Klohn Crippen Berger

August 13, 2008

City of Revelstoke
Box 170
Revelstoke, British Columbia
V0E 2S0

Tim Luini
Senior Building Inspector

Dear Mr. Luini:

Big Eddy Construction Zones

This report provides the background and analyses which has led up to the delineation of construction zones and recommendations in the Big Eddy area of the City of Revelstoke. This report is in conformance with our April 22, 2008 proposal. This assignment was authorized by the City of Revelstoke on April 25, 2008.

Yours truly,

KLOHN CRIPPEN BERGER LTD.

Richard F. Rodman, P.Eng.
Manager, Nelson Office

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1. INTRODUCTION AND STUDY LIMITATIONS

Highway 23 and the dykes provide protection to the Big Eddy area of Revelstoke from Tonkawatla Creek and Columbia River flood levels. The City has requested that Construction Zones be delineated within this area, from the point of view of flooding and high groundwater levels.

The City is aware that development of the low lying areas behind the Big Eddy Dykes is directly dependent on BC Hydro's maintenance of the dykes; the three pump stations; and flood boxes. The pump stations and flood boxes remove seepage, rain and snowmelt water from behind the dykes. Failure of the dyke or mis-operation of the pumping stations and/or flood boxes could possibly cause internal flooding, septic field and septic tank problems, and foundation problems. Basement flooding has been reported without the failure of the flood protection works or pump stations.

The City has requested that this study be carried out on the assumption that the dykes do not fail and the pump stations and flood boxes are maintained and operated properly. Reliance on dykes, pump stations and floodboxes for determination of Flood Construction Levels (FCL) is contrary to generally accepted Provincial guidelines. For example, "Floodplain Mapping Guidelines and Specifications", prepared for Fraser Basin Council, March 19, 2004, recommend dyke breach modelling to determine construction requirements in areas protected by dykes. By not following these Guidelines the City and/or BC Hydro may be incurring liability in the event of a flooding incident.

This report was prepared by Klohn Crippen Berger Ltd. for the account of the City of Revelstoke. The material in it reflects Klohn Crippen Berger's best judgement in light of the information available to it at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Klohn Crippen Berger Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

2. SCOPE OF STUDY

The City has requested that construction zones be delineated in the Big Eddy area. Two types of zones have been identified by the City:

- Zone 1: No special flooding, foundation and septic requirements. Construction within this zone would have the usual requirements for construction in a zone not subject to flooding; and
- Zone 2: Engineering studies required addressing flooding, foundation and septic issues. Construction within this zone would require experienced professionals to provide a site specific report addressing flooding, foundation and septic issues.

Other issues addressed in this study include:

- Construction concerns/limitations/zoning pertaining to foundation waterproofing, basements, sump pumps, septic tanks and septic fields; and
- Identification of professional qualifications for various aspects of construction, specifically as it pertains to flood issues.

Klohn Crippen completed a September 17, 2003 study entitled “Columbia River at Revelstoke Floodplain Mapping Phase I Review of Data and Analyses” for the former Ministry of Water, Land and Air Protection. The present study builds on analyses carried out in the September 2003 study. A site visit was carried out to assist in delineating the areas, to look inside the BC Hydro pumpstations, and to review BC Hydro files on the Big Eddy area.

3. BACKGROUND INFORMATION

3.1 Big Eddy Area

The Big Eddy Area is protected from high Columbia River levels by dykes that were built by BC Hydro in the late 1960's, see Figure 1. As-built drawings for the dykes (C.B.A. Engineering Ltd., 1970) indicate a dyke crest elevation of 443.7 m. Seepage blankets, 1 m thick, extend up to 45 m in some areas, from the dyke toward the Columbia River. The design drawings indicate an upstream slope of the dykes of 5H:1V and a downstream slope of 2H:1V. Drawings and site visit observations indicated that areas facing the Columbia River have a layer of angular riprap with sizes varying from 200 mm to 400 mm. The dyke crest is approximately 4 m to 5 m wide, with no vegetation growing on the dyke faces.

3.2 Pumping and Groundwater Observations

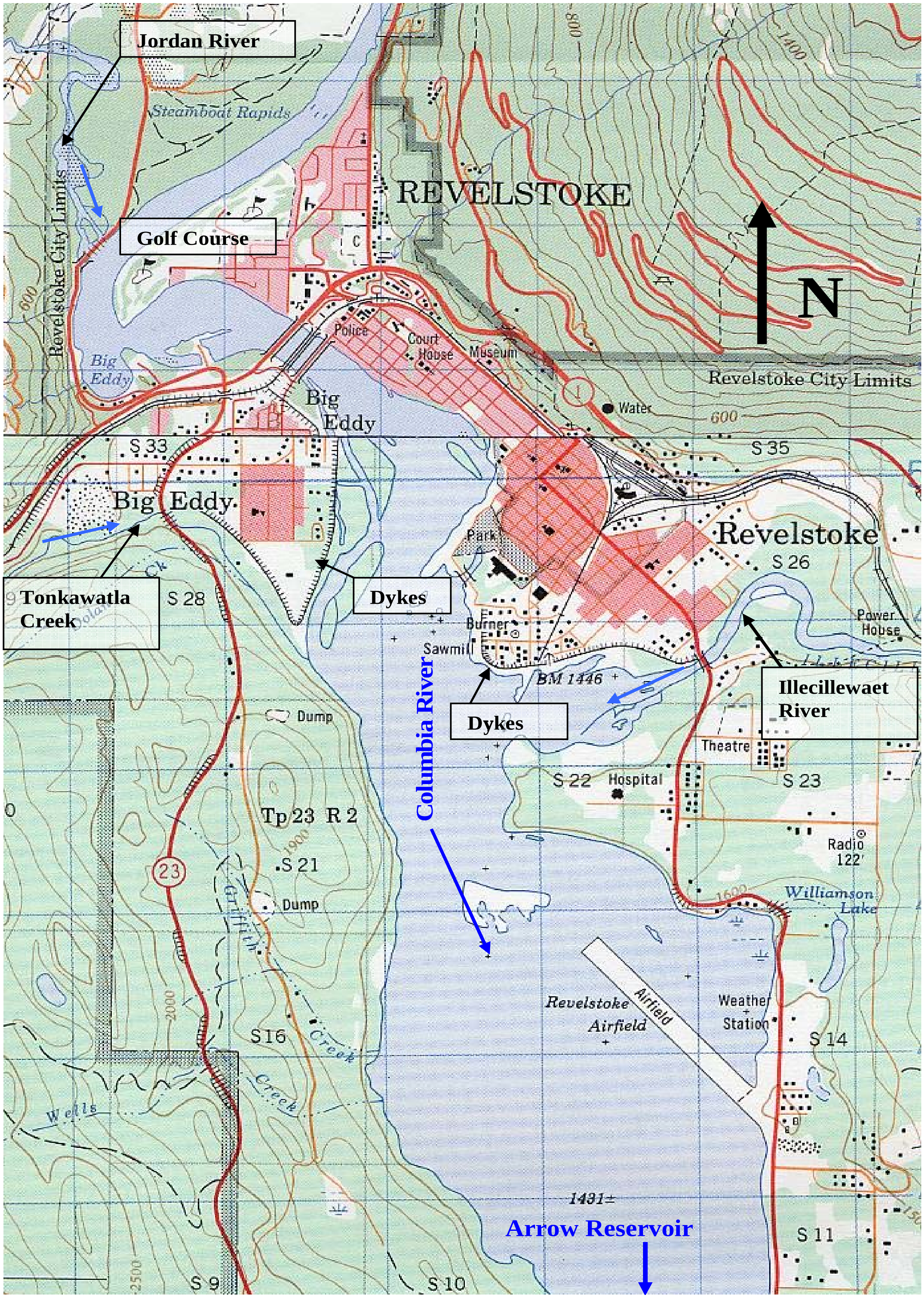
Three pump stations were installed and are maintained by BC Hydro, to pump out precipitation and seepage inflows from behind the Big Eddy Dykes, see Figure 2.

The pump capacities and pump on levels, presented in Table 1, were taken from the original Operating Instructions (C.B.A. Engineering Ltd., 1970). Pumps turn on as the water level rises. BC Hydro is reported to inspect the pumps and dykes regularly.

Table 1 Big Eddy Pumping Information

Pump Station	Pump Number	Pump on Elevation		Pumping Rate	
		(ft)	(m)	(Usgpm)	(m^3/s)
Main	**#1**	1435.00	437.39	16300	1.028
Main	**#2**	1435.25	437.46	16300	1.028
Main	**#3**	1435.50	437.54	16300	1.028
A	**#1**	1444.00	440.13	4200	0.265
A	**#2**	1444.00	440.13	4200	0.265
B	**#1**	1444.25	440.21	7700	0.486
B	**#2**	1444.25	440.21	7700	0.486

Ref: Operating Instructions for Big Eddy and Illecillewaet Dykes, C.B.A. Engineering Ltd., Jan 31, 1970



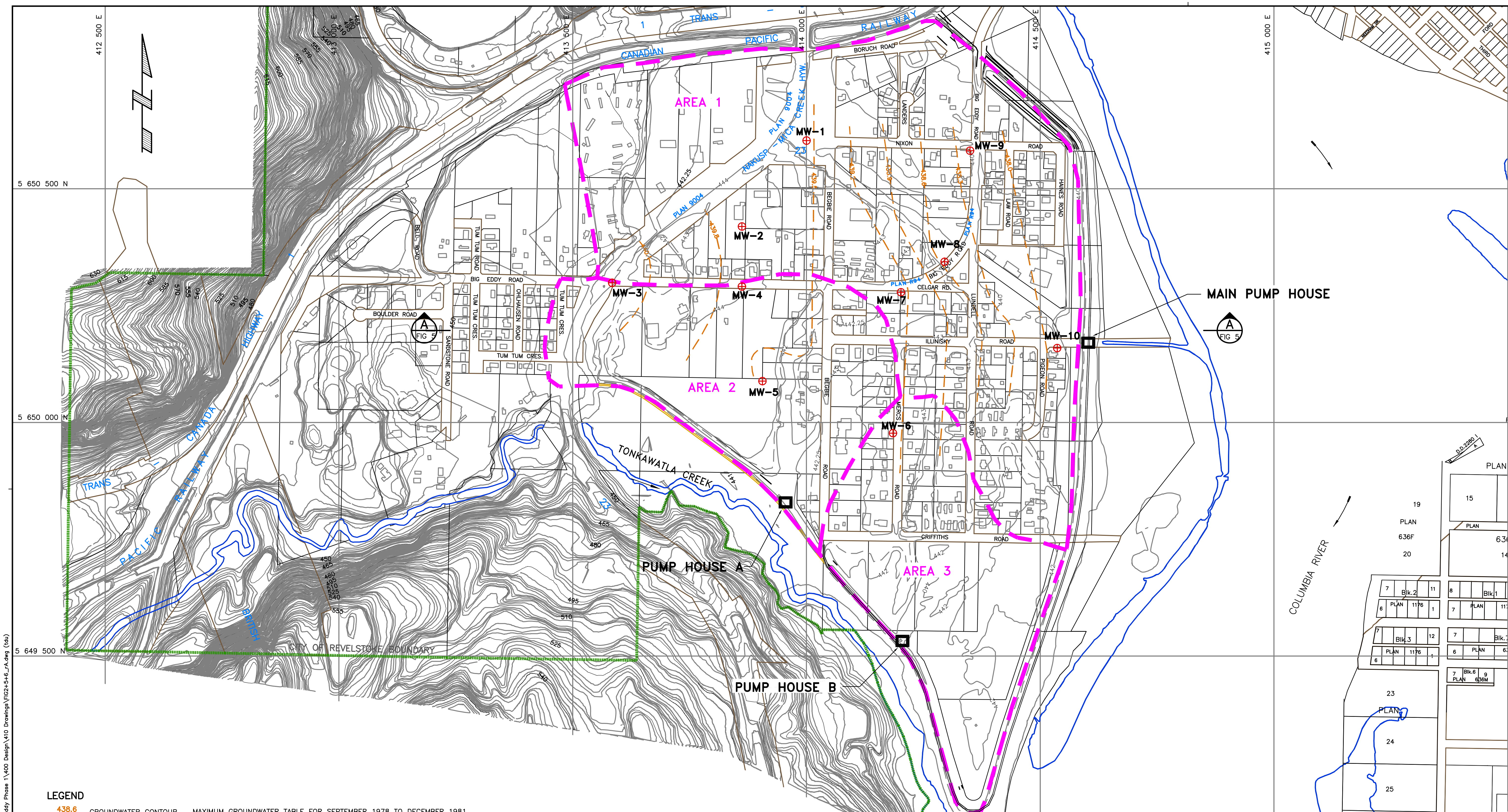
Klohn Crippen Berger

PROJECT: BIG EDDY CONSTRUCTION ZONES

TITLE: Location Plan

CLIENT: City of Revelstoke

DATE OF ISSUE	PROJECT NO.	FIG. NO.
13-Aug-08	M09248A02	1



LEGEND

438.6 GROUNDWATER CONTOUR – MAXIMUM GROUNDWATER TABLE FOR SEPTEMBER 1978 TO DECEMBER 1981 (REFERENCE: BRITISH COLUMBIA HYDRO AND POWER AUTHORITY, 1981)

443 GROUND SURFACE CONTOUR

DRAINAGE AREAS

MW-5 MONITORING WELLS

TO BE READ WITH KLOHN CRIPPEN BERGER REPORT DATED August 13, 2008

SCALE 0 200 m

CLIENT	PROJECT
CITY OF REVELSTOKE	BIG EDDY CONSTRUCTION ZONES
Klohn Crippen Berger	TITLE: GENERAL PLAN
	PROJECT No. M09248A02 — FIG. No. 2

Time: 9:50:60 Date: 8/11/2008 Scale: 1=3(PS) Drawing File: M:\M09248A02 - C of Revelstoke Big Eddy Phase 1\400 Design\410 Drawings\FIG2+5+6_rA.dwg (tdu)

KCB-R-MLD

A report by BC Hydro describes monitoring of ground water levels in the Big Eddy area from September 1978 to December 1981 (British Columbia Hydro and Power Authority, 1981). The report states that ground water levels peaked on two occasions due to high Arrow Reservoir levels and on two other occasions due to spring runoff on Tonkawatla Creek, located on the southwest side of the dyke, see Figure 1 and Figure 2. The observed ground water levels were always below the ground surface level, see Table 2 and Figure 2, but did come to within 1.5 m of the ground surface. Monitoring Well locations are shown on Figure 2. This report indicates that the pumping capacity appears to be adequate to control seepage inflows into the area under the conditions encountered during the monitoring period. The maximum reservoir level (Columbia River level adjacent to the Big Eddy Area) was 1445.6 ft (440.6 m) in late July/August 1980. The report does recommend monitoring of ground water levels during a spring runoff period that coincides with significant rainfall amounts and long duration rainfall.

Table 2 Groundwater Table below Ground Surface

Monitoring Well		High Water Levels In (ft)				Depth to Groundwater Table Below Surface (ft)			
No.	Ground El. (ft)	Tonkawatla		Reservoir		Tonkawatla		Reservoir	
		1979	1980	1978	1980	1979	1980	1978	1980
1	1456.6	1442	1441.3	1442.1	1441.6	-14.6	-15.3	-14.5	-15.0
2	1453.8	1442.6	1441.6	1442.4	1442.4	-11.2	-12.2	-11.4	-11.4
3	1455.5	1444.6	1444	1443.5	1443.2	-10.9	-11.5	-12.0	-12.3
4	1455.9	1442.2	1441.4	1442.6	1442.4	-13.7	-14.5	-13.3	-13.5
5	1450.1	1441.2	1440.9	1441.8	1441.6	-8.9	-9.2	-8.3	-8.5
6	1453.2	1440	1439.7	1441.2	1441.1	-13.2	-13.5	-12.0	-12.1
7	1451.3	1439.2	1439	1441.3	1439	-12.1	-12.3	-10.0	-12.3
8	1443.8	1438.2	1438.3	1438.9	1438.4	**-5.6**	**-5.5**	**-4.9**	**-5.4**
9	1442.8	1436.4	1436.5	1437.6	1437.2	-6.4	-6.3	-5.2	-5.6
10	1445.7	1434.0	1435.2	1436.7	1436.1	-11.7	-10.5	-9.0	-9.6
1	443.97	439.52	439.31	439.55	439.40	-4.5	-4.7	-4.4	-4.6
2	443.12	439.70	439.40	439.64	439.64	-3.4	-3.7	-3.5	-3.5
3	443.64	440.31	440.13	439.98	439.89	-3.3	-3.5	-3.7	-3.7
4	443.76	439.58	439.34	439.70	439.64	-4.2	-4.4	-4.1	-4.1
5	441.99	439.28	439.19	439.46	439.40	-2.7	-2.8	-2.5	-2.6
6	442.94	438.91	438.82	439.28	439.25	-4.0	-4.1	-3.7	-3.7
7	442.36	438.67	438.61	439.31	438.61	-3.7	-3.7	-3.0	-3.7
8	440.07	438.36	438.39	438.58	438.42	**-1.7**	**-1.7**	**-1.5**	**-1.6**
9	439.77	437.81	437.85	438.18	438.06	-2.0	-1.9	-1.6	-1.7
10	440.65	437.08	437.45	437.91	437.72	-3.6	-3.2	-2.7	-2.9

Ref: (British Columbia Hydro and Power Authority, 1981)

3.3 Floodplain Mapping

Floodplain Mapping was carried out by the British Columbia Ministry of Environment, as documented in their mapping, "Floodplain Mapping Columbia River at Revelstoke", Sheets 1 – 5, November 1983.

Figure 3 is Sheet 4 of 5, which included the Big Eddy Area. The maps show a fixed Arrow Reservoir Designated Flood Level of 442.25 m (including freeboard). This level extends from the downstream end of the mapping, just downstream of the Revelstoke Airport, to the Revelstoke Golf Course. The Designated Flood Level increases to 448.5 m immediately below the Revelstoke Dam.

As shown on Figure 3, the Ministry of Environment have defined the flood construction level behind the Big Eddy Dyke at El. 442.25 m. Klohn Crippen carried out a review of the Columbia River flood construction levels in the Big Eddy area (Klohn Crippen, 2003) and confirmed that El. 442.25 m is a reasonable value for the 200 year flood level on the Columbia River adjacent to the Big Eddy Area.

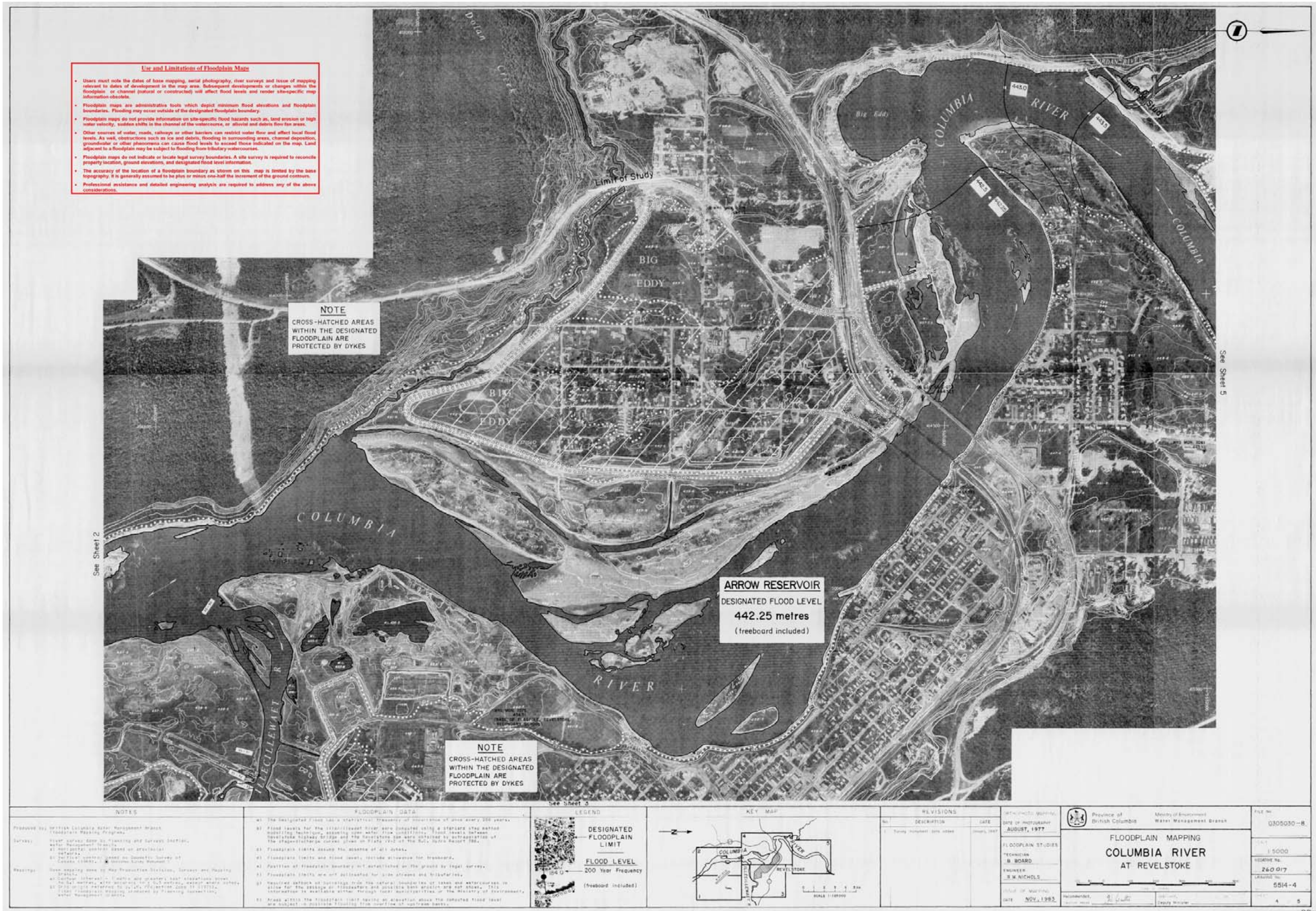


Figure 3 Ministry of Environment Floodplain Mapping

4. SITE VISIT

Mr. Rick Rodman, P.Eng., of KCBL, carried out a site visit on June 9 and 10, 2008. During the site visit Mr. Rodman met with Mr. Tim Luini, and was accompanied to the Big Eddy Area by Mr. Derek Low, Survey Technician. During the site visit the approximate surface drainage areas, leading to each of the three pump stations, were identified, see Figure 2.

Mr. Rodman met with Mr. Dale Bairstow, Maintenance Operations Manager, Revelstoke Generating Station, BC Hydro, and reviewed the BC Hydro files for Big Eddy Area. Mr. Greg Horton, BC Hydro Electrician, accompanied Mr. Rodman into each of the three pump stations. The present pump on/off levels were noted and are compared with the design levels in Table 3. Some of the levels have been lowered by up to 0.4 m. Apparently these changes were made to obtain the correct on/off level due to aging of the sensors (BC Hydro, 2008, Personal communication). BC Hydro have indicated that they intend to replace the pumps and controls in the near future.

At this time there is no backup power supply for the pump stations and there is no simple way to connect an emergency power supply. BC Hydro should consider a means of emergency power supply for the pump stations as part of their pump replacement program.

Table 3 Pump On/Off Settings

Pump #	1970 Operating Instructions		June 10, 2008 Site Visit	
	On (ft)	**Off (ft)**	**On (ft)**	**Off (ft)**
Main Pump Station				
1	1435.00	1434.00	1434.75	1433.50
2	1435.25	1434.50	1434.60	1433.50
3	1435.50	1434.75	1434.50	1433.50
Pump Station A				
1	1444.00	1443.50	1443.50	1444.00
2	1444.50	1444.00	1444.00	1444.50
Pump Station B				
1	1444.25	1443.75	1443.00	1443.50
2	1444.50	1444.00	1444.50	1444.00
Pump #	**1970 Operating Instructions**		**June 10, 2008 Site Visit**	
	On (m)	**Off (m)**	**On (m)**	**Off (m)**
Main Pump Station				
1	437.39	437.08	437.31	436.93
2	437.46	437.24	437.27	436.93
3	437.54	437.31	437.24	436.93
Pump Station A				
1	440.13	439.98	439.98	440.13
2	440.28	440.13	440.13	440.28
Pump Station B				
1	440.21	440.06	439.83	439.98
2	440.28	440.13	440.28	440.13

Photo 1 Intake to Main Pump House with sheet metal cover (June 10, 2008).

As shown in Photo 1 and Photo 7, a sheet metal cover has been added to the intake trashracks for all pump stations. Flap covers can be opened to allow more water into the pumps, although these would be difficult to open if the water level was high. BC Hydro have indicated that the extra openings in the sheet metal covers have to be manually opened, although no specific schedule or protocol exists for this. It is not known when these covers were installed but it is suspected they were installed due to vandalism (BC Hydro, 2008, Personal communication). Therefore there is a possibility that the extra openings might not be opened during a flood event. This, along with possible debris blockage, could reduce the pumping capacity to in the order of 50% of the original pumping capacity. BC Hydro must confirm this value.

As shown in Photo 2, on the date of the site visit water was flowing from the Columbia River into the Big Eddy area, most likely through a leaky flap gate. Once the water level reached the operating level for pump #1 in the Main Pump House, the pump turned on and pumped the water out again, see Photo 3 and Photo 4. Such unnecessary pump cycling is likely to cause undue wear on the pump, and the leaky flap gates should be repaired. Photo 5 and Photo 6 show the inside of the Main Pump House.

Photo 2 **Main Pump House intake with water flowing out of intake from Columbia River into Big Eddy Area most likely through a leaking flap gate (June 10, 2008).**

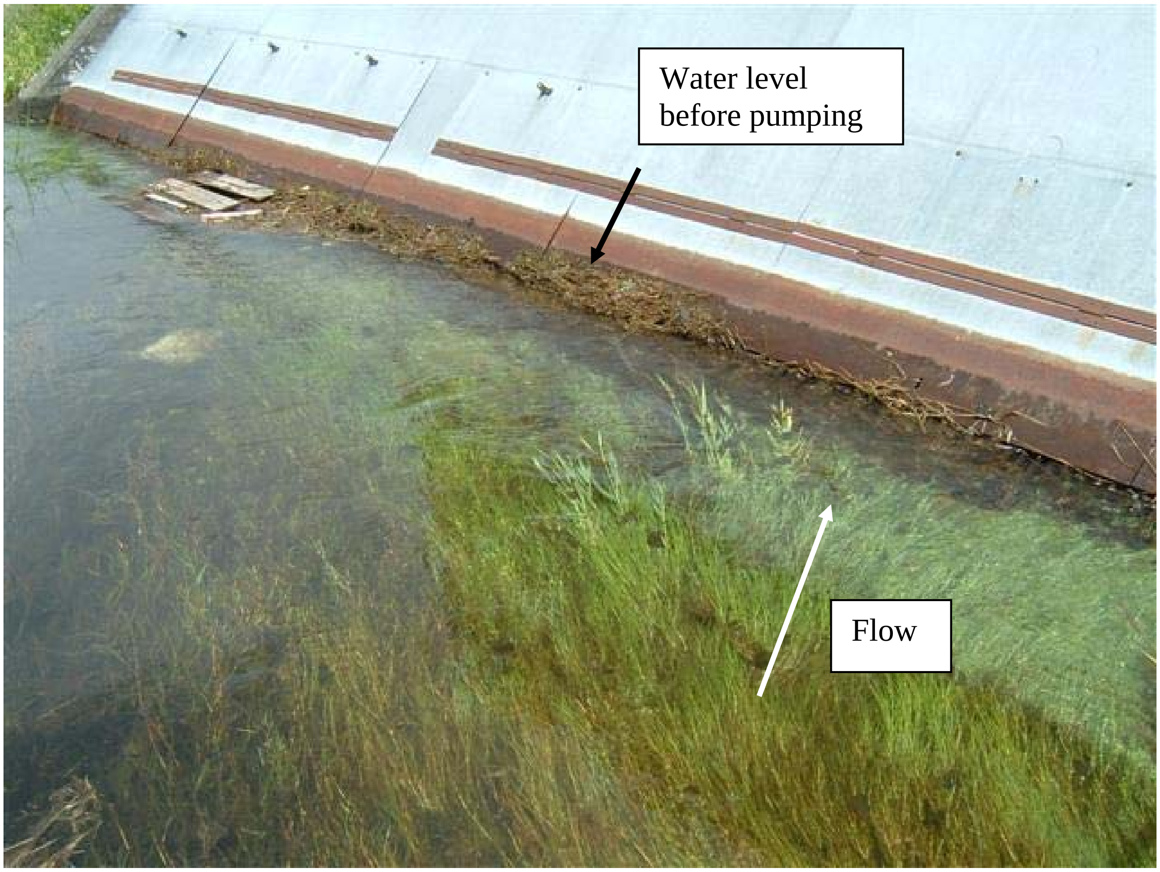


Photo 3 **Main Pump House with one pump operating. Note flow is towards intake and water level has dropped (June 10, 2008).**

Photo 4 Main Pump House outlet with one pump operating (June 10, 2008).

Photo 5 **Inside Main Pump House with control panel on left and pump motors on right (June 10, 2008).**

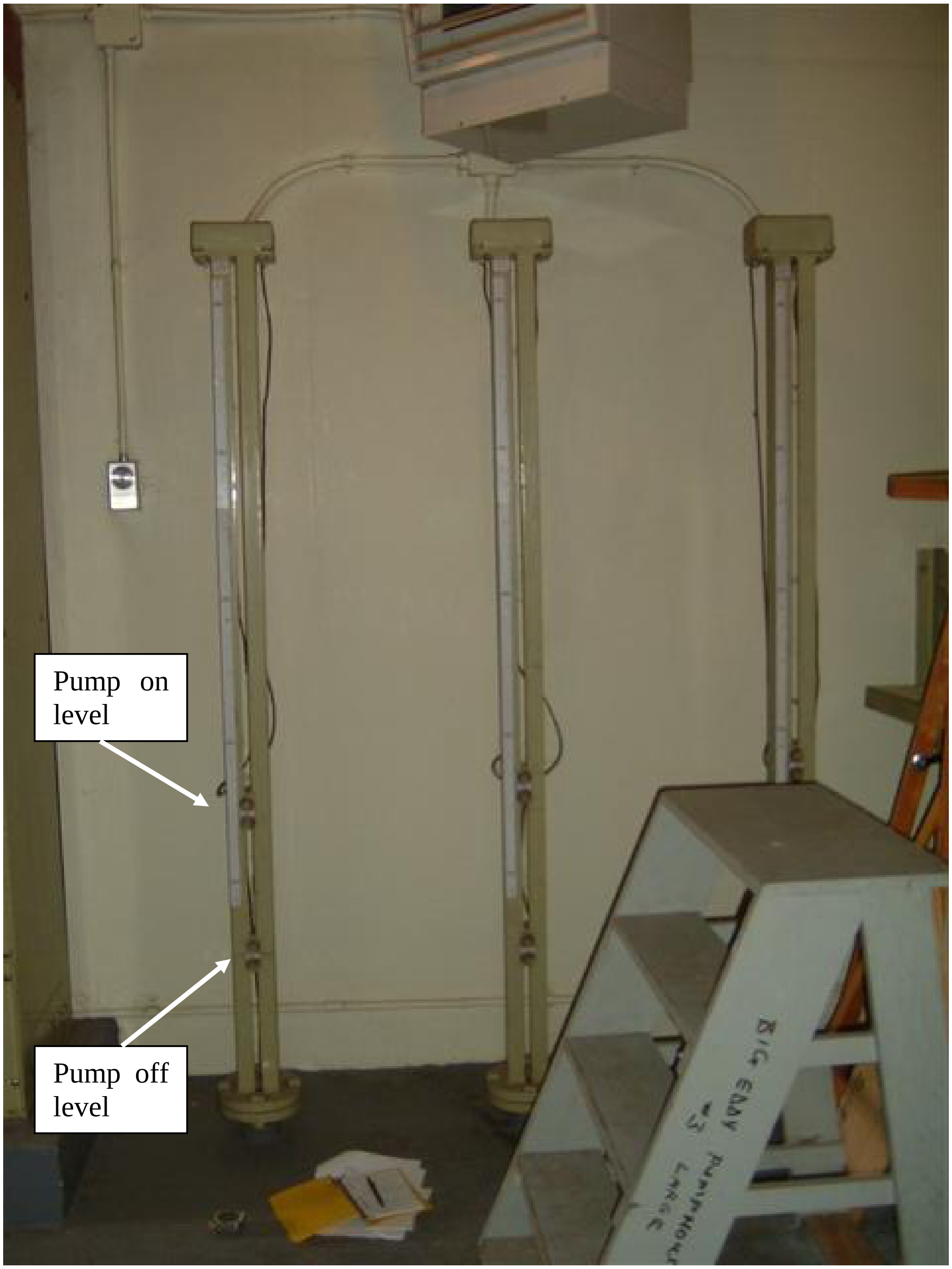


Photo 6 On/off setting for three pumps inside Main Pump House (June 10, 2008).

Both Pump House A and B had dry intakes and the pump logs showed that these pumps seldom operated, see Photo 7. BC Hydro confirmed that these Pump Houses have never operated (BC Hydro, 2008, Personal communication). Photo 8 shows the outlet for Pump House B, which is identical to Pump House A. Photo 9 shows the inside of Pump House B, which is identical to Pump House A.

Photo 7 Intake to Pump House B with sheet metal covering (June 10, 2008).

Photo 8 Outlet to Pump House B (June 10, 2008).

Photo 9 Twin pump motors inside Pump House B (June 10, 2008).

5. HISTORICAL FLOODING

BC Hydro documentation provided two specific instances of basement flooding in the Big Eddy area, one before the dykes were constructed and one after dyke construction. It is possible that there were other unrecorded basement flooding events.

A letter from British Columbia Hydro and Power Authority to Mr. Weir of C.B.A. Engineering documented 1961 flooding in the building shown in Photo 10 (British Columbia Hydro and Power Authority, 1965). The quote below indicates that high ground water levels, due to high river levels, were a problem before the present day dykes and Pump Houses were constructed.

> "There was a very rough gauge on the railway bridge just beside the City and on this gauge the 1894 flood was clearly marked and it is recorded as having been an elevation of 1446.6 ft. The 1961 peak appears to have been approximately 1442 ft. From discussions with various local inhabitants it would appear as if the 1948 flood was some two or three feet higher than the 1961 flood.
>
> In 1948 the water flowed across a large part of the Big Eddy. In 1961 it did not. This was in part due to the approach roads to the new bridge which acted as dikes and thus prevented some of the direct water getting on the ground. However, at Big Eddy the river flooded into one car wrecker's yard in spite of last minute efforts to build a dike to keep it out and a low slough rose and flooded one house.
>
> Discussions, however, revealed that several basements were flooded due to seepage. In particular, the basement of the Jehovah's Witness Meeting Hall was dry until the evening of June 8th, when moisture appeared. By 11 o'clock on the morning of the 9th the basement was flooded to a depth of some eight or nine inches. Without taking any levels it would appear as if the water level in the basement on Friday morning was very little lower than the water in the river outside, which was some 100 yards away at the nearest point and was the other side of the road forming a dike.
>
> It is thus quite clear that any method of protecting the Big Eddy with dikes will require not only a great length of dike on approximately three sides but will require very extensive work to control seepage. While it may be possible to waterproof some of the basements, all the properties on the Big Eddy are reported

to rely on septic tanks for sewage disposal. This would create a very serious problem for diking."

Photo 10 Church on corner of Big Eddy Road and Nixon Road which reported basement flooding on June 9, 1961 (June 10, 2008).

The following quote from a BC Hydro report (BC Hydro, 1991a) provides historical background and describes basement flooding on Law Road (see Photo 11) occurred coincident with high reservoir levels in June 1990.

"BC Hydro holds a water license to store water for the Arrow Reservoir up to an elevation of 1444 ft (440.1 m) with provision to store water up to the 1446 foot (440.7 m) elevation upon annual consent from the Water Comptroller. …

[Two] individual property owners report[ed] water in their basements in the Fall of 1990. This period coincided with Full Supply Level for Arrow Reservoir (1446 feet). The residences of concern are [on] Law Road. …

Sewage disposal behind the Big Eddy is by individual septic systems. The Revelstoke City Building Inspector, T. Ferguson, advised that the systems are inspected and approved by the Public Health Inspector. It is believed all systems are buried less than 3 feet deep. The area behind Bid Eddy Dyke is connected to the Big Eddy community water system supplied by the Dolan Creek Watershed.

Prior to the Arrow Project the area was affected by high groundwater during times of abnormal run-off and climate conditions. Properties Division files indicated that first post-project complaints regarding groundwater occurred in1969 when the reservoir was initially filled to elevation 1444 feet (440.1 m). …

In 1971, a subsurface drainage system was deigned by CBA Engineering Ltd. and installed by BC Hydro to control groundwater to the maximum elevation of 1438 feet (438.4 m) within the study area when the reservoir is at Full Supply Level [1446 ft – 440.7 m]. Production have maintained the drainage system since installation. …

The Big Eddy dyke was designed and constructed to protect the Big Eddy area from the operation of the Arrow Reservoir and to control seepage underflow to allow septic fields to operate properly. Following complaints received from residents after the initial filling of the Arrow Reservoir a collector system was installed within the area to keep water levels at about 1438 feet (438.4 m)."

Photo 11 Law Road, where basement flooding had been reported in the fall of 1990 (June 10, 2008).

6. ENGINEERING ANALYSES

To assist in determining flood construction zones and construction recommendations Klohn Crippen Berger Ltd. carried out groundwater and surface water modelling. These analyses were used as guides to provide information on possible water levels that could affect permanent structures in the Big Eddy area. The modelling is described in the following sections. The groundwater level is essentially the same as the "hydrostatic" water level.

6.1 Groundwater Modelling

To assess seepage rates under the dyke, and hence, required pumping rates to manage the seepage water, a 2-dimensional seepage model was developed. The model Seep/W (2004), by Geo-Slope International, was used for these analyses due to the subsurface stratigraphy. A representative section of the dyke near the Main Pump Station was used (see Figure 4). Stratigraphic and hydrogeological information was obtained form the following two documents:

- "Design Memorandum – Dyking of the Big Eddy Subdivision (2nd Draft)" (C.B.A. Engineering Ltd., 1966); and
- "Big Eddy Subdivision – Revelstoke - Memorandum on Groundwater Levels September 1978 to December 1981", (British Columbia Hydro and Power Authority, 1981).

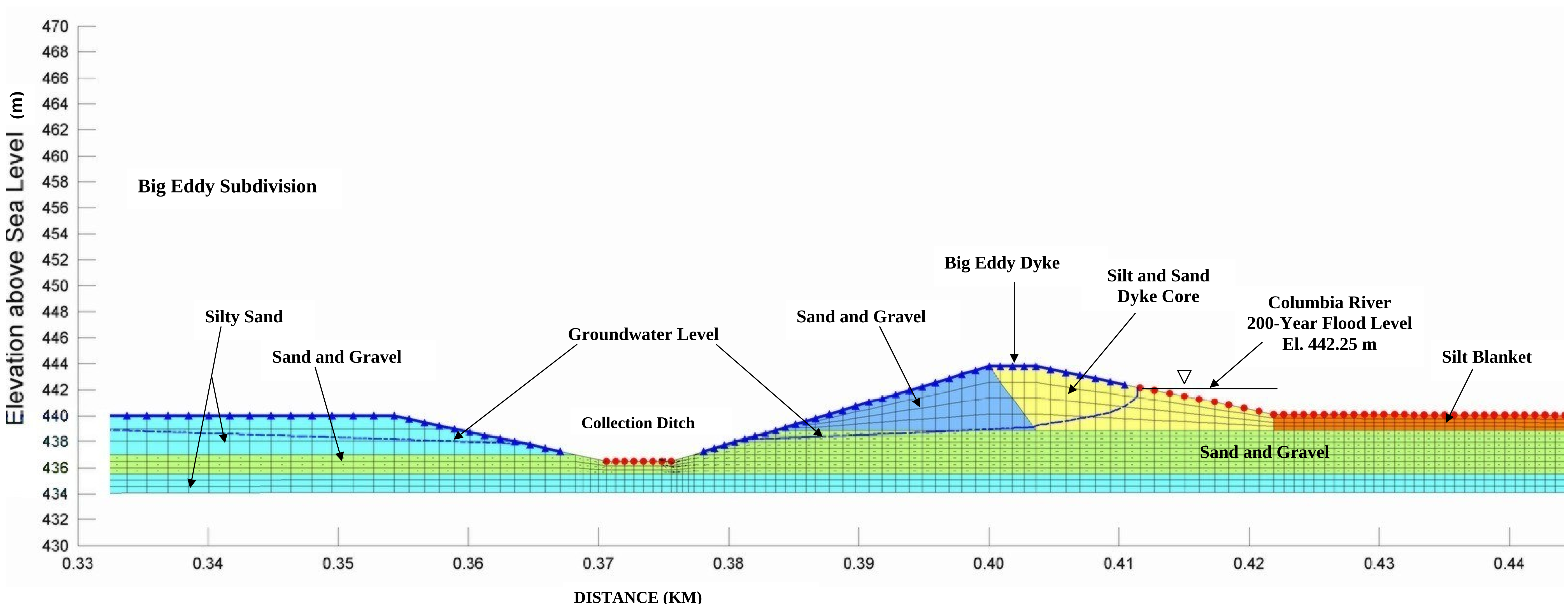


Figure 4 Groundwater Modelling Section

6.1.1 Model Assumptions

The following assumptions were made for the purpose of seepage modelling:

- Reported hydraulic conductivities are reasonably accurate. These were based on grain size and pumping test results which were unavailable for review;
- The natural silt blanket on the river side of the dyke is generally intact;
- The reservoir water levels recorded at Nakusp are representative of the Columbia River stage at the dyke;
- The dyke core is in good condition; and
- A total main dyke length of 1100 m.

6.1.2 Model Configuration

The model configuration was based on the stratigraphy shown on the borehole logs presented in the reference reports and as-built drawings obtained from CBA archived files.

As shown on Figure 4, the dyke is composed of a silt and sand core with a hydraulic conductivity of $5x10^{-7}$ m/s abutting sand and gravel fill, on the subdivision side of the dyke. A 0.9 m silt blanket unit, with a hydraulic conductivity of $1x10^{-6}$ m/s, extends from the toe of the dyke toward the river. The stratigraphy within the subdivision included a 3 m thick silty sand unit with a hydraulic conductivity of $1x10^{-5}$ m/s overlying a 1.5 m thick sand and gravel unit with a hydraulic conductivity of $1.5x10^{-3}$ m/s. This sand and gravel layer is underlain by a silty sand unit with a hydraulic conductivity of $1x10^{-5}$ m/s.

Although it is likely that the shallow surface silty sand unit observed within the subdivision extends toward the river under and beyond the dyke, the soils under the dyke, after clearing and prior to dyke construction, were described as sand and gravel.

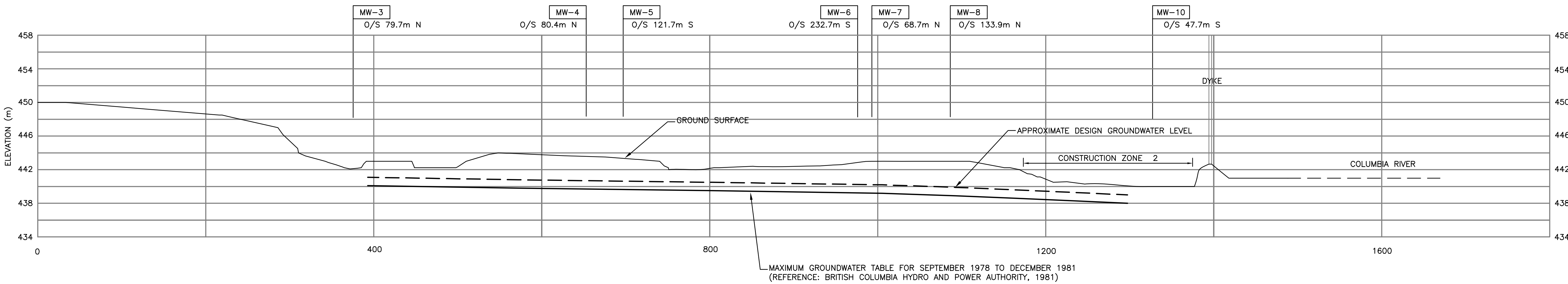
Therefore, in the model, the sand and gravel unit extends from the base of the dyke to a depth of approximately 3.5 m. This may produce an overestimate of seepage and will therefore provide a more conservative, that is higher, pumping rate required to pump out seepage water.

The boundary conditions used were constant heads in the vicinity of monitoring well MW-8 and at the eastern end of the silt blanket. Precipitation was represented by a nominal amount of 4 mm/day, using a unit flux of $2x10^{-8}$ m/s in the model. The water level in the ditch at the Main Pump Station was represented by a constant head of 437.5 m, closely corresponding to the pump on level and slightly less than the maximum recorded level for monitoring well number MW-10 (see Table 2).

6.1.3 Model Calibration

The model was run to replicate the approximate groundwater conditions that existed in October, 1980 (British Columbia Hydro and Power Authority, 1981). Using a Columbia River level of El. 439.8 m and a depth to groundwater at monitoring well MW-8 of approximately 4 m below grade, a pumping rate of approximately 0.12 m^3/s (1900 USgpm) was estimated by the model. Although pumping rate data is not available, the estimated pumping rate was considered reasonable with no contribution from surface runoff.

Groundwater levels similar to those used for calibration, are shown by the groundwater contours on Figure 2 and the water table on Figure 5.



SECTION A FIG 2

NOTE: VERTICAL SCALE TEN TIMES HORIZONTAL SCALE.

LEGEND

MW-5 MONITORING WELLS

O/S 79.7m N OFF SET 79.7m NORTH FROM SECTION A

TO BE READ WITH KLOHN CRIPPEN BERGER REPORT DATED August 13, 2008

SCALE 0 150 m

CLIENT: CITY OF REVELSTOKE

Klohn Crippen Berger

PROJECT: BIG EDDY CONSTRUCTION ZONES

TITLE: SECTION A GROUNDWATER TABLE

PROJECT No. M09248A02

FIG. No. 5

KCB-R-MLD

Time: 9:50:60
Date: 8/11/2008
Scale: 1=3(PS)
Drawing File: M:\M09248A02 - C of Revelstoke Big Eddy Phase 1\400 Design\410 Drawings\FIG2+5+6_rA.dwg (tdu)

6.1.4 Design Simulation

For the purpose of estimating the seepage inflow and therefore the required pumping rate to remove this inflow from behind the Big Eddy Dykes, 200 year flood conditions were modelled. A Columbia River level of El. 442.25 m was used, corresponding to the 200 year flood level. A low precipitation infiltration rate of 24 mm/day (unit flux of $2.8x10^{-7}$ m/s in the model) was used to represent antecedent rainfall.

Under the design conditions, a steady-state pumping rate of 0.35 m^3/s (5548 USgpm) was calculated by the model. It should be noted that this pumping rate includes only groundwater seepage and does not include surface runoff to the ditch.

6.1.5 Sensitivity Analysis

To assess the potential error of the model prediction, several input parameters were varied, individually and collectively as a worst case. These parameters included the hydraulic conductivities of the sand and gravel unit, the dyke core and the silt blanket. The results are shown in Table 4.

Table 4 Groundwater Model Sensitivity Analyses

Parameter	Hydraulic Conductivity		Resulting Pumping Rate for Upper Value (m^3/s)
	Estimated Value (m/s)	Upper Value for Sensitivity (m/s)	
Silt Blanket	$1x10^{-6}$	$1x10^{-5}$	0.45
Sand and Gravel	$1.5x10^{-3}$	$3x10^{-3}$	0.64
Dyke Core	$5x10^{-7}$	$1x10^{-6}$	0.36
Worst Case		All Above	0.78

Note: The pumping rate using the Estimated Values is 0.35 m^3/s.

The sensitivity analysis indicates that the most sensitive parameter in terms of pumping rates is the hydraulic conductivity of the sand and gravel unit. It should be noted that CBA (April 1966) reported hydraulic conductivities, based on a pumping test, ranging from 5.1×10^{-4} m/s to 1.0×10^{-3} m/s with an average of 7.6×10^{-4} m/s. The worst case conditions presented above include a sand and gravel hydraulic conductivity approximately four times higher than the average estimated from the pumping test and three times higher than the highest value estimated by CBA. This will provide a conservatively high estimate of the required seepage pumping rate.

6.2 Storm Routing

For the purposes of flood zone delineation, the Provincial standard is the 1 in 200 year return period event. KCBL carried out a routing of the rain, and rain plus snowmelt events to determine how high the water level might rise within the Big Eddy area. An allowance for seepage pumping, based on the seepage modelling described above, was included in the routing.

6.2.1 Storm Data

Klohn Crippen Berger obtained the Intensity/Duration/Frequency (IDF) data for the Environment Canada station at the Revelstoke Airport. Twenty five years of data, from 1969 to 1999 were available for the 1 to 30 day IDF data. Twenty four years of data, from 1970 to 1994 were available for the 24 hour IDF data. The IDF data is presented in Table 5. A synthesized rainstorm was developed with the IDF data. A 15 minute time step was used for the synthesized rainstorm, assuming that the peak 200-year intensities were contained within the longer duration intensities.

Table 5 200-Year Rainfall and Snowmelt Data

Duration	200-Year Rainfall (mm)		200-Year Intensity (mm/hr)	
	rain only	rain + snowmelt	rain only	rain + snowmelt
15 minutes	12.8	1.6	51.0	6.3
30 minutes	16.3	2.8	32.7	5.5
1 hour	20.9	4.8	20.9	4.8
2 hours	26.8	8.3	13.4	4.1
6 hours	39.6	19.9	6.6	3.3
12 hours	50.6	34.6	4.2	2.9
24 hours	61.4	60.0	2.6	2.5
2 days	77.9	104.2	1.6	2.2
3 days	98.7	149.3	1.4	2.1
4 days	106.2	191.8	1.1	2.0
5 days	111.3	230.1	0.9	1.9
6 days	113.4	275.6	0.8	1.9
7 days	119.0	315.3	0.7	1.9
8 days	125.2	346.7	0.7	1.8
9 days	127.6	377.2	0.6	1.7
10 days	133.3	403.4	0.6	1.7
15 days	156.6	526.2	0.4	1.5
20 days	179.0	616.1	0.4	1.3
25 days	209.9	671.7	0.3	1.1
30 days	229.6	723.2	0.3	1.0

6.2.2 Catchment Areas

The catchment area behind the dykes is 1,150,000 m^2, based on the site visit and digital mapping provided by the City of Revelstoke. The total catchment area was divided into sub-catchment areas draining to each of the three pump stations as shown in Table 6.

Table 6 Big Eddy Catchment Areas

Sub-Catchment	Downstream Pump House	Area (m^2)
1	Main	670,000
2	A	250,000
3	B	230,000
	Total	**1,150,000**

6.2.3 Elevation versus Storage

Elevation vs. storage curves were developed for each sub-catchment behind the dykes. Ditches run along the inside perimeter of the dykes for the purpose of conveyance of overland flow to the pump house intakes. Survey data, collected within the ditches, was used to develop elevation vs. storage relationship for water accumulating behind the dykes.

6.2.4 Storm Routing Results

Klohn Crippen Berger carried out storm routing analyses using: rainfall data from Table 5; the pumping information from Table 1; catchment area behind the dykes from Table 6; and the developed elevation vs. storage relationship. Two storms were considered: the 200-year return rainfall only storm; and the 200-year return rainfall + snowmelt storm. It was found that the 24 hour event with 15 minute time intervals resulted in higher water levels than the 30 day event with 6 hour timesteps. Only the 24 hour routing results are presented herein.

All flood routings assumed that the total drainage area behind the dyke (1,150,000 m^2) was handled by the three pumps in the Main Pump House and Pump Houses A and B were not used. This operation is consistent with the pump operating logs that were located in the pump houses, and comments from BC Hydro about Pump Houses A and B never actually functioning.

The results of the routings are presented in Table 7. The groundwater (GW) seepage flow was varied to see what effect it had on the maximum water levels behind the dyke, labelled as “Max. WS Elevation”. The “Pump Efficiency” was varied to account for blockage of the trashrack intakes to the pumps, either by debris or by the sheet metal covers on the trashracks. BC Hydro have indicated that the extra openings in the sheet metal covers have to be manually opened, and no specific schedule or protocol exists for this. Therefore there is a possibility that during a flood event, the extra openings are not opened. This is accounted for in the routings by reducing the pumping capacity by 50%.

The Peak Inflow includes the runoff and the seepage flows. The Peak Outflow is based on the maximum pumping capacity or the pumping capacity needed to approximately match the peak inflow. The Max. WS Elevation is the highest level that the water reaches in the collection ditches leading to the Main Pump House. This level will be the same as the groundwater level in the Big Eddy Subdivision, adjacent to the ditch. Four cases were considered as follows:

- Case 1 Ground water seepage inflow = 0 m^3/s, pump efficiency 100%
- Case 2 Ground water seepage inflow = 0.35 m^3/s, pump efficiency 100%
- Case 3 Ground water seepage inflow = 0.78 m^3/s, pump efficiency 100%
- Case 4 Ground water seepage inflow = 0.35 m^3/s, pump efficiency 50%

Table 7 Big Eddy 24 Hour Storm Routing Results

		Case 1		Case 2		Case 3		Case 4 (Design Case)	
Basin		Area 1,2,3		Area 1,2,3		Area 1,2,3		Area 1,2,3	
Event		rain	rain+snow	rain	rain+snow	rain	rain+snow	rain	rain+snow
GW Seepage Inflow	(m^3/s)	0	0	0.35	0.35	0.78	0.78	0.35	0.35
Pump Efficiency	(%)	100	100	100	100	100	100	50	50
Peak Inflow	(m^3/s)	16.3	2.0	16.7	2.4	17.1	2.8	16.7	2.4
Peak Outflow	(m^3/s)	3.1	2.1	3.1	2.4	3.1	2.8	1.5	1.5
Max. WS Elevation	(m)	438.3	437.3	438.4	437.3	438.5	437.3	438.8	437.4

As can be seen from Table 7 the rain only event results in higher water levels in all cases. Case 4 is the selected design case and results in a maximum water level in the collection ditch of El. 438.8 m. It allows for pumping required for the expected groundwater seepage and for partial blockage of the pump intakes. The blockage could be caused by floating debris and the possibility that the sheet metal flaps are not opened prior to the storm event. Therefore the design water level in the ditch is El. 438.8 m.

6.3 Combined Results

The design case water level in the ditch, El. 438.8 m, will provide the design groundwater level (hydrostatic level) adjacent to the ditch. Using this value, and the shape of the maximum recorded groundwater table, results in the Approximate Design Groundwater Level shown on Figure 5. Where the ground surface is at El. 442 m or less, the Design Groundwater Level is within 1 m of the ground surface. There are other areas where the ground is 2 m to 3 m higher than the Design Groundwater Level. The groundwater level rises the further away from the drainage ditch and pump station to a maximum level of approximately El. 441 m in Zone 1.

7. CONSTRUCTION RECOMMENDATIONS

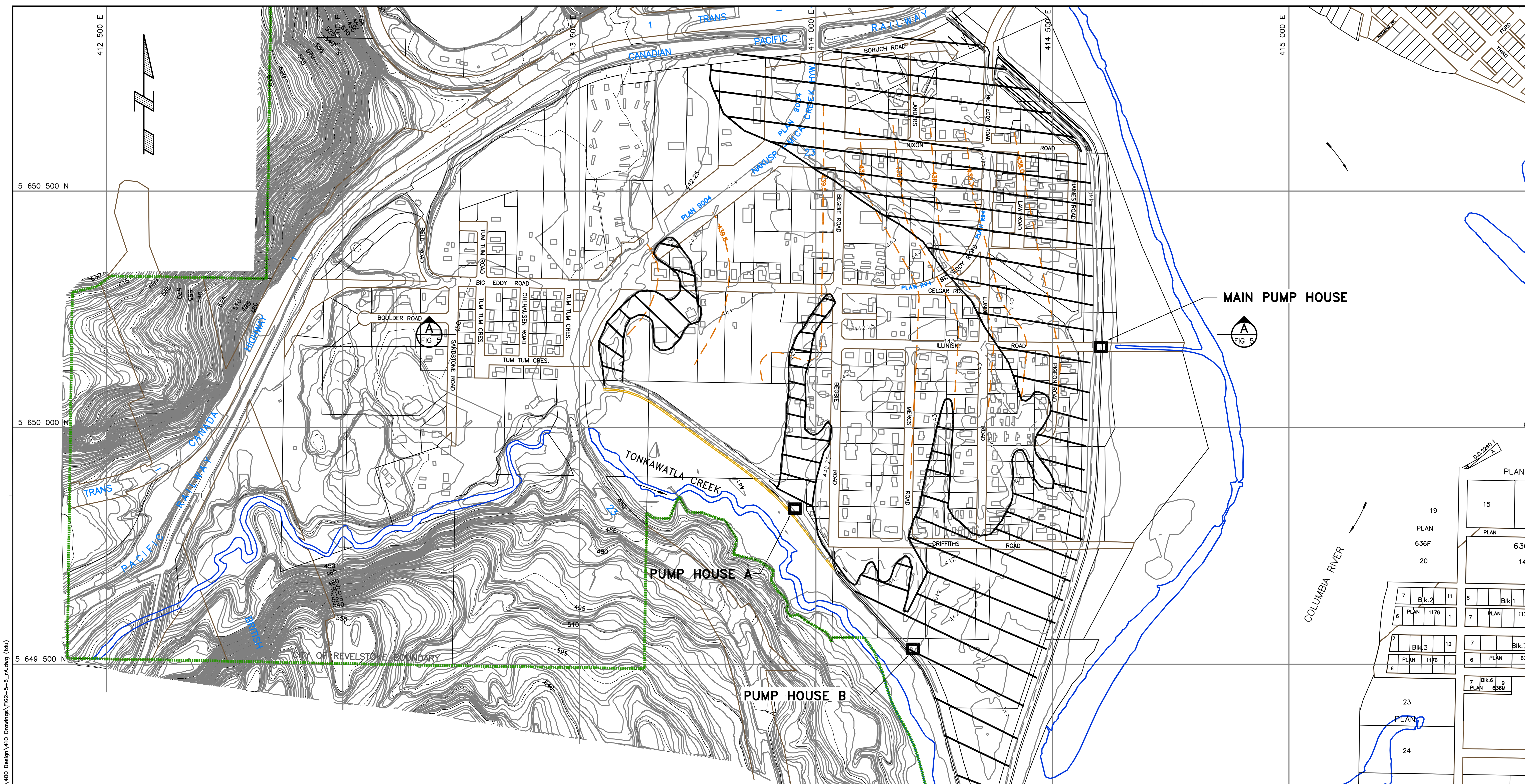
7.1 Zone Recommendations

The City has requested that construction zones be delineated in the Big Eddy area with the following criteria:

- Zone 1: No special flooding, foundation and septic requirements. Construction within this zone would have the usual requirements for construction in a zone not subject to flooding; and
- Zone 2: Engineering studies required addressing flooding, foundation and septic issues. Construction within this zone would require experienced professionals to provide a site specific report addressing flooding, foundation and septic issues.

All aspects of the proposed building must conform to the BC Building Code. Based on the analyses carried out for this study, we recommend that no basements be allowed within the Big Eddy Subdivision area were the existing ground level is at or lower than elevation El. 442 m. These areas are approximately outlined in Figure 6 and identified as Zone 2. For the purposes of this document a basement is an area intended for habitation that is below the ground floor of a building and is completely or partly below ground.

Zone 1 is defined as areas where the ground surface is higher than El. 442 m. If a building permit applicant proposes to build a basement, they should demonstrate to the City that the proposed building footprint lies entirely on natural ground with an elevation greater than El. 442 m and that the underside of the basement floor will be above El. 441 m. This would demonstrate that the proposed building and basement are within Zone 1 and above the estimated design groundwater level of El. 441 m. Adequate waterproofing should be provided for all basements, as per the BC Building Code.



LEGEND

438.6 GROUNDWATER CONTOUR – MAXIMUM GROUNDWATER TABLE FOR SEPTEMBER 1978 TO DECEMBER 1981 (REFERENCE: BRITISH COLUMBIA HYDRO AND POWER AUTHORITY, 1981)

443 GROUND SURFACE CONTOUR

APPROXIMATE LOCATION OF CONSTRUCTION ZONE 2 (GROUND SURFACE El. 442m AND BELOW) REMAINING AREA IS ZONE 1 (GROUND SURFACE ABOVE El. 442m)

TO BE READ WITH KLOHN CRIPPEN BERGER REPORT DATED August 13, 2008

SCALE 0 200 m

CLIENT: CITY OF REVELSTOKE

Klohn Crippen Berger

PROJECT: BIG EDDY CONSTRUCTION ZONES

TITLE: CONSTUCTION ZONES

PROJECT No. M09248A02

FIG. No. 6

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KCB-R-MLD

7.2 Floodproofing Recommendations

Due to the prevalence of low lying water and the lack of a defined surface runoff system within the Big Eddy area, all exterior wall openings into basements should be at least 0.3 m above any adjacent road that could pond water into the building footprint. Buildings with no basement should have the underside of their floor 0.3 m above any adjacent road that could pond water into the building footprint. These conditions apply to both Zones 1 and 2 and the building permit applicant would have to demonstrate that the proposed building will meet these floodproofing requirements and any other floodproofing requirements contained in the BC Building Code.

The City should consider designing and constructing an internal drainage system that would safely convey overland flow to the pump station collection ditches. This could result in modification of the above floodproofing recommendation, since the likelihood of water ponding behind roadways would be significantly reduced.

7.3 Septic Recommendations

Septic tanks and fields are reviewed and approved by the Local Health Authority. The Authority should ensure that a certified septic designer accounts for the high groundwater levels demonstrated in this report and reported by BC Hydro (British Columbia Hydro and Power Authority, 1981). Adequate ballasting must be provided for septic tanks to ensure that partially filled tanks do not “float” with the Design Groundwater Levels presented in this report.

7.4 Qualified Professionals

Within Construction Zone 2 a qualified Professional Engineer or Geoscientist, registered or licensed with the Association of Professional Engineers and Geoscientists of BC, under the provisions of the Engineers and Geoscientists Act and amendments thereto, should provide site specific construction recommendations consistent with the recommendations in this report and with the BC Building Code.

As of May 31, 2005, only an authorized person under the BC Health Act can design, plan, construct or do any maintenance work on a sewerage system. An authorized person is a professional or a Registered Onsite Wastewater Practitioner who has education or experience in sewerage system construction and maintenance. The Health Authority, when approving septic systems, should ensure that the system design has accounted for the information presented in this report.

7.5 Other Local Government Information

The following local governments were contacted to determine if they had specific bylaws pertaining to high groundwater levels affecting septic and building requirements:

- District of Squamish;
- City of Richmond;
- City of Mission;
- City of Pitt Meadows; and
- City of Abbotsford.

Not all of the local governments responded, but those that did respond stated that they did not have specific bylaws pertaining to high groundwater tables. Septic issues were always approved by the local Health Authority, and not the local government.

City of Richmond are in the process of formalizing a “Floodplain Designation and Protection Bylaw” which would require a report prepared by a qualified Professional for building permits within the floodplain. The City of Abbotsford requires a report prepared by a qualified Professional for building permits within the floodplain. The District of Squamish are using the following study as a guideline for their floodplain management, “Flood Hazard Management Plan” (Klohn Leonoff, 1994).

8. CONCLUSIONS

The City has requested that this study be carried out on the assumption that the dykes do not fail and the pump stations and flood boxes are maintained and operated properly. Reliance on dykes, pump stations and floodboxes for determination of Flood Construction Levels (FCL) is contrary to generally accepted Provincial guidelines. The following conclusions are based on these assumptions and others described in this report:

- There have been reports of basement flooding before and after the Big Eddy Dykes and Pump Houses were constructed.
- Within Construction Zone 2, where the natural ground level is at or lower than El. 422 m, the groundwater table could rise to within 1 m of ground surface.
- Within Construction Zone 2 no basements should be permitted.
- Within the Big Eddy area, all exterior wall openings into basements should be at least 0.3 m above any adjacent road that could pond water into the building footprint
- Within the Big Eddy area, Zones 1 and 2, buildings with no basement should have the underside of their floor 0.3 m above any adjacent road that could pond water into the building footprint.
- Where basements are allowed, Construction Zone 1, the underside of the basement floor will be above El. 441 m.
- Adequate waterproofing should be provided for all basements, as per the BC Building Code.
- All aspects of the proposed building must conform to the BC Building Code.
- Septic systems are approved by the Local Health Authority and must be designed by a professional or a Registered Onsite Wastewater Practitioner.
- BC Hydro is planning on replacing the existing pumps and controls in the near future. BC Hydro should consider emergency power supply for the pump stations as part of this pump replacement program.

In addition to implementation of the recommendations presented in this report, the City should:

- Provide this report to BC Hydro for their review and information prior to BC Hydro implementing their pump replacement program;
- Ensure that the flap gates on the pump station sheet metal intake covers are open prior to spring freshet and during periods of high Columbia River levels; and
- Consider designing and installing a surface drainage system in the Big Eddy area capable of safely conveying surface runoff to the pump station collection ditches.

It has been a pleasure providing Consulting services to the City of Revelstoke.

Yours truly,

KLOHN CRIPPEN BERGER LTD.

Richard F. Rodman, P.Eng.
Manager, Nelson Office

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