DUNVEGAN HYDROELECTRIC PROJECT
LEFT BANK SECTION MODEL
ADDENDUM NO. 3 TO TECHNICAL REPORT

DECEMBER 2004

nhc northwest hydraulic consultants
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Prepared For:

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ACKNOWLEDGEMENTS AND AUTHENTICATION

ACKNOWLEDGEMENTS

Numerical and physical model studies were conducted as part of the Dunvegan Hydroelectric Project development joint review process with Alberta Environment, the Alberta Energy and Utilities Board, the Alberta Natural Resources Conservation Board, and Fisheries and Oceans Canada. northwest hydraulic consultants was retained by Canadian Projects Limited on behalf of Glacier Power Limited (a subsidiary to Canadian Hydro Developers, Inc.) to conduct modelling studies. The authors of this report acknowledge the key assistance and information provided by the following individuals.

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EXECUTIVE SUMMARY

northwest hydraulic consultants (nhc) was retained by Glacier Power Limited (Glacier) to construct and test a 1:25 scale physical hydraulic model of the Dunvegan Hydroelectric Project. The project is proposed for development approximately 2 km upstream of the Highway 2 Bridge at Dunvegan, Alberta. The design of the project underwent several revisions over the course of the physical model study as a result of the model study findings. The current project design consists of a forty unit powerhouse facility, a seven bay spillway, two fishway ramps (one on each bank), ten fish bypass sluices and a boat lock along the right (south) bank.

The 1:25 scale “left bank section” model was constructed through modifications to the “right bank section” model. The left bank geometry was reproduced in mirror image within the existing model basin, and encompassed an area approximately 450 m long by 100 m wide (prototype dimensions) along the left (north) bank of the river at the project site. The model included the left bank fishway ramp, the ten northern-most powerhouse units (Units 31 to 40) and three fish bypass sluices.

The present study constitutes an addendum to earlier studies conducted on the right bank section model, which evaluated the upstream and downstream fish passage facilities located along the right (south) bank of the river and also examined engineering-related issues such as ice accumulation and passage, stage-discharge relationships for powerhouse overtopping conditions, stilling basin performance and debris passage at the project. The present report supplements the information related to upstream and downstream fish movement contained in three earlier reports: Right Bank Section Model Technical Report (May 2003); the Right Bank Section Model Addendum to Technical Report (December 2003); and the Right Bank Section Model Addendum No. 2 to Technical Report (July 2004). The current addendum report focuses on assessing the operating scenarios for acceptable flow patterns and velocities conducive to upstream fish movement along the left (north) bank of the river at the project site.

Testing in the left bank section model confirmed that the flow patterns and velocities in the vicinity of the fishway ramp entrance are very similar to those observed along the right river.
bank. However, the velocities approximately 100 m downstream of the fishway ramp entrance, in the area at the base of the 2:1 bank slope on the left bank, were noted to be slightly higher than the velocities recorded near the boat lock wall (same location) on the right bank.

Observation of flow patterns indicate that satisfactory attraction flow patterns for upstream migrating fish could be achieved in the vicinity of the left bank fishway ramp entrance for a wide range of operating scenarios, by providing additional attraction flow within the downstream end of the fishway ramp in combination with supplemental flows through the adjacent sluice and appropriate powerhouse operation.

Overall, testing on the model has demonstrated that the proposed facility has the capacity to deal with varying flow conditions by using plant operation to avoid adverse conditions for fish passage, while still providing economical power generation. The proposed design of the facility achieves the design criteria established for the project and provides enough flexibility in its operation to permit adaptive management techniques to be employed in the field.
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1.0 INTRODUCTION

1.1 GENERAL

The information contained in this report constitutes an addendum to the main technical report entitled “Dunvegan Hydroelectric Project, Right Bank Section Model, Technical Report” (May 2003)\(^1\) and the previous two addendum reports entitled “Dunvegan Hydroelectric Project, Right Bank Section Model, Addendum to Technical Report” (December 2003)\(^2\), and “Dunvegan Hydroelectric Project, Right Bank Section Model, Addendum No. 2 to Technical Report” (July 2004)\(^3\). All reports were prepared by northwest hydraulic consultants (nhc) for Glacier Power Limited c/o Canadian Projects Limited. The current addendum report provides a summary of the testing conducted on the 1:25 scale section model to assess upstream fish movement along the left bank of the river at the proposed Dunvegan Hydroelectric Project.

1.2 PROJECT DESCRIPTION

The Dunvegan Hydroelectric Project is a low-head, run-of-river hydroelectric development proposed for construction on the Peace River about 2 km upstream of the Highway 2 Bridge crossing at Dunvegan. A complete description of the project including the location plan, general powerhouse arrangement, the model layout drawings, the hydrology, and proposed operating rules for the project are all included in the May 2003 technical report.

Briefly, the project development will include a forty-unit powerhouse facility, a seven-bay spillway, two fishway ramps, ten fish bypass sluices and a boat lock. Upstream fish passage will be accommodated by the two fishway ramps and associated fishway headworks located along the north (left) and south (right) banks of the river. The flow patterns at the downstream end of the

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left bank fishway ramp were examined extensively in the present study to assess whether the patterns will be conducive to the upstream passage of fish, as previously demonstrated for the right bank fishway.

Based on earlier studies, it was determined that additional attraction flow supplied within the downstream end of the fishway ramp (in excess of the design ramp flow of $2 \text{ m}^3/\text{s}$) will be required to generate sufficient velocities at the ramp entrance. This flow will likely be supplied via a piping manifold system, which will permit the introduction of flow directly into the lower end of the fishway ramp through a series of ten diffuser chambers. The diffuser chambers will be installed in the pool sections between the ten downstream sets of V-baffles in the fishway ramps and were designed to provide a maximum upwelling velocity of 0.25 m/s, assuming a maximum discharge through each chamber of $5 \text{ m}^3/\text{s}$. The resulting size of the chambers was $2.5 \text{ m} \times 8 \text{ m}$. These chambers operating in conjunction with the fish bypass sluice located adjacent to the fishway ramp, are referred to as the Auxiliary Water Supply, or AWS.

### 1.3 Study Objectives

The project developer, Glacier Power, adopted a program of physical and numerical modelling of the proposed project to evaluate the fish-related aspects of the design and hydraulic performance of the structure as a whole. The modelling program was comprised of two-dimensional numerical modelling; a 1:10 scale flume model of the fishway ramp; and the 1:25 scale section model, as described here. The section model testing was the most comprehensive of the three modelling investigations, and its objectives, as defined in the May 2003 technical report, focused on the fish-related design considerations and their relation to the overall facility operation and performance.
1.4 **Design Guidelines**

Specific design guidelines were established for the Project’s fish passage facilities and are presented in CPL’s report dated January 15, 2002. Design guidelines specific to the section model study are included in the nhc’s May 2003 technical report. The guidelines for upstream fish passage that are associated with the current testing are listed below.

- provide downstream-directed attraction flows at the fishway ramp entrance with velocities in the range of 0.3 to 0.8 m/s (target velocity of 0.5 m/s),
- provide a uniform transition to high velocity flows issuing from the powerhouse tailrace,
- provide connectivity with the downstream migration corridor (shoreline zone where velocities are less than 1 m/s),
- provide flow depths greater than 0.5 m,
- minimize zones of re-circulation or areas where fish could “hold” for prolonged periods of time,
- minimize access to the powerhouse draft tubes and the area between the guidewall and fishway ramp entrance through the creation of velocity barriers (areas where velocities exceed 1.0 m/s) or similar,
- provide facilities that have enough flexibility in their design and operation to accommodate changes in these guidelines that may arise from the adaptive management program following construction of the facility.

In terms of model testing and determining whether a given operating scenario provided flow patterns conducive to upstream fish passage, the following two conditions were defined:

- “Preferred Conditions” – the mode of operation that provided velocities of approximately 0.5 m/s in the vicinity of the fishway ramp entrance, provided a uniform transition to the

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high velocity flows downstream of the powerhouse and created a 1 m/s velocity barrier to exclude fish from the area between the guidewall and fishway ramp; and,

- “2 m/s Barrier Conditions” – the mode of operation that maintained velocities of approximately 0.5 m/s in the vicinity of the fishway ramp entrance, but created a 2 m/s velocity barrier to exclude fish from the area between the guidewall and fishway ramp.
2.0 MODEL DESCRIPTION

A complete description of the section model, including a discussion of the model scale relationships, model controls and instrumentation, and the model layout, can be found in the May 2003 technical report. The south (right) bank section model was initially constructed and tested. The left bank fishway and shoreline geometry were then reproduced in mirror image within the same basin. At a scale of 1:25, the model encompassed an area along the bank of the Peace River approximately 450 m in length and 130 m in width (all dimensions are in prototype units unless otherwise noted). The model reproduced the fishway ramp, three fish bypass sluices, and ten of the forty powerhouse units, which are similar at both the right and left banks.

Prior to undertaking model testing for the left bank fishway, modifications to the existing 1:25 scale right bank model were completed. These modifications are listed below and shown in Figure 2-1 and Photo 2-1:

- The shoreline bathymetry downstream of the project, between the fishway entrance and the Hines Creek fan, was adjusted to represent the left bank bathymetry. This included formation of a 2:1 bank slope downstream of the left bank retaining wall. For the right bank model this had been a vertical wall (boat lock wall). No changes were made to the fishway ramp, sluice, guidewall or powerhouse structures (as these are identical on both banks).

- The model tail box was extended upstream along the left side of the model basin and included adjustable openings along the floor for withdrawing flow from the model. This was installed to reproduce the numerical model results which demonstrated that a significant portion of the flow along the left bank expanded towards the center of the river, particularly at the 95% and 50% exceedance discharge levels. In order to simulate the proper flow patterns, the physical model was calibrated to the numerical model results by adjusting the volume and location of water being withdrawn through the extended tail box.

- Two 127 mm drains were installed along the floor upstream of the extended tail box to permit flow withdrawal farther upstream (for the same purposes as the extended tail box). This was required because the tail box could not be extended further upstream due to structural constraints of the model.
3.0 TEST PROGRAM

The test program was divided into the following three phases:

**Model Calibration** – Tests conducted to determine the required volume of flow withdrawn through the extended tail box to reproduce the conditions predicted by the two-dimensional numerical model. The physical model was calibrated for the 95%, 50%, and 5% exceedance discharges. The respective river discharges and tailwater levels (based on the proposed May Rule Curve) are listed below:

- 95% exceedance: river discharge = 954 m$^3$/s, tailwater level = El. 340.5 m
- 50% exceedance: river discharge = 1,920 m$^3$/s, tailwater level = El. 341.7 m
- 5% exceedance: river discharge = 3,000 m$^3$/s, tailwater level = El. 342.7 m

**Preliminary Assessment Testing** – Testing conducted to examine a range of AWS discharges (either through the adjacent sluice and/or through the diffuser chambers installed near the downstream end of the fishway ramp) to determine the ‘preferred’ and ‘2 m/s velocity barrier’ conditions for the left bank. A total of twenty-five preliminary assessment tests were conducted at the three river discharges listed above.

**Detailed Documentation Testing** – After completion of the preliminary assessment tests, detailed testing at the same three river discharges was conducted. Detailed velocity measurements were made for the ‘preferred’ and ‘2 m/s velocity barrier’ conditions, as determined from the preliminary test results.
4.0 TEST RESULTS

4.1 MODEL CALIBRATION

The two-dimensional numerical model was used to provide the downstream boundary conditions and calibration data for the left bank section physical model. Further information on the numerical modelling analysis undertaken for the project can be found in the November 2004 report entitled “Dunvegan Hydroelectric Project 2-Dimensional Numerical Modelling Addendum to Technical Report”. The numerical model was previously calibrated to field measurements taken in the summer of 2004. This calibration demonstrated exceptionally good correlation between the numerical model results and the field measurements. On the basis of this, using the 2D model results for calibration of the physical model was considered to be reasonable. Consideration was given to calibrating the physical model to the field measurements directly. However, the area represented in the physical model was limited to approximately 300 m downstream of the project, and the numerical model results have shown that the presence of the project will have a significant influence on the flow patterns in this reach of the river. For that reason, the field measurements collected within this reach, prior to project construction, were deemed not appropriate for comparison to the physical model.

The flow patterns in the downstream portion of the section model were modified by adjusting the volume and location of water being withdrawn through the extended tail box. Adjustments were made until the flow directions observed with coloured dye matched those predicted by the numerical model. Velocities were then recorded along four transects in the section model, and compared to the magnitude and direction of the velocities predicted at the same locations in the numerical model. Figures 4-1 to 4-3 show the location of the transects and the comparison between the velocities recorded in the section model and those predicted by the numerical model.

The emphasis for model calibration focussed on the central portion of the river, because the two-dimensional numerical model was not able to accurately predict the three-dimensional effects of flow through and around the guidewall, and flow exiting the adjacent fish bypass sluice and fishway ramp. For that reason, the numerical model tended to underpredict the velocities.
downstream of the guidewall, near the shoreline. A vertical line has been shown on the calibration comparison charts (Figures 4-1 to 4-4) indicating the location of the guidewall. The physical model provides a more accurate representation of the flow conditions to the left of this line (downstream of the guidewall).

With this mind, adequate calibration was achieved when the flow patterns observed in the physical model matched those of the numerical model, and when the velocities were within ±0.25 m/s for the central portion of the river. These conditions are illustrated in Figures 4-1 to 4-4.

4.2 Preliminary Assessment Testing

Preliminary assessments of the proposed fishway ramp entrance geometry were conducted at the 95%, 50% and 5% exceedance discharges. Preliminary testing examined a range of combinations of AWS discharges, including flows through the fishway ramp and the adjacent fish bypass sluice. These preliminary tests were similar to the “preliminary assessment tests” described in the December 2003 Addendum Report. Documentation at each flow included injection of coloured dye, hand-written observations and sketches describing the flow patterns, and a limited quantity of velocity data collected in the vicinity of the fishway ramp entrance.

The results of these tests are summarized in the attached Tables 4.1 through 4.3. The following comments summarize notable trends in the results for the three discharge levels. Note that acceptable limits for attraction velocities remain between 0.3 and 0.8 m/s at the entrance to the fishway ramp and that this target velocity range should continue through the section downstream of the fishway ramp. Also, the AWS flows to the ramp listed herein are in addition to the ramp base flow of 2 m$^3$/s. Refer to Figure 2-1 for powerhouse unit numbers.

95% Exceedance Discharge

Testing conducted at the 95% exceedance discharge was conducted with powerhouse Units 36 - 40 operating and Units 31-35 closed, as this was the operating condition that was found to
generate the "preferred conditions" for the right bank fishway. Several preliminary tests were also conducted with every second powerhouse unit operating (Units 32, 34, 36, 38, and 40) to verify that this was true for the left bank as well. Note that operating one-half of the units is considered representative of the anticipated operating conditions, since the discharge available for power generation at the 95% exceedance condition will be sufficient to operate approximately one-half of the forty units. The results show that when powerhouse Units 36-40 operate, as compared to every second unit, less flow was required through the AWS adjacent sluice to generate adequate velocities for deterring fish from entering the vicinity of the sluice (velocities greater than 1.0 m/s). For that reason, this mode of operation was selected as the more favourable of the two operating scenarios.

In general, left bank velocities recorded farther downstream of the fishway ramp, specifically in the area of the 2:1 bank slope, were slightly higher than they had been at the same location along the right bank. This difference is likely attributed to the presence of the boat lock wall along the right bank, which provides more area for flow expansion, and hence lower average velocities. As a result, for the left bank fishway slightly less flow (2 m$^3$/s less) was required through the AWS ramp diffusers to achieve the “preferred” conditions within the ramp entrance.

It was also noted that velocities between the guidewall and the fishway ramp were generally lower on the left bank at the 95% exceedance discharge level than was observed on the right bank. This can be attributed to the fact that a significant portion of the flow along the left bank expands towards the center of the river, particularly at the 95% and 50% exceedance discharge levels, as it passes around the Hines Creek fan. For that reason, more flow (5 m$^3$/s more) was required through the AWS adjacent sluice on the left bank to create a 1 m/s velocity barrier to exclude fish from the area between the guidewall and fishway ramp.

Based on these tests, the “preferred conditions” at the 95% exceedance discharge were generated with Units 36 - 40 operating, 3 m$^3$/s through the AWS ramp diffusers and 10 m$^3$/s through the AWS adjacent sluice (refer to Test 7 in Table 4.1).
The results show that a 2 m/s barrier was attained within the area between the guidewall and fishway ramp when the AWS adjacent sluice flow was increased to 20 m$^3$/s and the AWS ramp flow was increased to 5 m$^3$/s (refer to Test 8 in Table 4.1). Again, the left bank required an additional 5 m$^3$/s of flow through the adjacent fish bypass sluice than was required at the right bank to compensate for the expansion of flow towards the centre of the river. However, for the “2 m/s velocity barrier” condition, the same discharge was required through the AWS ramp diffusers at both river banks to balance the increased flow from the AWS sluice and provide a uniform transition from the ramp entrance to the high velocity flows.

If subsequent field monitoring indicates a requirement for additional attraction flows, it was noted that higher attraction velocities could be achieved at the ramp entrance by increasing the AWS flow to the ramp diffusers. However, it was also noted that AWS ramp flows greater than 7 m$^3$/s generated entrance velocities exceeding 1.0 m/s. Similarly, it was demonstrated that AWS flows through the adjacent sluice ranging from 5 to 20 m$^3$/s generated sufficient velocities to deter fish from entering the direct vicinity of the sluice (velocities greater than 1.0 m/s).

50% Exceedance Discharge
The results for the preliminary tests in the left bank model at the 50% exceedance discharge were very similar to the right bank model test results. Testing at the 50% exceedance discharge was conducted with all powerhouse units operating as there would be sufficient power generation flows available.

Based on the results of the preliminary tests, the “preferred conditions” at the 50% exceedance discharge were generated with 10 m$^3$/s through the AWS ramp diffusers and 14 m$^3$/s through the AWS adjacent sluice (Test 1 in Table 4.2). Increasing the AWS adjacent sluice flow to 29 m$^3$/s generated a 2 m/s velocity barrier in the area between the guidewall and ramp entrance (Test 2 in Table 4.2). These operating conditions are identical to those obtained for the right bank fishway. Preliminary testing demonstrated that although a portion of the flow along the left bank expanded towards the center of the river at the 50% exceedance discharge, the effects were not significant enough to require additional flow from AWS system.
Similar to the right bank, higher attraction velocities were achieved at the entrance to the ramp by increasing the AWS flow to the ramp. Attraction velocities at the ramp entrance did not exceed 1.0 m/s until the AWS ramp flow was increased to 30 m$^3$/s. For adjacent fish bypass sluice flows from 10 to 30 m$^3$/s, adequate velocities were provided to deter fish from entering the direct vicinity of the adjacent sluice (velocities greater than 1.0 m/s).

**5% Exceedance Discharge**
At the 5% exceedance discharge, the results of the left bank model testing were again very similar to the right bank model results. However, it was noted that the velocities approximately 100 m downstream of the fishway ramp, in the area of the 2:1 bank slope, were slightly higher than those recorded along the right bank (due to the differences in the shoreline geometries). As a result, less flow (5 m$^3$/s less) was required through the AWS ramp diffusers for the left bank fishway to achieve the “preferred” and the “2 m/s barrier” conditions than required for the right bank fishway.

The “preferred conditions” at the 5% exceedance discharge were generated with 25 m$^3$/s through the AWS ramp diffusers and 30 m$^3$/s through the AWS adjacent sluice (Test 5 in Table 4.3). Increasing the AWS ramp flow to 30 m$^3$/s and the AWS adjacent sluice flow to 45 m$^3$/s, generated a 2 m/s velocity barrier in the area between the guidewall and ramp entrance (Test 2 in Table 4.3).

Again, if post-construction field monitoring indicates a requirement, higher attraction velocities can be achieved at the entrance to the ramp by increasing the AWS flow to the ramp up to 30 m$^3$/s, above which entrance velocities exceeded 1.0 m/s. For adjacent AWS sluice flows from 25 to 50 m$^3$/s, velocities greater than 1.0 m/s were provided to deter fish from entering the direct vicinity of the sluice. Note that for AWS sluice flows of 45 m$^3$/s or more, the AWS ramp should be increased to 30 m$^3$/s to maintain a uniform transition in velocities from the entrance to the fishway ramp to the area downstream of the guidewall.
**PRELIMINARY TESTING SUMMARY**

In general, the preliminary assessment tests demonstrated the following:

- The flow patterns and velocities in the vicinity of the left bank fishway ramp entrance are similar to the right bank for all three exceedance discharges;
- Slightly higher AWS sluice flows are required at the 95% exceedance discharge to compensate for the expansion of flows towards the centre of the river; and,
- Velocities downstream of the fishway ramp entrance, in the area at the base of the 2:1 slope were slightly higher along the left bank than they were in the same area along the right bank (near boat lock wall).

4.3 **DETAILED DOCUMENTATION TESTING**

After completion of the preliminary assessment tests, detailed testing at the same three river discharges was conducted. Testing and data collection were similar to the detailed testing conducted for the right bank section model, as described in the July 2004 Addendum Report. Detailed data was collected for the ‘preferred’ and ‘2 m/s velocity barrier’ conditions, as determined from the preliminary test results.

For the “preferred” mode of operation, data collection consisted of collecting approximately 180 mid-depth velocity measurements in the vicinity of the guidewall and fishway ramp entrance (sufficient to generate a velocity contour map). For the “2 m/s barrier” mode of operation, data collection consisted of collecting approximately 80 mid-depth velocities, concentrated in the immediate vicinity of the guidewall and fishway ramp entrance, to verify the barrier velocities and ensure no adverse impacts to the flow patterns in the vicinity of the ramp entrance.

The velocity contour plots for the right bank ‘preferred’ and ‘2 m/s barrier’ operating conditions at the 95%, 50%, and 5% exceedance discharges have been included as Figures A-1 through A-5 in Appendix A of this report.

**95% EXCEEDANCE DISCHARGE**

The ‘preferred’ operating condition for upstream fish passage was achieved when 3 m$^3$/s was supplied to the lower end of the fishway ramp through the first three AWS diffuser chambers and 10 m$^3$/s was passed through the adjacent AWS sluice. The resulting velocity contour plot is
shown in Figure 4-6 (upper plot). The results demonstrate that this operating scenario provided a well-defined migration corridor (velocities less than 1 m/s) for upstream fish movement, which converged uniformly towards the entrance to the fishway ramp. Attraction velocities of approximately 0.5 m/s were achieved at the entrance to the fishway ramp, and velocities exceeding 1 m/s limits access to the powerhouse draft tubes and sluice exit.

The results of the ‘2 m/s barrier’ test are also plotted in Figure 4-6 (lower contour plot). The results show that a 2 m/s barrier was attained at the sluice exit when the adjacent fish bypass sluice flow was increased to 20 m$^3$/s, and the AWS ramp flow was increased to 5 m$^3$/s. The 2 m/s velocity barrier was not continuous; however it did obstruct access to the sluice exit and a significant portion of the area between the powerhouse draft tubes and sluice exit. Overall, the barrier velocities ranged from 1.5 m/s to 2 m/s. Velocities downstream of the ramp entrance were slightly higher than those recorded for the ‘preferred’ operating condition and the migration corridor was narrower due to the increased sluice flow.

50% Exceedance Discharge

The results of both the ‘preferred’ and the ‘2 m/s barrier’ operating conditions are illustrated in Figure 4-7 (the upper plot presents the results for the ‘preferred’ conditions and the lower plot presents the results for the ‘2 m/s barrier’ conditions). The ‘preferred’ AWS operation was determined to be an AWS ramp flow of 10 m$^3$/s supplied through the first six diffuser chambers and 14 m$^3$/s passing through the adjacent AWS sluice. The resulting flow patterns demonstrated that attraction velocities of approximately 0.5 m/s were achieved at the entrance to the fishway ramp and that these velocities transitioned uniformly out towards the river channel. The shoreline zone or migration corridor was bounded by a 1 m/s velocity barrier that converged towards the entrance to the fishway ramp, and acted as an obstruction to the area downstream of powerhouse draft tubes and adjacent AWS sluice outlet.

Increasing the AWS sluice flow to 29 m$^3$/s, while maintaining an AWS ramp flow of 10 m$^3$/s, provided a 2 m/s velocity barrier at the adjacent fish bypass sluice outlet that extended downstream along the riverward side of the fishway ramp. Velocities between the guide wall and
the fishway ramp generally ranged from 1.0 to 2.5 m/s, which are expected to be sufficiently high to limit access to this area. The velocities downstream of the ramp entrance were slightly higher (0.6 to 0.8 m/s) at the base of the 2:1 slope than recorded for the ‘preferred’ operating condition. In addition, the migration corridor was narrower and the transition from the shoreline zone to the main channel was not as uniform as it was for the ‘preferred’ operation. Similar results were obtained for the right bank fishway.

5% EXCEEDANCE DISCHARGE
The results of both the ‘preferred’ and the ‘2 m/s barrier’ operating conditions for the 5% exceedance discharge condition are illustrated in Figure 4-8 (upper plot – ‘preferred’ operation; lower plot – ‘2 m/s barrier’ operation). The ‘preferred’ operation was determined to be an AWS ramp flow of 25 m$^3$/s supplied through all ten diffuser chambers in combination with 30 m$^3$/s passing through the adjacent AWS sluice. The resulting flow patterns demonstrated that attraction velocities of approximately 0.3 - 0.6 m/s were achieved at the entrance to the fishway ramp and that these velocities transitioned uniformly into the main river channel. A continuous 1 m/s barrier was attained downstream from the guide wall and the adjacent AWS sluice. Slightly lower velocities (0.6 to 1.0 m/s) were noted near the tip of the guide wall, but the area should not be accessible as it was bounded by flow velocities exceeding 1.0 m/s.

A continuous 2 m/s velocity barrier between the guidewall and the fishway ramp was not provided even when the adjacent AWS sluice flow was increased to 45 m$^3$/s and the AWS ramp flow was increased to 30 m$^3$/s. The velocity contour plot (lower plot on Figure 4-8) shows that a 2 m/s barrier extends downstream from the adjacent AWS sluice exit, but did not fully obstruct the area downstream from the guidewall, where velocities generally ranged from 1.0 m/s to 3.0 m/s. However, it was noted that with the high tailwater level (El. 342.7 m) associated with the 5% exceedance discharge, velocities downstream of the powerhouse units generally ranged from 1.0 to 2.5 m/s, and it was deemed impractical to generate a continuous 2 m/s barrier downstream of the guidewall. Similar conditions were also observed downstream of the right bank fishway. Again, a low velocity zone (0.5 to 1.0 m/s) was generated downstream of the
riverward end of the fishway ramp guidewall, but access to this area was restricted by the higher velocities surrounding it, as observed for the ‘preferred’ condition on the left bank.

**Agency Model Demonstration (November 30, 2004)**

Mr. Chris Katopodis and Mr. Doug Lowe of Fisheries and Oceans Canada, Mr. Ross Keating (by phone) and Mr. Bill Johnson of CHD, and Mr. Paul Kemp (by phone) and Mr. Richard Slopek of CPL observed the performance of the model during a demonstration at nhc’s laboratory in North Vancouver, British Columbia on November 30, 2004.

At the meeting, the results of testing for upstream fish passage in the left bank model, as described herein, were presented and reviewed. A selection of preferred operating conditions was then demonstrated in the model for the 95%, 50% and 5% exceedance discharges. Based on these demonstrations it was agreed that the flow patterns appeared conducive to upstream fish passage. The model was considered to illustrate the operational flexibility of the development to meet a wide range of operating needs in order to meet fish passage requirements.
5.0 SUMMARY AND CONCLUSIONS

A 1:25 scale model of the Dunvegan Hydroelectric Project was used to evaluate the performance of the upstream fish passage facilities and operating scenarios proposed for the project. The model was initially constructed to represent an area approximately 450 m long by 130 m wide (prototype dimensions) along the right bank of the river and included the boat lock, the right bank fishway ramp, ten powerhouse units and three fish bypass sluices. The model was then modified to represent a similar area along the left bank (mirror image), which included the left bank fishway ramp, the left bank bathymetry, ten powerhouse units, and three fish bypass sluices.

The model test program for this third addendum to the May 2003 technical report included assessments of the upstream fish passage facilities proposed for the left (north) bank over a range of operating scenarios, including detailed examination of velocities and flow patterns for a selected set of operating scenarios. Testing focussed on providing adequate attraction flow (volume and velocity) to the fishway ramp entrance to ensure upstream migrating fish are able to locate the fishways and avoid movement towards the powerhouse outlets or adjacent fish bypass sluice outlet.

Testing in the left bank section model demonstrated that the flow patterns and velocities in the vicinity of the fishway ramp entrance are very similar along both river banks. However, the velocities downstream of the fishway ramp entrance in the area at the base of the 2:1 graded slope on the left bank were noted to be slightly higher than the velocities near the boat lock wall (same location) on the right bank.

Observation of flow patterns indicate that satisfactory attraction flow patterns for upstream migrating fish could be achieved in the vicinity of the ramp entrance, for a wide range of operating scenarios, by providing additional attraction flow within the downstream end of the fishway ramp in combination with supplemental flows through the adjacent sluice and through appropriate powerhouse operation. Satisfactory attraction flow patterns include adequate attraction velocities (0.3 – 0.8 m/s) at the entrance to the fish ramp, and generating a uniform
transition from the lower velocity flows downstream of the fishway ramp entrance to the high velocity flows downstream of the powerhouse.

Operating scenarios that provided the most suitable flow conditions in terms of the performance guidelines for upstream fish passage were determined in the model. In addition, operational boundaries were established to demonstrate the system’s flexibility to meet potential requirements, which may evolve from future monitoring programs (once the Project is constructed).

Overall, testing on the model has demonstrated that the proposed facility has the capacity to deal with varying flow conditions by adjusting plant operation to avoid adverse conditions for fish passage, while still providing economical power generation. The proposed design of the facility achieves the design criteria established for the project and provides enough flexibility in its operation to permit adaptive management techniques to be employed in the field. It is considered that sufficient information has been accumulated through the current testing and measurement program to allow for the development of the adaptive management plan and operating procedures for the project. On the basis of this, it is recommended that these tests conclude the testing program for the left bank section model.
## TABLE 4.1
Summary of Results of Preliminary Upstream Fish Movement Testing at the 95% Exceedance Discharge

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Base Fishway Ramp Flow (m$^3$/s)</th>
<th>AWS Ramp Flow (m$^3$/s)</th>
<th>Operating AWS Valves</th>
<th>AWS Adjacent Sluice Flow (m$^3$/s)</th>
<th>Units Operating</th>
<th>Flow Pattern at Entrance to Fishway Ramp</th>
<th>Velocity at Fishway Ramp Entrance (m/s)</th>
<th>Velocity D/S of Fish Sluice (m/s)</th>
<th>Transition from zone d/s of the fishway ramp to zone d/s of powerhouse</th>
<th>Comments / Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>5</td>
<td>1 to 3</td>
<td>5</td>
<td>5</td>
<td>36 - 40</td>
<td>0.5 - 0.7</td>
<td>0.9 - 1.2</td>
<td>uniform</td>
<td>Similar to Right Bank Model except velocities downstream of ramp entrance are higher. Left Bank velocities downstream of ramp entrance are between 0.5 - 0.7 m/s</td>
</tr>
<tr>
<td>2</td>
<td>*</td>
<td>5</td>
<td>*</td>
<td>15</td>
<td>*</td>
<td>**</td>
<td>0.5 - 0.7</td>
<td>0.9 - 1.2</td>
<td>*</td>
<td>Similar to Right Bank Model except velocities downstream of ramp entrance are higher. Left Bank velocities downstream of ramp entrance are between 0.7 - 0.9 m/s</td>
</tr>
<tr>
<td>3</td>
<td>*</td>
<td>3</td>
<td>*</td>
<td>5</td>
<td>*</td>
<td>**</td>
<td>0.5 - 0.7</td>
<td>1.1 - 2.2</td>
<td>predominantly uniform</td>
<td>Velocities downstream of ramp entrance are between 0.6 - 0.8 m/s</td>
</tr>
<tr>
<td>4</td>
<td>*</td>
<td>0</td>
<td>*</td>
<td>0</td>
<td>*</td>
<td>**</td>
<td>&lt;0.5</td>
<td>0.9 - 1.1</td>
<td>uniform</td>
<td>The 1 m/s velocity barrier downstream from fish sluice is located closer to the guidewall and sluice exit and may not be continuous. Velocities near wall of fishway ramp are 0.6 m/s</td>
</tr>
<tr>
<td>5</td>
<td>*</td>
<td>0</td>
<td>*</td>
<td>5</td>
<td>*</td>
<td>Stagnant</td>
<td>&lt;0.5</td>
<td>0.9 - 1.3</td>
<td>*</td>
<td>Velocities downstream of ramp entrance are between 0.5 - 0.8 m/s</td>
</tr>
<tr>
<td>6</td>
<td>*</td>
<td>3</td>
<td>1 to 3</td>
<td>0</td>
<td>*</td>
<td>Velocities are higher</td>
<td>0.6 - 0.8</td>
<td>0.6 - 1.2</td>
<td>*</td>
<td>The 1 m/s velocity barrier downstream from fish sluice is located closer to the guidewall and sluice exit and may not be continuous. Velocities near wall of fishway ramp are 0.6 m/s</td>
</tr>
<tr>
<td>7</td>
<td>*</td>
<td>3</td>
<td>*</td>
<td>10</td>
<td>*</td>
<td>Although velocities of &lt; 0.5 m/s were recorded at fishway ramp entrance, all flow is moving downstream.</td>
<td>0.3 - 0.5</td>
<td>1.0 - 2.5</td>
<td>*</td>
<td>The 1 m/s velocity barrier is well positioned.</td>
</tr>
<tr>
<td>8</td>
<td>*</td>
<td>5</td>
<td>*</td>
<td>20</td>
<td>*</td>
<td>**</td>
<td>0.5 - 0.7</td>
<td>1.4 - 4.4</td>
<td>*</td>
<td>Velocities downstream of ramp entrance are between 0.6 - 0.7 m/s</td>
</tr>
<tr>
<td>9</td>
<td>*</td>
<td>3</td>
<td>*</td>
<td>15</td>
<td>*</td>
<td>Although velocities of &lt; 0.5 m/s were recorded at fishway ramp entrance, all flow is moving downstream.</td>
<td>&lt;0.5</td>
<td>1.4 - 2.2</td>
<td>predominantly uniform</td>
<td>For transition, zone downstream of fish sluice has higher velocities than downstream of powerhouse units.</td>
</tr>
<tr>
<td>10</td>
<td>*</td>
<td>3</td>
<td>*</td>
<td>5</td>
<td>32, 34, 36, 38, 40</td>
<td>**</td>
<td>&lt;0.5</td>
<td>0.5 - 1.0</td>
<td>uniform</td>
<td>Velocities downstream of ramp entrance are between &lt; 0.5 - 0.6 m/s</td>
</tr>
<tr>
<td>11</td>
<td>*</td>
<td>5</td>
<td>*</td>
<td>15</td>
<td>*</td>
<td>Velocities downstream of ramp entrance are between 0.6 - 0.7 m/s</td>
<td>0.5 - 0.6</td>
<td>0.6 - 1.5</td>
<td>predominantly uniform</td>
<td>The 2 m/s velocity barrier downstream from fish sluice is located just downstream of sluice exit.</td>
</tr>
</tbody>
</table>

---

**Test No.**
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11

**AWS Adjacent Sluice Flow**
- 5
- 15
- 5
- 0
- 10
- 20
- 15
- 5
- 5

**Units Operating**
- 1 to 3
- 3
- 3
- 5
- 5
- 20
- 3
- 3
- 5

**Flow Pattern at Entrance to Fishway Ramp**
- 36 - 40
- **
- **
- *
- **
- **
- **
- 32, 34, 36, 38, 40

**Velocity at Fishway Ramp Entrance (m/s)**
- 0.5 - 0.7
- 0.5 - 0.7
- 0.5 - 0.7
- <0.5
- <0.5
- 0.5 - 0.7
- <0.5
- <0.5
- 0.5 - 0.6

**Velocity D/S of Fish Sluice (m/s)**
- 0.9 - 1.2
- 0.9 - 1.2
- 1.1 - 2.2
- 0.9 - 1.1
- 0.9 - 1.3
- 0.6 - 1.2
- 0.6 - 1.2
- 1.4 - 4.4
- 1.4 - 2.2
- 0.5 - 1.0

**Transition from zone d/s of the fishway ramp to zone d/s of powerhouse**
- uniform
- *
- predominantly uniform
- *
- *
- *
- *
- *
- *
- uniform

**Comments / Notes**
- Velocities are slightly higher along right hand side (RHS) of fishway ramp (looking downstream).
- Similar to Right Bank Model except velocities downstream of ramp entrance are higher. Left Bank velocities downstream of ramp entrance are between 0.5 - 0.7 m/s.
- Velocities downstream of ramp entrance are between 0.6 - 0.8 m/s.
- Although velocities are < 0.5 m/s, all flow is moving downstream without stagnant areas.
- Velocities downstream of ramp entrance are between 0.5 - 0.8 m/s.
- Velocities downstream of ramp entrance are between 0.6 - 0.8 m/s.
- Velocities downstream of ramp entrance are between 0.5 - 0.7 m/s.
- Velocities downstream of ramp entrance are between 0.6 - 0.7 m/s.
- Velocities downstream of ramp entrance are between < 0.5 - 0.6 m/s.

---

**Operating AWS Valves**
- *
- *
- *
- *
- *
- *
- *
- *
- *
- *

**AWS Ramp Flow (m$^3$/s)**
- 5
- 5
- 3
- 5
- 5
- 5
- 5
- 5
- 5

**Base Fishway Ramp Flow (m$^3$/s)**
- 2
- *
- *
- *
- *
- *
- *
- *
- *

**Head Pond Level**
- El. 347.7 m

**Tailwater Level**
- 340.5 m

---

**DUNVEGAN HYDROELECTRIC PROJECT**
**NUMERICAL AND PHYSICAL HYDRAULIC MODEL STUDIES**
**LEFT BANK SECTION MODEL**

---

**TABLE 4.1**
Summary of Results of Preliminary Upstream Fish Movement Testing at the 95% Exceedance Discharge

Head Pond Level = El. 347.7 m, Tailwater Level = 340.5 m

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## Table 4.2

**Summary of Results of Preliminary Upstream Fish Movement Testing at the 50% Exceedance Discharge**

Head Pond Level = El. 347.7 m, Tailwater Level = 341.7 m

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Base Fishway Ramp Flow (m³/s)</th>
<th>AWS Ramp Flow (m³/s)</th>
<th>Operating AWS Valves</th>
<th>AWS Adjacent Sluice Flow (m³/s)</th>
<th>Units Operating</th>
<th>Flow Pattern at Entrance to Fishway Ramp</th>
<th>Velocity at Fishway Ramp Entrance (m/s)</th>
<th>Velocity D/S of Fish Sluice (m/s)</th>
<th>Transition from zone d/s of the fishway ramp to zone d/s of powerhouse</th>
<th>Comments / Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>10</td>
<td>1 to 6</td>
<td>14</td>
<td>31 to 40</td>
<td></td>
<td>0.5 - 0.7</td>
<td>1.1 - 1.3</td>
<td>uniform</td>
<td>Similar to results from Right Bank Model.</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>&quot;</td>
<td>&quot;</td>
<td>29</td>
<td>&quot;</td>
<td></td>
<td>0.5 - 0.6</td>
<td>1.9 - 2.4</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>&quot;</td>
<td>4 to 6</td>
<td>14</td>
<td>&quot;</td>
<td>Less flow exits over wall along left side (locking downstream) of ramp when valves 4 to 6 operate rather than AWS valves 1 to 6.</td>
<td>0.7 - 0.8</td>
<td>1.1 - 1.3</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>20</td>
<td>1 to 6</td>
<td>&quot;</td>
<td>&quot;</td>
<td>Velocities are higher along RHS of ramp (1.0 - 1.1 m/s). Rest of ramp width velocities between 0.6 - 0.7 m/s.</td>
<td>0.6 - 1.1</td>
<td>&quot;</td>
<td>&quot;</td>
<td>Velocities downstream of ramp entrance relatively high (0.6 - 1.1 m/s)</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>30</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>Flow exits over wall from left side of ramp. Downstream of ramp, a low velocity zone exists along left side while velocities exceed 0.9 m/s along right side.</td>
<td>&lt; 0.5 to 0.9</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>6</td>
<td>1 to 4</td>
<td>&quot;</td>
<td>&quot;</td>
<td>Flow exits over wall from left side of ramp. Although velocities are &lt; 0.5 m/s. all flow is moving downstream without stagnant areas.</td>
<td>&lt; 0.5 to 0.5</td>
<td>1.1 - 1.4</td>
<td>&quot;</td>
<td>Similar to results from Right Bank Model.</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>10</td>
<td>1 to 6</td>
<td>10</td>
<td>&quot;</td>
<td>Flow exits over wall from left side of ramp. Velocities are higher along RHS of ramp.</td>
<td>n/r</td>
<td>0.7 - 1.2</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Test No.</td>
<td>Base Fishway Ramp Flow (m³/s)</td>
<td>AWS Ramp Flow (m³/s)</td>
<td>Operating AWS Valves</td>
<td>AWS Adjacent Sluice Flow (m³/s)</td>
<td>Units Operating</td>
<td>Flow Pattern at Entrance to Fishway Ramp</td>
<td>Velocity at Fishway Ramp Entrance (m/s)</td>
<td>Velocity D/S of Fish Sluice (m/s)</td>
<td>Transition from zone d/s of fishway ramp to zone d/s of powerhouse</td>
<td>Comments / Notes</td>
</tr>
<tr>
<td>---------</td>
<td>-------------------------------</td>
<td>----------------------</td>
<td>----------------------</td>
<td>-------------------------------</td>
<td>----------------</td>
<td>---------------------------------------</td>
<td>--------------------------------------</td>
<td>----------------------------------</td>
<td>----------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>30</td>
<td>1 to 10</td>
<td>30</td>
<td>31 to 40</td>
<td>Flow exits over wall along LHS of fishway ramp. Velocities higher along RHS of ramp entrance than other points across width of ramp.</td>
<td>0.5 - 0.9</td>
<td>1.0 - 1.2</td>
<td>uniform</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>30</td>
<td>*</td>
<td>45</td>
<td>*</td>
<td>*</td>
<td>&lt;0.3 - 0.7</td>
<td>1.4 - 3.7</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>25</td>
<td>*</td>
<td>25</td>
<td>*</td>
<td>Majority of fishway ramp flow was re-directed out and over the wall on the LHS of the ramp. Upwelling at water surface visible at operating diffuser plates.</td>
<td>0.5 - 0.9</td>
<td>n/r</td>
<td>*</td>
<td>Similar to Right Bank, operating only AWS ramp diffuser plates 1 to 5 at this discharge or higher is not recommended.</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>30</td>
<td>1 to 5</td>
<td>30</td>
<td>*</td>
<td>Flow exits over wall along LHS of fishway ramp. Velocities higher along RHS of ramp entrance than other points across width of ramp.</td>
<td>0.5 - 0.9</td>
<td>n/r</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>25</td>
<td>1 to 10</td>
<td>30</td>
<td>*</td>
<td>Flow exits over wall along LHS of fishway ramp. Velocities higher along RHS of ramp entrance than other points across width of ramp.</td>
<td>0.5 - 0.8</td>
<td>n/r</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>20</td>
<td>*</td>
<td>30</td>
<td>*</td>
<td>Flow exits over wall along LHS of fishway ramp. Velocities low along LHS of ramp entrance.</td>
<td>&lt;0.5 - 0.8</td>
<td>n/r</td>
<td>*</td>
<td>Flow velocities &lt;0.5 at fishway ramp entrance. However, it is moving downstream and is not stagnant.</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>25</td>
<td>*</td>
<td>40</td>
<td>*</td>
<td>Flow exits over wall along LHS of fishway ramp. Velocities higher along RHS of ramp entrance than other points across width of ramp.</td>
<td>&lt;0.5 - 0.8</td>
<td>1.6 - 1.7</td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>
FIGURES
NOTES
1) ALL ELEVATIONS GIVEN IN PROTOTYPE METRES.
2) MODEL SCALE: 1 mm MODEL = 25 mm PROTOTYPE.
Section A: 09 Dec 2004 | Converted Excel Data

Downstream Boundary

Bed Elevation (m)

Model Limit

2 m

Distance from Model Edge (m)

Velocity (m/s)

0 0.5 1 1.5 2 2.5

0 12.5 25 37.5 50 62.5 75 87.5 100 112.5 125 137.5 150

2D Numerical Model Results

Section B: 09 Dec 2004 | Converted Excel Data

Section C: 09 Dec 2004 | Converted Excel Data

Section D: 09 Dec 2004 | Converted Excel Data

GLACIER POWER LIMITED

SUNPEAKS HYDROELECTRIC PROJECT

NUMERICAL AND PHYSICAL HYDRAULIC MODEL STUDIES

LEFT BANK SECTION MODEL

Left Bank Model Calibration Results

5% Exceedance Discharge

All Powerhouse Units Operating

FIGURE 4-3

Left (Units 31-40)

Right (Units 1-30)

Test Condition

River Discharge

Tailwater Level

Generation Flow

Spillway Flow

Fishway Ramp/Sluiceway Flow

5% Exceedance

3,000

348.4

342.5

340

338

336

334

348

346

344

342

340

338

336

334

332

330

328

326

324

322

320

318

316

314

312

310

308

306

304

302

300

200

100

0

Operation Units

Operating Units

3,000

450

400

350

300

250

200

150

100

50

0

1,350

1,142

1,000

875

750

625

500

375

250

125

0

Operating Units

1,142

1,000

875

750

625

500

375

250

125

0

20

29

All Units

All Units

All Units

All Units

5% Exceedance Discharge

All Powerhouse Units Operating
NOTES
1) ALL ELEVATIONS GIVEN IN PROTOTYPE METRES.
2) MODEL SCALE: 1 mm MODEL = 25 mm PROTOTYPE.

FIGURE 4-4

GLACIER POWER LIMITED
DUNVEGAN HYDROELECTRIC PROJECT
NUMERICAL AND PHYSICAL HYDRAULIC MODEL STUDIES
LEFT BANK SECTION MODEL

Upstream Fish Movement
Test Data Collection Grid

3468-605   REV. NO. 0   Oct-20-04
northwest hydraulic consultants
### MOST-FAVOURABLE CONDITION

<table>
<thead>
<tr>
<th>Test Number</th>
<th>C-951</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Rule: Max. Project Head</td>
<td>May</td>
</tr>
<tr>
<td>River Discharge (m³/s)</td>
<td>954</td>
</tr>
<tr>
<td>Reservoir Level</td>
<td>347.7</td>
</tr>
<tr>
<td>Tailwater Level</td>
<td>340.5</td>
</tr>
<tr>
<td>Powerhouse Units Operating</td>
<td>38-40</td>
</tr>
<tr>
<td>Fishway Ramp Flow (m³/s)</td>
<td>1.3</td>
</tr>
<tr>
<td>Operating AWS Valves</td>
<td>1.3</td>
</tr>
<tr>
<td>Fish Sluice Flow (m³/s)</td>
<td>10</td>
</tr>
</tbody>
</table>

### 2 m/s BARRIER CONDITION

<table>
<thead>
<tr>
<th>Test Number</th>
<th>C-954</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Rule: Max. Project Head</td>
<td>May</td>
</tr>
<tr>
<td>River Discharge (m³/s)</td>
<td>954</td>
</tr>
<tr>
<td>Reservoir Level</td>
<td>347.7</td>
</tr>
<tr>
<td>Tailwater Level</td>
<td>340.5</td>
</tr>
<tr>
<td>Powerhouse Units Operating</td>
<td>38-40</td>
</tr>
<tr>
<td>Fishway Ramp Flow (m³/s)</td>
<td>1.3</td>
</tr>
<tr>
<td>Operating AWS Valves</td>
<td>1.3</td>
</tr>
<tr>
<td>Fish Sluice Flow (m³/s)</td>
<td>20</td>
</tr>
</tbody>
</table>

---

**VELOCITY (m/s)**

- 3 - 3.5
- 2.5 - 3
- 2 - 2.5
- 1.5 - 2
- 1 - 1.5
- 0.8 - 1
- 0.6 - 0.8
- 0.4 - 0.6
- 0.3 - 0.4
- < 0.3

**DISTANCE IN MODEL MILLIMETRES**

1 mm = 20 mm (model)

0 200 400 600 800 1000

0 8 16 24 32 40

**DISTANCE IN PROTOTYPE METRES**

1 cm = 8 m (prototype)

---

**NOTES:**

1) MODEL SCALE 1 m = 25 m PROTOTYPE.
2) VELOCITY MEASUREMENTS WERE MADE USING A MINIATURE PROPELLER PROBE.
3) ISOPLOTS PRODUCED USING QUICKSURF SURFACE MODELLING FOR AUTOCAD 14 AND ARCVIEW 3.3 WITH 3D-ANALYST.
4) WATER LINE ALONG 2H:1V SLOPE AND FISHWAY RAMP WALL INDICATED BY BLUE LINE.

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**GLACIER POWER LIMITED**

DUNVEGAN HYDROELECTRIC PROJECT
NUMERICAL AND PHYSICAL HYDRAULIC MODEL STUDIES
LEFT BANK SECTION MODEL
TAILRACE VELOCITY CONTOURS
GEOMETRY 8J
95% EXCEEDANCE DISCHARGE

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FIGURE 4-5
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LEFT BANK SECTION MODEL
TAILRACE VELOCITY CONTOURS
GEOMETRY 8J
50% EXCEEDANCE DISCHARGE
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FIGURE 4-6
PHOTO PLATES
(1) View looking downstream at the left bank fishway entrance, simulated as a mirror image in the model basin. Note the extended tailbox along the left side of the basin used to draw flow towards the middle of the river. (IMG_3166)

(2) View looking downstream to the left bank. Note the 2:1 bank slope installed downstream of the left bank retaining wall. For the Right Bank Model layout, this had been a vertical wall representing the boat lock wall. (IMG_3169)
(1) **Preferred Operating Condition** (IMG_5386)
Fishway Ramp Flow = 2 m³/s
AWS Flow to Ramp Diffusers = 3 m³/s
Adjacent Fish Bypass Sluice Flow = 10 m³/s

(2) **“2 m/s Barrier” Operating Condition** (IMG_5402)
Fishway Ramp Flow = 2 m³/s
AWS Flow to Ramp = 5 m³/s
Fish Sluice Flow = 20 m³/s
(1) Preferred Operating Condition (IMG_5404)
Fishway Ramp Flow = 2 m$^3$/s
AWS Flow to Ramp = 10 m$^3$/s
Fish Sluice Flow = 14 m$^3$/s

(2) “2 m/s Barrier” Operating Condition (IMG_5409)
Fishway Ramp Flow = 2 m$^3$/s
AWS Flow to Ramp = 10 m$^3$/s
Fish Sluice Flow = 29 m$^3$/s
(1) **Preferred Operating Condition** (IMG_5445)
Fishway Ramp Flow = 2 m³/s
AWS Flow to Ramp = 25 m³/s
Fish Sluice Flow = 30 m³/s

(2) **“2 m/s Barrier” Operating Condition** (IMG_5430)
Fishway Ramp Flow = 2 m³/s
AWS Flow to Ramp = 30 m³/s
Fish Sluice Flow = 45 m³/s

DUNVEGAN HYDROELECTRIC PROJECT
LEFT BANK SECTION MODEL

5% Exceedance Discharge - Flow Patterns

PHOTO PLATE 4-3
APPENDIX A
### Test A

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Number</td>
<td>A-95</td>
</tr>
<tr>
<td>Operating Rule: Max. Project Head/Max.</td>
<td></td>
</tr>
<tr>
<td>River Discharge (m³/s)</td>
<td>954</td>
</tr>
<tr>
<td>Reservoir Level</td>
<td>347.7</td>
</tr>
<tr>
<td>Tailwater Level</td>
<td>340.5</td>
</tr>
<tr>
<td>Powerhouse Units Operating</td>
<td>1.5</td>
</tr>
<tr>
<td>Fishway Ramp Flow (m³/s)</td>
<td>2</td>
</tr>
<tr>
<td>AWS Flow to Ramp (m³/s)</td>
<td>6</td>
</tr>
<tr>
<td>Operating AWS Valves</td>
<td>1.3</td>
</tr>
<tr>
<td>Fish Sluice Flow (m³/s)</td>
<td>2.5</td>
</tr>
</tbody>
</table>

### Test B

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Number</td>
<td>B-95</td>
</tr>
<tr>
<td>Operating Rule: Max. Project Head/Max.</td>
<td></td>
</tr>
<tr>
<td>River Discharge (m³/s)</td>
<td>954</td>
</tr>
<tr>
<td>Reservoir Level</td>
<td>347.7</td>
</tr>
<tr>
<td>Tailwater Level</td>
<td>340.5</td>
</tr>
<tr>
<td>Powerhouse Units Operating</td>
<td>1.5</td>
</tr>
<tr>
<td>Fishway Ramp Flow (m³/s)</td>
<td>2</td>
</tr>
<tr>
<td>AWS Flow to Ramp (m³/s)</td>
<td>6</td>
</tr>
<tr>
<td>Operating AWS Valves</td>
<td>1.2</td>
</tr>
<tr>
<td>Fish Sluice Flow (m³/s)</td>
<td>1.5</td>
</tr>
</tbody>
</table>

### Velocity (m/s)

- 3 - 3.5
- 2.5 - 3
- 2 - 2.5
- 1.5 - 2
- 1 - 1.5
- 0.8 - 1
- 0.6 - 0.8
- 0.4 - 0.6
- 0.3 - 0.4
- < 0.3

**Notes:**
1. MODEL SCALE: 1 m = 25 m prototype
2. VELOCITY MEASUREMENTS WERE MADE USING A MINIATURE PROPELLER PROBE.
3. ISOLINES PRODUCED USING QUICKSURF SURFACE MODELLING FOR AUTOCAD 14 AND ARCVIEW 3.X WITH 3D-ANALYST.

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**Glacier Power Limited**

**Dunvegan Hydroelectric Project**

**Numerical and Physical Hydraulic Model Studies**

**Right Bank Section Model**

**Tailrace Velocity Contours**

**Geometry 8J**

**95% Exceedance Discharge**

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**Figure A-1**