# *Boundary Hydroelectric Project (FERC No. 2144)*

# *Total Dissolved Gas Attainment Plan*
# *Draft*


**Seattle City Light**



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# Draft Attainment Plan for Total Dissolved Gas Boundary Hydroelectric Project (FERC No. 2144)

## 1 INTRODUCTION

### 1.1. Regulatory Requirement

As part of the relicensing of the Boundary Hydroelectric Project (Project), Seattle City Light (SCL) will need to obtain water quality certification from the Washington Department of Ecology (Ecology). Developing a plan for abatement of total dissolved gas (TDG) above the 110 percent TDG saturation standard is part of this certification process. SCL's requirement is "Identification of all reasonable and feasible improvements that could be used to meet standards, or if meeting the standards is not attainable, then to achieve the highest attainable level of improvement" (Ecology 2006). The state of Washington's water quality standard is 110 percent TDG saturation; however the standard is waived for conditions where incoming TDG is greater than that leaving the Project and for flow exceeding the 7-day, 10-year (7Q10) flow event, which is 108,300 cubic feet per second (cfs) for the Project (Ecology 2006).

The 7Q10 event can be put into context using the Pend Oreille River Annual Flow Duration (U.S. Geological Survey [USGS] gaging station 12396500), showing percent exceedance of approximately 0.5 percent (R2 Resource Consultants 2008) for the 7Q10 flow, which corresponds to an average occurrence of approximately 1.9 days per year based on the 1987 through 2005 period of record.

This document describes the proposed attainment plan for TDG at the Project. SCL has been conducting studies of TDG at the Project since 1999. These studies include a review of abatement alternatives to determine potentially reasonable and feasible structural and operational improvements, and include actions already taken by SCL to test and implement TDG abatement measures. The results of efforts to date are reported in detail in the Evaluation of Total Dissolved Gas and Potential Abatement Measures (TDG Evaluation) Final Report (SCL 2009). The next steps to be taken toward meeting the TDG standard include the following:

- Develop engineering plans to identify possible reasonable and feasible structural and operational improvements to meet standards;
- Develop and calibrate computer and physical models to test identified improvements;
- Select preferred improvement(s) and priority implementation schedule;
- Implement prototype modifications at the Project;
- Monitor to assess success toward meeting predicted TDG performance goals;
- Refine ability to predict TDG performance of improvement(s); and
- Implement additional possible structural and operational measures until TDG standard is met, or until all reasonable and feasible alternatives have been tested and implemented as appropriate.

Washington water quality standards allow a maximum of ten years after issuance of the new Federal Energy Regulatory Commission (FERC) license and 401 water quality certificate to achieve compliance.

### 1.2. Phases of TDG Activities

The TDG Evaluation Final Report (SCL 2009) lists and summarizes literature associated with the TDG process, data collection, abatement measures, historical data analysis at the Project, relicensing field studies, and evaluation methods for potentially reasonable and feasible mitigation alternatives. The history and future of TDG activities at the Project can be summarized as follows:

- TDG analysis prior to 2007
- Relicensing Studies (TDG Evaluation Final Report [SCL 2009])
  - Literature search
  - Field studies
  - Comparative analysis of possible alternatives, resulting in a short list of three preferred alternatives
- Use engineering tools to study preferred alternatives and prioritize TDG alternatives
  - Physical model
  - Computational Fluid Dynamics (CFD)
  - Engineering Studies
  - Dam safety and operation and maintenance considerations
  - Consideration of potential effects on other resources
  - Preparation of design drawing and specifications for each preferred alternative
- Incremental implementation of TDG alternatives to evaluate effectiveness of measures
  - Implement prototype of most promising concepts
  - Confirm performance
  - Use results to improve prediction of performance of subsequent concept
  - Consider results and implement the next most promising alternative

## 2 ANALYSIS PRIOR TO 2007

The historic analysis sets the stage for understanding the TDG problem and identified additional data needs.

### 2.1. Historic Analysis

TDG issues have been previously studied at the Project. A review of the Project TDG studies, along with other TDG studies conducted by the scientific community and at other projects where TDG is an issue, provides an understanding of what information has been developed to date. An annotated bibliography of reference information, including its relevance to the Project, has been developed and is part of the TDG Evaluation Final Report (SCL 2009).

TDG data have been gathered at the Project since 1999. Historic data analysis at the Project was a separate exercise from examining structural abatement alternatives. The review focused on the goal of achieving compliance with the TDG water quality standard. The historic data were analyzed to relate TDG levels in the tailrace of Boundary Dam to upstream conditions and operations of the Project.

## 2.2. Results of Historic Analysis

At higher flows, the Project forebay TDG level is closely linked to upstream TDG levels from Box Canyon and Albeni Falls dams. Spill from these upstream projects causes relatively high Project forebay TDG at inflow near and slightly above the Project powerhouse total outflow of approximately 56,000 cfs. The Project tailrace TDG begins to increase slightly over the forebay TDG level for inflow above approximately 70,000 cfs (percent exceedance of approximately 2.6 percent [R2 2008])), which corresponds to an average occurrence of approximately 9 days per year. At inflow greater than approximately 80,000 cfs, the incoming TDG levels decrease due to removal of the spillway gates at Box Canyon Dam and corresponding elimination of overflow plunging into the tailwater at upstream projects at higher river flows (SCL 2009).

Low volume of spill flowing through either spill gates or sluice gates at the Project does not increase tailrace TDG above that in the forebay. At present river conditions, this low volume of spill is approximately 15,000 cfs or less. As upstream projects improve their TDG compliance and the TDG levels at the Project forebay decrease, the ability to pass low volumes of spill at the Project without raising tailrace TDG levels above forebay levels will become more difficult as the downstream TDG levels become dominated by the TDG performance of the Project spill gates and not the incoming TDG level.

### 2.2.1. Actions Taken to Reduce TDG

Changes to Project powerhouse operations were introduced in September 2003 for the Project's largest generating units (Units 55 and 56), resulting in a significant reduction in TDG levels at the USGS-FMS compliance point in the Boundary Dam tailrace, to the point that there is minimal addition of TDG by the Project powerhouse. In fact, at outflows less than the Project powerhouse total outflow of approximately 55,000 cfs, the Project tends to slightly reduce TDG below forebay levels. The analysis of historic data indicates that, with the Project powerhouse operational changes initiated in 2003, TDG exceeds the regulatory limit in the Project tailrace for flows between approximately 70,000 cfs and 108,300 cfs (which corresponds to spill flow of approximately 15,000 cfs to 53,300 cfs). These flow conditions correspond to an occurrence of approximately 7.4 days per year based on the 1987 through 2005 period of record.

Table 2-1 defines the days the Project provides a benefit to the Pend Oreille River by reducing the TDG from the forebay to the tailrace. This historical data indicate that the Project reduces river TDG approximately 9 days per year on average for spill flows up to approximately 15,000 cfs.

**Table 2.2-1.** Project spill influence on TDG under current Project operation.

| Spill (cfs) | Days/Year | % TDG Stripped (Reduced) or Added |
|---|---|---|
| >0–15,000 | 8.9 | 7% reduced to 0% change |
| >15,000–53,300 | 7.4 | 0% change to 24% added |
| 53,300 + | 1.9 | 110% TDG standard not applicable as flow is greater than 7Q10 flow |

Notes:
7Q10 – 7-day, 10-year frequency flood
cfs – cubic feet per second

The analysis of data indicates that the Project adds TDG to the river approximately 7.4 days per year on average, and for approximately 2 days per year the river flows exceed the 7Q10 river flow, at which time the TDG regulatory requirement of 110 percent is not applicable.

Figure 2.1-1 shows a plot of the average flow as well as the 80th percentile flows (based on average of 1987 – 2005 period of record). This plot illustrates some of the current challenges associated with TDG at the Project. TDG stripping occurs up to river flows of 70,000 cfs, a modest increase in added TDG occurs between 70,000 and 80,000 cfs, and there is a significant increase in TDG above 80,000 cfs.

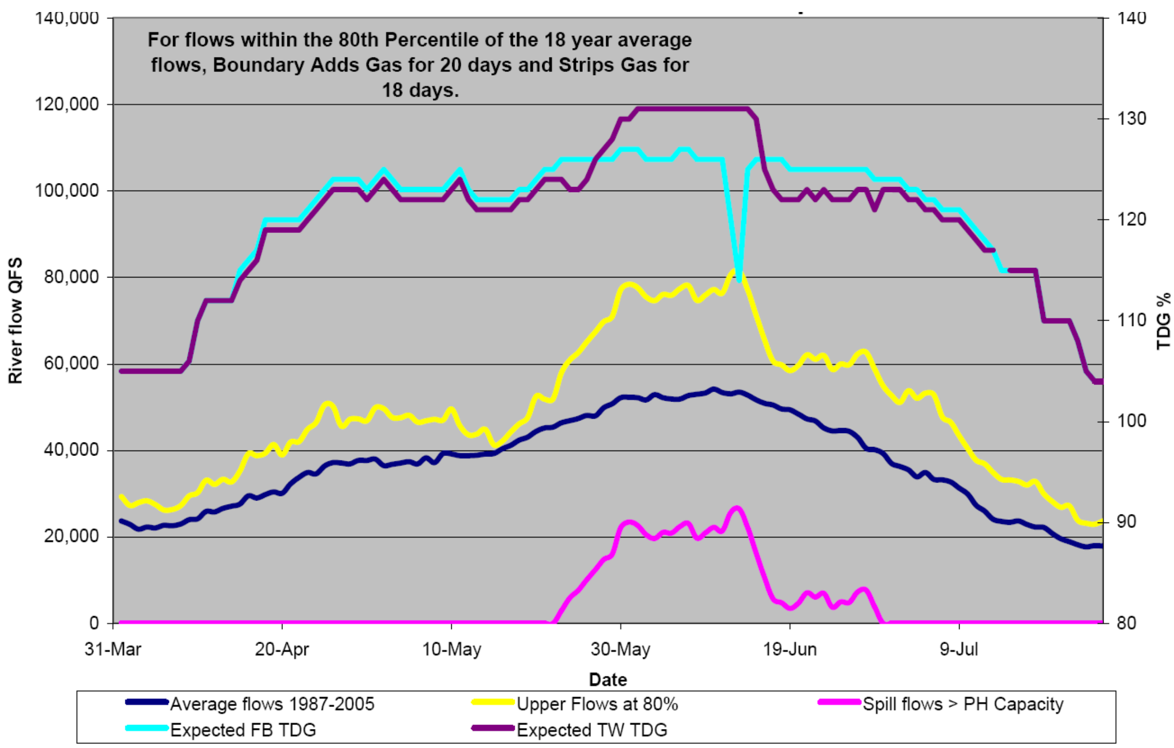


**Figure 2.2-1.** Average and 80th Percentile Flows (based on average of 1987 – 2005 hydraulic record).

# 3 RELICENSING STUDIES

## 3.1. Literature Search

Over 70 documents were collected and assembled in a Project TDG reference library. An annotated bibliography was developed that includes a complete document reference, summary, and each article's relevance to the TDG evaluation. These documents are presented in Appendix 1 of the TDG Evaluation Final Report (SCL 2009). Additionally, documents that are part of the FERC Part 12 supporting technical information (STI) have been gathered to provide technical background information on Project features. STI information is covered by FERC's Critical Energy Infrastructure Information (CEII) restrictions.

## 3.2. Field Studies

In 2007, two different types of field data were collected in support of the TDG studies: 1) hydrodynamic data for use in calibration of future hydrodynamic models of the Project tailrace and 2) TDG data to provide further insights into the effects of spill operations on TDG production.

The hydrodynamic data consisted of water surface profile measurements from three gages along either bank of the tailrace and velocity measurements at 11 fixed stations on three transects in the tailrace at varying distances downstream from the Project powerhouse.

TDG data were acquired using a total of nine meters. One was installed on the forebay trashrack, four on a transect just downstream of the extent of the frothy gas transfer zone downstream from the Project powerhouse, three on a transect at the location of the USGS tailrace fixed monitoring station (FMS), and one below a riffle in the river channel just across the US - Canada border.

The results of the 2008 field program can be summarized as follows:

- Developed an understanding of the Project TDG performance during conditions with low forebay TDG levels
- Confirmed previous spillgate tests and developed further understanding of effects of spill gate operation on TDG
- Examined the distribution of TDG in the river at different flows:
  - No spill flow—little variation in TDG across the river
  - Less than 10,000 cfs spill—the USGS meter reads highest of all meters along the same transect
  - More than 15,000 cfs spill—the USGS meter reads lowest of all meters along the same transect

### 3.3. Workshop

Six structural abatement alternatives were presented in the Revised Study Plan (RSP) by SCL (SCL 2007). These were the result of a series of meetings between SCL and an expert panel[1]. A group of experts was convened on October 1 and 2, 2007, to conduct a workshop for considering additional alternatives, evaluate various aspects of engineering and geology, and discuss issues relevant to potential TDG alternatives. Items discussed included:

- Spatial layout
- Preliminary design
- TDG performance
- Cost estimate

Prior to the 2007 workshop, an evaluation matrix was developed for reviewing the feasibility of potential alternatives. During the workshop, the matrix was further refined and an initial evaluation of alternatives was completed. After the workshop, further work was performed to fill in technical details and provide further detail on the feasibility of the alternatives. The alternatives were ranked, and the most promising ones were selected based on the results of the evaluation. The criteria for evaluation are summarized in Section 3.4 of this document, and discussed in detail in the TDG Evaluation Final Report (SCL 2009).

More advanced analysis will be used to further develop designs of the most promising three alternatives, and will inform the development and priority for implementation of preferred measures. These analyses will involve:

- A physical hydraulic model
- Computational fluid dynamic (CFD) modeling

[1] The expert panel that developed the six structural abatement alternatives included in the RSP included the following individuals: Henry Falvey (hydraulic engineering and TDG production), Glenn Tarbox (dam safety and civil design), and Ken Bates (fisheries). On October 1-2, 2007, a group of experts attended a workshop to further review the potential TDG abatement alternatives at the Project. Attendees included Keith Moen (Hatch Acres), John Gulliver (Univ. of Minnesota), Chick Sweeney (ENSR), Kim deRubertis, (Independent Consultant), Joe Groeneveld (Hatch Acres), Christopher May (Hatch Acres), Paul Oblander (Hatch Acres), Jim Rutherford (Hatch Acres), Bill Fullerton (Tetra Tech), Kim Pate (SCL), Dan Kirschbaum (SCL), and Paul Carson (Independent Consultant).

### 3.4. Evaluation

Six structural TDG abatement alternatives were short-listed by SCL in the RSP (SCL 2007). The six TDG abatement alternatives identified in the RSP for further evaluation during relicensing studies included:

- Throttle Sluice Gates
- Roughen Sluice Flow
- Right Abutment Tunnel with Submerged Discharge
- Open Existing Diversion Tunnel and Add Control Structure
- Penstock Draft Tube By-pass
- New Left Abutment Tunnel Next to Unit 51 Intake

This shortlist was further developed and evaluated by knowledgeable experts in geology, dam construction, hydraulics, TDG issues, gate design, and structural design, and an additional promising alternative (Spillway Flow Splitter/Aerator) was included. A full description of each alternative and the subsequent evaluation of the alternatives' feasibility are included in the TDG Evaluation Final Report (SCL 2009). The experts' qualitative evaluation included the following criteria for alternative selection:

- Low risk of fish injury
- High likelihood of improving TDG conditions downstream
- Technically feasible for construction and permitting;
- Minimal dam safety concerns
- Lower cost for implementation
- Maintenance and access are not impaired
- Existing Project operations are not impacted
- Ability to prototype concept
- Concept can be phased and adjusted

Based on the evaluation of the above criteria, and three alternatives were selected for more detailed examination and implementation in order to meet TDG implementation goals:

- Throttle Sluice Gates (Option 1-3), which involves operation of sluice gates in partially open positions
- Roughen Sluice Flow (Option 3-2), which entails modification of the sluice gate outlets to break up and spread flow
- Spillway Flow Splitter/Aerator (Option 2 – New), which entails modifying the spillways to aerate, break up and spread flow

These three gate alternatives all involve spilling flow through existing outlets (the seven sluice gates and two spillway gates) into the plunge pool and rely on reduction in TDG production by spreading the flow and limiting plunging effects of the confined jets. The historical performance of these outlets at small gate openings indicates the potential for successfully reducing tailwater TDG levels.

The four alternatives not selected for more detailed analysis at this time all employ various tunnel configurations with submerged outlets or surface jets outside the plunge pool.

# 4 ENGINEERING STUDIES

## 4.1. Study of preferred alternatives

Resolution of many of the hydraulic design issues will rely heavily on the results of both physical and numerical hydraulic models. Both models will be used in complementary roles in order to maximize their particular strengths. The greatest strength of the numerical model is the capability it offers designers to explore, develop, and compare various design concepts relatively quickly and easily. Modifications can be made quickly in a “numerical flume,” and tested to ensure a proposed design alteration performs as expected. The model will also be used in the near future to assist in predicting the relative TDG performance of each of the preferred alternatives.

### 4.1.1. Computational Fluid Dynamics Modeling

The goal of the numerical hydraulic model or computational fluid dynamic (CFD) model studies will be to continue development of the models of the sluices and spillways that can be:

- Used to analyze, in conjunction with the physical model, modifications to the sluices and spillways to provide greater dispersion of the jets and lower jet momentum entering the tailwater;
- Verified versus physical model results; and
- Incorporated into an overall model of the plunge pool area and downstream river at a later date to provide the hydrodynamic framework for an overall TDG predictive model for the Project.

#### *4.1.1.1. Development of CFD Model*

In 2008, the far-field CFD model was developed for the entire Project area, and a more detailed near-field model of the sluice gate area using the FLOW-3D software was developed. The CFD model of the sluice gate was compared to the original physical model results (Washington State 1963) and was found to be consistent.

Once the near field models have been developed, a series of runs will be undertaken to calibrate, and validate the CFD model results during 2009-2010. Ideally, prototype data from actual gate operations are desirable. However, the Project plunge pool is a challenging location for data collection and thus, limits prototype data in the plunge pool to qualitative observations and photos taken during historical operation of the sluiceways/spillways. While it is important to compare the CFD model against this type of data, a more detailed comparison can be made by replicating actual physical model study tests, and performing a more in-depth comparison between the CFD and physical model results. With this in mind, validation of the CFD model will be carried out using a two-phased approach:

- The CFD model replicates a known discharge condition for a single sluice gate or spillway gate.
- The model results are then compared to prototype observations to ensure a reasonable match (with the far field CFD model as a base to ensure compatibility of results).

SCL plans to continue development of the physical and CFD models between 2009 and 2011, and hopes to implement additional field tests in late 2009. Physical model test runs will continue prior to license issuance in order to better determine the implementation priority among the three gate alternatives. Physical model test results will be compared directly to the CFD model results test results to validate the CFD model. These validation tests will be performed for a single operating bay (either sluiceway or spillway). The CFD model will first be translated into a model scale to ensure complete compatibility with the physical model results, and then both models will be run for an identical test. For the sluiceway, the test will involve the partial opening of a single bay to provide a flow of 4,400 cfs. For the spillway, the test will involve the operation of single spillway with a discharge of 10,300 cfs.

Once both models have been run, a more rigorous comparison will be made between model results. This will include a comparison of:

- Downstream flow patterns and velocities
- Jet trajectory measurements
- Dimensions of jet impact area
- Qualitative observations of depth and extent of air entrainment

As required, pertinent CFD model parameters may be adjusted to achieve a better match with those of the physical model. Once a suitable match is obtained, both models will be rerun at a prototype scale to identify and document any scaling effects in moving to the larger, actual size prototype dimensions. These results will be compared to prototype observations to ensure a continued good fit between the CFD and prototype results.

Once a suitable match has been obtained, and the models have been validated, the final model results will then form the "baseline" for operation of a single sluiceway and single spillway bay. These runs will form the baseline data against which the performance of other modifications can be compared.

#### *4.1.1.2. Testing Structural Abatement Alternatives*

Following completion of the baseline and validation runs, the CFD and physical models will be changed to include the structural modifications proposed for potential TDG structural abatement at the sluiceway and spillway structures. The initial designs will be based on the conceptual designs described in the TDG Evaluation Final Report (SCL 2009), but these will be modified as required to optimize overall hydraulic design. CFD analysis will be performed iteratively with the design team to test the performance of various concepts.

Initial runs will involve a single gate test developing into multiple spill and sluice gate tests as the evaluation progresses. At the completion of each run, comparisons will be made with the baseline runs to determine the overall impacts on jet trajectory, impact area, and calculated air entrainment. These comparisons will be used to rank various alternative designs in the search for the optimal potential TDG reduction.

It should also be noted that as a continued validation exercise, these CFD test results would also be compared with results emerging from the concurrent physical model evaluation.

#### *4.1.1.3. Development of Numerical TDG Predictive Tool*

One of the key components of the numerical modeling exercise will be the eventual application of the CFD models to help predict the final TDG performance associated with each of the proposed modifications.

Two separate approaches will be used to achieve prediction of TDG performance. The first is the most comprehensive, and allows for the continuous computation of TDG directly within the FLOW3D model. This will require some customization of the FLOW3D software. The second approach involves application of the CFD and physical models to perform TDG calculations independently of the actual FLOW3D code. SCL will use both approaches to compare results, check sensitivity, and, ultimately, ensure compatibility and consistency between the approaches.

Each of the two approaches is described in more detail below.

##### *4.1.1.3.1. Approach 1 – Direct Modeling of TDG*

The CFD models will be modified to predict the TDG contribution of the Project. Source/sink terms are incorporated in the mass transport algorithm of FLOW-3D to simulate TDG. These source and sink terms represent the generation of TDG and also the escape of excess TDG at the free surface. FLOW-3D's existing capabilities will be utilized to determine the volume of entrained air, shear stress, and pressure in the water phase.

The simulation of TDG within the water column will be accomplished by implementing the following steps:

- Determine the number and size of air bubbles and their corresponding surface area in each computational cell as a function of shear stress and volume of entrained air;
- Determine the transfer of air mass to the dissolved phase as a function of pressure, temperature, air/water interface area, and initial (background) TDG concentration;
- Apply a boundary condition on the free surface to allow release of excess dissolved air into the atmosphere; and
- Utilize the existing transient capability of FLOW-3D to transport TDG throughout the flow field by: i) solution of an advection-diffusion equation; and ii) simple "mass" transport.

Hydraulic equations relating flow characteristics with the number and size of bubbles, transfer of air from bubbles to water, and release of dissolved gas into the atmosphere will be obtained from the work performed by Professor Gulliver and reported by Urban et al. (2008). No new research work will be involved in developing source/sink terms. However, incorporation of these processes into a transient 3-D CFD model will represent significant improvements over currently available methods.

##### *4.1.1.3.2. Approach 2 – Use of Discrete Particle Tracking*

The second approach is considerably simpler in nature, and similar to a technique developed and used on other studies to simulate TDG transfer, that has provided reasonable estimates of TDG performance.

This technique involves the "sprinkling" of a representative number of history particles within the air entraining area of a jet. These particles are given a buoyancy equivalent to a standard air bubble, and then their position is tracked as they move throughout the computational domain. The CFD model tracks time, pressure, air entrainment fraction, and velocities experience by these "bubbles" as they move through the mesh.

This information is then exported from the CFD model, and imported into a special spreadsheet model to estimate gas transfer. This spreadsheet estimates the amount of gas transfer which might occur for each bubble based on the pressure and velocity hydrographs experienced by each. The gas transfer associated with each bubble is then integrated to determine a total TDG percentage for the main flow field.

### 4.1.2. Physical Model

The physical hydraulic modeling will be performed using the 1:25 scale model constructed in late 2008 and early 2009.

The goal of the physical model studies is to develop a model that will:

- Provide a tool that can be used to test various sluice and spill gate operational scenarios and visualize the resulting jet interactions, water surface impact areas, and subsurface flow conditions and mixing in the plunge pool (This operational testing can be more readily done and results interpreted using a physical model than using a CFD model); and
- Provide a basis for verification of CFD models of the Project outflow release structures.

#### *4.1.2.1. Physical Model Testing*

Relative performance of the varying gate operations and modifications of the outlets will be judged on the depth and amount of air entrainment and the distance downstream that carries entrained air. It is expected that air entrainment and transport should be reduced by maximizing the surface area of jet impact. To a large degree, the relative performance will be judged on the basis of qualitative observations, however, there will be some quantifiable data collected as well. At a minimum, the following information will be collected for each test:

- Metered inflow using orifice flow meters in supply piping;
- Flow through each gate outlet (sluice and spillway gate based on ratings for each developed in the model);
- Water levels and wave action using point gauges and capacitance wire probes;
- Jet trajectories documented through point gauge measurements, photography, and video;
- Jet impact zones on water surface through visual assessment, photography, and video;
- Air entrainment through visual assessment, photography, and underwater video; and
- Selected velocities using Acoustic Doppler Velocometers (ADV) and miniature propeller current meters.

The structural configurations to be tested in the physical model include:

- Existing (to provide a baseline for comparison of modifications);
- Modified spillway gates (to provide greater aeration and dispersion of the flow);
- Roughened sluices (to provide better dispersion of flow); and
- Other configurations suggested by test results.

These configurations will be tested in an iterative manner to develop the best final configuration for reducing TDG at the Project.

### 4.1.3. Engineering Studies

The engineering study goals are to further develop the understanding of the structural abatement alternative using standard engineering analysis. These studies are in support of and in addition to the analysis described above to provide a comparative basis and foundation for decision making as the TDG attainment plan progresses. The engineering studies will examine the feasibility of actually constructing and implementing structural and operational changes at the Project and will consider the elements described further below.

#### *4.1.3.1. Design Development*

The design development will include several subtasks:

- Analyze hydraulic capacity of structural abatement alternatives,
- Conceptual and feasibility analysis of alternatives including geotechnical/geologic, structural, and mechanical (gates) quantitative analyses at a feasibility level to further the qualitative analyses, and
- Develop design details of favored alternatives including potential interactions with existing features of the Project (existing structural components of dam, dam abutments, sluice gates and spillway).

#### *4.1.3.2. Effects of Operational Change*

The effects of operational changes will continue with analysis of the existing sluice gate hoist mechanism to determine potential detrimental effects of a modified operational procedure associated with more frequent use of sluice gates. The analysis will examine the winches, cables, and other subsystems of the gates.

#### *4.1.3.3. Cost Estimates for Design and Construction*

The development of more detailed drawings that can provide better conceptual understanding and basis for cost estimates, and develop more detailed cost estimates and construction sequencing for favored alternatives.

#### *4.1.3.4. Sluice Gate Deflector Design*

Deflectors are being investigated for installation within the sluice gate water passage to improve operation during throttled gate operation. These are envisioned to be steel constructions attached to the existing steel liner and anchored into the supporting concrete. They will constrict the flow in the lower portion of the sluice gate to prevent the jet from entering the gate slot. Preliminary indications show the deflectors need 18-inches of offset to deflect the jet to the point where it will not impact the gate slots. This will have the effect of reducing the opening from 17-feet to 14-feet.

This task will include:

- CFD analysis to refine the shape of the deflector and provide water pressures to develop loading;
- Structural design of the deflectors including anchor attachments to transfer the loads to the surrounding structure and welding details to transition between the existing liner and the new deflector resulting in a package of design calculations ;
- Design drawings and technical specifications stamped by a Washington State PE to allow fabrication of the deflectors (the assumption is that the fabrication may be undertaken by the SCL metal shop); and,
- Submittal of design to the FERC Portland Regional Office for review.

## 4.2. Development of prioritized implementation

### 4.2.1. Field Studies

Monitoring TDG will continue using the USGS gaging stations located in the Project forebay and at the USGS-FMS compliance point in the tailwater. If the hydrologic conditions allow, SCL will take advantage of opportunities to fill in gaps in data records to continue to build a better understanding of the operational influences on TDG production at the Project.

Once operational changes have been implemented or a prototype abatement alternative has been installed at the Project, the TDG data will be collected and evaluated for actual performance and critically compared to the predicted performance to assess potential improvements.

### 4.2.2. Engineering Efforts

Results of modeling will lead to structural abatement configurations that can be further developed into design concepts. These design concepts will be evaluated and ranked for a range of criteria including:

- Details of alternatives and interactions with other Project features;
- Evaluation of the concept with regard to operating mechanisms for the sluice gates and spillway;
- Changes to hydraulic capacity of the Project;
- Effects of selected alternative on other resources; and
- Dam safety considerations.

The evaluation will result in a ranked order of development for prototype concepts. This ranking is considered a living document as the process of development of alternatives and testing prototypes will provide information that will influence future development.

# 5 TDG ATTAINMENT PLAN

## 5.1. Steps to Meet TDG Standards

To summarize, SCL's TDG attainment approach will have both operational and structural abatement components as follows.

Existing operational modifications:

- Voluntary sequencing of Units 55 and 56 (last on, first off operation), which began in 2003
- Spill gate operational sequence (preferred use of spill gate no. 2); implementation tested in 2008
- Modification of sluice gates to allow use of sluice gates after dam safety requirements are met, and operational constraints are identified (ongoing)

Implementation of abatement alternatives will use an iterative evaluation and implementation approach to determine the most effective configuration of operational and structural changes to the nine gates (seven sluice gates and two spillway gates) as an adaptive management approach. Each gate alternative or combination of alternatives will be evaluated using the following steps:

- Develop engineering plans to identify possible structural and operational improvements to meet standards;
- Identify improvement(s) and implementation schedule;
- Implement prototype modifications;
- Monitor to assess success based on predicted TDG performance and dam safety goals;
- Refine ability to predict performance; and

- Evaluate and implement additional possible structural and operational measures until the TDG standard is met, or until all reasonable and feasible abatement alternatives have been tested and implemented as appropriate.

## 5.2. Schedule

The compliance schedule is a maximum of ten years after the issuance of the water quality certificate. The License Application and 401 Application will be filed in late 2009. SCL will continue to refine tools between filing of the License Application with FERC and the 401 Application with Ecology. At the time of license issuance and an approved 401 Certification, SCL expects to have available the following:

- TDG predictive tool for analysis of alternatives
- Prioritized list indicating the order in which the preferred TDG abatement alternatives will be evaluated and implemented

### 5.2.1. Considerations that Influence the Plan Schedule

The following elements have been considered in developing this schedule and planning:

- The Sluice Maintenance Gate (a traveling gate upstream of the existing seven sluice gates that allows dewatering of the sluice gate water passage) is scheduled for repair and rehabilitation:
  - Planned during 2010 for one year, which will prevent safe access to the sluice gates;
  - Once completed, the program will enhance safety for future abatement alternative installation.
- Dam safety issues to consider:
  - Arch dam structure and any potential interaction that could cause additional stress on the arch structure;
  - Potential effect of changing flow patterns on rock abutments and foundations;
  - Hydraulic capacity of the Project and ability of Project to continue to pass the Probable Maximum Flood (PMF).
- Operation and maintenance (O&M):
  - Increase hoist operational frequency may add stress to components;
  - Increased use will increase gate seal wear;
  - The new abatement alternatives will have their own O&M requirements.
- Effects on other resources:
  - Fish entrainment – effect during passage (strike, shear, impacts on fish)
  - Coordination with plans for abatement/mitigation plans for other resources

### 5.2.2. TDG Attainment Plan Schedule

Once SCL receives a new FERC license and an approved Clean Water Act (CWA), Section 401 water quality certification from Ecology, the activities and schedule will begin as follows:

- **Year one –** Develop design (plans and specifications) for first choice on prioritized structural abatement alternative list for prototype development and build prototype, annual report, and consultation with Ecology;

- **Year two –** Field testing, gather operational and performance data for implemented designs, analyze results, recalibrate predictive tool, annual report, and consultation with Ecology;

- **Year three** - Develop design (plans and specifications) for next choice on prioritized abatement alternative list for prototype development – build prototype, field testing, gather data operational and performance data, analyze results, recalibrate predictive tool, annual report, and consultation with Ecology;

- **Year four –** Field testing, gather data operational and performance data, analyze results, recalibrate predictive tool, annual report, and consultation with Ecology;

- **Year five** - Develop design (plans and specifications) for next choice on prioritized abatement alternative list for prototype development – build prototype, field testing, gather data operational and performance data, analyze results, recalibrate predictive tool, annual report, and consultation with Ecology;

- **Years six to ten** - Repeat years 4 and 5 as necessary; evaluate potential combinations of gate operations to optimize TDG reduction.

- **Year ten -** Monitor and evaluate progress of the attainment program and results of implementation of the preferred abatement alternatives. Once an optimum combination of potential sluice and spill gate alternatives are implemented, evaluate level of compliance with Washington water quality standards. Determine whether additional abatement is required and if necessary determine if additional measures are available, and evaluate their feasibility.

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