Klohn Crippen Berger

July 17, 2013

City of Nanaimo
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Nanaimo, BC
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Scott Pamminger, A.Sc.T.
Project Manager, City of Nanaimo

Dear Mr. Pamminger:

Conceptual Review of Overwinter Pumping Options
Middle and Lower Chase Dam Removal
Nanaimo, BC

Klohn Crippen Berger (KCB) was requested by the City of Nanaimo to conduct a brief conceptual assessment of the feasibility of pumping water from the Middle and Lower Chase reservoirs, to maintain low water levels in the reservoirs over the winter of 2013-2014. KCB's initial assessment, discussed at meetings on June 28 and July 3, 2013, was that while pumping of winter flows and floods could theoretically be possible, it was our opinion that it was not practical. Since July 3, 2013, we have looked further into these matters and have further investigated the technical, operational and cost implications of trying to pump winter flows over the dams.

Design Flows

The following assessments are based on designing a system to convey 21 m^3/s (336,000 gpm), which is less than the capacity of the Lower Dam spillway and corresponds to the peak of a 1:10 year flood. As shown in Figure 1, long-term flow averages for the winter months (November to March) are in the 1 to 2 m^3/s range, but monthly averages can be up to 5 m^3/s. However, peak flows of approaching the capacity of the Lower Dam spillway (25 m^3/s) have been witnessed in recent years. Therefore the 21 m^3/s, 1:10 year flood, is considered a reasonable design criterion for the dewatering system capacity, to keep the lakes dewatered over the winter.

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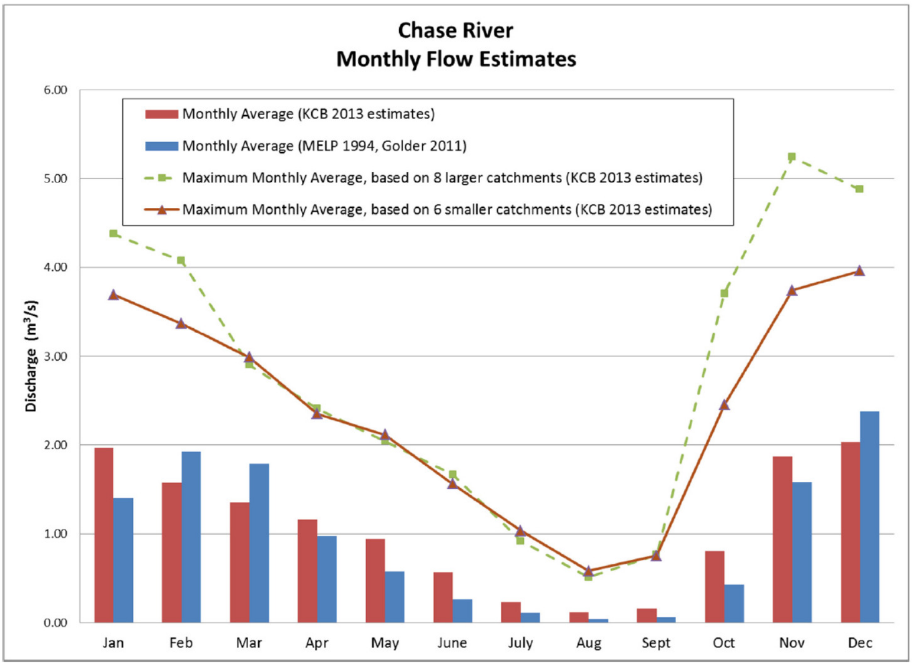

Figure 1: Chase River Flow Estimates

The lakes are too small to provide significant downtime for the dewatering system. Therefore the dewatering system needs to be reliable and operational 24 hours a day, 7 days per week. For instance, if the pumps are off and the Middle Lake is at target water level (say 2m deep, elevation 64 m):

- An inflow of 2 m^3/s will raise the water level to the spillway in 12 hours.
- An inflow of 5 m^3/s will raise the water level to the spillway in 5 hours.
- An inflow of 12 m^3/s will raise the water level to the spillway in 2 hours
- An inflow of 21 m^3/s will raise the water level to the spillway in 70 minutes

The same timings apply to a shortfall of dewatering capacity vs. lake inflow. Therefore, in order to ensure that the lakes are kept dewatered over the winter, the dewatering system must be designed for the maximum expected inflow. A combination of lower system capacity and lake storage will not be adequate.

In summary, a dewatering system capacity of 21 m^3/s (336,000 gpm) has been used to evaluate the possibility of a 1:10 year flood occurring over the 2013/2014 winter months. However, the system would also need to operate at lower, normal (i.e. non-flood) winter flows, in the 1 to 5 m^3/s range, for long periods.

Discharge Pipe Routing

KCB considered both siphon and pump systems. In both cases, a pipe route over the existing spillways would seem to offer the most direct route, with lower head requirements than running the pipes over the dam crest. However, as will be demonstrated below, the number and size of pipes required to handle the design flow (for instance 20 no. 450mm diameter) would occupy a significant part of the spillway area.

It is recommended, for safety reasons, that the spillways be kept open (not obstructed) to allow for the possibility that a flood greater than 21 m^3/s (1:10 year) could occur during the coming winter. Therefore, the discharge pipes must cross over the dam crests or abutment areas: minimum elevation 88.1 m for the Middle Dam, 73.5 m for the Lower Dam.

Safety Considerations

It is not considered to prudent to rely on automatic pump control or monitoring systems to maintain the safety of the school, daycare and residences downstream of the dam, due to the risks of equipment breakdown, controls power failure or other malfunction. Even under routine winter flow conditions, as discussed above, the lake(s) will fill quickly to an unacceptable level (spillway level) in only a few hours if the dewatering system malfunctions. Therefore full-time (24/7) operating crew attendance and a significant amount of system redundancy (spare pumps, spare parts etc.) is considered necessary.

Siphons

KCB considered both siphon and pump systems. In this context, where there is positive head available between the reservoir water level and the downstream channel, siphon systems would initially seem advantageous compared to pumps and have been used previously to lower the level of these lakes over a period of days. The costs for this full-time supervision is included in the estimated costs discussed below.

When the lakes are full and priming is a simple operation, siphons can be “passive” pipes which don’t have the same operational, size and cost constraints as pumps. Once the siphon is primed, it can be capable of moving a higher rate of water flow than pumps. However, unless the upstream water level is allowed to rise to near the elevation of the pipe high point, to fill the pipe by gravity flow, siphon systems require pumps to prime the siphon to establish the suction action that lifts water from the reservoir and conveys it over the spillway to the discharge point.

The siphon flow rate is reached when the head losses (pipe friction, inlet losses and flow restrictions such as control valves) match the head differential between the lake level and the pipe discharge. In theory, the lower the pipe discharge end of the siphon, the greater the flow rate achieved. However, when the max negative pressure at the high point of the pipe (over the spillway) reaches about 9 m (10 m is the theoretical limit) cavitation (water vaporization) will occur and the siphon action will cease.

- At the Lower Dam, the height between the lowest reservoir floor (62 m elevation) and the dam crest (73.5 m elevation) is 11.5 m. Therefore a siphon, no matter how well designed or equipped, cannot dewater the Lower Reservoir completely.
- If the siphon discharge at the Lower Dam was in the pool below the waterfall (el. 46m), a 750mm diameter siphon pipe could theoretically convey up to 6 m^3/s, but would cavitate when the lake level gets down to only 68.0 m – with 6m depth remaining in the reservoir.
- To extend the siphon's range, to operate down to a target water level of, say, 65m (3 m lake depth), the pipe discharge would need to be raised by 18m to 64m elevation. But then, due to the smaller head differential, the 750mm siphon would only be discharging approximately 2 m^3/s per pipe.

The Middle Dam is slightly less high: the height between the lowest reservoir floor (78 m elevation) and the dam crest (88.1 m elevation) is 10.1 m vs 11.5 m. However, the effective performance of an ideal 750 mm siphon pipe would be approximately the same; 2 m^3/s.

Therefore, approximately 11 no. 750 mm siphon pipes would be required to meet the 21 m^3/s design flow at each dam. This does not include any consideration of practical issues like redundancy in siphoning capacity, the hydraulic effect of control valves, the need for pumps to prime the siphons and their associated power and/or fuel sources and the need for full time monitoring and manual control while the siphons are in operation. Note that the pipe system would need to be rigid and robust enough to withstand up to the 9 m negative pressure at the crest, without collapsing. This rules out cheaper flexible pipes.

A more significant operational problem is that with routine flows (in the 1 to 5 m^3/s range) there will be periods of rising reservoir levels until siphoning can be started followed by a brief periods of siphon operation. Unless a very sophisticated (and therefore expensive) system of level detection, automated valves, check valves, priming pumps and automatic control panel <u>for each individual siphon pipe</u> is provided, the siphon action will cease and the siphon pipe will empty each time the lake is siphoned down to the target level. Therefore siphon priming would need to be done (involving manpower, pumps, valves etc.) many times a day due to the continually shifting balance between siphon flow and river flow.

The siphons would need to be continually operational (and supervised 24/7), as a net inflow of only 5 m^3/s (a typical winter flow rate) will fill a lake from near-empty to full (spillway level) in only 5 hours.

<u>Pumps</u>

Various types of low-head, high flowrate pumps were considered. A practical limit for pumps which are appropriate for a temporary field application like this, as opposed to a permanent pumping facility, is approximately 18,000 gpm per pump (1.1 m^3/s). This applies across a variety of pump types ranging from, say, 400mm diameter centrifugal pump sets to 800 mm diameter axial (propeller) pumps. Therefore, approximately 20 pumps (and 20 discharge lines of up to 750 mm) would be required to handle the 21 m^3/s flood flow rate.

Note that the 9 m vertical suction head limit (due to vaporization/cavitation), discussed above for siphons, also applies to the suction line of a diesel pump set sitting on, for instance, the crest of the Lower Dam. The laws of physics will not allow a pump at elevation 74 m (on the dam crest) to lower the water level below approximately 65 m (3 m lake depth).

Alternatively, a set of up to 20 axial propeller pumps in 800 mm inclined tubes on the upstream face of each dam, with 750mm discharge pipes over the dam, powered by diesel generators, would provide approximately the same discharge (1.1 m3/s, 18,000 gpm per pump). However, each pump tube would have to be supported off the floor of the reservoir to reduce sediment mobilization, and the overall set-up would represent a large, complex and environmentally intrusive system. It should be noted that this would be an extremely unusual application for this type of pump, which is designed to be installed vertically in a permanent pump station.

For a number of technical, operational and availability reasons, discussed with dewatering contractors, one of the feasible pump arrangements would probably feature the type of diesel/pump set pictured below: 16" (400mm) pumps each powered by a 350 hp diesel engine and producing up to 18,000 gpm (1.1 m^3/s) at low-head "run-out".

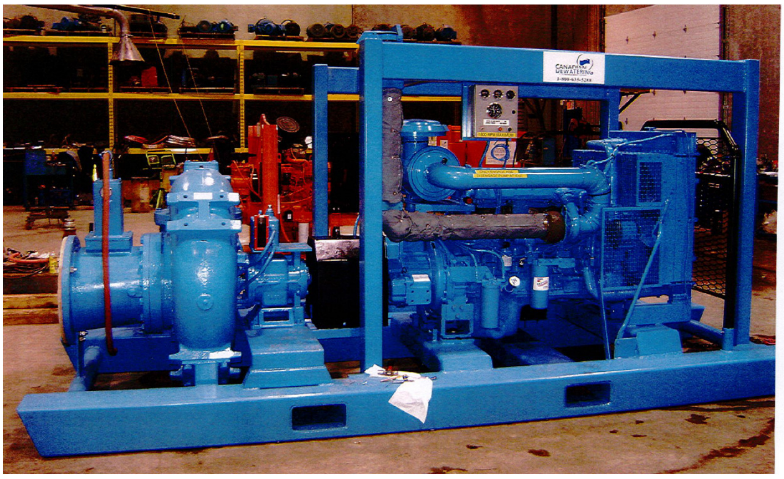

Figure 2 – Example of a 16" diesel powered pump set

In the case of the Lower Dam, the pumps would sit on the dam crest (or off to the side, for environmental protection reasons) at an elevation of approximately 73.5m. The pump volute would be at approximately 74.5 m elevation. Allowing for suction line losses, the minimum water level possible would be approximately 65.5m, leaving 3.5 m depth (approximately 15,000 cu.m) in the lake.

Each of the 20 diesel pump sets would consume 56 litres per hour when operating and pumping 18,000 gpm (1.1 m^3/s) each. With reference to Figure 1, the monthly average winter pumping rate would be approximately 2 m^3/s (2 pumps) with the number of pumps in operation changing frequently to accommodate actual, varying river flows. Therefore, the average expected fuel requirement, for each dam, would be approximately 81,000 litres ($97,000) per month.

Costs

Temporary pumping systems of this magnitude are extremely unusual. The following is a sample of information KCB has gathered from various sources, including specific discussions with Canadian Dewatering Ltd. (CWL), the primary providers in Western Canada for this type of large-scale temporary pumping system. The following table is based on typical rates quoted by CWL for this type of equipment for similar projects, including the summer diversion (1 m^3/s) for the Colliery Dams project.

Table 1: Approximate Monthly Dewatering Cost, per Dam

Item	Description	Quantity	Unit	Unit rate	Monthly cost
Pump rental	16" pump, 350hp diesel pump set	20	each	$ 16,700	$ 334,000
Pipe	400mm pipe, 50m each pump	1,000	lin.m.	$ 35	$ 35,000
Fuel	Average 2 pumps @ 56 l/hr	80,640	litres	$ 1.20	$ 96,768
Supervision/Monitoring	weekdays	44	12-hr shift	$ 1,400	$ 61,600
Supervision/Monitoring	weekends	16	12-hr shift	$ 1,700	$ 27,200
			MONTHLY TOTAL, PER DAM		$ 554,568
not included:	pipe fittings, valves				
	automatic controls, level switches				
	environmental protection (pump/engine group)				
	pump suction rafts/supports				
	back-up equipment (safety redundancy)				
	mobilization/demobilization				

All of these topics would be addressed in a detailed design of this system, and some alternatives are possible. For instance, multiple pumps could discharge into a smaller number of, say, 900mm pipes. Or a larger number (~ 50) of smaller, electrical submersible pumps (say 10”) could be powered by large engine/gensets. However, the complexity and cost of such a system would probably be similar to what is presented in Table 1.

Environmental

It is equally important to discuss the environmental impact of attempting to maintain the dams in their current state through on-going dewatering of the reservoirs. As it is expected that the reservoir level will cycle up and down in a range of, say, 2 m as pump operation varies in reaction to lake inflow, it will not be possible to implement the erosion and sedimentation control measures currently within the tender drawings. Firstly, the dam excavation rock fill and gravel to construct the berms adjacent to the channel will not be available for use which would require import of off-site materials at a high cost. Secondly, it will not be possible to mulch the surface of the reservoir bottoms nor hydroseed. Repeated inundation will inhibit or prevent grass growth and will likely cause floatation of the organic materials within the mulch. As a result, pumping would likely transfer the organics downstream with consequences for depressed dissolved oxygen levels downstream in the spawning grounds.

As a result of not being able to implement an erosion and sedimentation control program within the lakes, the influx of water into the reservoirs and over the exposed lake sides via the river channel and also overland from the former reservoir rims will result in the water behind the dams becoming turbid with suspended solids. Repeated pumping and turbulence at the pump suction intakes will result in turbid water being discharged downstream of the dams with corresponding impact on the spawning grounds.

KCB is familiar with the Chase River valley conditions downstream of the Lower Chase Dam and have concluded that there is no other practical location where the siphons can discharge to without creating an erosion and sedimentation problem that could impact the spawning grounds in the lower reaches of the Chase River, unless significant and intrusive armouring work is carried out.

In addition to the sediment control implications of a lake dewatering program, there are significant environmental concerns related to noise, exhaust and the storage and handling of diesel fuel for such a large number of diesel engines in the park.

Summary

As a result of this conceptual assessment, KCB has concluded that the over winter pumping operation with the dams left in place in their current condition is not practical and presents unacceptable environmental, operational and safety risk to the lower reaches of the Chase River. Moreover, the flood hazard risk to the public is not fully addressed through such a program. Costs are likely to exceed $4,000,000 per dam for an 8-month winter program of lake dewatering. KCB does not recommend conducting a more detailed study on this option.

Please do not hesitate to contact the undersigned if you have any questions or comments regarding this letter.

Yours truly,
KLOHN CRIPPEN BERGER LTD.

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Principal, Water Resources

RJF: jt
cc: Chris Gräpel, P.Eng.