Mount Woodside Erosion

(Kent Site G-1)

prepared for
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Purpose of this report

In recent years, the right (north) bank of Fraser River immediately upstream of Mount Woodside has been under attack by the main arm of the river. This site is referred to by the British Columbia Ministry of Environment, Lands and Parks (MELP) as Kent Site G-1. In this area the strongest currents are directed against the bank as the river meanders around the Gill Island complex (Figure 1). Although the bank is heavily armoured with rip-rap, the current alignment could potentially undermine the bank protection. Contemporary management objectives for the river are focused on the need to prevent flooding outside the channel zone of the river, and to discourage erosion beyond the active channel zone. The integrity of the dike is not of immediate concern as it is set well back from the main channel (Figure 1).

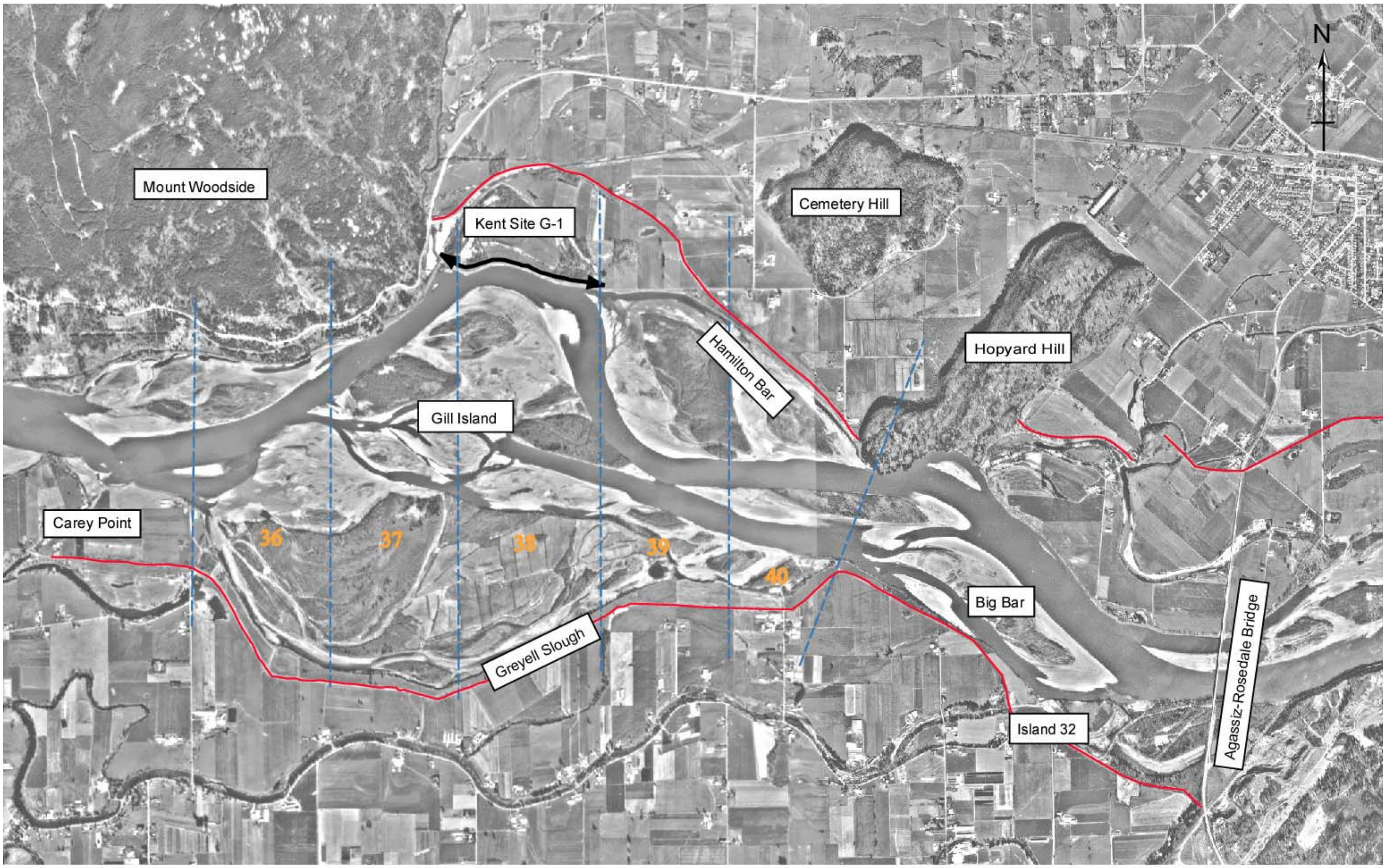
MELP has requested a report that documents channel changes in this reach during the recent past and considers potential future developments. The basis of this analysis is an ongoing study of the sediment budget (volumetric channel changes derived from channel surveys), and changes in channel morphology of Fraser River between Laidlaw and Mission. This recent work updates a previous study of similar scope conducted between 1982 and 1987 (cf. McLean and Mannerstrom, 1984; McLean and Church, 1999).

Historical changes in the vicinity of Mount Woodside

The channel zone around Mount Woodside is one of the widest places along the gravel reach (3000 m) and has been a zone of persistent aggradation for decades. An island complex around Greyell Slough occupies a majority of the channel zone and flows have largely been confined to the northern side (Figure 1). The ultimate limit of erosion to the north by the river is constrained by Hopyard Hill and Mount Woodside.

The Greyell Island complex has been present since the time of the first land survey near the end of the 19th century. The persistence of this depositional feature is explained by the alignment of the river further upstream. At the site of the Agassiz-Rosedale Bridge, the river turns in a northwesterly direction where it encounters hard, high ground on the left (south) bank. This sets up a secondary circulation that has promoted sediment deposition on the right bank downstream to Hopyard Hill. Downstream from this accumulation the river commences a reverse oscillation to pass, as it must, in front of Mount Woodside. This turn sweeps bed material to the left bank and deposition in the Gill Island area. Flowing around that accumulation, the tendency has been for the river to flow against the north bank, which consists of erodible floodplain and alluvial sediments. To protect agricultural land and to keep the river well removed from the dykes, the north bank has been riprapped.

Figure 1 Mount Woodside and vicinity, March 20, 1999; Mission flow 699 m^3/s. Source Resource Surveys and Mapping Branch, British Columbia Ministry of Environment, Lands and Parks. To facilitate comparisons, a similar scale is maintained for Figures 2 through 8. Numbered cells are sediment budget accounting units while the red lines represent dike locations.



In contrast to the Greyell island complex, the remainder of the reach has changed considerably since the turn of the century. Air photography of July 15, 1928 (Figure 2) reveals that flow was directed against the right bank immediately downstream of Hopyard Hill. At this time, Site G-1 was part of a small island complex (with a small secondary channel flowing around its perimeter) and hence was protected from erosion. The Gill Island complex was established by this date, although occupied by notably immature woodland. Over the years, Gill Island has changed considerably in spatial extent and position because that mid-channel zone site has been subject to continuing erosion and deposition. Despite these changes, islands forming in middle portions of this reach have historically (and within this report) been referred to as Gill Island.

Although flows were high at the time of photography, traces of a point bar deposit off Gill Island are apparent on the 1928 airphotos. The low flow of the 1949 photography reveals dramatic outward growth of this now major point bar, around which the river formed a tight meander (Figure 3). The photograph also prominently shows a diagonal riffle running from the point of Hopyard Hill to Gill Island, which turns the river against the right bank. Between 1928 and 1949 significant erosion occurred opposite this bar, near the east end of the study site, consuming a small part of the Gill Island complex and near the downstream end of Greyell Island (Figure 3). Much of this activity was in response to the Gill Island point bar growing in size and forcing more of the flow against the north bank. A large point bar is also apparent off Mount Woodside at the downstream end of the study site, forcing the main thread of the river south toward Carey Point. Material eroded from the north bank would likely have been deposited at this location.

During the 1950's gravel was removed from the point bar off Gill Island, as heavy machinery could be driven onto the bar. Removal volumes were small since demand was not high in those days (Weatherly and Church, 1999). By the mid 1960's removals had ceased as increased flows through the Gill Island complex isolated the site even during winter low flow.

During the 1950's erosion occurred in front Of Ferry Island as the thalweg of the river moved toward the left bank at the Agassiz-Rosedale bridge site, and a crescentric bar appeared immediately downstream (off Island 32), probably the deposit of most of the material eroded upstream. This began to turn the river toward the long-established bar-island on the right bank immediately upstream of Hopyard Hill. The upstream end of this bar-island came under erosional attack, leading to the downstream growth of the bar off Hopyard Hill. Nearer the study site, erosion of the right bank continued between 1949 and 1962, as the point bar off Gill Island persistently grew outward and downstream (Figure 4). Eastern portions of the point bar had begun to vegetate as the main flow formed a tightening meander around the Gill Island complex. The apex of the meander also shifted slightly to the west and, as a result, the remaining small island off Site G-1 was eroded. It is not known whether the north bank was riprapped by this time but the airphotos show that the apex of the meander bend is hard against a road and somewhat flattened, indicating a resistant ban

Figure 2 Mount Woodside and vicinity, July 15, 1928; Hope flow 5,780 m^3/s. Source National Air Photo Library, Canada Department of Natural Resources.

Figure 3 Mount Woodside and vicinity, March 23, 1949; Hope flow 733 m^3/s. Source Resource Surveys and Mapping Branch, British Columbia Ministry of Environment, Lands and Parks. Arrows indicate sites of erosional attack

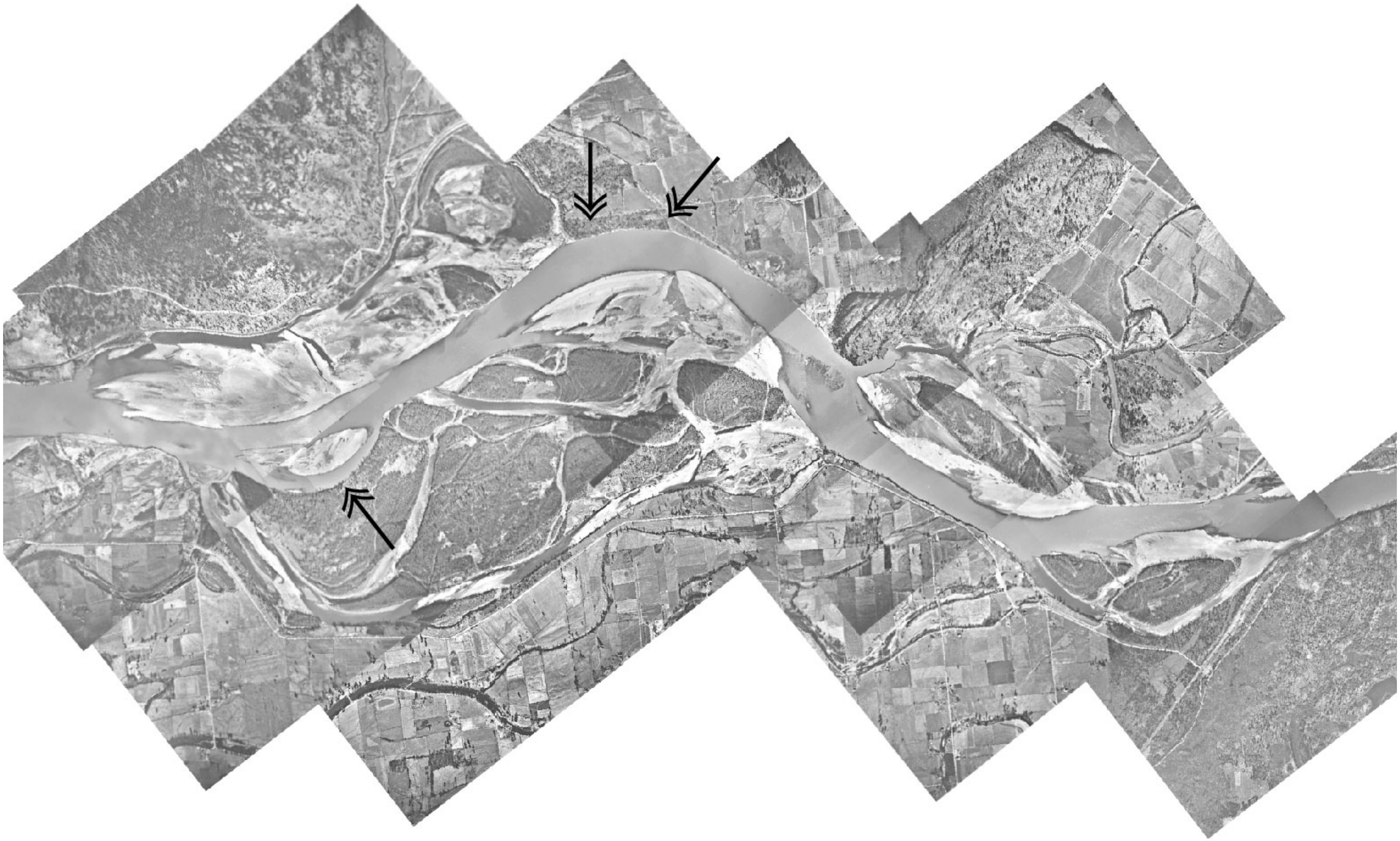


Figure 4 Island 32 and vicinity, May 7, 1962; Hope flow 2,940 m^3/s. Source Resource Surveys and Mapping Branch, British Columbia Ministry of Environment, Lands and Parks. Arrows indicate sites of erosional attack.

By 1971, the bar off Island 32 had grown downstream to form the nucleus of what is now Big Bar, causing the river to further trim the Hopyard Hill bar-island. Deposits from that process formed a large right bank bar downstream, forcing flow into the study reach more to the west through Gill Island. These changes shifted some of the flow away from the north bank (although one arm of the river continued to form a tight bend around Gill Island). Vegetation continued to develop on the now isolated point bar off Gill Island while the upstream (eastern) end of the Gill Island complex was eroded (Figure 5). Despite the relatively low flow of the 1971 photography, a number of wet channels are visible on the airphotos, including a channel behind the bar and island complex off Mount Woodside. This indicates a significant division of flow through this reach with the possibility for significant channel switching of flow. It also indicates that the right bank channel past the study site was already relatively deep at this time. A road visible along the study site indicates that the north bank was riprapped in its present position along its entire length by this time.

As the result of channel switching, significant changes continued to occur after 1971. The main changes were within the Gill Island complex and off Mount Woodside. By 1983 vegetation was well established on the now isolated old point bar off Gill Island (in the area presently referred to as Hamilton Bar) as well as on the new bar off Hopyard Hill (Figure 6). As such, the main flow was directed further to the west before being guided to the northwest by the new eastern margin of Gill Island. The net result of these changes was the introduction of an additional bend between Hopyard Hill and the apex of the Gill Island complex. As a result, the strongest currents of the river were now being guided directly against the study site at the meander apex and the right bank channel past Mount Woodside was growing larger.

The same general alignment became more clearly established through the 1980s, with continued deposition and initial vegetation along the margins of the "new" Gill Island point bar (Figure 7). At the relatively high water level shown on the 1983 photography, some of the flow was diverted between Gill Island and the Greyell Island complex and some across Gill Island. Such an alignment would have tended to ease flows along the north bank. Nevertheless, it is likely that Site G-1 would have eroded significantly by this time were it not for the riprap placed along the bank. On the right bank, the old point bar at Gill Island, now a well-wooded island, was becoming incorporated into the sedimentation zone immediately downstream of Hopyard Hill, whilst the upstream portion of that bar – also well vegetated – lay in midstream and was being incorporated into the prograding Big Bar complex. Both of these developments represent switches of the main channel around sediment blocks, so they moved from the vicinity of one bank to the other. A complex, multi-channel river had developed near the study site which, by 1991, effected the closure of the channel across Gill Island and extensive siltation of the channel to the right of Hamilton Bar. As a result, the main channel was directed straight onto the study site.

Figure 5 Island 32 and vicinity, March 19, 1971; Hope flow 799 m^3/s. Source Resource Surveys and Mapping Branch, British Columbia Ministry of Environment, Lands and Parks. Arrows indicate sites of erosional attack

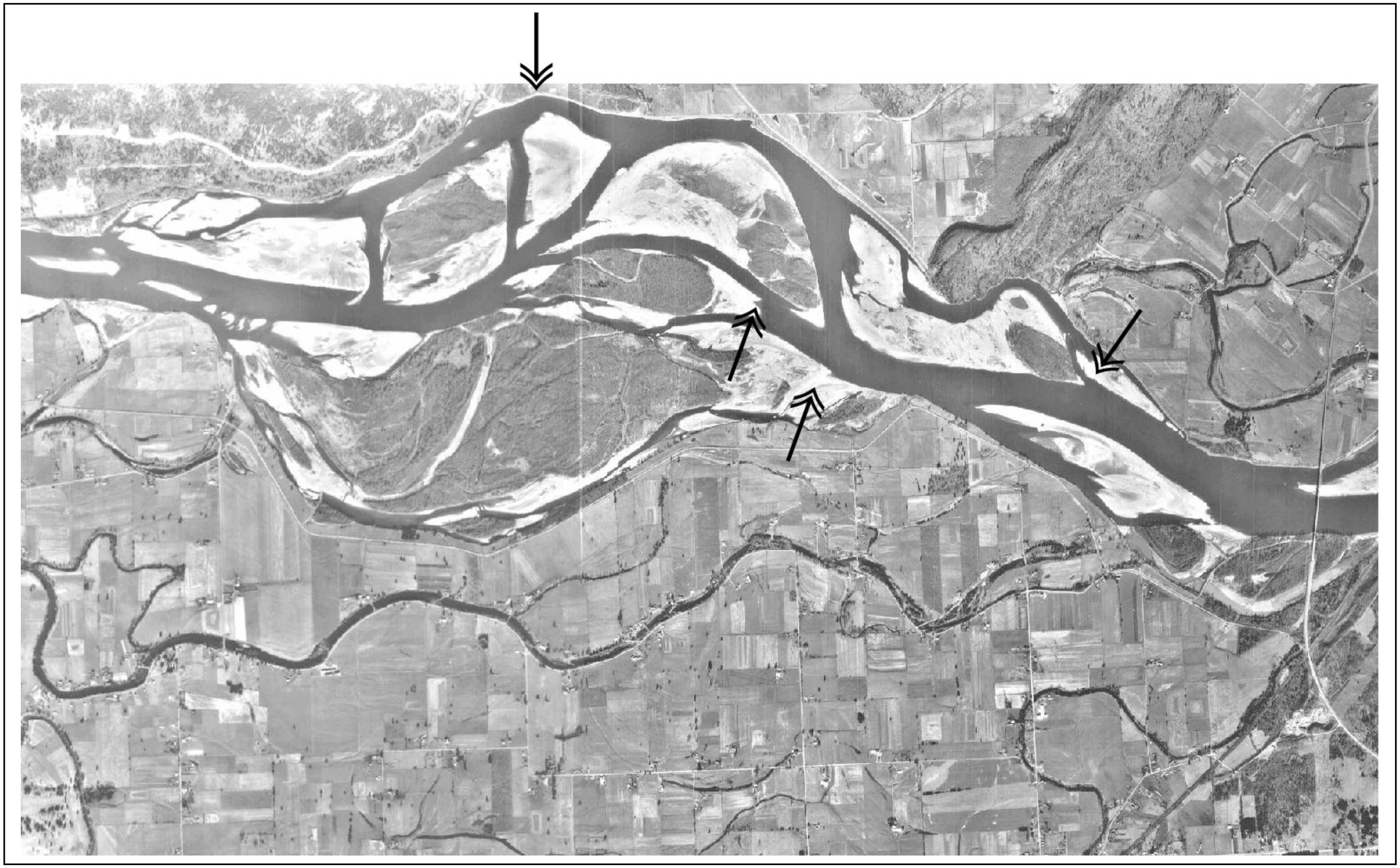


Figure 6 Island 32 and vicinity, July 22, 1983; Hope flow 5,380 m^3/s. Source Resource Surveys and Mapping Branch, British Columbia Ministry of Environment, Lands and Parks. Arrows indicate sites of erosional attack.

Figure 7 Island 32 and vicinity, September 5, 1991; Hope flow 4,410 m^3/s. Source Resource Surveys and Mapping Branch, British Columbia Ministry of Environment, Lands and Parks.

Although flow stage in the successive airphotos makes strict comparison difficult, it appears that the channel between Gill Island and the Greyell Island complex had aggraded somewhat by 1999. As well, the low stage of the 1999 photography makes clear that the channel to the right of Hamilton Bar had been largely filled with sediment. As such, a majority of flow is now being directed against the study site. The meander curvature at the study site also appears to have increased since 1991 and erosion has occurred on the left bank of Gill Island, prompting the development of a small reverse eddy bar off the Gill Island point bar, perhaps indicative of imminent meander cutoff. The armoured bank continues to resist erosion along the north side.

The changes described above can be assessed quantitatively by using historic channel maps of channel bar, island, and bankline positions. By digitizing airphotos for the gravel reach of Fraser River, channel maps for 1928, 1949, 1962, 1983, 1991 and 1999 have been created. Bankline positions from these years for the study reach have been plotted on Figure 8a to 8d. Erosion of the north bank between these dates is as follows:

Table 1 Historic erosion of north bank in vicinity of Kent Site G-1.

Period	Erosion (m^2)	per year (m^2)
1928 – 1949	291,870	13,900
1949 – 1962	305,350	23,490
1962 – 1983	78,590	3,742
1983 – 1999	0	0

The active erosion between 1928 and 1962 is a product of the Gill Island bend progressively shifting downstream, forcing erosion of the right bank. Since 1962 erosion has significantly decreased, primarily in response to armouring of the bank. The bedrock flank of Mount Woodside restricts further downstream progression of the bend and hence further erosion in the immediate vicinity. It should be noted that the deposition and erosion areas shown on Figure 8 refer to island/floodplain creation and destruction. They do not refer to within channel changes, such as from gravel bar to main channel. Such changes have no reference on these maps since each year represents a different flow level (for example, 1983 was a year of high flow and hence there is little gravel bar area showing in comparison with other years).

The progressive shift of the bend to the west is a product of aggradation within the reach, as illustrated by the growth of Hamilton Bar, the bar off Hopyard Hill and changes in the Gill Island complex (Figure 1). These aggradational changes have been assessed quantitatively by comparing bathymetric surveys completed in 1952, 1984 and 1999 (Church et al., 2000). In this analysis, the gravel reach was broken up into a number of computational cells and volume changes were determined for each cell by overlaying the surveys in a GIS environment. For the study reach the relevant cells are 36 to 40 (Figure 1).

Figure 8 Bankline position of Mount Woodside study reach: a) 1928 to 1949, b) 1949 to 1962, c) 1962 to 1983, and d) 1983 to 1999.

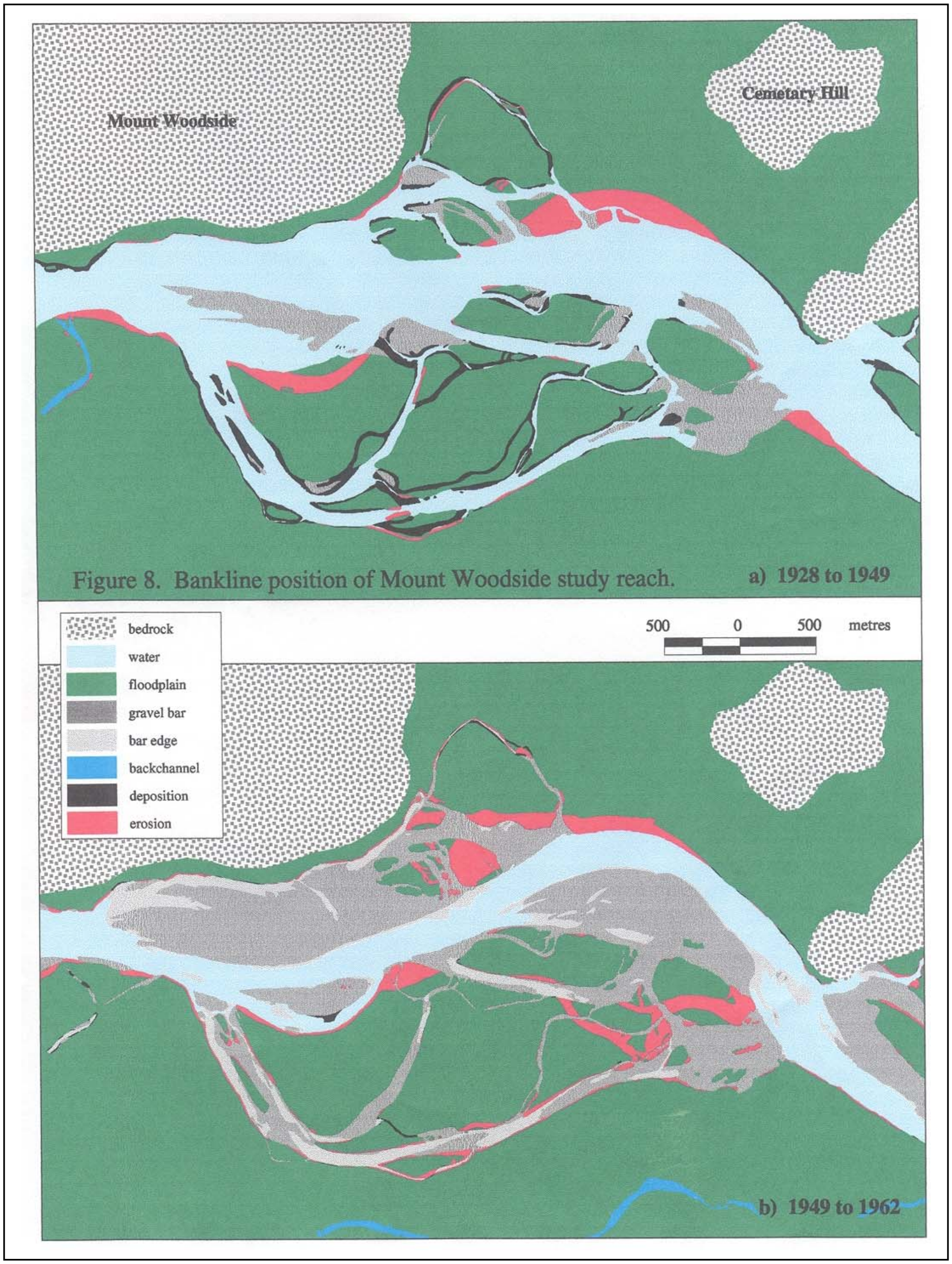


Figure 8 cont'

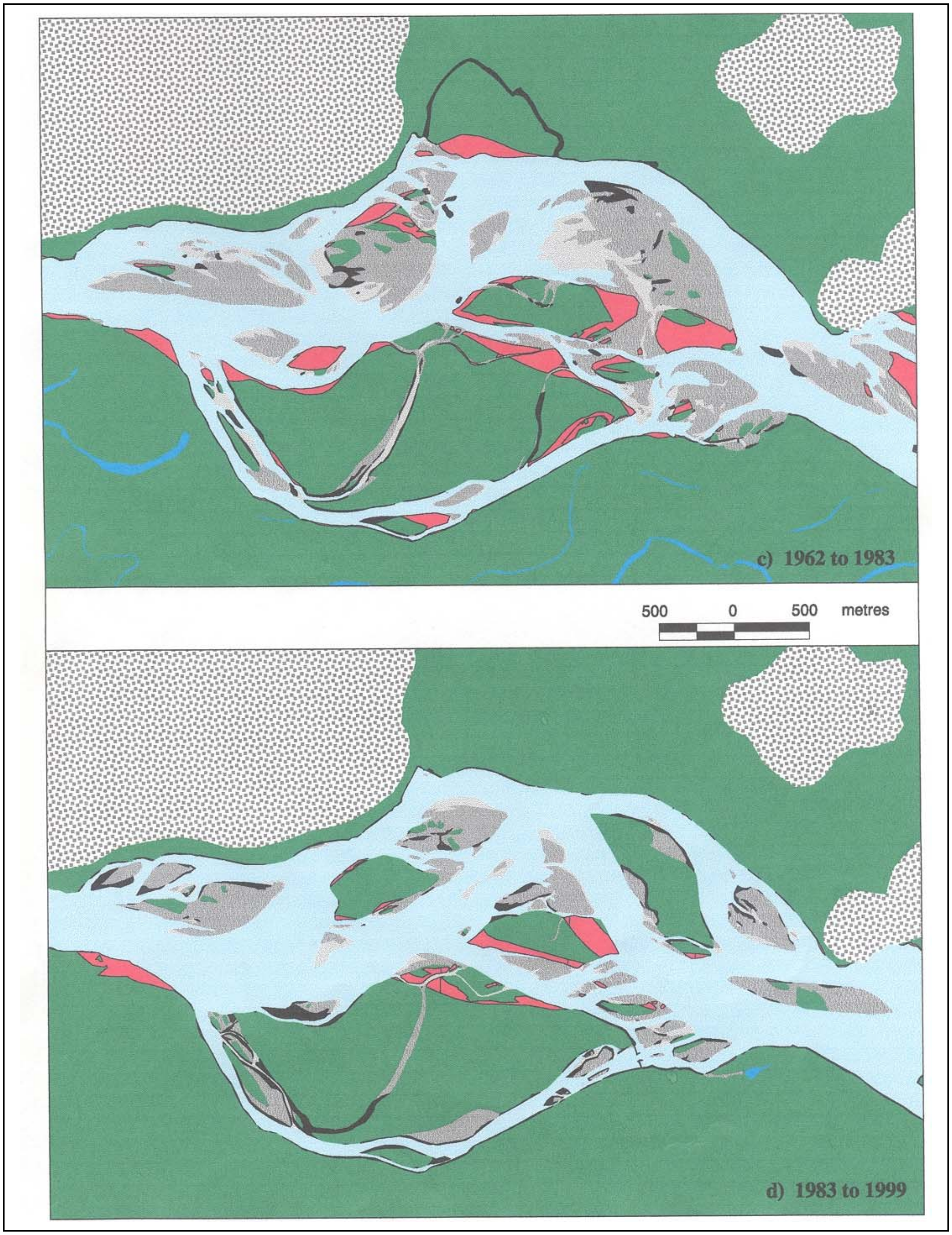


Table 2. Sediment volume changes in sub-reaches 36 to 40, 1952 to 1999. The bold row indicates the location of Kent Site G-1.

Cell	1952 – 1984 (10^3 m^3)	1984 - 1999 (10^3 m^3)	1952 – 1999 (10^3 m^3)
36	-62	306	244
37	-249	858	609
38	**450**	**326**	**776**
39	585	119	704
40	1332	188	1520
total	*2056*	*1797*	*3853*

In the early part of the period (at least to 1971), there was significant sediment exchange within the reach, with local erosion as well as deposition. After 1971, however, sedimentation trends appear to have been almost purely aggradational, apart from erosion within the Gill Island complex. Since 1971 much of the deposited material moving into the reach must have been originating upstream of the bridge. Table 2 shows net deposition throughout the 1952-1999 period between Hopyard Hill and Mount Woodside. The move of the river to the right hand side at the study site is the consequence of this sedimentation.

At a more local scale, the progression of the meander at Kent Site G-1 can be assessed by comparing bathymetric surveys of the channel completed in 1984 and 1999. Three cross-sections through the bend (Figure 9) have been constructed from these bathymetric surveys and their locations are shown in Figure 10. Since 1984 there have been relatively minor changes on either side of the bend apex (cross-sections 1 and 3). At the apex, however, the point bar off Gill Island has extended and the river has become increasingly confined against the right bank (cross-section #2).

Figure 9 Cross-sections through the study area from 1984 and 1999.

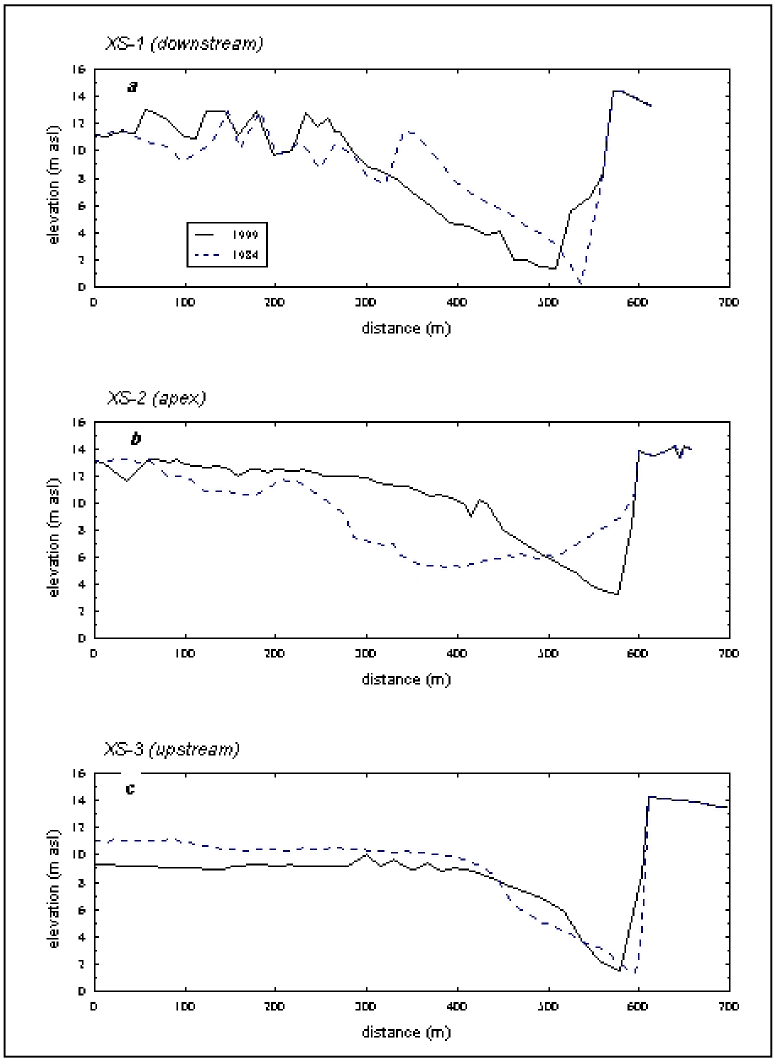
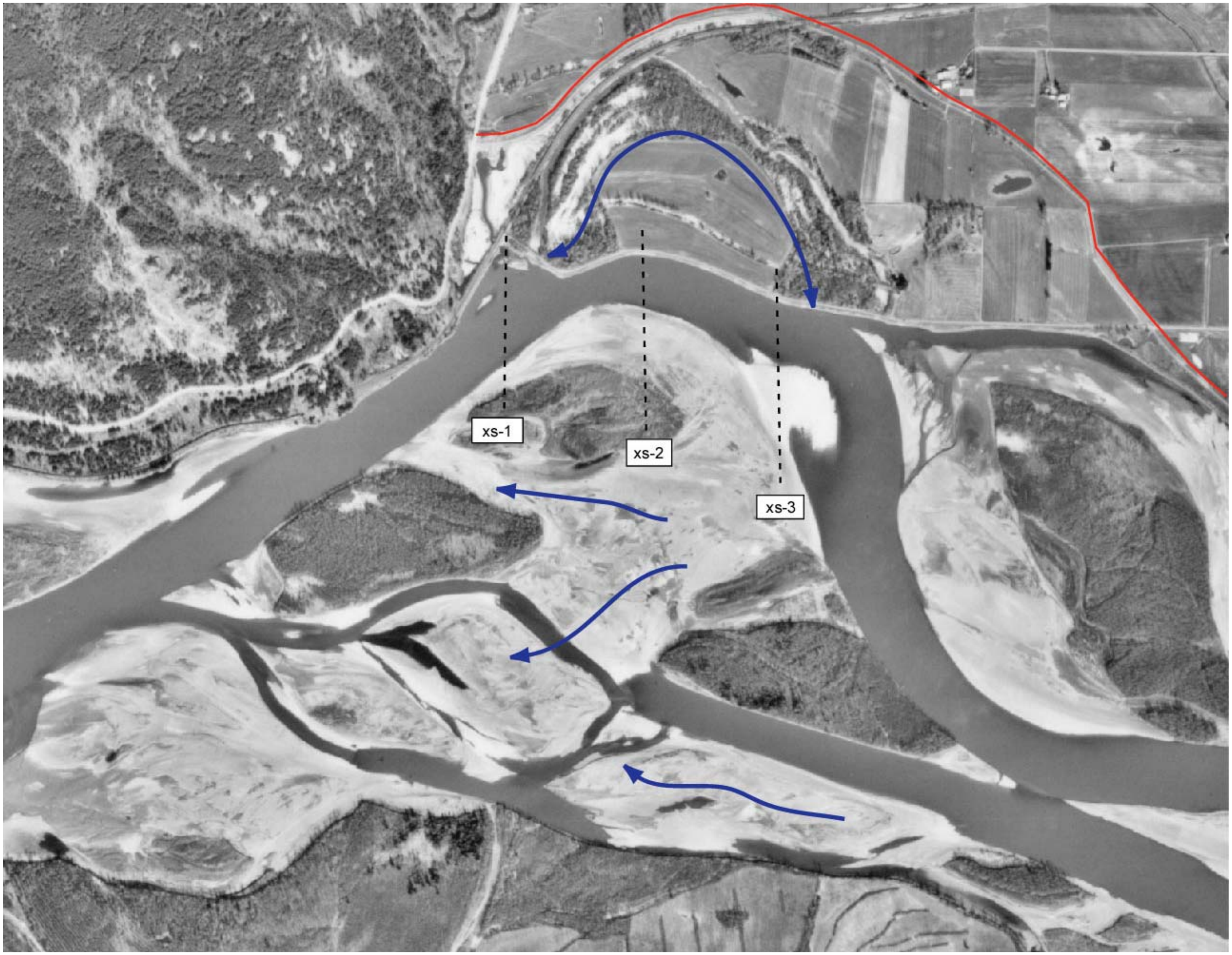


Figure 10 Potential future developments at study site and cross-section locations.



Possible future developments at Kent Site G-1

The pattern of meander development at Kent Site G-1 suggests that the bend is firmly entrenched against the north bank and could conceivably undermine the bank protection. Before the 1960s, there was room for the main channel to move both northward by bank erosion and further west in response to upstream aggradation off Hopyard Hill. In this manner the bend around Gill Island progressively shifted downstream. However, bank protection has effectively stopped bank erosion for the past thirty years and the channel has become deeper in response (Figure 9b). Further downstream movement of the bend is inhibited by the bedrock flanks of Mount Woodside.

Without bank protection, the bend would have continued to develop to the north into the area upstream of Mount Woodside where it evidently has been before, until the curvature became too great and a cut-off developed through the Gill Island complex. Despite the existing bank protection, this scenario could still develop if it succeeds in undermining the bank. Table 3 indicates the deepest scour points along the river. At 19 m below the floodplain elevation the scour at Kent Site G-1 is average for the set. Scour to 20 or 21 m appears to be not unexpected; exceptionally, it might extend to 24 or 25 m. Whether the scour at Kent Site G-1 will deepen will depend on the flow diversion upstream and how much comes against the bank. The meander presently forms a tight bend around the Gill Island point bar and a recently developed small bar off this deposit might represent the commencement of siltation in this channel, leading eventually to a new channel breakthrough at Gill Island, where erosion is occurring on the left bank. These two scenarios are outlined on Figure 10.

Table 3 Maximum scour depths along gravel reach of Fraser River, 1999 bathymetric survey data.

Location	Bank	Floodplain elevation (m asl)	Maximum depth (m asl)	Scour depth (m)
d/s of Sumas confluence	L	6	-12	18
u/s of Sumas confluence	L	6	-15	21
u/s of Cattermole Timber	L	6	-15	21
d/s of Island 22	L	8	-12	20
u/s of Queens Bar	R	9	-10	19
Harrison outflow	R	9	-8	17
Carey Point	L	11	-9	20
Kent Site G-1	R	13	-6	19
Hopyard Hill	R	16	-2	18
Agassiz-Rosedale Bridge	L	16	-2	18
upper end Peter's Island	R	22	-2	24

Overall sedimentation rates in the 1984 to 1999 period in cells 38 and 39 exceeded those of the 1952 to 1984 period. If this sedimentation pattern persists for a number of years, deposition will continue to occur off the Gill Island point bar and Hamilton Bar. Such sedimentation would increase the meander curvature, eventually forcing the river to straighten itself and erode through Gill Island.

Both of the above scenarios appear to have an equal likelihood of occurring. A close discrimination between the two will require aerial and ground reconnaissance of the site.

References

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