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Schmidt Creek Sediment Sources and the Johnstone Strait Killer Whale Rubbing Beach

by

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Cover photo: Beach 5, one of three beaches near Schmidt Creek that were monitored in this study.

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SUMMARY

The Robson Bight Ecological Reserve was established in the early 1980's to protect killer whale habitat. Killer whales frequently use the area in the summer months, and in particular rub themselves on well rounded pebbles on a beach to the east of Robson Bight. Two reports identified Schmidt Creek as the probable source of sediment for the beach (Peel Creek is the local name for Schmidt Creek used by Western Forest Products). A monitoring program supported by both the Vancouver Forest Region and Western Forest Products investigated:

- Whether sediment sources within Schmidt Creek were affected by forestry;
- Whether changes to the rubbing beach were likely should sediment output from the watershed change.

Large natural landslides in Schmidt watershed that occurred between 1934 and 1977 suggest that in decades past there have been large introductions of sediment to the beach system. These episodic natural sediment inputs in the past have been larger than logging-related sediment inputs. However, short term sediment input to Schmidt Creek has been significantly affected by forestry, with an approximate doubling of the amount of sediment delivered to Schmidt Creek since 1987.

The rubbing beach is composed primarily of a poorly sorted sandy gravel similar to sandy gravels found on beaches closer to Schmidt Creek. This indicates that longshore transport of sediment from Schmidt Creek delivers similar material to each beach. Although the original material delivered to each beach is similar, the appearance of the rubbing beach is very different since it has the well sorted pebble wedge on top of the sandy gravel sediment. This wedge is the result of a wave sorting process that removes the sand from the surface of the sandy gravel sediment, resulting in a lag deposit of pebbles.

The rubbing beach is exposed to the dominant easterly wave energy, and it is likely that this higher energy wave environment produces the better sorting present on the rubbing beach.

The beach profile and sediment characteristics of the killer whale rubbing beach depend on many factors. The amount and type of sediment delivered to the beach are undoubtedly fundamental in determining beach characteristics. However, it appears that wave transport and the resultant sorting of sediment are the critical factors in determining the nature of sediment on the rubbing beach.

Forestry activities appear unlikely to affect the rubbing beach, but given the nearly unique use of the beach by killer whales, management of the area should be cautious.

KEY WORDS

Robson Bight Ecological Reserve, Tsitika, wildlife habitat, killer whales, sediment, Peel Creek, Schmidt Creek, beach processes, longshore transport.

ACKNOWLEDGEMENTS

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1 INTRODUCTION

The Robson Bight Ecological Reserve was established in the early 1980's to protect killer whale habitat. Killer whales (Orcinus orca) frequently use the area in the summer months, and in particular rub themselves on well rounded pebbles on a beach to the east of Robson Bight (A very limited amount of whale rubbing occurs on a neighbouring beach). Concerns related to booming and transport of logs, and the introduction of logging-related sediment into Johnstone Strait prompted the establishment of the reserve (Ministry of Environment, 1981). Most of the concern at the time was related to proposed development in the Tsitika watershed. A report examining shoreline processes and sediment dispersion identified Schmidt Creek to the east of the Tsitika River as the likely source of sediment to the rubbing beach (Hay and Company, 1991). A further report agreed with Hay & Company that Schmidt Creek was the source of the rubbing beach sediment (Harper, 1995).

Schmidt Creek is the name of the watershed on the TRIM map and in the Provincial Gazetteer. Peel Creek is the local name used by Western Forest Products (WFP). Ed Cyr, watchman of the Naka Creek camp, stated that the name Peel Creek originally referred to a small watershed to the east of Schmidt Creek that the Peel mainline originally accessed, and that drains a portion of Mt. Peel. This report will use the name Schmidt Creek to avoid confusion.

The identification of Schmidt Creek as the probable source of sediment for the rubbing beach focused concern on the forestry operations that WFP had started in 1987 in the Schmidt watershed. A moratorium on logging in Schmidt watershed was in place from 1992 to 1997. The Tsitika Follow-up Committee agreed to the lifting of the moratorium provided the Vancouver Forest Region (VFR) and WFP agreed to participate in a monitoring program. WFP agreed to fund the program for one year, and the VFR and WFP both agreed to seek longer term FRBC funding. The monitoring program objectives were to investigate:

- Whether sediment sources within Schmidt Creek were affected by forestry
- Whether changes to the rubbing beach were likely should sediment output from the watershed change.

WFP and the VFR submitted proposals to FRBC for monitoring of the watershed and the beaches. Proposals were declined by FRBC, since they did not perceive the work to fit into either the inventory or WRP programs. WFP and the VFR funded this project from 1997 to 2000.

2 WATERSHED AND COAST DESCRIPTION

Schmidt watershed is part of the Vancouver Island Ranges of

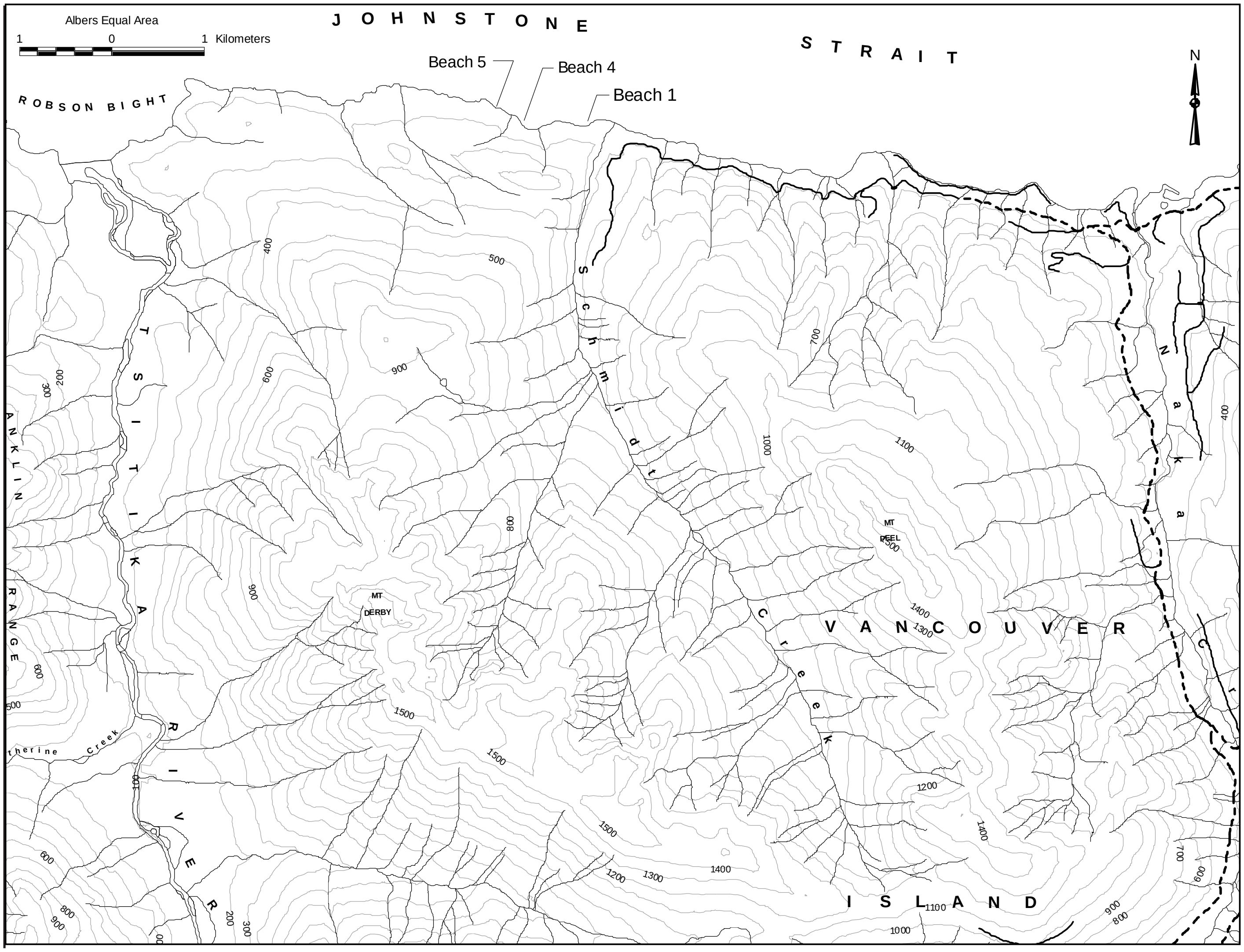

Figure 1. Location map of Schmidt Creek and the rubbing beaches.

the Vancouver Island Mountains (Holland, 1976). Topography is rugged, with elevations ranging from sea level up to 1658 m. Total watershed area is 32.5 km^2 (Figure 1). Bedrock is Karmutsen Volcanics (Mueller et. al., 1974). Thick till and some glaciofluvial blankets are common on the lower slopes of the watershed, with thinner till veneers and colluvium common on middle or upper slopes. Bedrock is often exposed in the highest areas of the watershed.

Schmidt Creek is a fourth-order stream, typically about 10 m wide in its lower reaches. Gradients in the lower reaches are about 8 – 10%. Most of its length is dominated by a boulder or bedrock channel bed, and very little storage of cobble or finer sediment is evident (with the exception of a new debris jam and sediment wedge that occurred as a result of a natural landslide in 2001). In most cases, it can be assumed that sediment delivered to the stream is quickly exported to the ocean, where Schmidt Creek has built a fan delta, as defined by Prior and Bornhold (1989).

Logging in Schmidt Creek occurred from 1987 – 1992. The road system was temporarily deactivated after logging, primarily through the installation of cross ditches. In 1996, WFP completed a Coastal Watershed Assessment (Heatherington, 1996). Three hundred and thirty-five hectares had been harvested, and 15.3 km of road constructed. The Equivalent Clearcut Area was 10.3%, and the road density was 0.47 km/km^2.

The rubbing beach (Beach 5) is located in Johnstone Strait between Robson Bight and the Schmidt Creek fan (Figure 1). Johnstone Strait is aligned nearly due east and west in this area for a distance of about 30 km, and the opposite side of the Strait is bounded by West Cracroft Island, approximately 3 km away. Spring tidal range is about 5 m. Dominant wave direction is from the east, with waves from the west also being important (Harper, 1995). Hay and Company (1991) estimated maximum annual wave heights of 2.9 m from the east, and 1.8 m wave heights from the west. Hay and Company estimated ten year maximum wave heights of 3.6 m and 2.3 m for waves from the east and west, respectively. When sediment from

Schmidt Creek is delivered to its fan delta, the dominant eastern waves transport most of this sediment to the west, as is evident from the asymmetrical form of the fan delta, which is much larger on its western side. The westward transport of sediment has created a set of pocket beaches between extensive areas of rock headlands.

Precipitation at Russell Creek, approximately 10 km west of the upper reaches of Schmidt Creek, has been measured by Rob Hudson of MOF since 1991. The mean annual precipitation is 1760 mm, the mean annual maximum 24-hour precipitation 86 mm, and the 10 year maximum 24-hour precipitation estimated at 117 mm.

3 SEDIMENT SOURCES – NATURAL AND LOGGING RELATED

Schmidt watershed has five very large natural landslides visible in the air photo record. These slides occurred between 1934 and 1977, with some of the slide tracks having more than one event (Guthrie, 1996). Guthrie reports a total volume of sediment from these landslides of 83,900 m^3, with approximately 60% of the sediment delivered into streams.

An additional natural slide occurred on December 13, 2001 during a windstorm event. The slide initiated from a gully headwall within an unlogged area and developed into a debris flow that crossed the Peel mainline road and then deposited most of its sediment directly into Schmidt Creek. Total volume of sediment introduced to Schmidt Creek from this event was about 1200 m^3.

Heatherington (1996) recorded ten clearcut or road related landslides, with a total area of 1.98 ha. One of these slides was 1.4 ha, or more than 70% of the total area affected. This slide did not reach the stream system. All other landslides reached the stream system. An additional road fill landslide occurred in April 1996, but did not reach Schmidt Creek. An additional slide that occurred on December 13, 2001 was probably road related. A portion of the headscarp is located on fillslope materials, and the rest of the headscarp is located in an unlogged gully area. No sediment from this slide reached Schmidt Creek. Assuming an average of 0.3 m of scour depth for the slides that reached the stream system, the total volume of logging related sediment that likely entered Schmidt Creek is about 1700 m^3 between 1987 and 2001.

A comparison of the amount of sediment introduced into Schmidt Creek from 1987 to 2001 from natural landslides and logging related landslides shows that there is a similar volume, with each contributing about 100 m^3/yr.

Natural landslides should be visible in air photographs for a period of 40 – 60 years (Jakob, 2000). Since the Schmidt Creek natural landslides are so large, it is likely they are visible for a longer period of time in the air photographs, and are assumed to represent a 100 year period of landslides. Using this 100 year period, the natural sediment input rate is about 500 m^3/yr. Thus in the short term (post-logging), the sediment input from logging-related slides approximately doubles the amount of natural sediment input, but when the longer term natural landslides are included, logging related landslides increase sediment input by about 20%.

Additional watershed monitoring for this project included approximately one week of field work in 1997. Landslides, roads and streams were surveyed. Most road sections in Schmidt Creek are not connected with the stream system, and therefore are not delivering sediment. Short sections of ditches are connected to a few stream crossings, however in only one location was the sediment delivered to the stream believed to be significant. Culvert and cross-ditch locations almost always deliver sediment onto hillslopes away from stream channels. Two of the larger tributary channels show signs of bed scour, which has resulted in some increased delivery of sediment to the mainstem Schmidt Creek that is up to cobble in size.

Since landslides dominate both natural and logging related sediment sources to Schmidt Creek, it is likely that the range and distribution of sediment sizes from logging related sediment sources are similar to natural sediment sources.

4 BEACH DESCRIPTIONS

4.1 METHODS

4.1.1 SEDIMENT SAMPLING

Grain size sampling on Beaches 1, 4, and 5 was done to characterize differences between beaches and to determine whether the sediment on the beaches changes over time. Grain size analysis at each beach was done June 1997, September 1997, September 1998, June 1999, September 1999, and June 2000, with the exception of Beach 1, which did not have samples collected in September 1999. Sample locations were repeated since September 1998 to enable analysis of grain size changes through time. Samples that were collected in June and September of 1997 did not have matching samples collected from the locations used during later sampling periods. Therefore, results for these samples are generally not reported.

During the sampling period from 1997 to 2000, no logging activity took place, and no landslides occurred in the Schmidt watershed.

Locations for the repeated sample sites were surveyed in September 1998 using a Geodimeter total station. For subsequent samples, the sample locations were relocated using triangulation from temporary benchmarks, and then resurveyed. This method resulted in all samples for each location being collected from within a circle with an average diameter of 3.4 m. In the worst case, the maximum diameter circle from within which samples were collected was 5.1 m.

At each sample location, the top five centimetres of sediment was removed to avoid measuring the coarser surface layer. (Surface samples of locations 5-1, 5-2, and 5-3 included the coarser surface layer, as total sediment depth of the pebble layer in this area was generally less than 10 cm). Samples were then collected from within a depth range of about 5 – 25 cm. The samples were sieved to 16 mm on-site. A subsample of the <16 mm fraction was bagged and analysed at the UBC Geography lab under the direction of Dr. Michael Church. Samples were typically between 15 and 30 kg in weight, and in all but two samples the largest stone was less than 2% of the sample weight. This sampling standard meets sampling criteria in Rood and Church (1994).

Three sample sites were established on both Beach 1 and Beach 4 (Photos 1 and 2). On Beach 1 the sample sites were clustered towards the western end of the beach, since the majority of Beach 1 was very coarse and primarily composed of Schmidt Creek fan delta deposits, rather than wave transported beach sediments. On Beach 4 the sample sites were located near the middle of the beach.

On Beach 5, nine sample sites in a 3 x 3 grid were established in the central portion of the beach, and ranged in elevation from near the storm berm height to locations that were submerged in most tidal conditions (Photo 3). On the lowest row of samples, two sediment types were evident (Photo 4), and both the surface layer (generally <10 cm deep) and the subsurface were sampled.

To accommodate the wide range of grain sizes present in typical sediment samples, analysis of sediment uses a logarithmic scale, where grain size in millimetres is converted to phi (ö) units as follows:

$$\varphi = -\log_2(\text{grain size in millimetres}).$$

The graphic mean grain size (μ) is defined as:

$$\mu = \frac{(\varphi 16 + \varphi 50 + \varphi 84)}{3}$$

where $\varphi 16$, $\varphi 50$ and $\varphi 84$ are the grain sizes at 16%, 50%, and 84% of the cumulative grain size distribution.

The graphic standard deviation (σ) describes how well sorted the sediment is, and is defined as:

$$\sigma = (\varphi 84 - \varphi 16)/4 \; + \; (\varphi 95 - \varphi 5)/6.6 \text{ (Leeder, 1982)}$$

Grain size classification follows the Terrain Classification System for British Columbia (Howes and Kenk, 1997). Table 1 summarizes the classification.

4.1.2 ABOVE WATER PROFILES

Repeated beach profiles above water level were surveyed using a Geodimeter total station. Profiles started at known locations at the top of the beach and followed the fall line to the water line. The fall line is the steepest slope on the beach, and is oriented approximately perpendicular to the shoreline. Elevations on each beach were tied to chart datum using repeated surveys of water surface elevation, combined with tidal height data from Port Neville, Port Harvey, and Alert Bay (Tide Tool software for Palm Pilot: http://www.freewarepalm.com/astronomy/tidetool.shtml). Error establishing beach elevations is probably about +/-10cm, however within each beach the use of the Geodimeter allows for greater accuracy, with error about +/- 2cm when comparing within-beach measurements.

The beach profiles were surveyed in September 1998, June 1999, September 1999, and June 2000. Beach 1 did not have profiles surveyed in September 1999. Three profiles were monitored on Beaches 1 and 4, and four profiles were monitored on Beach 5 (Photos 1, 2, and 3). At the top end of each profile there is very little error in horizontal position. Towards the bottom end of each profile, horizontal error tends to increase, but in most cases was less than 1 m.

Table 1. Grain size classification.

Name	Classification
boulders	Rounded particles >256 mm in size
cobbles	Rounded particles between 64 and 256 mm in size
pebbles	Rounded particles between 2 and 64 mm in size
sand	Particles between 0.0625 and 2 mm in size
silt	Particles between 2 µm and 0.0625 mm in size
clay	Particles less than 2 µm in size
gravel	A mixture of pebbles, cobbles or boulders

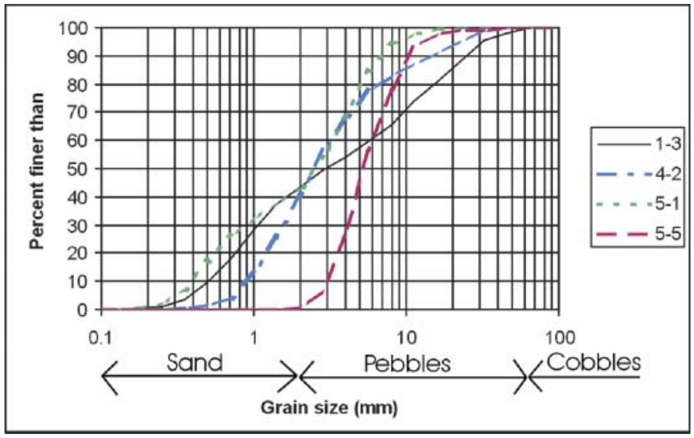

Figure 2. Typical grain size curves from each beach.

4.1.3 BELOW WATER PROFILES

Below water profiles were done using a sonar depth finder fixed on a boat. Two stakes in surveyed locations on the beach provided a defined line for the boat to follow, and a laser range finder was used to measure the distance to one of the stakes. Repeated profiles showed error could be as much as 30 cm, particularly where kelp interfered with measurements. Since repeated surveys were unlikely to show real changes in the underwater profile of the beach, they are not reported.

4.2 RESULTS

4.2.1 GRAIN SIZE ANALYSIS

Figure 2 shows the results of the grain size analysis for some typical sediment samples from each beach. For ease of interpretation, grain size is shown in millimetres in Figure 2; note that a logarithmic scale is used. Each curve represents a single sample from the June 2000 sample period. For each of these samples, the curves show that there was no sediment finer than 0.1 mm, and 100% was finer than 64 mm. Samples 1.3, 4.2, and 5-1(subsurface) all show a similar sandy gravel type of sediment. In each of these samples, sand (<2 mm) constituted

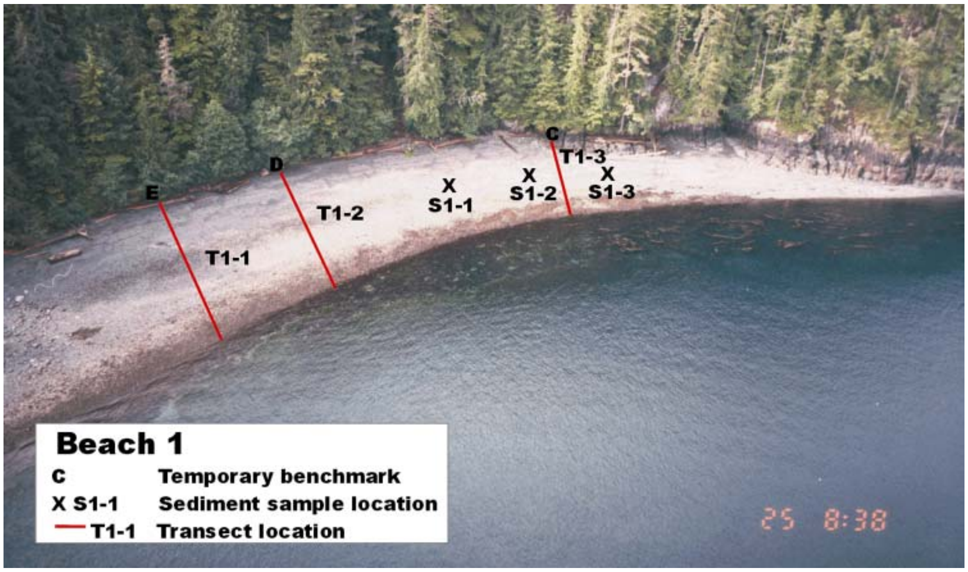

Photo 1. Beach 1, June 1998. Mouth of Schmidt Creek is about 200 m to the east (left side of photo). Note the much coarser sediment at the east side of the beach, which is more characteristic of the fan deposits of Schmidt Creek.

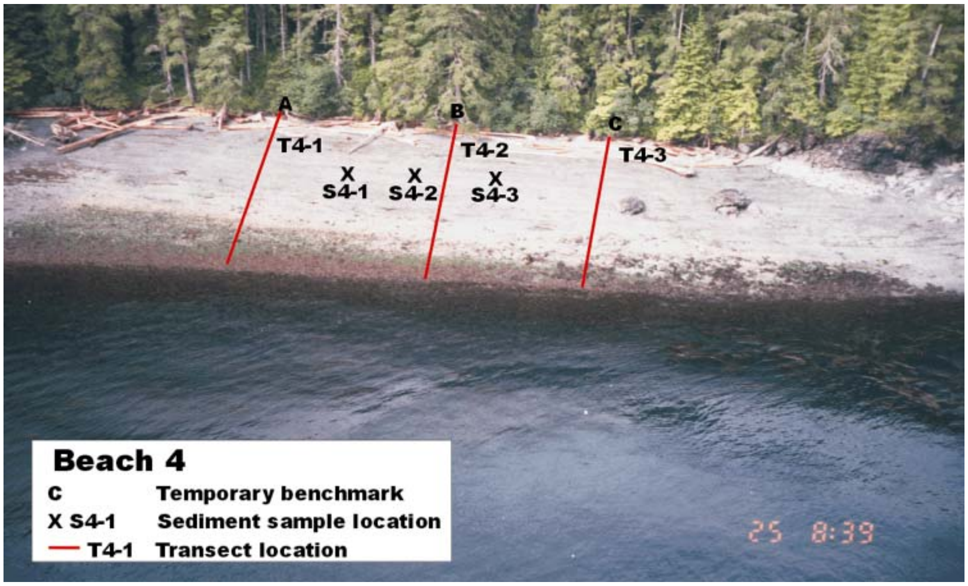

Photo 2. Beach 4, June 1998.

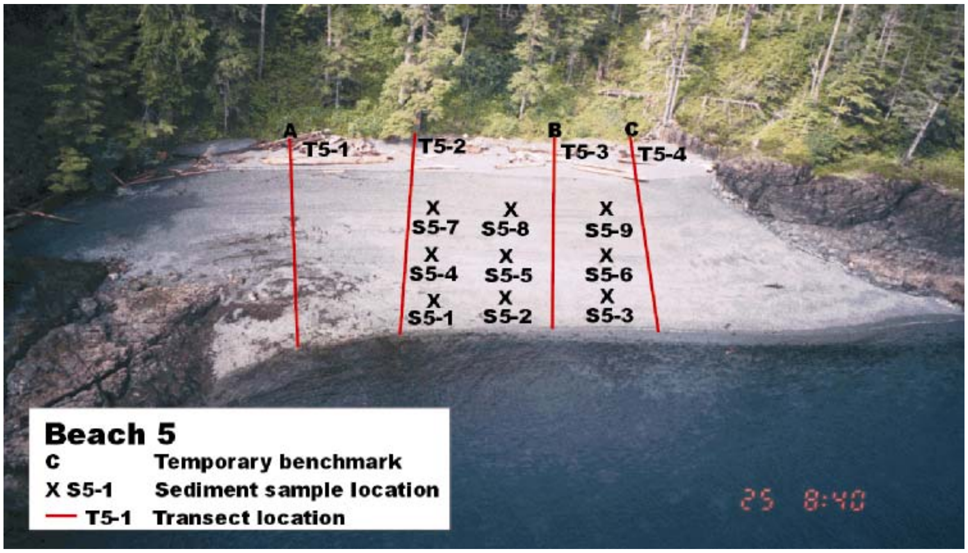

Photo 3. Beach 5, June 1998. Note well developed storm berm in area of T5-4. This transect shows an elevated storm berm in 1998.

Photo 4. Sediment profile on Beach 5. Typical sediment profile on lower portion of Beach 5 (Sample locations 5-1, 5-2, and 5-3), where the well sorted pebble layer was 5 – 10 cm deep. Surface sample included only the well sorted pebble sediment and included the uppermost surface (0 – 2 cm). Subsurface samples were from the sandy gravel layer.

Photo 5. Beach 1 sediment.

Photo 6. Beach 4 sediment.

about 40% of the sample, with the remaining 60% composed of gravel. Photo 4 shows the sediment profile near sample 5-1. Photo 5 shows Beach 1 sediment, and Photo 6 shows Beach 4 sediment. In contrast to the other samples, Sample 5-5 was the well-sorted pebble sediment characteristic of the whale rubbing beach. There was no sand in this sample, and the entire sample consisted of pebbles that ranged from 2 mm to 45 mm in size.

Sample 1-3 had the largest sediment sizes of the samples shown in Figure 2, with sediment ranging up to 64 mm in size. Some samples on Beach 1 had sediment as large as 90 mm. In contrast, none of the samples from Beaches 4 or 5 had sediment larger than 64 mm.

Table 2 shows the graphic mean grain size and the graphic standard deviation for each sample site. Table 2 values represent averages for the four main sampling periods (September 1998, June 1999, September 1999, and June 2000).

All three beaches had a poorly sorted or very poorly sorted sandy gravel present. Beach 1 samples had the coarsest sandy gravel (mean grain sizes of 5 – 7 mm), and Beach 5 samples had the finest sandy gravel (mean grain sizes of about 3 mm). As well, Beach 1 samples were very poorly sorted, whereas the sandy gravel samples on Beaches 4 and 5 were only poorly sorted. The decrease in sediment size, and the increase in sediment sorting from Beach 1 to Beach 5 is consistent with other evidence that shows that sediment from Schmidt Creek is transported to the killer whale rubbing beach.

Beach 5 is noted for the moderately well to well sorted pebble which is present in the upper and middle portions of the beach. Figure 3 shows a cross-sectional profile of the pebble layer. The pebble layer is a wedge, with the thick portion at the top of the beach, and the thin portion of the wedge pinching out about 1 m above chart datum. The dashed portion of the sandy layer line shows the assumed depth, since the maximum depth of the pebble layer we could determine was 0.75 m.

The sample locations from the middle and upper portion of Beach 5 had similar sediment. There was no significant difference in mean grain size between locations 5-4 through 5-9, inclusive (Kruskal-Wallis test, $p = 0.24$). Surface samples 5-1, 5-2, and 5-3 were significantly different from samples 5-4 through 5-9 ($p = 0.003$), most likely because of the sampling of the immediate surface layer.

Table 2. Grain size statistics.

Sample Location	Graphic Mean Grain Size		Graphic Standard Deviation (phi units)	Sediment Description
	phi units	mm		
Beach 1				
1-1	-2.22	5.02	2.15	Very poorly sorted sandy gravel
1-2	-2.61	7.05	2.41	Very poorly sorted sandy gravel
1-3	-2.59	6.84	2.14	Very poorly sorted sandy gravel
Beach 4				
4-1	-2.04	4.17	1.48	Poorly sorted sandy gravel
4-2	-1.82	3.57	1.49	Poorly sorted sandy gravel
4-3	-1.73	3.39	1.60	Poorly sorted sandy gravel
Beach 5				
5-1 Sub Sfc	-1.50	2.80	1.70	Poorly sorted sandy gravel
5-2 Sub Sfc	-1.63	3.12	1.72	Poorly sorted sandy gravel
5-3 Sub Sfc	-1.71	3.27	1.97	Poorly sorted sandy gravel
5-1 Surface	-3.48	11.2	0.56	Moderately well sorted pebbles
5-2 Surface	-3.32	10.0	0.59	Moderately well sorted pebbles
5-3 Surface	-3.29	9.90	0.69	Moderately well sorted pebbles
5-4	-3.03	8.28	0.60	Moderately well sorted pebbles
5-5	-2.93	7.60	0.59	Moderately well sorted pebbles
5-6	-2.98	7.96	0.58	Moderately well sorted pebbles
5-7	-3.13	8.91	0.54	Moderately well sorted pebbles
5-8	-2.98	7.99	0.49	Well sorted pebbles
5-9	-3.44	11.1	0.44	Well sorted pebbles

Sand: 0.0625 - 2 mm; Pebbles: 2 - 64 mm; Cobbles: 64 - 256 mm. Gravel includes pebbles and cobbles.
Note: 5-1, 5-2, 5-3 subsurface samples done only in September 1998 and June 2000.

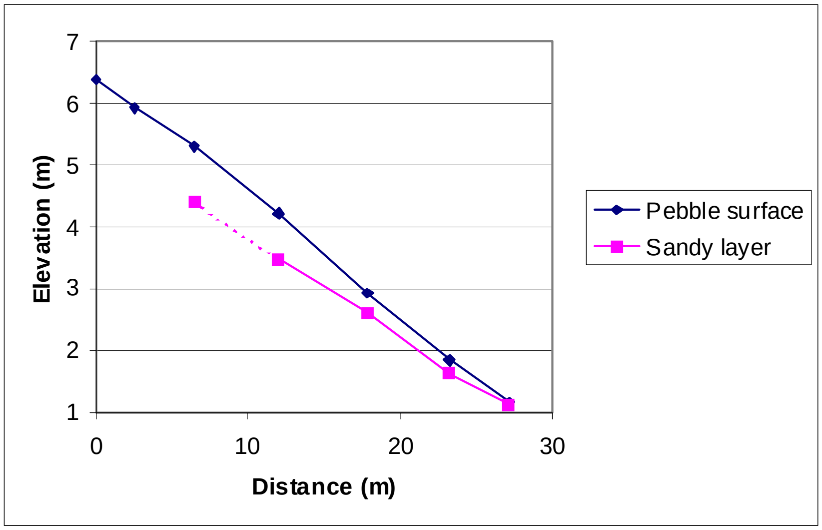

Figure 3. Structure of the pebble wedge on Beach 5.

There was little, if any, indication of grain size changes over the monitoring period (June 1997- June 2000). Neither Beach 1 nor Beach 5 showed any pattern of grain size changes. Beach 4 samples were generally coarsest in June 2000, and September 1999 samples tended to be finest. This may indicate that the beach sediment can change from one sample period to another, but does not indicate a trend, since the September 1998 and June 1999 samples were of intermediate grain size compared with the last two sample periods. Within the uniform samples on Beach 5 (sample locations 5-4 through 5-9), there was no trend in changes of graphic mean grain size with time (Table 3), and no significant difference between sampling periods (Kruskal-Wallis test).

Table 3. Beach 5 mean grain size by sample period.

Sample Date	Graphic Mean Grain Size[1]	
	phi units	mm
September 1998	-3.02	8.20
June 1999	-3.20	9.47
September 1999	-3.18	9.23
June 2000	-2.92	7.63

1) Sample locations 5-4 through 5-9, inclusive.

4.2.2 BEACH PROFILES

Each beach has a vegetated backshore, a foreshore on which waves break, and a below-water nearshore. Figure 4 shows a typical above-and-below water profile. The top of the profile is at the top of the beach, where the vegetation begins. The foreshore and nearshore form a smooth profile until an elevation of about –5m, below which the profile steepens significantly. The steeper profile section was observed to be bedrock (Harper, 1995), but above an elevation of –5m, beach sediments form the bottom. It is likely that the nearshore above an elevation of –5 m matches the sub-tidal bench that Hay and Company observed (1990).

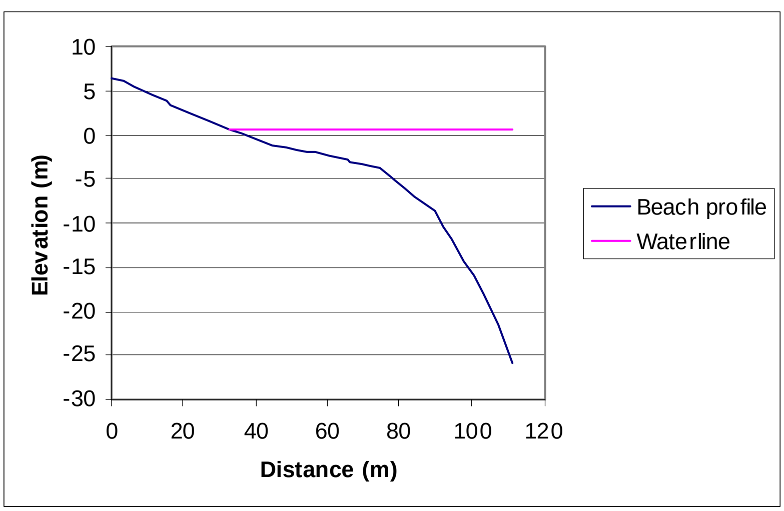

Figure 4. Beach 5, June 1999 above and below water transect.

Erosion has occurred on Beach 1. Temporary benchmarks installed in 1997 within the vegetation behind Beach 1 were not found in September 1998, and fresh erosion of the vegetated surface behind the top of the beach was evident. All three transects on Beach 1 had additional erosion to a maximum of 0.5 m (vertical measurement) between September 1998 and June 1999. Figure 5 shows the beach profile from Transect 1-3. Profiles on Beach 1 showed accumulation from June 1999 to June 2000.

There was little variation in profiles from Beach 4. Maximum change in profile height was about 0.3 m, but rarely exceeded 0.2 m. No erosion or deposition trends were evident.

Beach 5 profiles showed significant change. Transect 5-1 showed vertical changes of up to 1.3 m (Figure 6), Transect 5-2 had up to 0.8 m change, Transect 5-3 had up to 0.3 m change, and Transect 5-4 had up to 1.2 m change (Figure 7). No temporal trends were evident in the changes. For Transect 5-1, the June 1999 profile was clearly elevated above the other sampling periods (Figure 6), but this was not evident on the other transects on Beach 5. Transect 5-4 had a similar maximum amount of change in height between transects, but all four transects at this location were considerably different from one another (Figure 7). It appears that changes on one portion of the beach are not necessarily similar to changes on other portions of the beach.

The variability in beach profile was observed during the September 1999 work. Sampling was done on Beach 5 on September 24, but no access to the beach was possible on September 25 due to high winds and rough seas. When we returned to the beach on September 26, the profile of the beach had visibly changed.

5 DISCUSSION

Short term sediment input has likely doubled as a result of logging-related landslides. When longer term sediment inputs are considered, logging likely has resulted in an increase of about 20% over natural inputs. It is not known whether this increase in sediment has resulted, or will result, in changes to the beaches. However, several observations derived from the beach monitoring are worth noting.

Each beach is composed primarily of a poorly sorted sandy gravel, indicating that longshore transport of sediment from Schmidt Creek delivers similar material to each beach. The further the distance from Schmidt Creek, the better the sorting of the sandy gravel, and a reduction in average size also occurs, most likely because the largest sediment sizes (>45 mm) are rarely transported to either Beach 4 or Beach 5.

Although the original material delivered to each beach is similar, the appearance of Beach 5 is very different since it has the well sorted pebble wedge on top of the sandy gravel sediment. This wedge is not the result of different sediment being delivered to Beach 5; rather, it is the result of a wave sorting process that removes the sand from the surface of the sandy gravel sediment, resulting in a lag deposit of pebbles (Petrov, 1989). The velocity of the wave swash (wave runup onto the beach) is greater than the backwash as the wave retreats (Kirk, 1980). As a result, all particle sizes are moved up the beach during wave runup, but only finer sediment such as sand is carried back down the beach as the wave retreats (Bird, 2000). Superficial sorting that produces an upper layer of well sorted gravel at higher beach level, and a lower layer of sand has been noted by Bird (1984).

Both Beach 1 and Beach 4 have concentrations of well-sorted gravel on top of the mixed sand and gravel sediment (Photos 5 and 6), indicating that the sorting process occurs on these beaches as well as Beach 5. However these well-sorted deposits are limited in areal extent as well as depth, whereas this type of deposit is continuous on the upper portions of Beach 5. Beach 5 is more exposed to the dominant easterly wave energy, and it is likely that this higher energy wave environment produces the better sorting present on Beach 5. Bird (1984) notes that beaches with higher wave energy have coarser and better sorted sediments. The development and maintenance of the well sorted surface layer on Beach 5 is primarily dependant upon the wave energy environment, and not on the amount or type of sediment delivered to the beach.

The variability of Beach 5 profiles (Figures 6 and 7) shows that significant reworking of the pebble layer is occurring. In contrast to the easily measured changes in Beach 5 profiles, no significant temporal changes in grain size have occurred on Beach 5. This suggests that although profile changes are frequent, grain size characteristics on Beach 5 are likely to be stable.

Changes in beach profile can be cyclic, generally in response to seasonal wave differences that build the beach profile in summer and erode the profile in winter. If profiles were measured in winter, it is likely that there would be significant differences when compared with the June or September profiles. Changes in beach profile can also be part of an erosional or constructional trend (Bird, 2000). Beaches tend to erode if the supply of sediment is less than the amount of sediment transported away from the beach, and they tend to prograde (build towards the ocean) if the sediment supply is greater than the amount of sediment removed from the beach. Thus if changes in sediment supply occur, it is likely that changes in profile will show a trend over time.

However, it is likely that there is a limitation in the ability of Beach 5 to prograde. Figure 4 shows that the profile of Beach 5 steepens significantly below an elevation of about -5 m. This steep section marks the lower edge of the beach, and is likely to limit the extent to which Beach 5 could prograde, since additional sediment deposited on the beach would likely drop off the edge into much deeper water.

The large landslides in Schmidt watershed that occurred between 1934 and 1977 suggest that in decades past there have been large introductions of sediment to the beach system. Again, we do not know to what extent this sediment has influenced the beaches.

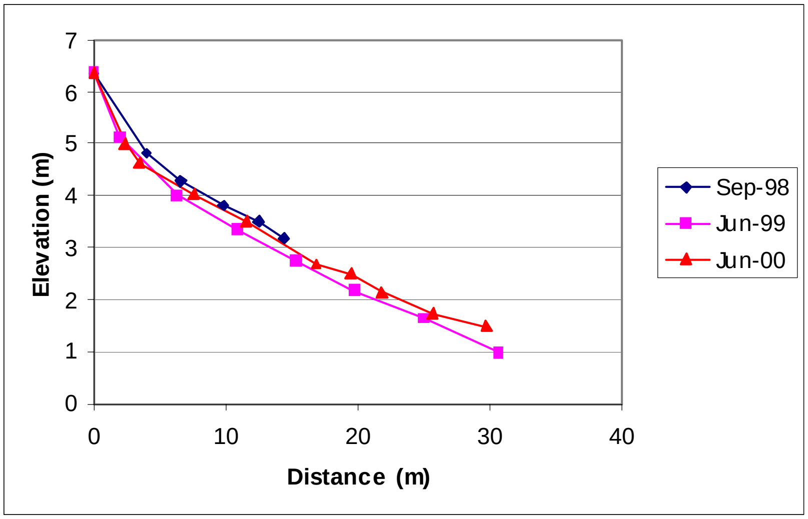

Figure 5. Beach 1, Transect 3.

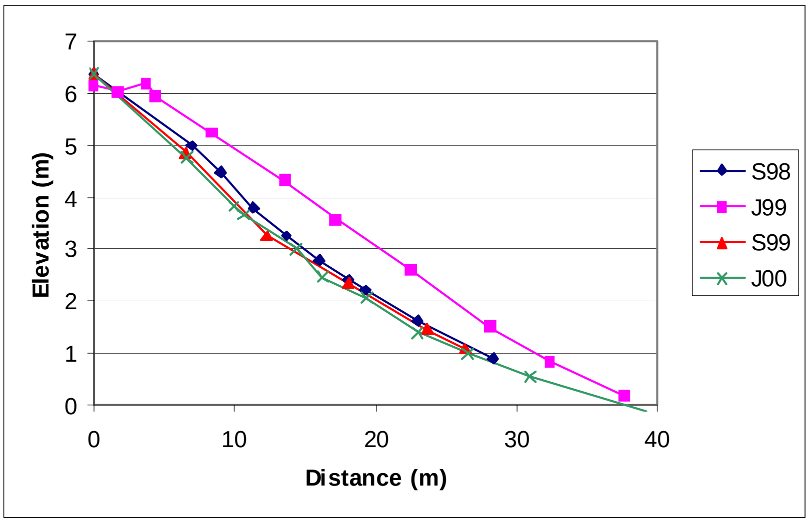

Figure 6. Beach 5, Transect 1.

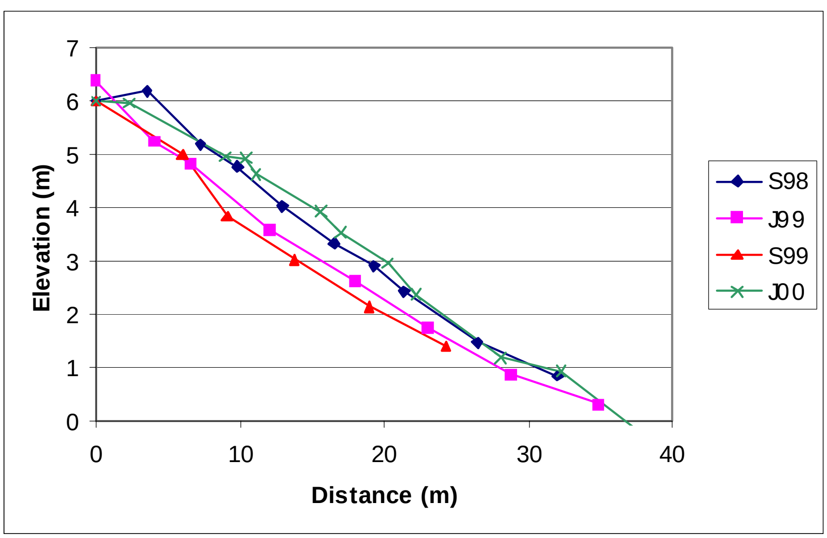

Figure 7. Beach 5, Transect 4.

6 CONCLUSIONS AND RECOMMENDATIONS

The beach profile and sediment characteristics of the killer whale rubbing beach depend on many factors. The amount and type of sediment delivered to the beach are undoubtedly fundamental in determining beach characteristics. However, it appears that wave transport and the resultant sorting of sediment are the critical factors in determining the nature of sediment on the rubbing beach. Beaches 1 and 4 have very similar sediment delivered to them, yet do not have the well sorted pebble layer that is present on Beach 5.

Short term sediment input to Schmidt Creek has been significantly affected by forestry. However, episodic natural sediment inputs in the past have been larger than logging-related sediment inputs. It is not known how much the beaches changed in response to these large inputs of sediment from Schmidt Creek. Since there is an apparent limit on the extent to which Beach 5 can prograde, it may be that the beaches had very little response to these large inputs of sediment.

Given the nearly unique use of the beach by killer whales, management of the area should be cautious. Cutblocks should be located in areas that have little chance of delivering landslide sediment into the stream system. Roads should minimize sediment delivery into the stream system. Ditches that feed into streams should be as short as possible.

Monitoring of Schmidt watershed and the beaches can be used to determine whether changes are occurring in either the amount of sediment delivered from Schmidt Creek or in beach characteristics. However, beach characteristics rely on many factors: sediment delivery to the ocean, longshore transport of sediment from the mouth of Schmidt Creek to the rubbing beach, and the wave action that sorts the sediment on the rubbing beach. Given this complex system, determining whether changes in sediment output are affecting the beaches is probably not possible unless extremely intensive monitoring is undertaken. Monitoring of sediment sources within the watershed can indicate whether forestry operations are affecting sediment inputs to Schmidt Creek.

REFERENCES

Bird, E. 1984. Coasts. Basil Blackwell. New York. pp. 109 - 146.

Bird, E. 2000. Coastal Geomorphology, An Introduction. John Wiley and Sons. Toronto. pp. 116 - 129.

Ministry of Environment, 1981. Killer whale and coastal log management: An overview of future uses of Robson Bight, British Columbia. APD Bulletin No. 6. Victoria. 45 p.

Guthrie, Rick. 1996. Schmidt Creek report. Internal report, Ministry of Water, Land and Air Protection, Nanaimo. 11 p.

Hay & Company. 1991. Shoreline Processes and Sediment Dispersion in Robson Bight, Johnstone Strait. Report prepared for the Ministry of Forest and the Department of Fisheries and Oceans. 38 p.

Harper, J. R. 1995. Final Report, Robson Bight Coastal and Nearshore Sediment Transport Survey. Report prepared for the Ministry of Forest, Nanaimo. 20 p.

Heatherington, E.D. 1996. Coastal Watershed Assessment for the Peel Creek Watershed. Prepared for Western Forest Products. 29 p.

Holland, S.S. 1976. Landforms of British Columbia A Physiographic Outline. Bulletin 48, British Columbia Mines and Petroleum Resources, Victoria, B.C., Canada. 138 p.

Kirk, R.M. 1980. Mixed sand and gravel beaches. *In* Progress in Physical Geography. 4:189-210.

Leeder, M.R. 1982. Sedimentology – Processes and Product. George Allen and Unwin. Boston. pp. 35 - 45.

Mueller, J.E., K.E. Northcote, and D. Carlisle. 1974. Geology of Northeast Alert Bay Map Area, British Columbia. Geological Survey of Canada, Open File 722.

Prior, D.B., and B.D. Bornhold. 1989. Submarine sedimentation on a developing Holocene fan delta. *In* Sedimentology. 36:1053-1076.

Petrov, V.A. 1989. The Differentiation of Material on Gravel Beaches. *In* Oceanology. 209:208 - 212.