Nechako River Geomorphic Assessment

Phase II: Detailed Analyses of Potential White Sturgeon Habitat Sites

Final Report, May 2003

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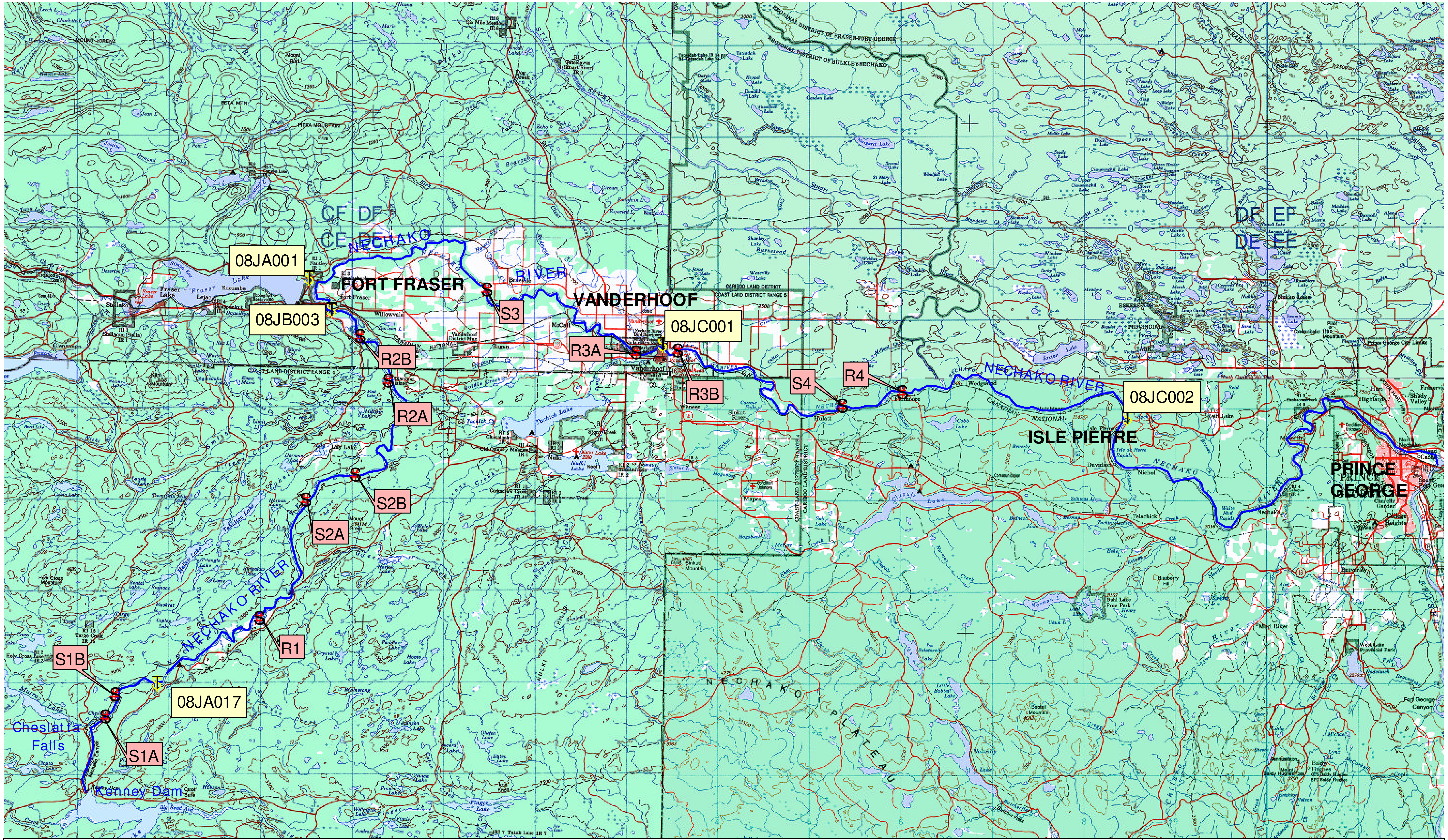
1. INTRODUCTION

The Kenney Dam and Nechako Reservoir have regulated flows in the Nechako River since 1952. Similar to sturgeon in many other impounded systems, white sturgeon in the Nechako River are under a serious conservation threat due to an ongoing recruitment failure. The evidence for recruitment failure comes from a variety of sources, but was best documented by Korman and Walters (2001), who used back-calculation of a recruitment index to demonstrate a catastrophic recruitment failure in the mid-1960's. The apparent lag between the dam construction in 1952 and the initiation of recruitment failure in the mid-1960's has led to some uncertainty, especially with respect to hypotheses explaining the recruitment failure. However, re-evaluation of results from Korman and Walters (2001), as well as consideration of other significant changes in the watershed (most notably, the 1961 Cheslatta River avulsion), leads to a combined hypothesis linking declines in white sturgeon recruitment to geomorphic change within the Nechako River.

The hypothesis being examined in this report proposes that alterations to Nechako River geomorphology are temporally (and therefore causally) related to recruitment failure. Phase I of this analysis (**nhc** 2003) assessed geomorphic changes in the lower Nechako River – from Vanderhoof to the Isle de Pierre Rapids – and provided evidence that a wave of Cheslatta-derived sand and granule bedload had passed the Vanderhoof area between 1964 and 1995. This sediment wave may have impacted sturgeon spawning and rearing habitat thoughout the Nechako River system. In Phase II, we selected four sets of potential sturgeon habitat sites along the Nechako River and constructed air photograph sequences to illustrate geomorphic changes over time. Each set of sites consists of a potential spawning site (fast-flowing chute or rapids) upstream of a potential rearing site (section of channel with numerous secondary channels and bounded by floodplain). The observed geomorphic changes are discussed in the context of previous geomorphic studies: Rood and Neill (1987) investigated changes along the upper Nechako River from Cheslatta Falls to Vanderhoof, and **nhc** (2003) investigated changes along the lower river from Vanderhoof to the Isle de Pierre Rapids (Figure 1). The observed geomorphic changes also need to be considered in the context of altered flow regimes and water levels, as well as changing land use patterns on the river floodplain.



Legend

Water Survey of Canada Stream Gauge

Study Site

10 0 10 20 Kilometers

Scale 1 : 400 000

N

Nechako River Geomorphic Assessment

Nechako River
Location Map

northwest hydraulic consultants

Figure 1

2. BACKGROUND

2.1 Modelling Sturgeon Recruitment Failure

Variation in Nechako River sturgeon recruitment dynamics can be demonstrated by using three different recruitment scenarios, which were modelled using mortality rates of 0.04, 0.07 and 0.1 (Figure 2; Korman and Walters 2001). Only the M=0.1 scenario shows any apparent trend during the period 1952-1964; however, it should be noted that this trend is not significant (p=0.14). For the other two cases, recruitment was variable prior to 1964, but without any particular trend. While the possible trend prior to 1964 for the M=0.1 case may be informative, the most striking feature of these plots is the catastrophic recruitment declines in the 1960's. In all cases there is a possible decline in 1964 and a definite decline in 1967.

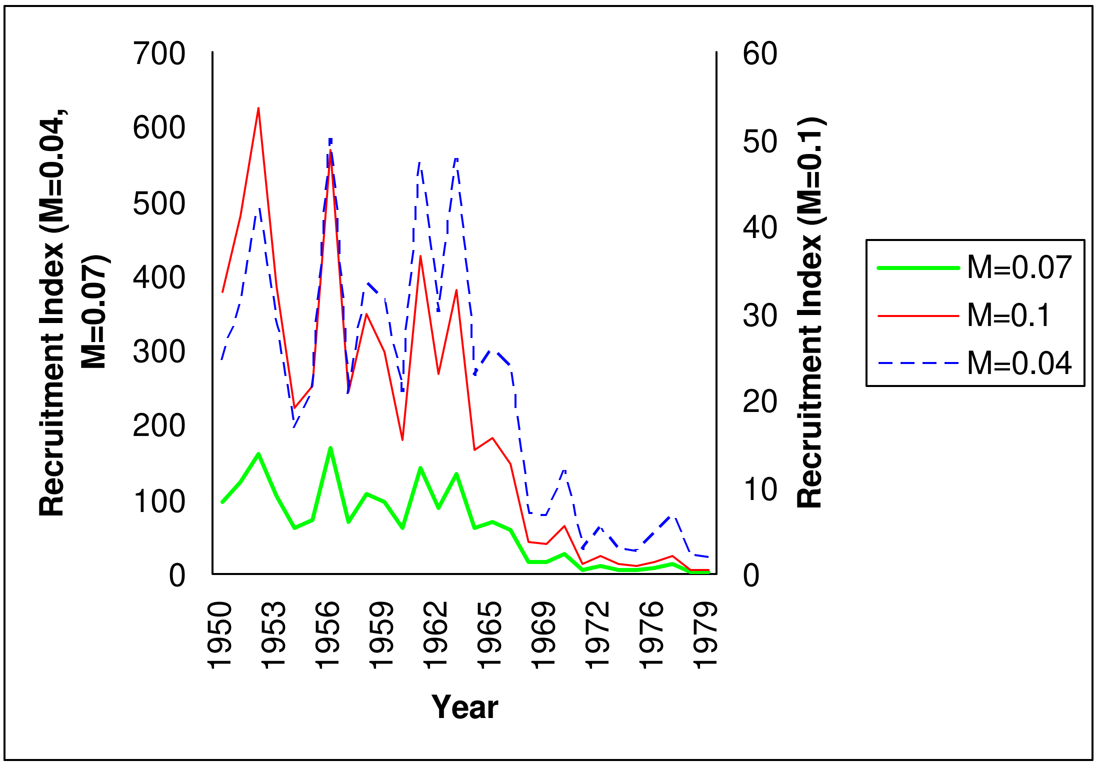


Figure 2. Variations in the Nechako River white sturgeon recruitment index, 1950-1980 (Note: values outside of the this time period are considered unreliable and are excluded from these plots).

One challenge in this analysis is that white sturgeon are currently distributed primarily in the lower Nechako River between Vanderhoof and Isle Pierre. Therefore, there are no clear indications of preferred habitats in the upper river, so the examination of these areas is based on their potential historic usage, rather than current use. If this analysis is successful, the identification of geomorphic changes at any point along the channel that are temporally coincident with the recruitment failure may provide an indication of the location and type of potential spawning and rearing habitats prior to disturbance. The possibility that geomorphic change may have influenced current white sturgeon distribution is implied by this sort of analysis; however, neither the plausibility of this suggestion nor the reasons for such a change (e.g. new shallow bars) can be readily examined by air photo interpretation.

2.2 Geomorphic Changes in Nechako River

A number of studies have examined the consequences of reduced annual flows, reduced annual peak flows, and increased sediment supply from the 1961 Cheslatta River avulsion, on the morphology of the Nechako River. A chronology of key hydrologic and geomorphic events to consider in our temporal analysis is presented below:

- Pre-regulation spring freshets: Mean annual flood (MAF) at Vanderhoof = 658 m^3/s.
- 1952: Kenney Dam constructed.
- 1952-1956: Nechako Reservoir filling.
- 1957-1979: Reduced spring freshet magnitudes, MAF = 426 m^3/s.
- 1961: Cheslatta River avulsion.
- 1964, 1967, 1972: modest flood events: 550 to 600 m^3/s.
- 1972: Second smaller Cheslatta River avulsion.
- 1976: Largest post-regulation flood: 745 m^3/s.
- 1980 to present: Maximum flows in summer, released to cool water temperature for salmon, MAF = 327 m^3/s.

Prior to regulation, sediment supply to the lake-headed Nechako River came from tributary streams and from the erosion of riverbanks and glaciofluvial and glaciolacustrine terrace scarps along the river. Reduction of flows following regulation has reduced the ability of the river to erode banks and scarps and has reduced its ability to transport material delivered by tributaries.

In contrast to these declining sediment sources, the 1961 Cheslatta River avulsion contributed between 0.4 and 0.5 million cubic metres of sand and gravel to the Nechako River downstream of the washout. The sand fraction of this material would certainly have moved during subsequent high flows. We expect that it would have deposited in naturally wider or deeper sections of the channel, possibly moving as a "wave" of diminishing deposition in successive flood events downstream from the source. Under pre-regulation hydraulic conditions, this material might eventually have been transported through the Nechako River without long-term effects, but the reduced transport capacity of the regulated river makes it more likely that long-lasting changes would be experienced.

Rood and Neill (1987) examined the upper Nechako River and concluded that regulation has resulted in a narrower channel through encroachment of riparian vegetation and abandonment of secondary channels; cobble and gravel fans have grown at the mouths of tributaries; sand and fine gravel deposits on the channel bed have been gradually spreading over gravel substrate; and that fine sand and silt have been deposited on bar surfaces, banks, and in substrate interstices.

In 2002, **nhc** extended the geomorphic analysis to the lower Nechako River and found evidence that the 1964 freshet had transported Cheslatta-derived sand bedload as far as the Hulatt / Finmore area, approximately 30 to 40 km downstream of Vanderhoof. This sand passed through the Vanderhoof without affecting channel morphology at the Water Survey of Canada (WSC) gauge, but probably blanketed the existing gravel substrate further downstream. The sand probably infilled some deep pools at the outside of meander bends as well. For the next three decades, a wave of slightly coarser sand and granule bedload derived from the Cheslatta avulsion passed the WSC gauge at Vanderhoof causing increasing water levels at specific discharges. The wave appeared to have passed by 1995 when the river bed began to degrade. In the lower Nechako River, the mainstem channel has narrowed slightly due to vegetation encroachment, but the loss of secondary channels has been minor. However, most of the seasonally wetted floodplain area (approximately 1200 ha), including numerous fingerlike floodplain channels, has been lost through a combination of lowered water levels and floodplain development.

3. GEOMORPHIC CHANGE AT THE STUDY SITES

The Nechako River White Sturgeon Recovery Team selected four sets of study sites for our Phase II analyses (Figure 1). Each set of sites consists of a potential spawning site(s) upstream of a potential rearing site(s). Using the available aerial photography (Tables 1 and 2), we constructed an historical air-photo sequence for each site (Appendix A). From these sequences, we described the geomorphic changes that have occurred over time. We did not attempt to quantify the changes because they tended to be subtle and progressive (e.g. vegetaton colonization of bars and secondary channel margins). Also, the large range in discharges between successive air photos made descriptive interpretation challenging enough, but would have made quantitative measurement of features virtually impossible.

3.1 Spawning Sites S1A and S1B

Spawning sites S1A and S1B are a series of narrow, bedrock-controlled chutes with rapid flow and rocky or bouldery substate. The sites are located about 1 to 5 km downstream from the Cheslatta River avulsion fan. The air photo sequences in Figures A-1 and A-2 contain air photos from 1953, 1974, and 1995. Between the chutes, bars show no obvious sign of change over time apart from increased vegetation cover, probably due to reduced sediment mobility and lowered water levels. There is no obvious sign of sediment deposition or other channel change within, or immediately downstream of, the fast-flowing chutes.

3.2 Rearing Site R1

Rearing site R1 consists of a meandering section of river with numerous secondary channels and cutoff oxbows, and bounded by floodplain. The air photo sequence in Figure A-3 contains air photos from 1947, 1961, 1974, and 1995. The 1961 photos were taken during a flood event. The variable water discharges between air photos makes it difficult to determine whether significant sediment deposition has occurred at this site. There has been a definite increase in vegetation on bars and in secondary channels. Minor encroachment by deciduous species ("bushy" looking on air photos) occurred on bar tops and channel margins prior to 1974, probably in response to lowered water levels. A more widespread colonization of bars and secondary channels by grasses and sedges occurred between 1974 and 1995, probably linked to post-1980 water levels that were further reduced in springtime, but were held at higher levels in summer to provide cooling for chinook salmon. Therefore, the vegetation patterns are not necessarily indicative of sediment deposition in the 1960's.

As early as 1947, there was some minor agricultural activity on the floodplain at Site R1, but this level had not increased by 1961. The cleared lands were not inundated by the high flows at the time that the 1961 air photos were taken. There was a large increase in floodplain land clearing between 1961 and 1974, including some areas that were inundated in the 1961 photos. There was no further floodplain land clearing after 1974.

3.3 Spawning Site S2A

Spawning site S2A is a narrow, bedrock-controlled chute with rapid flow and rocky or bouldery substate. The air photo sequence in Figure A-4 contains air photos from 1953, 1973, and 1995. Large bars above and below the chute show no obvious sign of change over time apart from increased vegetation cover, probably due to reduced sediment mobility and lowered water levels. There is no obvious sign of sediment deposition or other channel change within, or immediately downstream of, the fast-flowing chute.

3.4 Spawning Site S2B

Spawning site S2B is a bedrock canyon known as Larson's Canyon. Flow through the canyon is rapid with bedrock outcrops. A long, wide cobble bar runs downstream from the canyon outlet along the right side of the channel. The air photo sequence in Figure A-5 contains air photos from 1953, 1960, 1973, and 1985. There are no obvious differences in channel appearance at similar, moderate flows in 1960 and 1985, except that the water is noticably more turbid in 1960. There is no sign of sediment deposition in the canyon or on the cobble bar downstream of the canyon over time, although a small quantity of sediment may have deposited on the bar immediately upstream of the canyon between 1973 and 1985 (5 cm from the base of the 1985 photo).

3.5 Rearing Site R2A

Rearing Site R2A consists of a braided section of river containing a large, mid-channel island (Diamond Island) and numerous smaller islands, bars, and secondary channels. The air photo sequence in Figure A-6 contains air photos from 1953, 1960, 1973, and 1990. The 1960 and 1990 photos were taken at similar, moderate flows. Again, the 1960 flow was more turbid than the 1990 flow. The 1990 photos show a small but distinct increase in bar area, and a narrowing of secondary channels through vegetation encroachment. Vegetation encroachment on the bars and in the secondary channels commenced between 1960 and 1973, and progressed until 1990. Because of variable flows between photo dates, it is difficult to say whether sediment deposition prior to 1973 provided the conditions for vegetation encroachment, or whether encroachment was due to lowered water level alone.

There had been no agricultural land clearing on the floodplain prior to 1953. By 1960, some floodplain area along the right bank across from upper Diamond Island had been cleared, but the area does not appear to have contained any secondary channels. In 1973 and 1990, small amounts of additional clearing and low-density residential development occurred. Again, there do not appear to have been any channels affected.

3.6 Rearing Site R2B

Rearing Site R2B consists of a meandering section of river containing numerous islands, secondary channels, and cutoff oxbows, and bounded by floodplain. This site has better air-photo coverage than any of the other rearing sites. The air photo sequence in Figure A-7 contains air photos from 1946, 1960, 1966, 1973, and 1985. The 1960 and 1966 photos were taken at similar, moderate flows with turbid water, while the other three sets of photos were taken at lower flows.

Minor sediment deposition appeared to take place sometime between 1946 and 1973, but it is difficult to pinpoint the timing. We see no obvious sign of sediment deposition between 1960 and 1966 that could be related to the 1961 avulsion; however, channel changes could be obscured by the moderately high flows. Because of variable flows, it is difficult to determine whether deposition occurred between 1966 and 1973. More notable sediment deposition occurred between 1973 and 1985 toward the downstream end of the site, where bars were more exposed and the channel bed was more visible in the 1985 air photos than in the 1973 photos, despite the slightly higher flow in 1985.

Another obvious change at the site was the colonization of vegetation on bars and encroachment in secondary channels, particularly between 1966 and 1973, and continuing until 1985. The vegetation, possibly combined with sediment deposition, appears to have severely reduced wettedness over time in at least one long secondary channel (comparing 1946 to 1985).

There had been a small amount of agricultural land clearing on the floodplain prior to 1946, with little change by 1960. After 1960, each successive photo shows an increased area of floodplain cleared. The clearing prior to 1966 did not appear to affect any secondary channels or small floodplain channels, whereas the clearing after that time occurred in some areas inundated by flows as low as those in the 1966 photos.

3.7 Spawning Site S3

Spawning site S3 is a narrow, bedrock-controlled chute opening into a broad section of channel with an island and a bar. Flow through the chute is rapid with bedrock outcrops. The air photo sequence in Figure A-8 contains air photos from 1953, 1966, 1973, and 1985. Variable flows in the 1953, 1966, and 1973 photos make it difficult to discern any changes in that period. However, sediment accumulation is evident on the large mid-channel bar in the centre of the photos between 1973 and 1985.

3.8 Rearing Site R3A

Rearing site R3A is a braided section of channel immediately upstream of the Vanderhoof bridge. The site contains numerous bars, islands and secondary channels, and is bounded by floodplain. The air photo sequence in Figure A-9 contains air photos from 1946, 1953, 1966, 1973, and 1985. The 1953 and 1973 photos were taken at similar, low flows, while the 1966 photos were taken at moderate flows with turbid water.

The Water Survey of Canada (WSC) operates a streamflow gauge at the Vanderhoof bridge (*WSC Gauge 08JC001, Nechako River at Vanderhoof*) – the downstream end of Site R3A. WSC technicians regularly compile station analysis notes that document any channel changes that could affect the stage-discharge rating curve at a station. The Vanderhoof gauge notes indicate that large freshets in 1972 and 1976 caused significant movement of bar material upstream of the gauge (see **nhc** 2003). Given the changes noted at the WSC gauge, however, the air photo sequence shows surprisingly little evidence of sediment deposition or changes in channel pattern. While there is some evidence of sediment accumulation between 1953 and 1973 – for example, within the furthest downstream island – the lack of concordance between these two sources of information indicates that air photo analysis may not be the strongest tool for identifying changes in bed sediments, especially given the limitations on photo availability. With air photos we were able to identify a definite increase in vegetative cover over time, with deciduous species colonizing higher bar tops between 1966 and 1973, and grasses and sedges colonizing much broader areas between 1973 and 1985.

Urban, agricultural, and transportation development on the floodplain pre-dates the 1946 air photos and there was little increase after that time, except for a small residential development on the north (left) bank between 1953 and 1966. Much of the remaining floodplain and secondary channels lie on the south (right) side of the river and are protected from development by a migratory bird sanctuary.

3.9 Rearing Reach R3B

Rearing Reach R3B is a meandering section of river immediately downstream of the Vanderhoof bridge. The channel is single-thread, bounded by floodplain, and has no islands, secondary channels, or significant bars. The air photo sequence in Figure A-10 contains air photos from 1928, 1951, 1973, and 1985. The 1951 photos were taken during a typical pre-regulation spring freshet and clearly show the extent of typical floodplain inundation in this area. Although most of the floodplain is not wet, there are numerous small fingerlike floodplain channels connected to the main channel which extend far back onto the floodplain. The floodplain channels consist of parallel, arcuate swales called meander scrolls which are remnants of past channel migration, as well as back-watered channels of tributary streams.

There is litlte evidence of sediment deposition over time at this site. The WSC gauging station notes suggest that ongoing sediment deposition between the late 1960's and the early 1990's resulted in increasingly higher water levels at specific discharges. Again, this indicates the difficulty in using air photos to identify channel sedimentation. There has been a minor encroachment of vegetation along the channel margin, but not a significant amount because there was little bar area to colonize.

Urban, agricultural and transportation development on the floodplain pre-dates the 1928 air photos. Agricultural clearing expanded prior to 1951, including some areas flooded in 1951, but there was little if any blockage of the numerous floodplain channels. Between 1953 and 1973, urban development resulted in more intensive use of previously cleared areas, and many floodplain channels were blocked by roads, elevated building sites, and a sewage lagoon. Further development occurred between 1973 and 1985. None of these areas are diked, presumably because adequate flood protection is provided by flow regulation. However, even if a typical pre-regulation freshet were to occur now, the character of floodplain inundation would be markedly different than in the 1951 photos.

3.10 Spawning Site S4

Spawning site S4 is a shallow, bedrock-controlled rapids known as Hulatt Rapids, which runs out into a wide section of river with several bars. The air photo sequence in Figure A-11 contains air photos from 1953, 1966, 1973, and 1985. There is no obvious sign of sediment deposition in the rapids or in the channel immediately downstream. The rapids were sediment-free during our reconnaissance boat trip for Phase 1 in October 2002.

The large mid-channel bar about 2 km downstream of the rapids shows evidence of past sediment transport that has now diminished. In 1966, the bar showed evidence of active sand transport as one sheet with a well-defined, arcuate leading edge was in the process of overriding a lower layer. In later photos, the bar had adopted a rounded shape characteristic of an inactive remnant feature. During our 2002 reconnaissance, we noted that the bar surface was vegetated with grasses and sedges, typical of stable bars that are seasonally wetted by summer cooling flows. The observations regarding this bar provide one of the few observations of active sand transport in the mid-1960's, probably because most of the 1960's photography was taken during periods of higher flow.

3.11 Rearing Site R4

Rearing site R4 is a sinuous section of channel with one island and a small area of undeveloped floodplain. Cluculz Creek flows into the Nechako River at the upstream end of this site. The air photo sequence in Figure A-12 contains air photos from 1946, 1953, 1966, 1973, and 1985.

The main geomorphic change at this site is the growth of the Cluculz Creek fan and the formation of a gravel bar in the only secondary channel between 1953 and 1966. The sediment accumulation on the fan and in the secondary channel were probably caused by the lowered water levels in the Nechako River, which would have triggered channel degradation in the lower reach of Cluculz Creek, coupled with reduced transport capacity of Nechako River flows. The accumulated sediment is markedly coarser than the sands and silts found in the Nechako River upstream of Cluculz Creek, so the sediment must originate from the creek.

The floodplain is undeveloped apart from the railroad which pre-dates the 1946 photos. We have no photos taken at flood stage to illustrate the extent of floodplain habitat, but the area is small and is probably less important than the potential rearing sites upstream (R1, R2 and R3).

3.12 Summary

Our air photo analysis identified the following:

1) The dominant identifiable change at potential rearing sites is the encroachment of vegetation along channel margins, in secondary channels, and on bars. The vegetative colonization of secondary channels is important because it forms part of a feedback loop of

reduced flow velocity, deposition of fine sediment, and further vegetative growth, which eventually leads to effective abandonment of secondary channels. With the available air photo coverage, it is difficult to say whether vegetative colonization of secondary channels occurred in repsonse to lowered water levels alone, or whether it was encouraged by initial sediment deposition following the 1961 avulsion. In most cases, the vegetation first becomes noticeable in the early 1970's.

2) Floodplain clearing for agriculture and urban development pre-dates the earliest air photos in many places, but a rapid advance onto lower floodplain areas began in the 1960's, probably in a slightly delayed response to the flood control provided by river regulation and the increased population in the region. The newly developed areas often encroached across small fingerlike floodplain channels and ponds that were no longer wetted in a typical spring freshet. Thus, such development may not have constituted an immediate loss of floodplain habitat – the damage having been done already by reduced flood flows – but in the occasional large flood event such as 1976, the floodplain habitat available to rearing sturgeon would have been drastically different than pre-regulation due to the blockage of small floodplain channels and the loss of forest cover in and adjacent to flooded areas.

3) It is surprisingly difficult to detect any evidence of sediment deposition due to infrequent air photo coverage and variable flows. Even at sites where sediment deposition was reported by reputable sources (Water Survey of Canada records at Sites R3A and R3B), the evidence in the air photos is not strong, probably because the sand and silt tended to fill deep areas or blanket over exisitng bars and beds. However, where photo timing and flows allow reasonable comparisons, there are indications of sediment accumulation (for example, at Sites S3 and R3A between 1973 and 1985). The timing of these changes coincides reasonably well with changes noted at the WSC gauge at Vanderhoof.

4) It is unlikely that sediment has accumulated in the types of sites that we have identified as potential spawning sites because of the high velocities in the narrow chutes. However, if slightly slower velocity areas immediately downstream of these chutes are an important part of the spawning process, substrate composition in these areas may have changed, but we cannot detect this from the air photos.

4. DISCUSSION

The hypothesis that geomorphic changes in the Nechako River may have caused or contributed to the recruitment failure of Nechako River white sturgeon was based primarily on the coincident timing of the recruitment failure and high flows following the Cheslatta River avulsions. The known use of secondary channel habitat in the Lower Fraser River (Lane and Rosenau 1995), combined with significant losses of secondary channel habitat in the Upper Nechako River, likely during the 1960's (Rood and Neill 1987), made this a particularly appealing hypothesis. Further development of the hypothesis suggested that the lack of inundation of floodplain habitat subsequent to the regulation of Nechako River flows might also have contributed to recruitment failure.

The results of Phase I of the geomorphic analysis indicated that the nature of changes in the lower Nechako River were not nearly as obvious as those observed by Rood and Neill (1987) in the upper river. In particular, the abandonment of secondary channels was more common in the upper river. Records from the WSC gauge at Vanderhoof indicate that a bedload sediment wave passed through between the late 1960's and the early 1990's. We were able to identify a few depositional sites downstream of Vanderhoof – including the mid-channel bar downstream of Site S4 – that showed evidence of ongoing sand bedload deposition, starting prior to 1966. Several sites, including R2B and S3 showed evidence of sediment deposition in the 1970's and 1980's. We conclude that the hypothesis of a sediment wave resulting from the 1961 and 1972 Cheslatta avulsions is supported by our findings.

Analysis of changes in floodplain habitat provided somewhat equivocal results. Although there was a general increase in floodplain agriculture and urban development in the 1960's, conversion of some areas to agriculture was present prior to the 1960's. Floodplain land use tended to utilize areas that were no longer flooded on a regular basis due to river regulation, so land use does not provide a compelling explanation for the abrupt recruitment failure. Rather, land use would more likely be a factor that could limit improvements to recruitment in the event that the pre-regulation flood regime were restored.

While the loss of floodplain habitat may not coincide with recruitment failure, the loss of secondary-channel habitat appears to provide a better potential linkage with recruitment failure, since the major loss of secondary-channel habitat in the upper Nechako River occurred during the 1960's. However, even considering that secondary-channel habitat is of known importance to white sturgeon (Lane and Rosenau 1995), it is also important to note a number of other systems such as the lower Fraser River and the lower Kootenai/y Rivers (prior to construction of Libby Dam), where secondary- channel habitat has been diminished (not quantified) without ensuing recruitment failure. In addition, there are still a number of active secondary channels within the Nechako River (i.e. their number has been reduced but not eliminated). Therefore, while a decrease in the abundance of secondary channels may have an effect on the productive capacity of the river with respect to white sturgeon, it does not seem a likely candidate to explain an abrupt recruitment failure.

The results of this analysis therefore provide unclear results with respect to the original hypothesis. In such a case, comparison with the Kootenai/y and lower Fraser Rivers may be informative. In the Kootenai/y River, significant channel modifications and dyking occurred in the lower stretches prior to the completion of Libby Dam in 1974. The presence of sand in the spawning reach has been strongly implicated as a factor contributing to recruitment failure (Paragamian et al. 2001). Since the abstraction of the Kootenai River floodplain preceded impoundment by a number of years, this temporal separation provides an indication that recruitment is possible even when significant portions of the floodplain have been lost (note that the deltaic area at the south end of Kootenay Lake still remains), which is in line with the patterns suggested for the Nechako River.

The case of the Lower Fraser River also provides another interesting comparison. In this case there has been a significant historic loss of floodplain habitat due to dyking and draining of areas such as the Sumas Prairie. However, similar to the Kootenai River prior to the construction of Libby Dam, these changes have not been associated with recruitment failure. These changes suggest once again that recruitment can occur even with significant reductions in the extent of floodplain habitat, and that it may be channel features such as substrate composition that are more strongly linked to recruitment failure.

One important point that should be highlighted with respect to comparisons with the Fraser and Kootenai/y Rivers is that in both cases there still remains a functional estuarine or deltaic area at the river's terminus. This is not the case for the Nechako River, which may act to increase the importance of floodplain habitat, and therefore increase sensitivity to alterations of this habitat. Nonetheless, the analysis in this report coupled with comparison with other systems suggests that the loss of floodplain habitat does not appear to have been the principal cause of recruitment failure in the Nechako River.

The suggested effects of sand substrates in the Kootenai/y case, combined with the noted increase in the sand substrates within the Nechako River during or subsequent to the 1960's (Rood and Neill 1987, Norcan 2000, **nhc** 2003), suggests that a change in substrate composition may be a strong contributor to Nechako white sturgeon recruitment failure. Unfortunately, such changes are difficult to detect conclusively in an air-photo analysis. As a result, other means of analysis will be required to identify changes within the bed substrate and their potential temporal correlation with patterns in the white sturgeon recruitment index.

In conclusion, we recommend the following steps toward further understanding and restoring potential substrate changes that may have been associated with the white sturgeon recruitment failure in the Nechako River:

1) Examine other methods to identify temporal changes in bed substrates.

2) Determine flows that would be required to remove sands from those areas where they were identified to provide a rough idea of flows required to shift bed substrates in areas of potential importance to white sturgeon spawning and recruitment.

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Table 1. Nechako River air photo coverage

YEAR	UPPER NECHAKO									LOWER NECHAKO		
	S1A	S1B	R1	S2A	S2B	R2A	R2B	S3	R3A	R3B	S4	R4
1928							0	0	0	0		
1946							0	0	0	0	0	0
1947	0	0	0	0	0	0					0	0
1950	0	0	0	0	0	0	0	0	0	0	0	0
1951									0	0		
1953	0	0	0	0	0	0	0	0	0	0	0	0
1958								0	0	0	0	0
1960					0	0	0	0	0	0	0	
1961	0	0	0	0								
1966a							0			0	0	0
1966b							0	0	0	0	0	0
1971												
1973				0	0	0	0	0	0	0	0	0
1974	0	0	0									
1975	0	0	0	0	0	0	0	0	0			
1978a	0	0	0	0	0	0	0	0	0	0	0	0
1978b	0	0	0									
1980				0	0	0	0		0	0	0	0
1985					0	0	0	0	0	0	0	0
1986			0									
1988				0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0					0	0
1991					0	0	0	0	0	0		
1995	0	0	0	0							0	0
1996	0	0	0	0	0	0	0	0	0	0	0	0
1997				0	0	0				0	0	0
1999												0

Notes:
1. Dots indicate air-photo coverage.
2. Useful photos are shaded: good-quality photos with low to moderate discharge and clear water.

Table 2. Photos used in Nechako River air-photo sequences

Site	Location		1928	1946	1947	1951	1953	1960	1961	1966	1973	1974	1985	1990	1995
S1A	Upper	Km 9.7 - 11.1	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	BC1813: #87 (6.26)	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	BC7622: #9	- - - - - - - -	- - - - - - - -	BCB95071: #136
S1B	Upper	Km 12.5 - 14.3	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	BC1813: #87	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	BC7622: #93	- - - - - - - -	- - - - - - - -	BCB95071: #136
R1	Upper	Km 33.2 - 40.3	- - - - - - - -	- - - - - - - -	A11286: #48, 109	- - - - - - - -	- - - - - - - -	- - - - - - - -	BC4032: #106-107	- - - - - - - -	- - - - - - - -	BC7660: #92, 136	- - - - - - - -	- - - - - - - -	BCB95121: #114-115
S2A	Upper	Km 54.6 - 56.2	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	BC1578: #1	- - - - - - - -	- - - - - - - -	- - - - - - - -	BC7563: #164	- - - - - - - -	- - - - - - - -	- - - - - - - -	BCB95102: #44
S2B	Upper	Km 61.5 - 63.5	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	BC1578: #24	BC2930: #33	- - - - - - - -	- - - - - - - -	BC7563: #160	- - - - - - - -	BC85054: #93	- - - - - - - -	- - - - - - - -
R2A	Upper	Km 79.0 - 81.9	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	BC1578: #67	BC2931: #80	- - - - - - - -	- - - - - - - -	BC7559: #221	- - - - - - - -	- - - - - - - -	BCB90058: #109	- - - - - - - -
R2B	Upper	Km 84.6 - 91.2	A738: #16, 89; A739: #64	BC311: #45	- - - - - - - -	- - - - - - - -	- - - - - - - -	BC2915: #58-59	- - - - - - - -	BC5218: #141	BC7525; #139	- - - - - - - -	BC85040: #232; BC85041: #99	- - - - - - - -	- - - - - - - -
			- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -
S3	Upper	Km 127.9 - 129.2	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	BC1599: #17	- - - - - - - -	- - - - - - - -	BC5218: #116	BC7525: #51	- - - - - - - -	BC85040: #184	- - - - - - - -	- - - - - - - -
R3A	Upper	Km 155.6 - 158.2	- - - - - - - -	BC311: #56	- - - - - - - -	- - - - - - - -	BC1600: #15	- - - - - - - -	- - - - - - - -	BC5218: #65	BC7559: #109	- - - - - - - -	BC85041: #116	- - - - - - - -	- - - - - - - -
R3A/B	Upper / Lower	Km 153.5 (Upper) - 148.0 (Lower)	A737: #84, 85, 87, 89	- - - - - - - -	- - - - - - - -	BC1283: #29, 31, 38-40, 42-43	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	BC7559: #107, 109	- - - - - - - -	BC85041: #116, 118	- - - - - - - -	- - - - - - - -
			- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -
S4	Lower	Km 173.1 - 176.0	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	BC1652: #106	- - - - - - - -	- - - - - - - -	BC5212: #2	BC7560: #18	- - - - - - - -	BC85042: #57	- - - - - - - -	- - - - - - - -
R4	Lower	Km 180.1 - 183.1	- - - - - - - -	BC299: #110	- - - - - - - -	- - - - - - - -	BC1716: #51	- - - - - - - -	- - - - - - - -	BC5209: #257	BC7559: #260	- - - - - - - -	BC85041: #246	- - - - - - - -	- - - - - - - -

Notes:

1. Site locations refer to river kilometre markings on Nechako River air photo mosaics. The upper Nechako River mosiac was produced by the NFCP in the 1980's (specific reference unknown); Km 0.0 at Kenney Dam and Km 158.0 at Vanderhoof. The lower Nechako River mosaic was produced in Phase I of this study (**nhc** 2003); Km 142.0 at Vanderhoof and Km 217.2 at the Isle de Pierre Rapids.