Changes in stream morphology at two mining sites near Reefton

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Abstract

At many mining sites, rivers and streams are diverted, and the Department of Conservation needs to ensure that these streams are left in a stable condition. There is at present little scientific knowledge to guide the Department in specifying conditions in mining access arrangements to achieve this. This report describes a 5-year study at two mining sites, during which channel changes were photographed and surveyed.

The first site is at Giles Creek, where Dunollie Coal Mines Ltd have a large open-cast mine. The second site is in a tributary of Slab Hut Creek and has been left unrestored. At both sites the stream was diverted to the edge of the site.

Both channels have widened due to bank erosion and are approaching widths comparable to those predicted by recent research. In places erosion-resistant banks are slowing or halting this process. On the other hand, erosion-resistant material at Giles Creek is contributing to erosion of weaker banks by obstructing the flow.

Both channels are steep enough to form meanders and subsequently braids. At Giles Greek, erosion-resistant banks and artificial armouring may prevent this. At the Slab Hutt Creek tributary, meanders are becoming more pronounced. This should lead to the stream breaking out into a new bed, where the ultimate form is likely to be braids.

A more general conclusion is that the channel width and form - straight, meandering or braided - can be predicted approximately using recent research results. Erosion-resistant banks resist channel widening, so that a diverted stream formerly contained within erosion-resistant banks will need a wider channel if the banks are not armoured.

1. Introduction

1.1 BACKGROUND

Recent changes to New Zealand legislation governing “access arrangements” for mining (Crown Minerals Act 1991) require the miner to restore mined land as closely as practicable to a natural state (Resource Management Act 1991). This includes restoring the pre-existing flora, but also restoring land and waterways. When streams are diverted, it may be impracticable to restore the original stream bed. However, the miner will be expected to leave a stable channel, rather than one that is actively migrating, aggrading, degrading or changing its cross-section. At present, lack of knowledge of the subJect makes it difficult to specify conditions in the mining access arrangements which in fact achieve a stable channel at reasonable cost.

The regime form of gravel-bed channels has not been definitively solved. Overseas research on channel form has concentrated on lowland streams and rivers, usually with sand or silt as the bed material. However, Ikeda et al (1988) have produced a theoretical solution for the shape of a straight uniform gravel-bed channel with cohesionless banks. Macky (in press) has recently conducted some experiments which suggest that when discharge or valley slope is high, or when the bed material is relatively fine, channels are deeper and narrower than predicted by Ikeda et al.

Cohesive or erosion-resistant bank material results in channels narrower than for cohesionless banks. Bank vegetation also reduces channel width by reducing flow velocities at the banks (Ikeda & Izumi 1990). Both effects are difficult to quantify.

The assumption of a straight uniform channel may in any case be inapplicable for higher discharges and steeper slopes. There is ample evidence that there is a threshold above which meandering occurs, but there is no general agreement on where the threshold lies (Schumm et al. 1987). There is a further threshold above which meandering is replaced by braiding. Henderson (1961) suggested a form for the threshold equation, and recent unpublished work by the writer indicates that Henderson's approach is at least approximately correct. The situation is complicated by the existence of forms intermediate between meandering and braiding (Schumm et al. 1987).

Cohesive or erosion-resistant bank material is known to affect these transitions from straight to meandering and from meandering to braiding. In particular, braiding can be suppressed, and meandering gorges incised into rock are found where the river would braid if it were not confined. The Rakaia Gorge and Waimakariri Gorge in Canterbury are notable examples of this.

1.2 SCOPE

Channel changes were monitored by the National Institute of Water and Atmospheric Research Ltd (NIWA) between 1990 and 1995 in two streams at open-cast mining sites near Reefton (Fig. 1). The larger of the two sites is at Giles Creek, at an open-cast coal mine operated by Dunollie Coal Mines Ltd. This is the site of experiments into land restoration (Ross et al. 1995). The stream has been diverted to the edge of the site, and restoring the channel to a stable and reasonably natural form is desirable not only because the legislation requires it, but also because pronounced channel changes could threaten the land restoration trials or the mine itself.

The second stream is a tributary of Slab Hut Creek, and has been diverted to the edge of its valley. Unconsolidated gold-mining tailings occupy the rest of the valley. This situation arose partly because the mining company became bankrupt, so that funds for restoration were not available.

At both sites, streams that were once partly confined by bank vegetation and bedrock are now less confined; the banks along much of the two sites are loose mining tailings with little or no vegetation. It follows that the regime channel

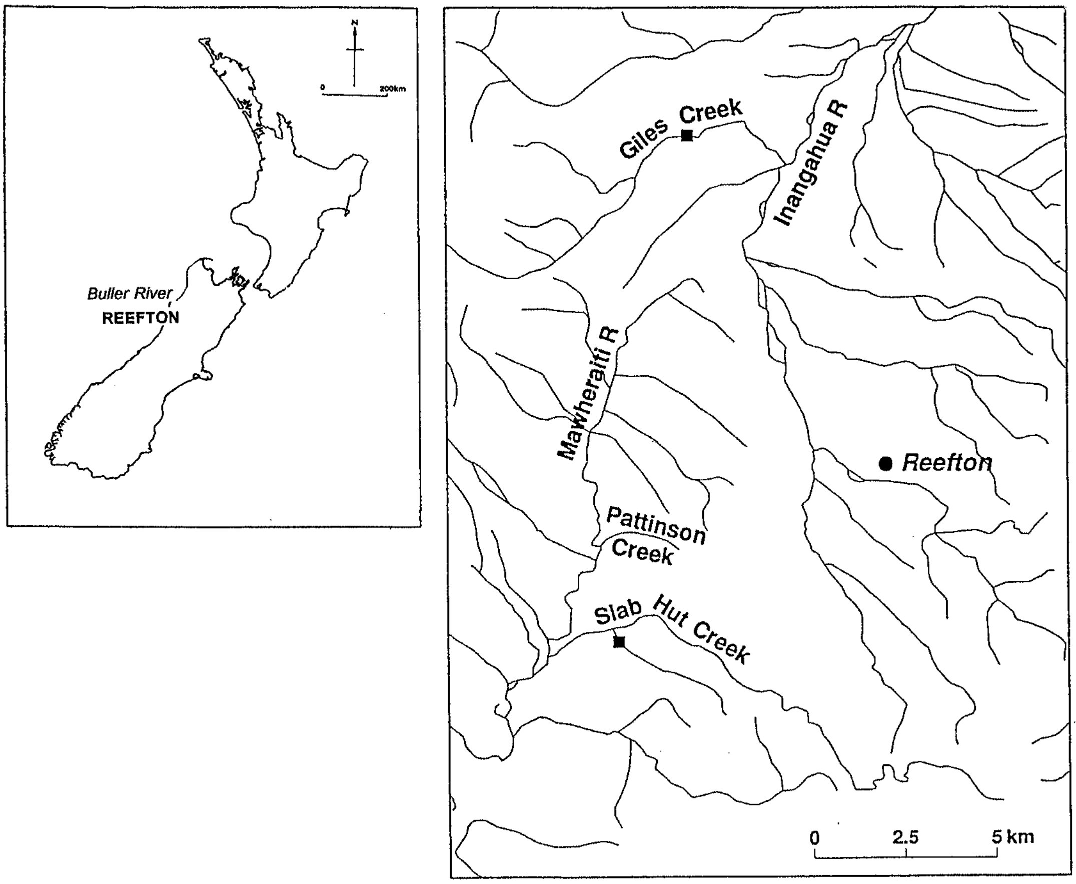

FIGURE 1. MAP OF THE REEFTON AREA, SHOWING SITES DESCRIBED IN THIS REPORT.

form for the natural parts of these streams may differ from that at the mining sites.

This study was commissioned by the Department of Conservation in order to: (i) predict the changes that will occur at the two particular sites; and (ii) improve knowledge of channel-forming processes in mountain streams, so that the Department can improve its management of artificial diversions of these streams at mining sites and other development sites.

This report completes a 5-year programme, and aims to:

(i) describe the observed changes;

(ii) predict future changes at the two sites;

(iii) recommend future monitoring, if appropriate; and

(iv) draw conclusions generally applicable to the diversion of gravel-bed mountain streams.

2. Giles Creek

2.1 SITE DESCRIPTION

Giles Creek is a tributary of the Inangahua River draining the eastern slopes of Mt Steel and Mt Stevenson. Figure 1 shows the location of Giles Creek and the mining site. In the late 1980s an open-cast coalmine was established at Giles Greek at map reference NZMS 260: L30 105074, about 3 km upstream of its confluence with the Inangahua River, which runs northwards into the Buller River. The catchment area at the mine site is about 33 km^2.

The stream was diverted to its present course to allow mining under its original bed. It is proposed to leave the stream in its present bed. Mined land is being progressively backfilled with mining tailings. At the mining site the stream cuts through several strata, including conglomerates, sandstones, mudstones and coal. However, most of the catchment is granite, and it is this material which is the predominant stream bed material. Bed material size was sampled upstream of the mine site using the Wolman (1954) method. The size distribution is shown in Fig. 2; the d_{50} and d_{90} sizes (for which 50% and 90% respectively of the bed material is finer) were 85 mm and 192 mm.

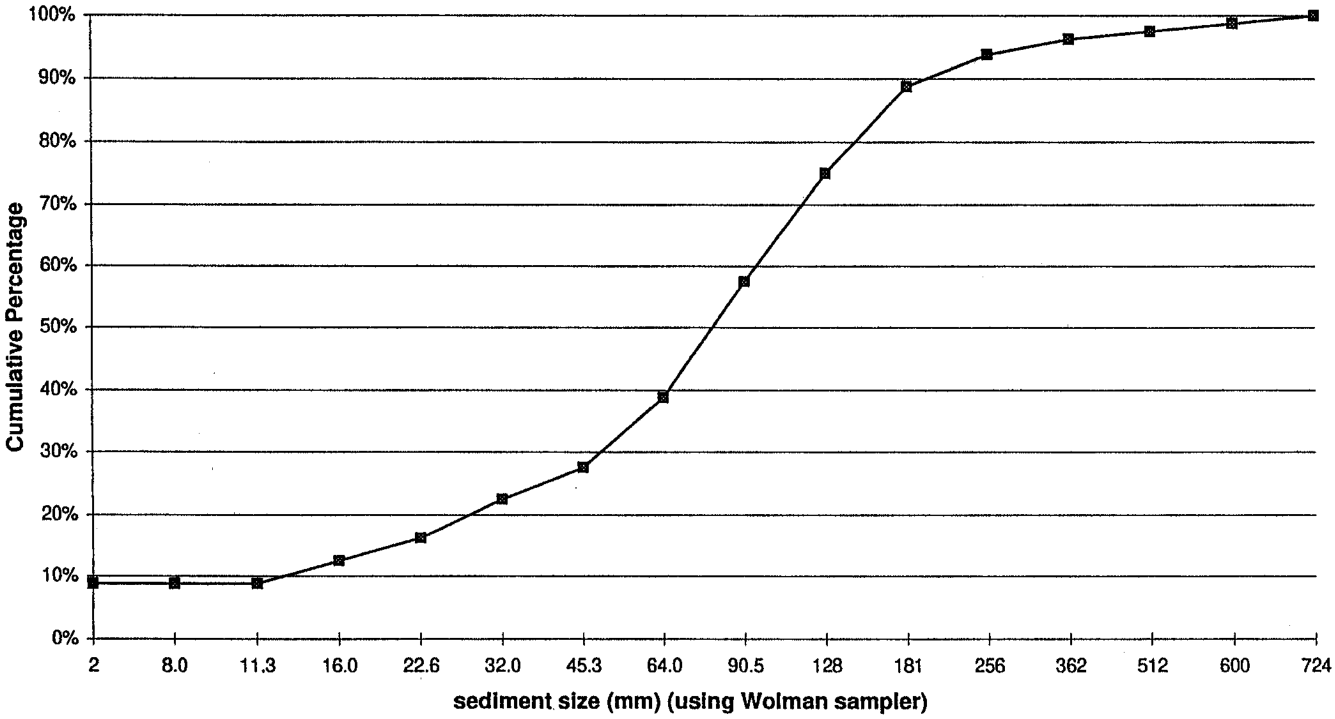

FIGURE 2. BED MATERIAL SIZE DISTRIBUTION FOR GILES CREEK.

Just upstream of the mine site the stream is about 40 m wide, and flows in a series of bends and straight reaches (Appendix Figs 1–3). The stream gradient is about 2%. Downstream of the site the channel is straight and slightly engorged. The bed width and gradient here are also 40 m and 2%. The survey data show the present bed gradient at the site to also be 2%, indicating that the original course (being less direct) was somewhat flatter.

Geological strata of widely ranging ages and types meet the surface at the mine site; variable gradients in the natural channel might therefore be attributed to varying erodibility of bedrock.

The channel diversion was cut by bulldozer. One 200 m section of channel is a contorted narrow gorge through mining tailings and native sandstone; it is understood that cutting this part of the channel was difficult. Forming the channel has left a protruding sandstone cliff at this section which is now eroding quickly (Appendix Figs 9 and 10).

2.2 SURVEY DATA AND PHOTOGRAPHS

Cross-sections were set out at about 50–100 m intervals upstream and downstream of the mine site and measured in December 1990. Repeat surveys were carried out in July 1991 and September 1994.

A plan of the surveyed cross-sections is shown in Fig. 3. Cross-section 1 (downstream) and 15-17 (upstream) lie outside the active mining site. The three sets of measured cross-sections are plotted in Figs 4 and 5. Individual surveyed points are marked in these figures. The straight lines between these points are believed to be approximately valid, but should not be assumed to be exact when inferring deposition or erosion from the cross-sections.

At each survey, photographs were taken from each survey peg, as well as additional photographs of the gorged and eroding middle parts of the site. The site was also visited and photographed in January 1992, May 1992, January 1993 and March 1995. The last visit, after the final survey, was made to observe the effects of floods since the previous September. It was clear from the appearance of both sites that they had experienced a major event. It is difficult to determine the severity of floods in Giles Creek because rainfall appears to vary quite widely within the region and there are no nearby gauged catchments. However, flows measured in Pattinson Creek on 7 November 1994 were the second highest in a record dating to 1978, and it is reasonable to assume that the Slab Hut Creek tributary also experienced a major flood on that day.

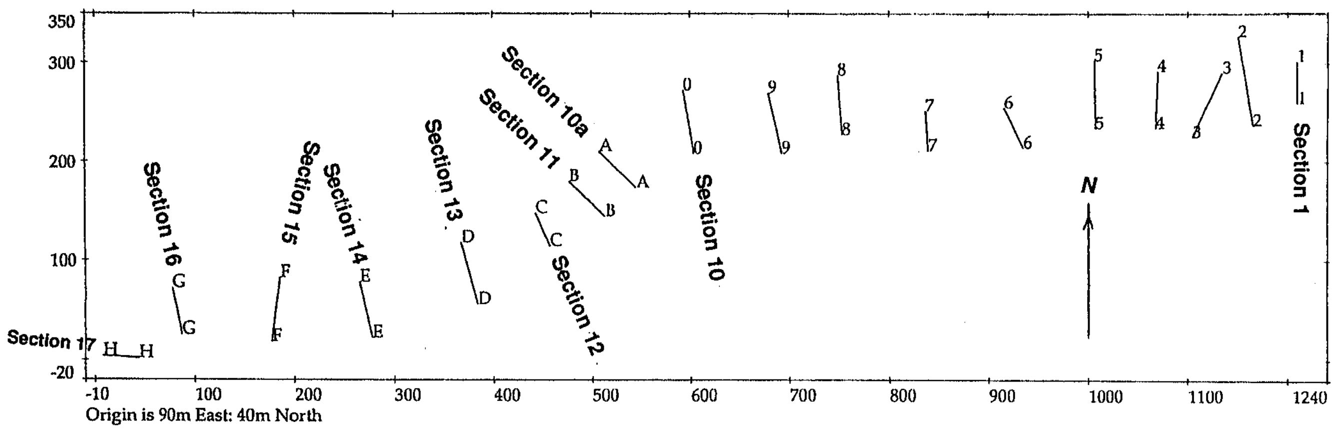

FIGURE 3. MAP OF SURVEYED CROSS-SECTIONS, GILES CREEK.

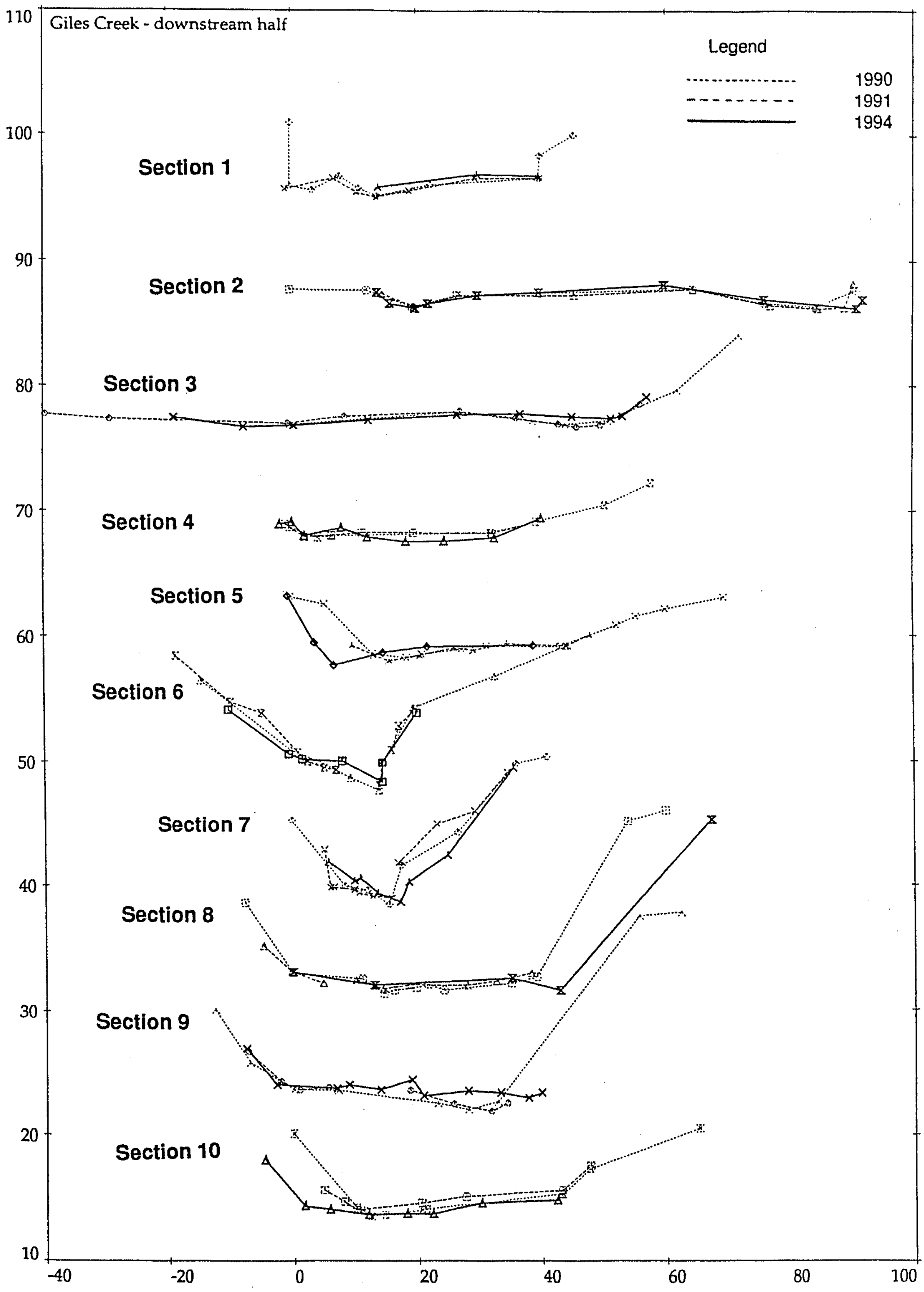

FIGURE 4. SURVEYED CROSS-SECTIONS DOWNSTREAM OF MINE SITE, GILES CREEK.

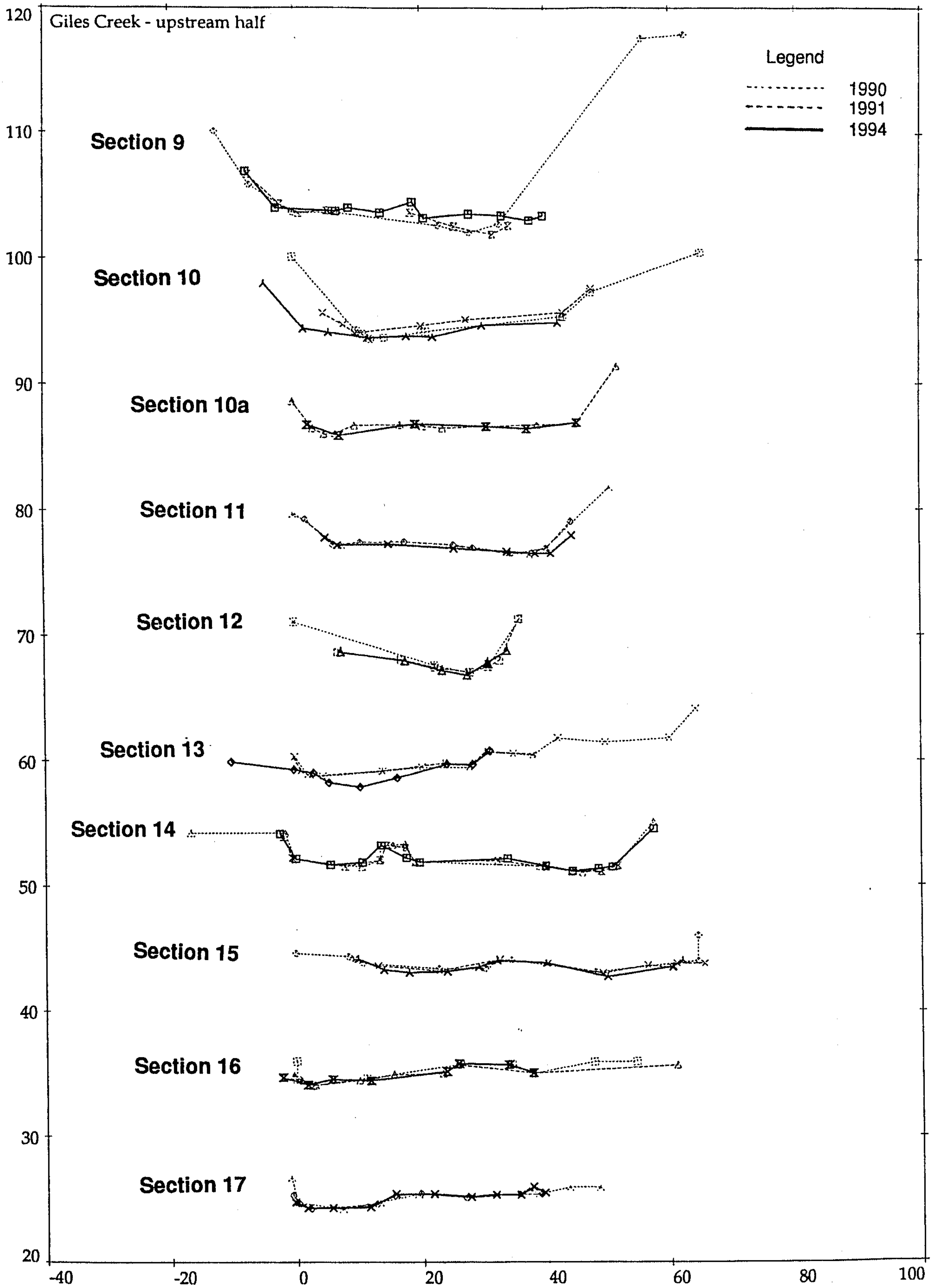

FIGURE 5. SURVEYED CROSS-SECTIONS UPSTREAM OF MINE SITE, GILES CREEK.

2.3 OBSERVED CHANGES

No change was measured at cross-sections 10a–17 between 1990 and 1994, and the January 1995 floods appear to have caused only minor bed changes and some bank erosion at Sections 10a–11 (Fig. 5). Sections 15–17 are in an undisturbed part of the natural channel, which appears from inspection to be fairly stable, with only gradual erosion on the outside of bends (see Appendix Figs 1–3). The artificial channel diversion starts at section 14, but the true right bank has been protected with rip rap rock and the channel is a similar width to the natural channel.

The banks are eroding at cross-sections 6–10 (Appendix Figs 4–10). The sandstone cliff on the true left bank between sections 7 and 8 is eroding rapidly; this narrow part of the channel is crooked and there is a large hole on the true right bank scoured by an eddy (Appendix Fig. 9). Flood flow through this section is particularly turbulent. Just upstream, between sections 8 and 10, the channel is much wider but is nevertheless continually eroding its banks (Appendix Figs 6 and 7), although on the left bank at sections 8 and 9 the process is at present too slow to show up in cross-section surveys. The thalweg meanders from bank to bank. The true right bank is composed of mining tailings on top of what appears to be native sandstone; much of the visible loss of land is due to slip failure of the tailings, which still form a steep and unstable face.

Cross-sections 5–6 lie in loose tailings mixed with some more solid material; the true right bank near section 5 has been protected with rip-rap rock (Appendix Figs 4 and 5). Changes here have been minor compared with sections 6–10, and mainly limited to erosion of the very loose material on the true left bank (Appendix Fig. 8).

Further downstream the channel returns to a wide, stable condition. At cross-section 1 the stream is back in its natural channel, where a hole too deep to survey has formed on the true left side since 1991.

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