30 Gostick Place | North Vancouver, BC V7M 3G3 | 604.980.6011 | www.nhcweb.com

northwest hydraulic consultants

MEMORANDUM

TO:	Nechako White Sturgeon Recovery Team	**DATE:**	3 June 2013
FROM:	Andre Zimmermann (NHC)	**NO. PAGES:**	11
CC:		**PROJECT NO.:**	300115
		REF. NO.:	
RE:	**Nechako White Sturgeon Recovery Initiate Geomorphology Research Questions**		

1 Introduction

Nechako white sturgeon are experiencing recruitment failure and the species was classified as a red listed species in 1998 (Nechako White Sturgeon Recovery Initiative, 2004b). The recruitment failure occurred in or about 1967 and has been attributed to the failure of eggs and larvae to survive as a result of changes in the substrate at the location where they are known to spawn (McAdam et al., 2005; McAdam, 2012)[1]. While aging inaccuracy creates minor uncertainty about the timing of decline, such effects should be minor (e.g. maximum of 2 years; McAdam pers. comm.).

Based on field and laboratory investigations, the type of the substrate at the spawning locations has been shown to have a critical influence on the survival of eggs and larvae. Adhesive eggs typically hatch after 6-12 days (McAdam, 2012) and egg attachment sites (substrate surface vs. interstitial) influences survival through this stage (Johnson et al., 2006). After hatching yolksac larvae hide in the substrate for an additional 12-14 days, and failure to access suitable hiding habitat leads to increased drift and decreased survival during this stage (McAdam, 2012). Subsequently, at roughly twenty to twenty-five days after fertilization and the consumption of endogenous yolk larvae transition to the feeding larval stage, which is associated with the initiation of exogenous feeding, emergence from the substrate and nocturnal drift. . On account of the temporal similarity of recruitment failure and changes in river bed elevation, and the influence of substrate on egg and larval survival (e.g. increased predation), the failure of the Nechako white sturgeon has been attributed to the substrate conditions. Thus there is a key linkage between the geomorphology of the Nechako River and the recruitment failure.

[1] It is also possible that the sturgeon began to spawn in a different location; however, because the recruitment failure occurred fairly suddenly (Figure 1) and the hydrology changes between 1953 and 1967 (prior to failure) are similar to those that occur after 1967 it is unlikely that an abrupt change in the location used to spawn occurred as a result of changes in hydrology.

To better understand the geomorphology of the Nechako River, and how changes to the river may be affecting the recruitment failure, a one day charrette[2] was held on February 28th, 2013. Geomorphologist with experience on the Nechako River and/or other large regulated rivers participated, along with biologist with white sturgeon knowledge. Members of the Nechako White Sturgeon Recovery Initiative (NWSTRI) also attended.

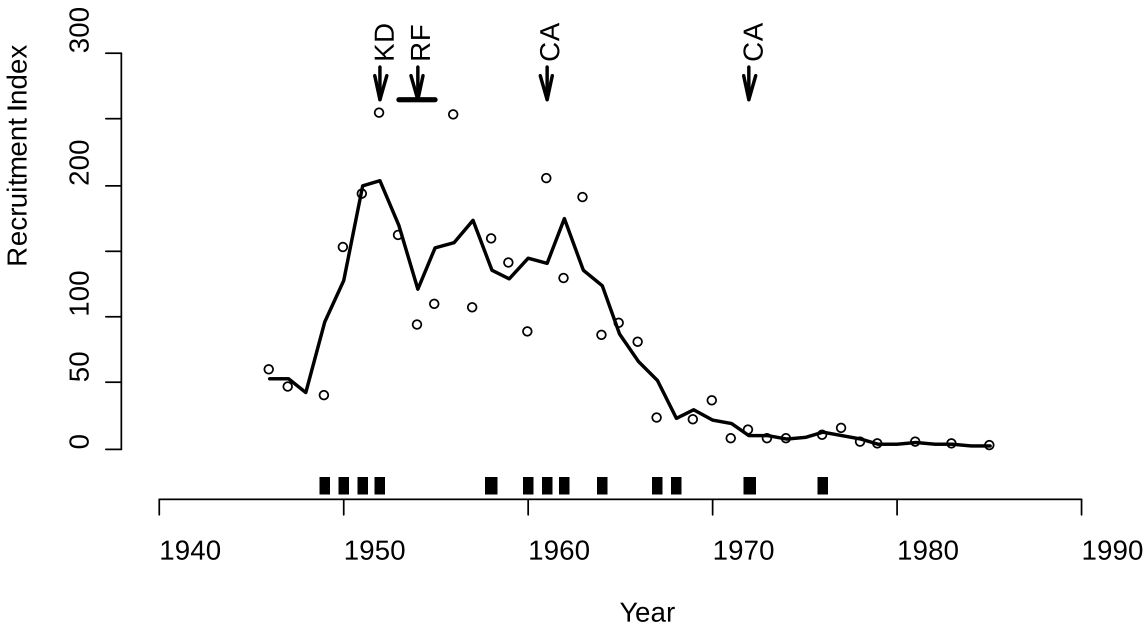

Figure 1 Historical pattern of projected recruitment in the Nechako River. From McAdam *et al.* (2005). Blocks on X axis indicate when flows at Vanderhoof exceeded 500 m^3/s. KD = completion of Kenney Dam, RF= reserviour fill period, CA= years during which upstream sediment inputs due to the Cheslatta avulsion occurred.

The objective of the workshop was to develop a foundation for a research program in the area of physical habitat/fluvial geomorphology, which could be implemented over the next 5 years, to assist sturgeon spawning habitat restoration, primarily focusing on the Vanderhoof Reach of the Nechako River. A complete set of minutes from the meeting has been prepared (Ciarniello, 2013) and the minutes provide a comprehensive description of the range of topics and ideas presented during the workshop.

---

[2] The word *charrette* may refer to any collaborative session in which a group of designers drafts a solution to a problem (Wikipedia, 2013)

The purpose of this memorandum is to summarize the key geomorphology research questions identified in the workshop that relate to the recruitment failure. While a number of aspects of the geomorphology of the Nechako River may be affecting the fitness of the white sturgeon population (e.g. side channel habitat and habitat availability for predators), the focus of this memorandum is the substrate in the Vanderhoof Reach and providing a means of getting eggs and larvae to survive until the larvae drift stage[3].

The memo provides a summary of the key research questions that need to be examined to inform the future development and implementation of habitat restoration that will improve egg and larval survival to the drift stage at the contemporary spawning locations. While the ideas and concepts presented in the memo are based on contributions from everyone who attended the charrette[4], the memo summarizes the research questions that NHC believes are most important and feasible to address based on our own professional experience and judgements.

2 Research Questions

A series of research questions are listed below and subsequently described in greater detail. These research questions are particular to the Vanderhoof Reach, and do not by any means address the range of research questions that were developed for the Nechako River as a whole (see Appendix 1). The questions are roughly sorted such that the easiest questions that will also help guide subsequent studies are first.

1. Extend the specific gauge analysis for the Vanderhoof WSC gauge
2. Review spawning telemetry data in a 2D hydrodynamic model
3. Examine timing of agricultural development and conduct a desktop study to assess potential sediment loading from agricultural lands
4. Consider flushing opportunities and if fines can be washed out of the main channel during high flows
5. Investigate the rates and timing of sediment transport in the Vanderhoof Reach and specifically assess the substrate condition during high flows
6. Conduct a sediment budget for the Vanderhoof Reach that includes quantifying the primary sediment sources and sinks upstream
7. Assess the longer term trajectory of the river (50-300 years) in terms of planform, substrate and stability

When considering each of these research questions it should be assumed that the watershed will continue to be regulated and managed in a similar manner and that restoring peak flows is not possible (because of residential and agricultural development on the historic floodplain among other things). An attempt has been made to provide rough budget and time estimates for each of the research questions to help the NWSRI make informed planning decisions. Actual budget and time estimates may vary considerably depending on the approach used for each research question and level of effort.

[3] To date, only 1-5 day old yolk-sac larvae have been found in the Nechako River.

[4] The consultants and academics who attended the Charrette attended on their own time. NHC and the NWSRI are very appreciate of the time and energy everyone put into the project.

2.1 Extend Specific Gauge Analysis

In 2003 a specific gauge analysis was done using the WSC gauge at Vanderhoof and the results suggest a modest sediment pulse passed the site (Northwest Hydraulic Consultants Ltd., 2003). The pulse followed the recruitment collapse and indicates a change in channel section and bed elevations. On account of the relatively large magnitude of the last two freshets and the even larger 2007 freshet, the specific gauge analysis should be updated. In addition, a specific gauge analysis for two or three other nearby gauges with similar lengths of record should be completed to assess the general range of variability associated with specific gauge analysis, and whether the observed changes should be considered to be significant.

Summary:

Specific question:	Is the channel cross-section and/or bed elevation at the WSC gauge in Vanderhoof changing?
Justification:	Helps determine if system is in a relatively stable state or progressively changing.
Time:	2 to 5 days; desktop study
Cost:	$2-4k

2.2 Review spawning telemetry data in a hydrodynamic model

Over the last 5 years eggs have been collected at a number of different locations within the Vanderhoof Reach, and each location has reasonably distinct substrate. It is believed that water depths and flow velocities, in addition to chemical imprinting, may be responsible for the choice in spawning locations. To date a quantitative understanding of the locations where sturgeon spawn during different conditions has not been possible because of a lack of knowledge of where the fish are; however, a proposed telemetry system will resolve this data limitation. If such a system is deployed, the telemetry data should be used along with a 2 dimensional hydrodynamic model (e.g., River 2D) to better assess what hydrodynamic habitats the sturgeon are seeking[5].

Depending on the spatial extents occupied by the sturgeon and the accuracy required, additional field data may need to be collected (channel topography in particular).

Summary:

Specific question:	**What are the hydrodynamic conditions where the fish are during spawning?**
Justification:	**Helps determine what causes sturgeon to move around year to year and will be needed to determine how to get sturgeon to better quality spawning beds.**
Time:	**1 to 4 months; up to a week of field work**
Cost:	**$5-40k**

[5] Combining the telemetry data and a hydrodynamic model wasn't discussed during the Charette, but rather it was formulated in subsequent discussions.

2.3 Conduct a desktop study to assess potential sediment sources and examine timing of agricultural development

Around the world agriculture is the primary source of sediment to the aquatic environment (Ongley, 1996) and given the scale of the agricultural development across the Nechako Plains it is likely that agriculture is an important source of sediment to the Nechako River. It has also been suggested that the timing of the recruitment failure could coincide with a rapid expansion in agriculture, particularly along the Nechako River. Initially a desktop study could be done to assess the extent of agricultural lands in the watershed, timing of development and potential for sediment generation from the agricultural lands.

This study would likely be expanded upon with case studies and field investigations as part of the sediment budget study proposed below. A particularly important aspect of the study will involve assessing the supply of bedload sized sediment from agricultural lands to the Nechako River. Fine sediments (clay, silts and fine sands) are certainly supplied to the river from agriculture, but these will be largely moved as suspended sediment and do not appear to be the cause of the recruitment failure.

Summary:

Specific question:	**What role might agricultural development play in the recruitment failure and supply of bedload to the Nechako River?**
Justification:	**Help determine a potential cause for the recruitment failure and direct mitigation options**
Time:	**2 to 6 months**
Cost:	**$10-40k**

2.4 Examine sediment transport pathway through the Nechako River and consider flushing opportunities along the main channel during high flows

Prior to regulation and development on the floodplains water would spill out of the main channel during the freshet and inundate the floodplain. Along with the water, some sediment from the channel would be carried out of the river and also be deposited on the floodplain. As a result of regulation, the historic floodplain is less frequently inundated, and when inundation does occur (e.g., 2007), river velocities are generally slower and floodplain velocities are faster. During these conditions, less sediment is moved from the river to the floodplain and there is the potential that the pathway that coarse sand is moving through the system has changed. A study could be conducted to assess what size of sediments could be flushed out of the main channel onto the floodplains based on the historic and modern flood regime.

The study would likely require a combination of 2D numerical modelling and field observations for calibration. The study reach should include the Vanderhoof Reach, but also extend a few to 10 km upstream to enable overall trends in floodplain storage to be characterized. Suspended sediment samples during high flow events that can be used to assess the concentration and grain size of the sediment in suspension should be collected at a representative site that can be reasonably modelled. Extending the model upstream will require additional survey data and hydrodynamic calibration data. The study should be coupled with overbank sedimentation studies that are suggested as part of the sediment budget study.

An additional component of the same study is an investigation of the shear velocities through the reach and the potential for medium and coarse sands to be mobilized from an otherwise stable cobble bed. This should begin with a review of the gravel flushing literature with a focus on conditions where the framework substrate remains relatively unchanged. From there a study design should be developed to assess if the interstitial sands found in the gravel and cobbles can theoretically be mobilized given the current flow regime. The rate and timing of sediment transport question (Q5) outlined below is intended to collect field data to help evaluate if fines can be flushed from the gravel/cobble substrate. The current study should attempt to address the same question using an analytical/modelling perspective.

Summary:

Specific question:	**What size of sediment can be mobilized and suspended in the reach and how does this vary spatially?**
Justification:	**Helps determine if the current flows have enough energy to flush sand and fine gravel out of the main channel and out of the spawning beds.**
Time:	**3 to 6 months**
Cost:	**$25-80k excluding major field work**

2.5 Investigate the rates and timing of sediment transport in the Vanderhoof Reach and specifically assess the substrate condition during high flows

An understanding of the rates and timing of sediment transport through the Vanderhoof Reach is critical to understanding how to improve the quality of the substrate in the reach and the design of sturgeon spawning beds. If the rates of supply are high and the beds cannot naturally flush, sturgeon spawning beds will need to be designed such that they can be cleaned/maintained, or with the acknowledgement that spawning beds will infill with fines sooner. If the sediment transport rates are low (unlikely) a different design strategy may be more appropriate. Furthermore, knowing the status of the beds and transport conditions during high flows is critical to understanding why the existing substrate at the upper site is not producing 15 day old larvae.

In general the focus of this sediment transport study should be on bedload that includes medium to coarse sand and fine to medium gravels (0.25-10 mm sediments; 0.5-2 mm primarily). Little to no movement of large gravels/cobbles occurs in the reach and suspended sediments are believed to be a relatively low concern. Nevertheless, the relative ease with which turbidity can be continuously monitored compared to bedload, suggests turbidity should be monitored in case an index relation between turbidity and bedload can be developed[6].

In general fine bedload is thought to move over stable cobbles/gravels and infill the pores, or move as sheets in areas exclusively composed of fine bedload (e.g. inside corner of beds/island complex). During high flows some of this material may be flushed out of the bed as near critical shear stresses are approached; however, the extent to which this happens, and the flows required for it to happen, are not known and should be investigated. In particular, does the coarse substrate become cleaner during high flow events due to winnowing?

[6] It should not be presumed that this approach will work on account of the sand size bedload that was mobile during clear water conditions.

During the development of this study, care will need to be taken to address the non-uniform distribution of transport rates across the width of the channel and the preferential transport of fine bedload on the inside corner of bends. The outside corner of the bends, at the placed substrate locations, have less fine bedload and it has not been resolved if this is because fine bedload is not supplied to these areas (only moves along inside corner of bends) or because the velocities are sufficient to clean the fine bedload out from between the larger cobble and gravel clasts.

It is anticipated the study will require direct field measurements of bedload transport in the Vanderhoof reach. Unfortunately, the grain size of interest may be the most difficult ones to directly measure as they will not move as suspended load (and thus will not be picked up by a turbidity sensor) and are too small to be sampled using many of the available techniques. During the September 2012 substrate investigations, strips of medium to coarse sand could be seen moving over stable gravel, and it was clear that there was considerable across channel variability. In addition, dunes could be seen moving at the Burrard Avenue Bridge site, but not at the upstream sites. This observation suggests different entrainment flows at different locations (this behaviour is related to the backwater that occurs, see NHC (2008)).

Efforts should likely be concentrated on the upper site where the naturally occurring substrate is most suitable for egg survival and the hydraulics are relatively simple and locations where spawning has recently been observed. Nevertheless, developing a sediment transport rating curve with some information about the size of grains that are mobile at different discharges will be a difficult task. Multiple approaches and a few field seasons may be required. There may exist some opportunities for part of this work to be done with a university collaborator.

Summary:

Specific question:	**What is the rate of bedload sediment transport in the Vanderhoof Reach and how does this vary with discharge and location?**
Justification:	**Required to assess if sediment supply is an issue and develop habitat restoration efforts**
Time:	**1 to 3 years**
Cost:	**$50-150k**

2.6 Conduct a sediment budget for the Vanderhoof Reach that includes quantifying the primary sediment sources and sinks upstream

A sediment budget is an accounting exercise that attempts to account for the movement of sediment through the landscape. It typically involves characterizing the amount of sediment stored in different areas and the flux of sediment between areas. In the case of the NWSRI, a sediment budget would help identify where the fine bedload at the spawning sites is coming from and the rates at which this sediment is moving through the reach. The results from the sediment budget would help determine if the sediment sources are persistent or singular events in time, and if they are local or distributed across the landscape. This information is critical to understanding if preventing the production of fine bedload is feasible, and required to assess the long term trajectory of the reach and watershed.

The sediment budget would incorporate the results from Q5 (rates and timing of sediment transport) and involve a fairly detailed mapping and targeted field campaign to identify key sediment sources and characterize their grain size and rates of delivery. For the NWSRI the sediment budget work will need to be grain size specific (track individual grain size fractions) or at least be targeted towards the fine bedload fractions. Depending on the approach taken, a sediment routing model may also be incorporated into the sediment budget. A sediment routing model would track the movement of sediment through the watershed using hydrodynamic and sediment transport models. See Tunnicliffe (2008) for an example of a fairly comprehensive sediment budget.

Given the current knowledge of the watershed and uncertainty associated with potential sediment sources a reconnaissance level assessment, that should include Q3 (desktop sediment supply study) would need to be done before a study design could be finalized. It is probable that opportunities exist for some of this work to be done with a university collaborator; however, developing a research question that is 'science' worthy that also provides the required information for NWSRI will require some effort.

Summary:

Specific question:	**Where does the fine bedload that is coming into the Vanderhoof Reach originate and what is the rate of supply from each major source?**
Justification:	**Needed to determine if sediment sources are persistent or temporary, and if the sources are local or distributed across the landscape. This information is critical to understanding if the current supply of bedload is likely to change with time, and if controlling the supply of sediment is possible and apt to produce results within the time frame that is required.**
Time:	**1 to 4 years**
Cost:	**$100-300k**

2.7 Assess the longer term trajectory of the river (50-300 years) in terms of planform, substrate and stability

The regulation of the Nechako River, development on the floodplain, and to a lesser extent, post-glacial history, has resulted in the Nechako River being out of equilibrium with contemporary sediment supply and hydrology. As a result it is probable that the current channel form and sediment transport processes are not representative of the form and processes that will be present 30 to 300 years into the future. In light of this knowledge, when it comes time to develop habitat restoration options for the Vanderhoof Reach of the Nechako River, knowing where the geomorphology of the river is trending will be a key question.

The research questions outlined above, particularly Q1, Q3, Q5 and Q6, provide data on the key drivers of change and should be used to assess the trajectory of the river. A regime approach (e.g. UBC Regime Model) and/or a one dimensional modelling approach may provide the best means of assessing the trajectory of the river.

Given the anticipated time scale of a channel response, relatively low rates of coarse sediment supply and under-fit nature of the river (it is flowing in a channel that use to have larger flows) the response times will be long and numerical modelling will be difficult to do accurately. General qualitative descriptions of the anticipated changes may be reasonably straightforward to produce; however, it is likely that quantitative predictions will require lots of data and will still have relatively large uncertainties.

At the time of commissioning such a study it will be particularly important to discuss the anticipated accuracy of the results. This study is particularly well suited to an academic research question as the prediction of long term evolution of channels in response to a change in the governing conditions continues to be an area of active research.

Summary:

Specific question:	**What is the anticipated channel morphology and bed texture in the Vanderhoof reach in 30 to 300 years?**
Justification:	**Having an understanding of how the channel is changing and where it is going is necessary to ensure that any habitat restoration options being considered align with the ongoing changes that are occurring within the watershed.**
Time:	**1 year or less; ideally completed after Q1, Q3, Q5 and Q6**
Cost:	**$10-40k**

3 Closure

If you have any questions, please do not hesitate to contact me at 604.980.6011.

Sincerely,

northwest hydraulic consultants ltd.

original signed by

Andre Zimmermann P.Geo.
Geomorphologist

Reviewed by Barry Chilibeck, P.Eng. (NHC)

4 References

Ciarniello, L. (2013), Geomorphology charrette: Meeting minutes,

Johnson, J. H., S. R. LaPan, R. M. Klindt, and A. Schiavone (2006), Lake sturgeon spawing on artificial habitat in the St. Lawrence River, Journal of Applied Ichthyology, 22, 465–470.

McAdam, S. O. (2012), Diagnosing causes of whte sturgeon (Acipenser transmontanus) recruitment failure and the importance of substrate condition ot yolksac larvae survival, University of British Columbia, Vancouver, B.C., September.

McAdam, S. O., C. J. Walters, and C. J. Nistor (2005), Linkages between white sturgeon recruitment and altered bed substrates in the Nechako River, Canada, Trans. Amer. Fish Soc., 134, 1448–1456.

Nechako White Sturgeon Recovery Initiative (2004), Recovery Plan for Nechako white sturgeon, Prepared by Golder Associates Ltd., pp. 87.

Northwest Hydraulic Consultants Ltd. (2003), Nechako River Geomorphology Assessment. Phase I: Historical Analysis of Lower Nechako River, Prepared for BC Ministry of Water, Land and Air Protection, Victoria BC, North Vancouver.

Northwest Hydraulic Consultants Ltd. (2008), Nechako River at Vanderhoof Hydrodynamic Model Upgrade Final Report, Prepared for BC Ministry of Environment, North Vancouver, pp. 39.

Ongley, E. D. (1996), Control of water pollution from agriculture - FAO irrigation and drainage paper 55, Food and Agriculture Organization of the United Nations, Burlington, Canada. [online] Available from: http://www.fao.org/documents/en/detail/21105 (Accessed 21 March 2013)

Tunnicliffe, J. F. (2008), Holocene sedimentary history of Chilliwack Valley, Norther Cascade Mountains, Ph, University of British Columbia, Vancouver BC.

Wikipedia (2013), Charrette - Wikipedia, the free encyclopedia, Charrette - Wikipedia, the free encyclopedia. [online] Available from: http://en.wikipedia.org/wiki/Charrette (Accessed 21 March 2013)

Appendix A

Geomorphology Charrette

Summary of Key Findings

NECHAKO RIVER WHITE STURGEON RECOVERY INITIATIVE

Geomorphology Charrette

Summary of Key Finding

DATE: February 28, 2013
VENUE: Alan & Margaret Eyre Boardroom, Vancouver, BC
TIME: 08:30 – 16:33

Prepared by: Lana Ciarniello

Workshop Objective: The objective of the workshop was to develop the foundation for a research program in the area of physical habitat/fluvial geomorphology to assist sturgeon habitat restoration in the Vanderhoof Reach of the Nechako River. The timeline identified was within the next 5 years.

Nechako white sturgeon are experiencing recruitment failure. Recruitment failure appears to be due changes in substrate quality at spawning locations and to decoupling of spawning from freshet conditions; incubation and early larval rearing habitat is now decoupled from the natural hydraulic and geo-morphological processes.

Key Points for Restoration*: Restoration for the Nechako must consider*: adult habitat choice (multiple locations, imprinting, hydraulics) and substrate quality (egg/yolk sac larvae, interstitial habitat).

- Restoration needs to consider both egg and larvae stages. Eggs are adhesive. Eggs located below the substrate surface (e.g. between substrate grains) likely have the highest survival. Yolk sac larvae survival depends on the availability of interstitial habitat to decrease predation and drift.
- We do not need the substrate conditions available all year, just for the spawning window, maybe as short as three to four weeks.
- The goal is good substrate every year but this could be every other year.

The key challenges to restoration are:

(1) Matching the location of restoration with the location and timing of spawning; and,

(2) Maintaining a suitable substrate quality through the spawning window.

Sediment and Deposition: The Cheslatta avulsions deposited a large load of sediment in the Nechako with some material flowing downstream through the Nechako. During historical floods material along the banks would have washed downstream but this is no longer possible with the reduced and regulated flow, current human settlement and land use patterns.

- Cheslatta sediment load: Despite past modelling efforts some people were still concerned about the Cheslatta sediment load and wondered how fast it is/has been moving and where it has been deposited. Others were confident in the modelling results that showed that most of the load would be deposited upstream and be too large to ever make it to the Vanderhoof Reach.
- There is evidence that much of this material may have deposited upstream of Vanderhoof. There was a difference of opinion as to whether or not the Cheslatta fan is relevant to the current sediment and recruitment failure (sediment load).

The hydrograph has changed. The group agreed that channels are becoming smaller and there appears to be a lot of sand. The source of sand has not been pinpointed (banks, agricultural, Cheslatta avulsion).

What emerged from the discussion is that we need to know a lot more about the sediment budget.

- Vanderhoof reach does not have typical hydrodynamic conditions.
- A long profile may be needed to gain more information on the river, particularly the gradient.
- A hydraulic model may be needed to confirm fine sediment loads.

There was debate over the type of profile required. It was noted that if we were interested in substrate movement, a hydraulic model could be used to confirm how much fine sediment is moving under different flow conditions. If our main interest is local sediment deposition and the timing of deposition, hydraulic modeling at different flows would be more beneficial than a long profile. However, there is information from the long profile that would also be useful for examining sediment loads. There was general agreement that:

- The river is becoming narrower and the secondary channels are diminishing.
- In 1928 the Vanderhoof reach was a depositional reach and it remains a depositional reach today. However, there was also discussion that this reach may be transitioning to a transport reach.

There was a general consensus that we need to know the amount of sediment and its timing and then we can determine if long profiles are required.

- Is it too much sediment, sediment of the wrong quality, and/or timing of when the fish want to spawn and sediment load?
- We need to understand the local amount and the timing and particularly how it relates to the high flow periods.

Scale: The question of which spatial and temporal scale to address was debated throughout the workshop. The variety of opinions was due partly to the critical state of Nechako white sturgeon; biologists stated that there is insufficient time to investigate some options due to impending extinction.

Three primary scales were identified: channel, reach, or spawning ground site-specific. A fourth scale may be the interstitial scale.

- Biologists wanted to focus on where the fish are known to spawn (Vanderhoof reach).
- *There was general consensus among geomorphologists that examining just the Vanderhoof reach was too narrow a scale. Processes should be examined to some point upstream, or maybe at the entire watershed scale from the Kenny dam to Prince George.*
- As the time scale of interest increases, so does the spatial scale.

Alternate Spawning Location: The geomorphologists identified Reach 4 (Rood, 1993, km 66.7-100.4) as a reach that appeared to be in good condition and offer the necessary requirements for spawning. The biologists noted that adult fish have not been recorded to use Reach 4. The questions became: Do you bring the habitat to where the fish are or do you bring the fish to the habitat? Can we think about other locations we could set up to make them more successful?

- The number of multiple sites similar to the reach is very, very small. The number of sites where fish can pick the hydraulics that they want is very small.
- Two points emerged from the biologists. First, it is important to focus on habitats the fish are currently selecting, since we currently have no means to coerce them to alternate locations. Second, egg placements in alternate locations (e.g., Reach 4) may be a reasonable experiment. The immediate need was still spawning habitat restoration work within the Vanderhoof reach.

There was a general consensus that we need to know more about the nature of the substrate.

- Recent substrate evaluations conducted by NHC were done at low flows for ease of gathering the data. *There was general consensus that future substrate work should evaluate high flow periods.* The current pictures at low flows only show that the sediment has already settled. Looking at the substrate at different flow rates will aid in determining if there are in-season transitory conditions that may provide short term changes in substrate condition that are sufficient for recruitment to occur.

The group debated the evolution of the river channel and determined that *more information is required on channel evolution.*

- Knowledge of the evolution of the river channel will influence what we expect to do at the reach.
- Cores and fingerprinting may be used to gain knowledge on the evolution of the river channel and the effects of agricultural and other land-use activities.

The group placed their questions into whether they were related to geomorphology and hydrology or habitat.

Geomorphology and Hydrology Questions:

1. What is the evolution of channel morphology?
   - Is it is in transition?
   - How long will the transition persist?
   - What will the final stable state look like?
2. What is the transitory substrate condition associated with high flows?
3. What is the source of fine sediment and has it changed? This item includes evaluation of the sediment budget.
4. How unique is the Vanderhoof Reach? What factors are responsible for its uniqueness? Can these factors be preserved, enhanced, or recreated elsewhere?
5. What is the accurate long profile for the river?
6. Can we engineer the river geometry to create long term egg and larvae habitat when it is needed?

Habitat Questions:

1. What is an accurate description of egg/larvae habitat?
2. What is the description of other habitat types which may also be compromised by the altered river hydrology and morphology (e.g., off channel)?
3. What is the fish biota in the Vanderhoof reach, especially species that may be preying on sturgeon eggs/larvae, and are there implications to sturgeon survival?
4. What are survival rates by life stage (particularly during early life history)?

The group generally agreed that the following areas required further investigation to provide support to the Nechako white sturgeon recovery efforts:

- A sediment budget is required.
- We need to know where the sediment is coming from and its fate. Where the sediment is coming from may not be as important as its fate (e.g., how it moves through the system and where it ends up).
- Images of the sediments should be obtained at different flow stages.
- It should be determined whether there are any flows (working within the bounds of the regulated flow) at which sediment could be evacuated.
- We need to understand the local amount and the timing of sediment and particularly how it relates to the high flow periods.
- We need a good working model to run flow/sediment scenarios, for example how would large sand inputs behave when comparing the flow of historic and present regimes. There was not agreement the best modeling method to use (the River2D model was stated to not be good at modeling sand transport).
- While the camera and video work provides useful insight empirical data is required to inform the models. Channel geometry and gradients need to be known.

- It is uncertain whether the material from the Cheslatta fan led to recruitment failure. Agriculture was also stated to be a potential cause. However, there was general agreement that understanding sediment sources may affect the restoration option chosen.
- There was general agreement that Investigation of the long term channel evolution will provide information on how to manage habitats in this reach over the long term.

Detailed background notes are available for this workshop.

Rood, K. (1993), Nechako River secondary channel geomorphology studies: Phase II final report, Prepared by K. Rood & Associates for Nechako Fisheries Conservation Program, pp. 18 + maps.