# MURPHY CREEK

## Investigative Plan Template

## Section A: Project overview

### Project, size and purpose

Murphy Creek Power Corp. (MCPC) proposes to build, own and operate a 275 MW powerplant. This will be primarily a run of river plant, with a small head pond to regulate flows.

### Location, project history and main features

The location will be Murphy Creek, on the Columbia River, at the Town of Oasis, approximately 3.2 km (2 miles) upstream from the City of Trail. The site is about 35 km (21 miles) downstream of the Keenleyside Dam on the Columbia River and about 25 km (15 miles) downstream of the Brilliant Dam on the Kootenay River. It is about 33 km (20 miles) from the US border. The location is illustrated in Figure 1.

MCPC took over the proposed project from North Pacific Power Corporation (NPPC), a wound-up company that was working with Bechtel. The NPPC/Bechtel partnership updated some of the initial work done by BC Hydro in the nineteen seventies and eighties. BC Hydro designed the dam to a preliminary level to optimize the outputs in the Kootenay/Columbia dam system. In all, at least fourteen background and feasibility studies have been done on the site and its hydrographical, geotechnical, topographical and other considerations. These were reflected in a concept-level design dam.

In 2003, MCPC adopted a refinement developed by Bechtel, to use a hydrocombine design, similar to that of the successful Wells dam on the mid-Columbia system between Chief Joseph and Rocky Ridge Dams. This proven design, which incorporates the spillway and powerhouse into a single structure, should be friendlier to fish and less disruptive than a dam with a separate spillway.

The reservoir surface area at normal operating level (el. 424 m) will be approximately 1,300 ha.

Transmission lines will likely connect the plant to the BC Hydro substation at Selkirk, and also possibly to a potential major customer.

## Project Status

This document updates the status of the Application for Water Licence submitted in November 2003 by MCPC. That application precisely followed the template asked for by the government at time. (The 2003 application was the second; the first was filed by NPPC in April of 1989, also reflecting requirements of that time.)

## Summary of 2003 Water Application

In brief, our status as of the 2003 application was:

- The background feasibility and concept design are done
- The concept design was updated to a hydrocombine approach, reflecting advancements in dam design since the concept design. As well, the consideration of a potential fish ladder has been added.
- The Crown lands claimed are relatively small, since the run-of-river approach basically means that the Crown land requested is the riverbed and shore of the Columbia River above the Town of Oasis and below the City of Castlegar. Crown land above the level of the river is largely unaffected.
- Few impacts on terrestrial wildlife are anticipated, since the project is essentially run-of-river.
- Private lands affected by the dam site are identified, and they are a few private citizens in Oasis, as well as Teck Metals Corp and the Canadian Pacific Railway.
- Although no First Nations lands appear to be affected, a complete review and meetings of First Nations, agencies and other stakeholders was anticipated in later stages
- Access Roads are not an issue since the project is located at the town site of Oasis, just off Highway 22. The further the shortening of the powerhouse as a result of the hydrocombine refinement means that Highway 22 and the CPR railway will not require relocations, as was expected in the original BC Hydro design.

## Progress since 2003 Water License Application

The next steps at the time of the 2003 application anticipated a comprehensive Environmental Assessment, review by regulators including Environment Canada and Department of Fisheries and Oceans, full First Nations and Stakeholder review. After this, we would proceed to the awarding of a design-build contract for the power plant.

We were concerned in 2003 that there might be some aquatic environmental issues, since that that had been the case with several other power projects in the Columbia River corridor, such as Brilliant Upgrade and Expansion and Waneta Expansion, upstream and downstream of Murphy Creek, respectively.

To get an understanding of the scope of issues that might be of concern, and as a preliminary step to our anticipated Environmental Assessment, we commissioned

Golder Associates, via Klohn Crippen Berger, to conduct a study on The Aquatic Environmental issues Relating to the Proposed Murphy Creek Power Project. This report, completed in November 2005, underscored a number of potential environmental impacts of the Murphy Creek Power Plant. The greatest area of concern centred on the power plant's impact on White Sturgeon *Acipenser transmontantus.*

Specifically, the report outlined concerns about:

- Possible impeding of upstream and downstream passage of white sturgeon;
- Possible entrainment mortality of the white sturgeon, since the project was to be as run-of-river so that much of the flow would pass through turbines;
- Possible eddy effects on the habitat on white sturgeon;
- Possible but unknown impact of the physical changes in the head pond area.

The concern about sturgeon had been recognized for some time. Researchers have recorded spawning, but have found very few young fish, indicating that few young sturgeon are surviving to adulthood. Available population estimates show that within the Canadian portion of the upper Columbia River basin, including the Arrow Lakes Reservoir, the white sturgeon population is about 1,000 wild fish. From the Canada-U.S. border to the Grand Coulee Dam in Washington Sate, about 3,200 adult wild sturgeon reside. Almost all fish are greater than 30 years old, suggesting a population of aging fish with relatively few young to replace the old. In August 2006, the federal Canadian government officially listed the upper Columbia white sturgeon population as Endangered under the Species At Risk Act (SARA) The Upper Columbia White Sturgeon Recovery Initiative (UCWSRI) began in 2002. (Source: UpperColumbiaSturgeon.org)

Since the 2003 application, we confirmed that the projected influences of the other Columbia River projects appeared to be proceeding as had been anticipated in the 2003 application. Of course, the optimization of the reservoir system of the upper Columbia would need to be re-examined before further detailed work was undertaken.

As well, we have had encouraging preliminary discussions with both Teck Metals and the Canadian Pacific Railway, both being important stakeholders.

## Section B: Cadastral Plan

### Perimeter boundaries

The project will be run of river with some storage, using the fall of water between the Keenleyside and Brilliant tailraces and the Oasis dam site.

As noted earlier, the Crown lands in the application generally relate to the riverbed of the Columbia River between Oasis and Castlegar and the shoreline elevation 424 m. This falls within the floodplain of the river. Figure 2 outlines the perimeter boundaries.

The project will be primarily run of river, but there is some storage. The land to be flooded comprises about 300 ha above the existing mean high water level in the reach between the Murphy Creek dam site and Keeleyside and Brilliant Dams. The total reservoir surface area at normal operating levels (el. 424 m) will be approximately 1,300 ha. The reservoir in the City of Castlegar and across the river in Brilliant will not flood any lands above those already in flood plain areas. The reservoir will have a normal operating level of el. 424 m as measured at the Castlegar Ferry crossing. It will be capable if handling floods up to the 200-year event without flooding significantly more lands above el. 424 m than at present.

Reservoir flow, duration and elevation levels are charted in Appendix III of Attachment 1.

### Proposed Location of Works

The geographic location, including longitude and latitude, appears in Figure 1, as noted earlier.

Figure 3 outlines the location of the features of the project, including the dam, powerhouse, and spillway and concrete diaphragm wall.

### Proposed location of Transmission Line Interconnection

There are two possible transmission lines. One is a 230 kV transmission line that could run 23 km (14 miles) from Murphy Creek to an interconnection point at the BC Hydro substation at Selkirk, near Trail. We are also exploring the possibility of joining with Teck Metal's transmission line from its Waneta generating station.

These options are illustrated in Figure 4.

## Proposed Water Source and Tributaries

The source of the water for generation at Murphy Creek is the Columbia River and its tributaries above the dam site. The total watershed area (see Figure 1 and Appendix V for topography) tributary to the dam site is 88,000 $km^2$, of which 50,000 $km^2$ drains into the Kootenay River, and the remaining 38,000 $km^2$ drains into the upper Columbia River above the confluence of the Kootenay at Castlegar, BC. This area can be seen in Figure 1.

## District Lots and Land Titles

Figure 5 outlines the district parcels. The private lands affected are relatively few:

| Side of River | Lot Number | Parcel Identifier | Registered Owner |
|---|---|---|---|
| East | 13 (indirectly) | 016-024-494 | Sims Investments Ltd |
| | 17 | 016-023-285 | Sims Investments Ltd |
| | 18 | 016-025-598 | Sims Investments Ltd |
| | 20 | 016-025-601 | Teck Metals Ltd |
| | 21 | 016-769-007 | Teck Metals Ltd |
| | 22 | 016-025-610 | Teck Metals Ltd |
| | 24 (indirectly) | 016-024-508 | R. Podovelnikoff |
| | 25 (indirectly) | 013-286-234 | V&M Loyola |
| | 26 (indirectly) | 006-521-975 | V&M Loyola |
| | 29 (indirectly) | 016-016-572 | Teck Metals Ltd |
| West | SL 30 of 4598 | 016-327-632 | Teck Metals Ltd |
| | RW 13 1609 | 016-858-123 | Cominco |
| | 5638 | 007-821-298 | CPR |
| | Railway R/W | 016-327-837 | CPR |

Ministry staff has advised us that neither the transmission line nor the reservoir area is likely to affect Crown lands, and if they do, it would be to a very minor extent.

Attachment 3 contains the Land Titles searches for these lands.

## Section C: Project Description/ Investigative Schedule.

### Project Description

The overview was summarized in Section A above. Descriptive are found in our November 2003 Water Development Plan Template that is found in Attachment 1 A; and its subsidiary Appendices I through Vl are found in Attachment 2.

### Investigative Schedule

As noted in Section A above, the most constraining issue that affects the project's moving forward relates to the protection of the White Sturgeon. Our reasoning is that, if the white sturgeon issue represents a "showstopper", there is no point in taking the time and expense to complete a formal environmental assessment of important but less critical elements, complete First Nation or stakeholder reviews, begin the process to acquire private land or anything else.

The white sturgeon question itself can be further narrowed into two areas, the impacts of the dam itself (fish passage) and those habitats above and below.

An important aspect of this important issue, of course, is the ability of white sturgeon to migrate through their range to spawn, and that means that the dam system has to allow passage. When the UCWSRI began in 2002, however, very little research had been done on ways to protect white sturgeon through fish ladders, and the use of screens to avoid dam turbines.

Since MC is operated as a run-of-river project, the white sturgeon would have no choice but to pass through the turbines, pass over the spillway or be isolated in the head pond above the dam. Therefore, passage of the White Surgeon upstream and downstream becomes the most constraining issue, although not the only one, relating to the environment. Our investigative plans therefore focus on this area. This in turn translates to passage around the dam via fish ladders, or over spillways to avoid the turbines of the dam.

**Regarding fish ladders**: Until very recently it was thought that it was not possible to divert white sturgeon around dams using fish ladders because they do not appear to use conventional fish ladders. New research by the US Geological Survey (M. Parsley et al, Attachment 4) and others is gradually clarifying that fish ladders that have

been designed for salmonids (including salmon, trout and whitefish) are not suitable for sturgeon. This is partially because the sturgeon are too big, the water depth and flow velocities did not appear to be appropriate to the speed bursts/resting requirements of white sturgeon. Further, it appears that white sturgeon do not find conventional fish ladders very inviting so they do not enter them.

Very recent research appears to cast some hope on this bleak situation. There is evidence that larger orifices, spiral designs and nature-like pathways for fish ladders promote passage of white sturgeon but do not also discourage the passage of smaller fish. Research is ongoing at the Dalles Dam and elsewhere to compare results and increasingly refine designs of fish ladders that promote the passage of White Sturgeon. Latest findings, especially by Webber *et al* are summarized at Columbia River Basin White Sturgeon Passage Workshop at *www.fishsciences.net/.../**columbia_sturgeon**/_.../2012_**Sturgeon**_III_* in January 2012 and *www-rohan.sdsu.edu/~kelpbass/**Webber**_et_al_2007.pdf.*

We will incorporate this research and further insights uncovered over the next five to eight years, into the decision about whether fish ladders that are likely to benefit white sturgeon can be incorporated into the Murphy Creek dam.

**Regarding screens to avoid dam turbines**: We are closely following the measures being put in place at the Waneta Expansion project. This is Murphy Creek's downstream neighbour, below Trail, so experience there is likely to be very applicable to Murphy Creek. Construction on Waneta began in 2011 and will be completed in 2015.

Waneta will not have fish ladders, because, as suggested above, even a few years ago during Waneta's design phase, it was thought that white sturgeon would not use fish ladders. The design at the Waneta expansion, therefore, focuses on preventing white sturgeon from entering draft tubes to avoid their being entrained in turbines. This is to be accomplished via screens and safety protocols during shutdowns, start-ups etc.

The evaluation of the effectiveness of Waneta's draft tube measures, and the impact of the Waneta expansion on white sturgeon habitat, will begin after completion in 2015, and proceed for a few years. We will likely not have information that we can incorporate into the next phase of the Murphy Creek project until the 2018-2020 time frame.

This longer time horizon will, we hope, coincide with the studies being conducted elsewhere on hydroelectric projects' impact on white sturgeon habitat, and ongoing research about the design fish ladders that are inviting and effective for white sturgeon.

A detailed schedule may not be meaningful since it is based on the white sturgeon constraint being addressed. This, in turn, reflects research that has not been conducted yet and is not being managed by us.

That being said, our investigative schedule would be roughly:

| Activity | Time Horizon |
|---|---|
| Review optimization of Columbia river water levels | Ongoing |
| Monitor White sturgeon research | Ongoing |
| In parallel with early findings from the above, begin research on other areas of Environmental Assessment | 2016-2020 |
| Continue the socio-economic assessment | 2016-2020 |
| Continue project engagement activities | 2016-2020 |
| Continue First Nations Information Requirements | 2016-2020 |
| After Environmental Assessment Certificate is granted, Award design-build contract for power plant | 2018-2020 |
| Final Site Acquisition completed | 2019-2021 |
| Excavation completed | 2021-2023 |
| Mechanical completed | 2023-2024 |
| Operational | 2024-2025 |

## List of Figures and Attachments

### Figures


| | |
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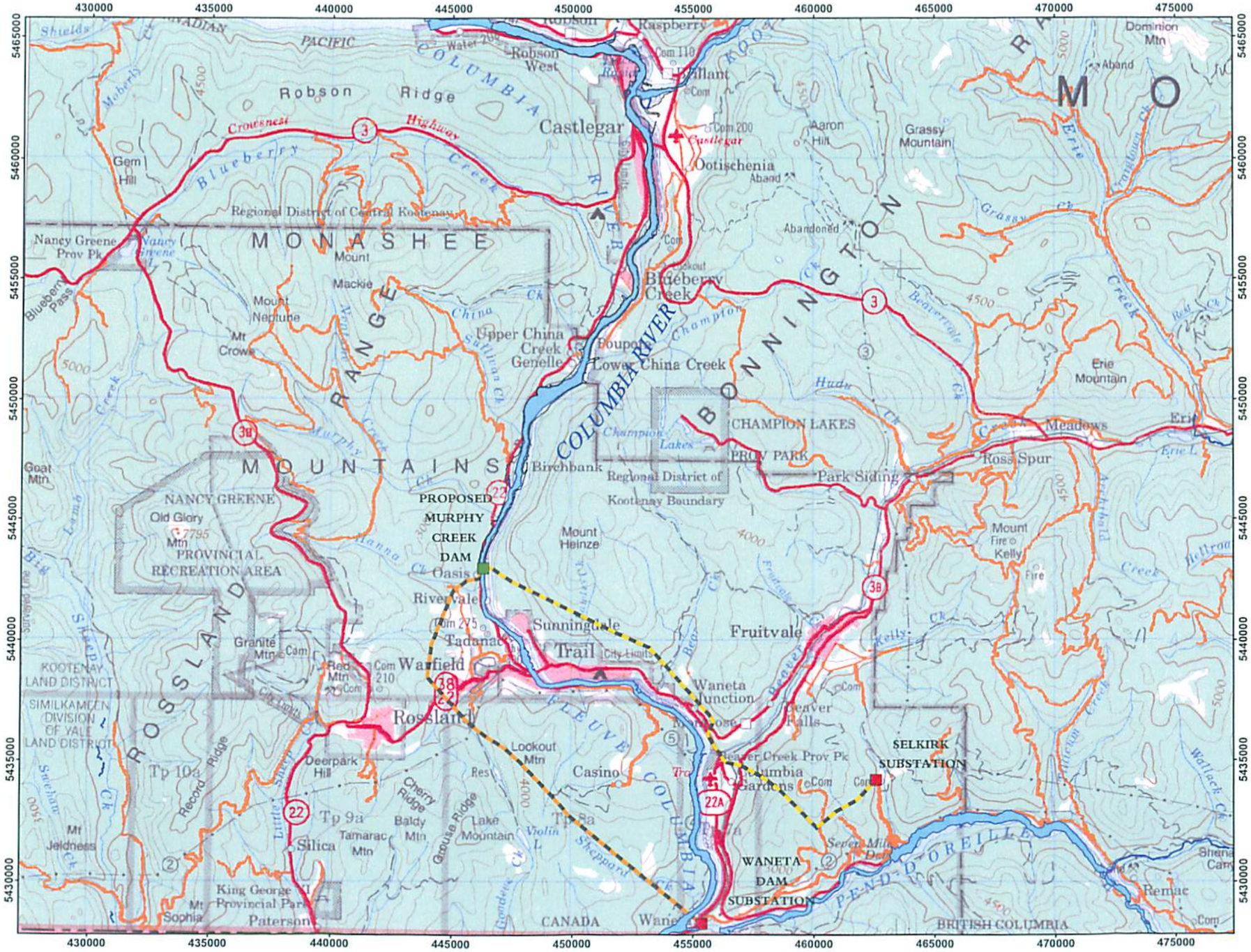
| **Figure 1** | **Regional Context Map** |
| **Figure 2** | **Crown Land Boundaries Map** |
| **Figure 3** | **Project Overview Graphic** |
| **Figure 4** | **Project Transmission Lines Map** |
| **Figure 5** | **Land Parcels Map** |


### Attachments


| | |
|---|---|
| **Attachment 1** | **Murphy Creek Hydroelectric Project** |
| | **Water Development Plan Template November 2003** |
| **Attachment 2** | **Appendices to Attachment 1** |
| I a | Hydrocombine concept, Wells Dam |
| I-b to k | Wells Dam design overview |
| I-l and m | BC Hydro's powerhouse and dam design (the hydrocombine will be similar but the spillway is located above the turbines, not beside them) |
| II a and b | Proposed transmission lines |
| III a to c | Reservoir flow, duration and elevation levels |
| IV | Parcel Identification (PID) numbers |
| V | Watershed typography |
| VI | Discharge hydrographs |

| | |
|---|---|
| **Attachment 3** | **Land Title Searches** |
| **Attachment 4** | **White sturgeon (*Acipenser transmontanus*) passage, Parsley *et al*** |




Project:
**Murphy Creek Hydroelectric Project**

Proponent:
**The Murphy Creek Power Corporation**

Drawing Title:
**Figure 1- Regional Context Map**

## Legend

- Murphy Creek Dam
- Substation
- Proposed transmission route 1
- Proposed transmission route 2
- Contour 424m
- River

Note: Information on this map is directly reproduced from digital material from different sources. Minor discrepancies may therefore occur. Where further clarification is considered necessary, this is noted through the use of text boxes on the map itself.

**Scale: 1:150,000**

Datum/Projection:
NAD83 UTM zone 11N

Based upon basemap data provided by Natural Resources Canada and the Province of British Columbia

0 1 2 4 Kilometers

N

| | |
|---|---|
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| Prepared by: | AV |
| Drawing No: | R101 |
| Revision Number: | 0.1.1 |
| Drawing File: | R101_MC_150k_v0.1.1 |

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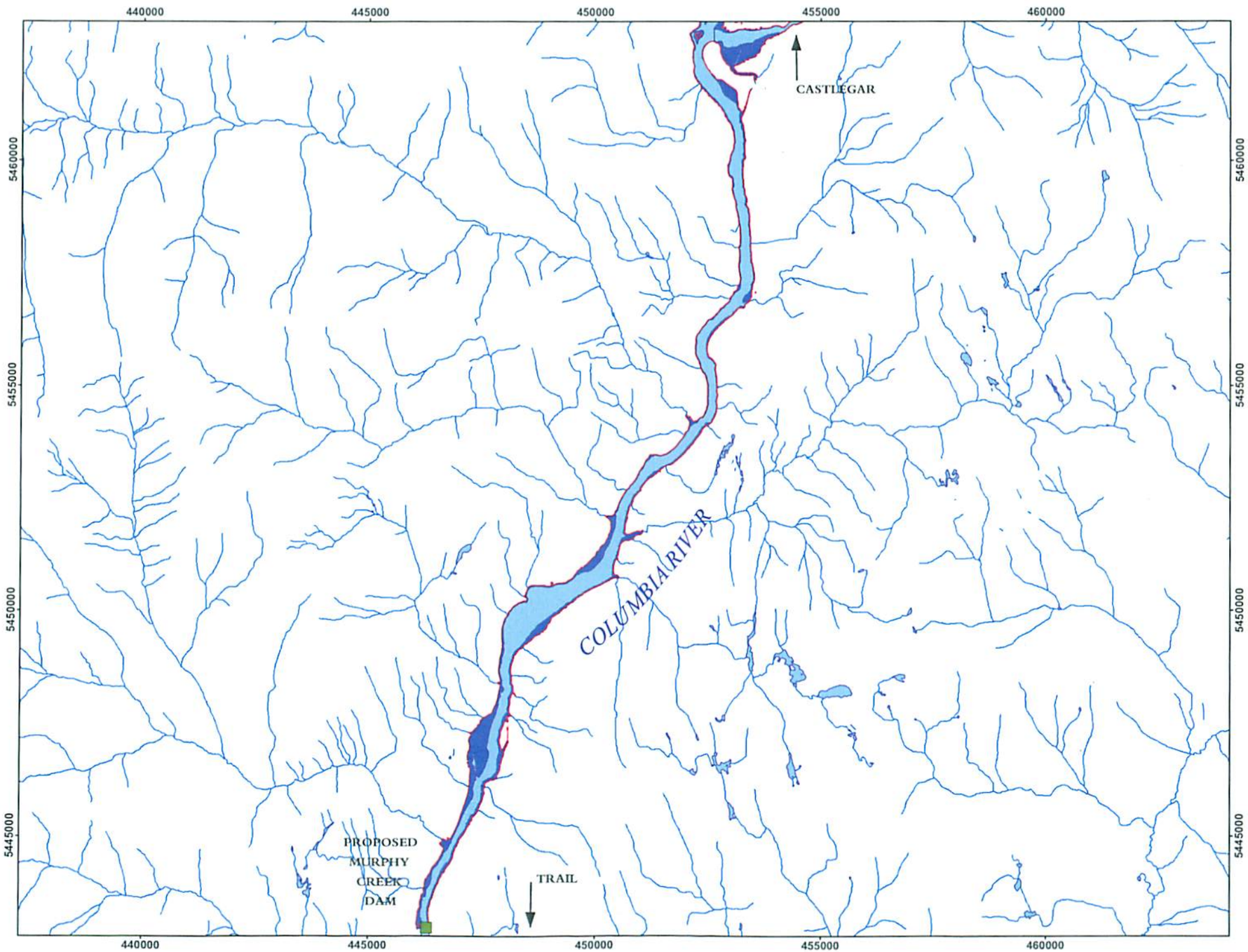


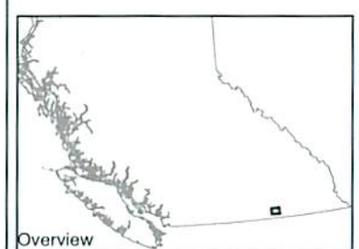

Project:
**Murphy Creek Hydroelectric Project**

Proponent:
**The Murphy Creek Power Corporation**

Drawing Title:
**Figure 2 - Crown Land Boundaries**

## Legend

- Murphy Creek Dam
- Contour 424m
- Watercourse
- River or lake
- Area between shore & 424m contour




Note: Information on this map is directly reproduced from digital material from different sources. Minor discrepancies may therefore occur. Where further clarification is considered necessary, this is noted through the use of text boxes on the map itself.

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Based upon basemap data provided by Natural Resources Canada and the Province of British Columbia

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| Prepared by: | AV |
| Drawing No: | R102 |
| Revision Number: | 0.1.1 |
| Drawing File: | R102_MC_150k_v0.1.0 |

Drawing by:

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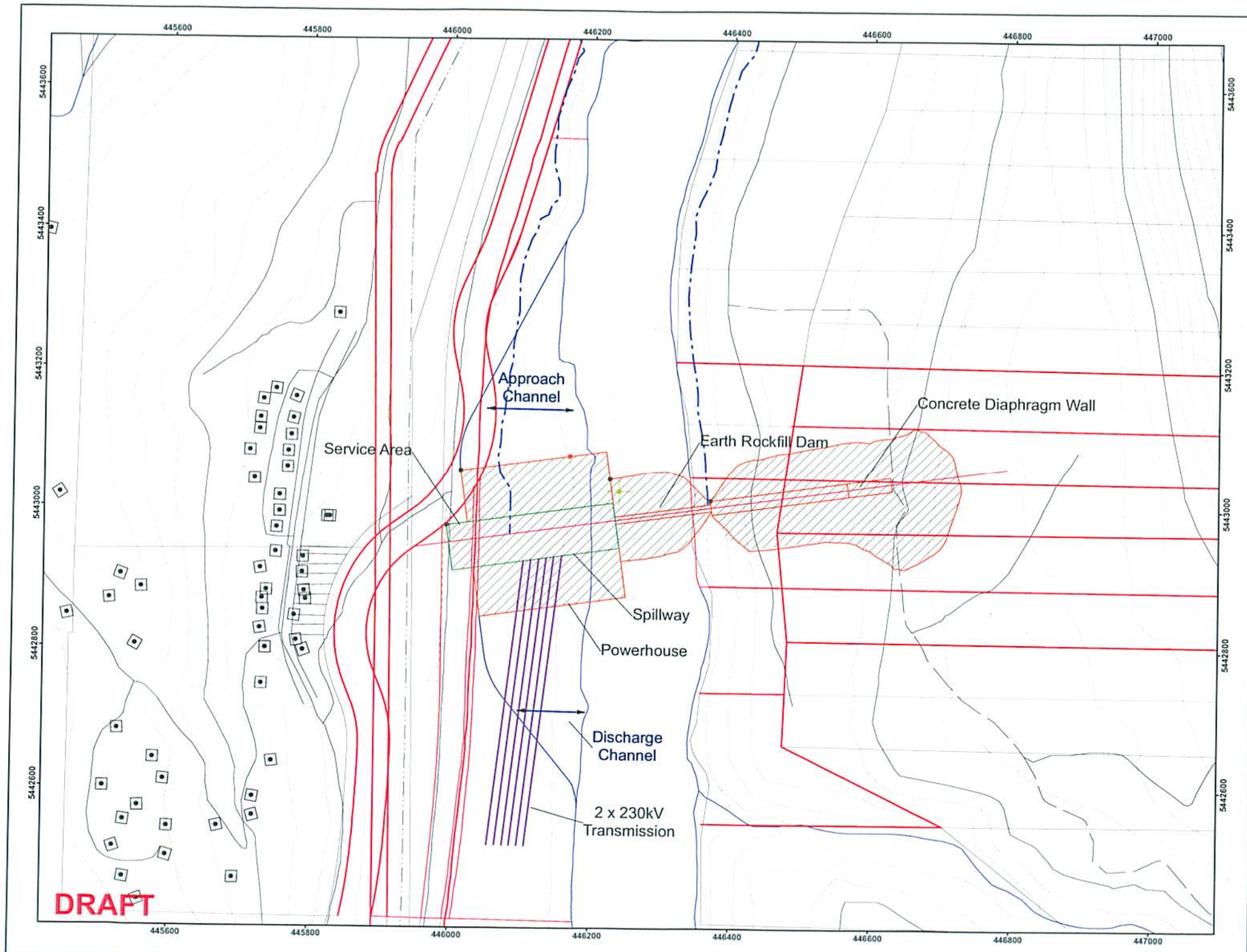


Project:
**Murphy Creek Hydroelectric Project**

Proponent:
**The Murphy Creek Power Corporation**

Drawing Title:
**Figure 3 - Project Overview**

## Legend

424m contour

Note: Information on this map is directly reproduced from digital material from different sources. Minor discrepancies may therefore occur. Where further clarification is considered necessary, this is noted through the use of text boxes on the map itself.

**Scale: 1:5,000**

Datum/Projection:
**NAD 1983 UTM Zone 11N**

Based upon basemap data provided by Natural Resources Canada and the Province of British Columbia.

0 50 100 200 Meters

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Date: **2012-08-28**

Prepared by: **AV**

Drawing No: **P100**

Revision Number: **0.1.2**

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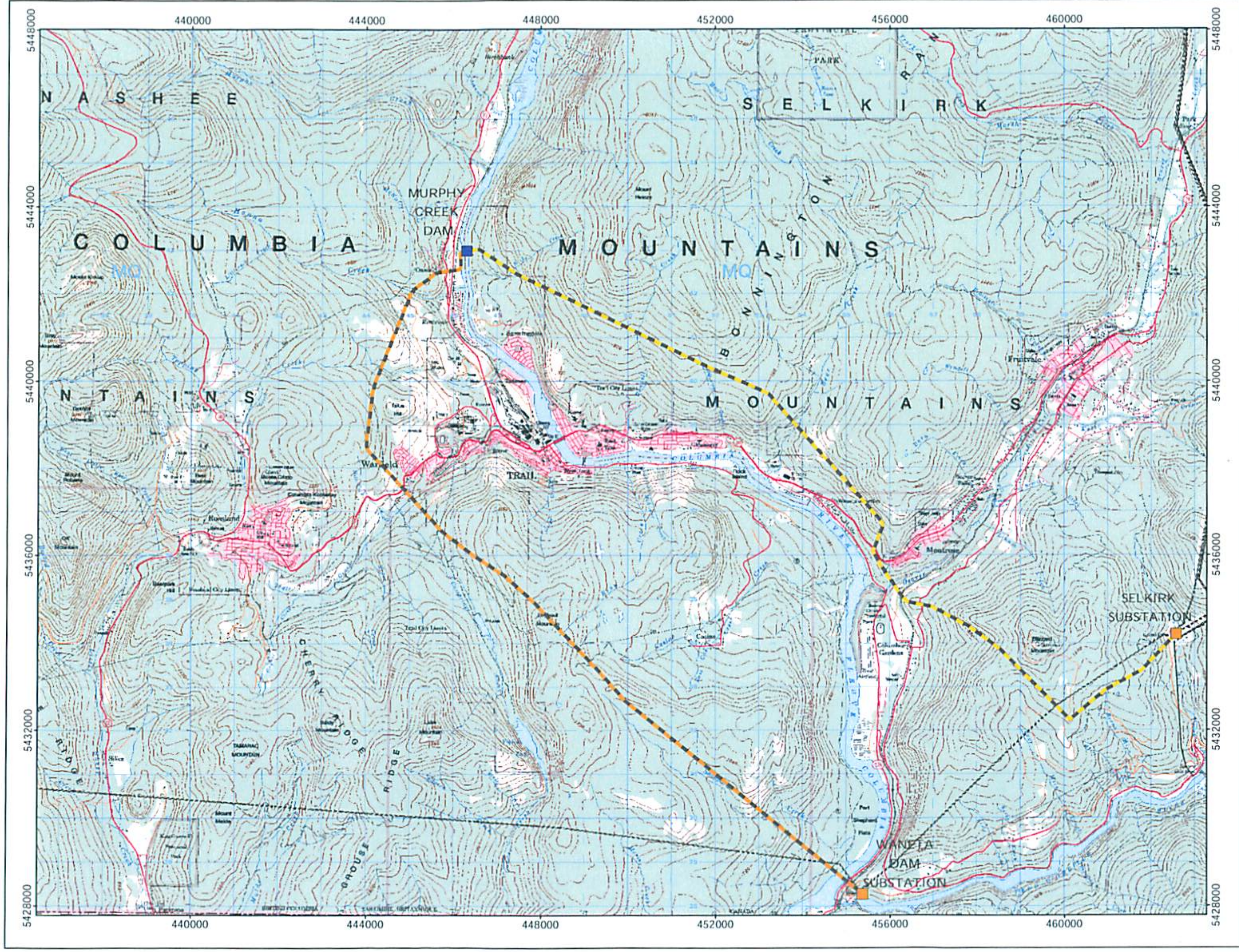


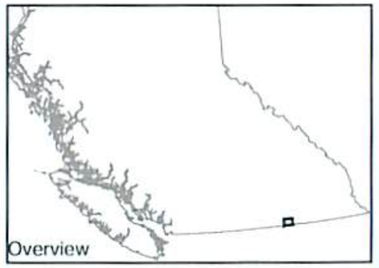

Project:
Murphy Creek Hydroelectric Project

Proponent:
The Murphy Creek Power Corporation

Drawing Title:
Figure 4 - Proposed Transmission Routes

## Legend

- Murphy Creek Dam
- Substation
- Proposed transmission route 1
- Proposed transmission route 2
- BC Electrical Grid

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Prepared by: AV
Drawing No: R100
Revision Number: 0.1.1
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Drawing by:

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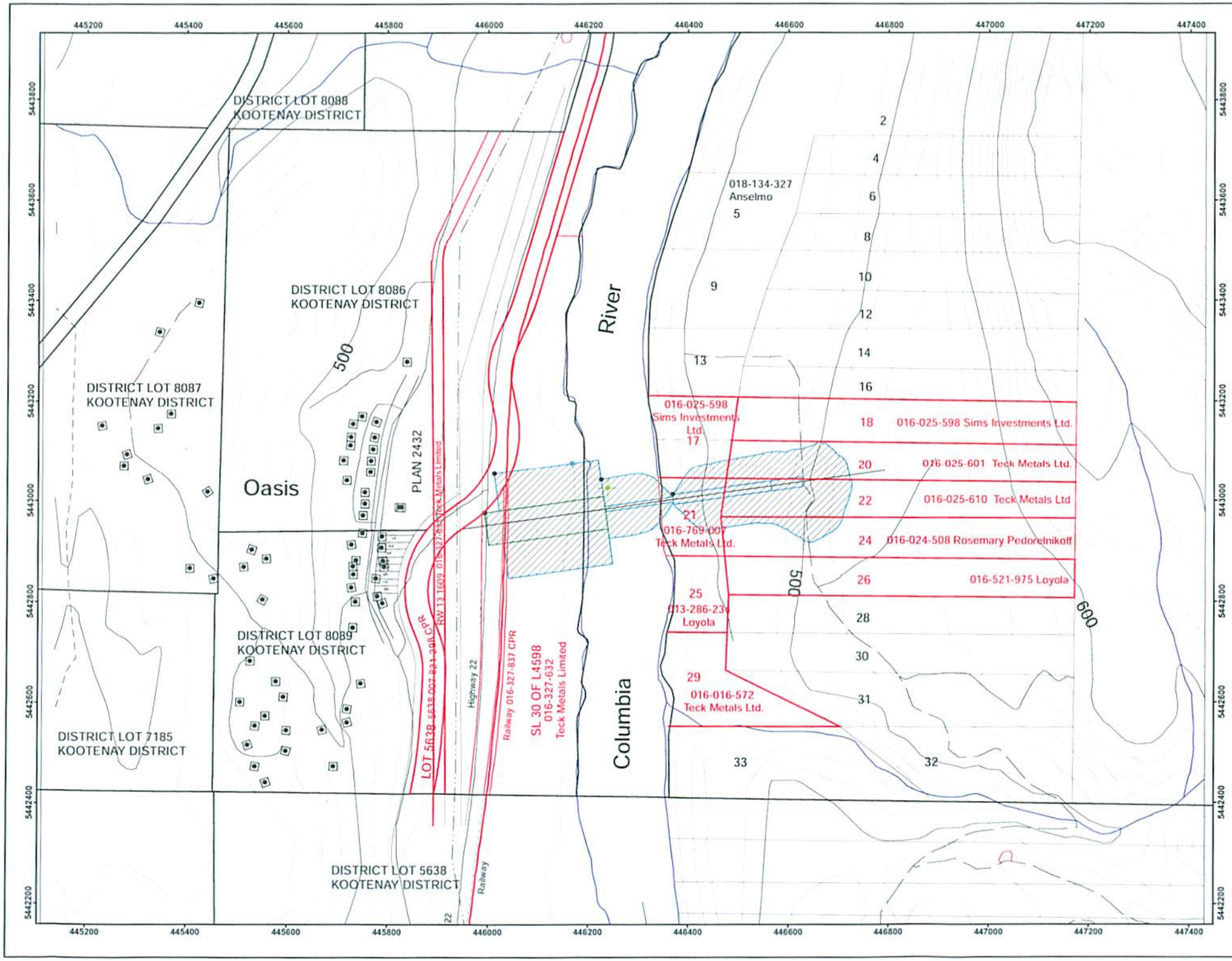


Project:
**Murphy Creek Hydroelectric Project**

Proponent:
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Drawing Title:
**Figure 5 - Land Parcels**

## Legend

- Land parcel of interest
- Land parcel boundary
- Dam structure

Note: Information on this map is directly reproduced from digital material from different sources. Minor discrepancies may therefore occur. Where further clarification is considered necessary, this is noted through the use of text boxes on the map itself.

**Scale: 1:7,000**

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Based upon basemap data provided by Natural Resources Canada and the Province of British Columbia

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| Prepared by: | AV |
| Drawing No: | P101 |
| Revision Number: | 0.1.0 |
| Drawing File: | P101_MC_7k_v0.1.0 |

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# THE MURPHY CREEK HYDROELECTRIC PROJECT

# Water Development Plan Template

# And

# Application Forms for Water License

**Submitted By:**

**Murphy Creek Power Corp.**
**November 7, 2003**

# THE MURPHY CREEK HYDROELECTRIC PROJECT

## Water Development Plan Template

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# MURPHY CREEK HYDROELECTRIC PROJECT

## Water Development Plan Template

## Introduction

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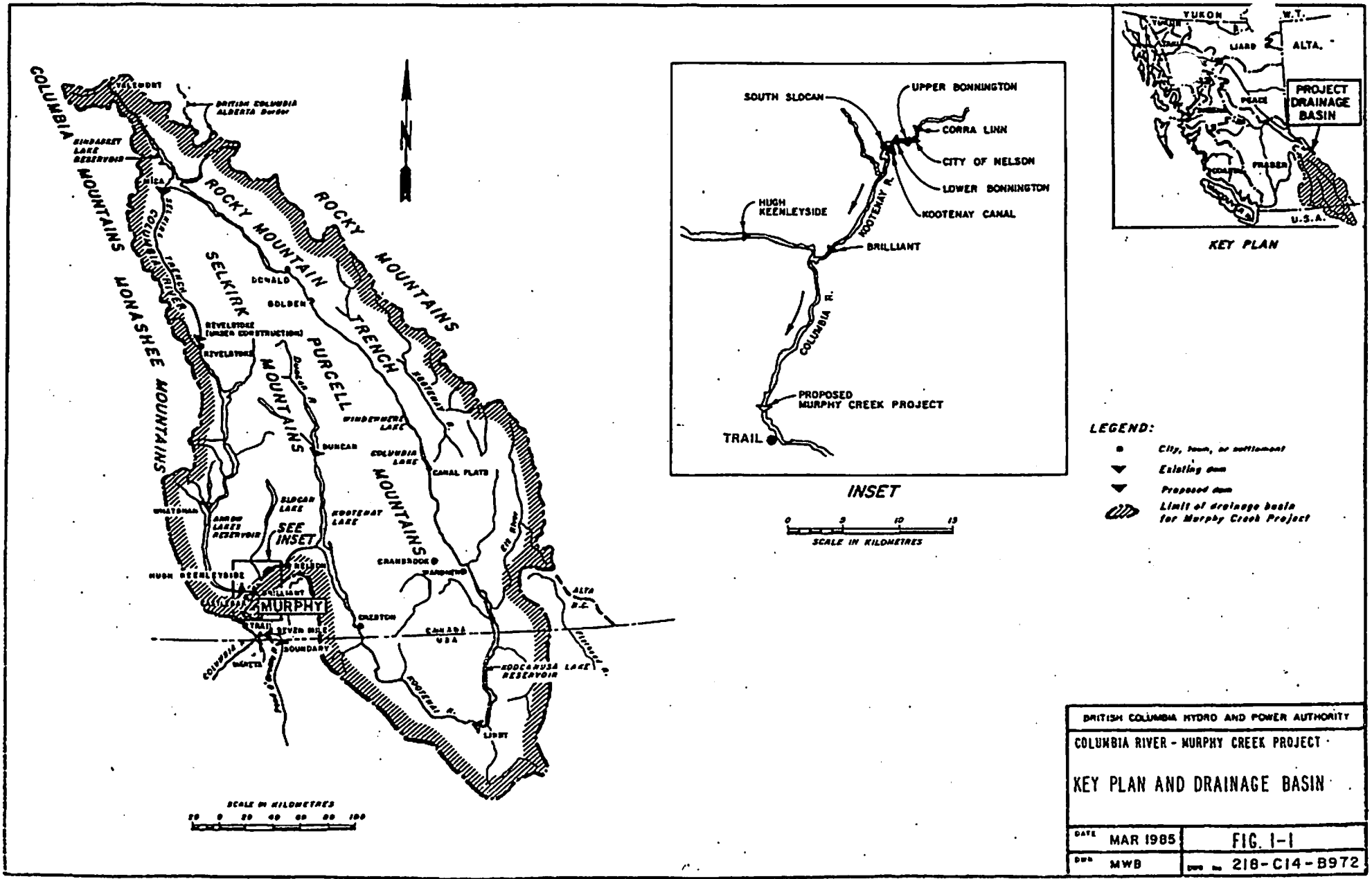
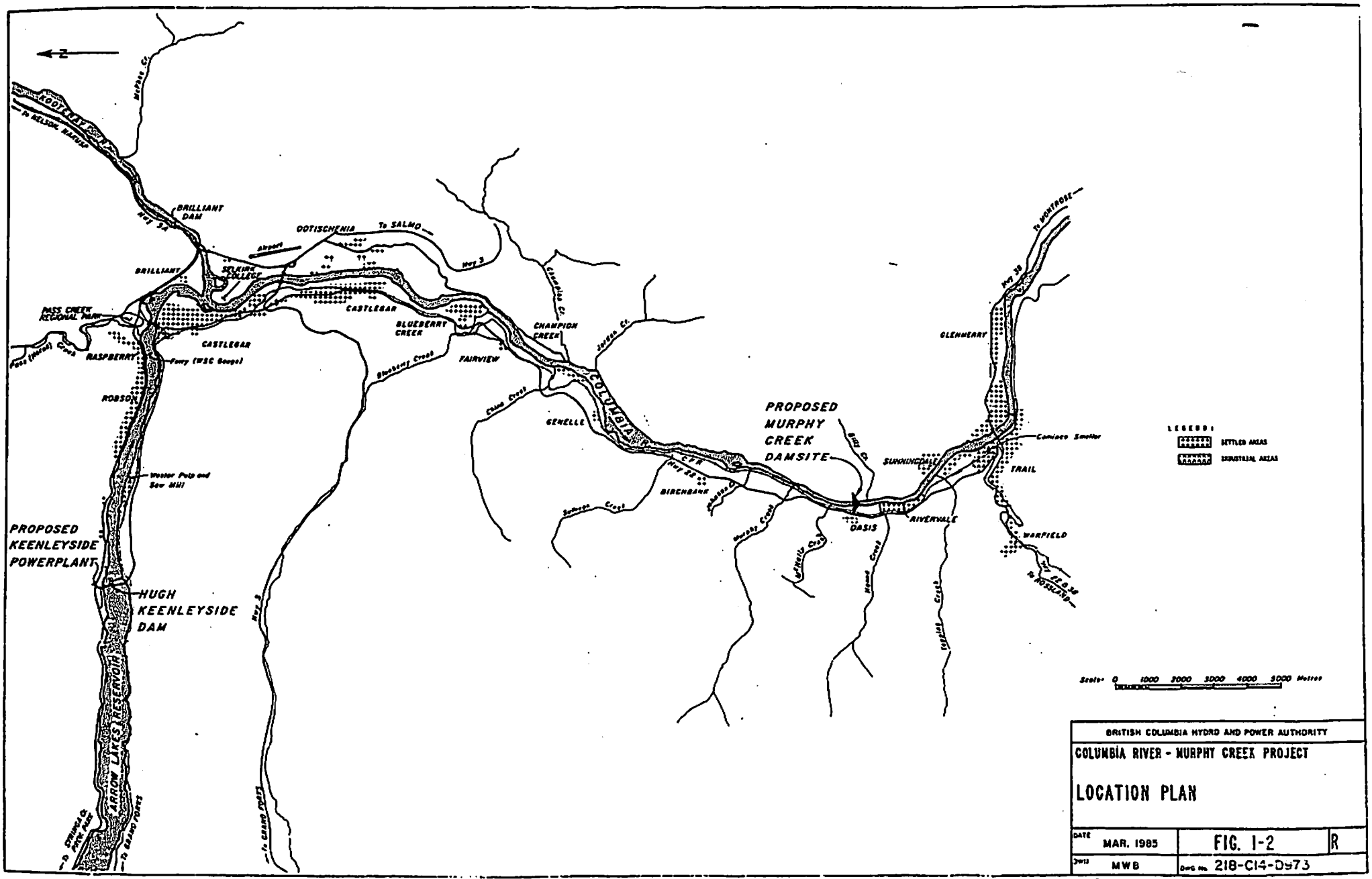

COLUMBIA MOUNTAINS
MONASHEE MOUNTAINS
SELKIRK MOUNTAINS
ROCKY MOUNTAIN TRENCH
ROCKY MOUNTAINS
PURCELL MOUNTAINS
SEE INSET
MURPHY
SCALE IN KILOMETRES
SOUTH SLOCAN
UPPER BONNINGTON
CORRA LINN
CITY OF NELSON
LOWER BONNINGTON
KOOTENAY CANAL
HUGH KEENLEYSIDE
KOOTENAY R.
BRILLIANT
COLUMBIA R.
PROPOSED MURPHY CREEK PROJECT
TRAIL
INSET
SCALE IN KILOMETRES
YUKON
N.W.T.
ALTA.
PROJECT DRAINAGE BASIN
U.S.A.
KEY PLAN
LEGEND:
City, town, or settlement
Existing dam
Proposed dam
Limit of drainage basin for Murphy Creek Project
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
COLUMBIA RIVER - MURPHY CREEK PROJECT
KEY PLAN AND DRAINAGE BASIN
DATE MAR 1985
FIG. 1-1
DWN MWB
DWG No. 218-C14-B972

Figure 1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HUGH KEENLEYSIDE DAM
ARROW LAKES RESERVOIR
PROPOSED MURPHY CREEK DAMSITE
BRILLIANT DAM
BRILLIANT
CASTLEGAR
RASPBERRY
ROBSON
FAIRVIEW
BLUEBERRY CREEK
CHAMPION CREEK
GENELLE
BIRCHBANK
OASIS
RIVERVALE
SUNNINGDALE
TRAIL
GLENMERRY
WARFIELD
GOOTISCHENIA
To SALMO
To NELSON, NAKUSP
To CRANBROOK
To GRAND FORKS
To MONTROSE
To ROSSLAND
Hwy 3
Hwy 3A
Hwy 22
Hwy 22A
Hwy 23
Hwy 23S
Hwy 33
Hwy 33A
Hwy 33B
Hwy 33C
Hwy 33D
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Scale: 0 1000 2000 3000 4000 5000 Metres
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
COLUMBIA RIVER - MURPHY CREEK PROJECT
LOCATION PLAN
DATE MAR. 1985
FIG. 1-2
R
DWG MWB
DWG No. 218-C14-D973
REPORT No. H1782

**Figure 2**

## Design Aspects

The Murphy Creek Hydroelectric Project will consist of a new dam, powerhouse including spillway, and reservoir. The project will be run of river with some storage, using the fall of water between the Keenleyside and Brilliant tailraces and the dam site.

### *Hydrocombine Approach*

MCPC will use the wealth of information (at least fourteen background and feasibility studies) and preliminary design of the BC Hydro dam, but will modify it to use a hydrocombine structure. Bechtel pioneered this innovative design on the Wells Dam on the Columbia River in 1968. The dam has performed well, exceeding all expectations since then. The design uses the excess space between the turbines to incorporate the spillway. This means that the powerhouse and the spillway can fit into a structure that is exactly the same length as the powerhouse alone in the earlier design. Although the Wells dam is somewhat larger than Murphy Creek, its unit proportions are quite similar.

The cofferdam and construction sequence proposed by BC Hydro can be applied to the hydrocombine with minimal change. The embankment dam and cut-off diaphragm wall will not be affected.

Drawings of the concept and components are found in Appendix I.

### *The Dam*

The embankment will be zoned earth and rockfill, with a central impervious core of glacial till, transitions and filters, with sand, gravel and rockfill shells. It will be about 152.4 m (500 ft) long and up to 27.1 m (89 ft) high. The crest will be set at elevation 427.0 m (1401 ft), yielding a freeboard of 2.2 m (7.2 ft) over the Probable Maximum Flood peak level of 424.8 m (1,394 ft). The upstream and downstream slopes will be 2H: 1V and 1.8H: 1V, respectively. The dam will contain approximately 167,500 m3 (218,000 $yd^3$) of fill.

### *Intake, Penstock and Powerhouse and Tailrace*

The intake structure will be integral to the powerhouse. It will be equipped with fixed-wheel operating gates for emergency shutdown, and facilities for bulkhead gates for maintenance of the operating gates. Each flow passage will be divided by piers *into three* gate openings. These will join together and transition into a concrete semi-spiral case, which, in turn, will convey the flow to the turbine distributor. After leaving the runner,

the flow will transit an elbow draft tube to decelerate smoothly for discharge into the tailrace. Each draft tube will be divided into three passages at the exit by two concrete piers. Draft tube gates will be supplied to permit the turbines to be dewatered for maintenance.

The hydrocombine structure will contain five, 55 MW-rated Kaplan turbine-generator sets. Each unit will be rated at 444 $m^3$/sec (15,680 cfs) at a net head of 13.9 m (45.6 ft) to produce 55,800 kW at the shaft coupling. Each turbine will drive a synchronous generator rated at 61,111 KVA at a 0.9 power factor at a synchronous speed of 72 rpm Rated voltage will be 13.8 KV.

## *Spillway*

Six gated bays, located between the units, and at the ends of the hydrocombine structure, will control the spillway functions. The crest will be set at el. 403.9 m (1,325 ft). Each bay will be controlled by a radial gate 20.7 m (68 ft) high by 12.8 m (42 ft) wide.

Application of the hydrocombine concept will eliminate a separate spillway entirely. This shortens the entire structure by at least 130 m (427 ft) and, in turn, means that the approach and tailrace channels will be only 120 m (394 ft) instead of 250m (821ft) as the BC Hydro design anticipated. Further, the spillway flows will be distributed over the entire 120 m (394) width of the structure, rather than being concentrated in the 91 m (299 ft) width of the spilling basin.

## *Fish Passage*

The hydrocombine design is one that is inherently friendlier to fish. The concern with dams on the Columbia system is that the juvenile fish, which tend to swim at shallow depths, get caught in the turbines of dams with conventional spillways. Hydrocombine dams have the spillway located directly above the powerhouse. This means that baffles can manage the path of the surface smolts so that they pass through the spillway, rather than getting drawn into the turbine intakes below. This is further described on page 13.

Should the environmental assessment require it, MCPC will build fish ladders on either side of the embankment so that adult fish will be able to ascend the river.

## *Access Roads for Operation and Maintenance of Completed Project*

The Murphy Creek project will not need any access roads because it is located at the town site of Oasis, just off Highway 22. Further, the shortening of the powerhouse as a result of the hydrocombine concept means that Highway 22 and the CPR railway will not require relocation, as was expected with the BC Hydro design.

### Switchyard and Transmission Lines

The generators will be supplied with a 13.8 kV vacuum-type circuit breaker to provide generator protection and synchronization services. The breakers will be installed inside the powerhouse in a protected area. Power will flow to and from the breakers via a naturally cooled isolated phase bus system.

The bus from each unit will deliver power to a single three-phase 60 hz power transformer. The transformers will step up the voltage from 13.8 kV to 230 kV transmission voltages. The transformers will each be rated at 61.1 MVA at 0.9 power factor. They will be FOA cooled, and will be located in the top deck.

The switchyard will contain $SF_6$ insulated 230 V metal clad switchgear consisting of two 230 kV breakers on the outgoing lines, and a tie breaker to permit interconnection of the two lines. Each breaker will be supplied with disconnect switches on both sides. MCPC will provide for switchgear terminations for an incoming line from a possible future powerhouse at BC Hydro's Keenleyside dam.

MCPC will provide protective relaying systems to make the project fully compatible with the BC Hydro system with which it may connect. As well, MCPC will coordinate with BC Hydro and Bonneville Power Authority at all stages of the design, construction and implementation to ensure that the project meets all requirements of both companies.

There are two possible transmission lines. One is a 230 kV transmission line that could run 23 km (14 miles) from Murphy Creek to an interconnection point at the BC Hydro substation at Selkirk, near Trail. We are also exploring the possibility of joining with Teck Cominco's transmission line from its Waneta generating station. Either way, the MCPC line will consist of a single circuit 230 kV line carried on wood pole towers, 19.8 m (65 feet) high. The conductors will be in flat formation suspended from tension insulator sets, with conductor spacing and impulse level set to the standards of the Canadian Standards Association (CSA) and major customers.

Appendix II outlines the path of the Selkirk transmission line.

## Reservoir Information

The project will be primarily run of river, but there is some storage. The land to be flooded comprises about 300 ha above the existing mean high water level in the reach between the Murphy Creek dam site and Keeleyside and Brilliant Dams. The total reservoir surface area at normal operating levels (el. 424 m) will be approximately 1,300 ha. The reservoir in the City of Castlegar and across the river in Brilliant will not flood any lands above those already in flood plain areas. The reservoir will have a normal operating level of el. 424 m as measured at the Castlegar Ferry crossing. It will be

capable if handling floods up to the 200 year event without flooding significantly more lands above el.424 m than at present.

The structures described above till impound a reservoir of about 140 x $10^6$ $m^3$ volume at normal operating level. Of the 1,300 ha total water surface are, about 300 ha will be new lands flooded above existing mean high water level in the Columbia River. The reservoir will extend 34 km from Murphy Creek Dam to the tailrace of Keenleyside Dam, about seven km upstream from the City of Castlegar. It will also extend to the tailrace of the Brilliant Dam in the Kootenay River a distance of 2.75 km upstream from the confluence with the Columbia in the City of Castlegar. Due to the long, shallow nature of the reservoir, backwater effects from the dam will extend to Castlegar and beyond during floods, and, to a minor extent, even during power operation. For this reason, the reservoir will be operated to maintain a constant level at the Castlegar Ferry gauge. This normal level was established by BC Hydro to be el.424 m as a result of optimization studies monitoring power production at Murphy Creek, Keenleyside and Brilliant Dams.

Reservoir flow, duration and elevation levels are charted in Appendix III.

## *Reservoir Performance during Flooding*

The spillway will have sufficient capacity to hold the reservoir to el. 424 m for all flows up to about 6,000 $m^3/s$ (approximately the 25 year flood). Above that flow, levels at Castlegar will be very nearly the same as currently existing flood levels of the Columbia River. For the 200-year flood (7,590 $m^3/s$) the level at Castlegar Ferry gauge will be el. 425.8 m, or about 20 cm above existing conditions for that flood. To maintain that level at Castlegar, Murphy Creek reservoir will be drawn down to el. 418.3 m at the dam during the 200-year flood peak. During the Probable Maximum Flood peak, the level at the dam will be el. 424.3 m, and the level at Castlegar Ferry will be about 430.9 m. By comparison, the natural Probable Maximum level at the dam would be el. 420 m, and the corresponding level at the ferry would be el. 430.3 m. The Probable Maximum Flood peak is 13,100 $m^3/s$.

MCPC will finish the reservoir rim with riprap to ensure slope stability and avoid erosion.

## *Relation with other Reservoirs*

As noted above, the Murphy Creek project will operate as a run-of-river power plant; it will make minor use of flows released from the Keenleyside Dam and the Brilliant Dam. (In all, 31.3 x $10^9$ $m^3$ of live storage is available at reservoirs impounded by Mica, Keenleyside, Duncan, and Libby Dams. Kootenay Lake can also be operated to a small degree for flow regulation.) The project will make only minor use of the Murphy Creek reservoir to smooth flows somewhat and provide a minor amount of hourly regulation to improve the dispatchability of the power.

## Geotechnical Considerations

The dam will be founded on granular glacier deposits which make up the left side of the existing river bed, and the left abutment. This material is locally quite deep, because the original, pre-glacial river bed was substantially to the left of the present bed. When the glacier receded, it left the Columbia River valley filled with sands, gravels, cobbles, and boulders. The post-glacier river eroded a new channel through these materials to form the present conditions. The present depth to rock in the left abutment area is as much as 130 m (427 ft) or about 99 m (325 ft) below the dam crest. Since the materials are extremely porous, MCPC will build a seepage barrier to protect the structures. MCPC propose a concrete diaphragm cut-off wall placed to sound rock.

The Murphy Creek project is expected to raise the ground-water table in the vicinity of the reservoir. MCPC plan to mitigate this by elevating roads and residences where feasible, relocating residences and replacing sewerage works and monitoring the ground-water quality during operation of the project.

## Seismic Considerations

The provincial (www.em.gov.bc.ca/Mining/Geolsurv/Surficial/quake/eq3.htm) and federal (www.pgc.nrcan.gc.ca/seismo/eqhaz/seishaz.htm) governments suggest that risk of earthquakes greater than 3.0 on the Richter scale appear to be very minor in the Castlegar/Trial area. MCPC will design the structures to meet all codes appropriate to this seismic zone.

## Land Related Issues

The land to be affected is about half Crown and half private ownership. The latter is primarily in the reservoir. The Parcel Identification (PID) numbers appear in the map in Appendix IV.

After MCPC has secured the necessary government approvals, MCPC will begin negotiations to acquire property. MCPC will update BC Hydro's previous data about land ownership and will hire agents to obtain options to purchase or easements on affected properties in covering parcels permanently affected, and others temporarily affected during construction. MCPC will include the reservoir areas, plus any shoreline required for slope stability, dam site and powerhouse areas, switching and transmission areas, plus maintenance sites and (unlikely) access road alignments.

MCPC will work with local planning officials to minimize disruption and provide the most benefit to citizens.

# Water Related Issues

## *Amount, Source and Restrictions*

BC Hydro has sized the Murphy Creek powerhouse to discharge a total of 2,220 $m^3/s$ at rated conditions. The maximum discharge capacity may be about ten percent greater under full gate conditions. MCPC will work with BC Hydro to complete an optimization study; the rated flow might be increased to 2,620 $m^3/s$ depending on the results. (The spillway will be capable of discharging the full Probable Maximum Flood level of 13,100$m^3/s$.)

The releases from Murphy Creek necessary to power the 275 MW power plant vary from 4,980 $m^3/s$ (summer) to 500$m^3/s$ (late fall, early spring). The long term average flow will be approximately 2,040 $m^3/s$, under project conditions based on forty years of flow records.

The source of the water for generation at Murphy Creek is the Columbia River and its tributaries above the dam site. The total watershed area (see Figure 1 and Appendix V for topography) tributary to the dam site is 88,000 $km^2$, of which 50,000 $km^2$ drains into the Kootenay River, and the remaining 38,000 $km^2$ drains into the upper Columbia River above the confluence of the Kootenay at Castlegar, BC.

The source will be managed in accordance with Annex A of the Columbia River Treaty, and the Columbia River Treaty Principles and Procedures for Preparation and Use of Hydroelectric Operating Plans.

## *Climate and Hydrology*

An overview of major climate factors in the Castlegar/Trail area, over a thirty-year period, appears at www.weather.ca/weather/stats/pages/C02089.htm?CABC0297. MCPC have reflected these factors into the design of the Murphy Creek Dam.

BC Hydro conducted extensive hydrological studies as part of the feasibility for the Murphy Creek Dam. Their inflow design and discharge hydrographs (including such key indicator values as Minimum, Mean and Maximum Annual Discharge) appear in Appendix VI

## *Water Quality*

Water temperature increases (estimated at a decrease of 0.4 degrees Centigrade) are less than the federal standard of 1.5 degrees Celsius.

The hydrocombine design, which distributes the spillway water across the length of the entire structure rather than in a narrow spill basin, means that the levels of dissolved gases such as nitrogen are reduced. MCPC expect that the Murphy Creek project will

actually enhance the existing water quality conditions by reducing the high total dissolved gas concentrations due to upstream spillage.

## In-stream Requirements

Murphy Creek Power Corp. are concerned about the welfare of the fish and other wildlife during construction and operation of the Murphy Creek project. What we know now is summarized below.

### Fish

The Murphy Creek project may affect dolly varden, walleye, mountain whitefish, white sturgeon, trout and salmon. The latter three are of the most concern.

Sturgeon are North America's largest and longest-lived freshwater fish. This ancient species has survived 175 million years, including ice ages, volcanic eruptions, flooding and mass extinction. The causes of the white sturgeon's decline are not fully understood. In the last 125 years, however, human development, construction of hydro electric dams, changes in flow patterns, loss of habitat and harvesting in the Columbia River has led to its decline and "critically imperiled" population status. While spawning has been recorded, young sturgeon are seldom found, indicating these fish are not reproducing successfully. Most recent estimates put the upper Columbia population, between Hugh Keenleyside Dam and the U.S. border, at approximately 1,400 sturgeon. Most of these appear to be at least thirty years old.

The Upper Columbia White Sturgeon Recovery Initiative (UCWSRI), which the BC government began, consists of more than 25 stakeholders, including Canadian and BC governments, U.S. federal and state governments, industry, First Nations, public and tribal agencies. They are working together to ensure that there is a better age distribution of white sturgeon in the upper Columbia. (Sources include: www.bchydro.com/news/2003/apr/release4852, and www.uppercolumbiasturgeon.org/images/WhitSturg_Broch_Aug02%20RVSD%20Sept%209th.pdf)

Murphy Creek site is not one of the four holding/feeding areas used by the white sturgeon for spawning in the Canadian section of the Columbia River below the Keenleyside Dam. MCPC will, however, be monitoring the UCWSRI project and will reflect its recommendations in the design of the Murphy Creek dam.

The Trail Wildlife Association (TWA) enhanced the spawning habitat of rainbow trout by building an in-stream side channel, through which about 40,000 rainbow trout descend from Murphy Creek into the Columbia River. MCPC will ensure there is a path for the trout to travel below the Murphy Creek dam.

MCPC expect that the most effective way to preserve fish and smolts is with the hydrocombine surface bypass approach that the Wells dam has successfully used. The US Army Corps of Engineers has evaluated the impact on fish of Columbia River power projects and concluded that this hydrocombine design is preferred. An excerpt from their

1998 study (www.nwcouncil.org/library/isab/isab98-7.htm#_Toc431639751 ) appears below:

"*The natural behavior of juvenile salmon... places them predominantly in the upper portion of the water column. As alternatives to turbine intake screens are considered, developers hope to make use of this characteristic behavior. It has been observed that where spill can be drawn from the surface, it is more effective in attracting fish than spill drawn from deeper water. Modification of spill gates is being investigated as a possible means of improving fish passage efficiency while maintaining spill volumes at levels that will meet water quality standards. Preliminary tests with sluiceway gates that were already designed to draw from surface waters have shown promise.*

*The primary source of encouragement for surface flow bypass development is the success at Wells Dam in the mid-Columbia Reach. Wells Dam includes the first successful surface flow bypass system for juvenile salmon. Testing of a prototype began in 1983. Full installation across the powerhouse was complete in 1989. Studies over the next three years showed that the bypass was successful in passing 89% of the juvenile fish that passed the dam, both in spring and summer (Skalski, 1993). To date, it is the only system in the Columbia Basin that achieves the 80% fish passage standard without the addition of spill.*

*One of the reasons for the success of surface collection at Wells Dam is the particular design of the dam itself, known as a hydrocombine, in which the spillway is located directly above the turbine intakes. Hydraulic model studies indicated the feasibility of the concept. In the prototype and final design, solid baffles were placed in front of the spillway entrances to a point 30 to 40 feet below the surface. In five of the eleven enclosed spillbays a vertical slot was left open for passage of water and fish in the center slot of those spill bays. Opening the top leaf of a spillway gate provided fish attraction flow that kept the fish in the upper strata of the water column, rather than sounding to pass through the turbine intakes (Johnson, 1995).*

*Another reason for the success of surface bypass at Wells Dam is that juvenile salmon generally follow the bulk flow into the forebay. Juvenile salmon are usually found in the upper 30-35 ft of the flow approaching the 1000-ft width of the hydrocombine. The turbine units draw from deep in the water column, and the lines of flow into the turbines are relatively flat. Hence the combination of fish distribution and hydrocombine hydraulics make it likely that the juvenile salmon will encounter one of the surface bypass entrances at Wells Dam.*

*The design and configuration of the entrances also play important roles in the success of Wells Dam surface bypass. Placement of the five entrances across the powerhouse is designed to ensure encounters by juvenile salmon. In addition to location, three factors are key to the success of the entrances; large size, appropriate acceleration coefficient, and high volume of flow relative to total discharge."*

MCPC will incorporate these design parameters into the Murphy Creek project.

### Other Environmental Impacts

Vegetation and wildlife will not be significantly affected by the project construction or operation. Stands of Rocky Mountain Juniper and lowland vegetation will lost, but these are not unique species, and these areas are already disturbed. There are no ecological reserves or areas of potential reserve status identified in the lowland areas to be affected. Firewood from clearing (estimated at about 100 cords) will be sold or given away to local residents. Potential minor impacts to wildlife have been identified: loss of deer winter range, affecting about 9 to 22 deer; reduction in merganser population and spotted sandpiper habitat.

The project will mitigate these impacts by providing reclamation and increasing carrying capacity of nearby deer winter ranges, scheduling initial reservoir fill to avoid bird breeding and mammal estivating periods, and monitoring osprey activity to determine whether artificial structures are needed.

### *Affected Water Users*

During river diversion and cofferdam installation, turbidity and suspended solids concentration in the river are expected to increase. Although this impact will be temporary, the project proposes to initiate a baseline and construction water quality monitoring program one year prior to construction. Another possibility for alleviating the temporary construction-related water-quality impacts is to operate a "closed system", i.e., no discharges to the river and construction "in the dry".

The Murphy Creek project will provide water treatment (filtering) to the Cominco users to allow for increased capacity and ensure continuation of the existing water supply. Ground-water wells may be installed where necessary to supplement the water supply for the nearby communities Cominco, Tadanak, Warfield, Oasis, and Riverdale. An upstream and downstream monitoring program will also be established by the project prior to construction. This program will also address impacts to fish.

## Project Schedule

MCPC will assume that the Murphy Creek project is reviewable under the terms of the British Columbia Environmental Assessment Office (i.e. "a new facility with a rated nameplate capacity of $\geq$ 50 MW of capacity that is a hydroelectric power plant"). The first year and a half of the seven-year schedule will involve updating the already extensive base studies, and meeting all provincial and federal regulations.

Our schedule below anticipates a regulatory go-ahead by March 2005, and full operation by spring 2011, as follows:

| Event | Target date |
|---|---|
| Submit first draft of Proposed Terms of Reference to the BCEAO | January 2004 |
| Meeting with agencies, First Nations and other stakeholders to review the draft Proposed Terms of Reference | February 2004 |
| Submit final draft Proposed Terms of Reference to the BCEAO | March 2004 |
| Issue final draft Proposed Terms of Reference to agencies, First Nations and other stakeholders for review | April 2004 |
| BCEAO, Environment Canada and DFO issue review comments and recommendations | June 2004 |
| Submit final Proposed Terms of Reference to BCEAO for approval | July 2004 |
| Final Terms of Reference Approved by BCEAO | July 2004 |
| Submit Project Report/Comprehensive Study Report | September 2004 |
| Environmental Assessment Certificate Issued and Decision by Federal Responsible Authority | Feb/March 2005 |
| Award Design-Build Contract for Power plant | August 2006 |
| Final site acquisition completed | March 2007 |
| Excavation completed | March 2009 |
| Mechanical completed | October 2010 |
| Operational | April 2011 |

## Safety Aspects

MCPC have examined schedule 1 of the Province's Dam Safety Regulation, and believe that the risk of areas downstream of the Project being affected by failure of the works is "very low" to "low". This classification means:

| Classification | Criteria |
|---|---|
| Low | Low potential for multiple loss of life, low economic losses, some loss or significant deterioration of regional fisheries habitat. |
| Very Low | Minimal potential for any loss of life and economic losses, no significant loss or deterioration to fisheries habitat. |

MCPC will provide hydrographs reflecting downstream impacts of dam failure as part of the environmental assessment process.

## Related Considerations

### *Archaeological Assessments*

Four cultural sites considered significant by a consultant have been found in the vicinity of the project site. These are at Pass Creek, Brilliant, Ferry Slip and Hamm Creek; the government and First Nations consultations and reviews mentioned above will consider these sites as required. MCPC will protect or salvage these sites prior to construction and inundation.

### *Other*

MCPC estimate that the project will create about 10,000 person-years of direct and indirect employment in BC during engineering design and construction. The operational phase of the project will create total long-term employment of at least 35 jobs, with another 35 indirectly.

## Summary and Conclusion

Murphy Creek Power Corp. are confident that the project we are proposing will be good for the Province of British Columbia.

The project will deliver a firm annual energy production of 1,671 gigawatt hours and an average energy production of 1,817 gigawatt hours. If BC Hydro does not develop Keenleyside, then the production at Murphy Creek can increase to 275 to 300 megawatts or more.

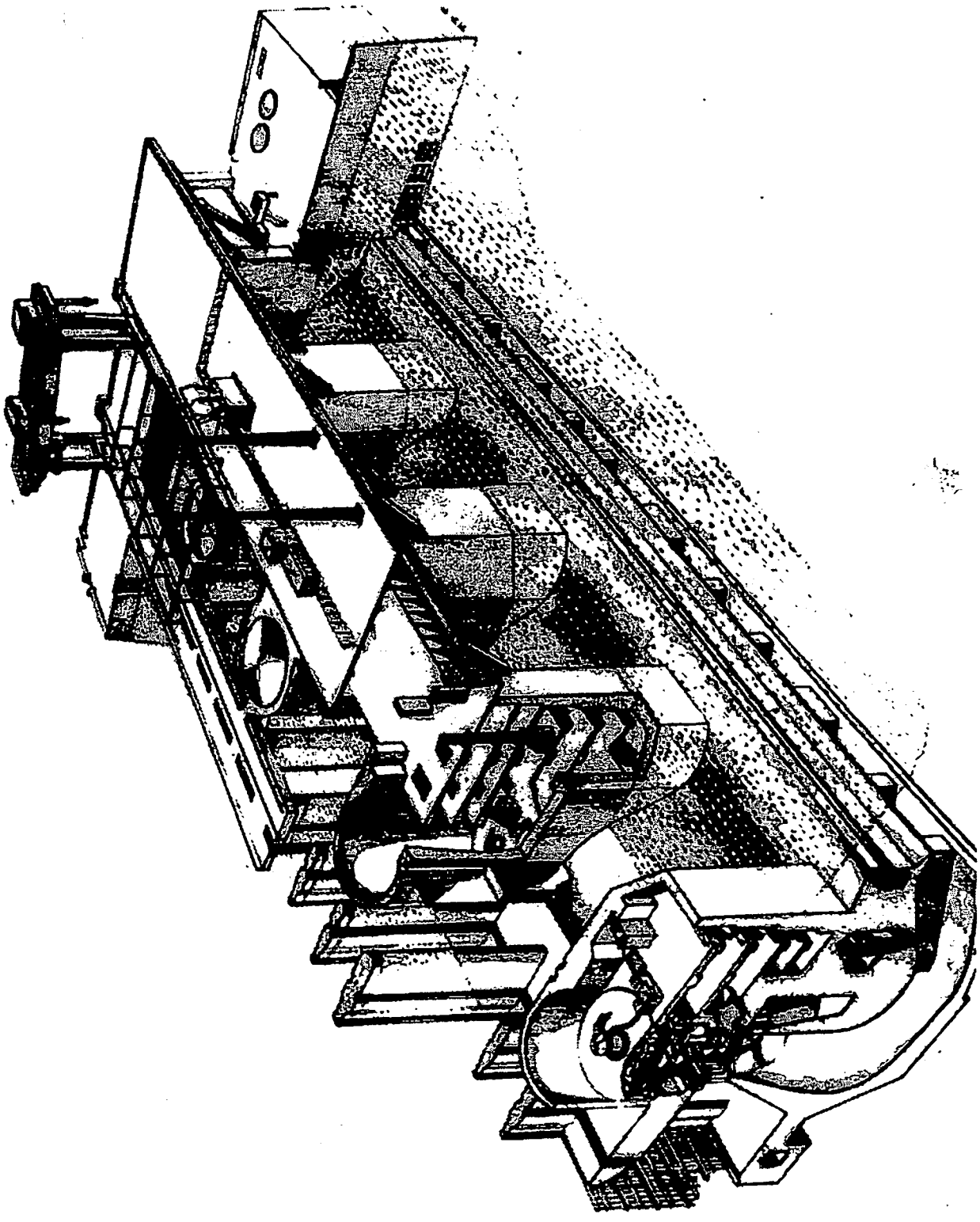
MCPC will be building on the extensive research and design done by BC Hydro for the site. MCPC will modify this base to use the proven hydrocombine approach: the structure will be smaller and will cause less environmental impact than a traditional design, while delivering the same output.

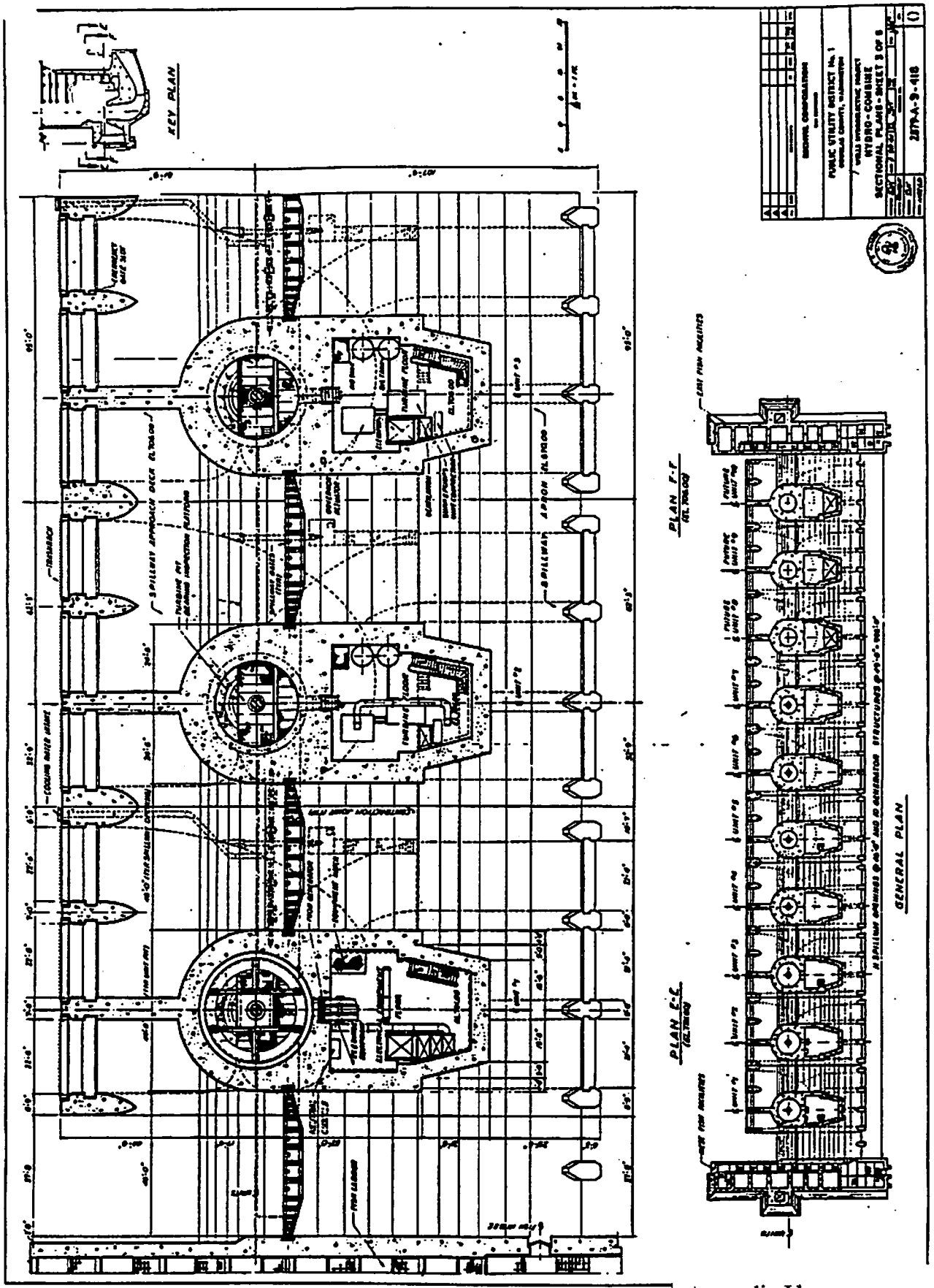
MCPC will work with all regulators and stakeholders to ensure that we have the proper studies and measures in place, and look forward to acquiring a water license so that we can move to the environmental assessment stage of the project.

# List of Appendices

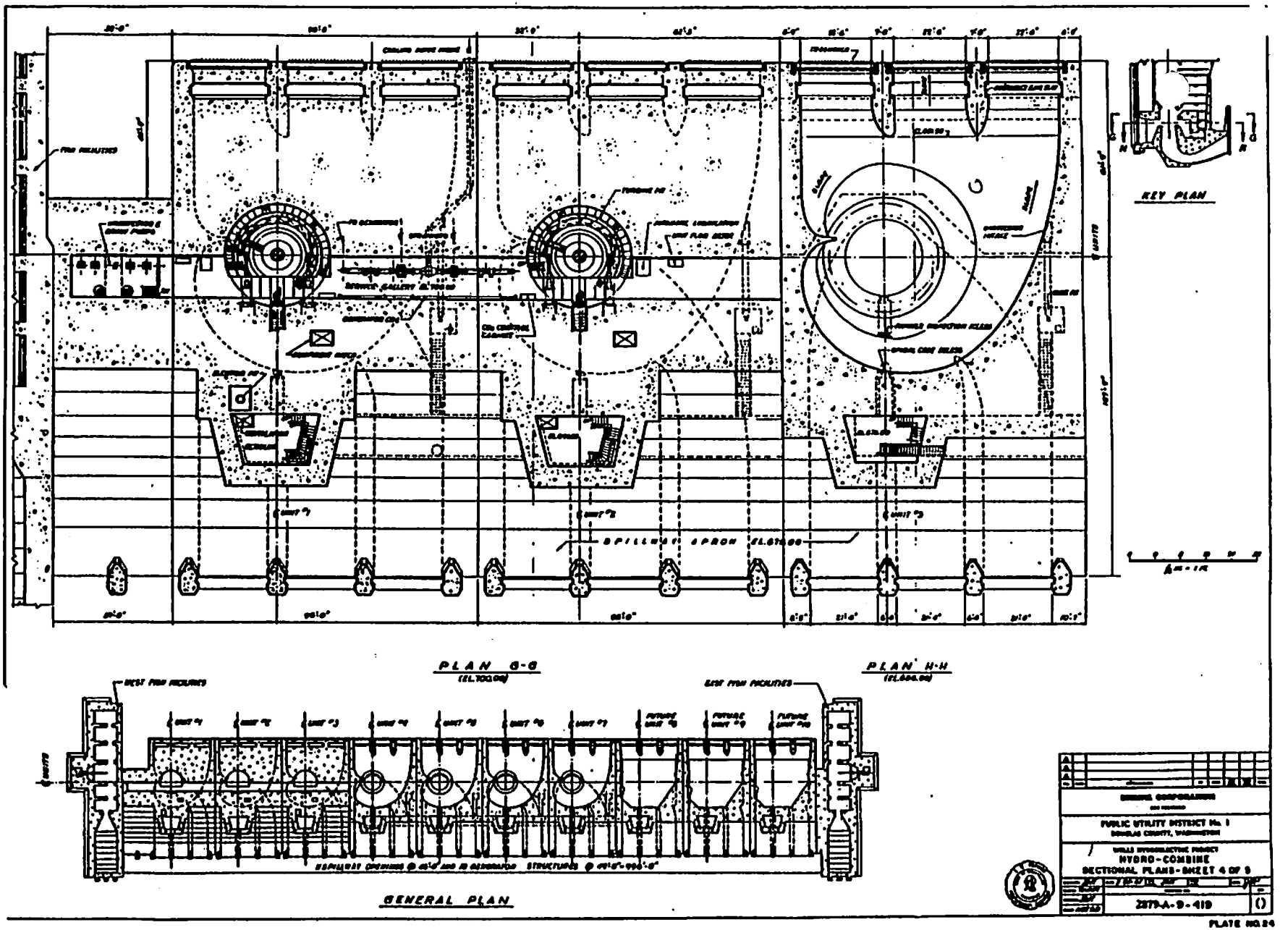
This is an overview of the appendices that appear on pages 18 through 38.

| | |
|---|---|
| I a | Hydrocombine concept, Wells Dam |
| I-b to k | Wells Dam design overview |
| I-l and m | BC Hydro's powerhouse and dam design (the hydrocombine will be similar but the spillway is located above the turbines, not beside them) |
| II a and b | Proposed transmission line |
| III a to c | Reservoir flow, duration and elevation levels |
| IV | Parcel Identification (PID) numbers |
| V | Watershed typography |
| VI | Discharge hydrographs |




KEY PLAN
PLAN F-F
PLAN E-E
GENERAL PLAN
PUBLIC UTILITY DISTRICT No. 1
HYDRO-COMBINE
SECTIONAL PLANS - SHEET 3 OF 8

Appendix I b


KEY PLAN
PLAN G-G
(EL.700.00)
PLAN H-H
(EL.666.00)
GENERAL PLAN
PUBLIC UTILITY DISTRICT No. 1
DOUGLAS COUNTY, WASHINGTON
WELLS HYDROELECTRIC PROJECT
HYDRO-COMBINE
SECTIONAL PLANS - SHEET 4 OF 9
2879-A-9-419
PLATE NO. 24

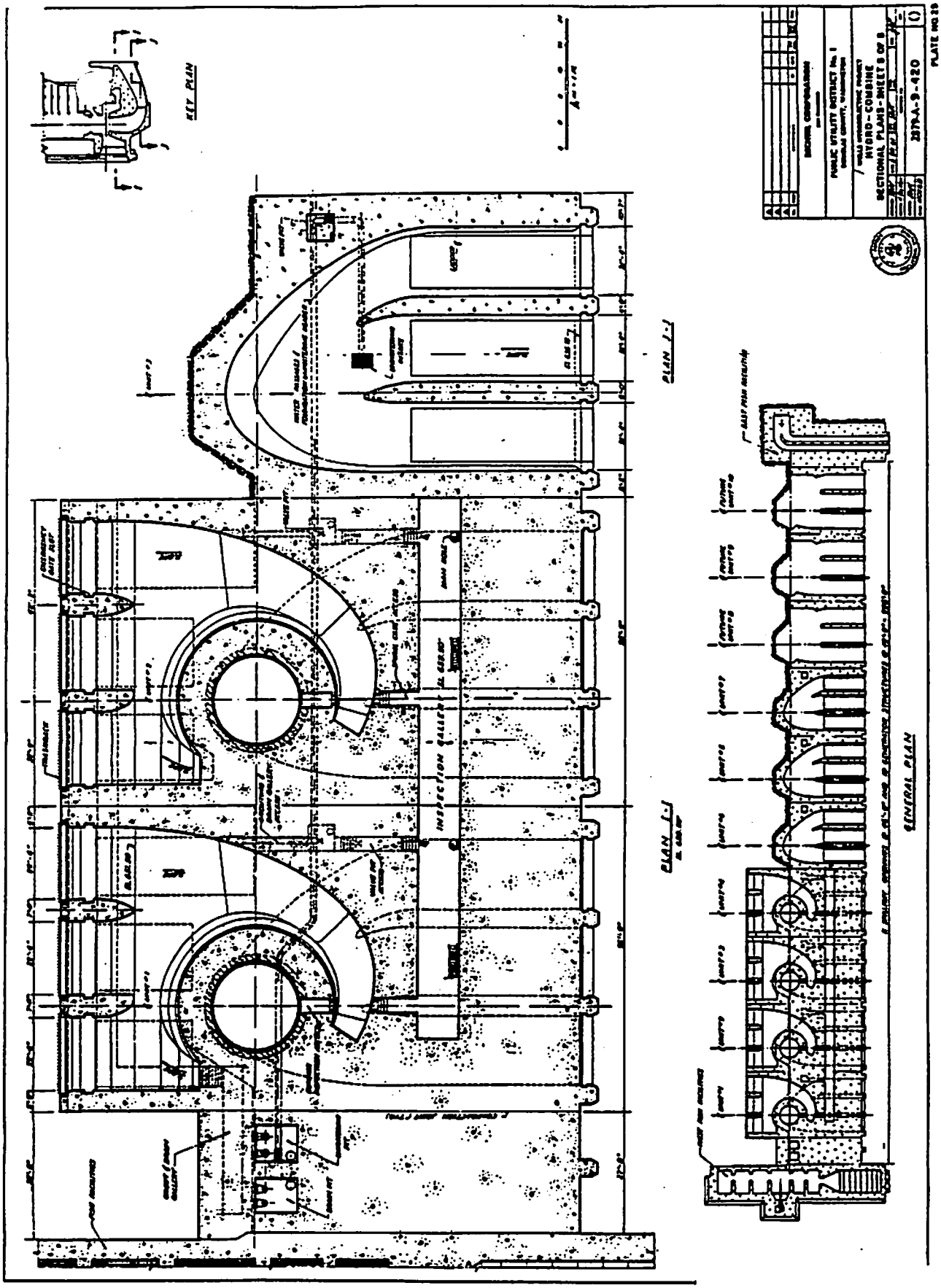
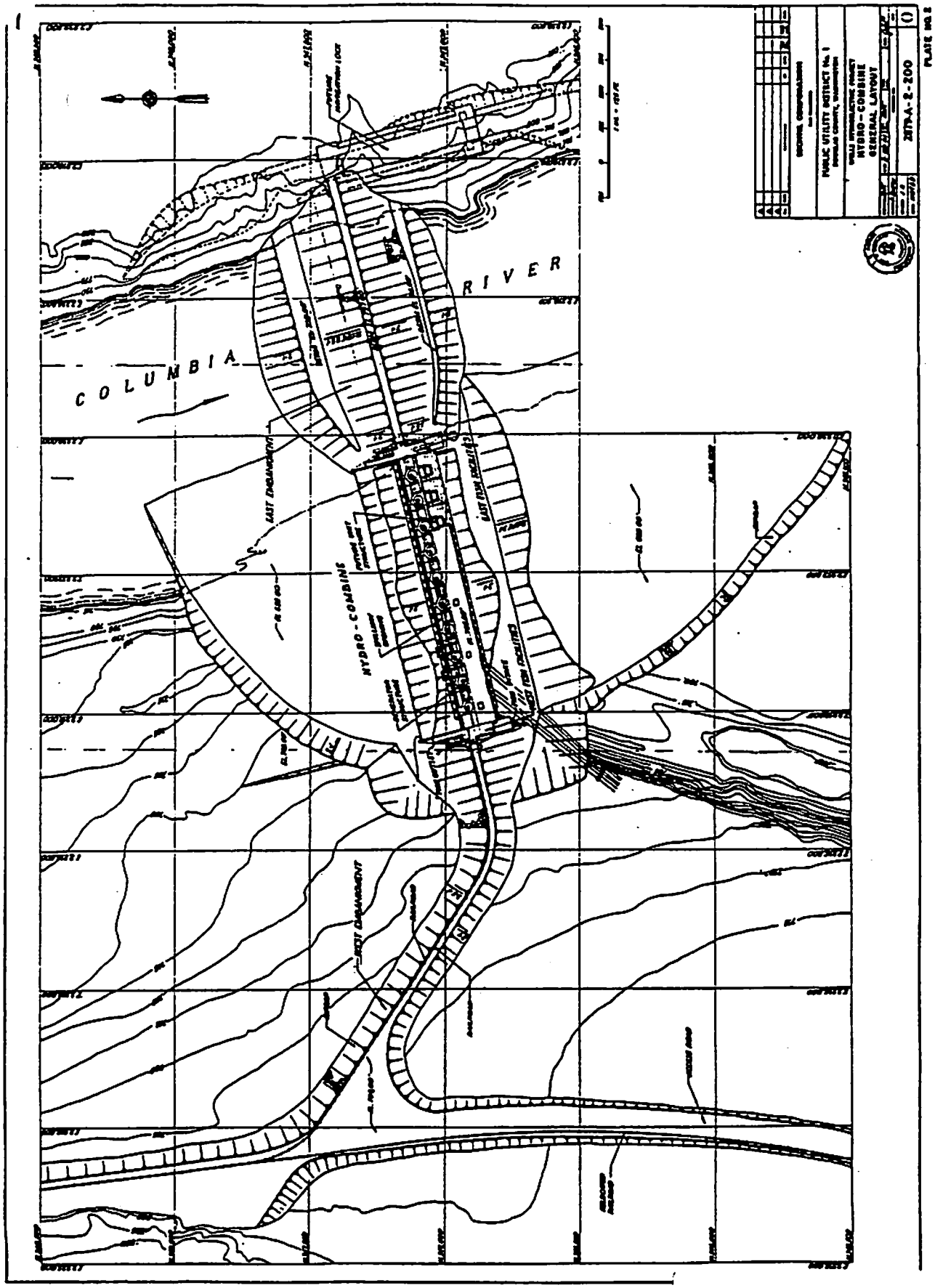
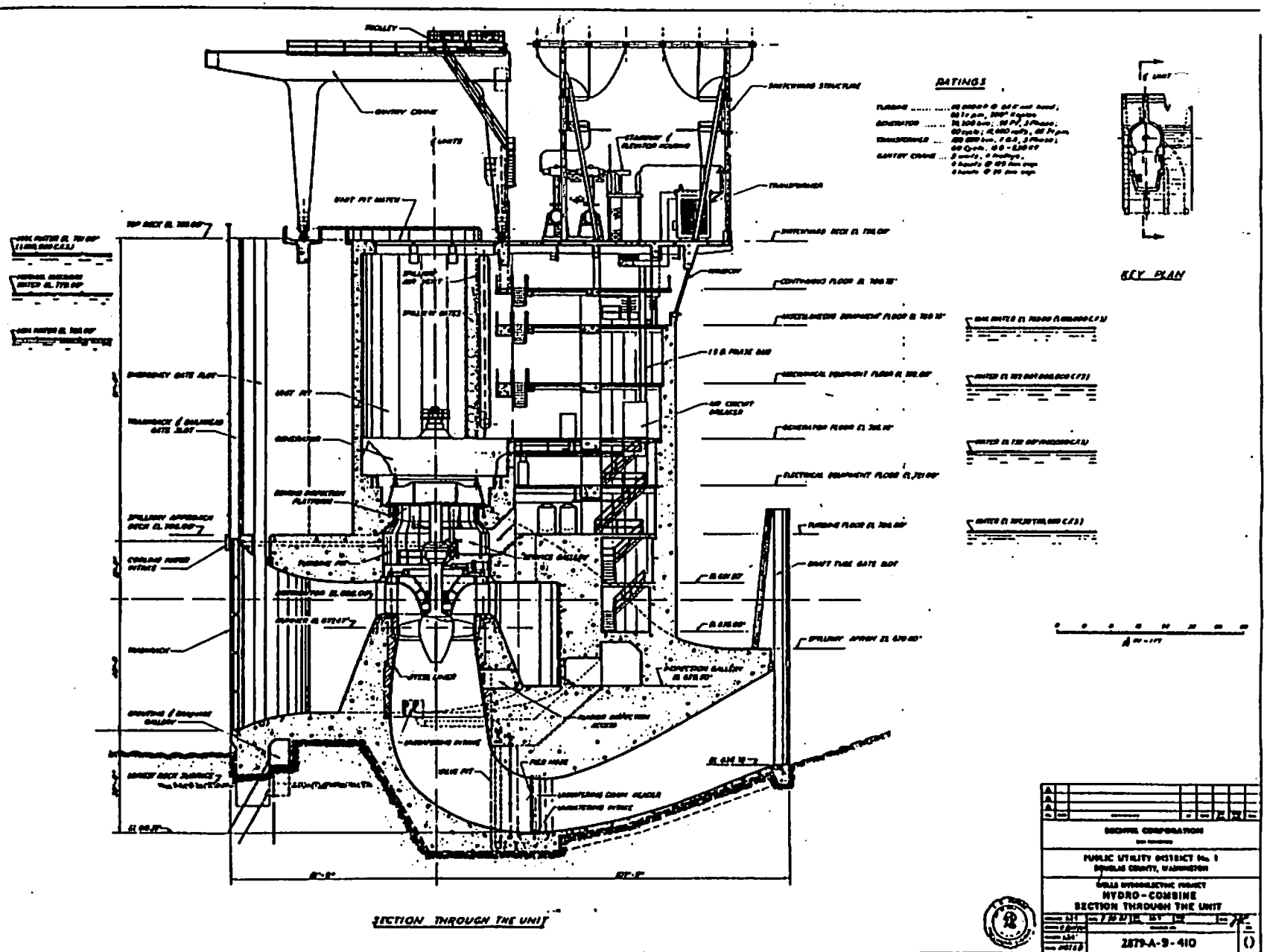


Figure 7.14

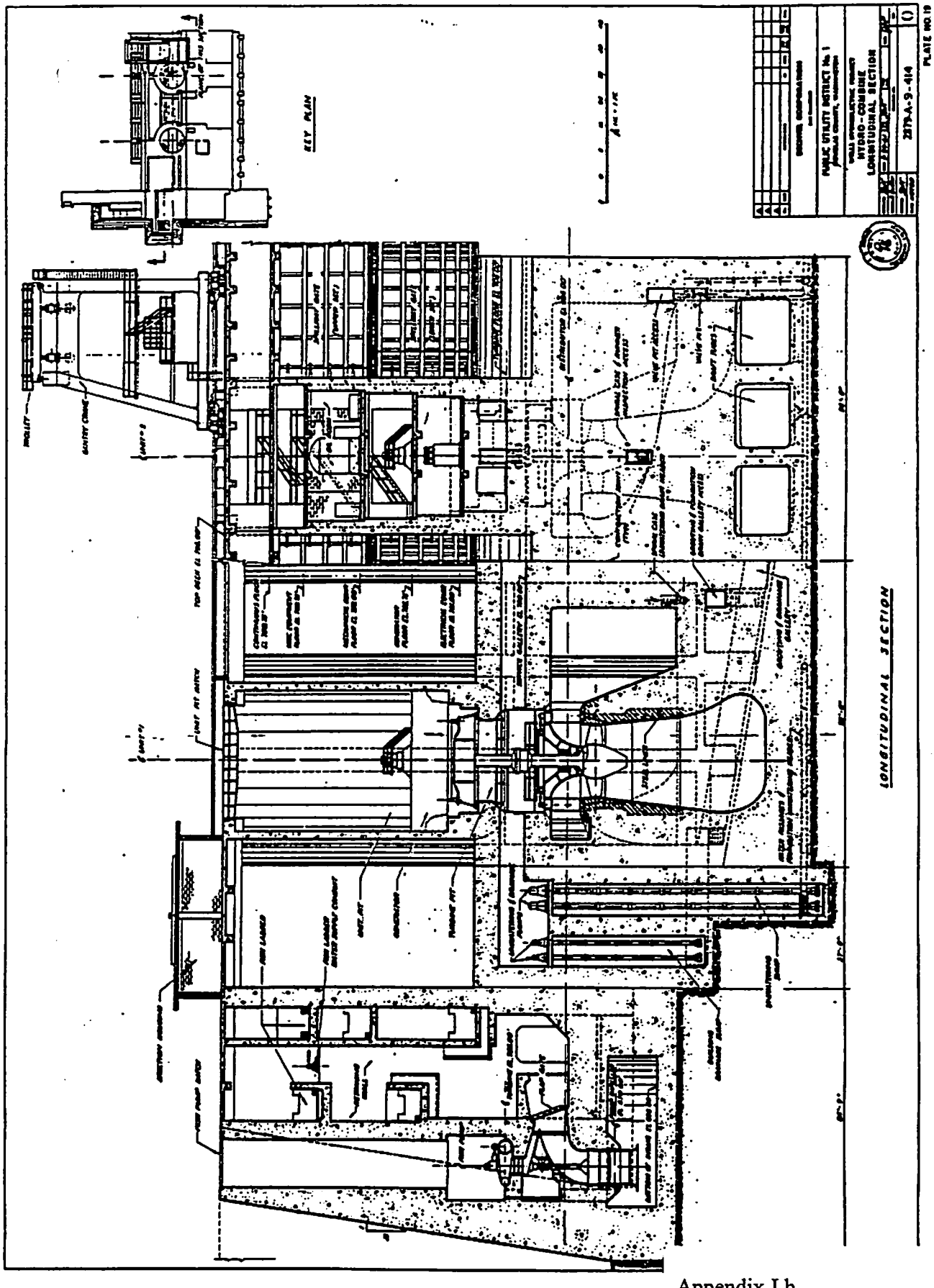
Appendix I d


COLUMBIA
RIVER
HYDRO-COMBINE
EAST EMBANKMENT
WEST EMBANKMENT
PUBLIC UTILITY DISTRICT No. 1
HYDRO-COMBINE
GENERAL LAYOUT
PLATE NO. 2

Appendix I e


RATINGS
KEY PLAN
SECTION THROUGH THE UNIT
PUBLIC UTILITY DISTRICT No. 1
DOUGLAS COUNTY, WASHINGTON
HYDRO-COMBINE
SECTION THROUGH THE UNIT
2879-A-9-410
PLATE NO. 15

SECTION THROUGH THE SPILLWAY
SPILLWAY RATING CURVE
KEY PLAN
PUBLIC UTILITY DISTRICT No. 1
SECTION THROUGH THE SPILLWAY


KEY PLAN
LONGITUDINAL SECTION
PUBLIC UTILITY DISTRICT No. 1
HYDRO-COMBINE
LONGITUDINAL SECTION
PLATE NO. 10

Appendix I h

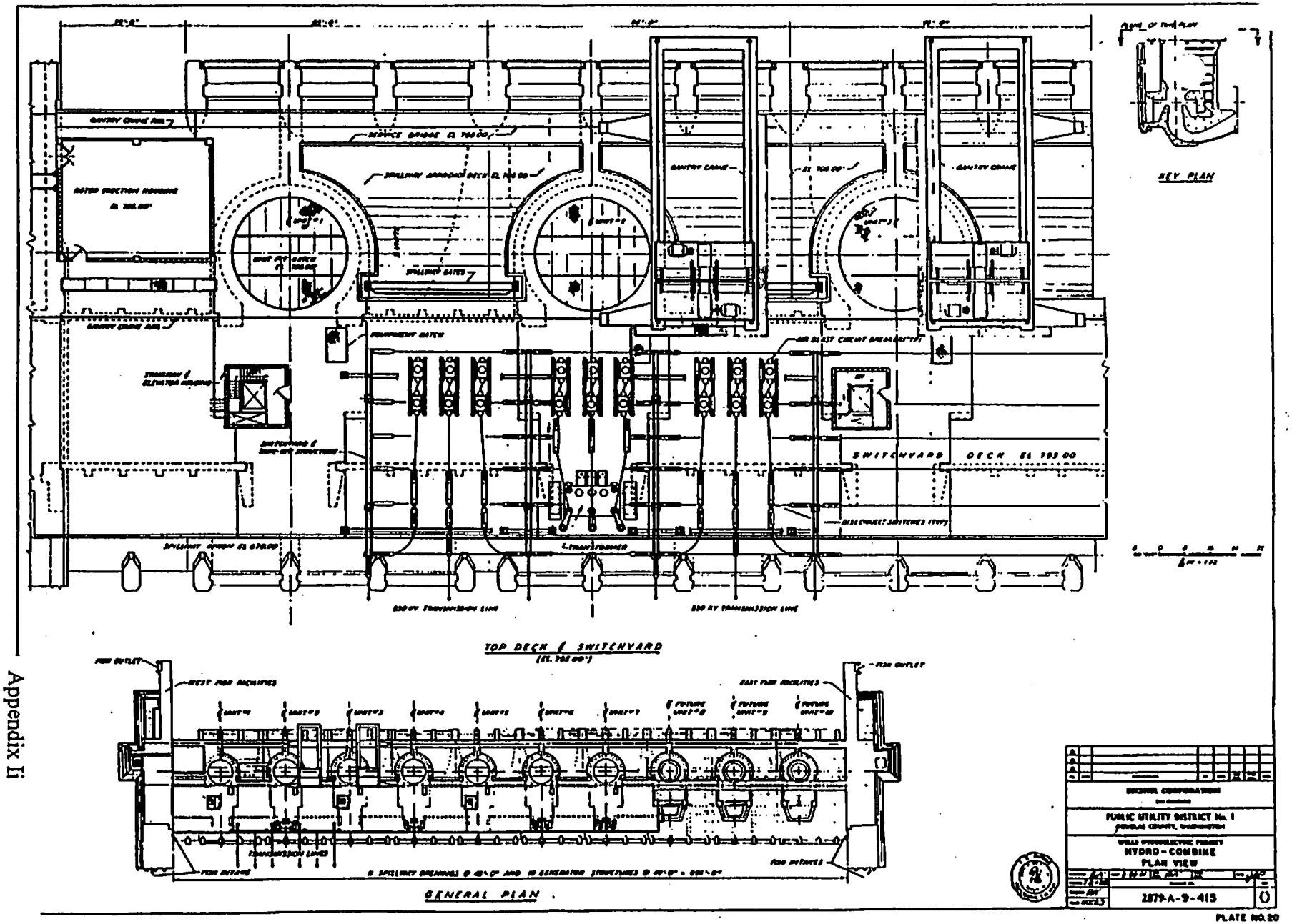
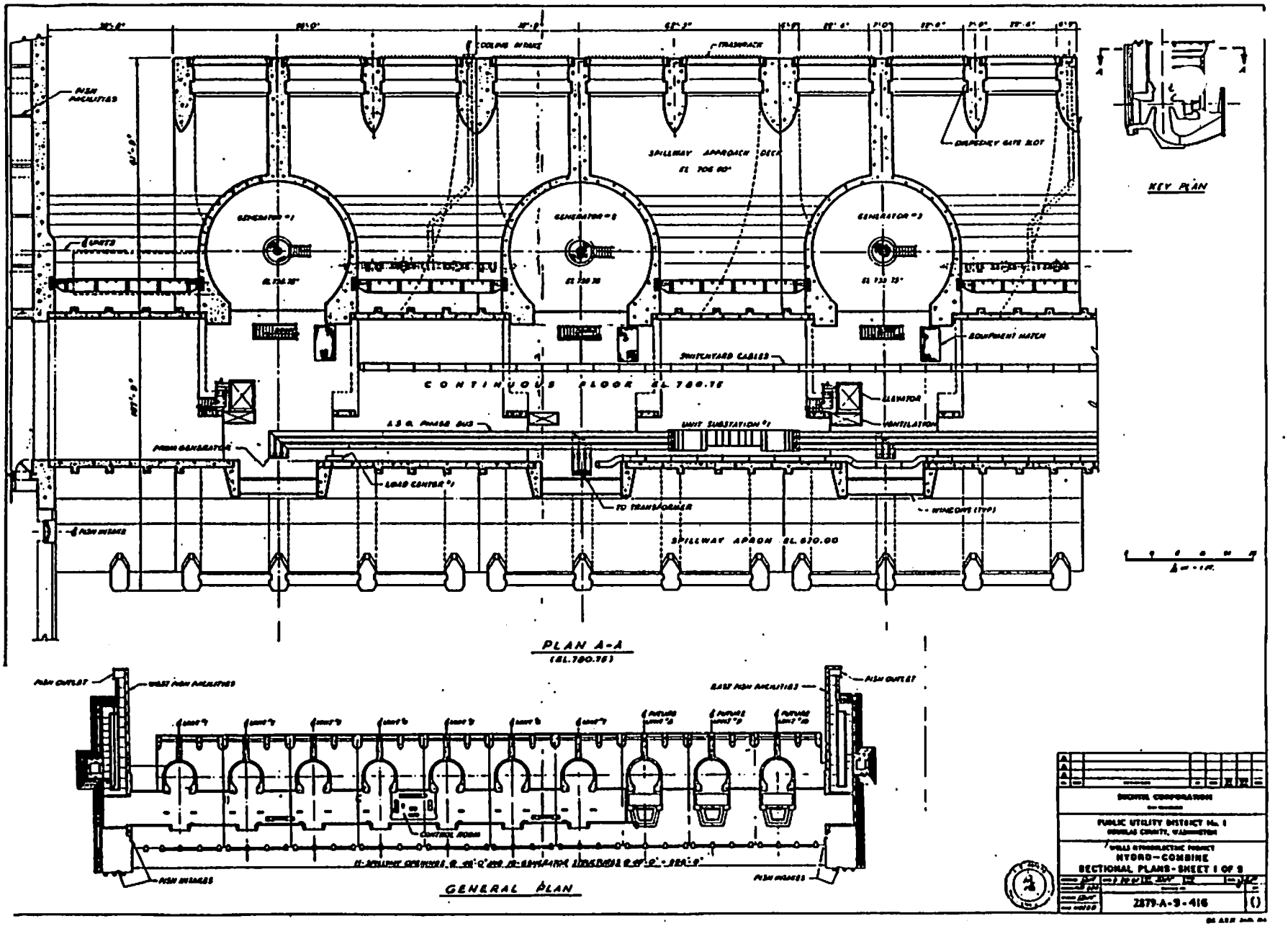
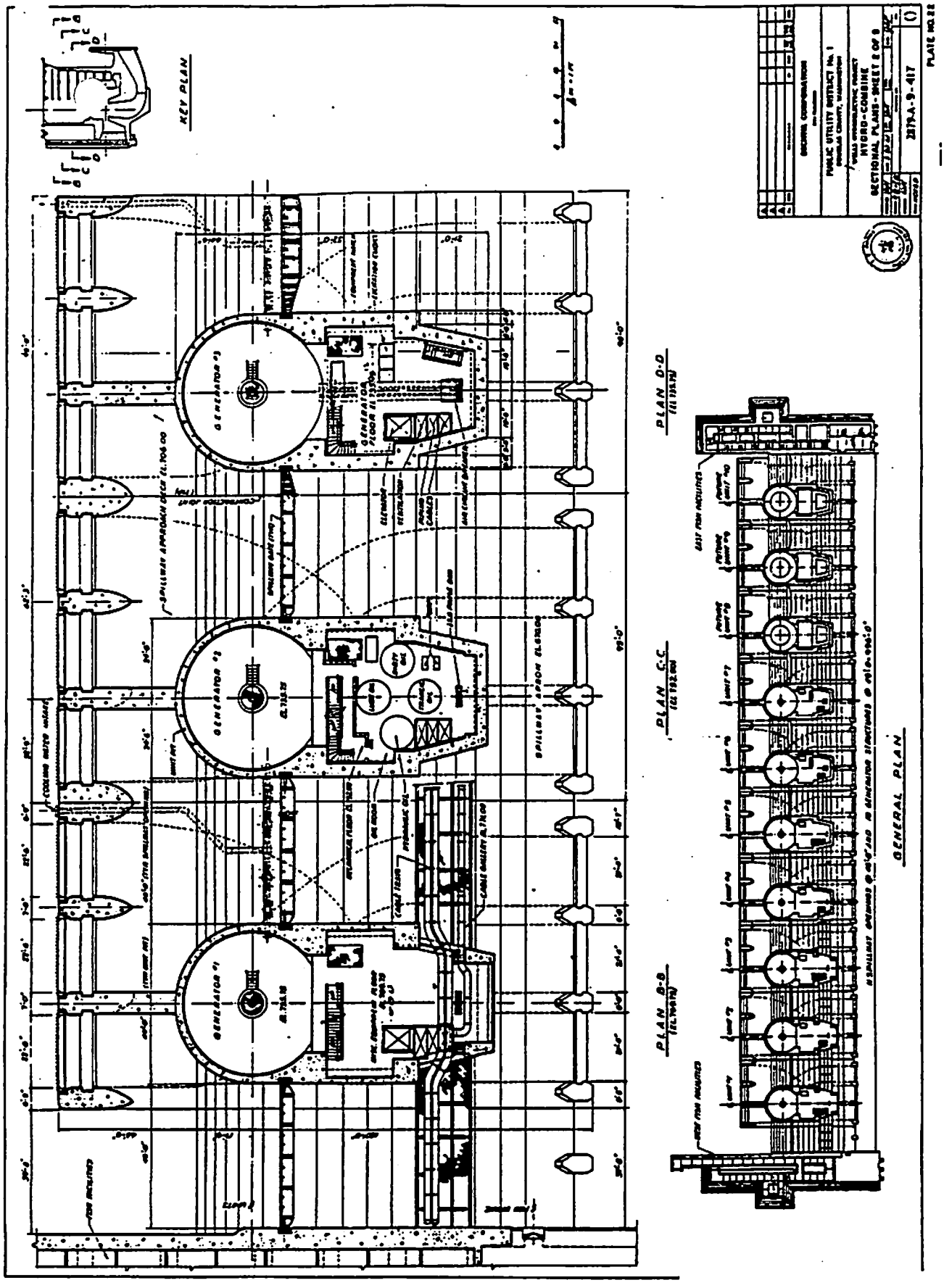
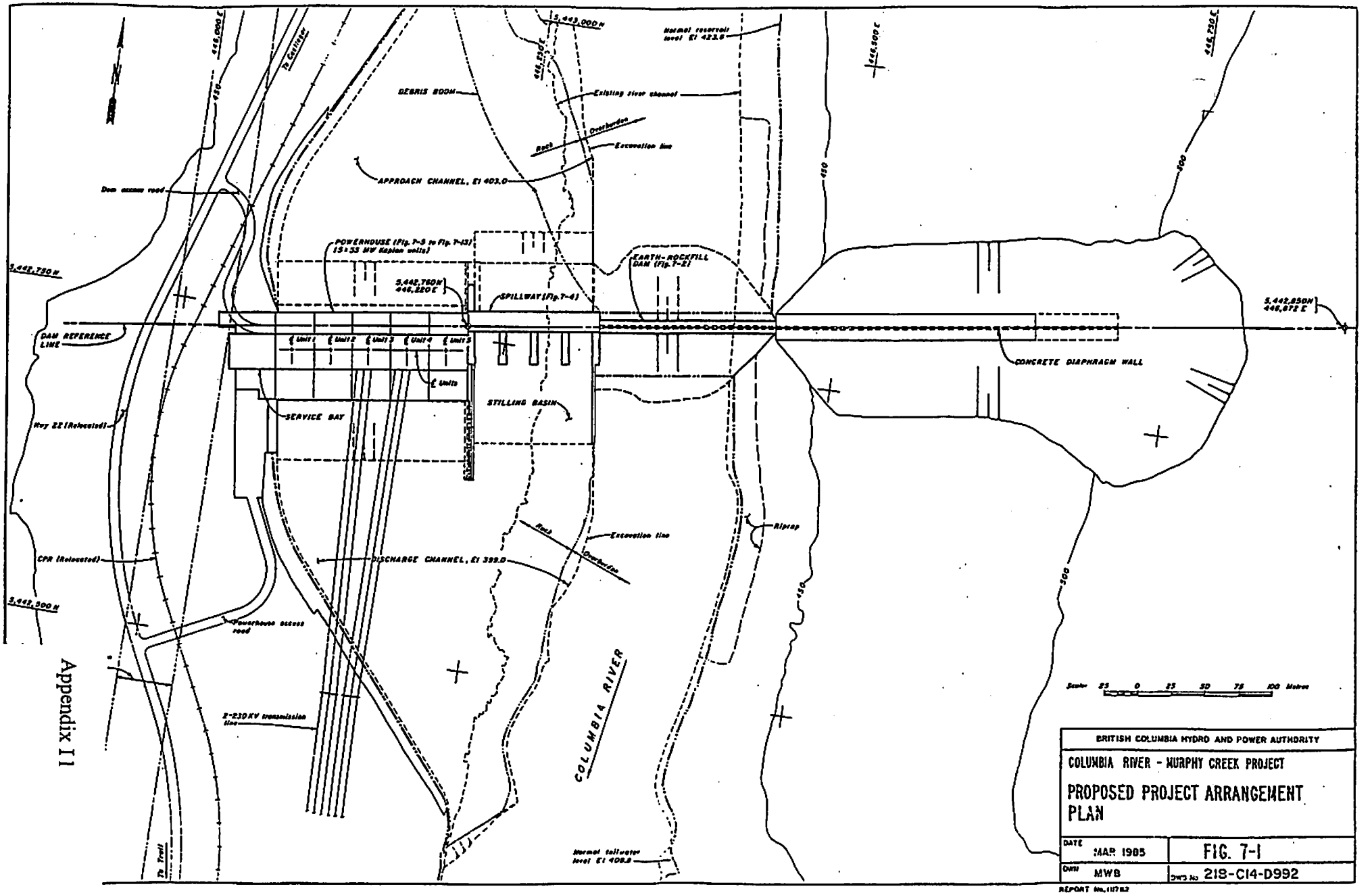

KEY PLAN
SWITCHYARD DECK EL 795.00
TOP DECK & SWITCHYARD
(EL. 795.00')
GENERAL PLAN
PUBLIC UTILITY DISTRICT No. 1
HYDRO - COMBINE
PLAN VIEW
2879-A-9-415
0

PLATE NO. 20


KEY PLAN
SPILLWAY APPROACH
CONTINUOUS FLOOR EL 780.75
SPILLWAY APRON EL 670.00
PLAN A-A
(EL.780.75)
GENERAL PLAN
PUBLIC UTILITY DISTRICT No. 1
DOUGLAS COUNTY, WASHINGTON
HYDRO-COMBINE
SECTIONAL PLANS-SHEET 1 OF 2
2879-A-9-416

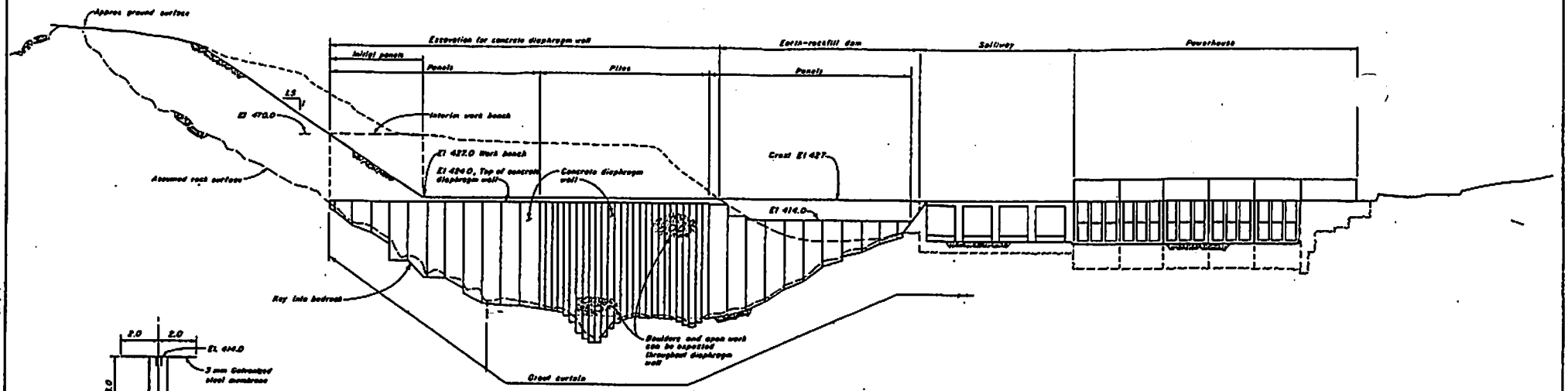

KEY PLAN
PLAN D-D
PLAN C-C
PLAN B-B
GENERAL PLAN
GENERATOR #1
GENERATOR #2
GENERATOR #3
SPILLWAY APPROACH DECK EL.706.00
SPILLWAY APRON EL.670.00
HYDRO-COMBINE
SECTIONAL PLANS-SHEET 2 OF 8
PLATE NO. 22

Appendix I k



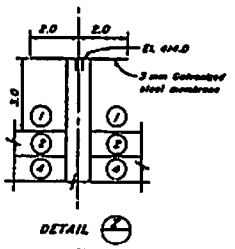
DEBRIS BOOM
Existing river channel
Normal reservoir level El 423.6
Rock
Overburden
Excavation line
APPROACH CHANNEL, El 403.0
Dam access road
POWERHOUSE (Fig. 7-5 to Fig. 7-13) (5 x 55 MW Kaplan units)
EARTH-ROCKFILL DAM (Fig. 7-2)
5,442,760 N 446,220 E
SPILLWAY (Fig. 7-4)
5,442,850 N 446,872 E
DAM REFERENCE LINE
Unit 1
Unit 2
Unit 3
Unit 4
Unit 5
Units
CONCRETE DIAPHRAGM WALL
STILLING BASIN
SERVICE BAY
Hwy 22 (Relocated)
Riprap
Excavation line
Rock
Overburden
CPR (Relocated)
DISCHARGE CHANNEL, El 399.0
Powerhouse access road
2-230 KV transmission line
COLUMBIA RIVER
Normal tailwater level El 408.8
To Castlegar
To Trail
5,442,750 N
5,442,500 N
5,443,000 N
446,000 E
446,250 E
446,500 E
446,750 E
450
500
Scale 25 0 25 50 75 100 Metres
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
COLUMBIA RIVER - MURPHY CREEK PROJECT
PROPOSED PROJECT ARRANGEMENT PLAN
DATE MAR 1985
FIG. 7-1
DWN MWB
DWG No 218-C14-D992
REPORT No. 11782

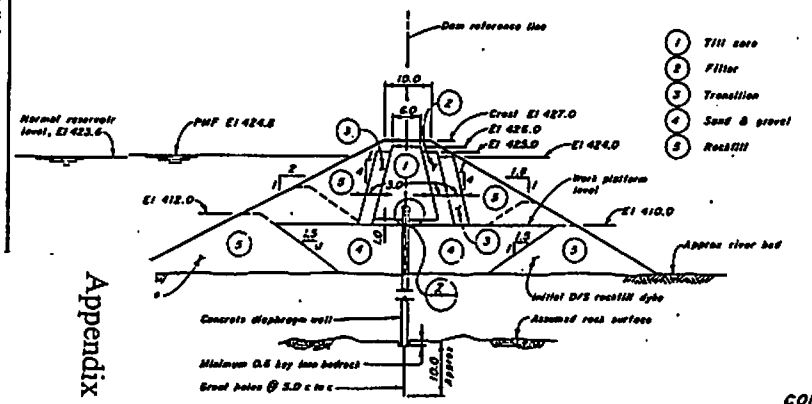

Appendix I1




SECTION ALONG DAM REFERENCE LINE (LOOKING DOWNSTREAM)

Scale A

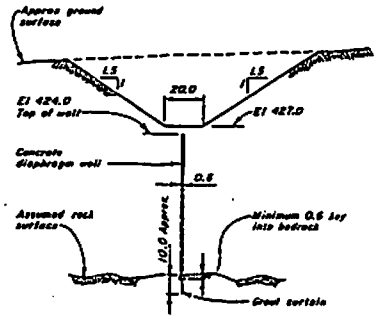



1. Till core
2. Filter
3. Transition
4. Sand & gravel
5. Rockfill

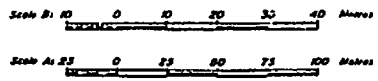
TYPICAL EARTH - ROCKFILL DAM SECTION

Scale B




CONCRETE DIAPHRAGM WALL SECTION - LEFT BANK

Scale A




BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

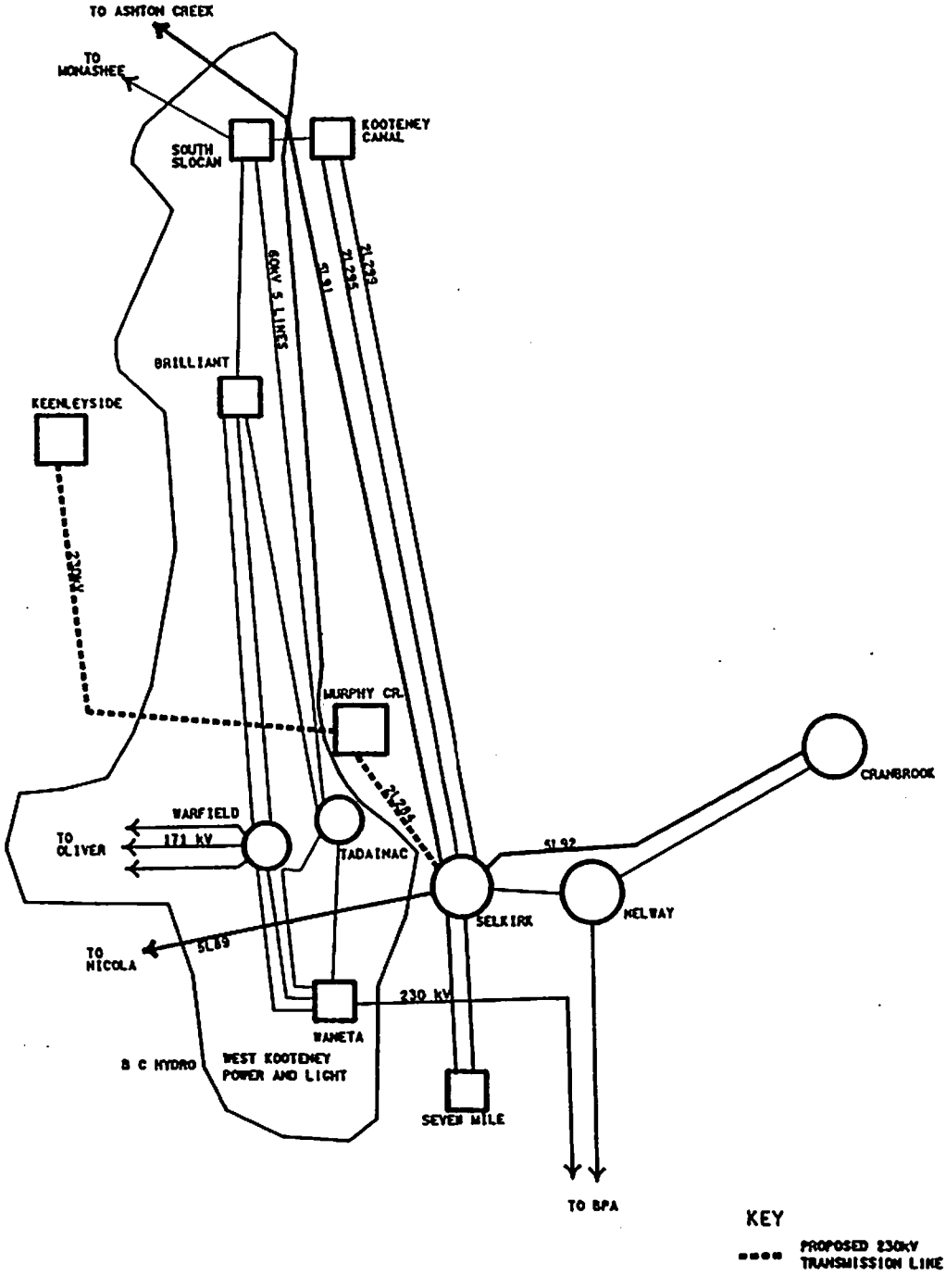
COLUMBIA RIVER - MURPHY CREEK PROJECT

PROPOSED PROJECT ARRANGEMENT ELEVATION & SECTIONS

| DATE | MAR 1985 | FIG. 7-2 |
|---|---|---|
| DWN | MWB | DWG No 218-C14-D993 |

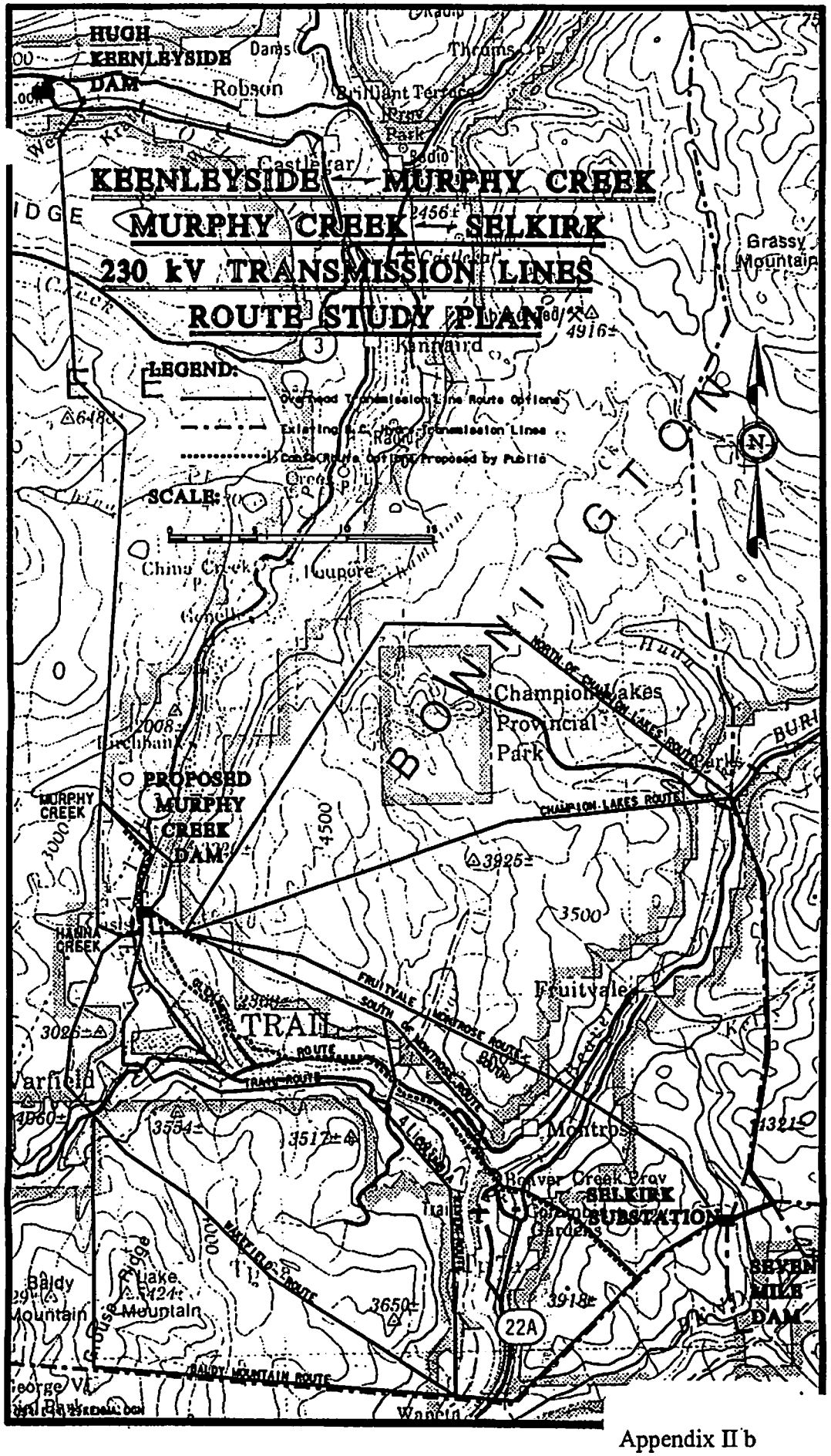
REPORT No. H1782

Appendix I m




KEENLEYSIDE - MURPHY
PROJECT
PREFERRED TRANSMISSON
SYSTEM

Appendix II a

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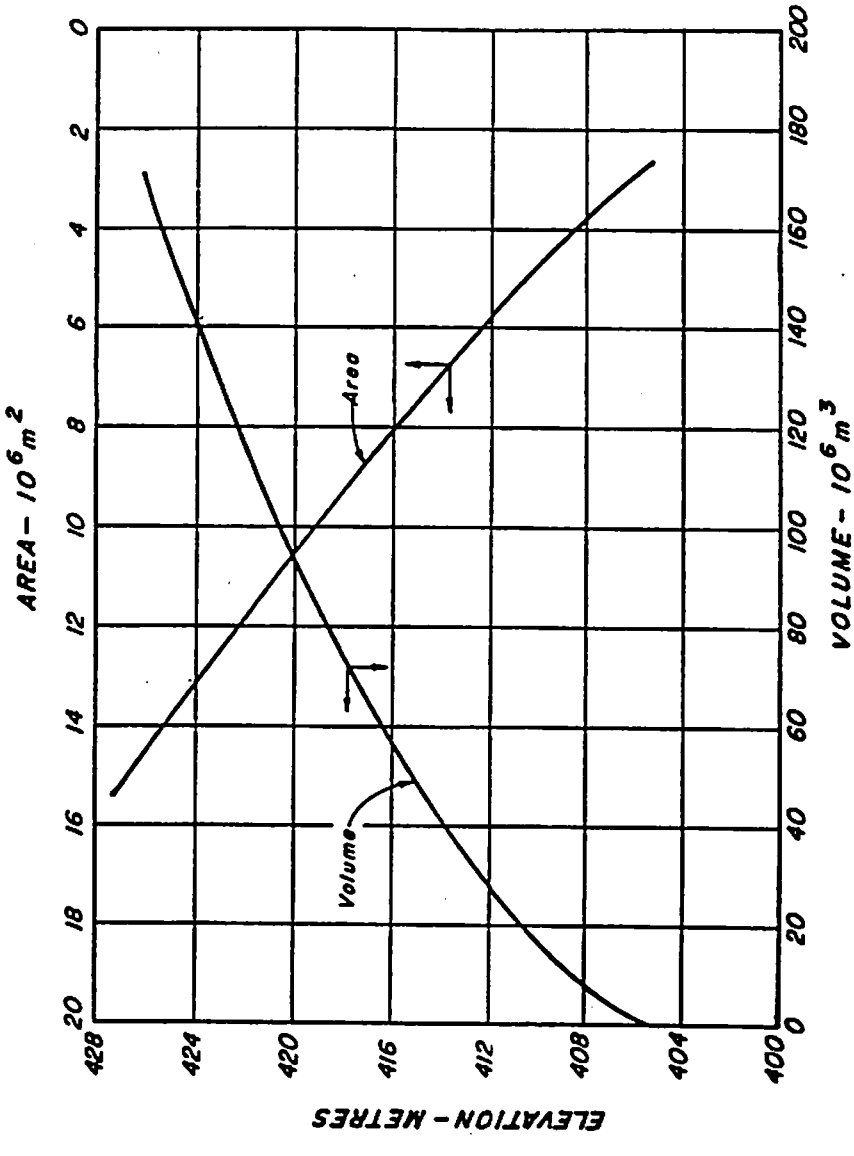



BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

COLUMBIA RIVER - MURPHY CREEK PROJECT

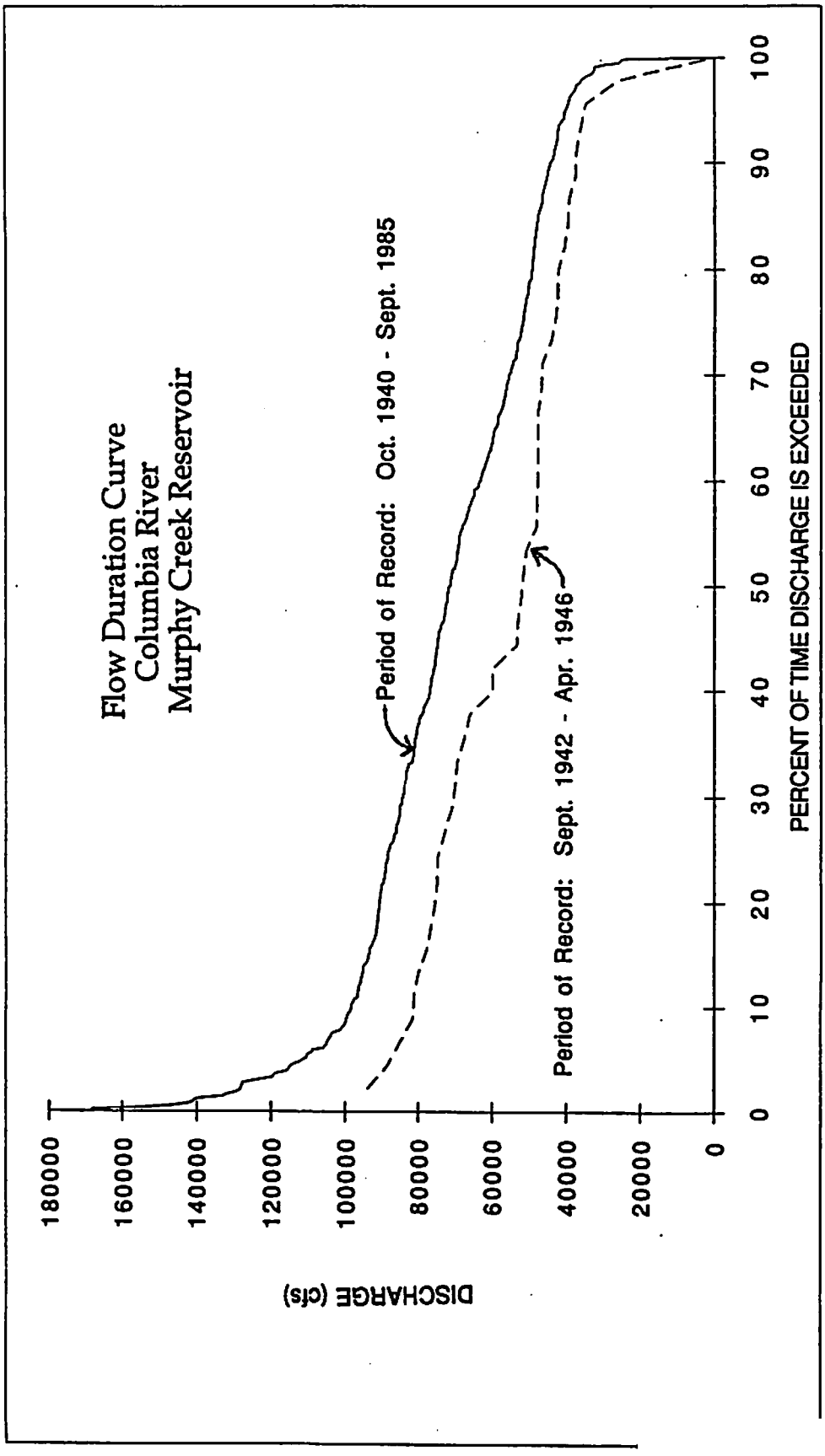
RESERVOIR AREA AND VOLUME CURVES

DATE MAY 1983

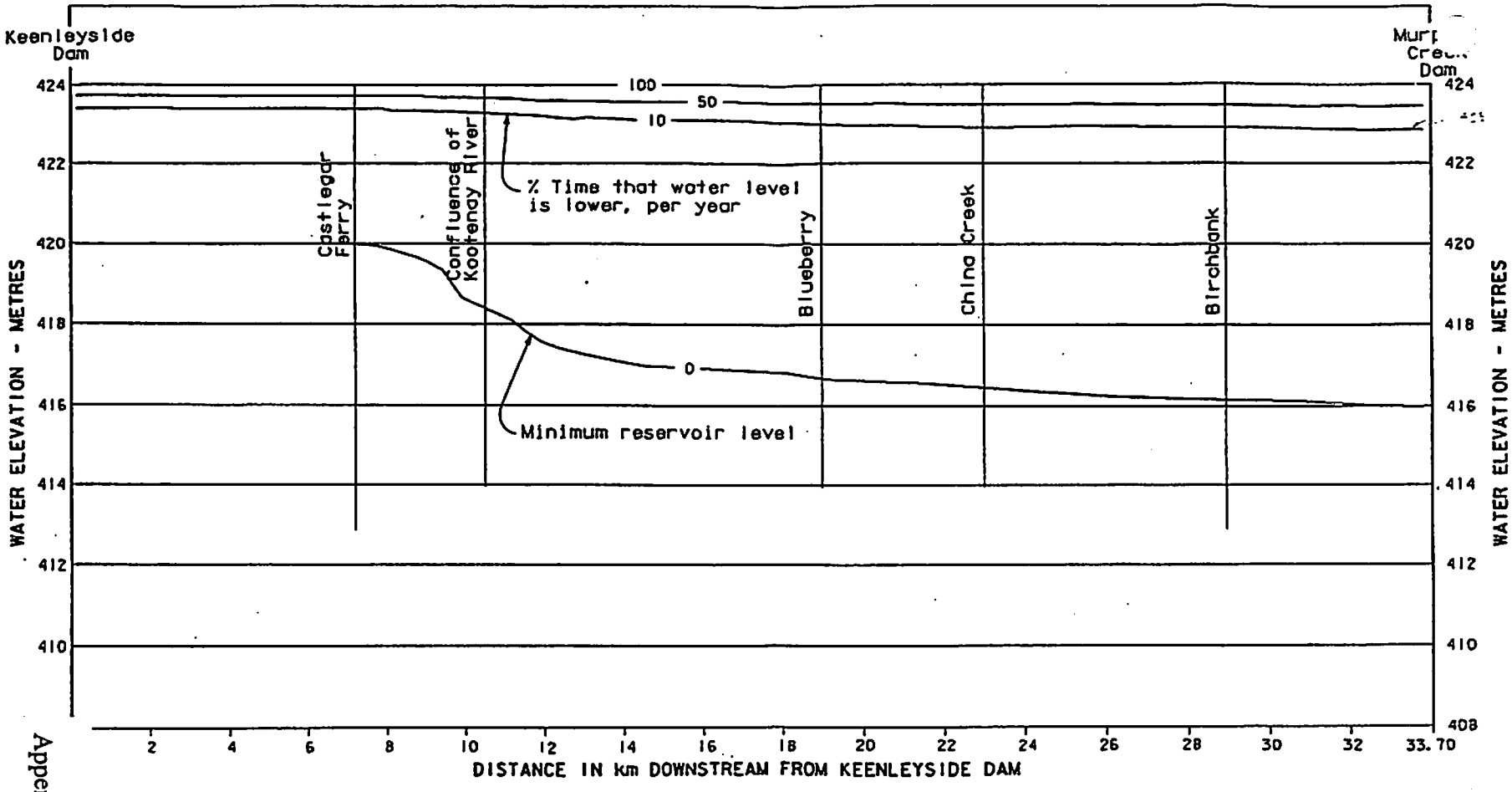
DWG N.O.

DWG No. 218-C14-B620

Appendix III a




Appendix III b




E S :
RESERVOIR LEVELS SHOWN ARE BASED ON A MAXIMUM OPERATING LEVEL OF EL. 424m AT CASTLEGAR FERRY WATER LEVEL GAUGE

RESERVOIR LEVEL DATA IS BASED ON 40 YEAR DAILY FLOW SIMULATION

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

COLUMBIA RIVER - MURPHY CREEK PROJECT

RESERVOIR LEVELS

REGIME 3

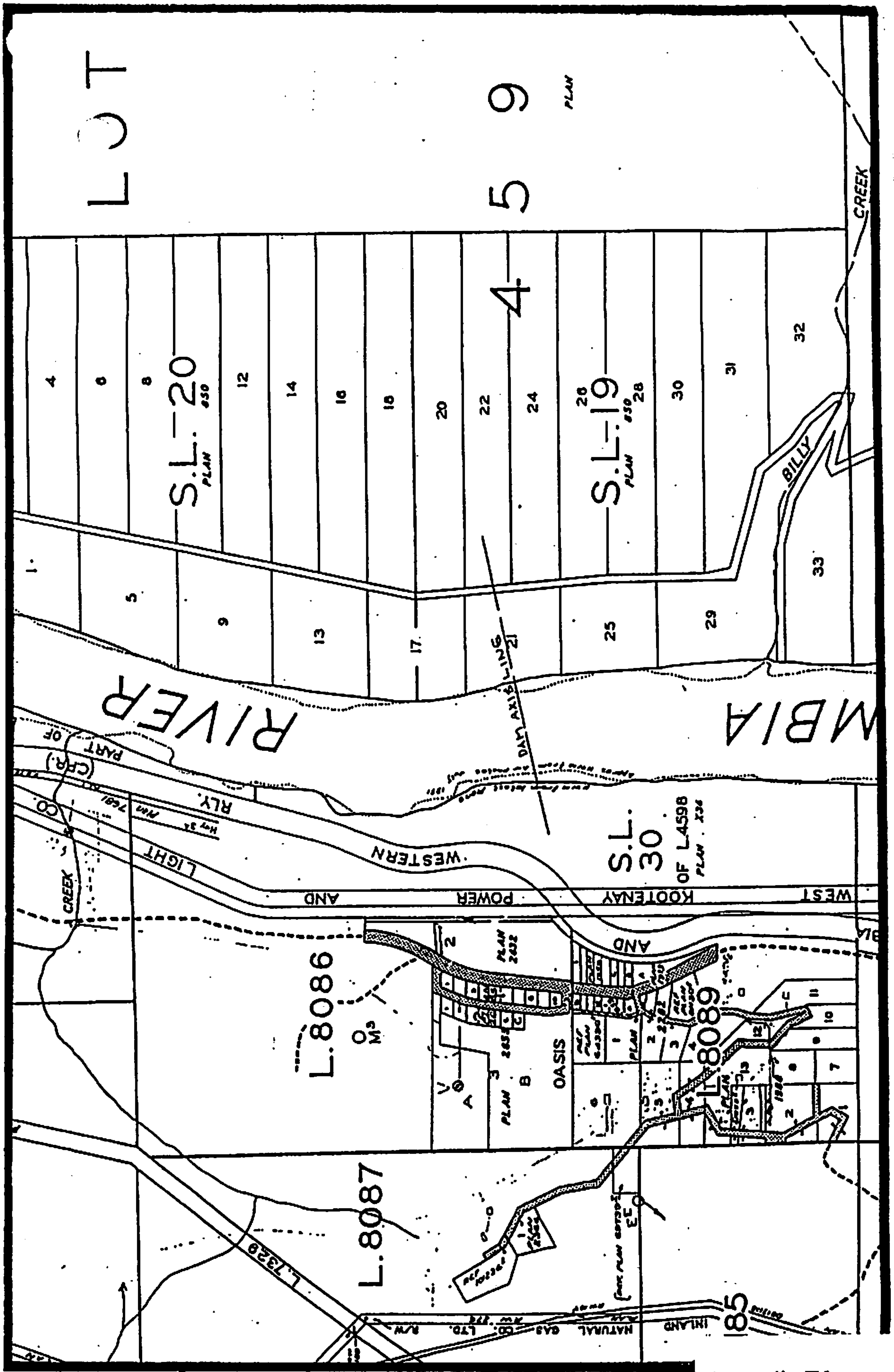
DATE MAR 1985

DWN MHB

DWG No. 218-C14-B980

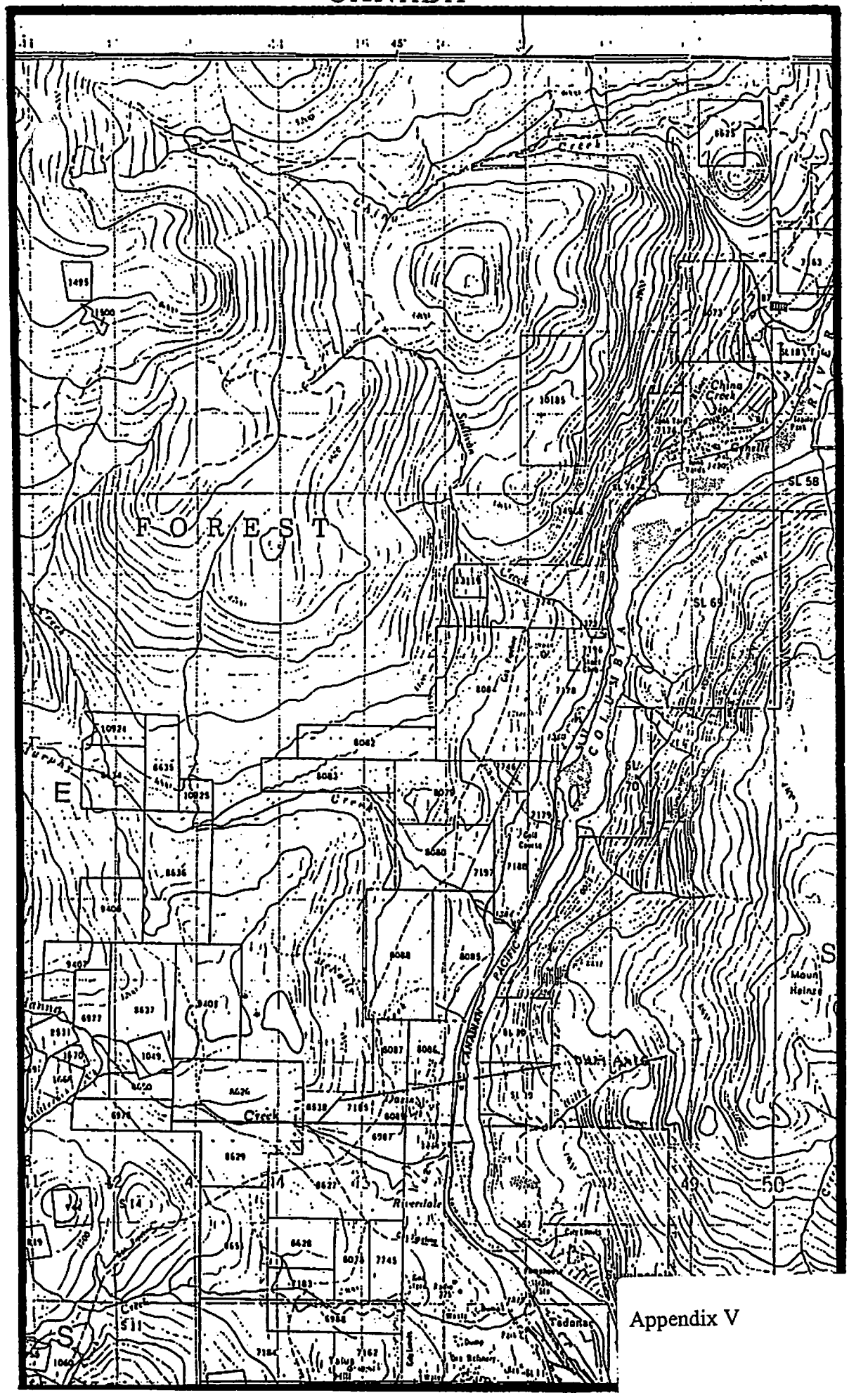
REPORT No. 81182

Appendix III c

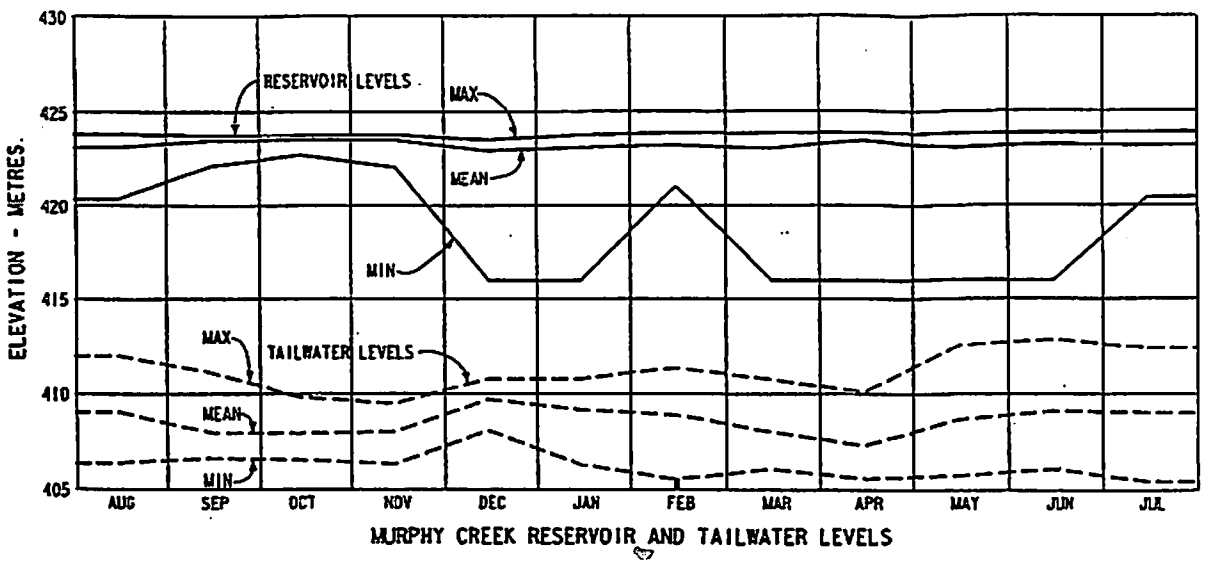

LOT 459
S.L. 20
S.L. 19
BILLY
CREEK
RIVER
DAM AXIS LINE
S.L. 30 OF L.4598
WEST KOOTENAY POWER AND LIGHT CO.
WESTERN
L.8086
L.8087
L.8089
OASIS
L.7328
INLAND NATURAL GAS CO. LTD. R/W

Appendix IV

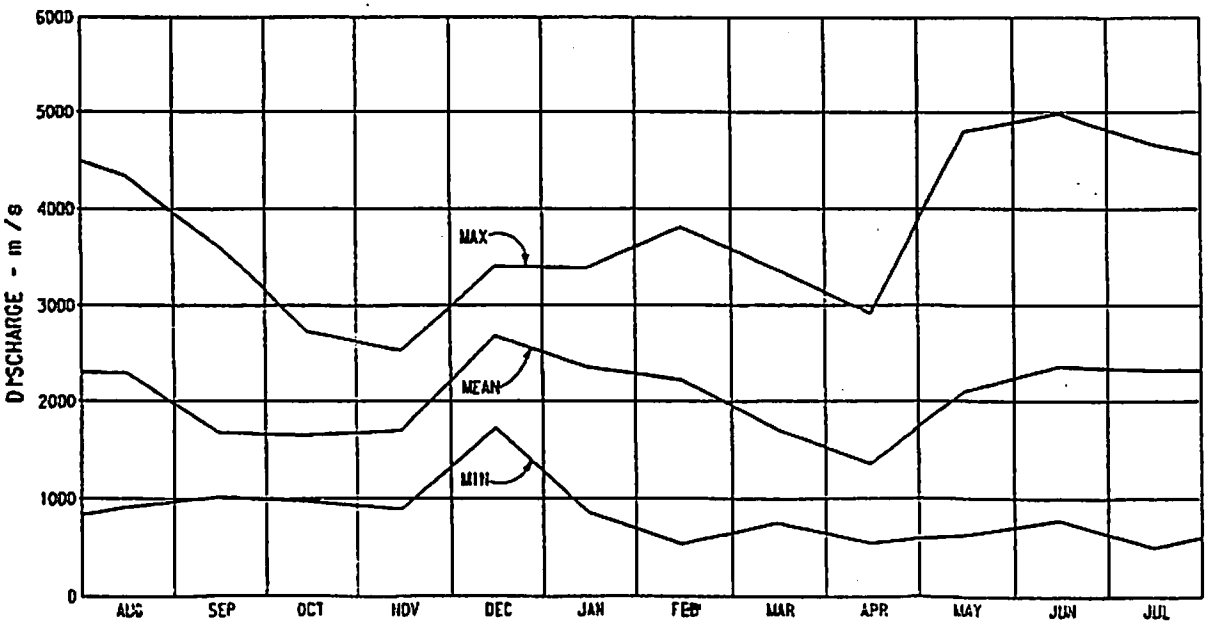
CANADA




Appendix V




MURPHY CREEK RESERVOIR AND TAILWATER LEVELS




MURPHY CREEK TOTAL DISCHARGE

NOTE:
RESERVOIR LEVELS SHOWN ARE AT THE DAM AND ARE BASED ON A MAXIMUM OPERATING LEVEL OF EL 424 AT CASTLEGAR FERRY WATER LEVEL GAUGE.

Appendix V1

| BRITISH COLUMBIA HYDRO AND POWER AUTHORITY | |
|---|---|
| COLUMBIA RIVER - MURPHY CREEK PROJECT | |
| WATER LEVELS AND DISCHARGE HYDROGRAPHS REGIME 3 | |
| DATE MAR 1995 | |
| [illegible] | DWG No. 218-C14-B979 |

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doi: 10.1111/j.1439-0426.2007.00869.x

# White sturgeon (*Acipenser transmontanus*) passage at the Dalles Dam, Columbia River, USA

By M. J. Parsley[1], C. D. Wright[1], B. K. van der Leeuw[1], E. E. Kofoot[1], C. A. Peery[2] and M. L. Moser[3]

[1]*U. S. Geological Survey, Western Fisheries Research Center, Columbia River Research Laboratory, Cook, WA, USA;* [2]*U. S. Geological Survey, Idaho Cooperative Fish and Wildlife Research Unit, University of Idaho, Moscow, ID, USA;* [3]*Northwest Fisheries Science Center, NOAA Fisheries, Seattle, WA, USA*

## Summary

White sturgeon (*Acipenser transmontanus*) ≥95 cm TL were monitored using acoustic and radio telemetry at a large hydroelectric dam (the Dalles Dam) on the Columbia River, during March 2004 through November 2005 to determine timing and routes of passage and to characterize general movements. Transmitters were surgically implanted into 148 fish during the study; 90 were released into the tailrace and 58 into the forebay. We documented 26 passage events by 19 tagged fish: eight upstream via fish ladders and 18 downstream, mostly through open spill gates. During the study 17 fish entered the two ladders one or more times; 11 entered only the east ladder, three entered only the north ladder, and three entered both ladders at sometime. Residence time within the ladders by individual fish was variable, ranging from about 1 min to nearly 6 months (median = 7.7 h). Only six fish successfully ascended the east ladder, one fish twice. We could not unequivocally determine which fish ladder one fish used to pass upstream. Differences in construction between the north and east fish ladders may account for the greater success of the east fish ladder in passing sturgeon upstream. Changes to operations at hydroelectric dams to benefit migrating anadromous salmonids may influence upstream or downstream passage by white sturgeon. Altering patterns and timing of spill discharge, altering fish ladder entrance attraction flows, and the use of lights, sound, and partial barriers to direct other species of fish to preferred passage routes have unknown effects on sturgeon passage. A better understanding of the consequences to the metapopulation of increasing or precluding upstream or downstream passage is needed.

## Introduction

White sturgeon *Acipenser transmontanus* are an important cultural, recreational, and commercial resource in the Columbia River Basin. Prior to dam construction, this amphidromous species likely responded to seasonal changes in food and habitat availability by ranging extensively between freshwater, estuarine, and marine environments. However, the construction of hydroelectric dams is believed to have created 24 functionally discreet populations within the basin in addition to the one geographically isolated population in the Kootenai River (Fig. 1). The populations vary considerably in abundance and age structure among river reaches (Beamesderfer et al., 1995). The greatest sturgeon abundance and density occurs in the 235 km long unimpounded river downstream from the lower-most dam in the basin. This is considered to be one of the largest and most productive sturgeon populations in the world (DeVore et al., 1995). Conversely, the geographically isolated white sturgeon population from the Kootenai River has been listed as endangered since 1994. Populations in many of the reservoirs appear to be persisting, but at an abundance lower than prior to impoundment. The variation in status among areas has been attributed to a number of factors including differences in exploitation rates and recruitment success, reduced access to marine food resources, and suitability of hydrologic conditions within available habitats (Beamesderfer et al., 1995; DeVore et al., 1995).

The dams have reduced spawning habitats (Parsley and Beckman, 1994), impacted primary and secondary production (Coutant, 2004), and limited upstream and downstream passage (Warren and Beckman, 1993). Because the physical, chemical and biotic characteristics of reservoirs vary greatly within the basin, individual impoundments may not contain optimal conditions for all life stages of white sturgeon (Parsley and Beckman, 1994; Beamesderfer et al., 1995). White sturgeon condition, growth, and size at maturity vary among the lower Columbia River reservoirs (Beamesderfer et al., 1995), presumably due to variations in resource availability among areas. In some impoundments suitable rearing habitat exists, but spawning habitat is lacking and recruitment of fish is poor (Parsley and Beckman, 1994). In others, spawning conditions are favorable but growth of young fish may be density limited (Beamesderfer et al., 1995).

White sturgeon seldom ascend the existing fishways at the hydroelectric projects probably because the fish passage facilities for upstream migrating fish at Columbia River Basin dams were designed primarily for anadromous salmonids. Although little is known about white sturgeon swimming performance, research conducted with lake sturgeon (Peake et al., 1997) demonstrated that the swimming abilities of sturgeons are substantially different from those of salmonids. In particular, Peake et al. (1997) found that lake sturgeon are poor swimmers compared with salmonids, particularly at burst swimming speeds. Sturgeons also generate greater drag than salmonids while swimming (Webb, 1986) and have a less efficient tail, resulting in greater energy expenditure while swimming in higher velocity areas. Wilga and Lauder (1999) showed that small white sturgeon (< 32 cm TL) exhibited undulatory swimming in current velocities of 0.5–2.0 body lengths $s^{-1}$, and that the transition to burst-and-glide swimming occurred when velocities reached 2.5 body lengths $s^{-1}$. The large body size of sturgeon may also impede progress through submerged orifices in fishways designed for salmonids.

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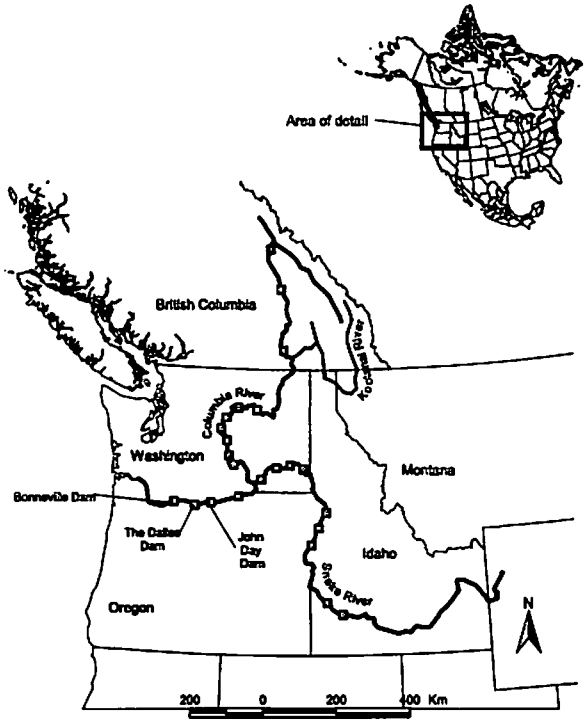


Fig. 1. Dam locations (solid squares) on Columbia and Snake rivers within the historic range of white sturgeon. Study conducted at the Dalles Dam

Unlike teleosts, sturgeons generate rapid swim speeds via increased body curvature (Long, 1995) and thus may be hindered by submerged orifices that were dimensioned to accommodate salmonids.

Although numbers are low compared to anadromous salmonids, limited upstream movement of white sturgeon between impoundments does occur, particularly at the Dalles Dam (river kilometer 309) on the Columbia River (Fig. 1). Warren and Beckman (1993) reported that during 1986 through 1991, 3181 white sturgeon (range = 187–791 fish per year) were counted at the Dalles Dam. In comparison, during the same period only 215 fish (annual range 19–60) were counted at Bonneville Dam, with even fewer (n = 68, annual range 4–29) observed at John Day Dam (Fig. 1). Upstream passage of white sturgeon was generally highest during the months of July and August. Similar late summer and early autumn upstream movement patterns have been identified in reservoirs and unimpounded river reaches (Haynes et al., 1978; North et al., 1993). Navigation locks at dams provide another possible passage route (upstream and downstream) for fish, but use of navigation locks by white sturgeon has not been confirmed (Warren and Beckman, 1993). A fish lift at Bonneville Dam was historically operated to pass white sturgeon upstream. Although numbers passed upstream were typically low during each lift, 119 white sturgeon were once passed upstream during a single day in 1951 (Warren and Beckman, 1993). The lock has not been used since 1971.

Fisheries sampling and angler returns of tagged fish have proven downstream movement past one or more dams but their routes of passage are unknown. North et al. (1996) reported that during 1987–1995, two recaptured white sturgeon had passed upstream and 86 recaptured fish had passed downstream through one or more dams. The spacing on trash racks at the entrances to turbines precludes passage of large white sturgeon but smaller fish can be entrained (Coutant and Whitney, 2000). Age-0 white sturgeon have also been recovered in the juvenile salmonid bypass collection systems, which suggests that some sturgeon do pass downstream through turbines. While downstream passage through spill gates can only occur when they are open, downstream passage through turbines could occur throughout the year.

Providing safe passage at dams could enhance the productivity of sturgeon populations (Beamesderfer and Farr, 1997; Secor et al., 2002). To better understand how to improve passage opportunities for white sturgeon we monitored their movements near the Dalles Dam using biotelemetry. We conducted this work at the Dalles Dam because this is where most white sturgeon passage currently occurs (Warren and Beckman, 1993). Our objectives were to characterize the distribution and movements of white sturgeon in the immediate vicinity of the dam and to determine timing and routes of passage.

## Materials and methods

### Study area

This study was conducted from March 2004 through November 2005 at the Dalles Dam (45°36′44″N, 121°08′04″W), located 309 km from the mouth of the Columbia River (Fig. 1). Construction of the dam began in 1952 and the dam was closed in 1957. The dam extends about 2.4 km from the southern shore to the navigation lock on the northern shore and has a head of approximately 24 m. The elevation of the reservoir is maintained at 47–49 m. The 22 turbine units provide a maximum hydraulic capacity of 10 600 $m^3 s^{-1}$. Trash racks at the turbine intakes extend to the river floor and have a maximum gap width of 14 cm. The 23 spillway Tainter gates can be independently operated to accommodate discharges that exceed hydraulic capacity of the turbines or to provide a route of downstream passage for fish. The depth of water to the spillway sill ranges from 10 to 11 m, depending on reservoir elevation. The sill extends above the river floor 13–14 m. The single-lift navigation lock at the Dalles Dam is 198 m long and 26.2 m wide. The reservoir upstream of the dam is 36 km in length, the reservoir downstream is 74.4 km long. White sturgeon are known to spawn in the upper reaches of both reservoirs (Parsley and Beckman, 1994).

The Dalles Dam has two fishways for upstream passage; both are overflow weir ladders with orifices. The north ladder has one entrance while the east ladder has three separate entrances (Table 1; Fig. 2). The U.S. Army Corps of Engineers operates the fish ladders to maintain entrance depths at approximately 2.4 m or greater below tailwater elevation, a hydraulic head of 0.3–0.6 m at the entrances, and a water velocity of 0.5–1.2 m $s^{-1}$ in the collection channels and lower portions of the ladders. The ladders are typically in operation throughout the year except for several weeks during December, January, or February when they are dewatered for annual maintenance.

Downstream passage by fish is possible through operating turbine units, open spill gates, the ice and trash sluiceway, or via the navigation lock. During the study period water was passed through the spill gates only during periods of high river discharge and juvenile salmonid passage (Fig. 3).

Table 1
General characteristics of fish ladders at the Dalles Dam

| | Fishway | |
|---|---|---|
| | East | North |
| Number of entrances | 3 | 1 |
| Entrance width | East powerhouse – 2.6 m<br>West powerhouse – 2.6 m<br>South spillway – 4.6 m | 4.6 m |
| Ladder length | 540 m[1] | 540 m |
| Ladder width (typical) | 9.14 m | 7.32 m |
| Slope (typical) | 4.4% | 4.4% |
| Number of weirs | 89 | 90 |
| Weir spacing | 4.67–4.88 m | 4.27–4.88 m |
| Weir configuration | Weirs 1 through 89 – Overflow with 2 orifices | Weirs 1 through 82 – Overflow with 2 orifices<br>Weirs 83 through 90 – non-overflow with 1 orifice and 1 vertical slot |
| Weir overflow slot width | 1.83 m | 1.68 m |
| Weir orifice size | 0.64 m W × 0.66 m H | 0.46 m W × 0.46 m H[2] |
| Weir vertical slot width | None | 0.30 m |

[1]Shortest length measured from the east entrance. Length does not include fishway channels leading from the west powerhouse and south spillway entrances to the east ladder.
[2]Orifice sizes in the upper weirs (weirs 83 through 90) are slightly larger at 0.46 m W × 0.61 m H.

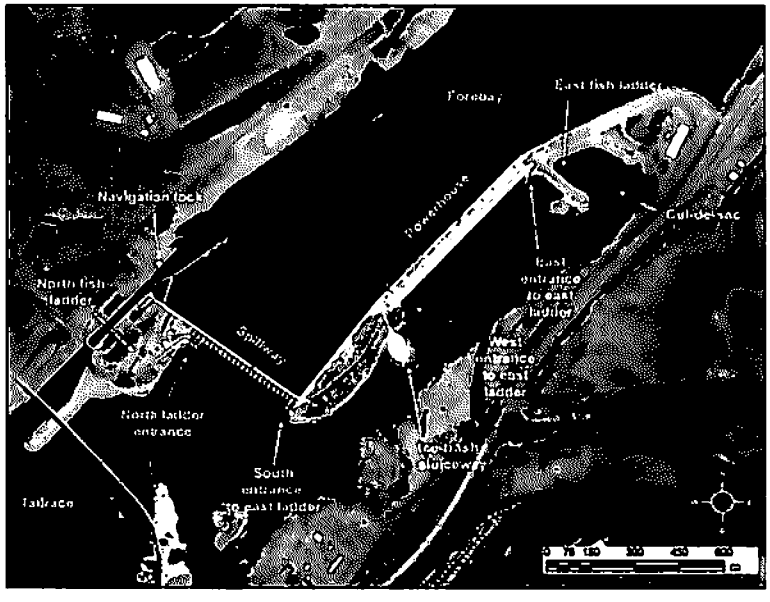


Fig. 2. Aerial image of the Dalles Dam with key features. Columbia River flows northeast to southwest

### Telemetry

A combination of acoustic and radio telemetry technologies was used to obtain information on white sturgeon as they resided and moved within the study area. We deployed Lotek SRX_400 radio receivers (Lotek Wireless, Inc., Newmarket, Ontario, Canada) and Lotek MAP acoustic receivers and hydrophones at strategic locations within the fish ladders and along the upstream and downstream faces of the dam (Fig. 4). When a tagged sturgeon was present within the detection range of either a radio antenna or hydrophone, the receiver logged the date and time of each transmitter signal detection for each port. Thus, the general location of individual transmitters was inferred by scrutinizing time of detection and signal strength among antenna or hydrophone locations.

The transmitters used were a hybrid that housed radio and acoustic components in one casing. The radio antenna was coiled internally and the entire transmitter was encased in biologically inert material. The tag transmitted an acoustic signal at 76.8 kHz and a radio signal at 149.460 MHz. The cylindrical transmitters were 16 mm in diameter and 80 mm in length and weighed 29 g in air and 15.5 g in water. The tags serially transmitted individually coded acoustic and radio pulses. Pulses occurred at 20 s intervals, with each radio pulse followed by two acoustic pulses. Thus, each transmitter emitted one radio pulse each minute separated by two acoustic pulses. The delay between signals was selected to reduce the potential to fill the storage capacity of the data logging receivers since sturgeon were expected to reside for considerable periods of time in some areas. Each transmitter was programmed to have a two-year operating life and tested prior to use.

Radio antennas and hydrophones were positioned to provide coverage of key areas (Fig. 4). Radio antennas provided coverage primarily of the fish ladders while hydrophones were

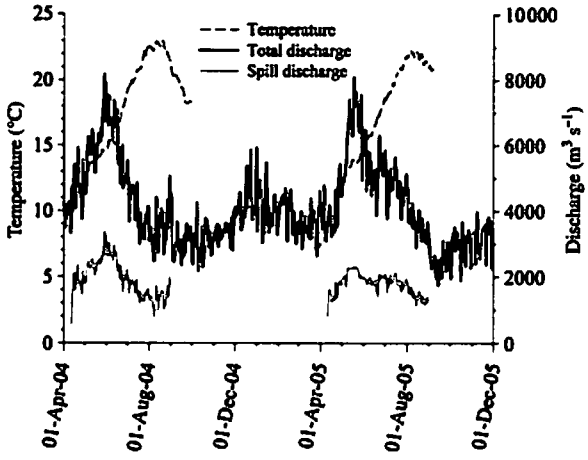


Fig. 3. Mean daily water temperatures (upper line), total river discharge (middle line), and spill discharge (lower line) during study period. Data from Columbia River Data Access in Real Time website (http://www.cqs.washington.edu/dart/). Temperature data not available for late autumn, winter, or early spring

used to provide coverage of areas where water depths would attenuate radio signals. During 2004, four acoustic receivers with seven hydrophones were installed in the forebay of the dam and one acoustic receiver with a single hydrophone was installed approximately 4.5 km downstream of the dam. Radio receiver sites remained fixed throughout the study period but additional acoustic receivers and hydrophones were added in 2005 (Fig. 4). Detection distances for the radio or acoustic signals depended on the physical location of the receiving antenna or hydrophone. Testing showed that detection range was influenced by radio interference and acoustic noise prevalent in close proximity to the dam. However, detection range did not have to be maximized to meet the study objectives. Testing showed that the radio signals were detected within the narrow confines of the fish ladders. Signal detection ranges for the hydrophones were highly variable due to local acoustic conditions, but were adequate to describe presence of transmitters in key areas upstream and downstream of the dam. Detection efficiency of radio or acoustic signals was not quantified since the objectives could be met with low detection efficiency.

During 2005 eight additional acoustic receivers with 13 hydrophones were added to the existing array (Fig. 4). These were positioned to increase the acoustic coverage of the tailrace, the forebay side of the powerhouse, and navigation lock, leaving the tailrace downstream of the spillway as the only unmonitored area. We assumed that any fish that passed downstream without being detected must have passed through the open spill gates. Opportunistic mobile surveys with portable radio and acoustic receivers and fixed receiver sites in the reservoirs also monitored sturgeon dispersal.

#### Fish capture and handling

Baited setlines were fished to capture sturgeon in the vicinity of the Dalles Dam. Fishing was performed in the forebay directly upstream of the dam and in the area referred to as the cul-de-sac on the downstream side of the dam. The cul-de-sac, a pool-like area east of the powerhouse (Fig. 2) is part of the historic river thalweg and has depths ranging to 38 m. Each setline consisted of a 91.5 m long mainline with an anchor at each end and float lines with inflatable buoys adjusted to depth. A variable number of circle hooks (10–25) of size 12/0, 14/0, and 16/0 were attached to each line as part of a gangion that could be easily clipped and unclipped from the mainline. Pickled squid (*Loliga* sp.) was used as bait on all setlines. Fishing effort (i.e. number of lines set and the number of hooks per line) varied depending on site conditions, the target number of fish to be caught, and catch rates.

Only sturgeon that were ≥95 cm TL and in good physical condition received transmitters. Transmitters were surgically implanted into the abdominal cavity. Surgical instruments and transmitters were sanitized and stored in Benzall solution (Xttrium Laboratories, Inc., Chicago, IL). Large fish were held ventral side up by bracing them with sand bags during the surgery. Smaller fish were held ventral side up in a padded cradle. An external health assessment of the fish was conducted and then measurements of fork length, total length, and girth were made to the nearest centimeter. A small pump and hose was used to irrigate the gills with river water during surgery. An incision approximately 35 mm long was made off the centerline and 50–160 mm anterior to the urogenital pore. Exact placement of the incision varied somewhat depending on the size of the fish. A transmitter was then inserted into the body cavity of the fish and a sterile absorbable suture of either coated Vicryl or PDS II (Ethicon, Inc., Piscataway, NJ) was used to close the incision. Four or five individual knots in a simple interrupted pattern were tied and a drop of Vetbond (3M, St. Paul, MN) tissue adhesive was placed on each knot. The sturgeon were then released near the location of capture.

We surgically implanted transmitters into 148 white sturgeon during the study; 90 fish were released into the tailrace and 58 into the forebay. Fish were collected by setlining between March 2004 and April 2005 during six distinct periods (Table 2). We made a total of 130 overnight setline efforts that were 18 and 26 h in duration during the study; 31 efforts were made in the cul-de-sac area of the dam (see Fig. 2) and 99 efforts were made in the forebay. More than 350 sturgeon were captured during two fishing periods in the cul-de-sac and four fishing periods in the forebay, and 146 of these received surgically implanted transmitters (Table 2). Two sturgeon were also obtained opportunistically during maintenance operations at the dam. A single sturgeon obtained during a turbine dewatering operation was tagged and released into the tailrace and another sturgeon obtained during dewatering and maintenance of the east ladder was tagged and released into the forebay. All tagged sturgeon ranged in TL from 95 to 280 cm (Fig. 5). The mean size of sturgeon tagged in the cul-de-sac (166 ± 32.8 cm; mean ± SD) was greater than the mean size of fish tagged in the forebay (126 ± 57.6 cm).

#### Data processing

Data were periodically downloaded from the fixed-site radio and acoustic receivers throughout the study period. The acoustic and radio datasets were then combined into a summary dataset. Daily individual fish histories were created by aggregating radio and acoustic data among antenna and hydrophone sites. Fish that were detected at more than one site during a given day were assigned to the location with the most detections. This enabled the display and examination of individual long-term movement patterns and passage events. Broader scale population movements were assessed by aggregating data from specific hydrophones and radio antennas located in close proximity to each other into single sites.

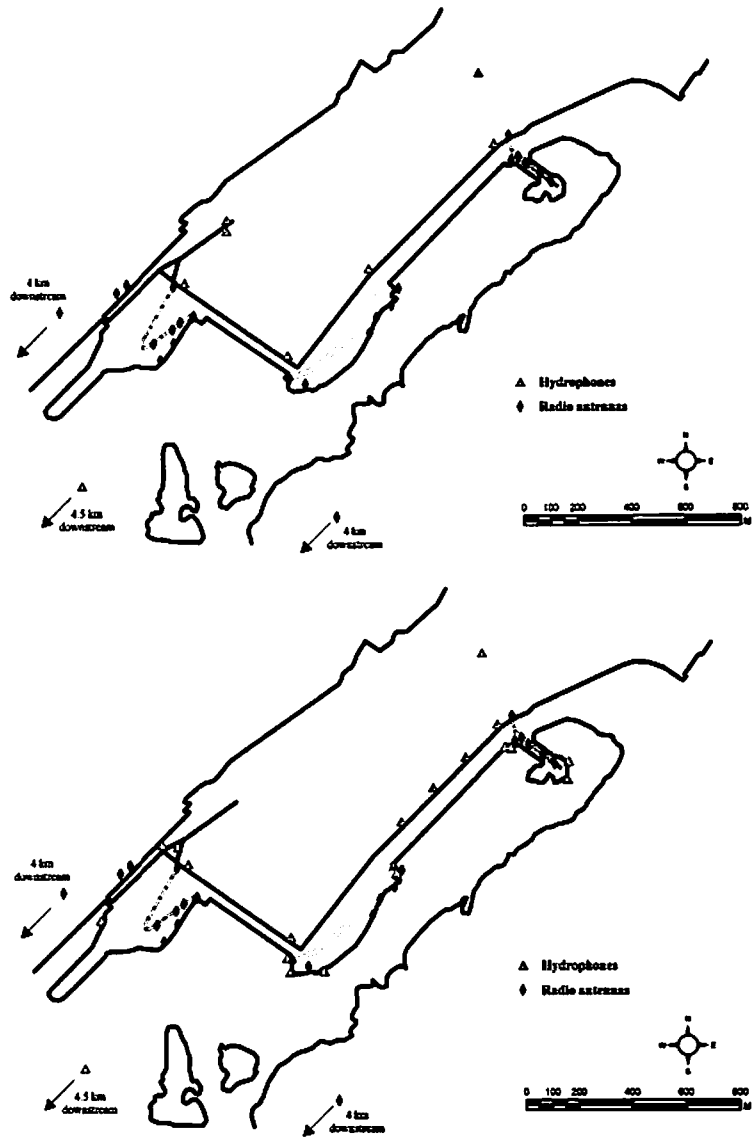


Fig. 4. Locations of hydrophones and radio antennas around the Dalles Dam during 2004 (upper graphic) and 2005 (lower graphic). Two radio antennas and one hydrophone 4 and 4.5 km downstream of the dam during both years not shown in their proper positions. Minor changes in location of some hydrophones (< 100 m) during 2005 not indicated here

Individual records from raw data were inspected when needed to investigate individual fish passage events or to clarify locations of individual transmitters. Identifying downstream routes of passage was sometimes problematic. We assumed that trash rack spacing on the turbine units would preclude downstream passage by larger fish, thus, any fish > 1.2 m TL that passed downstream via an unknown route during a period when the spill gates were open was categorized as having passed through the spillway rather than through a turbine unit.

## Results

All 58 fish released in the forebay were detected at some point during the study. Of the 90 fish released in the tailrace, 88 were subsequently detected (97.7%). At least 11 fish with transmitters (7.4% of all tagged fish) were harvested by sport anglers or Native American subsistence or commercial fishers during the study. It is probable that more fish were actually harvested since there were no external marks identifying fish with transmitters (sturgeon could have been filleted rather than gutted so the processor may not have known that the fish was carrying a transmitter).

### Dam passage

We documented 26 passage events at the Dalles Dam by 19 tagged fish; 8 upstream and 18 downstream (Table 3). Interestingly, 11 of these passage events (42% of the total) were made by just four fish. The 19 fish ranged in size from 97 to 207 cm TL. Seven of the upstream passage events were conclusively made through the east fish ladder; one fish passed upstream undetected in either ladder. Two fish were detected in the vicinity of the navigation lock but did not subsequently pass the dam. The limited monitoring infrastructure in place during 2004 precluded definitive determination of routes of downstream passage. However, in 2005 after substantially increasing coverage of the tailrace with hydrophones, 10 of 12 downstream passage events occurred through the open spill-

Table 2
Setlining and tagging efforts in the vicinity of the Dalles Dam between March 2004 and April 2005. All captured fish were not counted during the first capture period due to high catches of small sturgeon

| Dates | Location | Effort | | Sturgeon | |
|---|---|---|---|---|---|
| | | Setlines | Hooks | Captured | Tagged |
| 4 Mar–19 Mar 2004 | Cul-de-sac | 26 | 339 | – | 50 |
| 23 Mar–2 Apr 2004 | Forebay | 39 | 582 | 12 | 7 |
| 9 Aug–12 Aug 2004 | Forebay | 12 | 262 | 69 | 20 |
| 24 Jan–28 Jan 2005 | Forebay | 24 | 480 | 18 | 9 |
| 31 Jan–2 Feb 2005 | Cul-de-sac | 5 | 100 | 51 | 39 |
| 18 Apr–22 Apr 2005 | Forebay | 24 | 480 | 48 | 21 |

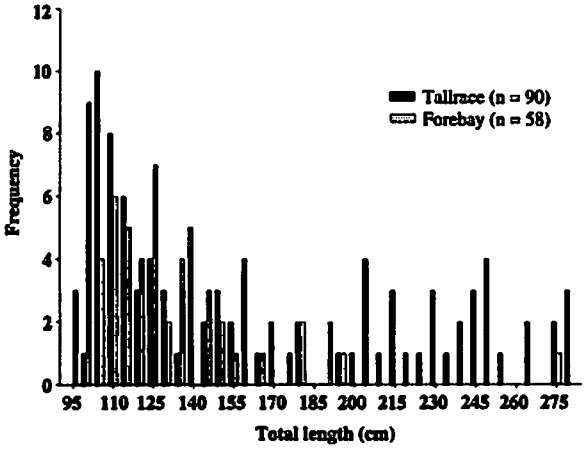


Fig. 5. Length frequency of fish tagged in the forebay and tailrace

Table 3
Individual fish passage events at the Dalles Dam

| Individual fish code | Fish total length (cm) at capture | Passage direction | Probable route of passage | Date of passage or of last detection |
|---|---|---|---|---|
| 19 | 141 | Up | East ladder | 7-Jul-04 |
| 21 | 207 | Up | East ladder | 10-Jun-04 |
| 44 | 117 | Up | East ladder | 10-Aug-04 |
| 51 | 129 | Down | Spillway | 16-May-05 |
| 52 | 97 | Down | Unknown | 25-Jul-04 |
| 52 | | Up | Unknown | 23-Aug-04 |
| 52 | | Down | Spillway | 3-Jul-05 |
| 53 | 112 | Down | Spillway | 8-Jul-05 |
| 55 | 106 | Down | Unknown | 30-Mar-04 |
| 56 | 180 | Down | Unknown | 31-Mar-04 |
| 56 | | Up | East ladder | 2-Jul-04 |
| 56 | | Down | Unknown | 9-Aug-04 |
| 56 | | Up | East ladder | 19-Sep-04 |
| 72 | 152 | Down | Unknown | 12-Aug-04 |
| 74 | 192 | Down | Spillway | 15-May-05 |
| 75 | 116 | Down | Spillway | 6-May-05 |
| 78 | 106 | Down | Unknown | 1-Sep-04 |
| 91 | 98 | Down | Unknown | 19-Jun-05 |
| 130 | 134 | Down | Spillway | 29-Apr-05 |
| 130 | | Up | East ladder | 14-Jul-05 |
| 133 | 108 | Down | Powerhouse or sluiceway | 26-Oct-05 |
| 134 | 187 | Down | Spillway | 6-Aug-05 |
| 141 | 143 | Down | Spillway | 29-Apr-05 |
| 143 | 101 | Down | Unknown | 22-Apr-05 |
| 144 | 125 | Down | Spillway | 28-Apr-05 |
| 144 | | Up | East ladder | 15-Jun-05 |

way gates. Combining both years, 25 of the 26 passage events occurred between the months of April and September. One fish passed downstream in October 2005. Since the spill gates were closed at this time, this fish (108 cm TL) passed downstream via either the ice and trash sluiceway, which was operating at the time, or through a turbine unit since this fish was small enough to pass through the turbine trash racks. While the detection history for this fish indicates that it did not pass downstream through the navigation lock, we were unable to resolve whether downstream passage occurred through the sluiceway or through a turbine.

#### Ladder use and occupancy

During the study 17 individual fish entered the ladders one or more times. Eleven individuals entered the east ladder, three entered the north ladder, and three entered both ladders at some point (Fig. 6). Residence time in the ladders was quite variable, ranging from about 1 min to nearly 6 months (median = 7.7 h). Six fish occupied the north fish ladder for variable periods; one individual (code 47; 154 cm TL) resided in the north ladder for a considerable period in 2004 and again in 2005 (Fig. 6). No fish were detected exiting out the top of the north fish ladder. In the east ladder there were 16 separate periods of occupancy by 14 individuals. Seven of these periods led to upstream passage events by six individuals (Fig. 6). Time spent in the east ladder during these seven successful upstream passages ranged from 1.8 to 43.3 days (median = 8.5 days). The east fish ladder has three entrances and we determined that seven fish entered through the east entrance, one entered from the south entrance, and one fish entered through the west entrance. We were unable to determine which entrance was used for seven periods of occupancy. Two of the fish that spent time within the fish ladder but did not pass upstream and then returned to the tailrace did so via the east entrance and two departed out the south entrance. We were unable to determine which entrance was used as an exit when five fish returned to the tailrace.

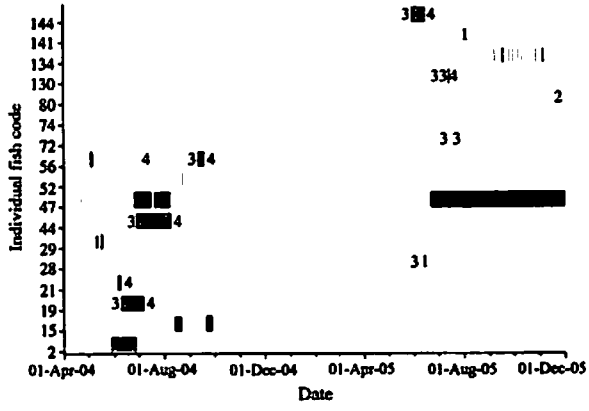


Fig. 6. Ladder occupancy by individual fish during study period. Black and gray bars or vertical lines indicate residence times in north or east ladder, respectively. Numbers indicate known entrance and exit locations at east ladder, where 1 = south entrance, 2 = west entrance, 3 = east entrance, and 4 = top of east ladder. The north ladder has only one entrance. No fish were confirmed to have exited the top of the north ladder. Two fish (codes 47 and 80) were in the ladders at the end of the study. East ladder dewatered for annual maintenance 7 December 2004–28 January 2005. North fish ladder dewatered 2–18 February 2005

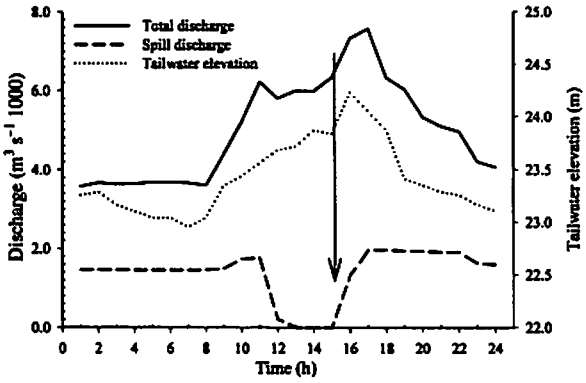


Fig. 7. Hourly river discharge and tailwater elevation at the Dalles Dam on 21 June 2005. On this day spill discharge and north fish ladder attraction flows temporally suspended for spillway inspections. A white sturgeon (154 cm TL) entered the north fish ladder at 1508 h (vertical arrow) and was detected at hydrophones located on southern end of spillway at 1330 h

White sturgeon may respond quickly to changes in local hydraulic conditions as dam operations change. One fish (code 47) that resided in the north fish ladder during 2004 again entered the north fish ladder on 21 June 2005 at approximately 1500 h (Fig. 7). Interestingly, spillway and north ladder attraction flow operations were suspended on this day for about three hours to allow a physical inspection of the spillway. Spill was stopped at approximately 1200 h and was restarted sometime between 1500 and 1600 h (Fig. 7). The fish was consistently detected at the hydrophone group located at the south end of the spillway from 9 May through 21 June. The last detection at this hydrophone group was at 1330 h on 21 June and the first detection on a radio antenna within the north fish ladder was at 1508 h, suggesting the fish moved across the stilling basin towards the north fish ladder entrance during the period when spill was shut off. This fish had resided in the north fish ladder for an extended period of time during 2004 and was in the north ladder at the conclusion of this study (Fig. 6).

Ladder use and occupancy times differed among years. In 2004, we released 50 fish into the tailrace and nine fish entered the ladders. In 2005, we released an additional 39 fish into the tailrace yet only nine fish from both release years entered the ladders. Ladder residence times were considerably shorter in 2005 (mean = 0.9 days) compared to 2004 (mean = 8.6 days) after excluding one fish (code 47) that appeared to have an affinity for the north fish ladder. Interestingly, counts of white sturgeon passing the viewing windows declined substantially in each ladder between 2004 (north ladder = 29, east ladder = 106) and 2005 (north ladder = 0, east ladder = 2). In 2004, we noted six upstream passage events and in 2005, despite a substantial increase in the number of fish with transmitters in the tailrace, we noted only two upstream passage events.

#### Individual and population movements

Individual sturgeon tagged at the Dalles Dam dispersed as far as 261 km downstream into the estuary and 38 km upstream to John Day Dam. Mobile telemetry surveys detected 20 fish downstream beyond our immediate study area and one fish was detected on a stationary radio receiver at John Day Dam. Two fish that had been tagged in the cul-de-sac moved downstream and passed Bonneville Dam into the lower Columbia River. These fish were located near river km 48 and 55. We do not know when or by what route these fish passed downstream through Bonneville Dam.

Seasonal patterns of aggregation and dispersal in the dam forebay and tailrace are evident when plots of the number of individual sturgeon detected each day at distinct hydrophones are examined (Figs 8 and 9). Since there were no hydrophones located in the immediate tailrace near the dam in 2004, only data collected during 2005 are used to show population movements downstream of the dam. Plots of the number of individual fish detected each day show an apparent abundance of fish in the cul-de-sac during winter months, dispersal downstream during spring and summer months, and a reformation of an aggregation in the cul-de-sac during the autumn (Fig. 8).

The tagged white sturgeon in the forebay showed a less distinct pattern of seasonal aggregation. During winter of early 2005 more white sturgeon were detected at a hydrophone near the spillway when compared to detections at a hydrophone located on a barge in the forebay (Fig. 9). Conversely, during

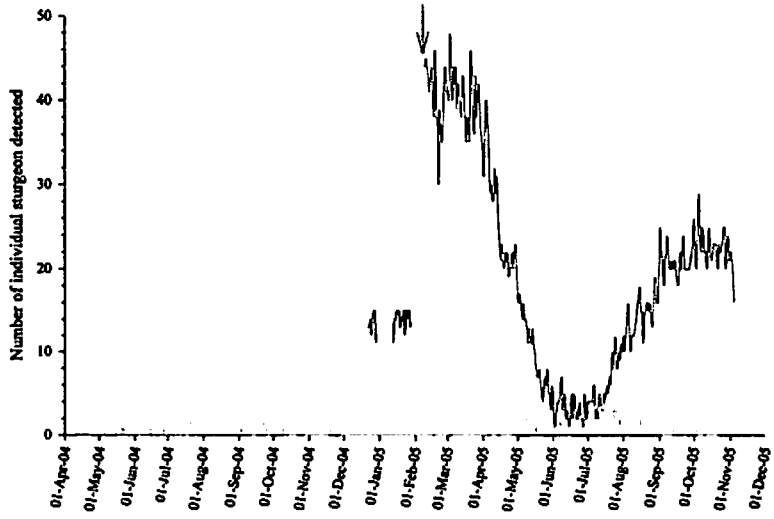


Fig. 8. Evidence of winter aggregation of white sturgeon in cul-de-sac and a summer dispersal downstream as indicated by number of individual fish detected at two hydrophones: one in the cul-de-sac (black line) and one 6 km downstream (gray line). The solar-powered hydrophone in the cul-de-sac installed in December 2004 experienced brief power outages due to low daylight conditions. Thirty-nine fish were released into the cul-de-sac during a tagging event (vertical arrow) from 31 January to 2 February 2005

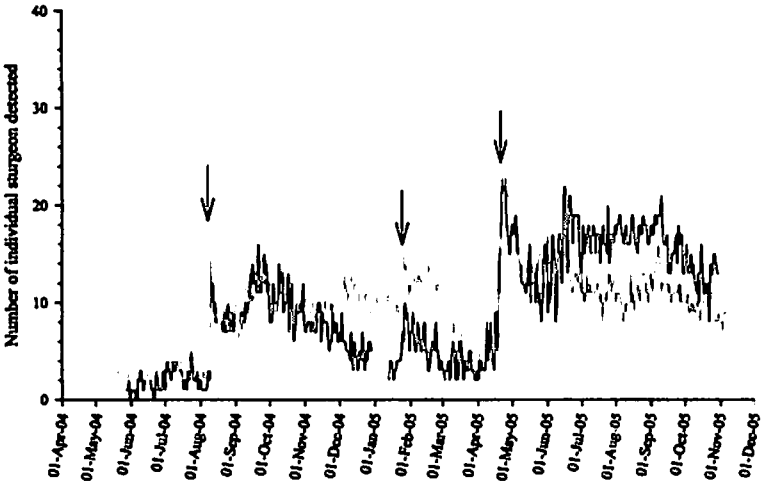


Fig. 9. Evidence of seasonal aggregation of white sturgeon in the forebay as indicated by number of individual fish detected at two hydrophones: one on a barge moored in the forebay (black line) and one deployed 1.7 km away along southern extent of spillway (gray line). The solar-powered hydrophone on the barge experienced a brief power outage during late December 2004 and early January 2005 due to low daylight conditions. Additional fish were released into the forebay during three tagging events (vertical arrows); 20 fish were released during 9–12 August 2004, 9 during 24–28 January 2005, and 21 during 18–22 April 2005

the late summer and autumn of 2005 a greater number of white sturgeon was detected at the forebay barge than at a hydrophone near the spillway.

## Discussion

Our results suggest that individual fishway design at the Dalles Dam results in differential upstream passage success between the two fishways. The east ladder was used almost exclusively for upstream passage even for fish that occupied the north ladder for a period of time. Historical counts of white sturgeon in the fish ladders at the Dalles Dam always show more fish counted in the east ladder than the north ladder. Our study showed that fish enter and reside within the north ladder, but evidently few exit out the top into the upstream reservoir. Construction drawings for the fish ladders indicate that there are physical differences between the north and east ladders. The north ladder is narrower than the east ladder and the orifices in the weirs in the north fish ladder are substantially smaller than the orifices in the weirs in the east fish ladder (Table 1). The cross-sectional areas of individual orifices in the north ladder are 0.21 $m^2$ while the cross-sectional areas of orifices in the east fish ladder are twice as large at 0.42 $m^2$. Also, the north ladder has eight weirs near the upper exit that have only one orifice and a vertical slot, while the east ladder has no vertical slot weirs. The vertical slots are 0.3 m wide. It is conceivable that the larger orifices or lack of vertical slot weirs facilitated upstream passage of white sturgeon in the east ladder. Higher counts in the east ladder could also be expected simply because more fish find and enter this ladder as it has three entrances that are located in close proximity to the river thalweg compared to the single entrance to the north ladder.

Our data show that larger white sturgeon (we tagged only sturgeon ≥95 cm TL) successfully pass downstream at the Dalles Dam primarily through open spillway gates. White sturgeon smaller than those we monitored could conceivably pass downstream through turbines at any time of the year. We are unaware of any published studies of spillway or turbine passage survival for sturgeons. Based on our work, the survival of fish ≥95 cm TL that passed downstream is relatively high, since none of the fish we noted passing downstream appeared to die.

During two years we documented a net downstream passage of 10 study fish at the Dalles Dam, resulting in a 17% reduction in the population of tagged fish upstream of the project. Additional monitoring of individual sturgeon at other locations is needed to determine if this is representative of downstream passage at other dams in the Columbia River Basin. Downstream movement of sturgeon most likely represents a loss to the upstream population since there are limited opportunities for fish to return to the source population. If downstream passage survival is high, as it appears to be from this study, downstream passage should provide benefits to the recipient population. However, even if downstream passage survival is high, there could be a negative effect on the sturgeon metapopulation if the input of additional fish from upriver impoundments exacerbates density limitations to growth in downstream impoundments. If the mortality of white sturgeon smaller than we studied passing downstream is high, there would be no benefit to the downstream population while there would be a loss to the upstream population, resulting in an overall net loss to the metapopulation. The magnitude and mortality of small white sturgeon passing downstream at Columbia Basin dams is unknown.

Seasonal aggregation and dispersal of white sturgeon in Columbia River impoundments has not been well studied. Haynes et al. (1978) reported that white sturgeon in a riverine section between two impoundments ceased movements during winter and occupied deeper areas than during summer. During warmer months, fish moved both upstream and downstream and distances were highly variable among individuals. In this study, we showed that white sturgeon aggregated in the cul-de-sac area downstream of the Dalles Dam during winter months and dispersed downriver as water temperatures rose during spring. Upstream of the dam, fish appeared to aggregate closer to the closed spill gates during winter and dispersed during spring and summer when the water temperatures were warmer and the spill gates were open. The deep, still waters of the cul-de-sac and forebay immediately upstream of the closed spill gates likely provide good habitat for fish during periods of reduced metabolic activity during winter.

Changes to operations at hydroelectric dams to benefit passage of other species, primarily migrating anadromous salmonids in the Columbia River Basin, may influence

upstream or downstream passage by white sturgeon. Operators of the hydroelectric dams in the Columbia River Basin are currently on an ambitious path to reduce the volume of water passed over the spillways while maintaining high passage survival of juvenile anadromous salmonids. One innovative alteration temporarily raises the sill of spillway gates so that juvenile salmonids do not have to sound to deeper depths to pass. This alteration may result in reduced downstream passage of sturgeon via spillways, since benthic oriented sturgeon would have to ascend nearly to the river surface to pass downstream via a spillway. This type of alteration has other unknown consequences to sturgeon since water would be diverted to turbines instead of spilled. It could result in increased passage of sturgeon through turbines or it could result in a greater retention of larger fish within the upstream reservoir. Other strategies to improve upstream and downstream passage of anadromous salmonids including altering patterns and timing of spill discharge, altering fish ladder attraction flows, and the use of lights, sound, and partial barriers to direct fish to preferred passage routes also have unforeseen effects on sturgeon. Additional studies may challenge the widely held belief that increasing passage at dams will benefit white sturgeon populations since the consequences are not obvious (Jager, 2005).

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