AN EVALUATION OF THE POTENTIAL AGGREGATE RESOURCES FOR SOOKE LAND DISTRICT, B.C. (92B/5)

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KEYWORDS: Surficial geology, aggregate, Sooke, sedimentation model.

INTRODUCTION

This study details potential aggregate resources within the Sooke Land District (Figure 3-5-1). A model which charts the interactions between Middle and Late Pleistocene ice-sheets and ice-marginal sedimentation was developed to assist in the process of identifying potential aggregate sources. Information concerning general bedrock and surficial geology has been derived from published sources (Muller, 1980; Senyk, 1972). More detailed data on surficial geology have been obtained from airphoto interpretation, ground survey, laboratory analysis and further published and unpublished sources.

Urban areas in the study area are within one hour's drive of Victoria and have considerable potential for future commercial and residential development. Ongoing improvements to Highway 14 are indicative of the need for further aggregate resources, a demand which will not decline in the foreseeable future. The urban areas of Sooke, Milnes Landing and Saseenos, have limited extraction potential, but aggregate resources located in these areas are also discussed on the premise that economic priorities often change.

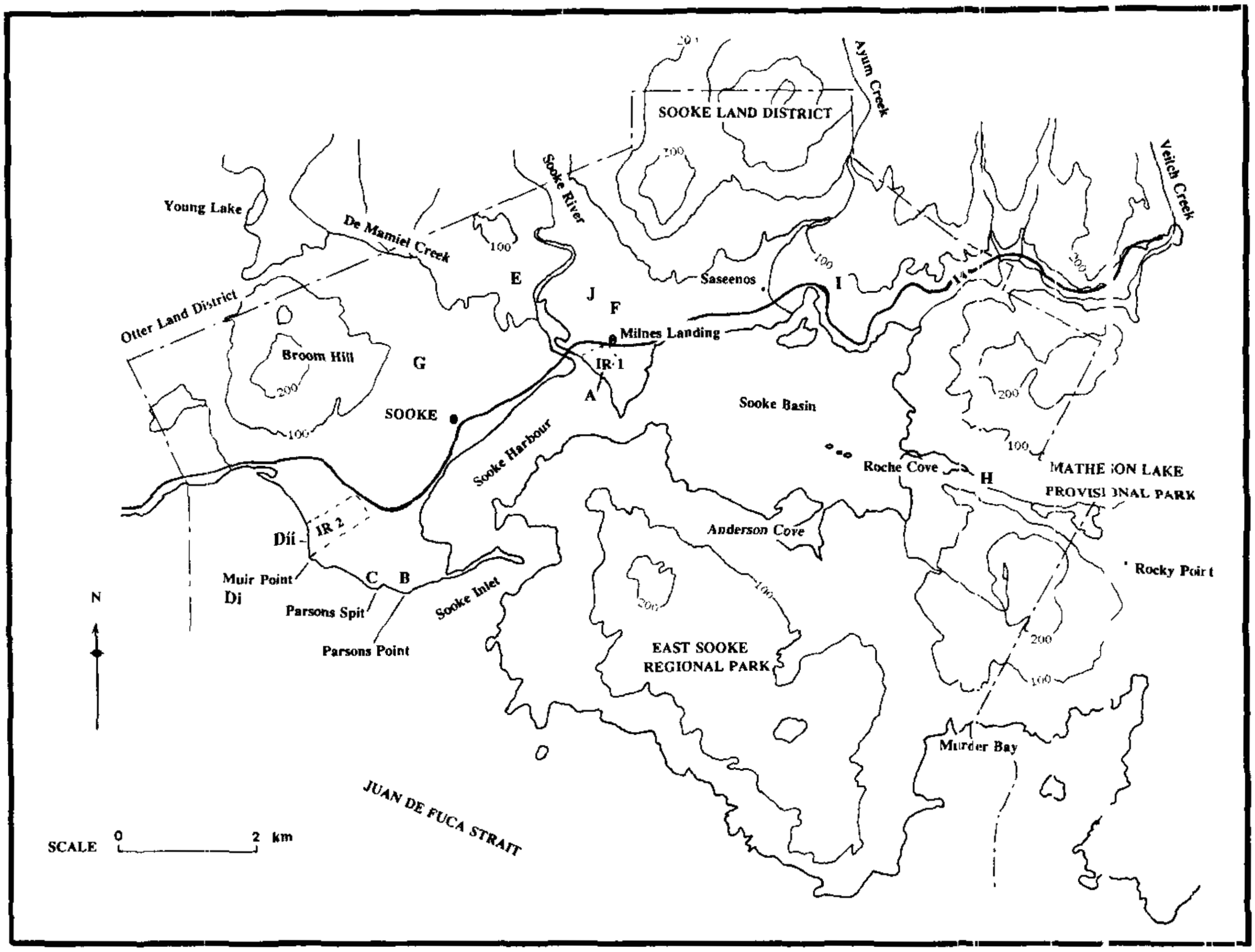
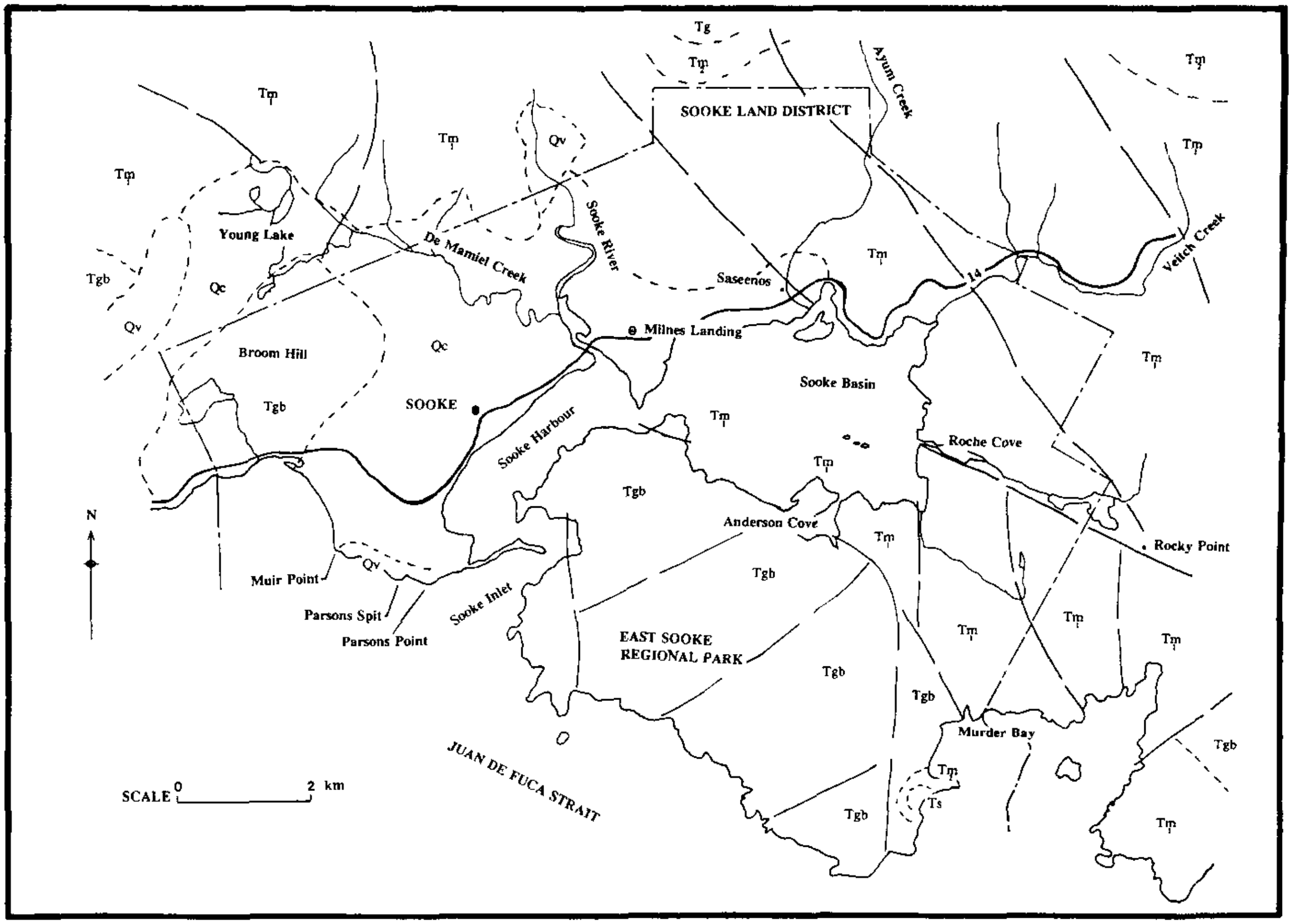


Figure 3-5-1. Sooke Land District — physiographic map (contours in metres; based on Energy, Mines and Resources, Canada, 1981).



QUATERNARY

Qc — CAPILANO SEDIMENTS: sand, gravel; silt, clay

Qv — VASHON DRIFT: gravel, sand, till

TERTIARY

Miocene ?

Ts — SOOKE FORMATION: conglomerate, sandstone, shale

Eocene (and older ?)

Tg — CATFACE PLUTONIC SUITE: quartz dolerite, agmatite

Tm — METCHOSIN VOLCANICS: Tm_1: pillow basalt, breccia, tuff; Tm_2: mainly basaltic lava

Tgb — SOOKE GABBRO: mainly gabbro

Geological boundary, approximate — — — —

Fault, approximate ———— ————

Highway ━━━

Figure 3-5-2. Sooke Land District — geology map (based on Muller, 1980).

BEDROCK GEOLOGY — GENERAL

The geology of Sooke Land District is dominated by two rock types: Sooke gabbro and Metchosin volcanics (Figure 3-5-2). Sooke gabbro constitutes the bedrock in the Broom Hill – East Sooke Regional Park area, while to the northeast, the remainder of the Sooke Land District is underlain by Metchosin volcanics.

SURFICIAL GEOLOGY AND GENERAL PHYSIOGRAPHY

Located in the southwest corner of Vancouver Island, the Sooke Land District is centred on Sooke Inlet. This physiographic relationship is reflected by a radial drainage pattern into Sooke Basin (Figure 3-5-1). The geology map (Figure 3-5-2) identifies some Quaternary deposits, namely: Capilano sediments (sand, gravel, silt and clay) and Vashon drift (gravel, sand and till) to the north and south of Sooke. Senyk's (1972) general terrain map provides further data, but results of ground surveys carried out during this study suggest that some refinement is needed and it is not reproduced. Sediment provenance and physiographic observations are combined to identify potential aggregate sources both in and around the Sooke Land District area.

Unconsolidated surficial materials are largely of Pleistocene or Recent age. Sedimentation by Pleistocene ice masses, meltwater and more recent subaerial processes has resulted in complex depositional sequences which have been only partially interpreted (Clapp, 1912; Bretz, 1920; Mayers and Bennett, 1973; Alley, 1979; Alley and Chatwin, 1979; Hicock, 1980, 1990; Thorson, 1980; Clague, 1981; Hicock and Armstrong, 1983; Hicock *et al.*, 1983; Hicock and Dreimanis, 1985; Alley and Hicock, 1986).

The following subsections detail the main physiographic features of relevance to potential aggregate sources. Site-specific data are discussed in more detail in the section titled Aggregate Resource Development. Finally, this information is collated under Sedimentation Model to produce a model of Middle and Late Pleistocene ice-sheet and ice-marginal sedimentation and the subsequent evolution of Holocene deposits.

Glacial Landforms and Deposits

Ground and airphoto surveys reveal no obvious depositional landforms, although till and diamicton were recovered from several sites. In general, glacial sediments have either been covered by even younger deposits or have been substantially eroded leaving isolated "till" islands. Deposits related to pre-Sangamonian (Illinoian ?) and Late Wisconsinan glaciations are exposed in coastal bluffs at Muir Point (Clague, 1981; Hicock and Armstrong, 1983). However, at Parsons Spit the lower, pre-Sangamonian till is no longer exposed above the beach. Moreover, the Late Wisconsinan till is discontinuous and is not found beyond the southwestern margin of Muir Point. Further evidence of glacial deposition is apparent on both banks of Ayum Creek, inland from the delta for about 2 kilometres. Although heavily incised and reworked by fluvial processes, this deposit generally retains its integrity as a till island surrounded by colluvially covered bedrock and recent fluvial sediments.

On the west side of Sooke River, ice-marginal deposits rest upon lacustrine sediments. This is indicative of glacial activity in the valley, although supplementary evidence appears to have been effectively removed by paraglacial processes during ice retreat. These deposits (and the underlying lacustrine sediments) have been sharply truncated at their southern end.

Evidence for erosional activity by glacier ice can be found in the widened valleys of Sooke River, Ayum and Veitch creeks. Of particular interest are two subglacial channels situated in the southeast of the Sooke Land District (Murder Bay to Anderson Cove, and Rocky Point to Roche Cove). Both are oriented northwest along fault lines; the more easterly valley incorporating the railway-line footpath and Matheson Lake (Provincial Park) is longer and wider than the other.

Sooke Basin, Harbour and Inlet are the best indicators of glacial erosion in this area. Their probable genesis was glacial scour by the combined ice flows of valley glaciers (Sooke River, Ayum and Veitch creeks) and the Juan de Fuca lobe. Ice streaming, associated with subglacial lubrication (from the two channels to the southeast of Sooke Basin), would have produced faster flowing ice into the basin than along the strait. Confinement by the valley glaciers of Ayum and Veitch creeks would have produced local ice build-up, rising compressive flow and subsequent scour. Sooke Inlet and Harbour, were probably created by ice flows redirected by the Sooke River glacier, following slowdown of the ice mass in Sooke Basin. This is considered to have occurred early in the glacial history of the area, perhaps pre-Sangamonian (Illinoian ?), because later deposits suggest a more passive glacial environment, closer to the limits of ice advance.

Stream Deposits Related to Glaciation

The complex glacial history of this area produced correspondingly complicated postglacial meltwater and fluvial sequences. Landforms are generally poorly defined, but deposits are extensive. Sand and gravel deposits of the Muir Point Formation are characterized by massive bedding structures as well as other paleocurrent indicators (imbrication structures, stoss-lee features and stone orientation). These deposits are exposed in the coastal bluffs between Parsons Point and Muir Point. The formation separates pre-Sangamonian and Late Wisconsinan tills. It pinches out before reaching the northern end of the bluffs. Here the Late Wisconsinan till unconformably overlies the pre-Sangamonian till. Furthermore, the sand and gravel beds are not found to the southeast of Sooke Inlet. Results of the ground survey and model development show that these deposits are derived from several sources. The lower section preserves evidence of derivation from the east northeast: the upper section from the south-southeast.

Muir Point also has meltwater deposits associated with a later period of ice-marginal conditions. These are located between Muir Point and the flanks of Broom Hill, but are thickest across the coastal frontage of Sooke Indian Reserve 2 (IR 2). Model development assisted in the identification of contemporaneous meltwater terraces on the east flank of Broom Hill which can be seen on aerial photographs (*e.g.*, much of the Sooke golf course and residential areas to the north of Sooke are built on these terraces). The sharp truncation of the Sooke River ice-marginal deposits suggests that the contemporaneous sediments of Sooke Indian Reserve 2 and the golf course terraces are evidence of a meltwater outburst, either along the edge of a retreating glacier, or by the breaching of stagnant ice. Deltaic deposits to the north of Milnes Landing indicate that Sooke River meltwater flowed into a small, temporary lake at about the same time. The sharp truncation of the west side of this delta confirms an outburst origin for the sediments on Sooke Indian Reserve 2. Additional evidence is difficult to assess because the southern boundary of this delta has been buried by subsequent fluvial deposition in Sooke Basin. In spite of this, aerial photographs show a marked break of slope, which would be a probable result of lake drainage to the west.

Two predominant meltwater deposits (lower section Muir Point and Sooke Indian Reserve 2) contain paleocurrent indicators showing that deposition was from the east. These could be the result of catastrophic outburst events produced by the draining of ice-dammed lakes. Russel *et al.* (1990) point out that these events involve rapid moraine erosion (*i.e.*, erosion of pre-Sangamonian and Late Wisconsinan tills, Muir Point ?) and that lake sediments are heavily incised (*e.g.*, Sooke River). Researchers agree that ice-dammed lakes were formed in side valleys adjacent to the Juan de Fuca lobe (Alley and Chatwin, 1979; Clague, 1981). Submerged "moraine" deposits in Juan de Fuca Strait may be evidence of this ice-marginal activity (*e.g.*, Mayers and Bennett, 1973; Solheim and Pfirman, 1985). This may explain the multi-genetic origin of the intertill sand and gravel deposit at Muir Point, the lowest unit representing a lag deposit (from lake outburst?), followed by backwater sedimentation and, finally, meltwater and outwash associated with the Vashon ice advance.

Recent Fluvial Sedimentation

Compared with the zones of meltwater deposition, recent fluvial sedimentation is minor. Relatively small deposits are found in conjunction with contemporary fluvial sources. These are listed in Table 3-5-1.

Recent Sooke River deposits are found mainly in a delta extending south, beyond the earlier meltwater sediments. However, most of this site is covered by residential and industrial development. In-channel and riparian deposits are found up-river, but all easily accessible sources associated with the Sooke River have been utilized. On the other hand, De Mamiel Creek valley has not been exploited. The creek flows into Sooke River from the west, cutting through the meltwater terraces discussed above. The valley is noteworthy, not only as a potential aggregate source within the Sooke Land District, but also as a possible source immediately to the north in the Otter Land District, in the vicinity of Young Lake. This site was not visited during the ground survey, but subsequent airphoto analysis and map interpretation indicates that sand and gravel deposits (which are buried by ice-marginal and lacustrine sediments in the De Mamiel Creek and Sooke River area) may well be exposed in the Otter Land District.

TABLE 3-5-1
RECENT FLUVIAL DEPOSITS

Site	Grid Reference	Deposit Location
Anderson Cove	512 565 517 564	Intermittent channel deltas
Ayum Creek	513 598	In-channel, riparian, deltaic
Doerr Creek	530 567	Deltaic, riparian (colluvially covered upstream)
Kemp Stream	432 576	In-channel, riparian
Veitch Creek	533 597	In-channel, riparian (colluvially covered upstream)

Colluvial Deposits

A considerable area of the Sooke Land District is covered by a colluvial veneer of varied thickness. Senyk (1972) indicates that this is underlain by fluvial gravels in several areas. Our ground survey suggests that these fluvial deposits are discontinuous and occur only as a thin layer. Recent fluvial sedimentation is considered to be more significant than this patchy, thin lag deposit of ice-retreat origin.

AGGREGATE RESOURCE DEVELOPMENT

Potential Aggregate Resources

The first priority of this study was to ascertain potential aggregate resources for the Sooke Land District. In order to provide the most useful information, a potential aggregate inventory, based upon sites analysed during the ground survey, is detailed below. Figure 3-5-1 indicates the locations of Sites A to J, and a summary is given in Table 3-5-2. Figure 3-5-3 graphically displays particle-size analyses of samples taken from potential aggregate sources.

SITE A

Sediments at the mouth of Sooke River are comprised of stable, well-drained, reasonably compact, deltaic deposits. The site is less than 0.5 kilometre from Highway 14, but is in an area of residential development near Sooke Indian Reserve 1 (IR 1). Old gravel pits within this area are almost exhausted, and the area of potential aggregate resource is correspondingly small. This site does not appear to be economically viable.

SITE B

Situated at Parsons Point, this site consists of a coastal bluff exposure of approximately 5 metres of interbedded sands and gravels. The upper 3 metres is predominantly sand and is compact, stable and relatively impermeable. Underneath are uncemented gravels, less compact, but stable. Beneath this, a cemented, poor-quality gravel is exposed as a raised beach – this is discussed in more detail under Site C. Paleocurrent indicators and bedding structures demonstrate that the upper sands and gravels were deposited by flows from the southwest and the east. This exposure of aggregate represents a thin strip of accessible material which extends northwest into Sites C and Di for approximately 2 kilometres. However, while its inland projection probably lies beneath most of this peninsula, residential development precludes access. At least three subdivision roads extend almost as far as the coastal bluffs along this strip, but coastal frontage is under private residential ownership. Coastal erosion is evident as far as Muir Point, and while the deposits are inherently stable, these is some undercutting. Extraction is not recommended here.

SITE C

Comments regarding Site B are equally applicable to Site C and only a technical description of the quality of aggregate deposits will be provided. Twelve metres of sands and gravels are underlain by a pre-Sangamonian till sequence. The upper section, again predominantly sand, is compact and clean. Paleocurrent indicators show that they were deposited by flows from the south-southeast and east, suggesting a similar origin to those at Site B. A review of the particle size information (Figure 3-5-3a) confirms this. Underlying gravels are the same cemented, poor-quality deposits which comprise the raised beach at Site B. Fabric analysis and paleocurrent indicators demonstrate an easterly origin and clast provenance (sub-rounded Leech River Formation, Metchosin volcanics and Karmutsen Formation) shows that some pebbles have been transported from the Shawnigan Lake region. In the sedimentation model discussed below these gravels are considered to be an outburst lag deposit from a glacially dammed lake, probably laid down at the beginning of the Sangamonian. This explanation provides an answer to the depositional history of the overlying multisourced sediments. The lower section, composed predominantly of organic-rich silt and sand with some peat (Alley and Hicock, 1986) represents a post-outburst backwater swamp deposit. The upper section, a mixture of organic-rich silt, sand and gravel is indicative of local reworking of the underlying sediment by meltwater flows from the southeast.

Access problems are similar to Site B although they are exacerbated by the increasing height of the coastal bluffs. This is partly a function of increasing stability brought about by the emergence of a resistant till layer at the base of the bluffs, but also the complete exposure of the overlying cemented gravels. Once again, extraction is not recommended.

SITE Di

This is part of a continuing sequence that becomes gradually more complex from Site B to Site D. At Muir Point the sands and gravels are sandwiched between underlying pre-Sangamonian and overlying Late Wisconsinan tills. However, these sand and gravel deposits pinch out and are no longer visible at the northwestern end of the section, where the Late Wisconsinan till rests unconformably on the pre-Sangamonian till (some 200 metres farther up the coast the bluffs rapidly decrease in height and are replaced by an outwash plain, Site Dii). Sand-filled tension fractures are

TABLE 3-5-2
SUMMARY OF STUDY SITES

Site	Location	Physical Features	Access	Suitability
A	487 588	New delta: surface deposit	**Good:** Highway 14	**Poor:** area developed
B	460 558	Coastal bluff: surface deposit	**Moderate:** residential area	**Moderate:** upper compact/clean; lower: uncemented
C	453 557	Coastal bluff: surface deposit	**Moderate:** residential area	**Moderate:** upper compact/clean; lower: cemented gravel
Di	443 563	Coastal bluff: exposed buried deposit	**Poor:** high bluffs, residential	**Moderate:** ltd. cementation, fairly clean
Dii	443 565	Outwash surface: surface deposit	**Moderate:** Sooke IR 2 road	**Good:** clean, noncompact
E	473 606	Fluvial terrace: exposed buried deposit	**Good:** loose-surface road	**Good:** Clean, noncompact
F	488 601	Old delta: surface deposit	**Good:** hard-surface road	**Good:** clean, noncompact
G	462 591	Fluvial terraces: surface deposit	**Good:** hard-surface road	**Good:** clean, noncompact
H	540 573	Valley floor: surface deposit	**Moderate:** via railway footpath	**Moderate:** veneer deposit, noncompact, fairly clean
I	520 604	"Till" island: surface deposit	**Good:** new road in subdivision	**Moderate:** fine sand only, compact
J	487 603	Old delta: surface deposit	**Good:** hard-surface road	**Good:** clean, noncompact

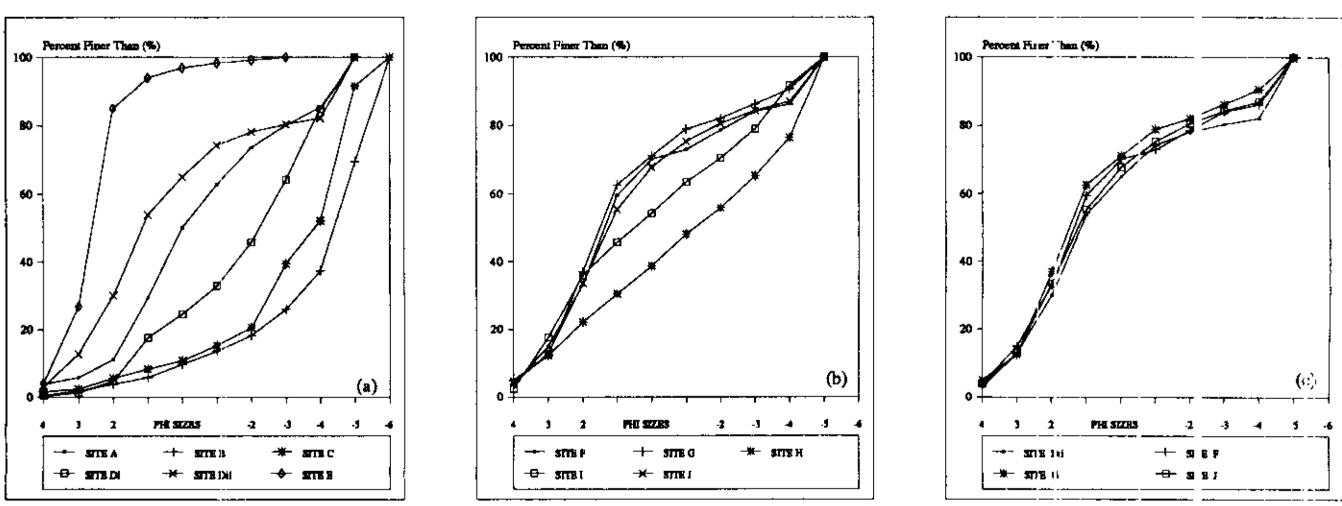


Figure 3-5-3. Particle-size distribution (sample sizes in excess of 20 kg in accordance with suggested criteria; Church *et al.*, 1987).

visible in the upper layers of the underlying pre-Sangamonian till, indicating a northwesterly ice movement (Hicock and Dreimanis, 1985). Deformation structures within the sands and gravels indicate some overloading by the Late Wisconsinan (Vashon) till. Particle-size analyses indicate that these sands and gravels are slightly coarser than those at Sites B and C, suggesting increased water percolation through the sediment along stress fractures. Muir Point is a coastal bluff susceptible to wave action. Although it is well drained and only a short distance from a paved road, it suffers from the same access problems as Sites B and C. No action is recommended here.

SITE Dii

An outwash plain under Sooke Indian Reserve 2 is the seaward margin of what was probably a meltwater outburst resulting from a combination of water from a glacially dammed lake and paraglacial Sooke River water. Vashon ice in Juan de Fuca Strait may have been sufficiently active to rework the Sangamonian sands and gravels to the southwest (Site Di) causing them to pinch-out, but the Vashon till at Site Di appears to have been passively deposited. It may have been deposited mainly by meltout from stagnant ice which temporarily dammed Sooke Inlet as valley glaciers retreated northeast, allowing lake build-up to occur in Sooke Basin. Alternatively, deposition may have occurred by lodgement as Juan de Fuca ice retreated after valley glaciers, causing a similar blockage. Eventual catastrophic breaching of the stagnant Juan de Fuca ice removed any underlying till and deposited sands and gravels to a depth of at least 3 metres at Site Dii. As can be seen from particle-size analyses (Figure 3-5-3c), Sites Dii, F, G and J have very similar compositions, corroborating this theory.

Site Dii has an easily accessible supply of aggregate (there is a paved road into Sooke Indian Reserve 2) of unspecified depth, which can be traced inland as far as Sooke River. Clearly most of the urban growth of Sooke overlies this source, but at Site Dii these surface deposits are clean, noncompacted and readily extractable. The exact areal extent of the accessible outwash plain is difficult to assess, but it could be about 1 square kilometre. Accessibility and aggregate quality are both good and extraction appears to be economically feasible.

SITE E

Fine ice-marginal and lacustrine sediments overlie sand deposits of unknown depth (in excess of 3 metres). The exposure, which is adjacent to a loose gravel road has been heavily incised by meltwater flows. This scenario is compatible with the suggested outburst theory and the track of the flood event. Sediments are noncompacted, easily accessible and close to De Mamiel Creek. Extraction would be facilitated by their occurrence as a river terrace, although the deposit is of limited areal extent because of truncation to the south and west by meltwater activity. Gradual physiographic constriction northwards along Sooke River valley is also a factor. The deposit could prove to be economically viable as an isolated extraction site for fine sands only.

SITE F

Interbedded sand and gravel deltaic beds are exposed to a depth of 10 metres at Site F. The beds dip south and have a particle-size distribution linking them with a westerly outburst event. We believe that these delta beds are the remains of the paraglacial Sooke River exit into a temporary ice-dammed lake occupying Sooke Basin. Ice-marginal and lacustrine deposits at Site E overlie paraglacial Sooke River sediments and show the extent of this lake. Rapid ice retreat up Sooke River valley built a delta into the lake, with marginal delta deposits being laid down beneath lacustrine sediments. The aggregate in the deltaic beds has been extracted to a limited extent in the past and is now adjacent to and partially covered by commercial and residential properties. Although the aggregate is clean and noncompact, in view of the northward expansion of the community of Milnes Landing this is not a good site for extraction. Road access is good, but extraction would be constrained by surrounding properties.

SITE G

Terraces exposed near Sooke golf course are as high as 10 metres in places and have a similar particle-size distribution to other post Late Wisconsinan outburst sites. Extraction is precluded at this location because of commercial and residential site coverage associated with the urban spread of Sooke.

SITE H

A continuous sand and gravel veneer, 1 to 5 metres thick, is situated between Roche Cove and Matheson Lake. This channel is of subglacial origin and the deposit is probably a lag from meltwater flows. The veneer overlies bedrock and is itself covered in places by some colluvial material. It is noncompacted, but due to some colluvial mixing is less clean than other sites. Pebble provenance shows that sub-rounded clasts of Sooke gabbro are of local origin, and rounded clasts of Wark gneiss are from the Victoria area. Access is reasonable along the railway-line footpath, but extraction is not recommended because some of the deposit is within the boundaries of Matheson Lake Provincial Park.

SITE I

Ice retreat northeast along the Ayum Creek valley deposited this sediment in an ice-marginal, lacustrine environment and as such the particle-size distribution is fine (Figure 3-5-3b). This appears to be a turbidite deposit, with many clasts found countersunk (dropstones) and transverse to flow direction (by rolling). Access is by a new subdivision road, and some residential construction already partially covers the site. Extraction seems to be precluded because of proposed and ongoing development. It represents the southern extent of a heavily incised, reworked till island which is compacted and relatively impermeable. Areal extent may be as large as 1.5 square kilometres although much is colluvially-covered and less accessible.

SITE J

Situated only a few hundred metres northwest of Site F, Site J is a continuation of the paraglacial Sooke River delta and was examined to assess the extent of the deposit. Particle size and aggregate qualities are similar to the other location, although there is no evidence of past extraction. Pebble provenance from both sites shows a similar origin to those at Sites C and D, with subrounded clasts of Leech River Formation and Metchosin volcanic lithologies. There has, as yet, been less urban development in the vicinity, although access is through a residential area. Residential development is more concentrated to the north, along Sooke River valley, and as such, the site has limited extraction potential. In view of the constricted area available for extraction, no action is recommended.

SEDIMENTATION MODEL

In order to thoroughly analyse the aggregate deposits in the Sooke District it was necessary to compile a sedimentary history of the area. Previous researchers have identified a pre-Sangamonian till (Illinoian ?) at Muir Point (Hicock, 1980; Hicock and Armstrong, 1983), making it necessary to consider both ice-sheet and ice-marginal sedimentation processes. An essential part of this operation required the development of a model which showed the interactions of these processes. This model was instrumental in predicting the location of Sites E, F and H.

DISCUSSION

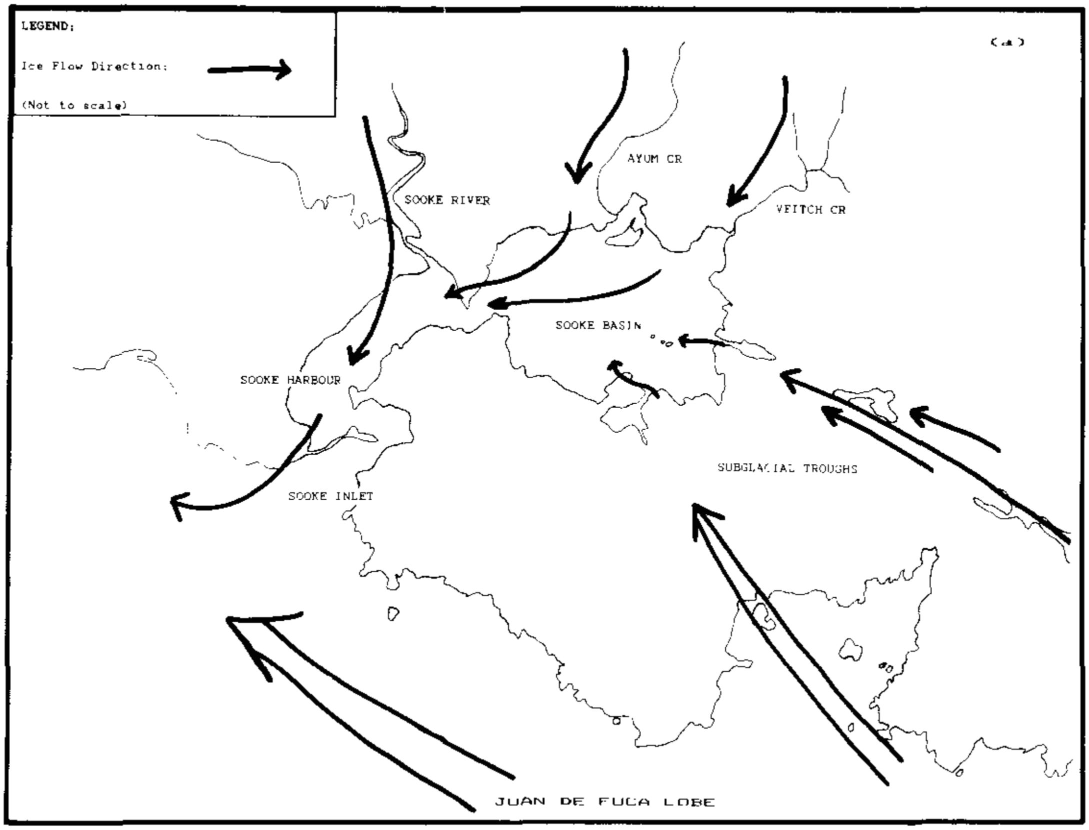
A pre-Sangamonian till at Muir Point (probably Illinoian – Westlynn glaciation, although it may be older; Hicock, 1980) represents the chronological starting point for this model. The till was deposited by an ice sheet which moved west-northwest along the Juan de Fuca Strait. Although little is known about earlier Pleistocene time, as the Juan de Fuca lobe moved northwest it would have risen out of the physiographic trough to the south and east of Vancouver Island, while undergoing compressive flow (Hicock *et al.*, 1983). A similar process, on a smaller scale, must have occurred as the ice over-rode the area to the southeast of Sooke Basin (East Sooke Regional Park - Matheson Lake Provincial Park). This scoured the land surface (which remains largely colluvially-covered bedrock today) accentuating weaknesses within the bedrock. This is particularly evident in the two subglacial channels carved along recognized fault lines. Occupation of these troughs by subglacial meltwater created lubrication for a faster moving ice stream into the Sooke Basin area.

However, glaciers flowing southwest along Ayum and Veitch Creek valleys; (Alley and Chatwin, 1979) blocked the northwesterly progress of this ice stream, inducing compressive flow and dissipating its energy by scouring out the Sooke Basin (effectively creating a low-lying cirque). General ice flow out of Sooke Basin was diverted southwest by a strong Sooke River valley glacier, thereby scouring out Sooke Harbour and Inlet. Here, ice flow and entrained rock debris joined the northwest-moving Juan de Fuca lobe (Figure 3-5-4a). Tension fractures, shear planes and till wedges in deposits along the eastern coast of Juan de Fuca Strait (at Muir Point) indicate that the till was deformed by two phases of ice-sheet advance to the northwest (Hicock, 1980; Hicock and Dreimanis, 1985).

During deglaciation, valley glaciers retreated more rapidly than the Juan de Fuca lobe, forming an ice-dammed lake in Sooke Basin. Evidence for a catastrophic outburst is found in the lower cemented gravels at Muir Point, which appear to represent a lag deposit, with paleocurrent indicators showing a westerly flow direction. It seems likely that valley deglaciation, and associated paraglacial activity, was waning by the time this occurred because no related meltwater deposits of any significance overlie these gravels. It is possible that Sooke Inlet was blocked by stagnant ice, and that the sedimentary evidence was removed by the outburst (Russel *et al.*, 1990; Figure 3-5-4b).

Overlying sediments show that this event was followed by a quiescent period during which organic-rich silt and sand were deposited (Alley and Hicock, 1986). Radiocarbon dates indicate that a backwater-swamp environment existed for tens of thousand years. A mixture of sand, gravel, diamicton and organic-rich silt overlies these deposits (Alley and Hicock, 1986). The heterogenous nature of these sediments points to fluvial reworking of distal nonorganic deposits (diamicton and gravel) followed by proximal activity (organic-rich sand and gravel), possibly associated with the late Wisconsinan advance (Vashon till) from the southeast along Juan de Fuca Strait. A more passive regime is proposed for this advance because of the preserved sand and gravel sequence at Muir Point, although this disappears at the northwestern margin of the site. This can be explained if one assumes that overlying Vashon till was mainly formed by stagnant ice meltout. Previous sand and gravel sediments occupying this site were gradually washed out (prior to the area being ice-covered) by westerly flowing meltwater from the valley glaciers to the northeast. A thin sand layer between the pre-Sangamonian and Late Wisconsinan tills may indicate such an event. This fits with the explanation of the subsequent outwash plain found immediately northwest of Muir Point.

Several surficial deposits were laid down during the deglaciation of the late Wisconsinan ice mass. A combination of subglacial low-pressure zones caused by the decaying ice front (*e.g.*, Hooke *et al.*, 1990), and a simple lag deposit, produced a sedimentary veneer on the Matheson Lake – Roche Cove valley floor. More significant, from an aggregate point of view, is the extensive Sooke River outburst. Valley glacier retreat was slow, with Ayum Creek and Sooke River showing evidence of ice-marginal deposits in their lower reaches, close to another ice-dammed lake in Sooke Basin. However, sufficient deglaciation had taken place in the Sooke River valley to create a fairly extensive delta into the lake. Either ice-margin collapse or catastrophic breaching of a stagnant ice blockage caused both lake drainage and temporary redirection of Sooke River flows to the west. As suggested above, these events commonly lead to the rapid erosion of morainal deposits and the deep incision of lacustrine sediments (*e.g.*, Russel *et al.*, 1990; Fitzsimons, 1990). Evidence for the erosional nature of this event is found in the terraces to the north of Sooke, the southern and eastern truncation of deposits at Site E and the southerly truncation of the old Sooke River delta (Figure 3-5-4c). Headward erosion by De Mamiel Creek to the northwest from Sooke River breached the terraces and undoubtedly caused sediment redistribution, redirecting



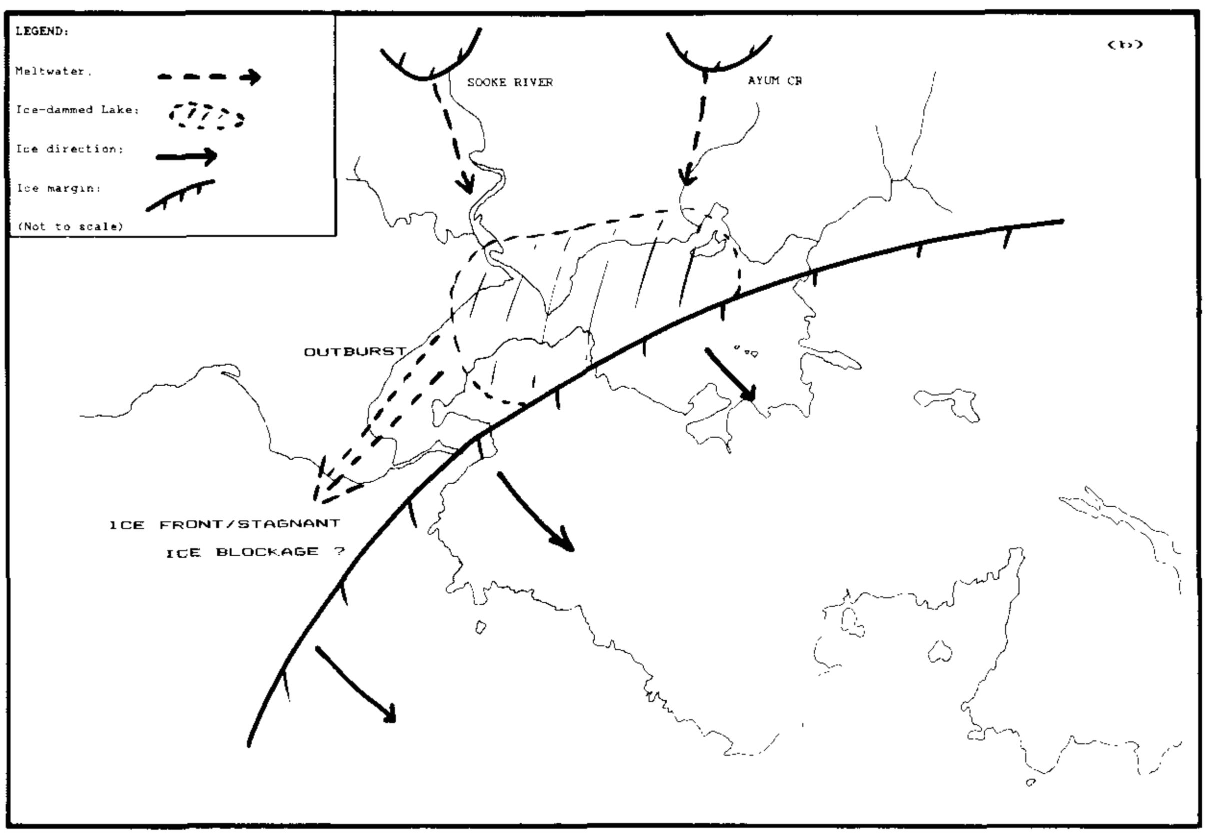
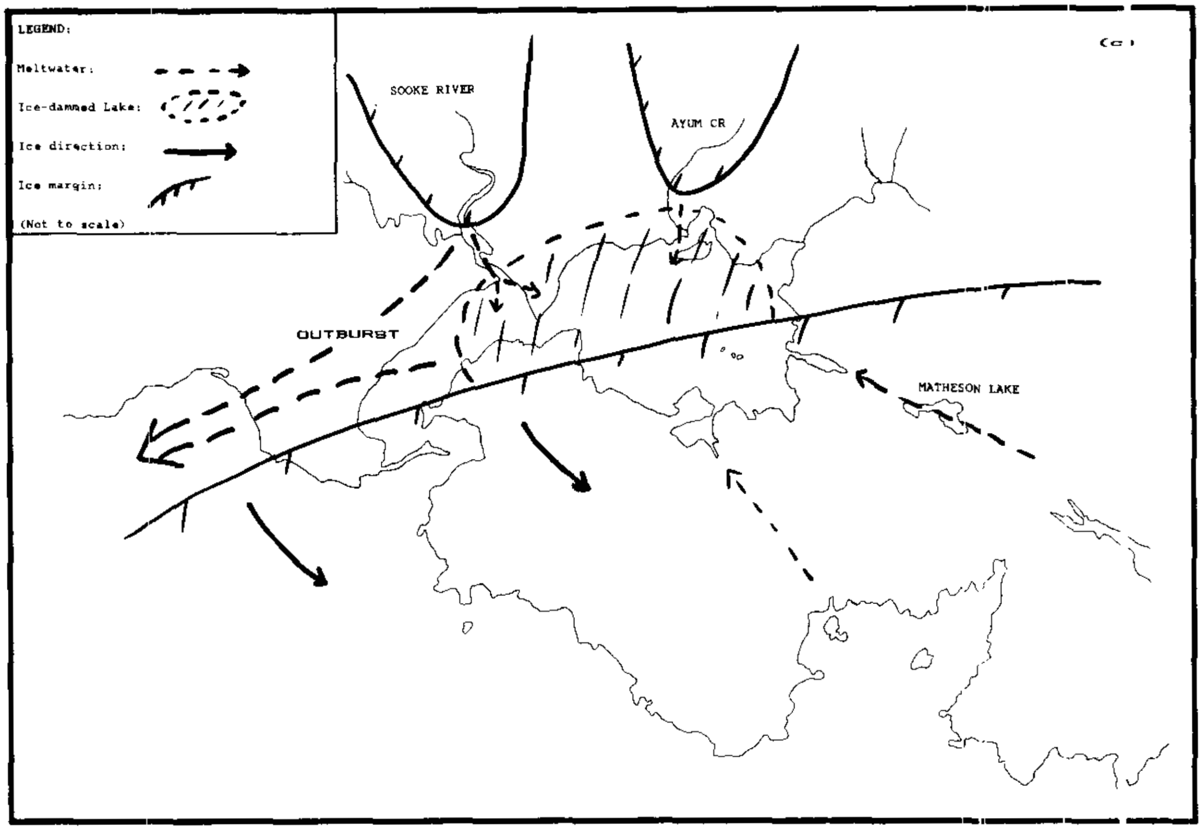


Figure 3-5-4. Sedimentation model: (a) Pre-Sangamonian, (b) Early Sangamonian, (c) Late Wisconsinan ice retreat, (d) Recent changes.


LEGEND:
Meltwater:
Ice-dammed Lake:
Ice direction:
Ice margin:
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SOOKE RIVER
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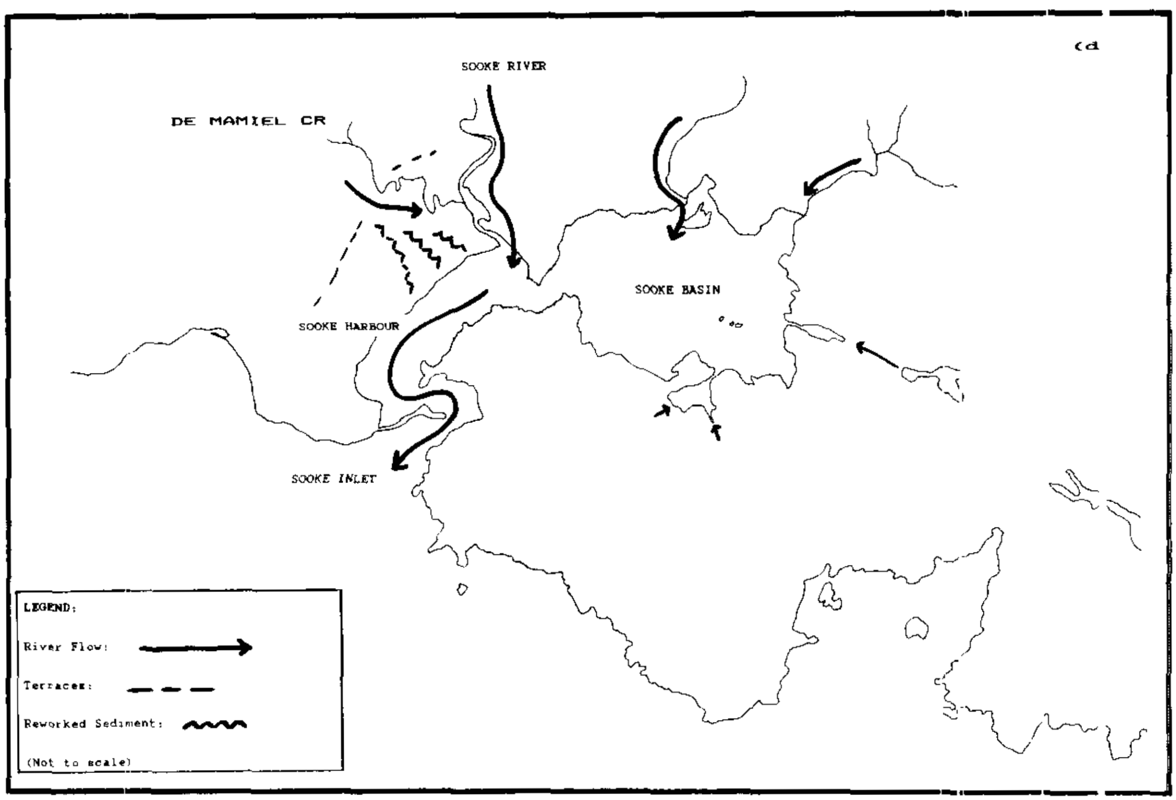
OUTBURST
MATHESON LAKE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SOOKE INLET
LEGEND:
River Flow:
Terraces:
Reworked Sediment:
(Not to scale)

Sooke River flows to the south into the drowned cirque of Sooke Basin. Subsequent drainage of Sooke Basin, by dominant Sooke River flows to the south, has reopened Sooke Harbour and Inlet (Figure 3-5-4d).

CONCLUSIONS

With few exceptions, potential aggregate resources in the Sooke Land District area are poor and difficult to extract. The Sooke River outwash deposit is a significant potential resource with several potential extraction sites. Possible extraction sites include:

- Site Dii — Sooke Indian Reserve 2 (good).
- Site E — De Mamiel Creek – Sooke River interfluve (good).
- Site H — Matheson Lake – Roche Cove (limited by site-specific problems).
- Site I — New Ayum Creek sub-concession (fine sand only — moderate).
- Site J — North Milnes Landing (limited by adjacent buildings — good).

The findings of this study show that the importance of developing a sedimentation model cannot be overemphasized. The model helped identify possible aggregate sites and, because airphoto analysis was inconclusive, these locations were later confirmed by ground survey.

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