stabilize the foundation prior to and during channel excavation. These assumptions have a significant bearing on the total cost of this option.

The total cost of the Meandering Pilot Channel option was estimated to be $1,410,000. This cost estimates, which is still very preliminary and based on some major assumptions, included the following:

- additional drilling and geotechnical investigation;
- site survey;
- engineering design;
- construction supervision;
- contractor mobilization and demobilization;
- access road improvement;
- pilot channel excavation, hauling to the Scour Canyon, and wasting there;
- dewatering, including temporary sediment pond;
- limited ground stabilization;
- diversion of the existing channel during construction through the "Neck;"
- wing dyke construction;
- permanent culvert through the wing dyke;
- site restoration and reclamation; and
- 30% contingency.

4.4.8 Evaluation of Short-listed Concepts

The remaining concepts considered were:

Option 12	Meandering Pilot Channel proposed by Hayco (2000);
Option A	Reactivated Natural Channel;
Option B	Reactivated Natural Channel with Side Channel; and
Option C	Downstream Slot.

Each of these options was ranked using Hayco's evaluation matrix and the results are presented in Table 4.4.8-1 below. The reader is referred to Hayco (2000) for a description of the matrix and each of its categories.

All four options require a considerable degree of channel enlargement by commissioning flow releases from the CWRF, and associated flushing flows via the Skins Lake spillway. This is potentially the largest component of the total cost, and it is not included in the costs listed in the above table. However, since this cost is expected to be similar for all four options, assuming the commissioning flows would be implemented in the same years in all cases, this cost would not be a determining factor in the selection.

It is clear from the above evaluation that Option 12 and Option C should be eliminated. The two remaining concepts rank very closely with one another. Option B is more expensive, but offers some enhanced fish habitat and vegetation features. Option A is the least cost option; however, each of the four independent elements of Option B (i.e., the pilot side channel, the two berms, and rounded rock revetment) offers modest environmental benefits for modest cost. Any of these four elements could be added to Option A without affecting the outcome of the evaluation significantly. It is our recommendation that Option A be advanced to the next stage of study and evaluation, without precluding the possible addition of any of the four elements of Option B later.

Table 4.4.8-1 Evaluation matrix for options to move water across the Cheslatta Fan

	BENEFIT POINTS[1]			
	Meandering Pilot Channel	**Reactivated Natural Channel**	**Reactivated Natural Channel with Side Channel**	**Downstream Slot**
Option:	**12**	**A**	**B**	**C**
Criterion:				
Commissioning Issues				
Sediment mobilization	1	1	1	2
Management of canyon debris	3	3	3	1
Long Term Issues				
Reliability	2	3	3	2
Sediment mobilization	1	1	1	2
Fluvial geomorphology	1	1	1	1
Fish rearing habitat	2	2	3	2
Fish passage	3	3	3	2
Spawning habitat	2	3	3	2
Downstream spawning beds	1	1	1	1
Resident fish habitat	3	3	3	3
Aquatic plants	1	1	1	1
Waterfowl	2	2	2	2
Other wildlife	3	3	3	3
Aesthetics	3	3	3	1
Maintenance	3	3	3	2
Total Benefit Points:	31	33	34	27
Mitigation possibilities[2]	4	4	4	2
Adjusted Benefit Points:	35	37	38	29
Cost ($K)	$1,410	$0	$667	$2,300
Cost per Point ($K)	$40	$0	$18	$79

[1] 0=poor, 1=fair, 2=good, 3=excellent

[2] Additional points that can be scored by use of flushing flows to mitigate downstream impacts

4.5 Selected Concepts

4.5.1 Constructability

As the channel will be formed by flow releases from the CWRF in a way that mimics natural channel development, the issue of 'constructability' is primarily an issue of the commissioning flows and the consequences to the aquatic environment downstream. These topics are discussed in Section 5. The present section deals with those items that would be constructed in the traditional sense, such as the berms and the pilot side channel.

4.5.1.1 Foundation Conditions

Viewed from the surface during the site inspection, the proposed sites of the berms and pilot channel did not appear to have unusual construction challenges. However, the Cheslatta Channels Design Report (Klohn Leonoff, 1991) identified some locations where extremely weak soils were discovered at depth, where drill casings sank under their own weight, or standard penetrometer tests resulted in blow counts of 1 or 2 blows per foot.

The possibility of weak foundation conditions under the proposed berms and under the pilot side channel could not be confirmed because specific drill hole and test pit data for these sites, beyond the Cheslatta Channels Design Report (Klohn Leonoff 1991), either did not exist or was not available to the study team. The report identifies that very weak zones in particular soil units do exist, but the cross sections in that report delineating the units were labeled with question marks, indicating inferred or approximate delineations. Three drill holes containing very weak zones were identified in the report, but these were located in the area of the Neck and the former scour hole downstream of the "Neck." It is strongly recommended that additional subsurface exploration be undertaken along the precise alignments of the berms and pilot side channel to determine whether such weak zones exist at these locations.

If the foundations in specific locations are found to be very weak, there are several construction techniques that can be employed to prevent equipment from sinking in the soil, from winter construction to take advantage of a frozen surface layer, to the use of portable pads, which evenly distribute the weight of equipment to the ground below. If the soil under the proposed dykes is too loose to bear the weight of the berms, they could be built in phased lifts, allowing time between lifts for the foundation soils to consolidate. As the berms are intended to deter erosion rather than retain water like a dyke, and recognizing that they could be ultimately sacrificed to long-term future erosion, even large magnitudes of settlement during and after construction would not constitute a failure.

The pilot side channel is intended to erode with the commissioning flows soon after excavation; therefore long-term stability of the sides of the channel excavation is not a concern. Given the uncertainty of the soil conditions along this route, the design of the side channel would need to be finalized after more geotechnical data are made available. The shape of the cross section shown in Figure 4.4.3-2, especially the side slopes, must be considered conceptual and subject to possible change.

4.5.1.2 Availability of Construction Materials

The Scour Canyon shown in Figure 4.4.2-1 and the upper part of the Cheslatta Fan near its apex contain a vast supply of potential construction materials spanning a wide range of sizes from large boulders to fine sands. These materials have been partly sorted by the action of water during the large erosion events that formed the Cheslatta Fan. It is certain that an adequate quantity of the necessary materials can be found from these two sources. Since the grain size distribution of the materials from which the berms will be constructed does not need to be tightly specified, it appears unlikely that any screening of the borrow materials will be required. Instead, an exploration program consisting of test pits to identify the precise sources of the materials to be used in the berm construction will be necessary. In order to preserve the aesthetics of the area, a comprehensive plan for the development of access routes to these borrow sites, their excavation and reclamation after construction, including removal of access routes and establishment of native vegetation, will be required.

4.5.1.3 Disposal of Excavated Materials

The volume of material that would be excavated to create the pilot side channel was estimated to be approximately 9,600 m^3. This material will contain a large proportion of sand. In order to remove this sand as a potential future source of river-borne sediment, it should be trucked out of the fan into the Scour Canyon for disposal. It may have the potential to be used as landscaping material that could be incorporated into the reclamation plan for the Scour Canyon borrow areas. Otherwise, it would require a reclamation plan of its own.

4.5.1.4 Access

A narrow access road to the Cheslatta Fan currently exists, which could provide easy access for tracked construction equipment. Some widening and grading of this road may be required to allow large trucks to access the fan. Since almost all of the volume of materials required for construction of the berms is locally available in the Scour Canyon and on the fan, this access road would not be subjected to many repeated trips by large trucks. Some access routes on the fan and in the Scour Canyon would be required to access the berm construction materials and to dispose of the excavated soil from the pilot side channel.

4.5.1.5 Dewatering the Pilot Side Channel Excavation

The pilot side channel concept was developed on the premise that it would not be necessary to lower the water level in Scour Hole Lake in order to allow construction of the pilot side channel. This excavation should be developed while leaving the upstream and downstream ends intact to isolate sediment-laden water from entering the water bodies upstream and downstream prior to the release of commissioning flows.

There are two approaches to dealing with the water that would seep into the excavation. One approach would leave it and work in the wet, and the other would be to pump it to a settling or exfiltration basin nearby that would ensure sediment-laden water does not make its way into the Nechako River. Both options present difficulties. The conceptual design of the pilot side channel has a bench located at the elevation near the expected water table in the soil with the expectation that the upper part of the excavation should be achievable with little or no dewatering necessary. The deeper part of the channel, which would be about 1.5 m deep, could be excavated from one side. The decision on which approach to use cannot be made without detailed site specific subsurface data. For cost estimating purposes it was assumed that a modest dewatering system would be employed.

If the foundation conditions are found to be extremely difficult along the route of the pilot side channel, this portion of Option B should be dropped from consideration.

4.5.1.6 Timing of Construction

Any instream work would be restricted to May and June, based on regionally defined instream works timing windows. The upstream berm (near Scour Hole Lake) could be built outside of this timing window, as it would not disturb any watercourse. The downstream berm would require crossing the existing channel. If a temporary crossing using culverts would be constructed during the May - June time window, then construction of this berm could be completed during a later season, if necessary.

4.5.1.7 Bioengineering

The amount and type of riparian vegetation will at least partially determine the eventual width of the proposed channel across the fan. If present, riparian vegetation will also help control sediment production, provide shade, allochthonous materials and an eventual source of woody debris or cover for fish. Bioengineering techniques have the potential to expedite this process. Live palisades, such as those illustrated on Plate 4.5.1-1 could be constructed to provide erosion resistant banks. Live gravel bar staking, such as illustrated on Plate 4.5.2-1, might be used to expedite vegetation development on poorly vegetated sections of the Cheslatta Fan surface in the vicinity of the proposed channel. Wattle fencing, illustrated on Plate 4.5.1-3, could also be used to help stabilize steeper cutslopes and address any areas of local sediment production or erosion. These techniques could be readily applied using local willow or cottonwood cuttings. There is the potential that some of this work could be completed prior to channel commissioning. This would reduce the time necessary to develop a mature vegetation cover and, if well established, could provide local erosion protection during the process of channel formation.

Costs associated with bioengineering treatments have not been estimated as the present scope of this work and material source areas have not yet been established.

4.5.2 Estimation of Costs

Preliminary costs of key elements of the four options were estimated in this study for the purpose of concept selection and determination of feasibility. As such, some costs were identified but did not require estimation, because they were equal or likely very similar among all four options. These include the following:

- the cost of water for channel commissioning;
- cost of bioengineering for bank protection;
- cost of environmental studies in advance of the channel commissioning;
- costs associated with applying for and obtaining permits and approvals; and
- costs for monitoring before, during and after channel commissioning

Plate 4.5.1-1: Example of live palisade construction to protect bank areas from erosion (photos by Dave Polster, R.P.Bio.).

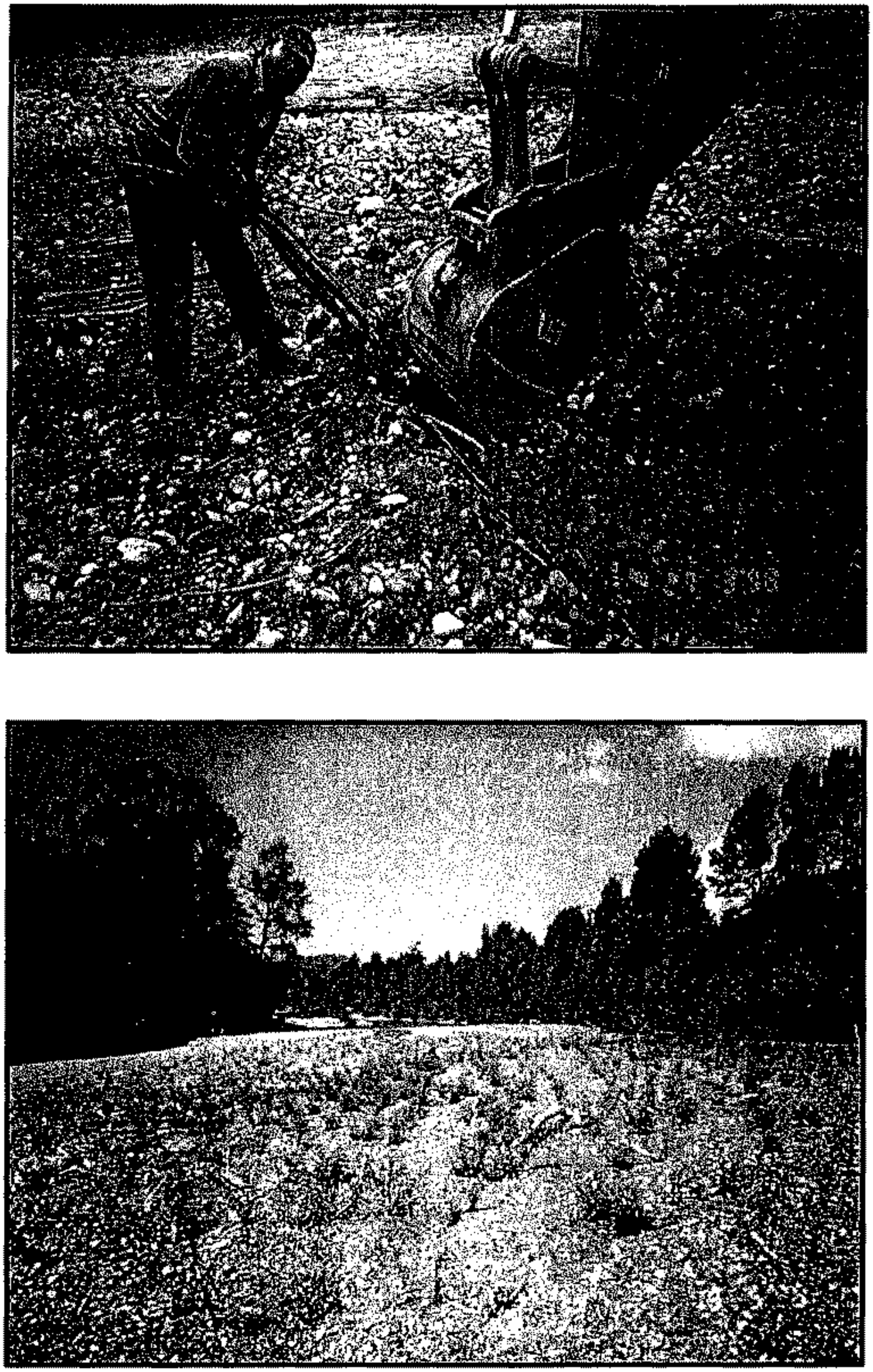

Plate 4.5.1-2: Example of live gravel bar staking to expedite revegetation of well drained soils and stabilize mobile sediments (photos by Dave Polster, R.P.Bio.).

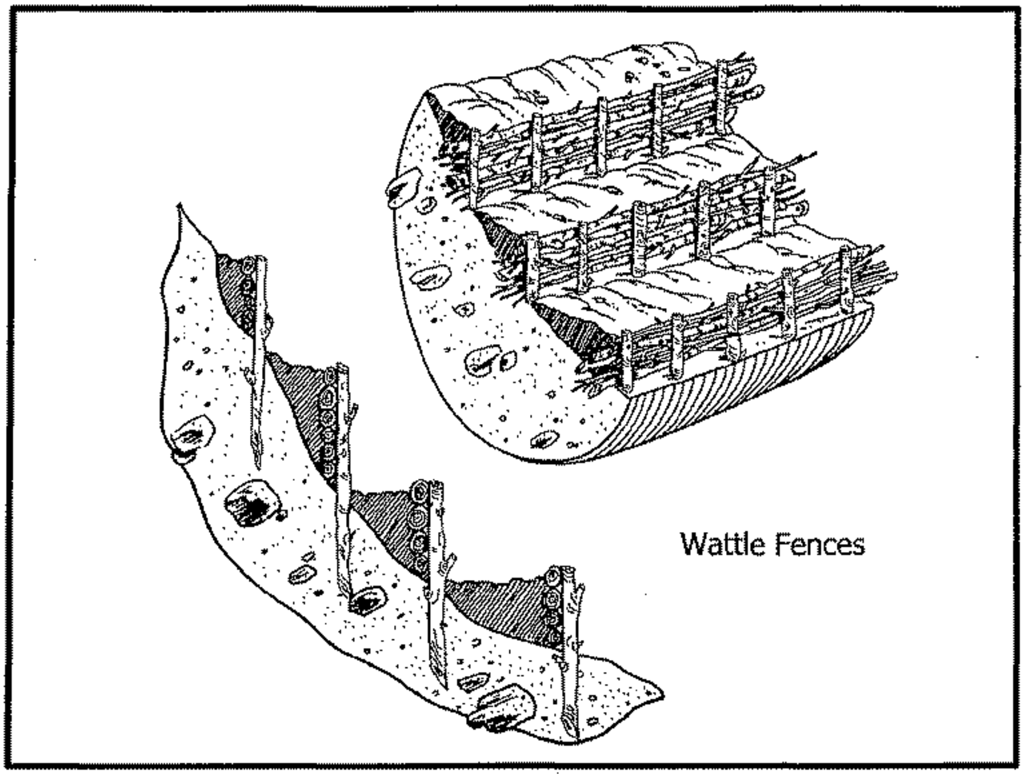

Plate 4.5.1-3: Example of wattle fencing used to stabilize areas of local erosion or sediment production.

For Options A and B there is a potential economic cost for the water required to create these channels and to flush the resulting sediment through the Nechako River channel downstream. "Cost" in t' context refers to the value of alternative uses of the water required for the commissioning flows. Broadly, water is presently released from the Nechako Reservoir to meet legal obligations (i.e., base flows and cooling flows), generate electricity (at the Kemano power plant), and spilled for safe management of the reservoir and flood control. In the latter case, the water may be considered "surplus" and of zero economic value to the project. The legal obligation is an operating constraint that must be met before water may be released to Kemano. Any commissioning water that might reduce the water available for meeting base flow and cooling flow requirements will have to be made up by reducing electricity production. Hence the cost of non-surplus water is the value of electricity production at Kemano (net of operating costs).

The lowest cost method for obtaining commissioning flows is utilizing as much of the surplus water as possible. Table 4.5.2-1 provides an indication on an annual basis of the extent surplus water may be available for commissioning flows.

Table 4.5.2-1 Indication of availability of adequate surplus water for commissioning

Pulse	Commissioning Flow[a] (m^3/s, annualized)	Surplus Water[b] at Annual Average Annualized Flow (m^3/sec)		
		Average	90%	110%
Initial	14.5	18.9	11.5	50.5
Second	21.1	18.9	11.5	50.5
Third	22.5	18.9	11.5	50.5
Fourth	17.0	18.9	1.5	0.5

[a] from Table 5.2.2-1, column 6 multiplied by annual reservoir inflow

[b] from Nechako Water Balance, Revised (J. Chess pers. comm. Sept. 10/02)

A deficit condition, where the commissioning flow exceeds the available surplus, is denoted in red. That is, given average and low water conditions (i.e. 90% of annual reservoir inflow) the commissioning flow volume exceeds the spilled volume for the second and third pulses. For low water years, there is not adequate surplus water to fully satisfy any of the proposed commissioning pulses, while in high water years (110% of annual reservoir inflow) there is ample surplus water to meet all commissioning requirements. The reality is more complex than portrayed by the table, as the surplus water may not be fully available during the June 1 to August 20 period when commissioning would occur. This matter will require further investigation.

To the extent the commissioning water is not satisfied from surplus, as noted above, electricity production from Kemano would be reduced. Presently, the estimated net value of power from Kemano is $15 US/MWh. (pers. comm. D. Dhaliwal, Alcan). Kemano produces 6 MW of electricity for 1 m^3/s of water down the Kemano penstock (NWC Issues Records, Hydro-Electric Generation at Kemano), or 1 MWh for 600 m^3/s. These factors may be used, once the volume of non-surplus water is known, to estimate the cost of commissioning water in terms of foregone power production.

For example, the commissioning water needs for the second pulse is an annualized 21.1 m^3/s. Assuming all of the surplus water is taken first, then 2.2 m^3/s (i.e., 21.1-18.9) would be drawn from electricity production. This annualized flow is equivalent to 69 million m^3/year, which could produce 115,600 MWh, presently worth some $2.6 million Cdn.

In high surplus years it is anticipated that the commissioning water would be essentially costless. While the cost of commissioning water can be minimized by maximizing the use of surplus water, or committing the flows during high water years, there is a cost in waiting for such periods. The financial cost is interest on the invested capital that is not productive until commissioning is complete. This cost of waiting will vary with the project cost (i.e., higher capital cost higher the cost of waiting), and the stage of commissioning. As the project concept becomes better defined it is expected that a management strategy will evolve to balance the trade-off between proceeding with commissioning and waiting for surplus water.

Since Option A features no constructed works in the fan, there are no construction costs associated with this concept. However, there will be the aforementioned costs, such as the costs of water, bioengineering, environmental studies, permits and approvals and monitoring.

Option B has four constructed features: the pilot side channel, a revetment of rounded riprap boulders, an upstream berm near Scour Hole Lake and a downstream berm below the Neck. The construction costs for these four features are listed in Table 4.5.2-2.

Table 4.5.2-2 Summary of preliminary cost estimate for Option B features

Item	Cost
Additional drilling & geotechnical report	$20,000
Site survey	$6,000
Engineering design	$30,000
Site supervision	$38,000
Contractor mobilization & demobilization	$10,000
Access road upgrading	$6,000
Pilot Side Channel excavation, haul & waste	$70,000
Dewatering, including temp sediment pond	$52,000
Upstream berm construction	$75,000
Downstream berm construction	$145,000
Rounded riprap revetment	$28,000
Site restoration & reclamation	$33,000
Subtotal	$513,000
30% Contingency	$154,000
Total	$667,000

These costs, which are very preliminary, do not include the costs of water, bioengineering, environmental studies, permits and approvals from regulatory agencies or monitoring associated with the channel commissioning.

The costs listed in Table 4.5.2-2 are substantially less than our estimated construction cost of the Option 12 Meandering Pilot Channel ($1,410,000) for two major reasons. First, Option B involves much less excavation volume (9,600 m^3 instead of 95,600 m^3), as the Option B side channel is much shorter and narrower than the Option 12 channel. Also, being only a side channel, it does not require any temporary flow diversion as the Option 12 channel would through the Neck and downstream. The second reason Option B is cheaper is that it avoids any work in the known soft foundation area through the "Neck" and the former scour hole immediately downstream of the "Neck." For estimating the costs of Option 12, it was assumed that that it would be necessary to install some ground stabilization measures involving a system of well points to draw down the groundwater table prior to channel construction. For Option B, it was assumed that no such ground stabilization measures would be required. This assumption would need to be confirmed with the drilling program and additional geotechnical investigation including the next phase, if any elements of Option B were to be selected.

5.0 COMMISSIONING AND MONITORING: ADAPTIVE MANAGEMENT APPROACH

5.1 Commissioning

5.1.1 Strategy and Criteria

The prime objectives of the commissioning flows are to flush out the accumulated sediment and vegetation from the Nechako Canyon and to enlarge the reactivated channel across Cheslatta Fan, while minimizing any possible negative impacts on the downstream aquatic habitat of the Nechako River. This can be achieved by carefully controlled releases from both the CWRF and Skins Lake Spillway.

The CWRF discharges would be increased in stages over time to control the quantity of sediment mobilized by the flow. Small discharges through the canyon and fan would be used at the outset, and this would allow large quantities of dilution water to be applied at Cheslatta Falls. The primary means of protecting the downstream habitat would be an adaptive management technique wherein the turbidity and/or suspended sediment concentration would be continuously monitored, and would ultimately determine the rate of flow being released through the canyon and fan. Also, intensive monitoring of sand and fine material in prime gravel spawning areas would be conducted before and after each set of releases, allowing the schedule for the next set of releases to be adapted as necessary to prevent the entrainment of unacceptable quantities of sands and fines in the spawning gravels.

Because the adaptive management approach requires the flexibility to modify the releases as they occur, it is not possible to precisely define in advance the magnitudes and durations of the flow releases from both the CWRF and the Skins Lake spillway. However, a release plan is required at the outset in order to have an initial target to aim for.

Establishment of a target release plan should be based on several rational principles and criteria. The principles and criteria applied in this case are listed below:

- The initial discharges through the canyon and fan should be small, because this would limit potential negative impact of unexpectedly high sediment concentrations, and would provide proportionately more dilution water from the Skins Lake Spillway to deal with the expected high sediment concentrations. The initial releases will flush out most of the available fine material, therefore their suspended sediment concentrations are expected to be much higher than those of later releases.
- In addition to beginning the reactivation of the channel, the first set of commissioning releases would be intensively monitored to provide data that could be used to plan subsequent sets of releases.
- The suspended sediment concentrations should be measured on a continuous basis at the downstream end of the fan, and these should be used to adjust discharges through the canyon and fan to limit the maximum downstream concentrations. If the suspended sediment concentration at the downstream end of the fan (upstream of the Cheslatta confluence) should be found to exceed 10 g/L, then the discharge should be reduced in succession by half of the last increase and the suspended sediment concentration determined again. This would be repeated until the concentration falls below 10 g/L.

- Conversely, to ensure that significant progress is being achieved in the reactivation of the channel, if the suspended sediment concentration upstream of the Cheslatta confluence should fall below 2 g/L, then the discharge should be increased at the next convenient opportunity to the next step in the release schedule.
- Once the release through the canyon and fan has ended, or is reduced to such a low flow that the mobilization of new sediment effectively stops, the pulse of sediment laden water still needs to be flushed all the way to the confluence of the Nechako and Fraser Rivers at Prince George. To ensure that the lower river has been cleared of suspended sediment, the flushing flows from the Cheslatta River should not be substantially reduced for at least 5 days after the cessation of releases through the canyon and fan. The estimated water travel time, in the anticipated discharge range, from Cheslatta Falls to Prince George is approximately 4 days.
- To flush sand and fines from the gravel portions of the riverbed, the peak discharge of the flushing flows downstream of Cheslatta Falls should at some time after cessation of releases through the canyon and fan equal or exceed the peak discharge downstream of Cheslatta Falls during the releases through the canyon and fan. It would be desirable that this peak flow be great enough to mobilize the surface armour layer in most gravel spawning areas.
- The flushing discharges from the Cheslatta system should not be constant, but fluctuate as much as possible to provide a series of rising and falling flows to winnow sand and fines from the channel bed and gravel bars to the channel margins and to local sand deposits on bar tails and near eddy pools.
- The combined flows from the CWRF, from Skins Lake spillway and from local inflow should not exceed levels that would cause flood damages to developments located within riparian areas along the Nechako River.
- The commissioning flows should be released in the period from mid-May to August 20. It would be preferable to start the initial releases as early as possible to take advantage of increased dilution flows from downstream tributaries and mimic the natural conditions in which the natural sediment concentrations are typically higher in May and June than in July and August. Depending on the runoff conditions in the year that it occurs, the last release may need to be scheduled late in the period to allow the largest commissioning flow to coincide with the least downstream tributary flows in order to avoid flooding developed riparian areas.
- Even though the first set of commissioning flows would be small, it is possible that the CWRF could be operated immediately afterward with the limitation that the cooling water discharges would be some amount less than the peak commissioning discharge released through the CWRF. The exact magnitude of that limiting discharge could only be determined during the latter stage of the commissioning flow on the basis of suspended sediment concentration monitoring.

There is no precise point at which the new channel across Cheslatta Fan can be objectively defined as "fully commissioned". Instead, there would be a gradual continuum from initial channel forming releases through successively larger releases up to the maximum release flow that is limited by the constraint of flood potential at downstream locations. Beyond that there would be occasional large spillway releases from Kenney Dam during flood events, probably in the distant future. This continuum would represent a transition from a managed situation with a high potential sediment impact to a natural situation with no unusual or unnatural sediment impacts. Over time, the establishment and growth of bank vegetation will tend to stabilize the self-formed channel across the fan, thereby reducing erosion and sediment entrainment during the occasional flood period.

5.1.2 Flood Wave and Sediment Travel Times

Upon completion of the CWRF, there would be two alternative routes for Nechako-bound water released from the reservoir: one route would be through Skins Lake spillway, down the Cheslatta River, through Cheslatta and Murray Lakes, then over Cheslatta Falls to the confluence with the Nechako River. An inspection of the gauged data indicates that a flow change at Skins Lake takes approximately 36 to 72 hours to be observed at Cheslatta Falls.

The other route through the Nechako Canyon is much shorter and contains no lake storage. As a result, a flow change at Kenney Dam would be transmitted relatively quickly to the confluence with the Cheslatta River. Based on simulated flow velocities from the HEC-RAS model, wave celerities were estimated , indicating that, at a flow of 40 m^3/s, the travel time of a flow change through this 9 km long reach would be approximately 3 hours.

Flow changes from Skins Lake are modified as they travel through Cheslatta and Murray Lakes, because the lakes detain the flow change as they fill or drain in response to the change in lake inflow. This response to the effect of storage transforms sharp flow changes at Skins Lake into gradual rises and falls. To meet any specified flushing flow quantity at Cheslatta Falls, a certain volume of water must be released in advance to fill Cheslatta and Murray Lakes to the required levels that will achieve that specified outflow. There is also a delay, or lag, due to travel time in the river channels from the time the flows are released at Skins Lake until the beginning of the flow change at Cheslatta Falls.

These flow characteristics must be accounted for in the planning of any commissioning flow releases. This can be done reliably with currently available dynamic hydraulic modeling software, and adequate data exists to calibrate such a model.

The storage effect in Cheslatta and Murray Lakes places a limit on the maximum rates of rise and fall that can be achieved in the Nechako River by flows changes at Skins Lake. As it appears desirable to have rapidly varying clean water flushing flows to dissipate suspended sediment from the main river channel to the channel margins, the Skins Lake spillway should be operated to produce the fastest allowable flow change when generating the flushing flows. It was observed that in 1994, the discharge from Skins Lake was rapidly increased and decreased between 14 m^3/s and 453 m^3/s several times. The effect of these flow changes downstream are shown in Figure 5.1.2-1, which shows that 5 different peaks of 453 m^3/s at Skins Lake were diminished to values ranging from 206 m^3/s to 289 m^3/s by the time they reached the gauge below Cheslatta Falls. A similar range of flow variation at Skins Lake should be applied for the clean water flushing flows.

A review of the WSC discharge records revealed that the time required fro a flow change at Cheslatta Falls to be transmitted to Isle Pierre at above average dischaiges typically varies from 1.5 to 2.5 days, As the speed of a flow change exceeds the velocity of the flowing water by a factor of 1.5 the time for water to travel from Cheslatta Falls to Prince George was estimated to be approximately 4 days at an above average flow. Thus the duration for a sustained high discharge that would keep suspended sediment in suspension and would transport it out of the Nechako River channel was estimated to be 5 days.

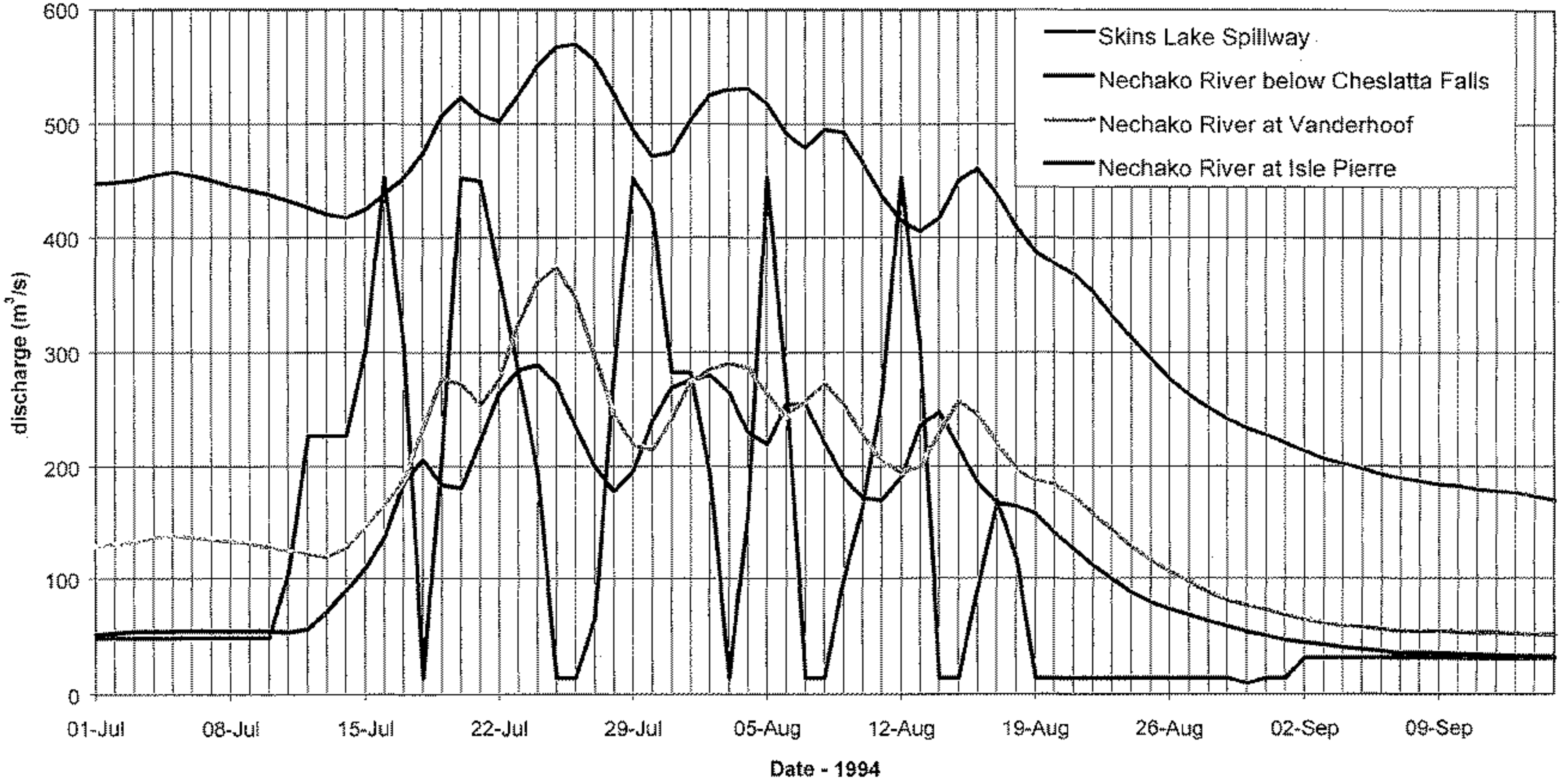

Figure 5.1.2-1 Nechako River Flows - 1994

5.1.3 Uncertainties and Risks

The establishment of a self-forming channel using controlled releases from a reservoir inherently involves some risks to the downstream environment. However, these risks can be greatly reduced with a cautious adaptive management approach, such as the one described above, is applied.

This approach is not without risks, because the rate at which sediment (particularly fine sediment) that would be entrained into the flow, and the distribution of its deposition cannot be predicted exactly. However, there is research and several precedents that suggest this could be achieved without harming and possibly even enhancing the aquatic habitat downstream for all species of fish that use the Nechako River. Nonetheless, some risk of unexpected consequences remains. This risk is unavoidable in the case of the Nechako Canyon. On the Cheslatta Fan, the risk is potentially avoidable by constructing massive, expensive, and environmentally destructive works (e.g., concrete-lined channel). In our view the risk is well worth taking, even on the Cheslatta Fan.

One precedent that provides a basis for comparison is the very large discharge associated with the formation of the Cheslatta Fan in 1961 and 1972. Despite the estimated 450,000 m^3 of material, which contained a large proportion of sand, silt and clays that was released in an uncontrolled manner into the lower Nechako River, there exists a very healthy salmonid fishery resource in the Nechako River. An examination of the Nechako River chinook salmon escapement data (FISS 2002) suggests that there was no impact on chinook spawning success following the events of 1961 and 1972 as there was no decline in escapement four years after these events (chinook generally have a four life-cycle). This demonstrates that the river can recover from this large uncontrolled influx of sediment. In comparison, the volume of material that the commissioning flows would remove from the canyon and fan is likely to fall in the range from 120,000 m^3 to 180,000 m^3. These volumes would be released in a controlled manner, and flushed with large volumes of clean water during and immediately after each set of releases through the canyon and fan.

Another precedent is the controlled 1996 flood in the Grand Canyon of the Colorado River, which was released from Glen Canyon dam for the purpose of restoring fish habitat and beaches that had not been replenished with sand. A large interdisciplinary team of scientists intensively studied the morphology, hydraulics, sediment transport, biology and ecology of the affected reach before, during and after the event. A collection of research papers that resulted from these studies is published in a single volume by the American Geophysical Union (Webb et al. 1999). In general the findings showed that large floods were necessary to maintain the natural processes and native species in the canyon. Most relevant to the Nechako case was the finding that the large flood flows moved sand from the central part of channel bed toward the channel margins and into localized sand deposits near eddy pools. This suggests that there is a way through flow manipulation to remove sand and fine material from gravel bars where spawning occurs.

More recent research done by Wu (2000) on the effects of fine sediment deposition in spawning gravels on embryo survival found that large flows over gravel bars, even if not large enough to break up the armour layer, can cleanse fine material from spawning gravel.

These precedents and research indicate that, while the approach to create a self-eroding channel using controlled flows does have some risks of unexpected consequences, these risks are not great, and any negative consequences are likely to be short term, manageable and reversible.

5.2 Magnitude and Durations of Commissioning Flows

As outlined earlier, the release scenarios presented in this section are preliminary, speculative and not expected to remain unmodified during the adaptive management process. The total volume of water represented by this release plan only represents our best preliminary estimate of the amount required, and may be found to be insufficient or excessive by a considerable margin to fully commission the channel.

5.2.1 Initial Release Scenario

The initial set of commissioning flows would have to be planned without the benefit of monitoring data from a previous release. A preliminary release plan is shown in Figure 5.2.1-1. This plan was developed using an approximate routing model to estimate flows at Cheslatta Falls for various releases from Skins Lake.

As shown in Figure 5.2.1-1, the initial flow from Skins Lake prior to the commissioning flows is assumed to be a constant 49 m^3/s, which is the typical flow released during June and July under current operating practices (Bouillon pers. comm.). The Skins Lake release is increased to 453 m^3/s, held at that flow for four days, then decreased to 200 m^3/s. The purpose of this pre-release would be to elevate the clean water discharge from Cheslatta Lake to approximately 250 m^3/s, which would mix with and dilute the initial release of 10 m^3/s that would travel through the canyon and fan.

The initial flows through the canyon and fan are expected to be heavily laden with suspended sediment, much more so than the larger flows planned for latter phases of commissioning. These initial flows would not have the energy necessary to mobilize much of the sand. Sand picked up in the canyon would deposit in Scour Hole Lake under such low flows.

The 10 m^3/s discharge through the CWRF would be increased to 20 m^3/s, then 30 m^3/s, and finally 60 m^3/s. The flow would be maintained at each of these steps for 48 hours. These discharges would be contingent on not exceeding the 10 g/L suspended sediment criterion. The discharge should be stepped down after the 60 m^3/s flow. At each step the flow should be given enough time to travel through the canyon and fan, before the suspended sediment concentration is tested. The purpose of this would be to determine the discharge that can be released from the CWRF without entraining any amount if fines. It would be this discharge that would set the upper limit of cooling water flows that could be released in an operational mode at anytime after the flushing has ended.

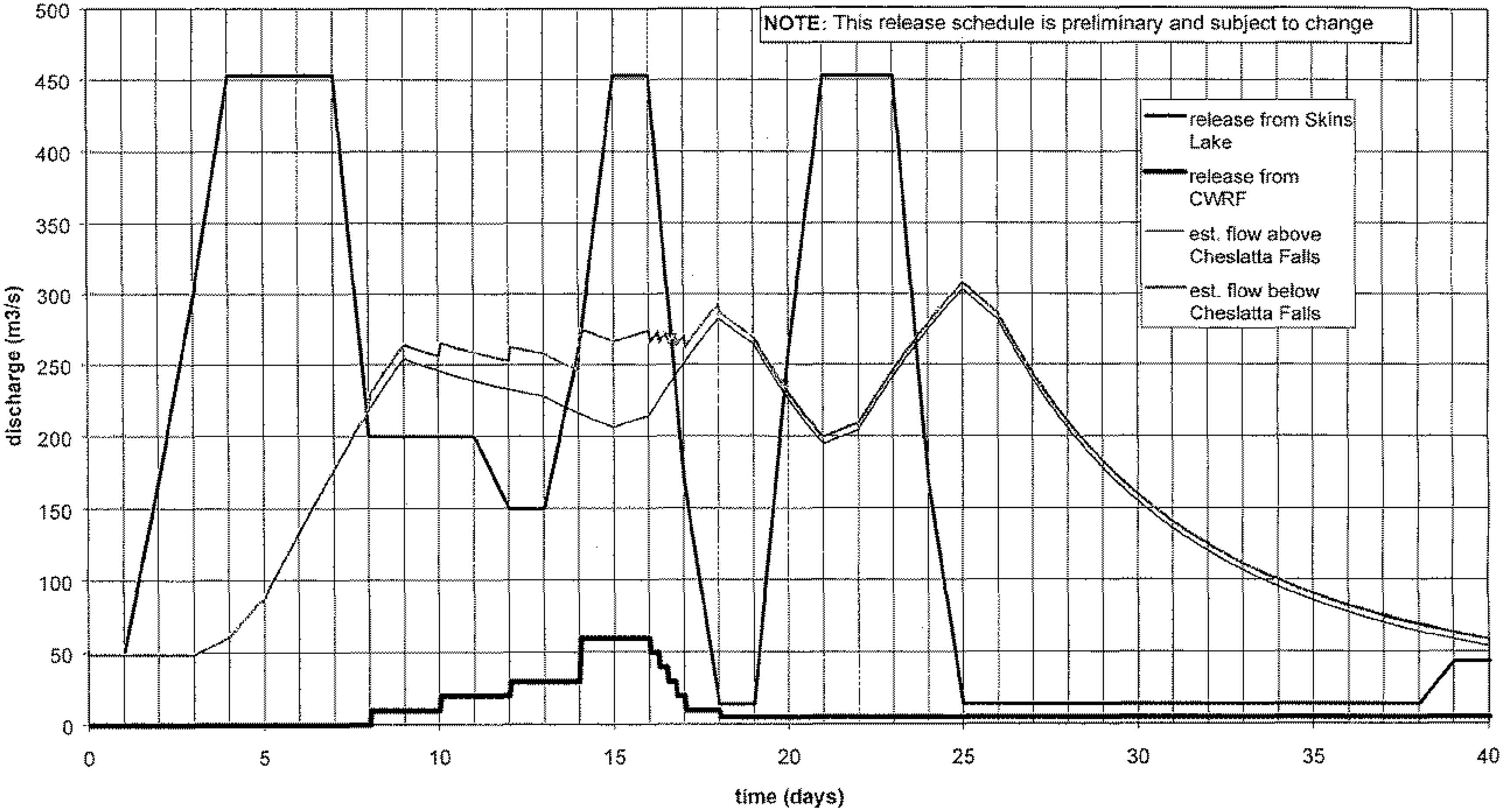

Figure 5.2.1-1 Assumed magnitude and duration of initial pulse (test pulse)

Concurrent with the reduction of the CWRF release to a low maintenance flow (assumed to be 5 m^3/s in the scenario), the flushing flow from Skins Lake spillway should be rising at Cheslatta Falls to maintain a high flow downstream to carry suspended sediment through the system with minimal deposition. The flushing flow should then fall and rise to a higher peak than the earlier discharges during channel reactivation in the canyon and fan. The purpose of these fluctuations would be to winnow sands and fines from gravel areas in the Nechako River downstream of Cheslatta Falls. The entire duration of this event from the initial opening of the spillway gates at Skins Lake to the time when the last flushing flow peak recedes to a normal magnitude is estimated to be 37 days.

The possible interaction with cooling flow requirements was not investigated in this study, as this set of discharges is recommended to take place before the cooling flows may be needed. Also, the extent to which the CWRF could be used for cooling flow purposes in the first year cannot be predicted until the sediment concentration results from the latter stages of the initial pulse through the canyon become available.

We estimate that the suspended sediment concentration upstream of the Cheslatta confluence averaged over the entire initial pulse to be approximately 0.4 g/L. With the approximate overall 8:1 dilution ratio at the Cheslatta confluence proposed in this scenario, this average concentration would be reduced to 0.05 g/L downstream of the Cheslatta confluence. The short-term peak suspended sediment concentrations could be much higher than the averages. Their magnitude is not predictable; however, managing the releases and limiting the maximum concentration at 10 g/L before dilution (1.25 g/L after dilution), will provide some measure of security that excessive sediment concentrations will not occur downstream.

As the commissioning of the regime channel and flushing material from the canyon is a unique situation, we propose that the duration and exposure model developed by Newcombe and Jensen (1996) and Newcombe (2002) be used for assessing the impacts on downstream fish populations rather than using the normal regulatory limits. These models examine the exposure concentration and duration and apply these to a Severity-of-Ill-Effects scoring. The turbidity and suspended sediment data collected as part of the monitoring (as discussed above) can be applied to the Newcombe and Jensen (1996) model to determine the potential effects. The use of the models could provide feedback into the adaptive management process to adjust flow and dilution rates to keep the level of exposure to within the sub-lethal effects range as defined by Newcombe and Jensen (1996).

The downstream impacts and proposed mitigation are the same as for the Nechako Canyon (refer to Section 3.6). A review of the Newcombe and Jensen (1996) model indicates that for the periods of highest sediment concentration, the effects can maintained in the 8-10 range (Table 5.2.2-1)

Table 5.2.2-1 Duration and exposure effects of predicted sediment concentration

Duration	Concentration (g/L)	Severity of Effect
37 days	0.4	9 to <10
37 Days	0.05	8
12 hours	10	9 to <10

5.2.2 Subsequent Releases Scenario

It has been assumed in this study that subsequent releases would occur in later years, although the option of achieving two sets of releases in a single year should be kept open and the monitoring data indicates that this could be done without exceeding downstream suspended sediment criteria. This could be an interesting option in a surplus water year. Conversely, if the inflows into the reservoir are unusually low, the commissioning flows could be released deferred.

It should be recognized that if the data collected at the end of the first commissioning episode establishes that significant cooling water can be released through the canyon without entraining sediment, this cooling water would be freeing up some of the water in the reservoir that is currently assigned to the large cooling flow releases through Skins Lake. These freed up flows could be reassigned to the next commissioning episode.

It is unknown how many sets of releases will be required to commission the channel. Here we have assumed that a total of four sets, counting the initial set described above, would be required. After the monitoring data from the first one or two sets become available, more reliable projections will become possible.

Assumptions of the magnitudes and durations of releases were made in order to estimate order of magnitude volumes of water required, and the shape of these flow release hydrographs are presented in Figures 5.2.2-1 to 5.2.2-3. It must be stressed that these volumes are highly speculative and preliminary. It is certain that they will be modified when the results of the monitoring data are applied to the criteria as part of the adaptive management approach. It is also anticipated that some of the criteria may be reconsidered as experience and knowledge are gained.

A summary table of the volumes of water associated with all four of the assumed commissioning flow release scenarios is presented in Table 5.2.2-2 below.

Table 5.2.2-2 Volumes and durations for a commissioning scenario of four flow pulses

	Total Duration of Event including Recession (days)	**CWRF (Canyon and Fan) Flow Volume (m^3/s-days)**	**Skins Lake Spillway Flushing Flow Volume (m^3/s-days)**	**Net Flow Volume over Normal Discharges[1] (m^3/s-days)**	**Net Volume as % of Mean Annual Inflow to Nechako Reservoir[2] (%)**	**Net Volume as Approximate Difference in Reservoir Level[3] (m)**
Initial Pulse	37	385	6730	5310	7.4	0.55
Second Pulse	43	1380	8560	7700	10.8	0.79
Third Pulse	46	2560	8000	8240	11.5	0.85
Fourth Pulse	39	1980	6370	6240	8.7	0.64
Totals	**165**	**6305**	**29,660**	**27,490**	**38.4**	**2.83**

[1] Normal discharge was assumed to be 49 ,3/s

[2] Long-term mean annual inflow = 195.6 m^3/s

[3] Centred about a reservoir level of 851.7 m