Franz Josef Glacier access road - security of road-end facilities

T R Davies
Department of Natural Resources Engineering
Lincoln University

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Abstract

Lack of adequate information on the past behaviour of the upper Waiho river and valley makes reliable prediction of the nature, magnitude and timing of future erosive and depositional events extremely difficult. Management of facilities in the valley requires such information; it is recommended that a monitoring programme be commenced immediately, and that information of this nature presently in DoC archives be catalogued and organised into a historical record.

The information kiosk and car park at the Franz Josef Glacier access road end are presently at significant risk from either or both of river bed aggradation and river bank erosion. The toilet building at this site is less at risk.

The two viable strategies for reducing this risk are relocating the kiosk and developing additional car park space elsewhere, or protecting the river bank against erosion. The former is much more likely to be effective than the latter.

In the short to medium term (0 to 5 years or so), adequate security could be attained by moving the kiosk about 50 m back along the road. In the longer term (5 to 50 years) it is possible that further substantial aggradation could necessitate further relocation of kiosk, toilet and car park to a significantly higher terrace by the 1894 terminal position.

In the longer term the viability of facilities at the present road end could be subject to external factors such as maintaining the access road farther down the valley.

1. Introduction

About 100,000 people a year visit the Franz Josef Glacier by road. Many leave motor vehicles at the road-end car park and walk to the glacier, having visited the information kiosk. Any substantial interruption to the availability of these facilities would have a serious effect on visitor numbers, so the security of the facilities against destruction is a high priority. Of the several potential hazards, river action is the most likely and the most serious.

The upper Waiho is one of the most energetic river environments in New Zealand. The river has its source in the Franz Josef Glacier, and is fed with sediment by the glacier and by mass wasting on the high, steep valley walls. Runoff in the steep, rocky and glaciated catchment is very rapid and the frequent intense rainstorms give rise to rapid, fierce floods carrying very high sediment loads. The valley is crossed by a number of spectacular faults, probably splinters from the Alpine Fault which crosses the river about 8 km downstream of the car park. Fig. 1 shows the situation of the upper valley with

most of the locations referred to herein marked; it should be referred to by the reader throughout this report.

The upper Waiho valley has only recently been deglaciated. The present car park area probably emerged from beneath the ice of the retreating glacier about a century ago, and about 40 years ago the terminal face was close to its present position; in this 40 years the glacier has retreated about 2 km into a rock-bound gorge and advanced out of it again.

In this energetic and dynamic environment it is very difficult to establish permanent facilities. Even today's sophisticated technology and huge earthmoving capability are no match for the erosive power of the Waiho river in full flood, with its ability to also deposit huge volumes of sediment in a very short time. Siting facilities to avoid these processes is therefore of the utmost importance.

This report attempts to foresee the likely behaviour of the upper Waiho river valley system in the short- to medium-term future (0 to 20 years) and the implications of this behaviour for the security of the car park and information kiosk. Some possible strategies are suggested for improving the security of the facilities.

2. Terms of reference

The terms of reference for this report are to evaluate the current road-end options for the relocation of the kiosk, car park and toilets:

1. Provide an assessment of the current and predicted future aggradation rates at or near the road end, assuming current rates and processes;

2. Explain how this aggradation does or will influence river behaviour in the vicinity of the road end;

3. Identify sites least vulnerable to erosion at or near the road end;

4. Estimate probability (and predicted time frame) of erosion at these sites.

3. History

Given the fact that the upper Waiho has for many years been visited by large numbers of people and administered by a government department, there are remarkably few data available with which to reconstruct the past behaviour of the system. One set of historical survey data has been identified (Hoey 1990), and a further set is now being prepared (Wilshire 1997); apart from this, occasional aerial photography (NZ Aerial Mapping 1965, 1981 and 1985;

DoC, 1995, 1996) and personal recollections of persons who have regularly traversed the valley (Melsop 1997; Miller 1997) are the only sources of information. The archives of the Department of Conservation at Franz Josef might well contain valuable information but this is not in a useable form at the time of writing this report.

Comparison of the Hoey (1990) and Wilshire (1997) surveys will provide the only available data on aggradation rates in the upper Waiho valley. This information is however not yet available. When it becomes available it should be used to check the recommendations of the present report.

The reports of Mosley (1983), Hoey (1990) and Thompson (1991) all consider the causes and inferred future behaviour of the troublesome aggradation of the Waiho river bed at the SH 6 highway crossing about 8 km downvalley of the road end. All attempt to relate this aggradation to glacier behaviour, with different conclusions in each case. Their conclusions are of limited value in the present study, because conditions at the SH 6 bridge are significantly influenced by the Callery river which flows into the Waiho about 500 m above the bridge; the Callery has a larger catchment than the Waiho, and larger area of glaciation. Nevertheless their discussions of the effects of glacier advance and retreat on sediment delivery to the river system are interesting, particularly that of Mosley (1983).

The general behaviour of the glacier to the early 1990s is summarised by Brazier et al. (1992) and references therein.

The following sequence of events relevant to the evolution of the present situation in the upper Waiho valley is tentative, due to the paucity of firm historical information presently available.

The glacier terminal face retreated southwards past the present carpark area in the early year of the present century, leaving moraine material to be reworked by the river and transported downstream. At or prior to this time a stream flowed through the small valley occupied by the present road, high above the main river bed. During the 1930s and 1940s, a large lake occupied the present river bed upstream of the line of *roches moutonnees* running out from Sentinel rock. This gradually infilled with sediment, finally disappearing (probably by breaching) in the 1940s. In the 1965 air photos, the terminal face of the glacier was about a kilometre upvalley of its present (March 1997) position; the river bed was quite deeply incised into the valley fill, which appears to have been a little below its present level, along the whole of the upper valley. The presence of vegetation established on much of the valley fill indicates that the river position was fairly stable.

By 1981 the river, although still somewhat incised, had reworked the whole width of the valley bottom as shown by the absence of vegetation; this indicates that general aggradation had occurred since 1965. The road now extended up the south side of the valley to the vicinity of Split Apple Rock, presumably indicating that the river had not impinged against the western valley side for a considerable time prior to 1981. By 1985, however, the car park was on the river bed just upstream of the present kiosk site, indicating that the river was again laterally mobile in spite of remaining incised. At this

time, erosion (basal undercutting) of the high moraine wall on the west side of the valley commenced. During the early 1980s there were two very heavy rainstorms and commensurately high flows, which did considerable damage in the vicinity of Franz Josef township but the 1985 air photos show little sign of significant river behaviour change in the upper valley. These storms, however, probably caused the river channel movement that forced the car park to be moved back downvalley.

In about 1983 the glacier began an advance that has so far lasted until 1997. This long advance was not expected, and even in 1990 Hoey, in a report to the West Coast Regional Council, did not anticipate its long continuation. As noted above, it seems likely that aggradation in the upper valley had been ongoing for at least a decade prior to the beginning of this latest advance. In January 1994, and in January and December 1995, flood events occurred that led to further substantial aggradation of the upper valley; the two January floods coincided with local subsidence of parts of the glacier surface (Melsop 1997). Delivery of sediment to the upper valley from the December 1995 event was massive, resulting in a prominent central bulge in the valley floor; this was surfaced with many very large, sub-rounded boulders underlain by massive, unsorted debris reminiscent of debris flow deposit, though with occasional stratification being apparent. The river has since begun to incise the upstream end and true right edge of the massive deposit, reworking it downstream.

During the last year or so the river has remained close to the true right boundary of the valley as far down as the car park. At present, however, it is showing signs of lateral instability at several positions below the terminal face, and it is very likely that it will begin to move across the valley again soon. This will probably be as a result of further reworking of the aggradation deposit, so any avulsion is more likely (though by no means certain) to occur within a kilometre above the car park, since this reworking involves removal of sediment from the upper part of the valley (by river incision) and its redeposition farther downstream where the valley slope is less. This redeposition causes river bed levels to increase and braiding to occur, and tends to cause the river to break out sideways ("avulse") to follow a path across the valley.

The future behaviour of the glacier obviously influences the future behaviour of the river very significantly. Certainly, the river valley has been aggrading during the present advance, and it seems reasonable to expect that if the advance continues, so will the aggradation. The year-round westerly wind components appear to correlate fairly well with glacier behaviour, in that strong westerly components are associated with subsequent glacier advances. Westerly components have been high since about 1980; they appear to be still increasing (Larsen 1997), and as a consequence there is little reason to expect that the present advance will cease in the near future. There is thus correspondingly little reason to expect the present aggradation to cease in the near future.

4. Processes

In assessing the likely future behaviour of the river system, in particular the probability of bank erosion or aggradation at the information kiosk, it is helpful to appreciate the processes that influence river behaviour.

Rather than going into the details of sediment transport and deposition mechanisms, it is useful to consider the upper Waiho river valley to be an alluvial fan, that is, an area in which sediment is temporarily stored after being delivered from upstream by the river and before being moved away downstream. Most alluvial fans are undergoing long-term aggradation, because the sediment-transporting capacity of the river delivering sediment to the area is greater than that of the river as it flows through the area, due to the reduction in confinement and slope as the river exits from (in this case) the subglacial tunnel; this is likely to be the case in the upper Waiho valley and it is certainly true of the lower fan downstream from the Callery confluence (Davies 1997).

Process studies of alluvial fans (Zarn and Davies 1994) show that the river feeding the fan typically moves from side to side over the whole fan surface in oscillatory fashion. As the river builds up its bed by depositing sediment on it, the river level becomes higher than that of adjacent parts of the fan and there is an increasing tendency for the river to avulse on to the adjacent lower surface and to build up that in turn. In this way the fan surface (or, in the case of the Waiho, the valley surface) aggrades relatively evenly.

Sediment is delivered to the proximal (i.e. fan-head) area in the subglacial river flow; in the Waiho case it can also enter from the valley sides and small tributary streams, but this contribution is probably fairly minor judging by the usually small size of the fans from these tributaries. Aggradation in the proximal area due to large sediment delivery is termed *primary* aggradation. In the Waiho, the massive deposition following the 1994/1995 storms was of this nature, and it extended about as far as Sentinel Rock. In the absence of sediment input from these primary sources, the river will erode material from primary deposits by incising itself into them and literally eroding its banks; in so doing it reduces its gradient and forms a *fan-head trench.* The material it thus carries is then deposited farther downstream, below the primary deposit, there forming a lower-angle sub-fan by *secondary aggradation.*

5. Application to the Waiho

Sediment input is the primary variable determining the response of the upper Waiho river and valley system to storms. Sediment input may well be related to glacier behaviour (Melsop 1997), but this relationship is not well understood at present. Two distinct scenarios are possible in the future: either sediment inputs will be high, or they will not.

If sediment inputs are high, there is a strong possibility that the primary aggradation that occurred in 1994/1995 will be repeated. This conclusion is independent of the source of the sediment. In this case the aggradation experienced in the proximal area will increase and extend downstream, probably affecting the car park and kiosk area as in 1994/95.

If, on the other hand, sediment inputs in future storms are significantly *lower* than previously, then the proximal fan area will become entrenched and a sub-fan will begin to develop lower down. There is evidence that this is presently occurring in the Waiho, with distinct incision and lateral erosion just below the glacier terminal face and a sub-fan of finer material beginning to accumulate in the vicinity of the Sentinel Rock Teichelmann Rock *roches moutonnees.* These form a significant obstacle to flood flows, allowing sediment to deposit. This conclusion is supported by the fact that the valley floor slope decreases perceptibly just above the car park section; the lower slope will encourage deposition of sediment and aggradation. Thus both a surplus and a lack of sediment input are likely to give rise to aggradation in the car park area.

In either case, the main stream of the river is quite capable of altering its present course to flow close the present kiosk site, as it did prior to December 1995. During present medium to high flows the river is obviously close to avulsion in the 500 m above the *roches moutonnees,* and a minor fresh could result in the main flow abandoning its channel along the north side of the valley and passing through the gap in the *roches* close to the kiosk. Since the incised channel in the proximal area is less likely to change its course dramatically, the river is likely to flow diagonally across the valley towards the car park soon. This is more likely to occur as a result of low sediment inputs than as a result of massive inputs like those of 1994/95. A repeat of those events could also lead to the river channel changing its position, but such massive valley-centre deposition seems likely to cause the new channel to follow one or other of the sides of the valley as far as the Sentinel Rock section, rather than approaching the car park area diagonally across the valley.

Future sediment inputs of a moderate nature could conceivably supply just enough sediment to the river to allow it to maintain its present position and gradient. This would be a coincidence, and it is much more likely that sediment input will be such as to over- or under-supply the river.

If significant *degradation* were to occur at the car park site, this would result in the bank supporting the kiosk being undercut and becoming unstable. This only seems feasible if the river impinges directly on the site; degradation, by contrast with aggradation, is a local phenomenon and affects only the immediate area of the river channel. It is, however, a correspondingly more energetic and destructive process, and protection of the kiosk site against its action would be a huge challenge. Degradation seems, however, to be unlikely given the present processes operating. It could only occur once the massive sediment deposit in the upper valley was no longer being reworked by the river, and the river would need to become very deeply incised higher up the valley unless the whole width of the valley fill had been reworked downstream.

In summary, irrespective of the behaviour of the glacier, there is reason to believe that further aggradation is likely to occur soon in the vicinity of the kiosk and car park. It is also likely that the river will soon alter course so as to flow to the south towards the kiosk site. Although it is impossible to predict the timing of these events, if indeed they take place at all, the threat of river erosion seems rather more urgent than that of aggradation, but the most likely scenario is that of *combined* aggradation and erosion.

6. Preventive action

There is no action that can be taken to reliably prevent the river either aggrading or avulsing; such things are beyond present engineering capability, and would in any case be undesirable due to the unforeseen consequences that could result from altering the behaviour of a powerful, complex and poorly understood natural system.

It is possible to attempt to protect the present kiosk site from river erosion by *rock lining* of the bank below the kiosk. The existing rock groyne upstream of the kiosk will afford some protection if the river approaches the site by flowing along the valley side, but none at all if the river approaches from its present position on the other side of the valley. It is, however, asking too much of rock protection of the standard affordable in such a situation to withstand the concentrated flow of the Waiho river. It is my opinion that even with rock protection in place the kiosk at its present site would remain liable to destruction by river erosion. Such erosion would also threaten the lower part of the car park.

Protection against aggradation can only be provided by erecting a *stop-bank*, as has been done at the Holiday Park site below the SH 6 bridge. This is in principle a denial of the power of natural processes; once implemented, it locks the users of the "protected" site into a battle against nature which there is very little possibility of winning in the long term, and which there is a very high probability of losing catastrophically in the short to medium term. From the point of view of the visitor, a massive gravel bank obscuring the view of the glacier would in any case be an obtrusive and inappropriate structure.

The strategy of *relocating the facilities* to be out of reach of river aggradation and erosion is a much more sensible one, particularly in a National Park setting. If the kiosk were moved back to a slightly higher position at the present entrance to the lower car park, it would be beyond reach of river erosion; in order for the river to gain access to it, it would have to flow into and out of a narrow embayment between moraine walls, which it could not do with the force needed to erode the ground underneath the kiosk. The suggested site, being at a higher level than the present one, would be less susceptible to aggradation. Relocation would thus remove the threats of both erosion and aggradation for a time. In the longer term (a few major storm events, or a few years) it is certainly conceivable that the river could widen the embayment, and the suggested site would then become much more susceptible to river erosion.

If aggradation and/or erosion were to continue so as to make the suggested site untenable, a further site is available at the higher terrace by the 1894 terminal face location where a picnic shelter is at present. This is several metres higher than the present site, and would be ideally suited for a kiosk, with a good view of the glacier and protection from inundation by flood debris from the valley sides. Across the road, between this site and Sentinel Rock, the same raised terrace would provide ample car park space but would be liable to occasional flooding and sedimentation from small valley-side creeks. These latter sites are fairly safe from river hazards for many years; by the time they do become thus threatened, it is almost certain that other access problems (such as maintaining the road alignment farther down the valley) will have become much more serious.

The present toilet site is sufficiently far back from the river bank, and at a slightly higher elevation, that no relocation is recommended as being necessary in the near future. If it becomes necessary to relocate the kiosk to the higher site by Sentinel Rock, relocation of the toilet would be needed also at that time.

7. Discussion

Whether the above options are economically justified is open to question. Relocation of the kiosk will not be cheap, and it might be preferable to wait to see what happens to the river system with a view to relocating the kiosk only when it is seriously damaged. Although the indications are that aggradation and/or erosion will be renewed at the site soon, there is no certainty as to when "soon" will be, and it is conceivable (though in my opinion unlikely) that the kiosk could remain undamaged at its present site for several years. It could also be suggested that money spent on rock protection of the present site, though only postponing the inevitable, would be a worthwhile investment if it delayed the cost of relocation, as is possible (but by no means certain).

As suggested above, the question of how to maintain facilities at the road-end is not independent of the whole question of access to the Franz Josef glacier; if the access road is unable to be maintained along its whole length the facilities at its end become a bit academic. In addition, the effort put into maintaining access at Franz could well depend on the access situation at Fox, as well as on what is happening to hazard management at the SH 6 bridge and in Franz Josef township in general.

The present lack of information on the behaviour of the river/glacier system must be rectified as soon as possible if management of human use of the system is to improve in the future. Regular aerial photography, with sufficient scale, control and overlap to allow stereo viewing and measurement of elevations by photogrammetry, needs to be introduced immediately so that a database can be built up recording the changes in the valley floor and, if possible, on the glacier as well. The present survey (Wilshire 1997) is an excellent opportunity to establish ground truth for such photography.

It is apparent from the nature of the analysis above that little is presently understood about the way in which the glacier responds to weather patterns or about the way in which the river system responds to glacier fluctuations. The qualitative response of the river system to variations in sediment input is understood in general terms, but the details are by no means clear; for example, the process that deposited the massive bulge in the valley floor in the 1994/95 events, and the source of the sediment that constitutes it, are unknown and possibly new to the science of glaciofluvial geomorphology. The recommendations that follow are therefore made, and must be considered, with a clear appreciation of;

1. the erosive power and sediment delivery capability of the upper Waiho river system.

2. the inability of present-day understanding and technology to reliably and sustainably modify the behaviour of the system.

3. the largely unknown dynamics of the system.

4. the largely unknown future behaviour of the system.

The recommendations are therefore precautionary in nature, being intended to have a reasonable probability of being effective without implying catastrophic consequences if they are not.

8. Recommendations

1. Serious consideration should be given immediately to relocating the present information kiosk to a position approximately 50 m back along the road, where it is a relatively safe distance from the river bank and at a significantly higher elevation than its present site. The present toilet site is probably safe for the short-term future.

2. The car park should not extend beyond the new site of the kiosk.

3. No further attempt should be made to impede erosion processes in the vicinity of the present kiosk site.

4. In the event that the recommended new kiosk and car park sites become threatened in time, consideration be given to further relocation to the higher terrace close to the 1894 terminal face position; unless by that time other factors make this unnecessary.

5. In order to improve the information available for future decision-making about management of facilities at the road-end (a) regular monitoring of valley floor levels and river position should be commenced as soon as possible, and (b) the information on past valley floor levels and erosion/aggradation events presently in Department of Conservation

archives should be extracted and made available to managers as soon as possible.

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10. References

Brazier, V, Owens, I F and Soons, J M (1992): Report on the Franz Josef Glacier. *Zeitschrift fur Geomorphologie*, Suppl.-Bd 86, 35-49.

Davies, T R (1997): Waiho River fan, Westland, New Zealand - LongTerm Management Planning on an Active Alluvial Fan. Submitted to *Journal of Hydrology* (New Zealand).

Department of Conservation (1995): Franz Josef valley and glacier, routine photography.

Department of Conservation (1996): Franz Josef Glacier access - terminal to township. Photography 65/3 and 4, 22/2/96.

Hoey, T (1990): Aggradation in the Waiho River - Final Report to the West Coast Regional council 15 p _ App.

Larsen, S (1997): *Personal communication*, Dept of Natural Resources Engineering, Lincoln University.

Melsop, M (1997): *Personal communication,* Franz Josef.

Miller,A (1997): *Personal communication,* Franz Josef.

Mosley, M P (1983): Response of the Waiho River to variations in Franz Josef glacier. *Report No WS 858*, Hydrology centre, Christchurch.

New Zealand Aerial Mapping (1965): Photographs 3721/26 and 27.

New Zealand Aerial Mapping (1981): Photographs SN 5773 F/1 and F/2.

New Zealand Aerial Mapping (1985): Photographs SN 8478 E/I1 and E/12.

Thompson, S M (1991): SH 6: Waiho bridge waterway requirements. *Report No CR91.01*, Hydrology Centre, Christchurch.

Wilshire,J (1997): MSc thesis, Geography Dept, University of Canterbury.

Zarn, B and Davies,T R (1994): "The significance of processes on alluvial fans to hazard assessment". *Zeitschrift fur Geomorphologie*, 38, 4 487-500.

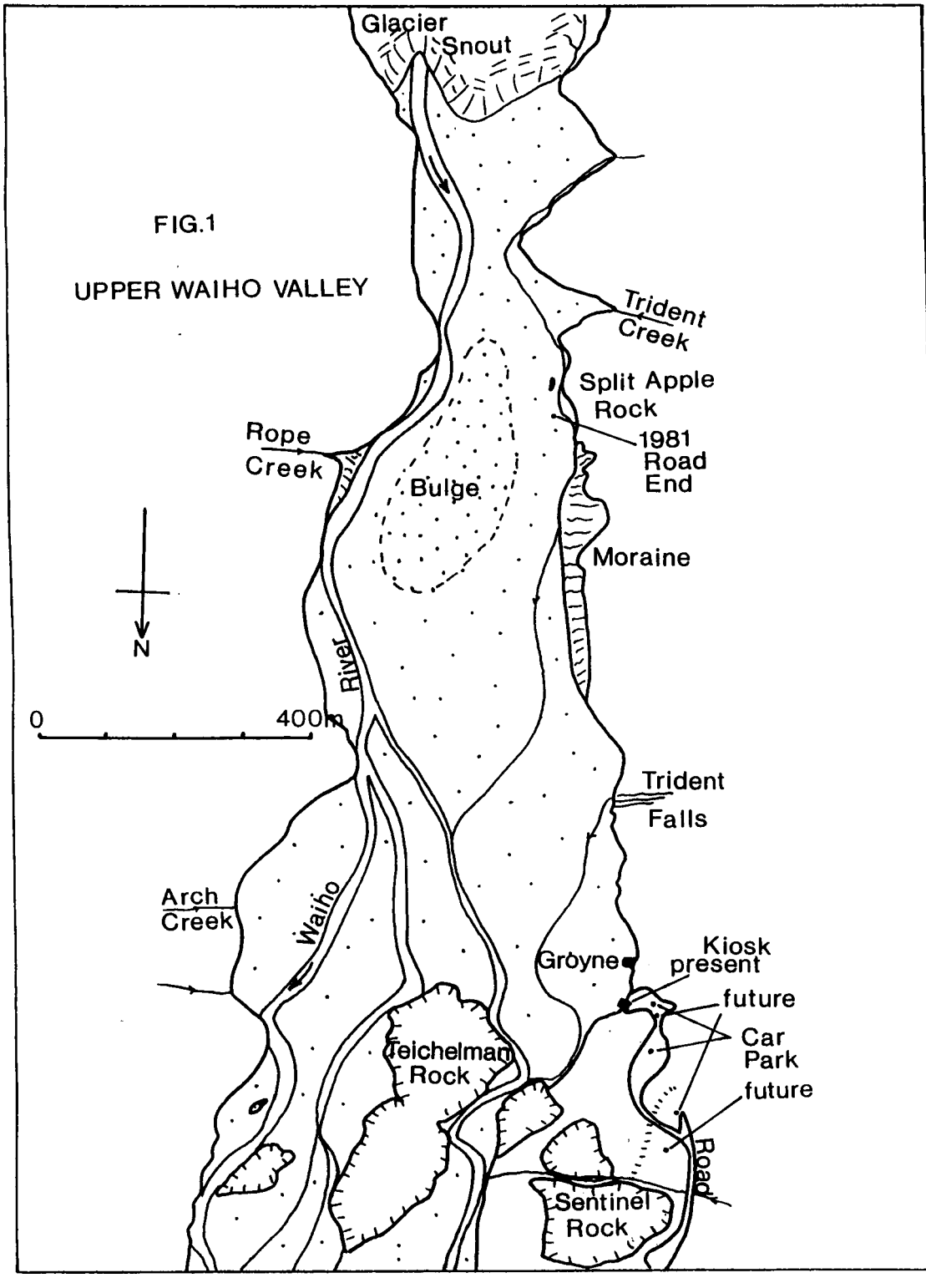

Figure 1: Upper Waiho Valley