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Structural Alternatives for TDG Abatement at Grand Coulee Dam, Preliminary Concepts Report

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by

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Figure 1. - Overall view of Grand Coulee Dam showing a small flow over the spillway, the adjacent left and right power plants, the third power plant, located normal to the original dam, and a portion of the downstream river channel. (fn:gcbw1.bmp)

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INTRODUCTION

Problem Description

Total dissolved gas (TDG) levels in the Columbia River downstream from Grand Coulee Dam commonly exceed the Washington State and Colville Confederated Tribes' water quality standard of 110 percent of saturation. Exceedances are due to the combined impacts of spill operations at Grand Coulee Dam and to downstream transfer of flow with high levels of TDG generated at B.C. Hydro dams in Canada. Concerns regarding Columbia River dissolved gas supersaturation problems and potential for gas bubble disease and mortality in anadromous fish have received increasing attention over the past several years because of above-average flow conditions requiring flood control spills, and ESA salmon recovery efforts which utilize increased spill to accommodate fish passage through reservoir facilities on the lower Columbia and Snake Rivers. Dissolved gas levels as high as 138 percent of saturation were measured during flood control operations at the monitoring site located downstream of Grand Coulee Dam in June 1997.

At the request of the National Marine Fisheries Service, the states of Washington and Oregon waived the 110 percent total dissolved gas water quality standard in the lower Snake and Columbia Rivers during the 1995 through 1997 spill seasons. A short-term waiver was also obtained to allow voluntary spills from Grand Coulee for endangered salmon migration in the Columbia River in 1996. Temporary standards of 115 percent in reservoir forebays and 120 percent in tailwaters were adopted based on scientific evaluations which weighed the improved salmon migration conditions accomplished through increased spill against the mortality associated with gas bubble disease. The standards waiver applies only to dissolved gas conditions induced by salmon migration spills, and does not apply to flood control spills. Washington State standards contain a clause which waives the 110 percent dissolved gas standard when flows exceed the 10-year 7-day high flow, which provides some regulatory relief during flood control operations. Standards apply at the point of measurement which is located at a stream gaging site 6 miles downstream of Grand Coulee Dam.

Study Framework

In response to water quality concerns, adverse effects of gas supersaturation on resident fisheries downstream of Grand Coulee Dam, and the contribution of spills at Grand Coulee to system-wide gas problems, Reclamation has initiated a series of operational changes and study efforts to reduce TDG added to the river. These efforts are both long term and short term in nature. In the short term, it has been determined that specific operational changes in outlet works configuration can reduce the TDG added to the river during spill operations. In the long term, information will be developed to determine the feasibility of structural modifications to Grand Coulee Dam that will reduce TDG produced during flood control spills.

A draft plan of action to reduce TDG from spills in the mainstem Columbia and Snake Rivers has been developed in cooperation with the National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service, U.S. Environmental Protection Agency, U.S. Army Corps of Engineers (COE), Bonneville Power Administration, and the states of Washington, Oregon, and Idaho. Under the action plan, in its current form, Reclamation would conduct the Grand Coulee Dissolved Gas Management Study, culminating in a fiscal year 2000 feasibility-level report which evaluates structural gas management measures to remediate TDG problems. The study would be closely coordinated with the COE's Dissolved Gas Abatement Study. Upon completion of the Grand Coulee Dissolved Gas Management Study and the COE's Dissolved Gas Abatement Study, Reclamation will cooperate with regional decision makers to assist in development of priorities and funding strategies for implementing TDG abatement measures at Federal Columbia River Power System (FCRPS) facilities. At the present time, the System Configuration Team (SCT) has lead responsibility for establishing system-wide priorities for structural changes needed to improve the configuration of the FCRPS to meet ESA requirements.

Objective

To develop a prioritized list of alternatives to abate TDG at Grand Coulee Dam including a brief definition of the proposed modifications with TDG analysis, sketches, quantities, costs, and a listing of advantages and disadvantages.

Brainstorming Team Members

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These people participated in the week-long brainstorming effort. Steve Sauer and Dave Zimmer from the area office at the dam and the PN regional office, respectively, provided valuable information during the first 1½ days of the session regarding the requirements of the program, the power and spill operations, answered questions about the structures, and provided input on potential acceptability of many of the alternatives.

Andy Murphy participated during the morning of the initial brainstorming session, providing input regarding his development of a water treatment process that would potentially be applicable for gas abatement at Grand Coulee and other dam sites.

DESIGN PARAMETER DEFINITION

This section discusses the parameters used to develop the alternatives and to evaluate the alternatives that were developed. The section provides a brief discussion of the generation of supersaturated gas, describes the project, the way the project is currently operated, the spill flow and power releases that are being used, the target TDG levels, the point of compliance for TDG, and boundaries of Reclamation-owned property.

Principles Behind Generation of Supersaturated Gas

The rate of gas transfer across an interface is directly proportional to the difference between the dissolved gas concentration in the water, C, and the saturation concentration in the water at the corresponding pressure and temperature, C_s. This relationship is given by:

$$\frac{dC}{dt} = K_L a (C_s - C) \qquad \textbf{(1)}$$

where K_L is a liquid film coefficient, and a is the ratio of the total bubble surface area to total air-water mixture volume.

The resulting gas level below a hydraulic structure depends on the dissolved gas level in the reservoir, the potential dissolved gas level in the stilling basin, the length of time that the gas is being dissolved into the flow, and a constant that is specific to the geometry of the structure and the operating condition.

The dissolved gas potential in the stilling basin depends on:

- the basin depth,
- water temperature,
- barometric pressure,
- and the characteristics of the jet entering the tailwater.

Typically, evaluation of the TDG levels generated due to flow passage through a stilling basin has been accomplished using Reclamation report, "Prediction of Dissolved Gas at Hydraulic Structures" (1). This approach uses the site geometry, temperature, pressure, an assumed reservoir dissolved gas level, and graphical methods to determine the constant, K_L, which includes assumptions regarding the diffusion of the jet in the tailwater.

The gas bubble will try to come to equilibrium in solution. Under pressure the bubble will dissolve into the surrounding water. Near the surface, the pressure will be significantly less and the dissolved gas will transfer out of the water into the atmosphere.

Nitrogen and oxygen are the major components of the atmosphere (78 and 21 percent, respectively). The dissolved gas response of each gas must be handled separately and then combined to determine TDG levels generated. Nitrogen concentrations, because nitrogen is relatively inert, tend not to be affected by changing biological action. Nitrogen concentrations are, therefore, a better indicator of dissolved gas supersaturation content than oxygen.

Project Description

The geometry of the hydraulic structures, discharge capabilities, reservoir and tailwater elevations, reservoir stratification, barometric pressure, and water temperature are all important when considering dissolved gas levels and potential operational or structural modifications. The hydraulic height and geometry of the hydraulic structures at Grand Coulee Dam makes addressing the dissolved gas issue more complicated than at many of the other dams on the Columbia and Snake River systems.

Grand Coulee Dam was constructed from 1933 to 1942, with the forebay and additional powerhouse constructed from 1967 to 1974. The dam is located on the Columbia River, 28 miles northeast of Coulee City, Washington, and forms Franklin D. Roosevelt Lake which stretches to the Canadian border. The dam provides most of the storage for the lower Columbia River system. The dam has a hydraulic height of 350 ft. The hydraulic structures are a 1,650-ft-wide gated spillway, an outlet works comprised of 40 conduits through the dam in two tiers with twenty outlets each, left and right powerplants, and the third power plant located approximately parallel to the right dam abutment. An overall view, general location map, and the spillway section and elevation are shown on figures 1, 2, and 3.

The spillway is located in the center of the dam with a crest elevation of 1260. Eleven 28-ft-high by 135-ft-wide drum gates control releases up to 1,000,000 ft^3/s at maximum water surface of el. 1290. The spillway face has a 0.8:1 slope terminating in a submerged roller bucket energy dissipater, at el. 874.4. The roller bucket discharges onto the rock surface downstream. The spillway crest elevation prevents spillway releases during times of the year when the reservoir pool is drawn down.

The outlet works conduits discharge onto the downstream face of the spillway, also utilizing the roller bucket dissipater. The outlet works has a capacity of 191,920 ft^3/s at reservoir el. 1290. The outlet works are generally used to lower the lake level in the spring when high runoff is expected and the lake level is below the spillway crest at el. 1260. Lower level conduits at el. 935 of similar geometry were plugged with the construction of the third power plant.

The power plants have a total capacity of about 300,000 ft^3/s and discharge from the reservoir to the tailrace under submerged conditions.

The tailwater is influenced by the level of Chief Joseph Dam downstream and discharge fluctuations associated with peaking power generation. The maximum tailwater fluctuation per day is restricted to 22 ft to ensure stability of the 6-mile riprap channel below the dam.

The geometry of the hydraulic structures has a major influence on the gas transfer characteristics in the tailrace and allowed some operational flexibility.

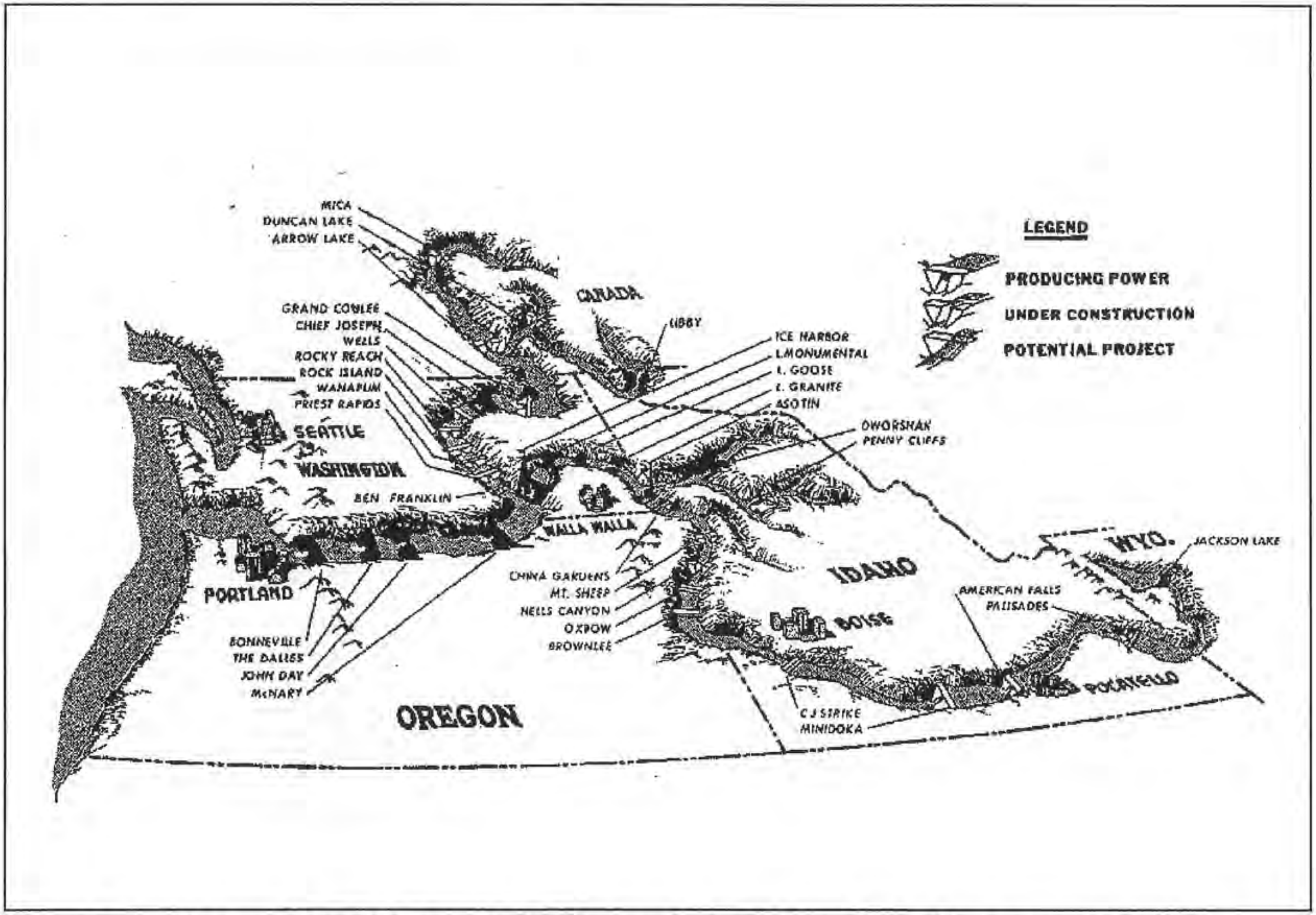

Figure 2. - Location map for Grand Coulee and other dams on the Columbia and Snake River systems (circa 1970).

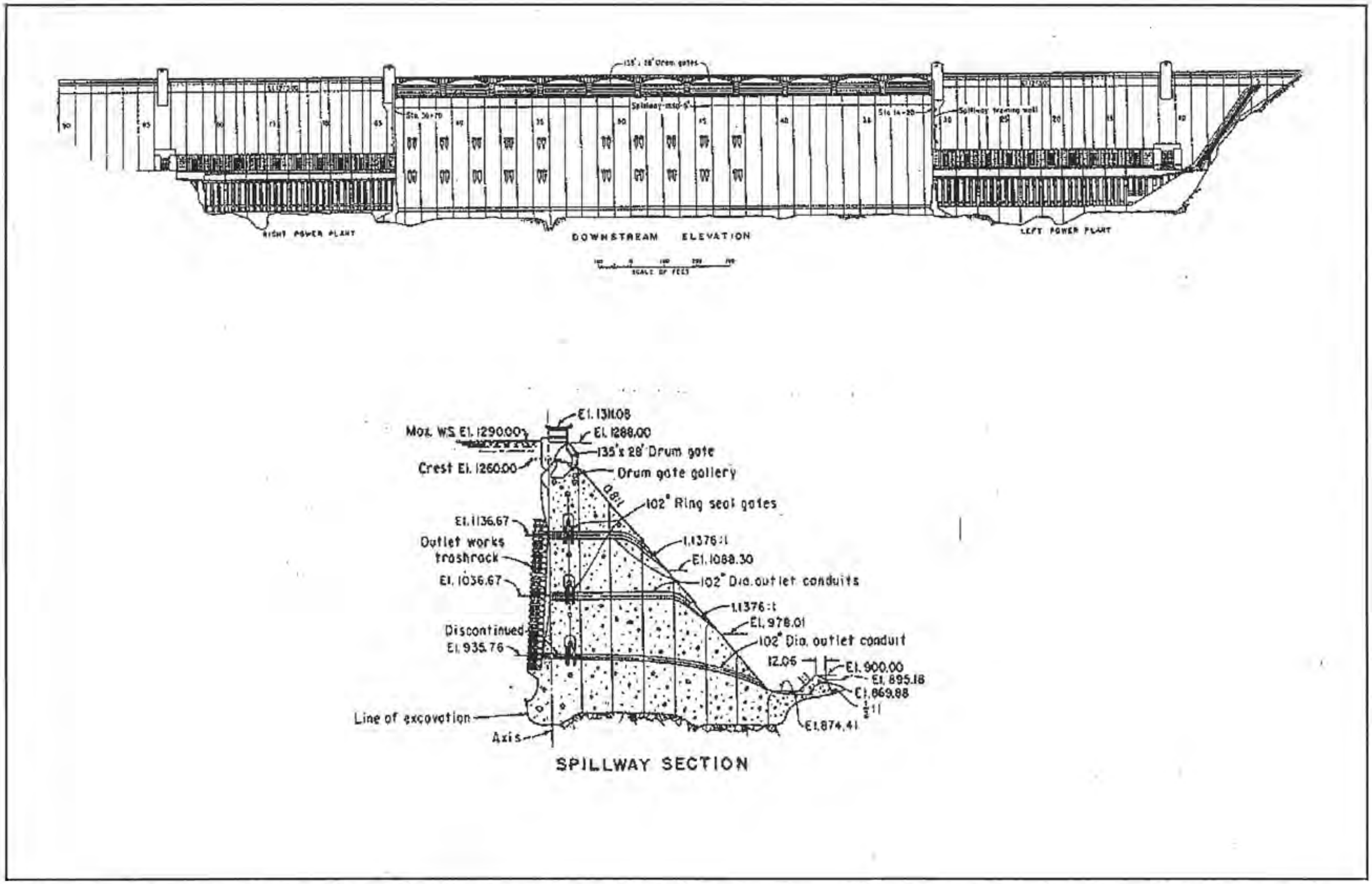

Figure 3. - Downstream elevation and spillway section of Grand Coulee Dam. The downstream view shows the drum-gated spillway, the location of the outlet works on the face of the dam, and the left and right power plants. The spillway section shows the relative locations and the elevations of the spillway, outlet works conduits, and roller bucket energy dissipater. (fn:pl&sect.bmp)

Current Operational Conditions

Total Dissolved Gas Levels in Lake Roosevelt

- High levels of TDG are recorded by the gage at the International Boundary with Canada. These levels are transmitted through Lake Roosevelt to the dam over a period that varies from an optimistic 10 days to 4 months, depending upon the rate of inflow and outflow and the lake level. Some dilution occurs in the lake, but TDG levels have been measured up to 120 - 125 percent at the dam (2). The basic result is that water entering Lake Roosevelt from the Columbia River often exceeds the Washington State standard of 110 percent.

Current Operations

- The power plants are always the first option for downstream releases. The centerline of the left and right power plant intakes is at elevation 1041. The centerline of the third power plant intake elevation is 1130 with the invert at elevation 1110. The power is ordered by the Bonneville Power Administration (BPA) and the power plants are operated to provide peaking power. The capacity is about 100,000 ft^3/s through the combined operation of the left and right power plants and 200,000 ft^3/s through the third power plant. Power release magnitudes are typically limited by power market demand.

- Flood control elevations in the lake are managed by the COE.

- Outlet works spill is used with power plant releases to draft the reservoir down to the required flood control elevation in the spring when the reservoir level is below the spillway crest. The centerline of the mid- and upper-level outlet works are at elevations 1036 and 1136, respectively. (These elevations are commonly referred to as elevations 1050 and 1150, respectively, which are the elevations of the associated galleries.) The capacity of the existing outlet works is about 191,000 ft^3/s at reservoir elevation 1290. Each outlet works conduit is capable of passing 4,000 to 5,000 ft^3/s depending upon the lake level. The outlet works can only be operated either fully open or closed and are currently operated in an over/under combination.

- The spillway is used for spill releases only for flood passage in the summer months. The spillway can only be used when the lake level is above el. 1260. A reservoir elevation of 1265 is required to generate spills of significant magnitude. The spillway has a capacity of about 1 million ft^3/s through all 11 bays at maximum reservoir el. 1290. All drum-gated spillway bays are operated uniformly.

- The safe river channel capacity is 300,000 ft^3/s.

Frequency and Period of Spill

Since the third power plant came on line, spillway and/or outlet works releases occur infrequently. Spills occur almost entirely during the months of March through July, with June operation occurring the most frequently at 17.5 percent of the time or once every 6 years. During years of high flooding (1981, 1982, 1983, 1997), the outlet works and spillway operate almost continually through the spring and summer months, compared to no spills for the dry years between 1985 to 1995.

Outlet works releases are made when the lake level is low, definitely below the spillway crest elevation. The minimum reservoir level obtained for flood control occurred in 1997 when the reservoir was drawn down to el. 1208. This elevation also corresponds to the minimum lake level for operation of the third power plant. The reservoir level rises during late spring and summer until typically reaching el. 1260 in June. At this time spillway releases could occur if needed for flood control. If not, the reservoir level could continue to rise behind the spillway drum gates to el. 1290.

Current Information on Total Dissolved Gas Levels Associated with Spill

- The Washington State standard for TDG is 110 percent and is based upon the 12-hour average of TDG. This gives some flexibility with regard to using power release to dilute TDG levels associated with spill.

- The majority of the flow from all structures mixes in the pool downstream from the dam before entering the river channel.

- Significant dissipation of the gas plume occurs as it travels downstream through the Columbia River below Grand Coulee Dam to the permanent monitoring station at 6 miles and the Columbia River Fish Farm (CRFF) at about 15 miles (3). About a 10 percent difference in TDG was measured between the measurement station 2.3 miles below the dam and the fixed monitoring station. An average of about an additional 5 percent decrease was noted at the CRFF. These values may be different under flow conditions other than those measured at that time.

- The point of compliance for TDG levels at Grand Coulee is assumed to be at the existing fixed monitoring station which is located in the river about 6 miles downstream from the dam.

Power plant releases pass or transfer the TDG levels that are present in the lake. Power releases are called for by the BPA and vary with demand (high in the morning and evening hours, low overnight and on weekends). Power plant releases pass the TDG level present in Lake Roosevelt producing violation of the 110 percent state standard during the summer months.

Outlet works in two tiers of 20 each for a total of 40 tubes release reservoir water at els. 1050 and 1150 when the reservoir is below the level of the spillway crest. These flows follow the face of the dam and discharge into the submerged roller bucket stilling basin that is shared with the spillway. These flows always increase the TDG levels from those in the lake. Studies have shown that the outlet works should be operated in an over/under combination to minimize increases in TDG with spill (3).

Spillway releases fall over the drum gates onto the face of the spillway, into the tailwater to the submerged roller bucket energy dissipater, and out into the river channel. Small unit discharges from the spillway, in the range of 30-40 $ft^3/s/ft$, should degas with larger flows diving down to the bottom and increasing the TDG levels. The less concentrated nature of the jet, compared to outlet works releases, produces lower TDG levels for spillway operation.

Figure 4 shows the 1997 spill data for below Grand Coulee from the COE. This data shows that the outlet works produce much higher levels of TDG than the spillway when operating at the same flow rate. The presented values show the combined influence of the spillway and outlets works flows and power operations.

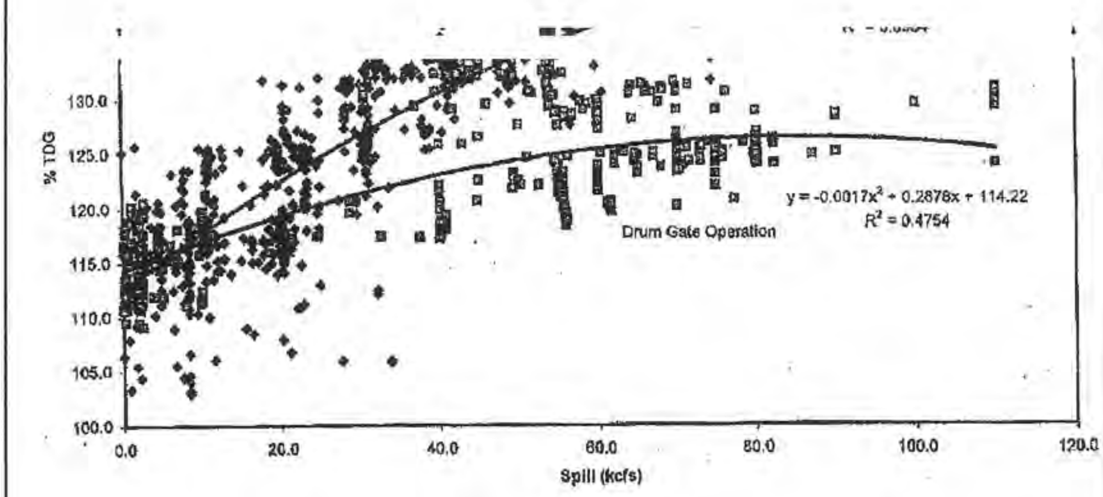

Figure 4. - 1997 spill data from the COE Portland Division office based upon the fixed TDG monitor below Grand Coulee (unedited). (fn:flowcoe.wpg)

Grand Coulee Dam is a storage facility with temperature stratification occurring during the summer months. This means that the water is colder near the bottom of the reservoir where power plant and outlet works releases are made and warmer near the surface where spillway releases are made. Little investigation has occurred regarding the temperature and TDG effects in the lake, but a simple profile was obtained on August 12, 1997. This causes another parameter for consideration during the TDG analysis, because the percent saturation increased with depth.

Also, the river temperature at the fixed monitoring station 6 miles downstream from the dam indicates that the water temperature in the river steadily increases until 18°C (Washington State standard) is exceeded in the late summer.

Design Flow and Tailwater

The TDG level in the reservoir is assumed to be 120 percent for the purposes of this study. This high level of TDG occurs in the summer months. The spring releases from lower levels in the reservoir are used to draft the lake down but could potentially be used more extensively when TDG levels are lower in the reservoir. This could only be the case, however, if the supersaturation production characteristics of the outlet conduits can be significantly reduced. The months under investigation are April through August which includes spring drafting, summer flood releases, and the period of the highest level of TDG in the reservoir.

Spill, whether through the spillway and/or the outlet works, and power plant releases comprise the total flow from the dam. However, power plant releases produce most of the dam releases. During years where flooding is expected and during high runoff, the outlet works and eventually spillway are used to draft down the lake and pass flood releases, respectively. The State of Washington has developed a standard value of the 7-day 10-year flow event that is used for design of TDG alternatives. This flow event is the highest flow rate that occurs during any 7-day period with a reoccurrence interval or return period of 10 years.

The 7-day 10-year flow event for Grand Coulee Dam was computed from hydrologic data from the USGS web site for the gage below the dam at Grand Coulee. The event was computed for the period of 1975-1997. This time period is post development of Canadian dams and post completion of the majority of the third power plant at Grand Coulee. The 7-day 10-year design flow rate that was used during this study for determining the potential benefits of structural alternatives for TDG abatement at Grand Coulee is 210,000 ft^3/s. This value includes both power plant releases and total spill from the dam, whether outlet works or spillway.

The influence of abatement structures on the TDG levels for the total release is dependent upon the distribution of discharge between spill and power releases. In lieu of having the daily flow records and this distribution established in advance of the meeting, we obtained average monthly flow data and computed an average power plant release value for the months of April through August when spill is most likely to occur and the reservoir TDG levels are at the highest. Average monthly power plant releases for the years closest to the 7-day 10-year flow event were available for 1981 (Q_{PP} =

119,000 ft^3/s) and 1996 (Q_{PP} = 155,000 ft^3/s). For the purposes of this study, the average monthly power plant release was determined to be 160,000 ft^3/s. This will need to be refined further with respect to the 7-day 10-year event as the abatement concepts are refined. However, the findings presented show relative significance and give general guidance of concept selection.

The design flow values were separated as shown below:

Spill release	= 50,000 ft^3/s
Power plant release	= 160,000 ft^3/s
Total release	= 210,000 ft^3/s

Thus, TDG abatement alternatives were developed based upon these ratios of spill and power plant release for a total of 210,000 ft^3/s. Note that peaking power operation will cause total release and release distribution ratios to vary from the 7-day 10-year event and that the evaluated condition represents generated TDG with maximum discharge.

The tailwater is gaged about one-half mile below the dam and ranges in depth from 60 to 90 ft over the range of flows expected. Spill plunging into this deep tailwater can dramatically increase TDG levels. The minimum tailwater level corresponds to about el. 951. The tailwater at the design flow rate of 210,000 ft^3/s is about el. 972. The maximum daily tailwater fluctuation is restricted to about 22 ft because of bank stability of the riprap channel downstream. For the design 7-day 10-year event, the tailwater is not expected to fluctuated more than about 6 feet. Potential fluctuation in tailwater will have a major influence upon the design of TDG abatement alternatives.

Reclamation has right-of-way along the river on both sides which may be used to perform work in the river or near the left abutment of the dam. A map of Reclamation-owned property was provided by Steve Sauer of the Grand Coulee Power Operations Office.

Target Total Dissolved Gas Levels

Alternatives were developed to meet three categories of TDG water quality. Within each category, perceived optimum abatement alternatives were developed. The perceived TDG goal was to satisfy the state water quality standard of 110 percent, if possible.

The three categories are:

- Transfer - defined as passing the TDG levels present in the lake to the river channel downstream without an increase in TDG levels (i.e. submerged releases from lake to river).

- Reduce production - defined as reducing the known increases in TDG caused by present operations of existing structures. This would be accomplished by structural and/or operational modifications to the dam. (i.e. deflectors on the dam face).

- Degas - defined as decreasing the TDG levels in the river from those in the lake by structural or operational modifications (i.e. turbulent stripping or small drum gate releases).

Alternatives were separated initially by their ability to transfer (T), reduce gas production (R), and degas (D). Alternatives were also separated by where they physically would be built, in the river upstream or downstream from the dam, on the dam face, or through the dam or abutments. Some of the alternatives developed will treat all of the water released from the dam, others only the spill, others a portion of the mixed power plant and spill release.

ALL IDEAS FROM BRAINSTORMING SESSION

Ideas were grouped by the location where they would be constructed. Locations for alternatives included on or through the dam, in the river upstream or downstream from the dam, in the reservoir upstream from the dam, or through the abutments. Other ideas that would work but would not directly address the problem were also considered.

Typical rules of a brainstorming session were applied during generation of ideas. All ideas were discussed by the group and the decision to carry them forward or not was made after considering TDG levels, construction, cost compared to other ideas projected to obtain similar TDG levels, or general acceptability of the idea. Some ideas were incorporated as part of other alternatives that were carried forward.

The following tables list all ideas, categorized according to the location of the alternative with comments about whether it would degas, reduce production, or transfer upstream TDG levels. Alternatives that are being investigated further are shown in bold font. More information about those ideas not carried forward may be found in the Appendix of this report.

Table 1. - Ideas for structural modifications on the dam.

Idea		Transfer	Reduce	Degas	Result
A.	Abandon 1 of the 18 units in power plant for submerged flow through dam.	X	X		Not carried forward.
B.	Bifurcate off of existing penstocks for submerged flow passage.	X	X		Not carried forward.
C.	Reactivate lower outlets at el. 950 for submerged release.	X	X		**Carried forward as alternative #1.**

Idea		Transfer	Reduce	Degas	Result
D.	Baffled apron-type structure on dam face with free surface flow.		X		Not carried forward, but idea incorporated into other alternatives.
E.	Cover and extend outlet works conduits down face of dam under tailwater for submerged release. Excavate grooves in dam face to make surface flush.	X	X		**Carried forward as alternative #2.**
F.	Flare release from outlet works to achieve smaller unit discharge, add flip bucket, spreader, splitter, combine paired tunnels. Free surface flow.		X		Not carried forward alone, but incorporated into other alternatives.
G.	Deflectors or flip lips to produce skimming flow. Mechanically raise/lower, fix single units at different elevations under outlets or make solid all the way across. Free surface flow.		X		**Carried forward as alternative #4.**
H.	New outlet works through dam where there are currently no outlets on left side of dam for submerged releases.	X	X		Not carried forward.
I.	Drop elevation of a few spillway bays to lower than el. 1260. Free surface flow.		X	X	Not carried forward.
J.	Unhooded Howell Bunger valves attached to end of existing outlet works at el. 1050. Mount inside end of conduit to protect from spillway releases. Free surface flow.		X	X	Not carried forward.
K.	Stepped spillway on dam face to break up jet - Below outlet works only - Below spillway gates on entire face. Free surface flow.		X	X	Not carried forward, but incorporated into other alternatives.
L.	Flow over left and/or right power plant sections with submerged or free flow.	X	X	X	Not carried forward.
M.	Modify portion of existing spillway where there are no outlets, four gates, 640-ft wide. Free surface flow.		X	X	Not carried forward.
N.	Combination of baffled apron/lower elevation of existing spillway/flips		X	X	Not carried forward.

Table 2. - Ideas for structural modifications through the abutments.

Idea		Transfer	Reduce	Degas	Result
O.	Pipe through forebay dam abutment for submerged release.	X	X		**Carried forward as alternative #3.**
P.	Left-side abutment pipe for submerged release, around pumping plant, town, left power plant.	X	X		Not carried forward.
Q.	Cascade release from forebay dam over abutment adjacent to 3rd power plant using a baffled, stepped, etc., structure with low unit discharges for free surface flow.		X	X	**Carried forward as alternative #5.**
R.	Install additional power plant by forebay dam for submerged releases.	X	X		Could be carried forward as an amendment to alternative #3 if power is needed.

Table 3. - Ideas for structural modifications downstream or upstream from the dam.

Idea		Transfer	Reduce	Degas	Result
S.	Elevated tailrace to create shallow flow depth. Ramp up from existing river invert below pool in the river. This would treat the entire flow in free surface flow.			X	Not carried forward.
T.	Elevated tailrace immediately below the stilling basin creating shallow free surface flow.		X		Not carried forward.
U.	Build low head structures with low unit q in the river channel, such as baffle drop, rock cascades, labyrinths, infusers. Free surface flow.*			X	Not carried forward, but incorporated into other alternatives.
V.	Raised basin - Fill in roller bucket spillway with horizontal apron. Create shallow free surface flow.		X		Not carried forward.
W.	Inject microbubbles into stepped spillway?? surface water.*			X	Not carried forward.
X.	Widen river to create shallow free surface flow.*			X	Not carried forward.

Idea		Transfer	Reduce	Degas	Result
Y.	Widen river with other structures to degas.*			X	**Carried forward as alternative #7.**
Z.	Create bends in the river.*			X	Not carried forward.
AA.	Channelize and bend river.*			X	Not carried forward.
BB.	Pump and/or flood side channel along river and drop to river with free flow.*			X	**Carried forward as alternative #8.**
CC.	Aerators - fountains.*			X	Not carried forward.
DD.	Enclose roller bucket energy dissipater with walls and horizontal drop to force water back to surface.			X	**Carried forward as alternative #6.**

* Alternatives that could also be used upstream of the dam in the river.

Table 4. - Ideas for structural modifications in the reservoir.

Idea		Transfer	Reduce	Degas	Result
EE.	Construct a selective withdrawal system in reservoir to withdraw from higher levels - less saturation in summer months.		X	X	Not carried forward.
FF.	Construct a barrier at the entrance to the 3rd power plant forebay to release less saturated flow in the summer. Barrier could be a curtain, stoplogs, fill, etc.			X	Not carried forward.
GG.	Strip TDG in reservoir with introduction of microbubbles of pure oxygen.			X	Not carried forward.
HH.	Introduce blue-green algae to change composition of N_2 to organic forms thus reducing TDG.			X	Not carried forward.

Table 5. - Ideas other than structural modifications.

Idea		Transfer	Reduce	Degas	Result
II.	Develop additional power demand to eliminate spill, such as manufacturing plant, etc.	X	X		Not carried forward.
JJ.	Buy out net pen operator.				Not carried forward.

Idea	Transfer	Reduce	Degas	Result
KK. Lower net pens/fish to depth where TDG levels are closer to equilibrium.				Not carried forward.
LL. Shift power in system to Grand Coulee.	X	X		Not carried forward.
MM. Mitigation payments every 5-6 years with fines for violating TDG levels about $10,000/day.				Not carried forward.

ALTERNATIVES CARRIED FORWARD FOR INVESTIGATION

Alternatives from each category have been carried forward for further investigation of gas characteristics and cost estimates.

List of Alternatives Carried Forward

Transfer spill flow - 50,000 ft^3/s capacity

- No. 1 Reactivate the low-level outlet works at el. 950
- No. 2 Extend and cover the mid-level outlet works at el. 1050 down the dam face to below the tailwater
- No. 3 Pipe through the forebay dam abutment area to river channel

Free-flow alternatives to reduce or degas spill flow

- No. 4 Add outlet works deflectors - treat 50,000 ft^3/s
  - a. 10 conduits - 5000 ft^3/s each
  - b. 40 conduits - 1250 ft^3/s each
- No. 5 Forebay cascade - treat 50,000 ft^3/s
- No. 6 Enclosed stilling basin - potential to treat higher spill flows

Tailwater degassing of all or part of the design flow

- No. 7 Widen river and add labyrinth and gates, treat entire design flow
- No. 8 Side channel canal with drop to river, treat 100,000 ft^3/s

Description of Alternatives

Each alternative that is being carried forward is described in the following sections. The discussion briefly addresses the amount of flow being treated by the alternative and whether the TDG level will be transferred, production reduced, or degassed.

The TDG abatement effectiveness of all alternatives and the estimated construction/estimated cost of all alternatives is dependent upon the fluctuation of the tailwater caused by peaking power production. These fluctuations particularly affect the size of cofferdams, the location of drop structures, and the location of the deflectors. Assumed design values and tailwater levels, as previously stated, were used. Investigating further restrictions on power and lake levels during construction is beyond the scope of work at this time.

Designs discussed in this report are very preliminary, best described as pre-conceptual. Where sizes are discussed, very general assumptions were made regarding flow velocities, etc. Elevations are approximate, based upon assumed tailwater levels and expected hydraulic performance. Stepped drops or baffled apron designs may be interchangeable depending upon later evaluation of performance.

Estimate sheets for all alternatives showing the estimated quantities and parts may be found in the appendix of this report. The cost estimates are only "ball park" values at this scope of work.

Construction durations were also included; however, they are relatively conservative given the unknown nature of the processes involved at this scope of investigation.

No. 1 - Reactivate the low-level outlet works

This alternative will transfer the entire spill flow volume (50,000 ft^3/s) at the TDG level of the reservoir.

This alternative will reopen ten of the low-level outlet works that were plugged during construction of the third power plant, figure 3, 5. The outlet works conduit is plugged from 7 feet upstream of the emergency gate to the regulating gate. The emergency gates and all operators were removed. The regulating gates were sealed in place with concrete in the closed position and all operators were removed. The 16-inch-diameter air vent pipes and 2.5-foot-diameter manhole shaft were also filled with concrete. To rehabilitate the low-level outlet works, a large cofferdam would be required to allow access to the outlets from the downstream end. Bulkheads would need to be installed at the upstream end to allow for removal of the plug. A large quantity of concrete would be removed from inside the dam to allow for replacement of the emergency and regulating gates. Ring follower gates would be used for both new gates for control and regulation. With the new gates installed, concrete would be placed to refill the over excavation. New air vents and manhole conduits would be formed in the replacement concrete. A new steel liner would be placed in the downstream conduit to prevent cavitation damage.

A high cofferdam would have to be constructed, most likely in sections, to dewater the downstream end of the conduits. An upstream bulkhead would also be required to inspect/repair damage to the conduit entrance. A great deal of work will be performed in an area with extremely limited access and space. The construction period is estimated at 3 years.

To rehabilitate the low-level outlet works, the following items would be required:

1. A hydraulic model study is needed due to documented poor flow conditions with previous operation of the low-level outlet works.
2. Bulkhead the outlet works at the trashrack structure. The bulkheads are likely available and may be in place now.
2. Construct a large cofferdam.
3. Dewater roller bucket area. (81' x 1650' x 143'= 19,111,950 cubic feet, 439 ac-ft)
4. Dewater for duration, but discharge is unknown at this time.
6. Construct overhead transmission towers and install transmission lines.
7. Remove power cables from outlet works access gallery.
8. Remove a block of concrete with a size similar to the original gate blockout. It would not be practical to remove the concrete used to plug the outlet and reinstall similar gates. The total concrete to be removed is approximately 710 cubic yards per pairs of outlets. There would be approximately 34 feet of 8.5-foot-diameter reinforced steel pipe that would be removed in the concrete.
9. Install new gates and steel pipe, replace operators.
10. Install new downstream steel liner.
11. Replace concrete, 635 cubic yards.
12. Remove bulkheads and cofferdam.

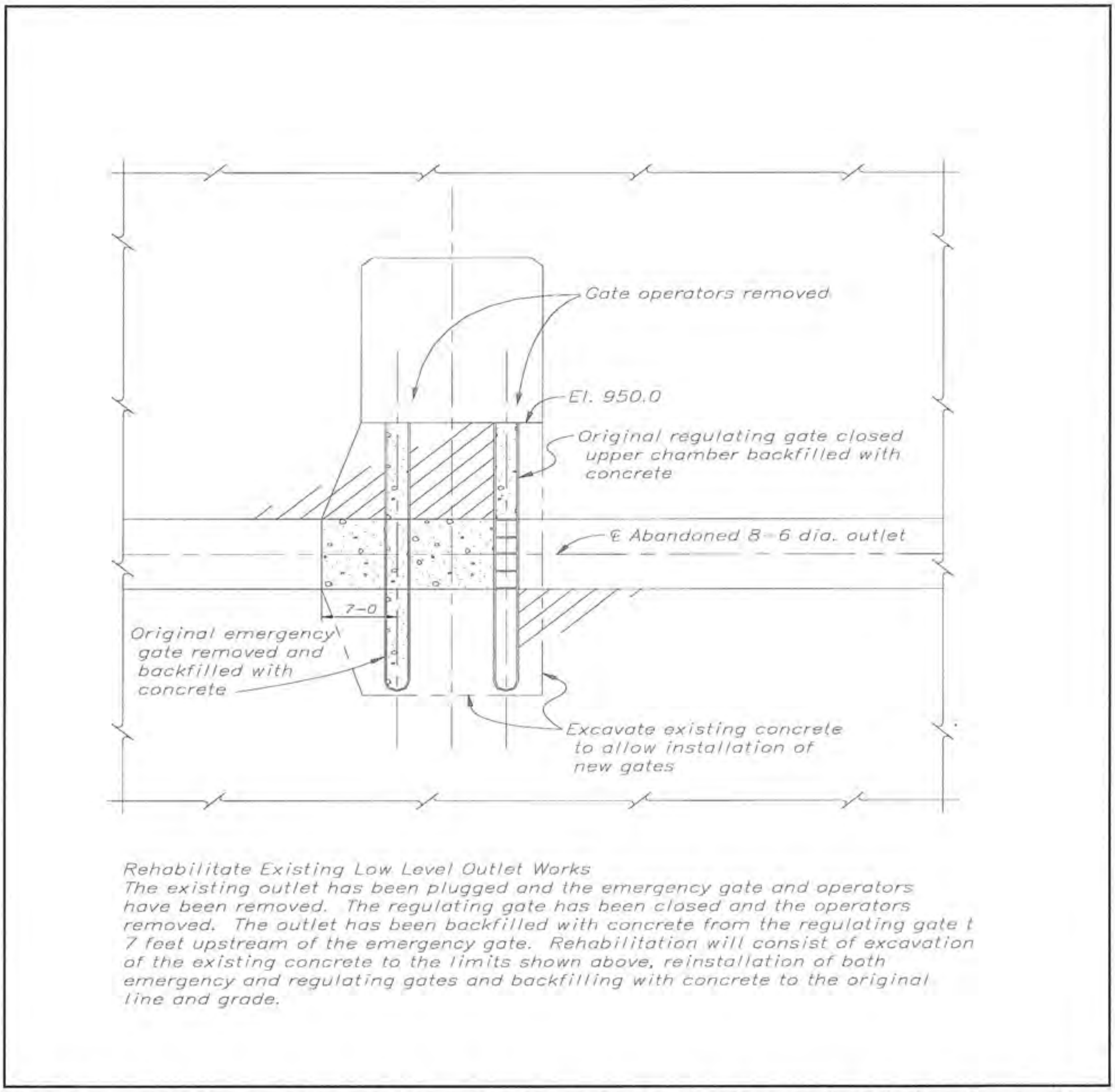

Figure 5. - Existing condition of the low-level outlet works and the required limits of excavation to reopen the conduits. (fn:rehab.wp)

<u>No. 2. - Extend and cover the mid-level outlet works</u>

This alternative will transfer the spill volume at the TDG level of the reservoir.

Ten mid-level conduits at el. 1050 will be modified to provide for submerged release of the outlet flows, figures 3, 6, 7. Extending the mid-level outlet works would consist of excavating into the face of the dam for five pairs of the outlets. The excavation would intersect the existing 102-inch-diameter steel liner just upstream of the end of the bend. The bend would be continued for a few degrees to make the liner parallel with the dam. The excavation would be approximately 25-feet wide, 14-feet deep and 153 feet in length for each pair of outlets. New 102-inch-diameter steel pipe would be attached to the existing conduits and continued down the face of the dam to approximate elevation 930.0. At this point, the pipe will be turned to exit onto the face of the dam.

Construction of an approximately 105-foot-tall cofferdam is required. The cofferdam could be constructed across the entire length of the basin or in sections to allow for access to only a few outlets at a time. The construction period is estimated at 3 years.

To extend the mid-level outlet works, the following items would be required:

1. Conduct a hydraulic model study to assure absence of subatmospheric pressures in the extended conduit and to optimize the exit.
2. Construct a large cofferdam.
3. Drain roller bucket area. (81' x 1650' x 143' = 19,111,950 cubic feet, 439 ac-ft)
4. Dewater for duration. Unknown discharge at this time.
5. Excavate approximately 7,750 yd^3 of concrete from the dam face
6. Install 102-in-diameter steel pipe 1,021,000 pounds.
7. Replace concrete 6600 yd^3.
8. Remove cofferdam.

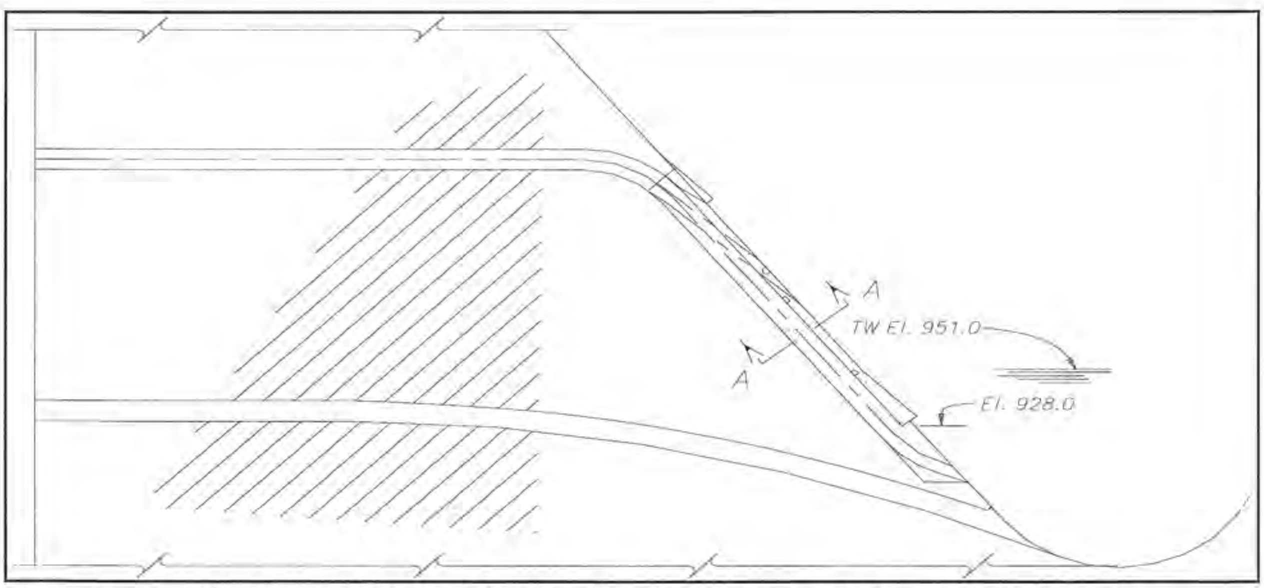

Figure 6. - Section view of the modification for extending the mid-level outlet works for alternative No. 2. (fn:extend.wp)

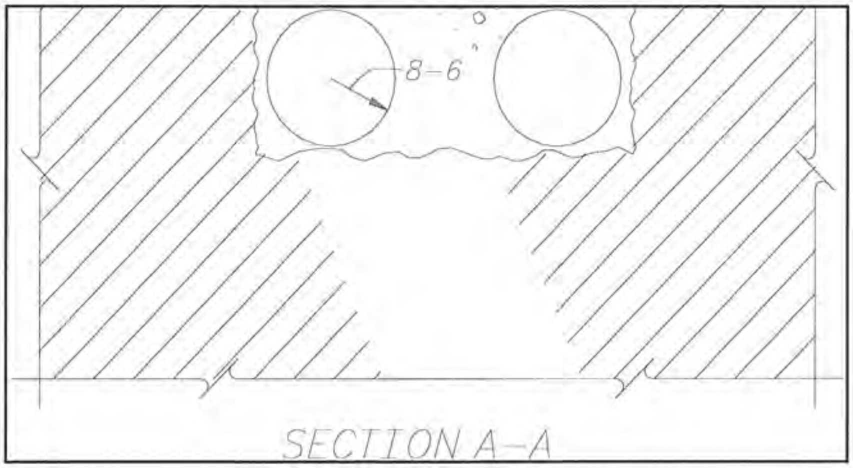

Figure 7.- Upstream elevation view of the proposed excavated cross section to extend the mid-level outlets down the dam face to below the tailwater (alternative No. 2). (fn:extend.wp)

No. 3. - Pipe through forebay dam

This alternative would transfer TDG levels in the reservoir for the spill flow of 50,000 ft^3/s. This alternative has the potential to add an additional power plant if that is seen as beneficial at a later date. There are potential advantages for gas stripping with refinement of the surface between the diffuser and the stilling basin proper.

The plan and sectional views of this alternative are shown on figures 8, 9, 10. This alternative involves constructing a concrete end wall in the forebay and putting a wheel mounted roller gate with hoist at that location. Then a 50-foot-diameter tunnel for the 40-foot steel pipe/penstock would be built. At the downstream end of the tunnel, a 40-foot-diameter jet flow gate would be constructed as the regulating gate for control. The flow would then empty into a perforated diffuser system and concrete stilling basin located in the North Service Yard. The jet flow gate would be housed in a 50-foot by 40-foot building. The diffuser would need to be approximately 900 feet long with one thousand 1-foot-diameter diffuser orifices. The diffuser system would be located below tailwater and empty into the stilling basin.

A cofferdam, approximately 1600 feet long, would be constructed to enclose the work area for activities in the stilling basin, including the stilling basin and the diffuser. The cofferdam would be approximately 20 feet high with 1:1 side slopes.

A second cloverleaf cofferdam would be constructed across the forebay. A head wall would then be constructed against the foundation of the forebay end for the wheel mounted gate which Construction of the cofferdam and the head wall will require a barge operation. This would involve loss of power generation from one unit of the third power plant during a portion of the total construction time.

This option would involve drilling and blasting a tunnel for the 40-foot-diameter penstock.

There will be minimal disruption to existing operation in the existing stilling basin. One unit of the third power plant would be removed from service during construction of the headwall and wheel mounted gate in the forebay. The gate would then be the bulkhead for the remainder of the work and service from the unit would resume for the remainder of construction. Additional power could be obtained with this alternative by expanding the design to replace the jet flow gate with a turbine.

There are no technological reasons why a 40-foot-diameter jet flow gate cannot be built, however, Reclamation hasn't built one larger than 8.5-foot diameter. For purposes of this estimate and with this pre-conceptual level design, a 40-ft-diameter jet flow gate was used rather than a skeleton bay with diffusers. The project would lose most of the existing north service yard and another might have to be constructed. There will be large volumes of excavated material for disposal. The construction period is estimated at 4 years.

Potential construction sequence/cost items (major items only):

1. Begin by excavating the stilling basin for the diffuser, remembering to have access for equipment so you won't fully excavate except in the upstream end of the stilling basin where the tunneling operation begins. Waste material into the cofferdam.
2. Excavate for tunnel beginning at downstream end.
3. Put in cloverleaf cofferdam, which will probably involve a barge operation. Then begin excavating the tunnel from upstream end, form up the concrete end wall and mount the wheel mounted roller gate, bulkhead guides, and trashrack structures.
4. Install pipe/penstock and place concrete.
5. Remove cloverleaf cofferdam (barge) and use the gate as the bulkhead for the remainder of the work.
6. Construct the control house for and install jet flow gate.
7. Finish excavation of stilling basin and place concrete.
8. Install diffuser.
9. Remove access road into stilling basin and remove cofferdam. This might be tricky if we need to excavate to el. 940 between the diffuser and stilling basin. May involve a restricted flow to "empty" the stilling basin as much as possible.

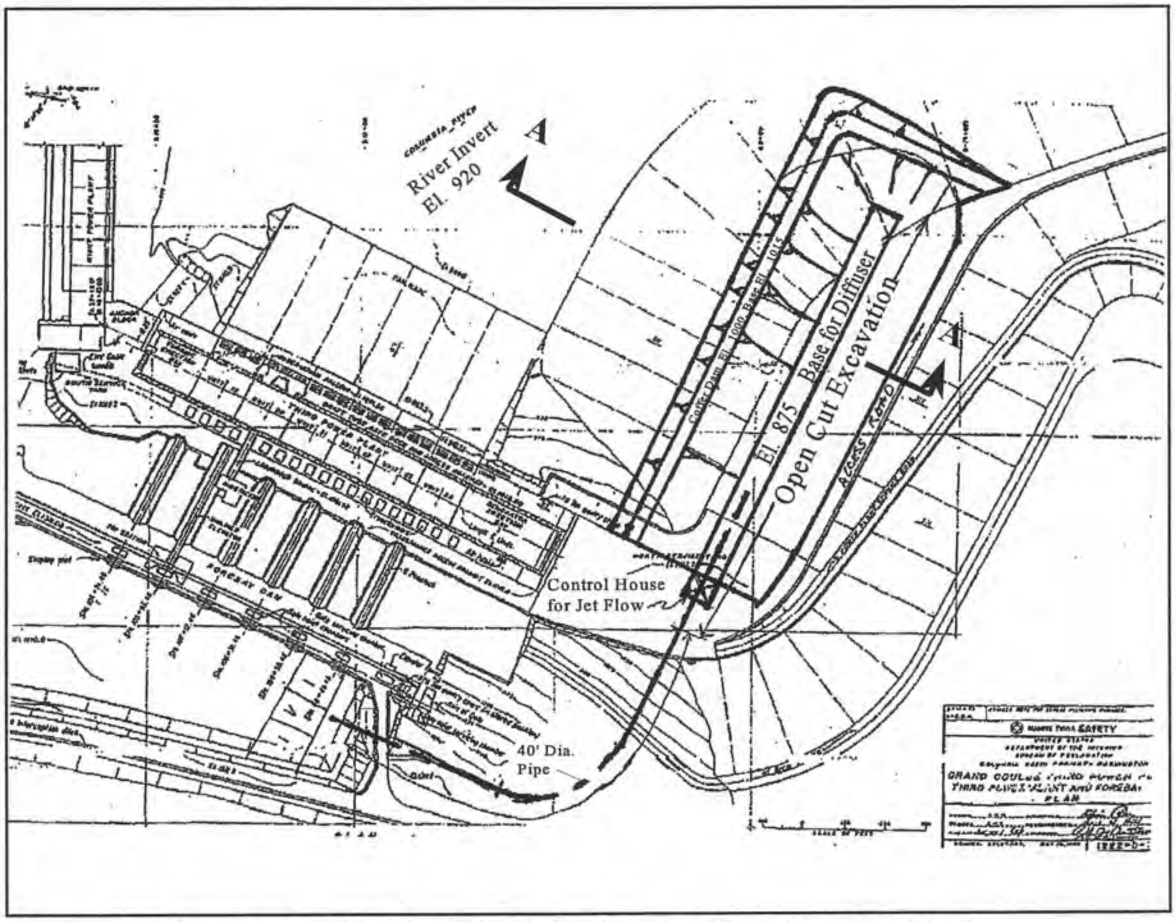

Figure 8. - Plan view of the pipe through the forebay dam alternative No. 3.
(Fn:alter#3.wpg)

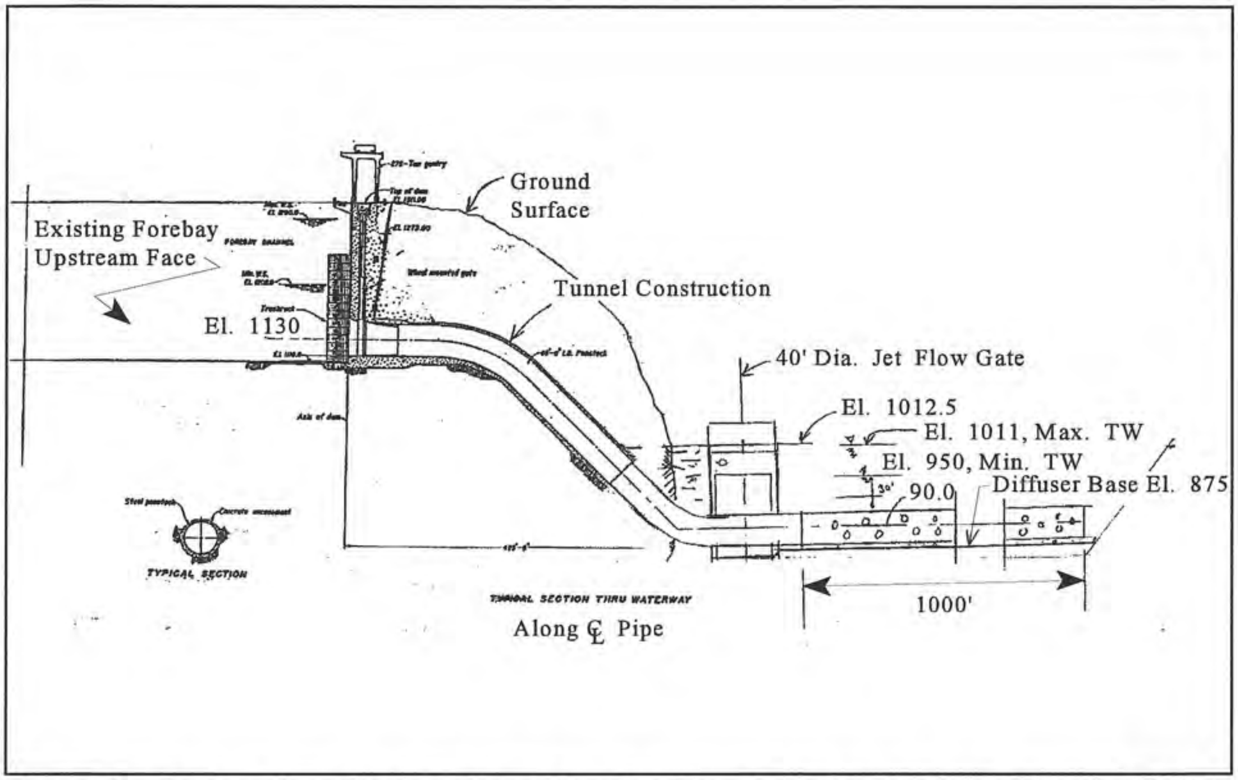

Figure 9. - Section along the centerline of the pipe through the forebay dam alternative (No.3). (fn:alter#3-2.wpg)

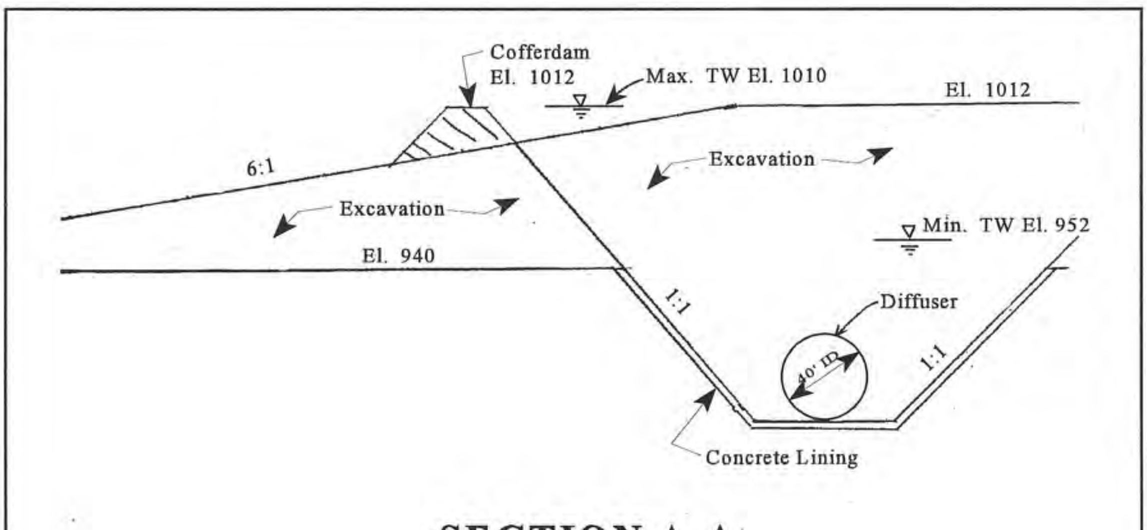

Figure 10. - Section through the stilling basin and diffuser for alternative #3, also showing the proposed excavation. (fn:atler#3-3.wpg)

No. 4a - Add outlet works deflectors for 10 conduits

This alternative will reduce production of TDG during typical spill periods, but is predicted to be the least affective alternative in abating TDG. The deflectors will be exposed to spillway releases, and may have some affect on flow conditions at this size.

Figures 11 and 12 show the deflector block size and location on the downstream face of the dam. The alternative involves constructing a horizontal deflector block across the downstream face of the spillway below 10 of the mid-level outlet works. This first deflector option involves using the full capacity (about 5,000 ft^3/s each) of 10 of the mid-level outlet works conduits for a unit discharge of 250 ft^3/s. The deflectors need to be located at optimum tailwater. This implies approximately at the end of the discharge conduit. This option uses the COE deflector design of a 30-ft by 30-ft deflector with a 50-foot radius tangent to the dam face and the horizontal surface of the deflector. This larger deflector was selected because of the high unit discharges and steep downstream slope of Grand Coulee Dam.

Assume the work could be performed from barges and scaffolding. The contractor would build a small cofferdam which hangs off the face of the dam, approximately 30 feet tall, 20 feet wide, and 110 feet long. Then he would move the cofferdam to the next location and continue across the face of the dam. The effectiveness of the operation and the size of the cofferdam could be impacted significantly by the expected fluctuation in tailwater.

The contractor would need to excavate a portion of the downstream face to key the deflector in. There would be some surface preparation to achieve bond, reinforced concrete, and No. 11 anchors to provide additional connection between the deflector and the downstream face of the dam. Some kind of overhead delivery system or cranes required for the deflector construction.

This alternative would be relatively easy and quick to build. It would probably only take 2 years because there is only a 450-foot length of deflectors to build. Also, these have been constructed by the COE, so construction techniques are known. Power production would not be impacted and floods would be handled by passing flow in the bays not under construction.

These designs assumed a constant elevation for the deflectors as shown in the drawings and for cost estimates. The possibility of staggering the deflector elevation will be investigated in conceptual- or feasibility-level design if this alternative (or No. 4b) is chosen. Additional construction cost is not expected to exceed 5 percent.

A hydraulic model study would be required to optimize deflector geometry, verify deflector performance as a function of tailwater elevation, and evaluate deflector influence during spillway releases.

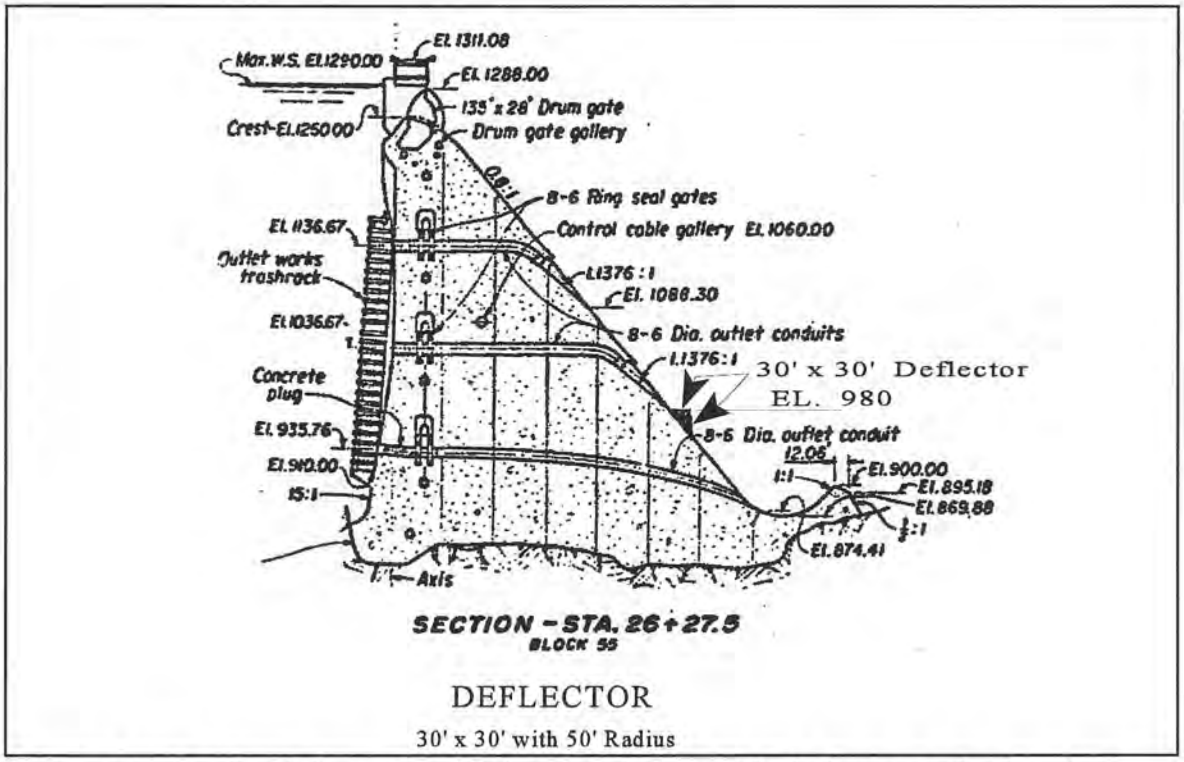

Figure 11. - Sectional view of the 30- by 30-ft deflector block shown on the dam face below the mid-level outlet works for alternative No. 4a. (Fn:alter#4a2.wpg)

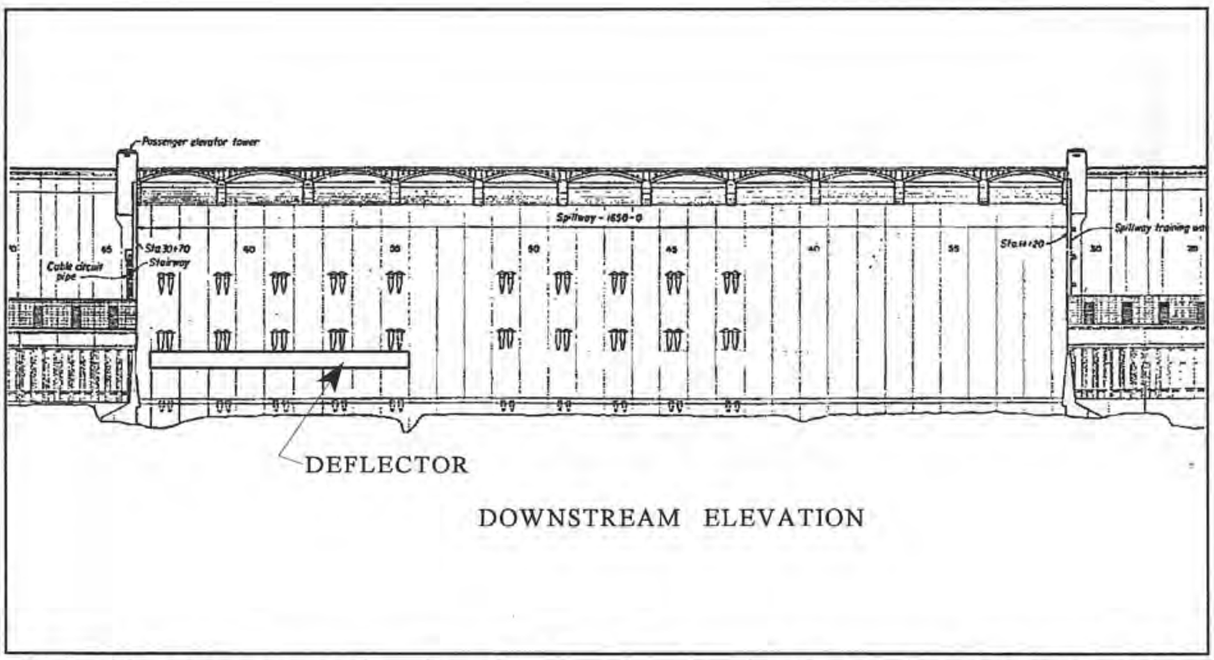

Figure 12. - Downstream elevation of the dam face showing the location for the 30-by 30-ft deflector block for alternative No. 4a. (fn:alter#4a1.wpg)

No. 4b. Add outlets works deflectors for 40 conduits

This alternative will reduce production of TDG during typical spill periods. The smaller unit discharges associated with using 40 outlet works to release the design flow should provide additional TDG benefit. Over and under operation of the outlet works has already shown to have TDG benefit. The deflectors will be exposed to spillway releases, but should not have a significant affect on spillway flow characteristics at this smaller size.

Figures 13 and 14 show the features of alternative No. 4b. The alternative involves constructing a 12.5- by 12.5-ft deflector block with a 15-ft radius across the downstream face of the spillway below all of the outlet works and replacing the existing outlet works control gates. Both upper and lower outlets are used and the unit discharge per outlet is lowered to about 160 ft^3/s by using all the outlets. Replacing the gates permits control of the discharge through each outlet and the outlet works are operated at partial openings to discharge the total spill from all 40 outlets (upper and mid). The unit discharge is based on 50,000 ft^3/s spread out downstream from 40 outlets or 1250 ft^3/s from each tube and the opening width at the end of the outlet. The deflectors need to be located at optimum tailwater or staggered for various tailwaters. This implies an elevation at approximately the end of the lower discharge passage. This option uses a typical COE deflector design. This deflector was selected because the unit discharges are approximately half that of the larger flows and may be effective for this range.

Assume the work could be performed from barges and scaffolding. The contractor would build a small cofferdam which hangs off the face of the dam, approximately 30 feet tall, 110 feet long, located 20 feet off the face. The cofferdam would be moved as work progressed to the next block.

The contractor would need to excavate a portion of the downstream face to key the deflector in. There will be surface preparation to achieve bond, reinforce concrete, and No. 11 anchors to provide positive connection between the deflector and the downstream face of the dam.

This alternative is very similar to 4a to construct. The deflectors would be relatively quick to build. There is, however, considerable work removing and replacing the control gates for all 40 outlet works. Assume the top of the dam available for work area. Pumping probably required to deliver concrete to the regulating gate location inside the dam. Some kind of overhead delivery system or cranes are required for the deflector construction. Confined, small work area for gate removal and replacement might be problematic. Construction time is 3 years, given the length of the deflector work and replacement of the regulating gates.

Again, a hydraulic model study would be required, as stated in alternative No. 4a.

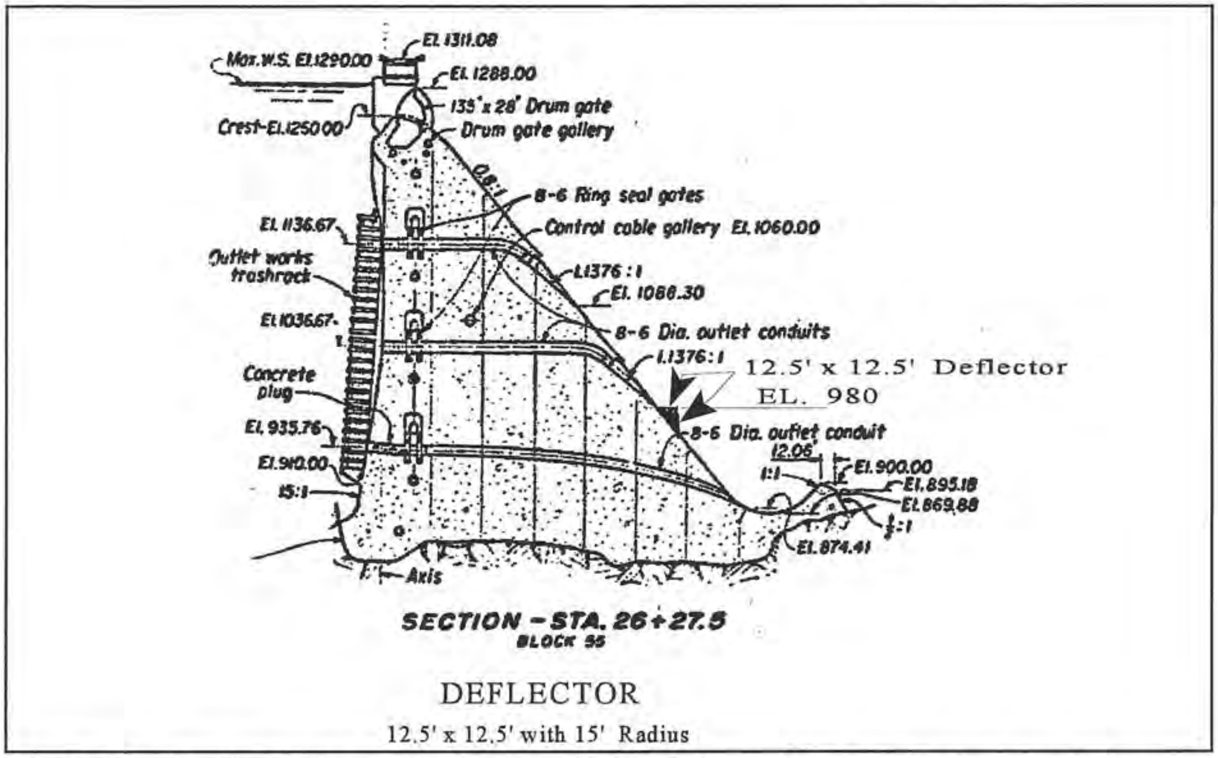

Figure 13. - Sectional view of the 12.5- by 12.5-ft deflector block on the dam face below the mid-level outlet works for alternative No. 4b. (fn:alter#4b2.wpg)

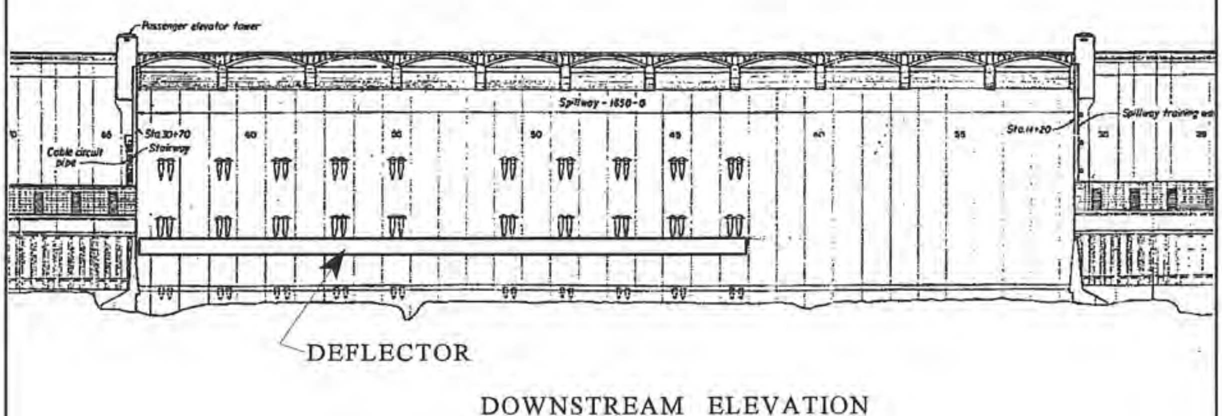

Figure 14. - Downstream elevation of the 12.5- by 12.5-ft deflector block on the dam face for alternative No. 4b. (fn:alter#4b1.wpg)

No. 5. - Forebay cascade

This alternative is similar to the Pipe through Forebay Dam (No. 3) in concept, but incorporates the use of a stepped roller compacted concrete (RCC) apron to degas the TDG levels prior to returning the spill to the river. The top- seal radial gate requires air to operate properly, so this alternative increases the TDG levels before stripping it back out. It is projected that this alternative will actually decrease TDG levels in the 50,000 ft^3/s spill.

Figures 15, 16, and 17 show the forebay cascade option that exits from the forebay dam through a tunnel controlled by a top-seal radial gate that discharges through a diffuser into a basin. From the basin, the flow will pass down a stepped apron, to cause degassing, into the river channel. This option also involves putting a wheel mounted roller gate on the end wall of the forebay dam. Then a 50-foot-diameter tunnel (40-foot-diameter pipe) connects to an excavated shaft housing a top seal radial gate and operator. The flow is then conveyed down a 40-foot-diameter pipe tunnel, under the access road to a perforated diffuser stilling basin to dissipate energy, then over a crest and down a stepped RCC apron where the dissolved gasses will be reduced.

There is a trade-off between length of tunneling, excavation, and pipe, with the size of the cofferdam. Hydraulics of a compound curve tunnel need to be studied for impacts on the effectiveness of the stilling basin. Further refinements would include evaluation of the use of a baffled drop structure instead of the steps.

Only a small cofferdam for work in the stilling basin is required. All work is fairly conventional with reasonable access to the right abutment and river bank area. There will be only minor loss of the north service yard, but placement of the diffuser basin could minimize this. There will be large volumes of excavated material for disposal. The cofferdam (cloverleaf) constructed across the forebay could involve potential impacts on operation of one unit of the third power plant during construction. The construction period is estimated to be 4 years.

A hydraulic model study would be required to verify and optimize the stepped apron transition to the tailwater, the hydraulic feature that strongly influences final TDG levels that may be generated.

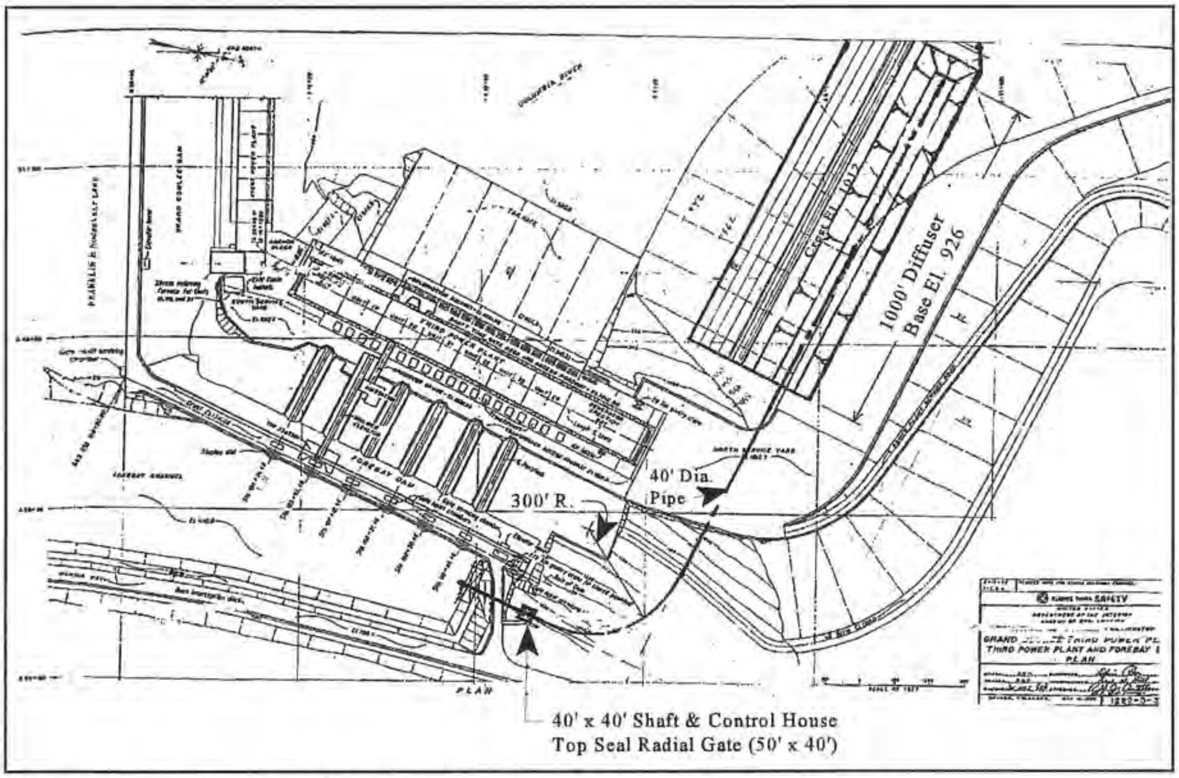

Figure 16. - Plan view of the forebay cascade alternative No. 5 (fn:alter#5-2.wpg).

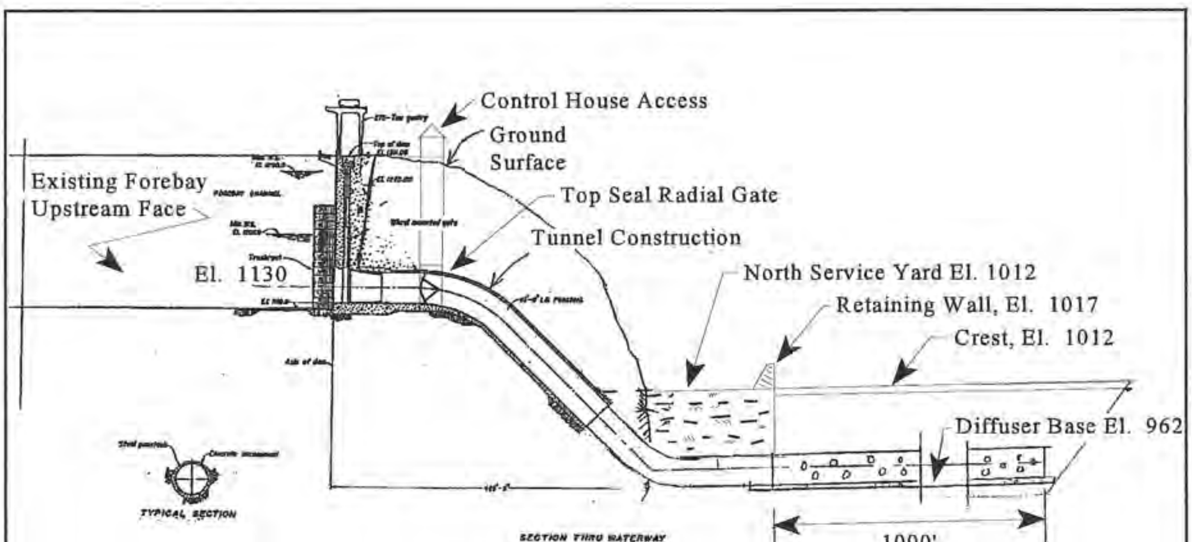

Figure 15. - Sectional view along the pipe centerline of the forebay cascade alternative No.5. (fn:alter#5-3.wpg)

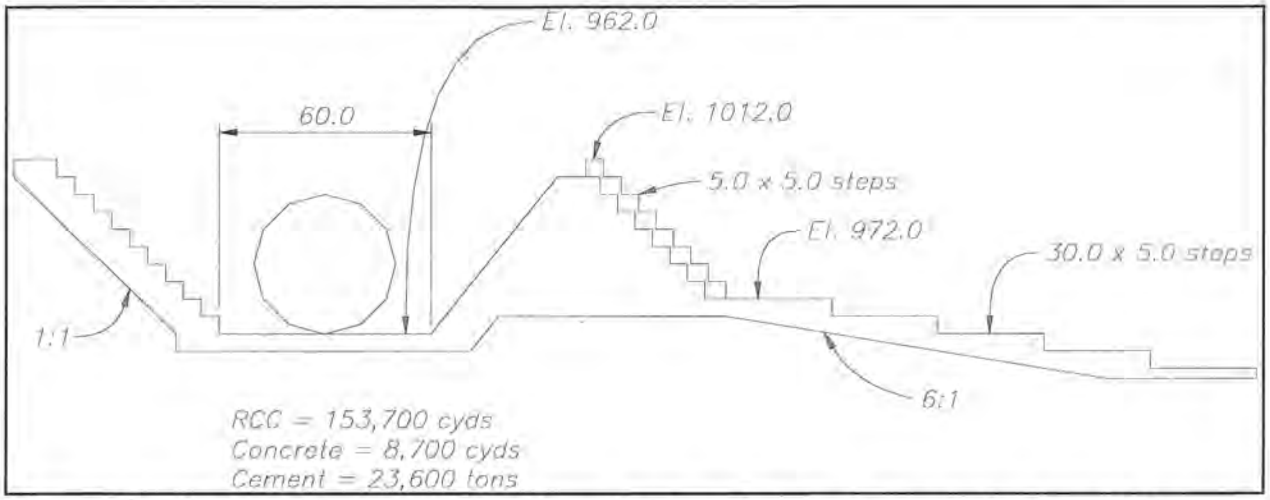

Figure 17. - Section view through the diffuser, basin, and stepped apron to the river for the forebay cascade alternative No. 5. (fn:rccalt.wp)

No. 6. - Enclosed stilling basin

This alternative will not alter spill operation as it is currently made. The spill will still plunge to the bottom of the roller bucket energy dissipater, but will then be forced over the top of the constructed dam to degas the flow before it enters the pool below. This alternative will treat the 50,000 ft^3/s spill and possibly higher spill flow rates depending upon the final geometry and tailwater fluctuations.

Figures 18 and 19 show the plan view and section of the enclosed stilling basin alternative. This alternative involves constructing a RCC dam to enclose the existing roller bucket energy dissipater. The elevation of the top of the dam will be set to force the spill back to the surface. The geometry for the top of the RCC dam would include baffles to provide stripping of TDG as the water passes over the top of the dam and back to the river channel.

The dam is 85 ft high with 10-foot excavation projected for the foundation. It has a 0.5:1 upstream slope and 1:1 downstream slope, and is 20 feet wide at the top.

A major portion of this work is construction of a cofferdam prior to placement of the RCC. The cofferdam is a cellular cofferdam built of sheet piles. It would be 100 feet tall and approximately 100 feet square at the base.

This alternative uses proven technology for dam construction; however, the size of the cofferdam would temporarily remove two to three units in both the left and right power plants (four to six total) during the construction period. It would also permanently remove the two units from both the left and right power plants adjacent to the wall for the life span of the project. The RCC dam would not allow the existing roller bucket spillway to self clean.

A 1985 estimate for a 100-foot-tall cofferdam for Shasta Dam was put together by the Concrete Dams Group. This estimate included 40 cells (100 feet by 100 feet cloverleaf by 100 feet tall) and required approximately 40,000 tons steel and 2 million cubic yards of gravel. The cofferdam would provide some flood protection and withstand a small amount of overtopping. The cofferdam would be constructed in three sections and the time to build and remove each section is estimated to be 6 months. The construction period is estimated to be about 3 years.

A hydraulic model study would be required to evaluate influences on stilling basin performance and to optimize degassing characteristics.

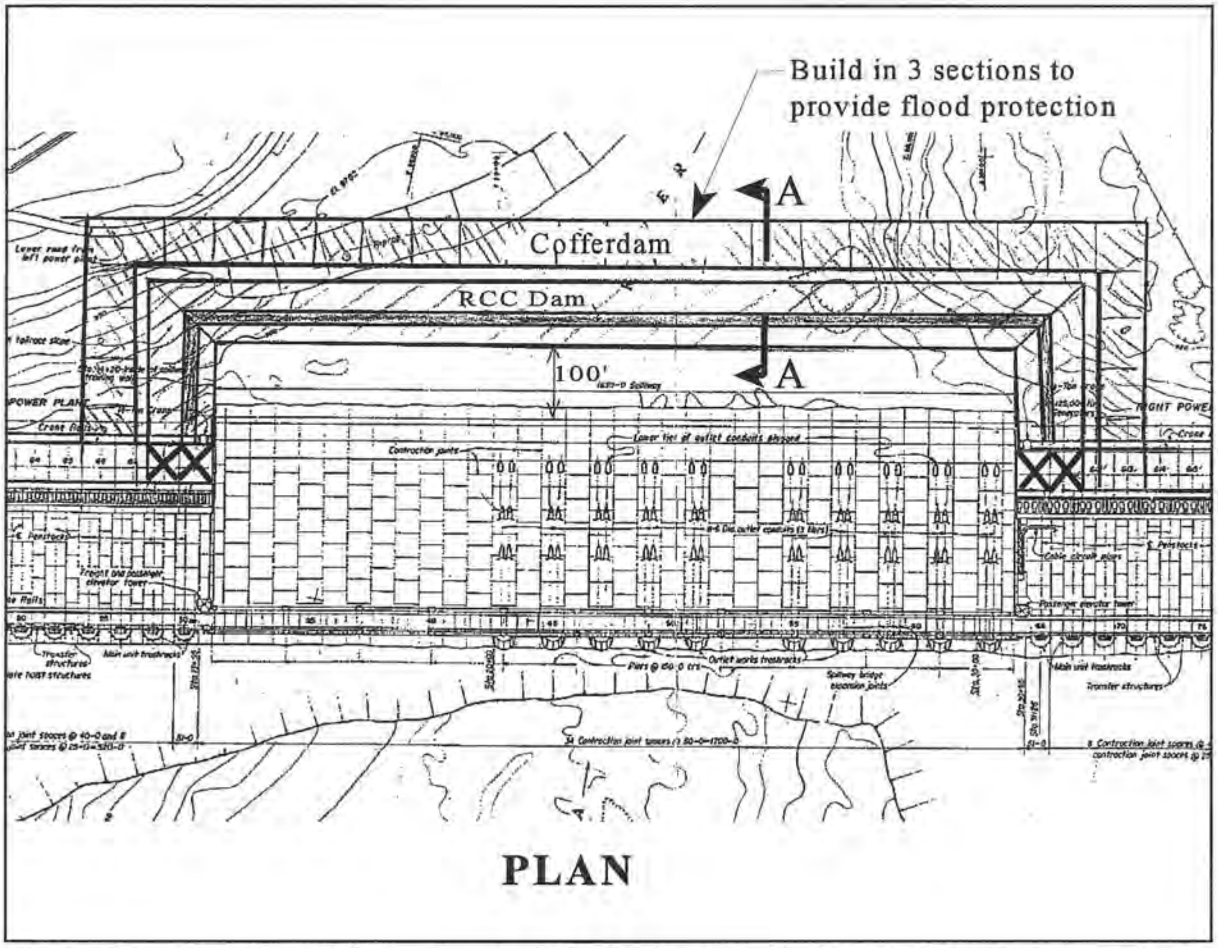

Figure 18. - Plan view of the enclosed stilling basin alternative No. 6. Note that two units in each adjacent power plant are projected to be out-of-service for the life of the project. (fn:alter#6-1.wpg)

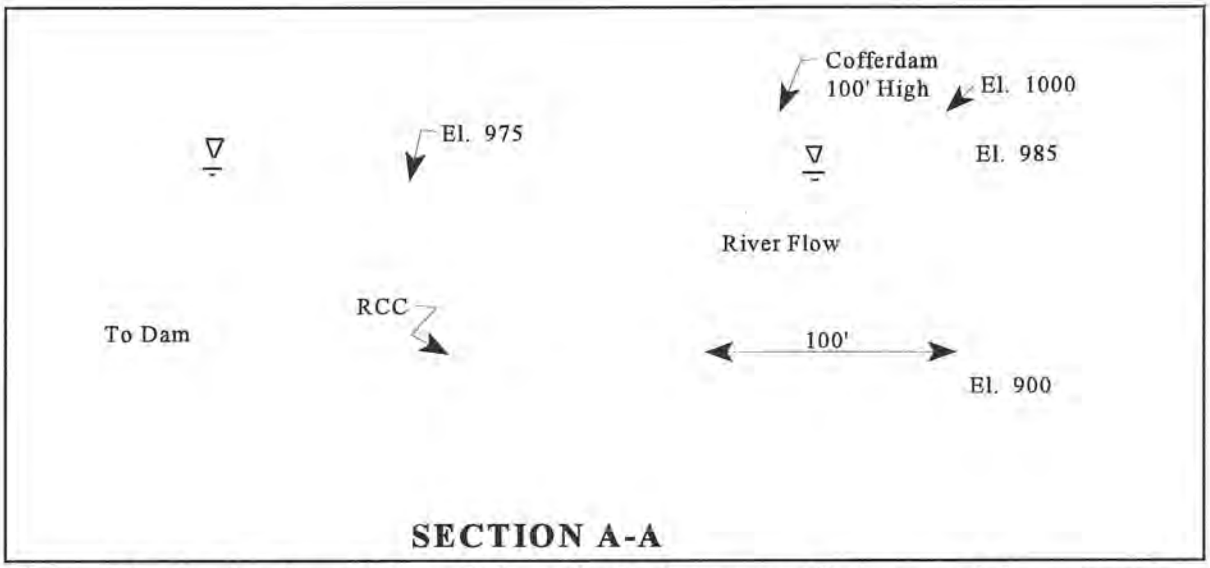

Figure 19. - Section through the existing roller bucket energy dissipater and the proposed RCC enclosure for alternative No. 6. The 10-ft-drop and baffles on top of the RCC dam are not shown. (fn:atler#6-2.wpg)

No. 7. - Widen river with labyrinth weir and gates

This alternative will degas the entire 7-day 10-year design flow of 210,000 ft^3/s by forcing flow over a combination labyrinth weir with a baffled and stepped apron, back into the river channel. This is the only option carried forward that will degas close to the state standard of 110 percent.

River flows would be diverted over the labyrinth by constructing a major gated structure in the river channel. The weir and gate structure would be located several miles downstream of the dam.

Figures 20, 21, and 22 show the features of alternative No. 7. For this modification, a portion of Washington flats approximately 3500 ft long and 1300 ft wide would be excavated to an elevation slightly below river level. A labyrinth weir approximately 4200 ft long would be constructed in the 1300-ft width of the new river channel. The weir would have a crest elevation of approximately 986 ft. A series of baffles and stair steps on the downstream slope of the weir would create white water turbulence to degas the river water. Upstream of the weir, the widened river channel would be excavated to about elevation 970 ft, and downstream the widened channel would be excavated to about elevation 952 ft. A gate structure with seven 100-ft-wide by 30-ft-high Obermeyer gates would be constructed in the existing river channel to divert water over the labyrinth weir during the spring and summer when the TDG exceeds the state standard. The gates would be lowered during low flow season to minimize loss of power production.

During construction of the gate structure, the river flows would be diverted in stages by constructing a cellular cofferdam. Existing terrace deposits would be left in place along the edge of the left bank to act as a cofferdam while Washington Flats is being excavated for the shallow channel.

Dewatering would be significant for shallow channel excavation below the existing river level. The labyrinth weir would be constructed mainly of RCC with a 5-ft-thick structural concrete cap and baffles on the downstream face. When the weir is in use, the tailwater on the power plant would be increased approximately 17 ft which would impact power generation.

This will be an extremely expensive modification as essentially a new dam is being constructed in the river downstream. There would be loss of power generation during the spill season. The crest elevation of the gate structure will be investigated further to minimize loss of power if this alternative is selected for concept level design. Over 20 million cubic yards of soil would have to be excavated and wasted. River diversion would be required for the gate structure. Extensive dewatering would be required in the shallow channel. Wildlife habitat would have to be replaced. Additional riverbank stabilization would likely be required along the left bank. Heavy equipment access to and from the site during construction would be difficult. The construction period is estimated to be about 4 years.

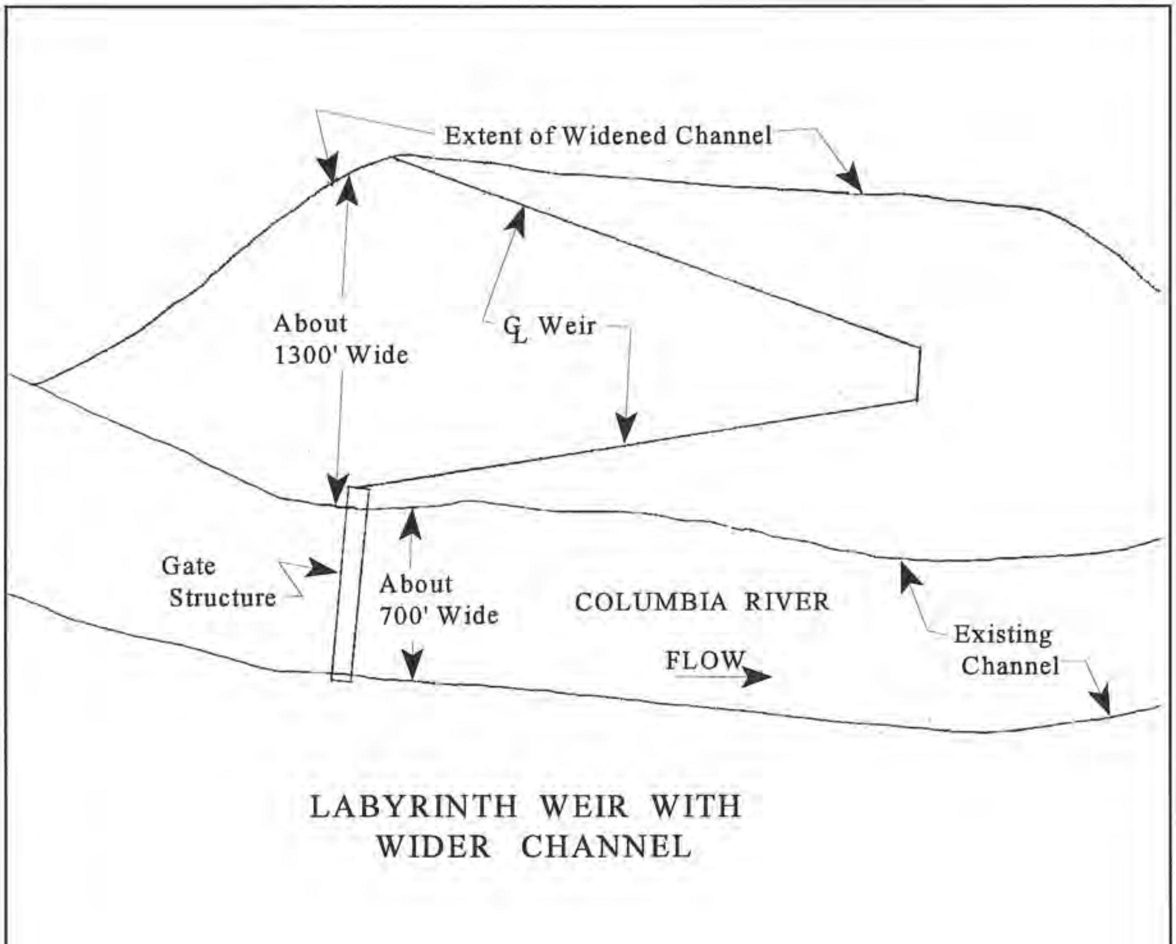

Figure 20. - Plan view of alternative No. 7 to widen the river channel with a labyrinth weir and gate structure. (fn: alter#7-2.wpg)

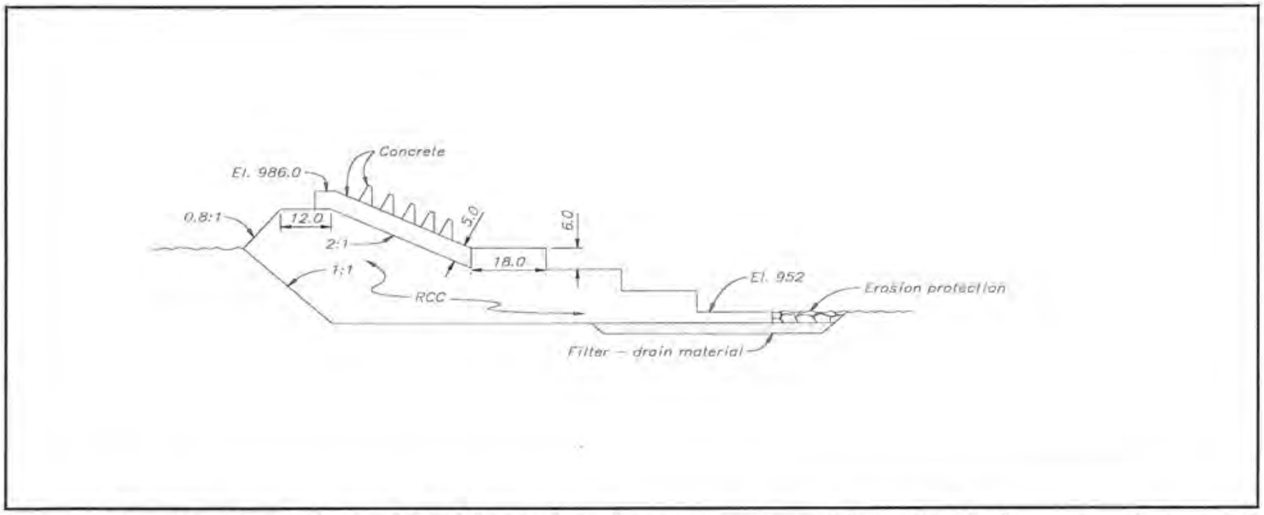

Figure 21. - Sectional view of the labyrinth weir construction with the baffled apron and stepped return to the river channel for alternative No. 7. (fn:gcrcc.wp)

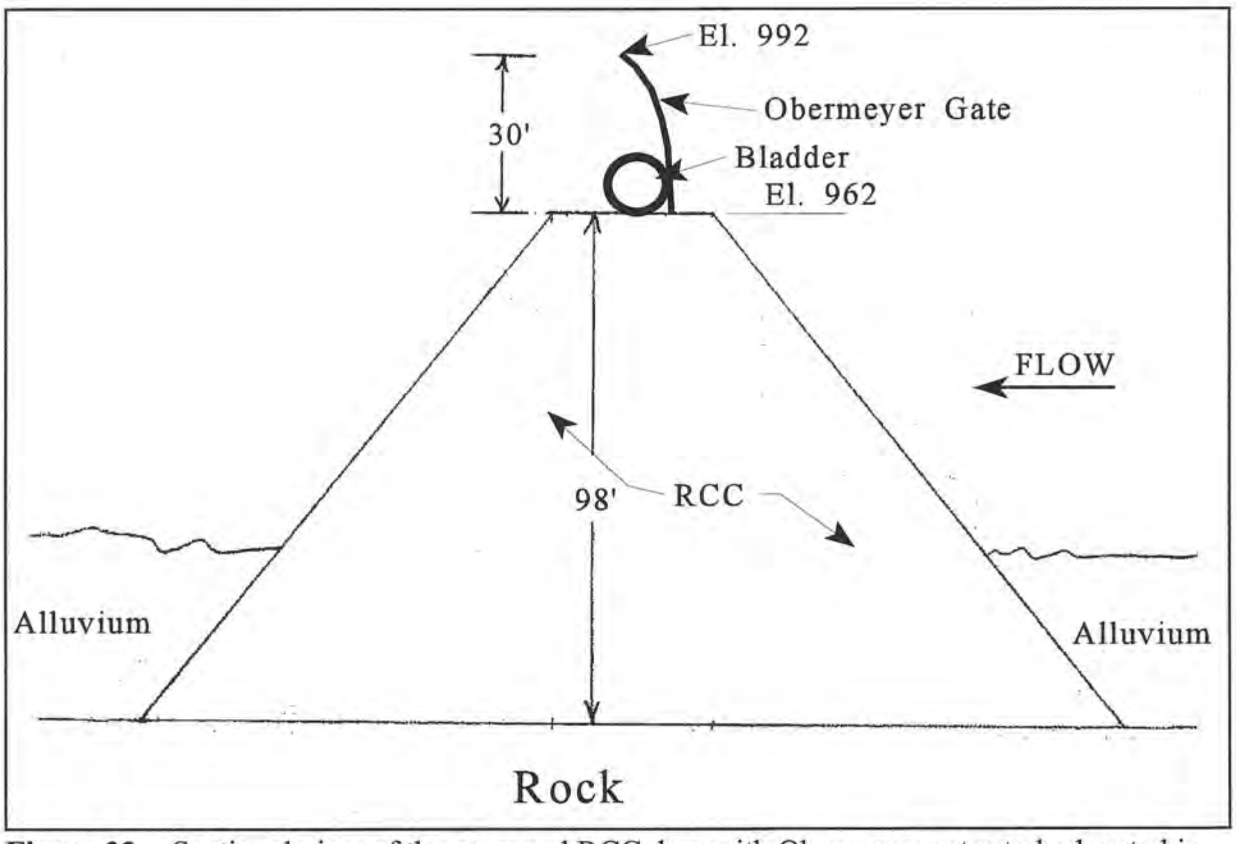

Figure 22. - Sectional view of the proposed RCC dam with Obermeyer gates to be located in the river for alternative No. 7. (fn:alter#7-1.wpg)

No. 8. - Side channel canal with drop to river

This alternative will degas a flow volume of 100,000 ft^3/s which is about one-half of the design flow rate of 210,000 ft^3/s. The flow with reduced TDG levels will then mix with the remaining river flow to provide an overall reduction in TDG levels at the fixed monitor location.

Figures 23, 24, 25, and 26 show the features of alternative No. 8. This alternative involves constructing manifolds and penstocks to take the flow as it exits from three units of the third power plant and transport that flow down river to a side channel. The side channel would be built of RCC and structural concrete and function to strip dissolved gas from 100,000 ft^3/s as the flow returns to the river over a baffled or stepped apron geometry. Either the stepped geometry (figure 26) or the baffled apron (figure 21) could be used.

The work would first include building the side channel section and running penstocks up to near the dam. A cofferdam would then be constructed to isolate three units of the third power plant (Unit 22, 23, and 24). The cofferdam would block flow from Unit 21 during construction. There are three draft tubes per unit and these would need to be manifolded together into a 40-foot diameter conduit. There would be three conduits exiting the power plant tailrace that would connect to the previously constructed lines running along the right river bank to the side channel.

This alternative requires a long section of land parallel to the river channel. It is proposed, from looking at the map of Reclamation-owned land, that the structure be located behind the city of Coulee Dam along the river. This alternative does not impact the performance of the outlet works or spillway. Most of the work could be done with shallow cofferdams or out of the river channel. Access to the work site is good, and the concrete batch plant could be sited relatively close so haul distances would be short. Using conduits attached to three units of the third power plant to supply water to the side channel allow use of the available head and precludes construction of a pumping plant to lift flow to the side channel. An appropriate size pumping plant would be estimated to need 20 pumps at 5,000 ft^3/s and a footprint of 1,000 ft by 120 ft which would still powered by three generators from the third power plant.

There will be permanent loss of approximately 20 percent of power production for three units of the third power plant. There will be loss of power production from four units of the third power plant for the duration of the work in the tailrace area (estimated at 1 year). There will be large volumes of excavated material for disposal. Relocation of the river bank stabilization features would be required. The construction period is estimated to be about 4 years.

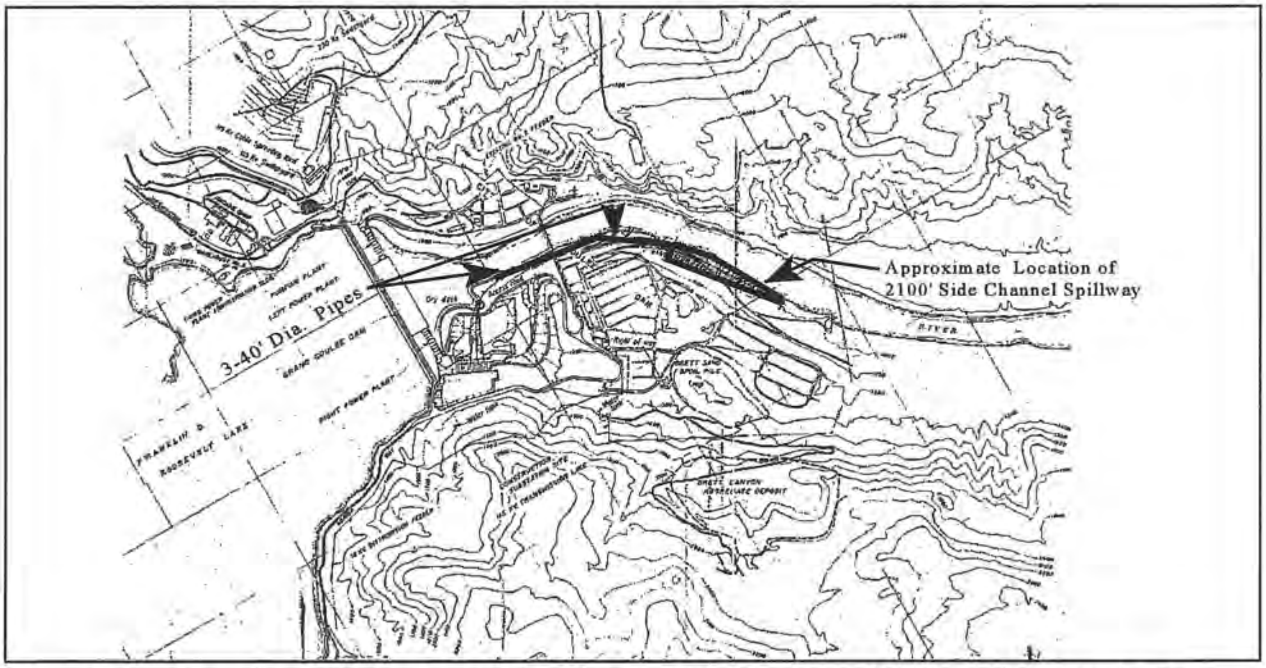

Figure 23. - Plan view of the proposed location for the side channel basin and penstocks for alternative No. 8. (fn:alter#8-2.wpg)

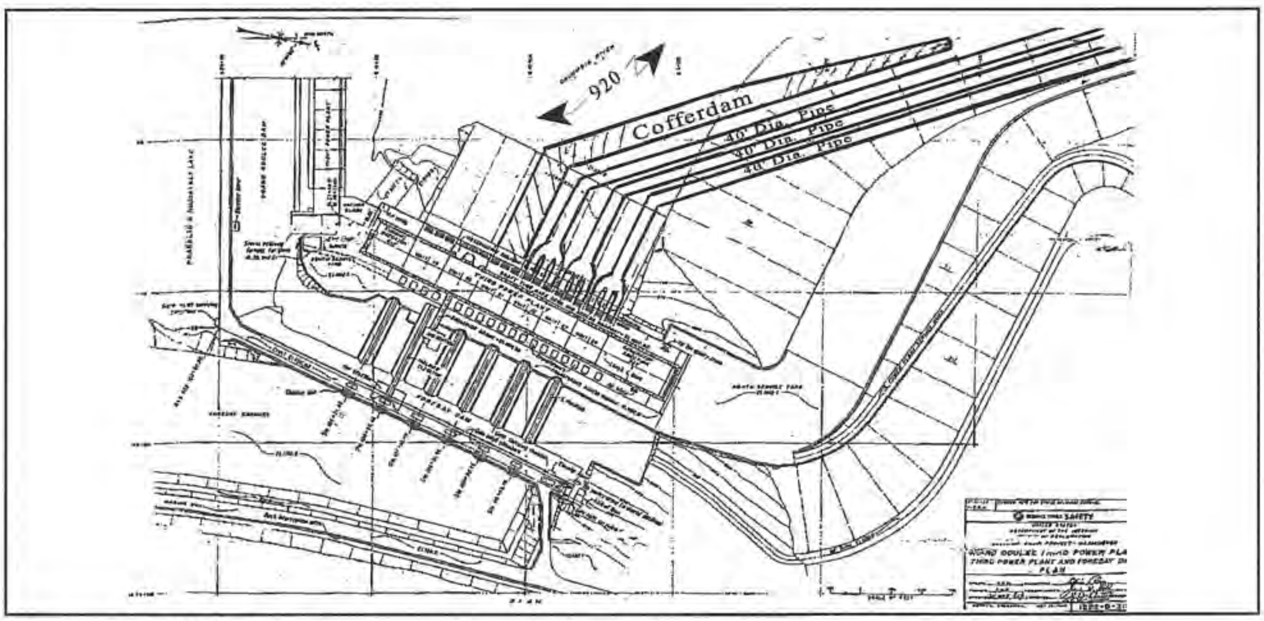

Figure 24. - Plan view of proposed penstock attachment to the third power plant units for alternative No. 8. (fn:alter#8-1.wpg)

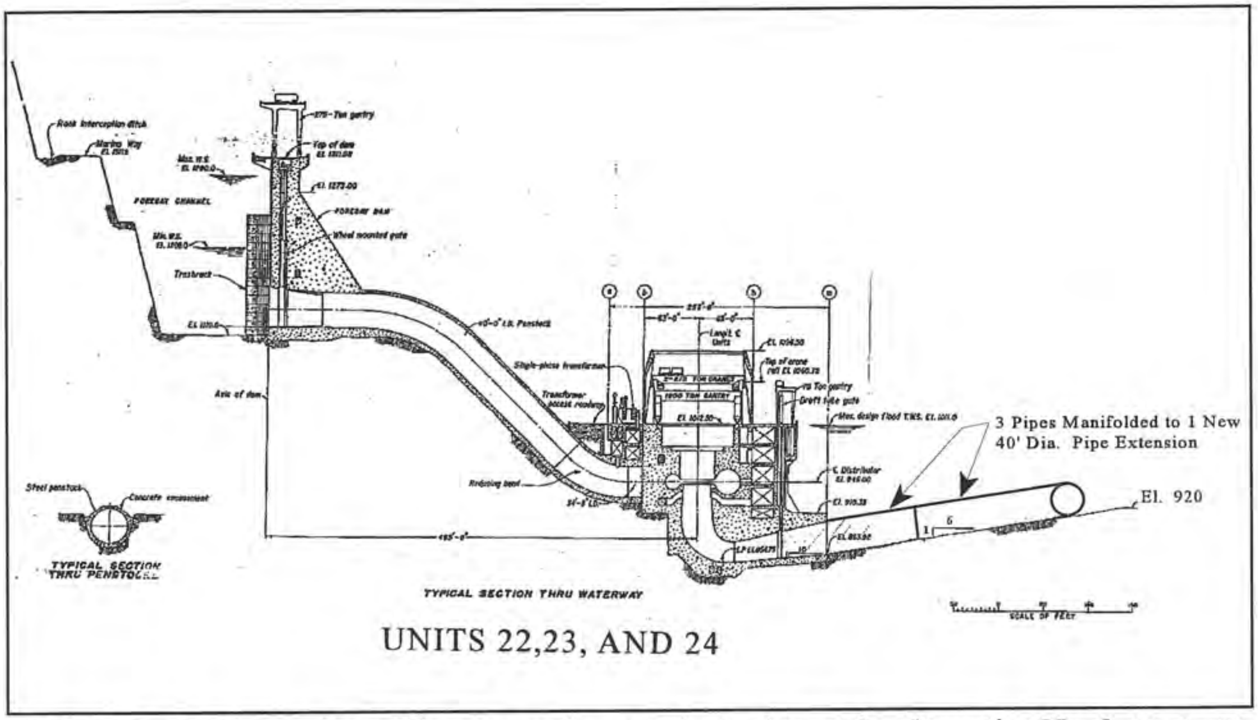

Figure 25. - Sectional view of the proposed penstock attachment for alternative No. 8. (fn:alter#8-3.wpg)

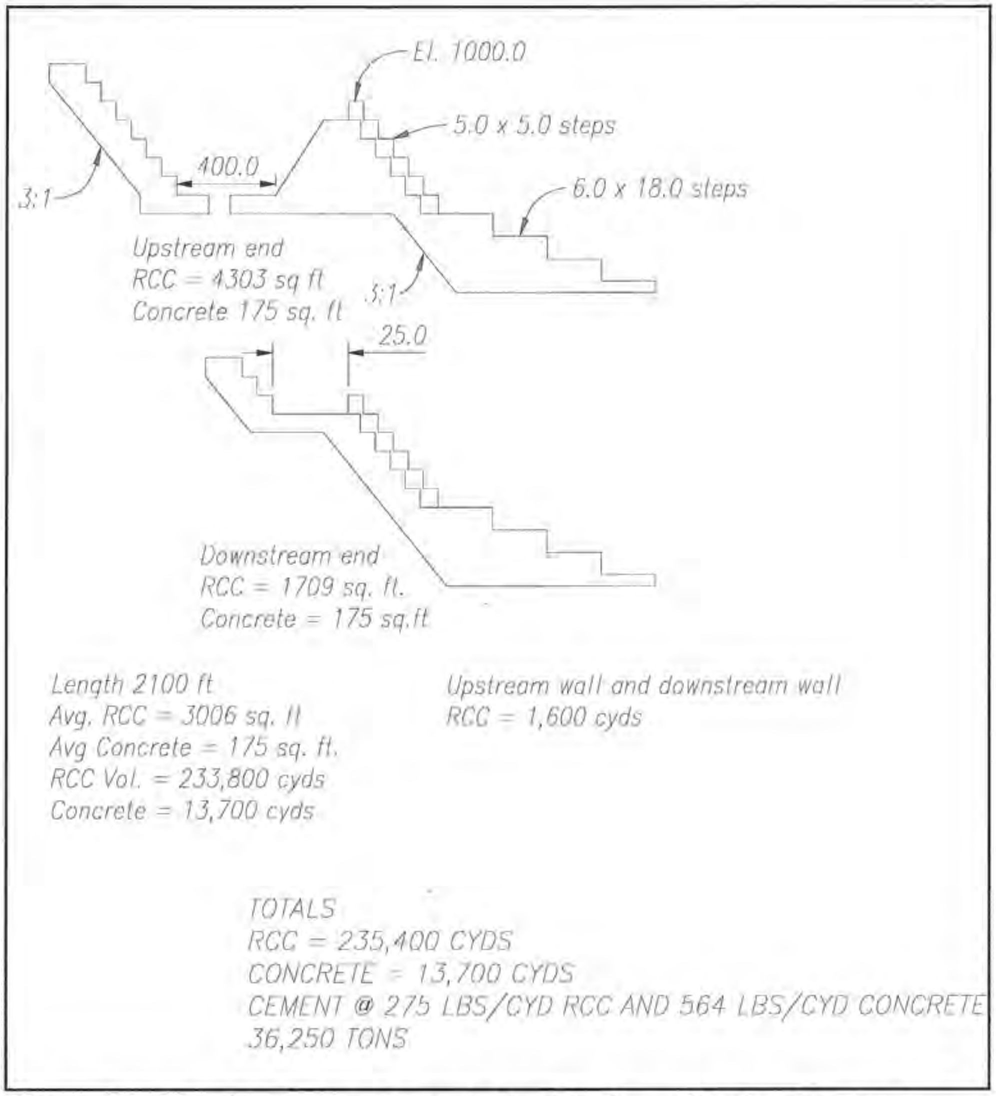

Figure 26. - Sectional views through the side channel basin showing a typical reducing of the area and the stepped return to the river channel, alternative No. 8. (fn:rccalt.wp)

Evaluation of TDG Transfer Characteristics

The first objective was to evaluate the TDG characteristics of the existing hydraulic conditions. Then computations were made for each alternative. All computations assumed the one-fourth spill and three-fourths power release proportions when considering the combined TDG levels.

Existing spillway and outlet releases

Near field TDG levels at the end of the stilling basin generated by operation of the spillway and outlets at Grand Coulee Dam have not been evaluated. Fixed station monitoring data, however, may be manipulated through consideration of the dilution influences of the power releases; to back compute TDG levels generated by spill and outlet works operation. To compute dilution influences, the discharge magnitudes of both the power release and the spill release is required. Likewise, the forebay TDG level, which is transferred to the tailrace by the power release, is also required. An average forebay TDG concentration of 120 percent was assumed. The design spill and power release magnitudes of 50,000 ft^3/s and 160,000 ft^3/s, respectively, were used in the determination of TDG levels generated by operation of the existing structure. In addition, TDG values from figure 4 at the fixed monitoring station were used as the basis for the concentrations computed in the near field. TDG production of the existing structures are:

Outlet works operation (250 $ft^3/s/ft$ unit discharge)	171 percent
Spillway operation (30 $ft^3/s/ft$ unit discharge)	138 percent

The 250 $ft^3/s/ft$ unit discharge is approximate and considers that the upper and mid-level outlets were operated simultaneously, and that flow from the outlets would spread about 40 ft as it passes down the spillway face. The combined TDG percent from operation of the existing outlet works structure would be 132 percent at the fixed monitoring station. This value is used throughout further discussions to compare predicted TDG benefit of each alternative with respect to the existing conditions.

Transfer alternatives using submerged releases

All three of these alternatives transport flow directly from the reservoir to depth in the tailrace. With proper design, the turbulence and shear generated by the flow release within the tailrace pool will be insufficient to entrain surface air and carry it to depth. With an absence of free air at depth, a source of gas is not available for transfer. As a result, TDG levels in the reservoir are transmitted to the tailrace with no change. Supersaturation is not generated. On the other hand, degassing or reduction of TDG concentrations from the supersaturated levels that occur in the reservoir, do not result.

- Alternative No. 1. - Reactivate existing low-level outlet works - Through reactivation and operation of the low-level outlets at el. 950, flow could be passed through those conduits to a submerged release immediately above the roller bucket. Each outlet conduit would have a discharge capacity of approximately 5,000 ft^3/s. Submergence of the release would be typically in excess of 70 feet and likely in excess of 90 feet during the high total release periods when releases would be required. A surface boil would result. This submergence should, however, be sufficient to limit velocity and energy levels at the tailwater surface and thus prevent air entrainment from the free surface. The alternative to reactivate the low-level outlet works is expected to produce a TDG level of 120 percent in the river downstream. This corresponds to a 9.2 percent decrease in TDG compared to the existing condition.

- Alternative No. 2. - Extend the existing mid-level outlet conduits - Extending the existing mid-level conduits to a submerged position immediately above the low-level outlets would allow releases with about 50 feet of submergence during the high flow periods. Each outlet conduit again would have a discharge capacity of about 5,000 ft^3/s. The orientation of the exit will determine whether the release flow will pass down into the roller bucket or disperse horizontally across the tailrace pool. Details of this dispersion pattern should be model studied if this alternative is pursued. Even though it is somewhat more uncertain that submergences would be sufficient to prevent entrainment of surface air and transport of free air bubbles to depth, it is probable that submergences would be adequate. The alternative to extend the mid-level outlet works is expected to produce a TDG level of 120 percent in the river downstream. This corresponds to a 9.2 percent decrease in TDG compared to the existing condition.

- Alternative No. 3. - Pipe through forebay dam - A closed conduit, or conduits, would be extended from the third power plant to the tailrace pool. Potential release structures would include either the jet flow gate shown on figure 9 or construction of skeleton turbine bays (with dissipaters) and a diffuser. The diffuser structure presented would release a maximum capacity flow of 50,000 ft^3/s through a series of 1.0-ft-diameter orifices. Approximately 1,000 orifices would be required, each with a discharge capacity of 50 ft^3/s. The orifices would be dispersed across the extended diffuser to minimize local energy levels, thus minimizing the potential to draw surface air to depth. A diffuser of this design would minimize submergence requirements and allow near bank placement that simplifies site dewatering requirements for construction. It is anticipated that minimum submergence on the diffuser orifices would be approximately 20 ft. The alternative to pipe through the forebay dam with a submerged release is expected to produce a TDG level of 120 percent in the river downstream. This corresponds to a 9.2 percent decrease in TDG compared to the existing condition.

Free flow alternatives

The following alternatives release the spill/outlet works flows in such a manner that TDG levels generated by the release are reduced from TDG levels generated through use of the existing structures. Dissolved gas levels generated are dependent on the hydraulic characteristics of the alternative, and in particular on the hydraulic and plunging characteristics of the outflow into the tailrace channel. The objective with free flow alternatives was to lower unit discharges and plunge depth. To minimize supersaturation levels generated, the outflow into the tailrace pool should be held near the surface. If the released air-water mixture can be kept in the upper 5 to 6 feet of the tailrace pool, resulting supersaturation levels can be kept at about 110 percent. With deeper plunging and mixing, higher supersaturation levels will result. It is very difficult with high velocity, high unit discharge flows, to maintain a shallow outflow. There are strong tendencies for both plunging and vertical mixing, thus performance certainty is less with these alternatives than with the submerged release alternatives.

These alternatives have no influence on the dissolved gas levels passed by the power releases. Because the spill release will typically be a relatively small portion of the total design release (about 25 percent), dissolved gas reductions are diluted and consequently design flow TDG reductions are less pronounced.

- Alternative Nos. 4a and 4b. - Outlet works deflectors - Deflectors would be placed below the mid-level outlet works on the face of the dam. Deflector designs would be similar to those developed by the COE for its Snake and Columbia River structure spill bays. The deflectors turn the flow to release it as a horizontal jet across the tailwater surface.

Deflector performance and generated TDG levels are strongly dependent on the relative position of the deflector to the tailwater surface. With low tailwater, the flow will plunge off the deflector and penetrate into the pool. With high tailwater, the jet will rise up with a standing wave and then plunge. The optimum tailwater range is relatively narrow. Grand Coulee experiences wide ranges of tailwater levels that are associated with peaking power operations, even with operations under the design flow event of 210,000 ft^3/s. As a consequence, it is proposed that vertically staggering the deflectors at two elevations with approximately an 8 foot vertical spacing be investigated during the next design phases. In addition, COE studies have shown that dissolved gas performance is also dependent on the unit discharge (4, 5). Typically, COE field evaluations have considered unit discharges ranging up to about 400 to 500 $ft^3/s/ft$. These upper end flow rates are representative discharges over deflectors placed below the concentrated releases from the outlet works at Grand Coulee.

The following are estimates of probable TDG levels generated by the two deflector alternatives based upon the previously mentioned factors:

deflector (No. 4a), unit discharge - 250 $ft^3/s/ft$	125 to 135% (combined 121 to 123.6%)
deflector (No. 4b), unit discharge - 160 $ft^3/s/ft$	120 to 127% (combined 120 to 121.7%)

This corresponds to an 8.3 to 6.1 percent decrease in TDG for alternative No. 4a and a 9.2 to 7.6 percent decrease in TDG for alternative No. 4b compared to the existing condition.

- Alternative No. 5. - Forebay cascade - With this concept, flow would be piped from the third power plant forebay to a headwater pool with a free water surface about 10 feet above the total design discharge tailwater level. Flow would pass from this pool over an extended crest and would drop over RCC steps to the tailwater surface. Supersaturated TDG would be stripped from the flow through this action. The steps also would dissipate energy and minimize flow velocities at the tailwater surface. Throughout the probable tailwater range, each step would be limited to a 5-foot drop and would include an 30-foot run (6 to 1 ratio). This extended step is proposed to minimize plunging and establish skimming action into the tailwater pool. The performance of this design and the transition to the tailwater pool is critical to the gas transfer performance and should be model studied if pursued.

  The discharge capacity of the cascade would be 50,000 ft^3/s. The cascade would therefore replace spill for operations up to the design flow event. To minimize plunging and vertical mixing at the tailwater surface, it is proposed that the flow pass over a long weir with a large lateral extent of RCC steps. The design proposed includes a 1,000-ft-long weir which would yield a unit discharge of 50 ft^3/s. It is expected that generated supersaturation levels, depending on tailwater elevation and flow transition characteristics off of the lower steps, would range from 110 to 116 percent for the spill release. Mixed with the power plant release gives an expected combined release of 117.6 to 119 percent which is a reduction of 11 to 9.6 percent over the existing condition.

- Alternative No. 6. - Enclosed stilling basin with cascade overflow - With this concept the spillway and outlet works stilling basin is enclosed by a RCC dam. All spillway and outlet works releases are forced to pass over the dam. The design flow event of 210,000 ft^3/s would need a minimum drop of 10 feet from the top of the dam to the tailwater pool. Periphery length of the dam crest would be approximately 1800 feet. With a spill of 50,000 ft^3/s, the unit discharge over the dam would be about 28 ft^3/s which is quite small. Roughness elements such as steps or baffle piers would be included to increase turbulence levels and increase dissolved gas stripping (not shown in figure 19). This is critical noting the substantial depth of the stilling basin and the associated supersaturation levels that would be generated within the basin.

This alternative would influence all spill and outlet releases and consequently must yield satisfactory energy dissipation performance, even for the PMF. The alternative should be model studied if pursued.

As with the forebay cascade, TDG levels that result due to flow passage over the dam is dependent on the turbulent stripping generated and on the transition characteristics to the tailrace pool. Considering the relatively short overflow structure that the dam allows, there is considerable uncertainty as to what resulting TDG supersaturation levels will be generated. With an optimum design, resultant supersaturation levels of 110 to 116 percent are possible for the spill release. The alternative to enclose the stilling basin is expected to produce a TDG level of 117.6 to 118 percent in the river downstream. This is a reduction of 11 to 10.3 percent over the existing condition.

Below dam treatments

These concepts degas flow below the dam and therefore have the potential to treat both spill and power releases. As a consequence, these alternatives offer the potential not only to prevent increases in TDG due to passage through Grand Coulee Dam, but offer the potential to actually reduce supersaturation levels below the levels in Lake Roosevelt. Because these options are oriented toward treating (at least in part) power releases, the resulting structures are very large.

The general hydraulic features as described above for the free flow alternatives are equally applicable to the below dam treatments. For both of the concepts presented, the flow is passed over long crests and drop structures to reduce unit discharges and thus increase degassing rates, and increase the potential for shallow flow transitions to the tailrace. The extended step design is again employed to generate shallow, skimming flow conditions over a range of tailwater surface elevations.

- Alternative No. 7. - Widened river channel with labyrinth weir - A labyrinth weir with a downstream baffled face and transitional stepped apron to the tailwater is used to produce smaller unit discharges and degassing. A one cycle labyrinth or "V" would be configured with a baffled drop spillway across the widened river section. The labyrinth drop is sized to pass 210,000 ft^3/s, with a unit discharge of 50 ft^3/s. As a consequence, the labyrinth crest length is 4,200 feet. A baffled drop is included in the design to generate high turbulence and air entrainment levels, thus optimizing supersaturated dissolved gas stripping and reducing outfall velocities to the tailrace. Extended steps have been included as a lower apron to optimize flow transition to the tailrace over a range of tailwater elevations.

The alternative treats the entire release flow including both the spill and power releases. As a consequence, the concept supplies maximum degassing benefits. The extended step arrangement and the transition to the tailrace is critical to minimizing generated supersaturation levels. The labyrinth configuration offers potential complications with the transition. If this alternative is pursued, both general and sectional hydraulic models should be studied. It is anticipated that this structure could yield resulting dissolved gas levels (for the combined flow) ranging from 110 to 116 percent, depending on tailwater elevation. This would be a reduction of 16.8 to 12.2 percent over the existing condition.

- Alternative No. 8. - Side Channel with drop to river - Hydraulic and degassing features of this concept are much the same as the labyrinth weir concept. Flow would be supplied or diverted to a canal that runs parallel to the river. Flow would be spilled to the river from the canal over an extended side channel crest. The structure is sized for a total discharge of 100,000 ft^3/s, which is about one-half the design flow. To maintain a relatively low unit discharge of 50 ft^3/s, the required side channel crest and canal length would be 2,000 feet. The resulting combined flow TDG level reflects a dilution of the treated flow and the untreated flow.

  The side channel crest is set sufficiently high to yield a 17-foot drop to the tailwater surface when operating at the design flow of 210,000 ft^3/s. Again, a baffled drop and an extended stepped apron have been included in the design to optimize supersaturated dissolved gas stripping and flow transition to the tailrace over a range of tailwater elevations. The sectional design should be model studied if pursued.

  It is anticipated that with proper design, the side channel will generate supersaturation levels ranging from 110 to 116 percent. When mixed with the untreated flow, resulting supersaturation levels for the combined flow would range from 115.2 to 118 percent. This would be a reduction from existing TDG levels of 12.8 to 10.3 percent.

<u>Summary of expected TDG performance</u>

The following table summarizes the expected TDG performance of the existing hydraulic condition and each of the alternatives. These values are all based on the previously discussed assumptions regarding the reservoir TDG level, the spill and power plant discharge ratio, and tailwater elevations.

Where ranges in TDG percentage is given, the value will depend upon the depth of plunge into the tailwater. Ideal design of this alternative will produce TDG values that approach the minimum levels. The TDG percentage for each alternative, including the spillway flow of the existing condition, is compared to the outlet works spill of the existing condition as a worst case.

Note that the spill percentage varies with alternative No. 8 because approximately half the water is being treated by the side channel structure.

Table 6. - Expected TDG performance of the existing structure and each alternative.

Alternative No.	Discharge Values				TDG%		Total Combined TDG%	Percent Difference in TDG%
	Power kcfs	Outlet Spill		Spillway Spill kcfs	Power	Spill		
		kcfs	cfs/ft					
Existing Condition	160	50	250	0	120	171	132.14	0.00
Existing Condition	160	0	0	50	120	138	124.29	5.9
1	160	50	300	0	120	120	120	9.2
2	160	50	150	0	120	120	120	9.2
3	160	50	300	0	120	120	120	9.2
4a	160	50	250	0	120	125-135	121.2-123.6	8.3 - 6.1
4b	160	50	160	0	120	120-127	120-121.7	9.2 - 7.6
5	160	50	50	0	120	110-116	117.6 - 119	11 - 9.6
6	160	50	28	0	120	110-116	117.6-118	11 - 10.3
7	160	50	50	0	120	110-116	110-116	16.8 - 12.2
8	110	100	50	0	120	110-116	115.2-118	12.8 - 10.3

Insight into the expected performance of the alternative with respect to its known ability to abate the TDG can be separated by the category of the alternative. Submerged alternatives provide good confidence that the lake's TDG can be transferred with no increase during spill. Free flow alternatives that deal with reduction of TDG during spill off the face of the dam produce the least amount of confidence (i.e. deflectors). The alternatives that degas in the forebay area or in the river provide an average level of confidence.

Looking into the future of the Canadian water quality issue, obviously, the transfer alternatives will simply pass hopefully improved water quality downstream. The potential would exist for the other alternatives to have enhanced performance with somewhat lower TDG levels in the lake and/or mixing with transferred power releases that are lower.

The advantages and disadvantages of each alternative and their relative ranking with respect to each other are discussed in the remaining sections.

Advantages and Disadvantages

The following tables provide basic comparison of the ability to construct the alternative, its potential for TDG abatement, potential for lost power revenues, etc.

Table 7. - Advantages and disadvantages of alternative No. 1.

No.	Alternative	Advantages	Disadvantages
1	Reactivate low level o.w.	• transfers TDG • adds capacity to dam • conduit is already bored • no lifetime power loss	• relocate power cables • new gates/controls needed • concrete waste removal and new concrete delivery • not meant for operation under high head • cavitation potential • documented poor flow conditions • high downstream cofferdam • upstream bulkhead problems • large amount of work performed in dam • access and space difficult

Table 8. - Advantages and disadvantages of alternative No. 2.

No.	Alternative	Advantages	Disadvantages
2	Extend o.w. @ el. 1050 for submerged release.	• Transfers TDG • easy construction, 2nd to deflectors • minimum dewatering • no lifetime power loss	• 105-ft-high cofferdam • disposal of excavated concrete • access by barge or scaffolding • concrete pumped or trammed • need to study energy dissipation

Table 9. - Advantages and disadvantages of alternative No. 3.

No.	Alternative	Advantages	Disadvantages
3	Pipe through forebay dam.	• Transfer TDG • minimal disruption to operation • potential to add power • minimal cofferdam • good construction access • no disruption to releases	• previously never designed jet flow gate • lose North service yard • large tunneling/excavation needed

Table 10. - Advantages and disadvantages of alternative No. 4a.

No.	Alternative	Advantages	Disadvantages
4a	Outlet works deflectors - 10 outlets.	• reduce spill TDG production • easiest to construct • no impact to power • small cofferdam attached to face • pass flow through o.w. not under construction • precedence	• barge or scaffold work • pump or tram concrete • structurally designed for PMF • minimal certainty about TDG performance due to tailwater fluctuations • least TDG abatement potential • potential influence on spillway operation

Table 11. - Advantages and disadvantages of alternative No. 4b.

No.	Alternative	Advantages	Disadvantages
4b	Outlet works deflectors - 40 outlets.	• same as 4a, except more installed which would lower unit discharge, thus enhance TDG abatement • no lifetime power loss	• same as 4a except more deflectors installed • gates and operators replaced for partial opening • minimal certainty about TDG performance due to tailwater fluctuations

Table 12. - Advantages and disadvantages of alternative No. 5.

No.	Alternative	Advantages	Disadvantages
5	Forebay cascade	• low unit q • degas • construction access reasonably good • minimal cofferdam • potential for new power production • additional capacity obtained	• major construction will take entire area • lose north service yard • similar to No. 3

Table 13. - Advantages and disadvantages of alternative No. 6.

No.	Alternative	Advantages	Disadvantages
6	Enclosed stilling basin.	• reduce TDG production from all spill • proven dam construction technique	• temporarily take 4 to 6 units out of service • permanently take 4 units out of service • large cofferdam • foundation adequate? • reduction of flood capacity during construction • basin not self-cleaning • possible hydraulic concerns

Table 14. - Advantages and disadvantages of alternative No. 7.

No.	Alternative	Advantages	Disadvantages
7	Widen river with labyrinth and gates.	• only option with potential for good degas benefit for entire flow • lifetime power loss during spill season	• lost power $1.4 m/ft of head loss/year • long weir • cofferdams and river diversion structure • huge excavation • bank stabilization • baffled apron drop and d/s stepped apron needed to achieve performance • large Obermeyer gates across river ever constructed • possible mitigation • large waste area needed • blocks river access

Table 15. - Advantages and disadvantages of alternative No. 8.

No.	Alternative	Advantages	Disadvantages
8	Side channel with drop to river.	• medium-sized cofferdam • treats ½ the total flow, thus 2nd best TDG abatement	• tailwater fluctuation • dedicate 3 units in 3rd power plant to supply flow • lost power estimated at 20%/year out of the 3 units • space/location problem along river • large excavation

ALTERNATIVE COMPARISON

Table 16 contains a summary of the alternatives with their TDG benefit and total cost (both for one time construction and life cycle). In addition, the combined ranking of the alternative is the TDG ranking multiplied by the cost ranking. In general, the more TDG benefit the higher the cost. Further detail regarding the cost per alternative may be found in the appendix with the estimate sheets for each alternative.

These are general cost estimates to give a comparison between the outlined alternatives. The confidence in these costs is much lower than traditional conceptual-level cost estimates, even to the point of going with experience and judgment where the magnitude of the cofferdams is concerned.

Table 16. - Ranking of alternatives considering TDG benefit, impact on power, and cost.

No.	Alternative	Expected Combined TDG percent	TDG Ranking	Cost (millions)	Construction Power Loss	Life Time Power Loss	Cost Ranking
1	Reactivate low level o.w.	120	5*	99	YES	NO	3
2	Extend and cover mid level o.w.	120	5*	24	NO	NO	2
3	Pipe through forebay dam	120	5*	270	YES	NO	6
4a	Add 10 o.w. deflectors	121.2-123.6	7	15.5	NO	NO	1
4b	Add 40 o.w. deflectors	120-121.7	6	135	NO	NO	4
5	Forebay cascade	117.6-119	4	340	YES	NO	7
6	Enclosed stilling basin	117.6-118	3	145	YES	YES	5
7	Widen river channel with labyrinth	110-116	1	460	YES	YES	8
8	Side channel with drop to river	115.2-118	2	550	YES	YES	9

* All transfer alternatives (submerged releases) should provide the same level of TDG abatement.

As might be expected, alternative No. 7 to widen the river and treat all the design flow is the alternative that has the best potential for meeting the state water quality standard and is the best option to abate the TDG levels. Unfortunately, this alternative is also the second most expensive alternative, only less expensive than the side channel alternative No. 8.

In addition, alternative No. 4a to add deflectors below 10 of the mid-level outlet works is projected to be the least effective TDG alternative. This alternative is also the least expensive.

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(1) Johnson, P. L., "Prediction of Dissolved Gas at Hydraulic Structures," USBR, GR-8-75, July 1975.

(2) Frizell, Kathleen H., "Dissolved Gas Supersaturation Study for Grand Coulee Dam," USBR, PAP-724, March 1996.

(3) Frizell, Kathleen H., "Grand Coulee Dam Total Dissolved Gas Tests Outlet Works Test Results," Progress Report, May 1997.

(4) US Army Corps of Engineers, Dissolved Gas Abatement, Phase I, Technical Report. April 1, 1996.

(5) US Army Corps of Engineers, Dissolved Gas Abatement, Phase II, Technical Report, 30 percent draft, March 1997.

APPENDIX

Advantages and Disadvantages of Alternatives Not Carried Forward

Upon completion of the brainstorming session, all ideas were discussed with respect to TDG benefit, feasibility of construction, power generating concerns, and acceptability. The alternatives were not discarded due to overall cost. Alternatives were discarded based upon relative comparison between alternatives, i.e. alternative E would give comparable TDG benefit to alternative H for much less cost. This was a quick process and did not involve any laborious calculations; only approximate numbers and judgment. The items listed in table A1 are all the ideas developed during the spontaneous brainstorming session and were developed from the notes taken during that time.

Table A1. Full listing of brainstormed ideas with advantages and disadvantages listed.

No.	Alternative	Advantages	Disadvantages
A.	Abandon power plant units for submerged flow.	• transfers TDG • precedent for doing this • could be inexpensive	• large power loss with about 10 in old pp or 2 in 3rd pp
B.	Bifurcate off existing penstocks for submerged flow.	• transfers TDG	• geometry of old pp won't work • large power loss when in use • complicated geometry if units can even remain on line
C.	Reactivate lower outlets (el. 950) submerged flow.	SEE CARRIED FORWARD ALTERNATIVE	
D.	Baffled apron-type structure on dam face with free surface flow.	• could reduce production of TDG • cause turbulence and jet break up	• cavitation potential • high flow problems structurally • still need terminal structure
E.	Cover and extend outlet works conduits down face of dam for submerged flow.	SEE CARRIED FORWARD ALTERNATIVE	
F.	Flare release from outlet works to achieve smaller unit discharge, add flip bucket, spreader, raised crown, splitter, combine paired tunnels.	• could reduce TDG production • could combine with other alternative	• probably won't spread as much as anticipated • cavitation potential • redesign of eyebrows
G.	Deflectors or flip lips to produce skimming flow.	SEE CARRIED FORWARD ALTERNATIVE	

No.	Alternative	Advantages	Disadvantages
H.	New outlet works through dam where there are currently no outlets on left side of dam.	• transfer • potentially easier than reactivating lower level o.w. • adds capacity	• 10 outlets needed to be bored through dam • dewater u/s and d/s • more expensive than extending existing o.w. for submerged releases • reservoir level restricts location
I.	Drop elevation of a few spillway bays to lower than el. 1260. Free flow.	• would reduce TDG production • would replace o.w. spill	• might need to dedicate 4 bays to flow • very large gates, high velocities • baffles/stepped needed • terminal structure needed • cofferdam/dewatering huge • PMF concerns if limit flow to TDG spill only • construction access poor - 3 yrs
J.	Unhooded Howell Bunger valves attached to end of existing o. w. at el. 1050. Free flow.	• degas to saturation • extreme jet break up	• spray! • ice! Either could damage power lines, buildings, etc • must excavate out o.w. conduits to recess valves for spillway flow • impractical
K.	Stepped spillway on dam face to break up jet - below outlet works only - Below spillway gates on entire face. Free surface flow.	• degas spill • breaks jet	• not enough fall to be effective on o.w. also high velocities • cavitation potential • limited use for spillway flows
L.	Flow over left and/or right power plant sections with submerged or free flow.	• transfers submerged • degas spill if free	• no room inside blocks to perform submerged release alternative • flow over would interrupt pp use • relocate transmission lines • more complex than other alternatives
M.	Combination of baffled apron/lower elevation of existing spillway/flips.	• reduce spill TDG levels • concepts combined with other alternatives	• complex
N.	Pipe through forebay dam abutment for submerged flow.	SEE CARRIED FORWARD ALTERNATIVE	

No.	Alternative	Advantages	Disadvantages
O.	Left-side abutment pipe for submerged release.	• transfers gas	• pumping plant interference • town interference • left power plant interference • construction access • longer pipe than 3rd pp forebay side
P.	Cascade release from forebay dam through abutment by 3rd power plant. Free flow.	SEE CARRIED FORWARD ALTERNATIVE	
Q.	Install additional power plant by forebay dam for submerged flow.	• additional power and Q obtained	• not all power used now • other submerged release alternatives less expensive
R.	Elevated tailrace in the river.	• treat all the water • creates shallow free surface flow	• not reliable structurally during higher flows • lose power revenue life time • huge quantities of fill • high velocities • no entrained air bubbles in flow after stilling basin • huge cofferdam • huge cost
S.	Elevated tailrace immediately below the stilling basin.	• creates shallow free surface flow • reduce TDG production	• treats spill only • not reliable structurally during higher flows • cofferdam • channel stability • other alternatives better from a TDG standpoint
T.	*Build low head structures with low unit q in the river channel, such as baffle drop, rock cascades, labyrinths, infusers.	• treat all the water • creates shallow free surface flow • incorporated into other alternatives in some manner	• lose power revenue • huge structures • $21 million lost power with 15 ft of head
U.	Raised basin - Fill in roller bucket spillway with horizontal apron. Create shallow free surface flow.	• creates shallow free surface flow • reduce production	• treats spill only • potential for extremely poor energy dissipation, downstream apron likely • replunging downstream of basin likely • cofferdam • PMF problem • high velocities • minimal gas benefit

No.	Alternative	Advantages	Disadvantages
V.	*Inject microbubbles into stepped spillway surface water.	• degas	• must be used with shallow depth option • unknown performance • power demand high • couldn't use air because under pressure would transfer more gas into flow • possibly pure oxygen needed
W.	*Widen river with other structures.	SEE CARRIED FORWARD ALTERNATIVE	
X.	*Widen river with piers for turbulence.	• creates shallow free surface flow	• huge excavation needed • huge cofferdam • no air bubbles or high enough velocity in flow
Y.	*Create bends in the river.	• potentially create turbulence and mixing of flow to strip gas	• huge excavation needed • huge cofferdam • no air bubbles or high enough velocity in flow
Z.	*Channelize and bend river.	• potentially create turbulence and mixing of flow to strip gas	• huge excavation needed • huge cofferdam • no air bubbles or high enough velocity in flow
AA.	*Pump and/or flood side channel along river and drop to river with free flow.	SEE CARRIED FORWARD ALTERNATIVES	
BB.	*Aerators - fountains	• degasses all or a portion of the water depending upon the number used about 115% • Mixing pp ½ & ½ • Can add more or disband fairly easily	• need thousands of them • O&M problems • anchorage problem for high flows • power cost would be significant, 30-35,000 hp @ 10 psi, Q=100,000 cfs • Piping for system
CC.	Enclose roller bucket energy dissipater with walls and gradient drop.	SEE CARRIED FORWARD ALTERNATIVES	

No.	Alternative	Advantages	Disadvantages
DD.	Construct a selective withdrawal system in reservoir to withdraw from higher levels - less saturation in summer months.	• reduce saturation of withdrawn water • proven technology	• only effective during summer months when reservoir is temperature stratified
EE.	Construct a barrier at the entrance to the 3rd power plant forebay to release less saturated flow in the summer. curtain, stoplog, fill, etc.	• transfers TDG • could be relatively inexpensive	• only effective during summer months when reservoir is temperature stratified
FF.	Strip TDG in reservoir with introduction of microbubbles of pure oxygen.	• degas	• transfer is slow • must be in conjunction with other structure • power demand high • unproven • pure oxygen
GG.	Introduce blue-green algae to change composition of N_2 to organic forms thus reducing TDG.	• non-structural • degas reservoir, thus all releases	• could be aesthetically unattractive • in summer only therefore limited benefit
HH.	Develop Las Vegas Grand Coulee or other power hungry business causing increased power demand to eliminate spill.	• good for local economy • would make money in the long run	• not likely • doesn't address problem
II.	Buy out net pen operator.	• potentially inexpensive	• doesn't address the problem
JJ.	Lower net pens/fish to bring TDG levels closer to equilibrium.	• fish have less exposure to high TDG levels	• doesn't address the problem
KK.	Shift power in system to Grand Coulee.	• reduce spills at Grand Coulee, thus reducing gas production	• could cause other problems in system operation

No.	Alternative	Advantages	Disadvantages
LL.	Mitigation payments every 5-6 years with fines for violating TDG levels about $10,000/day.	• could potentially be inexpensive	• doesn't address the problem

Cost Estimate Sheets

Initial cost estimates were prepared for each alternative based upon the brief assessment of the elements, quantities, and intangible elements involved with each alternative. The total cost from these sheets was used to rank the alternatives from a cost standpoint.

)DE: D-8170 **ESTIMATE WORKSHEET** SHEET ____ OF ____

FEATURE: 04-Feb-98 Grand Coulee Dam Total Dissolved Gas Study Alternative Reactivate Existing Low Level OW	PROJECT: Columbia River Project DIVISION: FILE: C:\FILE-JOB\GRANDCOU\BRAINTDG\GCD-ALL.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Diversion - This will be a barge operation			LS		$12,000,000.0(
		Cofferdam is approx. 1000 tons					
		Remove and relocate transmission lines			LS		$16,000,000.0(
		Remove concrete and embedded 102"steel pipe		3550	CY	$1,500.00	$5,325,000.0(
		Install 102" dia. Ring Follower Gates		3400000	LB	$8.00	$27,200,000.0(
		Install 102" dia. steel pipe		331500	LB	$2.00	$663,000.0(
		Concrete		3200	CY	$400.00	$1,280,000.0(
		Reinforcement		532500	LBS	$0.60	$319,500.0(
		Cement		900	TONS	$100.00	$90,000.0(
		Mobilization					$3,100,000.0(
		Subtotal					$65,977,500.0(
		Unlisted Items	+/- 15%				$10,022,500.0(
		Contract Cost					$76,000,000.0(
		Contingencies	+/- 30%				$23,000,000.0(
		Field Cost					$99,000,000.0(
		Estimates may not include all construction considerations.					

QUANTITIES		PRICES	
)Y **rnie Hall**	**CHECKED**	**BY** **Keith Copeland**	**CHECKED**
)ATE PREPARED **01/29/98**	**APPROVED**	**DATE** **02/04/98**	**PRICE LEVEL** **Concept**

EATURE: 04-Feb-98 Grand Coulee Dam Total Dissolved Gas Study Alternative Extend Mid-level OW to El. 930.0	PROJECT: Columbia River Project DIVISION: UNIT: C:\FILE-JOB\GRANDCOU\BRAINTDG\GCD-ALL.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Diversion - This will be a barge operation			LS		$5,000,000.00
		Cofferdam is approx. 1000 tons					
		Excavation - Concrete on downstream Face		9800	CY	$600.00	$5,880,000.00
		Sawcut		1725	LF	$15.00	$25,875.00
		Install 102" dia. steel pipe		1021000	LB	$1.50	$1,531,500.00
		Concrete		6600	CY	$350.00	$2,310,000.00
		Reinforcement		990000	LBS	$0.60	$594,000.00
		Cement		1900	TONS	$100.00	$190,000.00
		Mobilization					$780,000.00
		Subtotal					$16,311,375.00
		Unlisted Items	+/- 15%				$2,688,625.00
		Contract Cost					$19,000,000.00
		Contingencies	+/- 30%				$5,000,000.00
		Field Cost					$24,000,000.00
		Estimates may not include all construction considerations.					

QUANTITIES		PRICES	
BY **Ernie Hall**	**CHECKED**	**BY** **Keith Copeland**	**CHECKED**
DATE PREPARED **1/29/98**	**APPROVED**	**DATE** **02/04/98**	**PRICE LEVEL** **Concept**

CODE: D-8170 **ESTIMATE WORKSHEET** SHEET ____ OF ____

FEATURE: 04-Feb-98	PROJECT: Columbia River Project
Grand Coulee Dam Total Dissolved Gas Study Alternative Pipe through end of Forebay dam (Transfer option, 50,000 cfs)	DIVISION:
	FILE: C:\FILE-JOB\GRANDCOU\BRAINTDG\GCD-ALL.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Diversion -		1	LS		$12,000,000.00
		1600 ft cofferdam by 20 foot high for stilling basin					
		45000 cy cofferdam fill material					
		250 foot wide by 120 foot tall sheetpile cofferdam in the forebay					
		3000 tons of steel and 135,000 cy gravel fill					
		Excavation - common in stilling basin		1,565,000	CY	$5.00	$7,825,000.00
		Excavation - Rock		100,000	CY	$160.00	$16,000,000.00
		Waste excess excavation		1,500,000	CY	$2.00	$3,000,000.00
		Backfill for service yard & access		150,000	CY	$7.00	$1,050,000.00
		Concrete - Forebay		8,800	CY	$300.00	$2,640,000.00
		Concrete - pipe		10,000	CY	$350.00	$3,500,000.00
		Concrete - control house & around jet flow		5,200	CY	$300.00	$1,560,000.00
		Concrete - stilling basin		50,000	CY	$275.00	$13,750,000.00
		Reinforcement		740,000	LBS	$0.60	$444,000.00
		Cement		21,000	TONS	$100.00	$2,100,000.00
		Steel Penstock - 40 feet diameter, 1350 lf		16,000,000	LBS	$1.50	$24,000,000.00
		Wheel mounted roller gate		3,700,000	LBS	$5.00	$18,500,000.00
		Jet Flow Gate		8,000,000	LBS	$7.50	$60,000,000.00
		Hoists and misc metal work		600,000	LBS	$6.00	$3,600,000.00
		Mobilization					$8,500,000.00
		Subtotal					$178,469,000.00
		Unlisted Items	+/- 15%				$31,531,000.00
		Contract Cost					$210,000,000.00
		Contingencies	+/- 30%				$60,000,000.00
		Field Cost					$270,000,000.00
		Estimates may not include all construction considerations.					

QUANTITIES		PRICES	
BY Pitsy Cohen	**CHECKED**	**BY** Keith Copeland	**CHECKED**
DATE PREPARED Jan 30, 1998	**APPROVED**	**DATE** 02/04/98	**PRICE LEVEL** Concept

ODE: D-8170 | **ESTIMATE WORKSHEET** | SHEET ____ OF ____

FEATURE: 04-Feb-98 Grand Coulee Dam Total Dissolved Gas Study Alternative 12.5- by 12.5-foot 15-Foot R Deflector	PROJECT: Columbia River Project DIVISION: UNIT: C:\FILE-JOB\GRANDCOU\BRAINTDG\GCD-ALL.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Diversion - This will be a barge operation			LS		$2,200,000.0
		Cofferdam is 40'x50'highx110'long(approx. 100 tons)					
		Excavation - Concrete on downstream Face		1500	CY	$600.00	$900,000.0
		Excavation - Concrete around regulating gates		6700	CY	$600.00	$4,020,000.0
		Surface Preparation		4000	SY	$9.00	$36,000.0
		Sawcut		2100	LF	$15.00	$31,500.0
		Drilling (2" dia.)		5300	LF	$25.00	$132,500.0
		Concrete - on downstream face		5500	CY	$350.00	$1,925,000.0
		Concrete - around gates		6700	CY	$350.00	$2,345,000.0
		Reinforcement		1800000	LBS	$0.60	$1,080,000.0
		Dowels		57000	LBS	$0.70	$39,900.0
		Cement		1600	TONS	$100.00	$160,000.0
		Remove 40 102-inch Ring Seal Gates & Bonnets		6800000	LB	$1.00	$6,800,000.0
		each gate is 170,000 lbs					
		Install 40 new 102 Jet Flow Gates		8800000	LB	$7.50	$66,000,000.0
		each gate is 220,000 lbs					
		Mobilization					$4,300,000.0
		Subtotal					$89,969,900.0
		Unlisted Items	+/- 15%				$15,030,100.0
		Contract Cost					$105,000,000.0
		Contingencies	+/- 30%				$30,000,000.0
		Field Cost					$135,000,000.0
		Estimates may not include all construction considerations.					

QUANTITIES		PRICES	
BY **Bitsy Cohen**	**CHECKED**	**BY** **Keith Copeland**	**CHECKED**
DATE PREPARED **1/29/98**	**APPROVED**	**DATE** **02/04/98**	**PRICE LEVEL** **Concept**

)DE: D-8170 **ESTIMATE WORKSHEET** SHEET ____ OF ____

FEATURE: 04-Feb-98 Grand Coulee Dam Total Dissolved Gas Study Alternative 30- by 30-foot by 50-foot R Deflectors	PROJECT: Columbia River Project DIVISION: UNIT: C:\FILE-JOB\GRANDCOU\BRAINTDG\GCD-ALL.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Diversion - This will be a barge operation					$1,500,000.0(
		Cofferdam is 40'x50'highx110'long(approx. 100 tons)					
		Excavation - Concrete on downstream Face		3000	CY	$600.00	$1,800,000.0(
		Surface Preparation		4500	SY	$9.00	$40,500.0(
		Sawcut		900	LF	$15.00	$13,500.0(
		Drilling		4600	LF	$25.00	$115,000.0(
		Concrete - on downstream face		13700	CY	$350.00	$4,795,000.0(
		Reinforcement		2100000	LBS	$0.60	$1,260,000.0(
		Dowels		50000	LBS	$0.70	$35,000.0(
		Cement		3900	TONS	$100.00	$390,000.0(
		Mobilization					$500,000.0(
		Subtotal					$10,449,000.0(
		Unlisted Items	+/- 15%				$1,551,000.0(
		Contract Cost					$12,000,000.0(
		Contingencies	+/- 30%				$3,500,000.0(
		Field Cost					$15,500,000.0(

QUANTITIES		PRICES	
BY **Bitsy Cohen**		**BY** **Keith Copeland**	**CHECKED**
DATE PREPARED **Jan 29, 1998**	**APPROVED**	**DATE** **02/04/98**	**PRICE LEVEL** **Concept**

ODE: D-8170 **ESTIMATE WORKSHEET** SHEET ____ OF ____

FEATURE: 04-Feb-98

Grand Coulee Dam
Total Dissolved Gas Study
Alternative
Forebay Cascade (50,000 cfs)

PROJECT:
Columbia River Project

DIVISION:

UNIT:
C:\FILE-JOB\GRANDCOU\BRAINTDG\GCD-ALL.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Diversion -			LS		$15,000,000.0
		1400 ft cofferdam by 20 foot high for stilling basin					
		4000 Tons steel & 47000 cy fill material					
		140 foot wide by 110 foot tall sheetpile cofferdam in the forebay					
		3000 tons of steel and 120,000 cy gravel fill					
		Excavation - rock (tunnel & shaft)		110,000	CY	$160.00	$17,600,000.0
		Excavation - open cut for Stilling basin		127,000	CY	$6.00	$762,000.0
		Waste excess materials		150,000	CY	$2.00	$300,000.0
		Backfill (around Penstocks in service yard & access)		90,000	CY	$3.50	$315,000.0
		Concrete - Forebay		8,800	CY	$300.00	$2,640,000.0
		Concrete - around Penstocks and for shaft		15,000	CY	$325.00	$4,875,000.0
		Concrete for Top seal radial gate		40,000	CY	$275.00	$11,000,000.0
		Concrete - RCC		154,000	CY	$40.00	$6,160,000.0
		Concrete - Structural		90,000	CY	$225.00	$20,250,000.0
		Cement		30,000	TONS	$100.00	$3,000,000.0
		Reinforcement		900,000	LBS	$0.60	$540,000.0
		Steel Penstock (40 foot diameter, 2970 lf)		35,000,000	LBS	$1.40	$49,000,000.0
		Wheel Mounted roller gate		3,700,000	LBS	$6.00	$22,200,000.0
		Top Seal Radial Gate		8,500,000	LBS	$7.00	$59,500,000.0
		Hoist and misc metal work		600,000	LBS	$6.00	$3,600,000.0
		Mobilization					$11,000,000.0
		Subtotal					$227,742,000.0
		Unlisted Items	+/- 15%				$32,258,000.0
		Contract Cost					$260,000,000.0
		Contingencies	+/- 30%				$80,000,000.0
		Field Cost					$340,000,000.0
		Estimates may not include all construction considerations.					

QUANTITIES		PRICES	
BY Bitsy Cohen	**CHECKED**	**BY** Keith Copeland	**CHECKED**
DATE PREPARED Jan 30, 1998	**APPROVED**	**DATE** 02/04/98	**PRICE LEVEL** Concept

DDE: D-8170 **ESTIMATE WORKSHEET** SHEET ____ OF ____

FEATURE: Grand Coulee Dam Total Dissolved Gas Study Alternative Enclose Roller Bucket with RCC dam	04-Feb-98	PROJECT: Columbia River Project
		DIVISION:
		UNIT: C:\FILE-JOB\GRANDCOU\BRAINTDG\GCD-ALL.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Diversion - Major diversion structure			LS		$75,000,000.00
		40,000 tons of steel for walls					
		2,000,000 cubic yards gravel for inside cells					
		mobilization					
		Dewatering			LS		$100,000.00
		Draining the stilling basin (est 1500 AF water)			LS		$200,000.00
		Excavation - Rock		121500	CY	$15.00	$1,822,500.00
		Concrete - RCC dam 85 ft high & 2050 Ft long		550000	CY	$30.00	$16,500,000.00
		½ to 1 upstream slope, 1 to 1 downstream slope					
		This option would remove two units from each of the					
		left and right powerhouses permanently from service					
		(total 4 units removed permanently from service)					
		Mobilization					$4,700,000.00
		Subtotal					$98,322,500.00
		Unlisted Items	+/- 15%				$16,677,500.00
		Contract Cost					$115,000,000.00
		Contingencies	+/- 30%				$30,000,000.00
		Field Cost					$145,000,000.00
		Estimates may not include all construction considerations.					

QUANTITIES		PRICES	
BY Bitsy Cohen		**BY** Keith Copeland	**CHECKED**
DATE PREPARED Jan 29, 1998	**APPROVED**	**DATE** 02/04/98	**PRICE LEVEL** Concept

FEATURE: 04-Feb-98	PROJECT: Columbia River Project
Grand Coulee Dam Total Dissolved Gas Study Alternative Labyrinth Weir - Widen River Channel	DIVISION: UNIT: C:\FILE-JOB\GRANDCOU\BRAINTDG\GCD-ALL.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Diversion			LS		$75,000,000.00
		Excavate for gate structure		475000	CY	$5.00	$2,375,000.00
		Excavate above el. 970 and waste		22000000	CY	$4.00	$88,000,000.00
		Excavate el. 952 to 970 and waste		1400000	CY	$5.00	$7,000,000.00
		Excavate for weir el. 946 to 970 and waste		3400000	CY	$5.00	$17,000,000.00
		Cement		110000	TONS	$100.00	$11,000,000.00
		Concrete		42000	CY	$200.00	$8,400,000.00
		Reinforcement		6300000	LBS	$0.60	$3,780,000.00
		Place RCC		685000	CY	$25.00	$17,125,000.00
		Filter drain material		25000	CY	$25.00	$625,000.00
		Obermeyer Gates			LS		$63,000,000.00
		Riprap		7000	CY	$35.00	$245,000.00
		Mobilization					$15,000,000.00
		Subtotal					$308,550,000.00
		Unlisted Items	+/- 15%				$41,450,000.00
		Contract Cost					$350,000,000.00
		Contingencies	+/- 30%				$110,000,000.00
		Field Cost					$460,000,000.00
		Estimates may not include all construction considerations.					

QUANTITIES		PRICES	
BY Steve Young	CHECKED	BY Keith Copeland	CHECKED
DATE PREPARED 1/29/98	APPROVED	DATE 02/04/98	PRICE LEVEL Concept

CODE: D-8170

ESTIMATE WORKSHEET

SHEET ____ OF ____

FEATURE: 04-Feb-98	PROJECT:
Grand Coulee Dam Total Dissolved Gas Study Alternative Side Channel Option (100,000 cfs)	Columbia River Project
	DIVISION:
	UNIT: C:\FILE-JOB\GRANDCOU\BRAINTDG\GCD-ALL.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Diversion - Cellular Cofferdam			LS		$17,000,000.00
		9000 tons Sheetpile + 285,000 cy gravel					
		Excavation - Stilling basin		650,000	CY	$6.00	$3,900,000.00
		Excavation - pipes		1,000,000	CY	$3.00	$3,000,000.00
		Waste excess materials		1,100,000	CY	$2.00	$2,200,000.00
		Backfill (around Pipes)		560,000	CY	$3.50	$1,960,000.00
		Concrete - Structural		137,000	CY	$250.00	$34,250,000.00
		Concrete - around Pipes		80,000	CY	$275.00	$22,000,000.00
		Concrete - RCC		235,500	CY	$35.00	$8,242,500.00
		Cement		50,000	TONS	$100.00	$5,000,000.00
		Reinforcement		1,400,000	LBS	$0.60	$840,000.00
		Penstocks (16,800 LF @ 11600 lbs/lf)		200,000,000	LBS	$1.25	$250,000,000.00
		Mobilization					$17,500,000.00
		Subtotal					$365,892,500.00
		Unlisted Items	+/- 15%				$54,107,500.00
		Contract Cost					$420,000,000.00
		Contingencies	+/- 30%				$130,000,000.00
		Field Cost					$550,000,000.00
		Estimates may not include all construction considerations.					

QUANTITIES		PRICES	
BY **Bitsy Cohen**	**CHECKED**	**BY** **Keith Copeland**	**CHECKED**
DATE PREPARED **Jan 30, 1998**	**APPROVED**	**DATE** **02/04/98**	**PRICE LEVEL** **Concept**

More Detailed Construction Concerns for Carried Forward Alternatives

Most of these comments have been incorporated into the advantages and disadvantages of each alternative and were reviewed to ensure that the cost estimates included all the items mentioned.

<u>No. 1 - Reactivate low level outlet works</u>

1) Dewatering under 300'± of head inside trash racks on upper end. Barge.
2) Removal and relocation of power cables in conduits.
3) Dewatering at lower end ≈ 90' of head - caissons. Barge.
4) New gates needed.
   A) Removal of old gates and frames.
   B) Concrete removal for new gate installation.
   C) Fitting new gates into gate chamber.
   D) Controls/automation for new gates.
   E) Same type or different gates.
5) Fill concrete removal.
   A) Ventilation - expanded air flow needed?
   B) Demolition equipment access.
   C) Concrete debris removal process.
6) Redo of conduit in fill concrete area.
   A) Repair lining.
   B) Replace lining.
7) Inspect and repair downstream conduit.
8) Vane installation in downstream conduit.
9) Concrete in conduits, how delivered?
10) Drainage issues in reestablished conduits.

<u>No. 2 - Extend and cover mid level outlet works</u>

1) Difficult access and work area on .8:1 slope. Lots of scaffolding needed.
2) Barge needed.
3) Tram for concrete or close road.
4) Excavation of existing concrete will be very deep in order to cover the bend in the new pipe to the extent needed to counteract bend forces. Also to eliminate two bends?
5) Removal of excavated concrete including protection of stilling basin.
6) Less depth of dewatering on lower end.
7) Gate replacement to accommodate multiple gate positions. Same gate/concrete concerns as extending lower outlets
8) New "brows."
9) Minimal dewatering. Easily sectioned off.
10) New pipe positioning and installation may require equipment mounted on barge or face of dam.
11) Interference with power plant discharges. Outages?
12) Seepage from upper gates.

<u>No. 3 - Pipe through forebay</u>

1) Hot tap - no.
2) Cast in place pipe or tunnel.
3) Dewatering both ends, less head on inlet (140'). Caissons. Large area at inlet.
4) Service yard and road affected. Power line?

5) Concrete batching and transportation to placement. Pump or tram.
6) Trashrack needed with inlet structure.
7) Interference with third power plant releases could impact downstream dewatering.
8) What is cross section of forebay end? Will it require additional structural work due to addition of a large hole. 50' dia.
9) Downstream dewatering and exit structure.
10) Exposed pipe on surface. Anchor details.
11) Large gates and operators. Power required.
12) Interference with power plant discharges. Outages?

Nos. 4a and 4b - Outlet works deflectors

1) Many of the same concerns as extending mid level outlet pipes.
2) Concerns over stability in major flood.

No. 5 - Forebay Cascade

1) Access for heavy equipment.
2) Lots of concrete.
3) Lots of excavation.
4) Gates.
5) Interference with existing installations.
6) Disposal of materials.
7) Interference with third power plant release.

No. 6 - Enclose stilling basin

No comments at this time.

No. 7 - Widen river with labyrinth

1) Major dewatering in excavation area and for labyrinth.
2) Replace wetlands.
3) Major concrete in labyrinth.
4) Disposal of material from excavation. How far? How wet?
5) Foundation of labyrinth.
6) River bank stability.
7) Riprap along river.
8) River diversion.
9) Access to and from site for heavy equipment.
10) Public access and fishing.
11) Tram for concrete.

No. 8 - Side channel spill

1) Same concerns as widening the river.
2) Very major pumping plant needed or other power source.
3) Switchyard needed.
4) Lots of concrete.