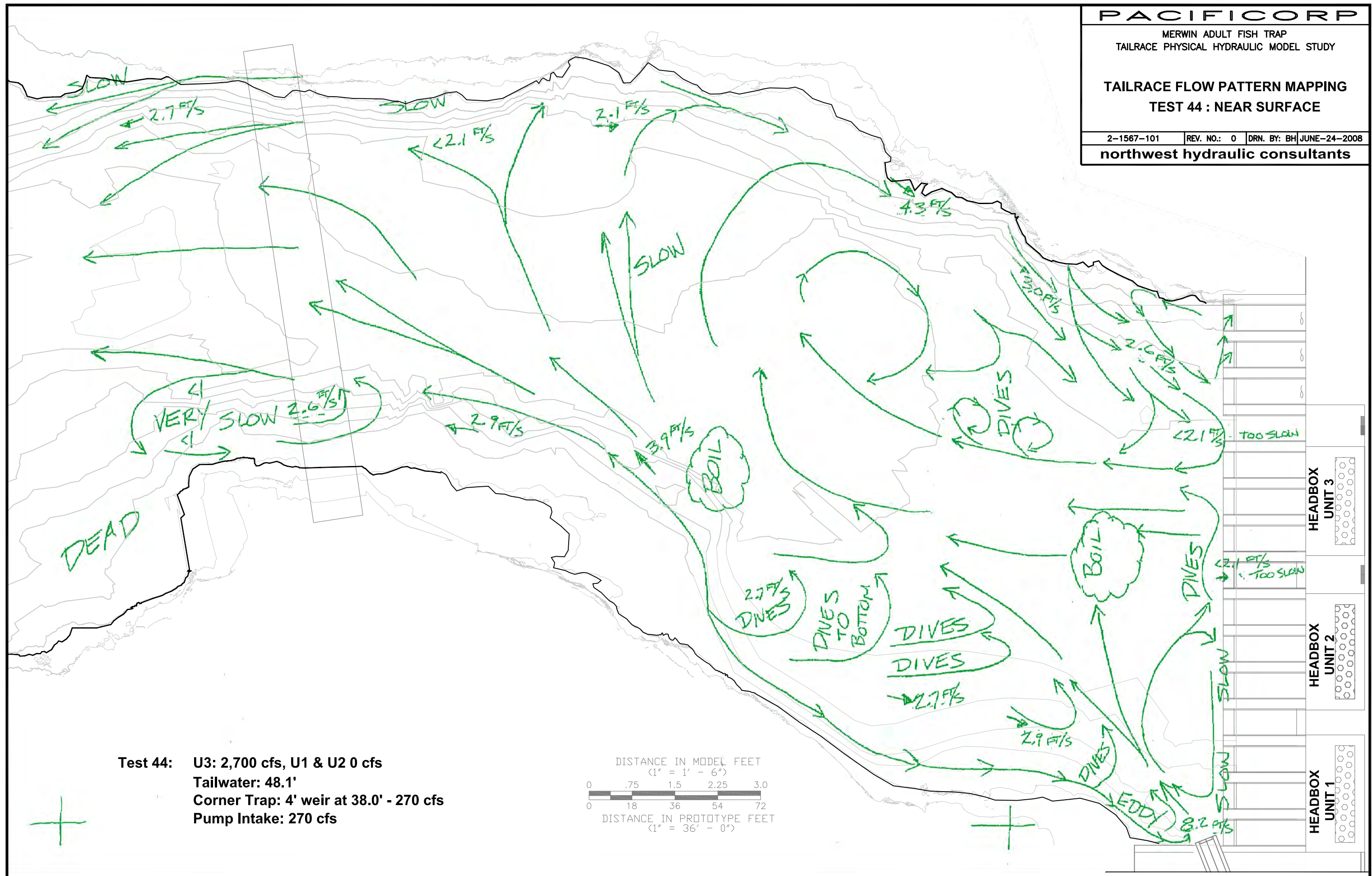
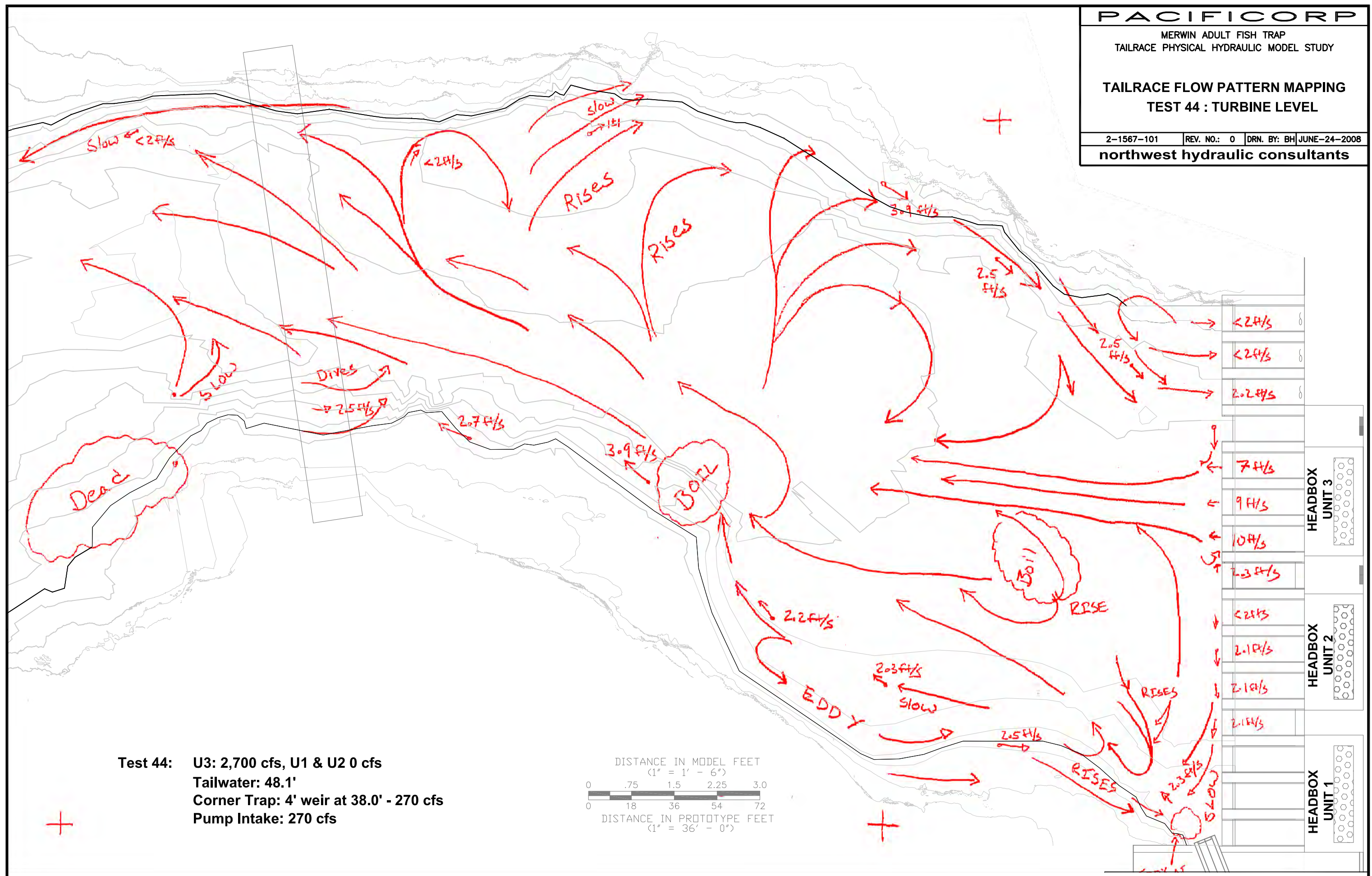


FIGURE 4.24



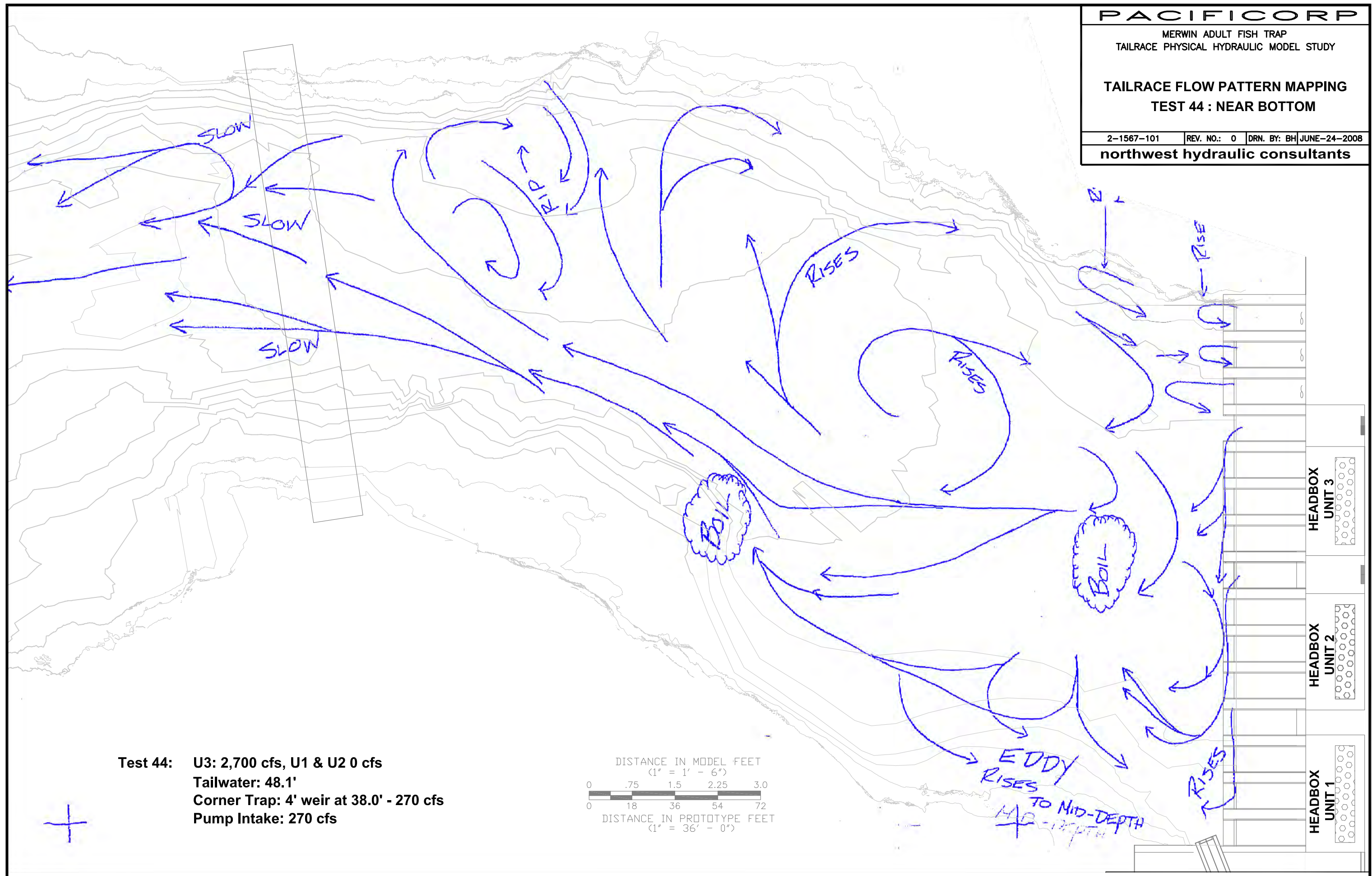


FIGURE 4.26

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MERWIN ADULT FISH TRAP
TAILRACE PHYSICAL HYDRAULIC MODEL STUDY

TAILRACE FLOW PATTERN MAPPING
TEST 45 : NEAR SURFACE

2-1567-101

REV. NO.: 0

DRN. BY: BH

JUNE-24-2008

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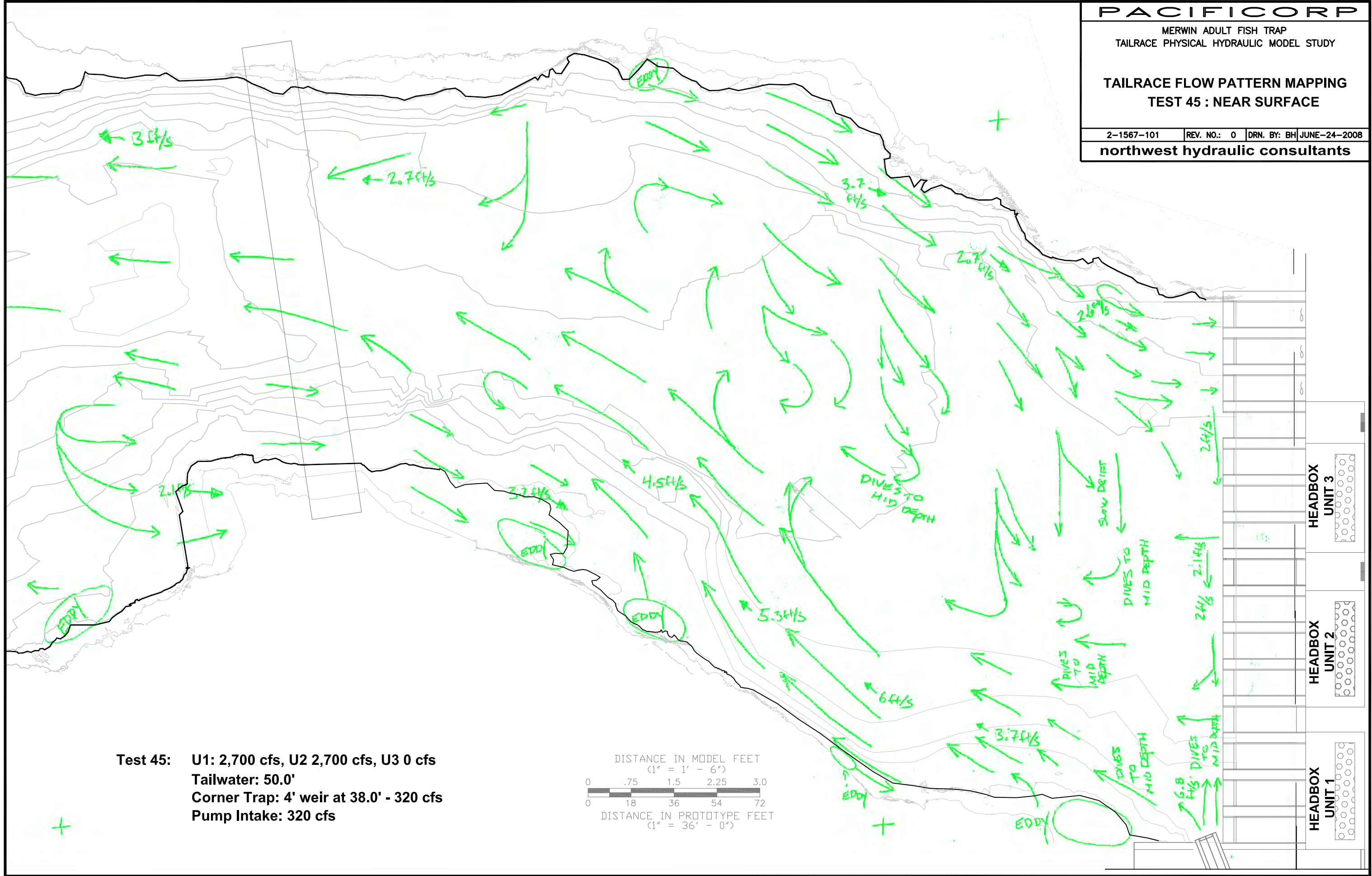


FIGURE 4.27

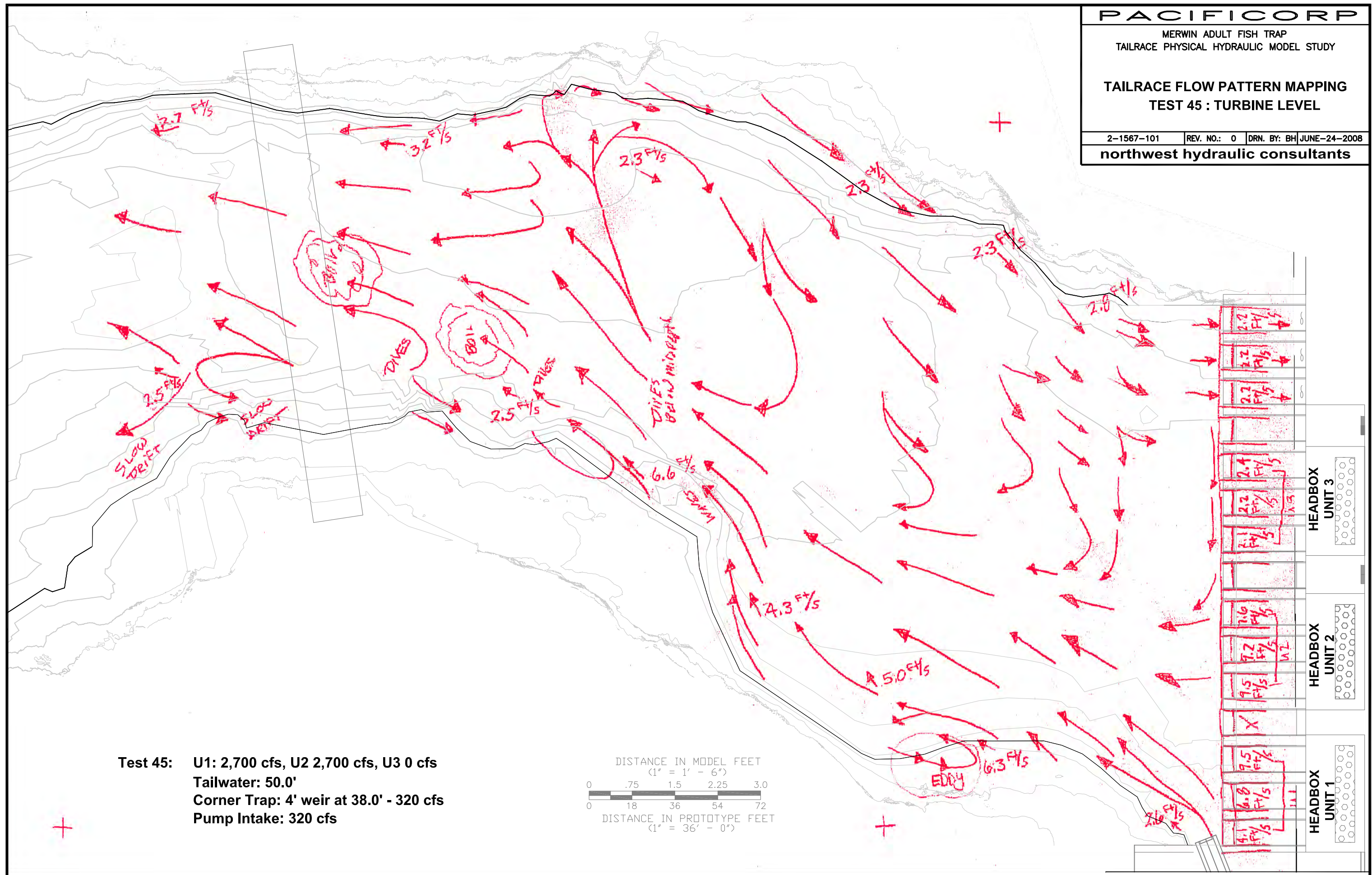
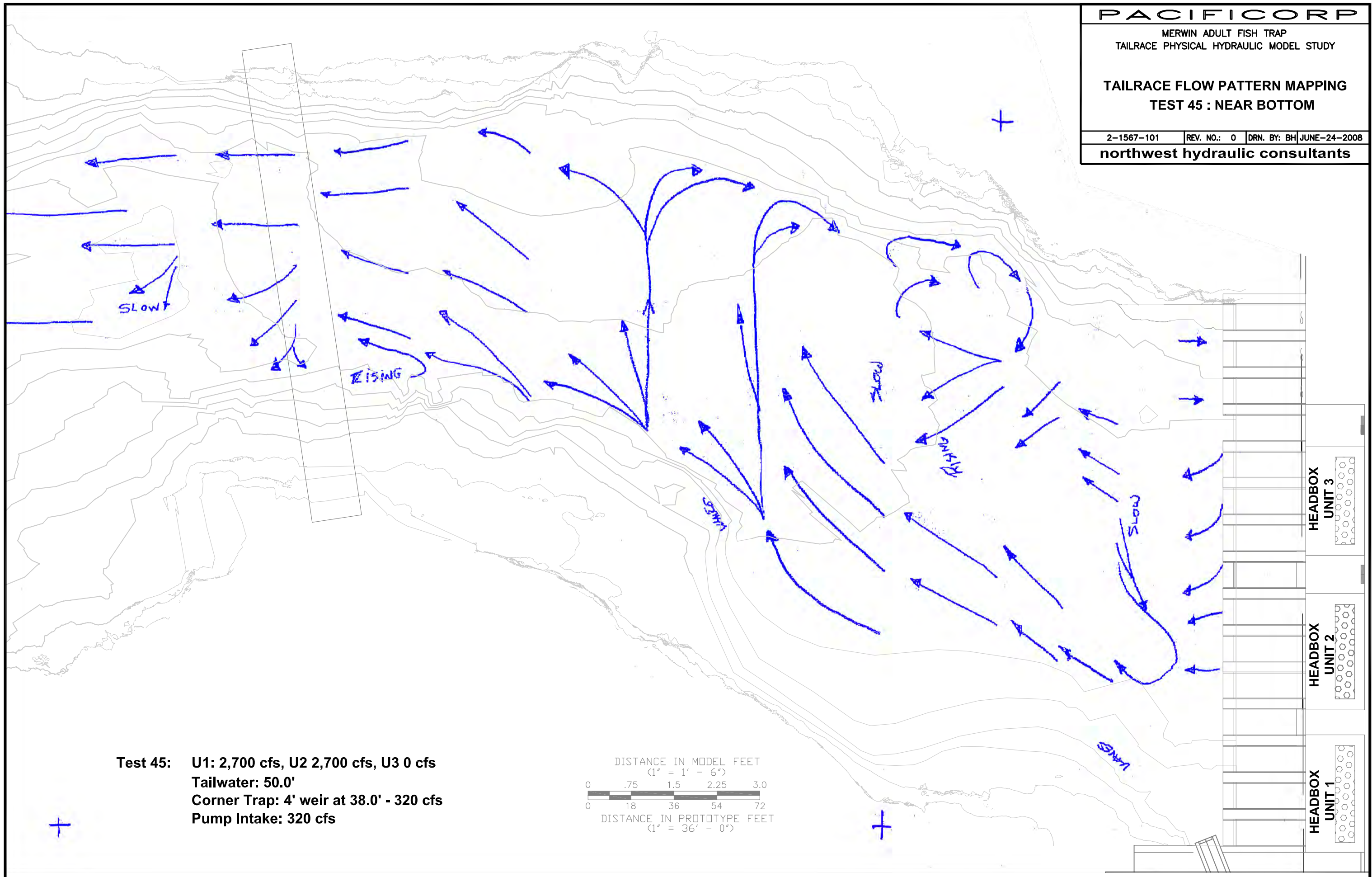


FIGURE 4.28



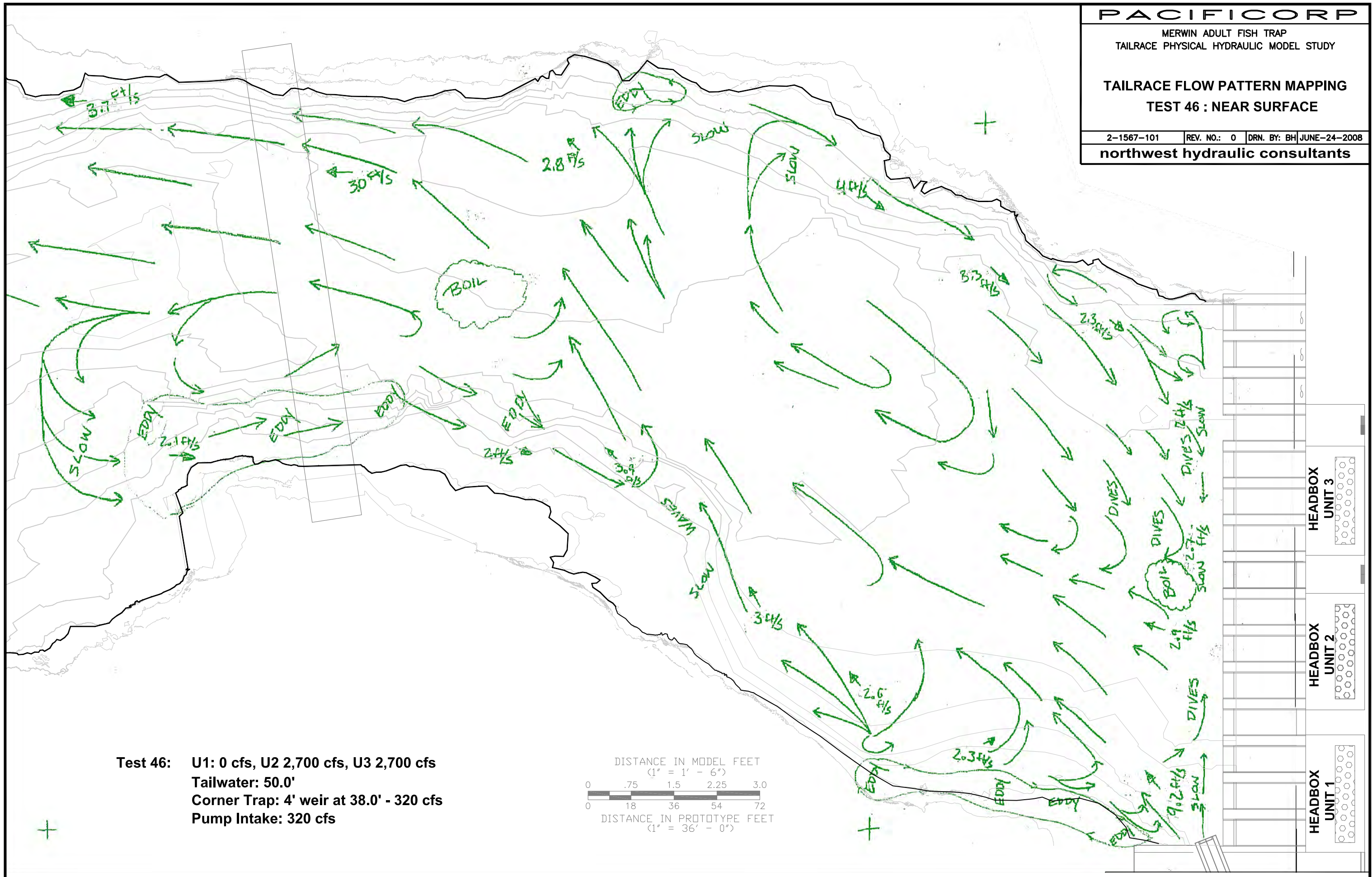


FIGURE 4.30

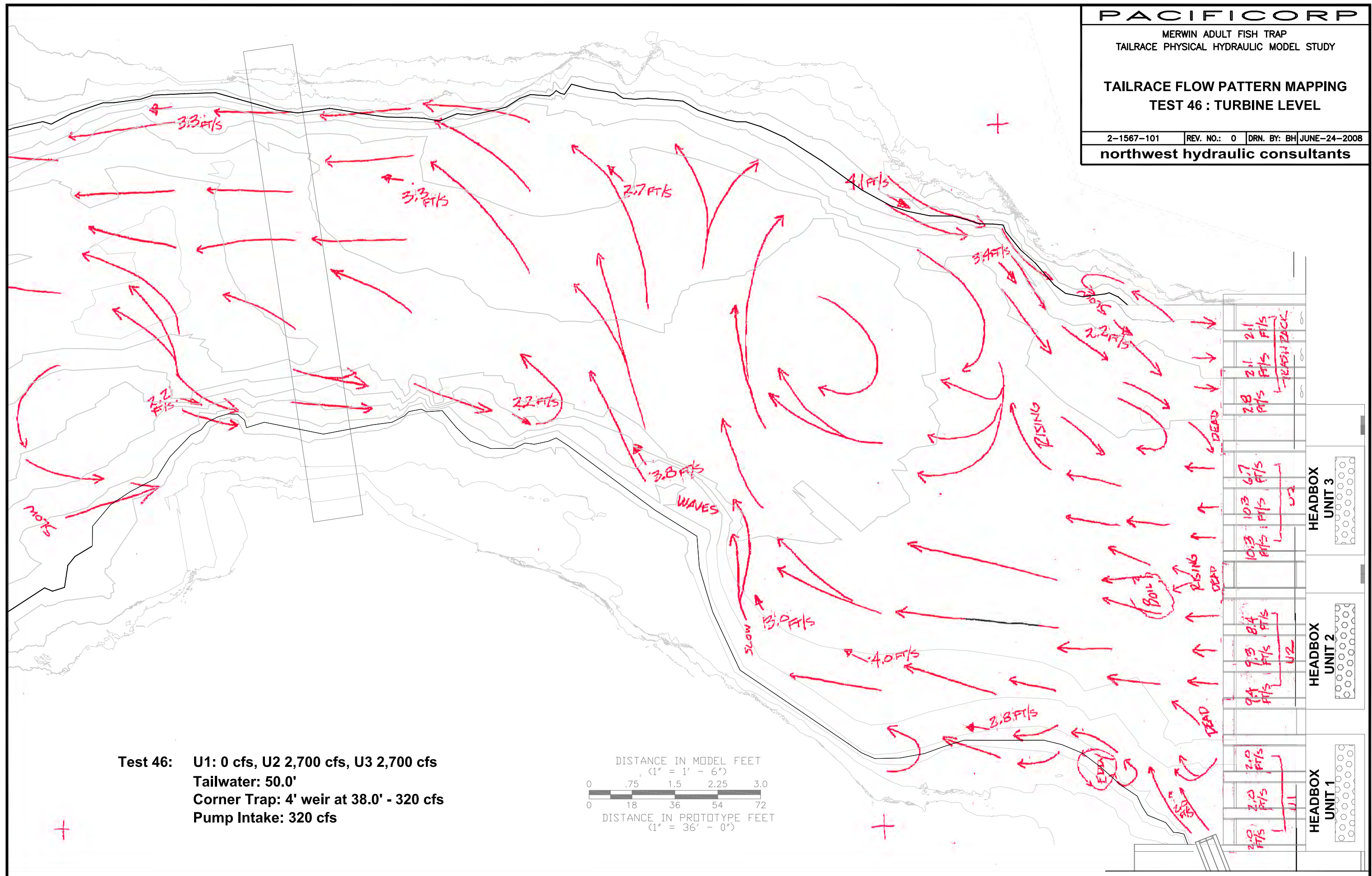
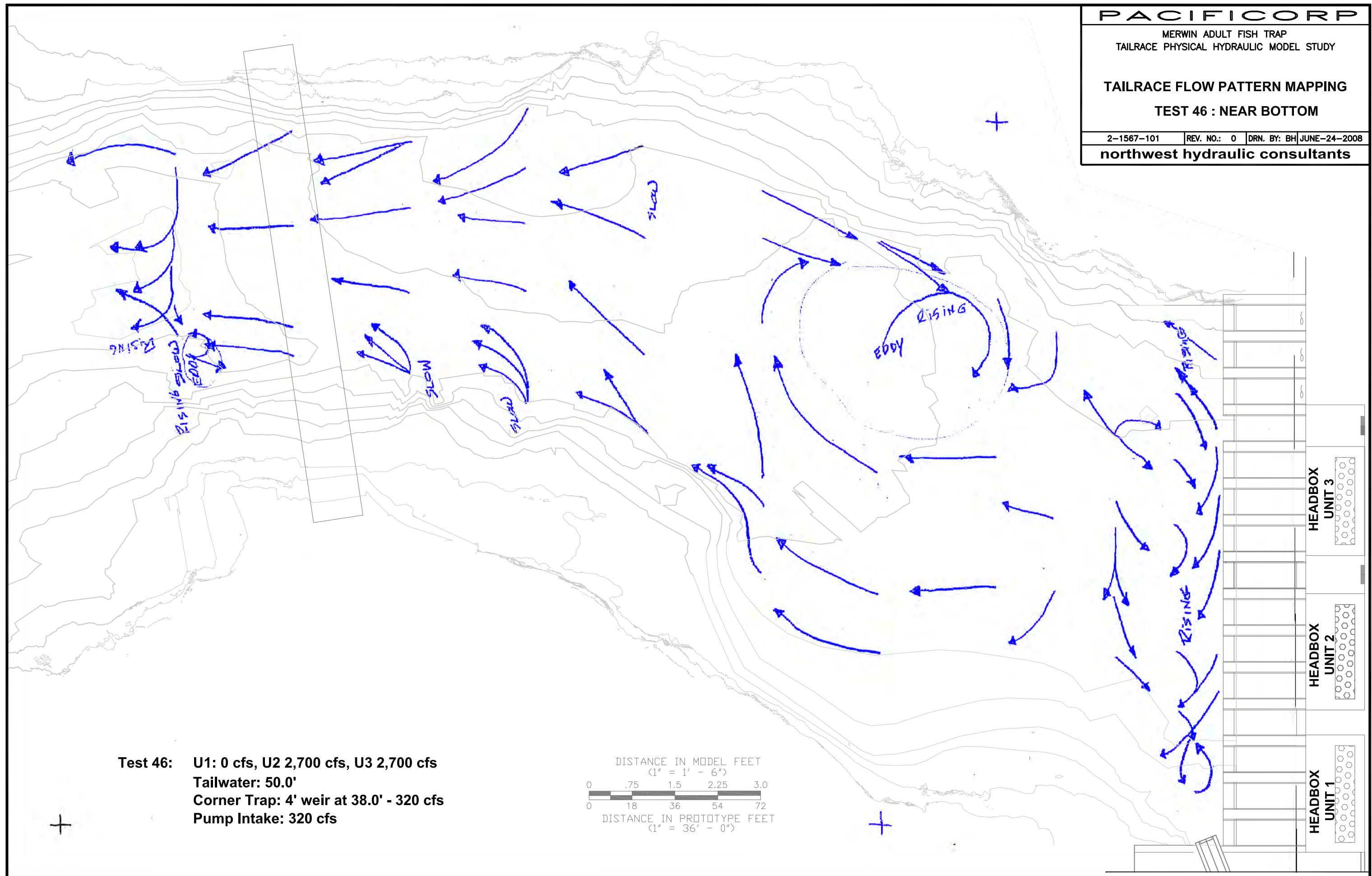


FIGURE 4.31



Test 46: U1: 0 cfs, U2 2,700 cfs, U3 2,700 cfs
Tailwater: 50.0'
Corner Trap: 4' weir at 38.0' - 320 cfs
Pump Intake: 320 cfs

DISTANCE IN MODEL FEET
(1" = 1' - 6")
0 .75 1.5 2.25 3.0
0 18 36 54 72
DISTANCE IN PROTOTYPE FEET
(1" = 36' - 0")

FIGURE 4.32



Photo 1.1 Merwin Dam Project Overview



Photo 2.1 Merwin Physical Model – Looking upstream.



Photo 2.2 Merwin Physical Model – Looking downstream.

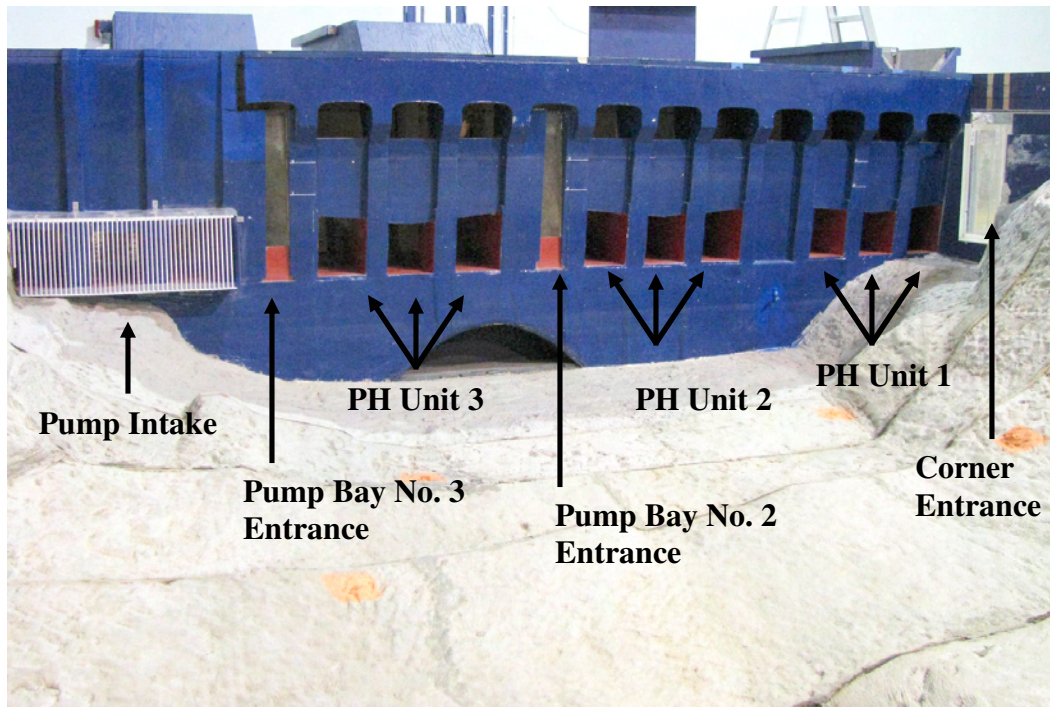


Photo 2.3 Merwin Powerhouse and Fish Entrances – Looking upstream



Photo 2.4 Merwin Corner Entrance – Looking across from right bank

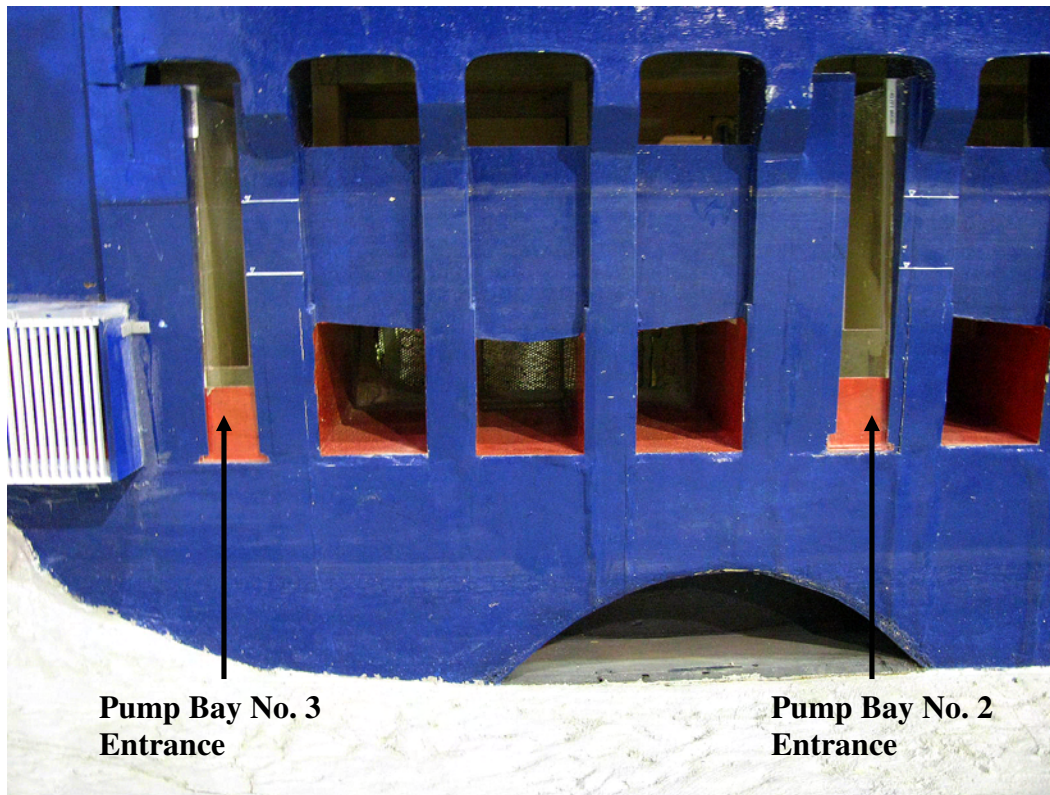


Photo 2.5 Merwin Pump Bay Entrances – Looking upstream



Photo 2.6 Merwin Pump Intake Rack – Looking upstream

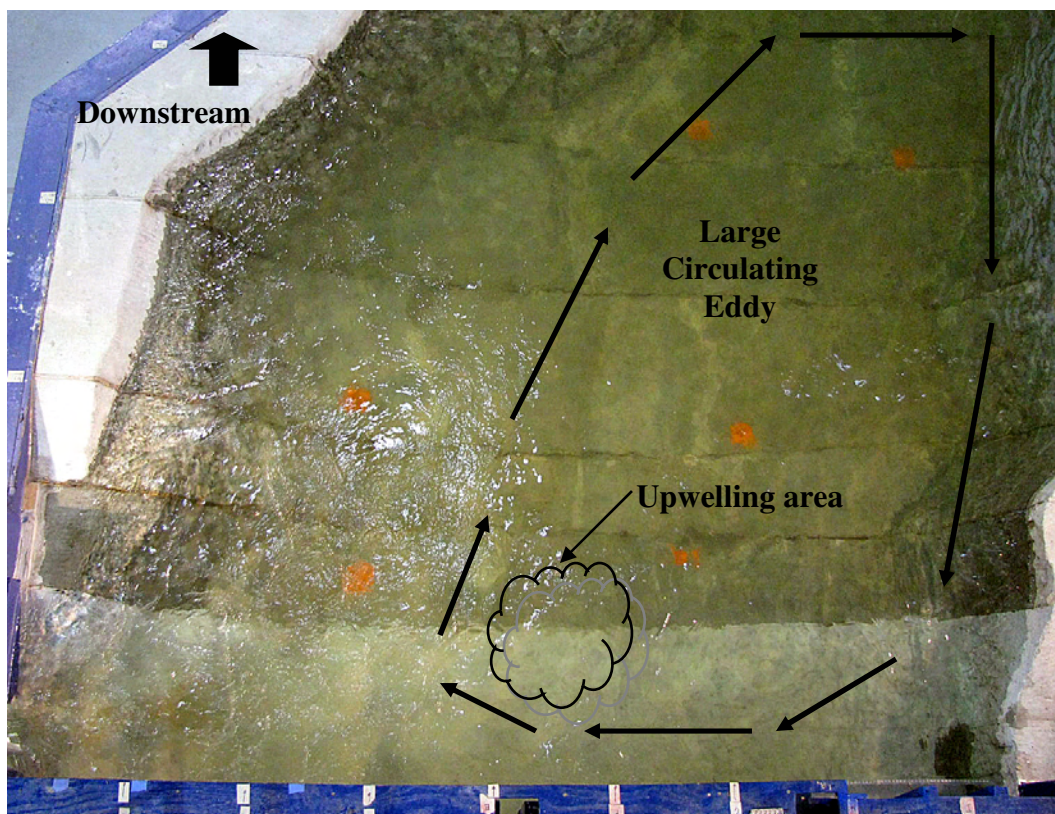


Photo 4.1 Baseline testing flow pattern features – Overhead View – Model operating at full generation.



Photo 4.2 Corner Entrance Fillet Concept – Looking across from right bank



Photo 4.3 Corner Entrance Without Fillet Concept – Corner entrance operating at 400 cfs, 4' wide weir, powerhouse operating at full generation – Looking across from right bank.

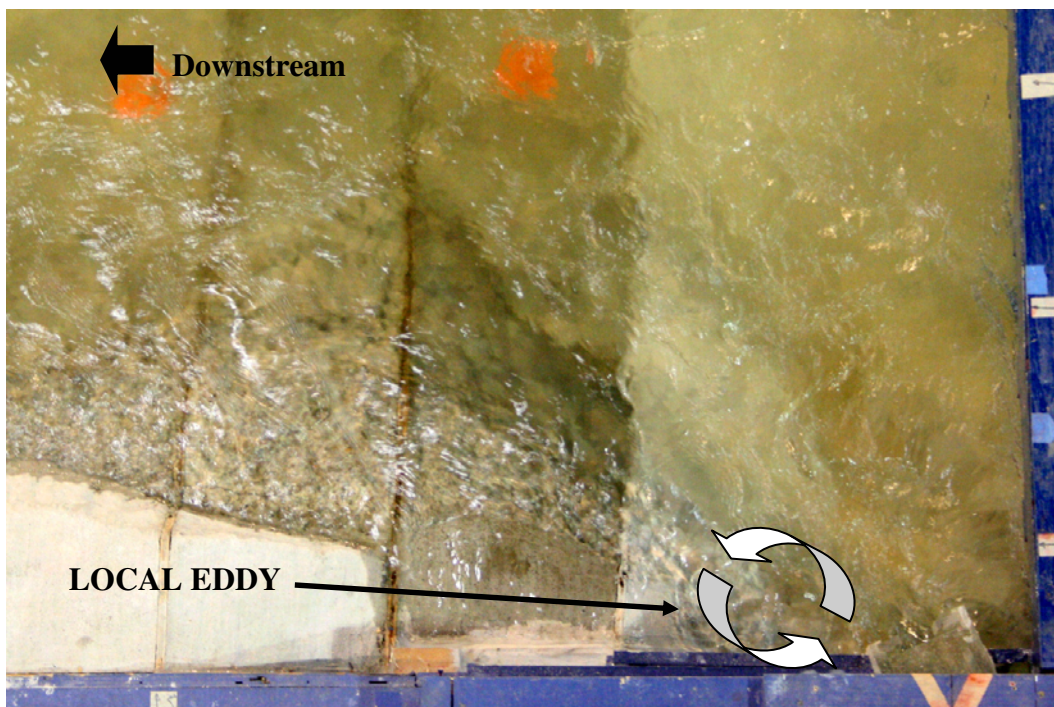


Photo 4.4 Left Bank Local Eddy – Corner entrance operating at 400 cfs, 4' wide weir, powerhouse operating at full generation – Looking overhead from left bank.



Photo 4.5 Clay Fillet used to Eliminate Left Bank Local Eddy.

APPENDIX A
Merwin Adult Fish Trap: Data Discs 1 (DVD) and 2 (CD)

APPENDIX B*
Model Observations and Decision Memorandum

* Information in Appendix B, although not a part of **nhc**'s modeling work, is included for convenient reference in the context of the subject matter of this report

Model Observation and Decision Memorandum, June 10, 2008
Lewis River License Implementation
Engineering Subgroup
(Attachment to the June 4, 2008 Meeting Notes)

This memorandum documents the Engineering Subgroup (ES) observations and discussion points regarding the Merwin Tailrace Physical Hydraulic Model, from the April 8th, 28th, and June 4th ES meetings. The memo is structured to address each of the design features of the new Merwin fish trap entrances. Decisions agreed to with the full ES based on the completion of the model program are also noted below.

1. Corner Entrance Weir Configuration (width, crest elevation, and control)

a. Observations and Discussion

- The team reviewed the entrance weir charts (Attachment A), which greatly helped to explain how the trap entrances could be operated without a control gate to maintain a head drop of 1.0 to 1.5' over a fixed submerged weir, using a variable capacity attraction flow supply.
- The charts were accepted by the team as presented for the current modeling program needs. During final design, it may be desirable to fine tune the hydraulic calculations using a variable weir coefficient "c" for various depths, flows, and depending on the final design details.
- A manually adjustable weir sill, through the use of a permanent type stop log, would be desirable to fine tune the final hydraulics and provide some flexibility in the range of entrance depth.
- After the discussion and viewing the model, the team agreed on the following entrance weir scenarios:
 - 400 cfs entrance, 4' wide fixed weir, crest elevation 38.0, no entrance gate.
 - 600 cfs entrance, 6' wide fixed weir, crest elevation 38.0, no entrance gate.
 - Provide necessary attraction flow to meet the 1.5' head drop over the submerged weir as a design condition, as shown on the tables, up to the high tailwater limit.
 - Additional flexibility in the pump curve operations is possible by operating the entrance down to 1.0' head drop over the submerged weir. Attraction flows that will provide this head drop will be less than the 400 or 600 cfs, and are indicated on the entrance weir charts.
 - A 500 cfs entrance could be accommodated with a 5' wide fixed weir, crest elevation 38.0, and no entrance gate. However, a 5' wide slot for 400 or 600 cfs doesn't match the goals well for either flow. Therefore, for the desired flows, the 4' wide or 6' wide configurations are preferred.
 - The entrance weir could be constructed to 6' wide, with inserts to reduce the width to 4' wide.

b. Decisions

- The corner entrance weir will be configured as follows:
 - 400 cfs entrance, 4' wide fixed weir, crest elevation 38.0, no entrance gate.
 - 600 cfs entrance, 6' wide fixed weir, crest elevation 38.0, no entrance gate.
 - The fixed crest will be set at elevation 37.0, with permanent style, smooth stoplogs provided to form a final crest elevation based on field observations.
 - The entrance weir will be constructed at 6' wide, with inserts to reduce the width to 4' wide. Entrance inserts will be made to be replaced, so other configurations are possible in the future.
 - Diffuser area and water supply will be provided for a maximum 570 cfs of AWS flow. The remaining 30 cfs to meet a maximum capacity of 600 cfs will be provided by fishladder flow.
 - The water supply will have variable flow control within the capability of the turbines that drive the AWS pumps, to allow operation at intervals less than the maximum, to allow the flow to follow the 1.5' to 1.0' of head across the entrance weir at all project design flows.

2. Corner Entrance Weir, Projection and Bottom Elevation

a. Observations and Discussion

- Model runs were conducted with the corner entrance projecting into the flow at the 70° angle from the powerhouse face. This configuration was noted to:
 - Produce a surface flow pattern that guides flow across the front of the powerhouse face, from left to right. This pattern is seen as desirable, as it provides a guiding flow for fish towards the entrance for fish that are in the area immediately downstream of the powerhouse face. Review of the additional ADV data with Run 6 confirmed that the entrance protrusion creates these flow patterns.
 - Induce the local eddy immediately downstream of the entrance. This was initially noted as a concern, and is discussed further below.
- For the initial model runs the weir box was constructed to extend all the way to the floor of the existing intake floor (EL 29.4). As the weir crest is being set at EL 38.0, the interior of the box can be set higher than 29.4 within the turbine flow path and the existing wall profile. The team examined whether or not opening the bottom of the weir box up to turbine flow, by raising the exterior floor up to EL 36.0, would help to reduce the local eddy.
- Upon running the model with both weir box configurations, raising the bottom of the weir box (thus opening up the bottom area to turbine flow under the entrance) did not noticeably change the eddy flow patterns.

b. Decisions

- After review on video and in the lab, it was decided that how the bottom of the weir is configured can be left to the discretion of the design team during final design, as it would not have a significant impact on the eddy or predominant flow patterns.

- The interior bottom of the entrance pool within the turbine flow path and the existing wall profile will be set at EL 36.0. The exterior bottom elevation (to account for structural dimensions); will be determined during the final design.
- The design team will explore how to best configure the bottom elevation to accommodate maintenance bulkheads and facilitate construction during final design.

3. Left Bank Local Eddy

a. Observations and Discussion

- Model runs were conducted with video and dye tests to examine the specific strength and characteristics of the local eddy located immediately downstream of the entrance.
- As noted above, the bottom of the weir box (open or closed), did not have much if any impact on the eddy.
- The eddy is predominant in this area at high turbine flow (full generation), with flow returning downward right along the powerhouse wall. Spot velocities in the range of 4 fps (prototype) were measured in the model using NHC's Nixon propeller meter immediately adjacent to the wall. The velocities reduced rapidly as the meter was moved away from the wall.
- The area is well defined, with corner entrance flows of 400 or 600 cfs, and appeared to be of the same size, shape, and magnitude with either flow. There is also a well defined transition zone between the eddy flow and the predominant entrance flow which moves downstream toward the rock outcropping.
- As the generation flow is reduced, the tailwater drops and the eddy weakens significantly. It is also more dependent on running Unit 1, as this flow seems to create the predominant pattern that sets up the eddy.
- Adding several plates to fill the area, or modify the eddy pattern, did not have much effect, but did change the flow patterns.
- NHC performed model testing of filling the eddy area along the control room face immediately downstream of the corner entrance with a clay fillet. This approach did eliminate the eddy at high tailwater conditions. However, based on the initial dye observations, it appeared that eliminating the eddy may increase tailrace velocities leading up to the trap entrance. There is concern that eliminating the eddy may not be desirable from a biological perspective, as it may eliminate a potential resting/holding area immediately downstream of the entrance.
- Additional velocity data was collected along the shoreline to supplement the video data of the dye releases, to help facilitate a decision on this issue. Spot velocities were collected along the left bank using NHC's Nixon propeller meter. Three data readings each were taken at 5-foot and 12-foot depths, starting just downstream of the trap entrance and ending about 70 feet downstream (see Tests 35 and 36). At the 5-foot depth, the velocities increased from 2.0, 3.5, and 9.0 fps along the shoreline (moving from upstream to downstream), to 2.7, 4.2, and 9.2 fps. At the 12-foot depth, the velocities changed from 2.7, 4.2, and 9.9 fps to 2.7, 5.7, and 8.7 fps.
- NHC documented the clay fillet dimensions and volume, as filling this area could be held as a concept for future adjustment if the eddy is shown to be negatively affecting ATE for the trap.

a. Decisions

- The subgroup members decided that the flow conditions without the fillet would likely pose less of a fish passage problem than adding the fillet, which was developed to streamline the flows and eliminate the eddy. The high velocities (~9 fps) observed along the left bank will require fish to expend energy to migrate past the rock edge. The small eddy will likely provide some resting area for fish before they have to pass the entrance weir. Eliminating this eddy could actually be more of a deterrent, as it would eliminate this rest area. Therefore, no fillet is proposed for the fish trap design.

Pump Bay Entrances

a. Observations and Discussion

- Dye tests were run at the Pump Bay Entrances (PB2 and PB3), as follows:
 - 170 cfs, 4' wide weir, crest El 46.2
 - 170 cfs, 3' wide weir, crest El 43.7
 - 330 cfs, 4' wide weir, crest El 40.7
 - 330 cfs, 3' wide weir, crest El 37.2
- The team reviewed video, and observed the high and low flows in the model with each weir configuration.
- Hydraulically, the flow patterns from PB2 carry further into the tailrace than PB3 due to the flow patterns. Flow from PB3 is diverted towards the left, and dissipates more quickly due to the large eddy along the right bank that intersects the flow.
- The 4' weirs induce flow patterns that carry further into the tailrace, and the flow from the deeper, narrower (3' wide) weirs breaks up more quickly.
- It is difficult to select a preferred location or weir width/depth based solely on hydraulics, as fish behavior may have more influence at the PB entrances.
- Based on the phased approach under consideration, a PB entrance would be constructed in the future after there was fish behavior data available. However, for the design team it is desirable to select the best entrance now to move forward with design. As long as the design could be changed to the other PB entrance in the future, the team can do it's best to select a preferred entrance.
- During initial discussions, part of the team felt that PB3 had advantages, as any fish near PB2 could likely find the corner entrance. Other team members debated whether or not PB2 had advantages, as the eddy pushes flow towards that entrance anyway. Concern was also expressed about potential pump noise from the attraction flow pump station being more likely to affect behavior at PB3 than at PB2.
- The weir width/depth could be made adjustable for the final design based on the above dimensions.
- Additional dye runs were made to examine the PB entrances with Tests 27-34 indicated in the Run Index Table (see model DVD)

- The dye traces acted as anticipated, and there were no surprises from the runs. Ultimately, the decision on which PB entrance will be a judgment call based on both hydraulics and anticipated fish behavior.
- The design team noted that selecting one of the PB entrances for the initial final design is desirable, as the piping, valving, and fish transport channel will need to be developed.

b. Decisions

- Based on a review of the final model dye tests and tailrace flow pattern sketches, the subgroup members agreed that PB3 is the preferred entrance for the initial design. This decision was based on the following observations:
 - There is a general convergence zone immediately downstream of the PB2 entrance, with an intermittent boil also documented in the tailrace downstream of PB2. If fish approach the powerhouse from the middle of the tailrace, they would likely follow one side of this convergence zone, along the higher velocity flowlines, which would lead them to either PB3, or to the corner entrance. If the entrance was located at PB2, they would likely have to negotiate another full circuit, or circle in the eddy, until they had another chance to find the entrance.
 - The team also noted that the surface flowlines from the corner entrance extend all the way to the PB2 entrance. The team believes that if fish approach the dam at the PB2 area, they would have enough velocity cues to follow the flow to the corner entrance, which is only about 70 feet away. The PB3 entrance provides a new opportunity for discovery further away from the corner.
- Even with the preference for PB3, the final design will need to anticipate how the entrance could be moved to the PB2 entrance location if biological monitoring indicates a preference for the other entrance. How to phase this and the level of design necessary will be addressed with the phased approach discussion and the design.
- The design team noted further dye penetration with the 4' wide entrance, as compared to the 3'. A similar adjustable width and crest elevation with stoplogs could accommodate both entrance configurations. A 4' width was selected for the initial design. The weir crest elevation will be set to accommodate the 4' width with a maximum flow of 300 cfs, but will be made adjustable such that a 3' width could be added in the field. A permanent type of stoplog system similar to the corner entrance is desired.

5. Design Ramifications, Phased Approach Considerations, and Total Attraction Flow Needs

a. Discussion

- The team identified flow limits for each entrance, which are listed below in the Decisions paragraph.
- If each entrance were constructed to the above limits, this would set the constraints for total flow at each entrance, and the individual entrance designs could progress. Not considering the flow supply limitations, this would result in a total flow capacity of $600 + 300 = 900$ cfs.
- How the flow limits are phased, and split between the entrances is a separate issue from the design of each entrance, as long as the necessary flow capacities of the entrance are provided for any phase. Upper total flow limits and distribution is a function of the pump and intake limitations, conveyance pipe, and valving needs. This can be worked out later; therefore, the entrance configuration designs can likely proceed after the next ES meeting.
- The current pump intakes under consideration (the turbine pumps) have an upper flow limit of about 200 cfs each in the 3 bays. PacifiCorp based their previous phased approach flow proposal based on these limitations.
- Higher flows would require larger pumps (not sure if this is possible based on existing infrastructure physical constraints), a separate pump station, or gravity flow.
- PacifiCorp does not want to impact their generation (which was preserved by the Settlement Agreement), and prefers not to provide the attraction flow from the forebay as this would result in lost generation.
- Based on the model data, Bryan Nordlund presented the coordinated agency response to PacifiCorp's phased proposal at the April 28th meeting, which identified five phases. See the April 28th, 2008 meeting notes for additional information and Bryan's attachment.

b. Decisions

- The team agreed to the following upper limit flow constraints for the trap entrance designs:
 - Corner Entrance, max $Q = 600$ cfs.
 - PB Entrance, max $Q = 300$ cfs
- PacifiCorp will review the 800 cfs maximum attraction flow proposal from the agencies. Additional research and design work would be necessary to expand the attraction flow from 600 to 800 cfs, based on the Unit 4 pump station conceptual design to date. Additional discussion is provided in the April 28th meeting notes. Alternate sources of water could include:
 - Expansion of the capacity for the three pumps in Unit 4 substructure
 - New 200 cfs pump station located elsewhere
 - Use of the Unit 4 penstock stubout, to use reservoir water, as opposed to pumpback flow from the tailrace (This would result in more energy loss to PacifiCorp.)

- PacifiCorp provided additional detail on the phased approach at the June 4th meeting. See June 4th meeting notes for additional detail. The phased approach to the project will be an ongoing subject as the design progresses.

6. Intake Rack

a. Observations and Discussion

- The design team is thinking that the smaller rack structure would be best, as angling the rack would not have much affect.
- For the final model velocity documentation, the top of the intake rack was removed, as was the divider wall between the rack and the PB3 entrance. Sketches and photos of the final rack configuration will be documented in the model report.
- The model was used to examine any turbine flow recirculation patterns (from Unit 3 into the intake) that could draw water with air into the pump intake. Velocity measurements were taken along the rack at three depths to quantify the magnitude of any cross velocities that are present which may impact pump performance. Velocities were measured at the top of the rack, in the middle, and at the bottom level of the rack, and within the rack at the centerline of the pump suction tunnels for two flow cases: full generation and no generation. Dye tests were also performed to evaluate the recirculation patterns for two flow cases: Unit 3 only at 2,700 cfs and Unit 3 only at 1,200 cfs.
- During full generation, the large eddy flow pattern results in flow vectors directed from right to left (looking downstream) along the left portion of the rack face. Given the model's configuration with a common sump downstream of the rack, an uneven flow condition was documented, with more flow entering the pump intake tunnel near the PB3 entrance due to the eddy momentum. This showed an artificially high entrance velocity along the rack at the middle and left intake tunnel, which would not exist in the real world as each pump bay would be isolated.
- During the no generation case, the large eddy was essentially eliminated, and a comparison of the velocity data results collected for this case and the full generation case illustrated the magnitude of the impact that the large eddy may have on the rack structure approach velocities.
- For the lower generation cases, the dye tests showed that the flow from Unit 3 travels significantly downstream before any of the flow returns back upstream within the large eddy flow pattern to the intake area. Thus, recirculation of the turbine flow into the pump station intake does not appear to be a problem.
- Model data was viewed at the meeting, and will be documented in the model report.

b. Decisions.

- The final design of the intake rake for the AWS pump station can move forward with a configuration similar to that modeled.
- The rack will be designed for a maximum 1.0 fps approach velocity, based on the gross rack area minus a reasonable percentage for major structural members (currently estimated at 10%, to be verified with the final design). The design team envisions divider walls and/or a baffle system (i.e. slots) to be considered as the design progresses to provide a means to mitigate approach velocity “hot spots” should the actual velocities exceed the design criteria.
- Bars of 1/4” to 3/8” by about 3” deep are envisioned at this time, which will also help guide and distribute flow more uniformly into the intake.
- Recirculation of turbine flow into the pump station intake is not a problem.
- Means of cleaning the rack will be considered during design; however, the group agreed that initial cleaning facilities will not be provided. Consideration of angling the rack in the vertical plane, personnel access, and potential automated cleaning systems will be addressed during the design.
- No additional modeling work with the existing model is necessary for the intake.

Attachments

Attachment A – entrance weir hydraulic charts

Attachment B – Run Index Table dated 6/20/08