INITIAL RECONNAISSANCE OF THE EFFECTS OF CYCLONE KINA IN CENTRAL AND EASTERN VITI LEVU

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INTRODUCTION

After several days of slow southerly movement well to the northwest of Nadi, Cyclone Kina passed through the Fiji Group on 2-3 January 1993. The cyclone followed an approximate southeasterly track from the Yasawas, through the Vatu-I-Ra Passage, Lomaiviti, and Southern Lau (Figure 1).

The cyclone caused extensive damage, initially estimated at F$160 million, and 23 people were killed. Major impacts on the physical environment, noted in this report, were caused by river flooding and bank erosion, coastal flooding, and the production of coral debris banks on the reef edge.

Once the road infrastructure in the Central Division became largely re-established, Mineral Resources Department in conjunction with SOPAC (South Pacific Applied Geoscience Commission) carried out a 4-day initial ground reconnaissance of the effects of Cyclone Kina during the period 6-12 January. The area covered was the larger part of Viti Levu, east of a line from Rakiraki to Galoa and includes the Rewa and coastal catchments of eastern and southern Viti Levu and the Navua delta (Figure 2). Access to the upper Wainimala-Monasavu area was prevented by a large landslide which completed blocked the road half way between Naivucini and Naitauvoli villages. Access to Namosi from Nabukavesi was also prevented by many landslides along the road, and from Naggali by a large landslide about half way between Wainawaga and Nasirotu Villages.

The inspection party comprised of R. Howorth from SOPAC, and B. Rao, S. Prasad, V. Baleivanualala, D. Reddy, S. Deo, J. Maikeli, S. Vakacegu and M. Naivia of the Mineral Resources Department.

This reconnaissance will be extended as full access becomes re-established. However, this report is intended to give some immediate indication of the effects of Cyclone Kina on the physical environment.

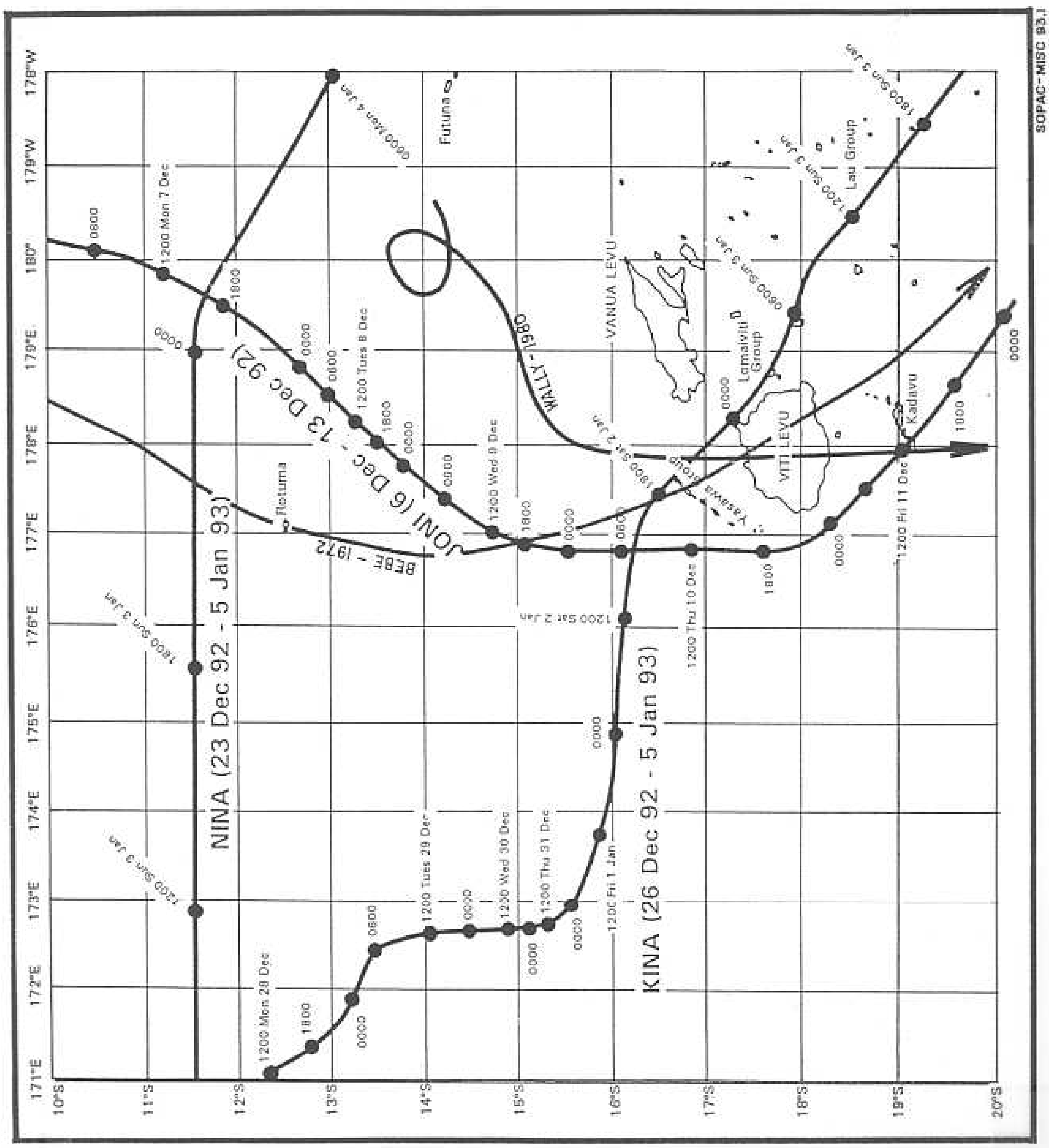


Figure 1. Tracks for Cyclones Kina, Nina and Joni (December 1992 - January 1993). Included for reference are the tracks for Cyclones Wally and Bebe, both similar to that for Kina close to Viti Levu.

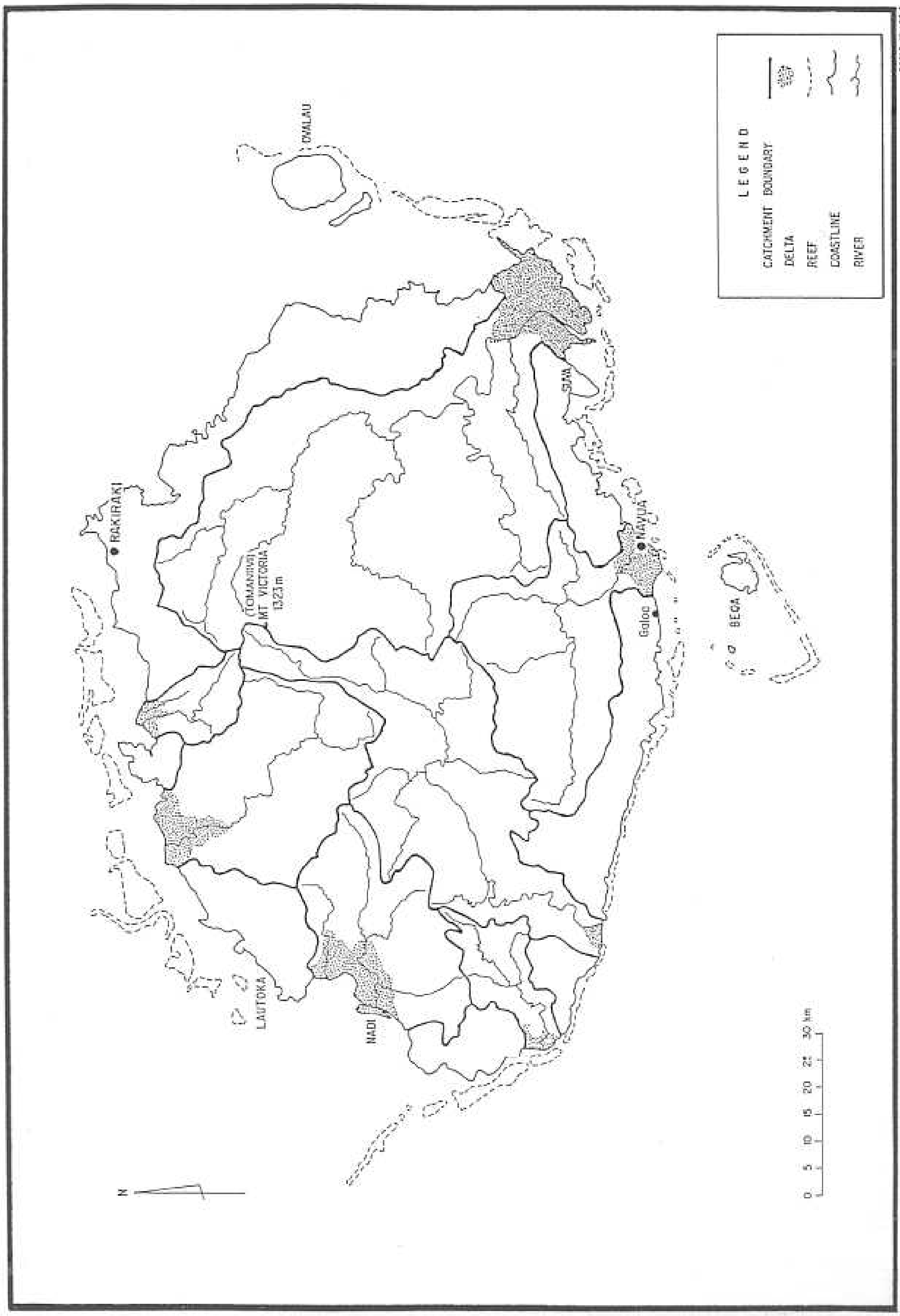


Figure 2. Viti Levu, showing major river catchments and areas of small coastal catchments.

OBJECTIVE

A study following any natural disaster is vital for planning purposes in developing countries. This report is part of the initial steps in implementing such a study for Cyclone Kina (Figure 3). In order to maximise the benefits of such a study, which may take 6-12 months, it is important that Government encourage and support the coordination of the study at the ministerial level well after the disbanding of the regular DISMAC meetings immediately post-disaster.

Without this coordination it is unlikely that the benefits, which include improved planning, better awareness and preparedness, disaster mitigation and reduced risk will be realised.

RIVER FLOODING AND RIVER BANK EROSION

Rewa River

Perhaps the most dramatic effect of Cyclone Kina yet evident was the high water levels and associated flooding and river bank erosion in the Wainibuka-Wainimala-Rewa rivers from the headwaters to the delta. Appendix 1 provides initial comments on the flood levels and magnitude of the event.

Evidence of the highest water level (Plate 1), for example grass trapped in fence wire, mud stains on trees, buildings, telephone and power poles, will soon be lost. For accurate assessment/prediction studies it is important that this evidence is recorded rather than rely on verbal accounts at some future date.

This major river system in eastern Viti Levu is characterised by an alluvial flood plain of varying width which is cut into by a meandering river channel. The alluvial plain is underlain by unconsolidated sands, silts and gravels.

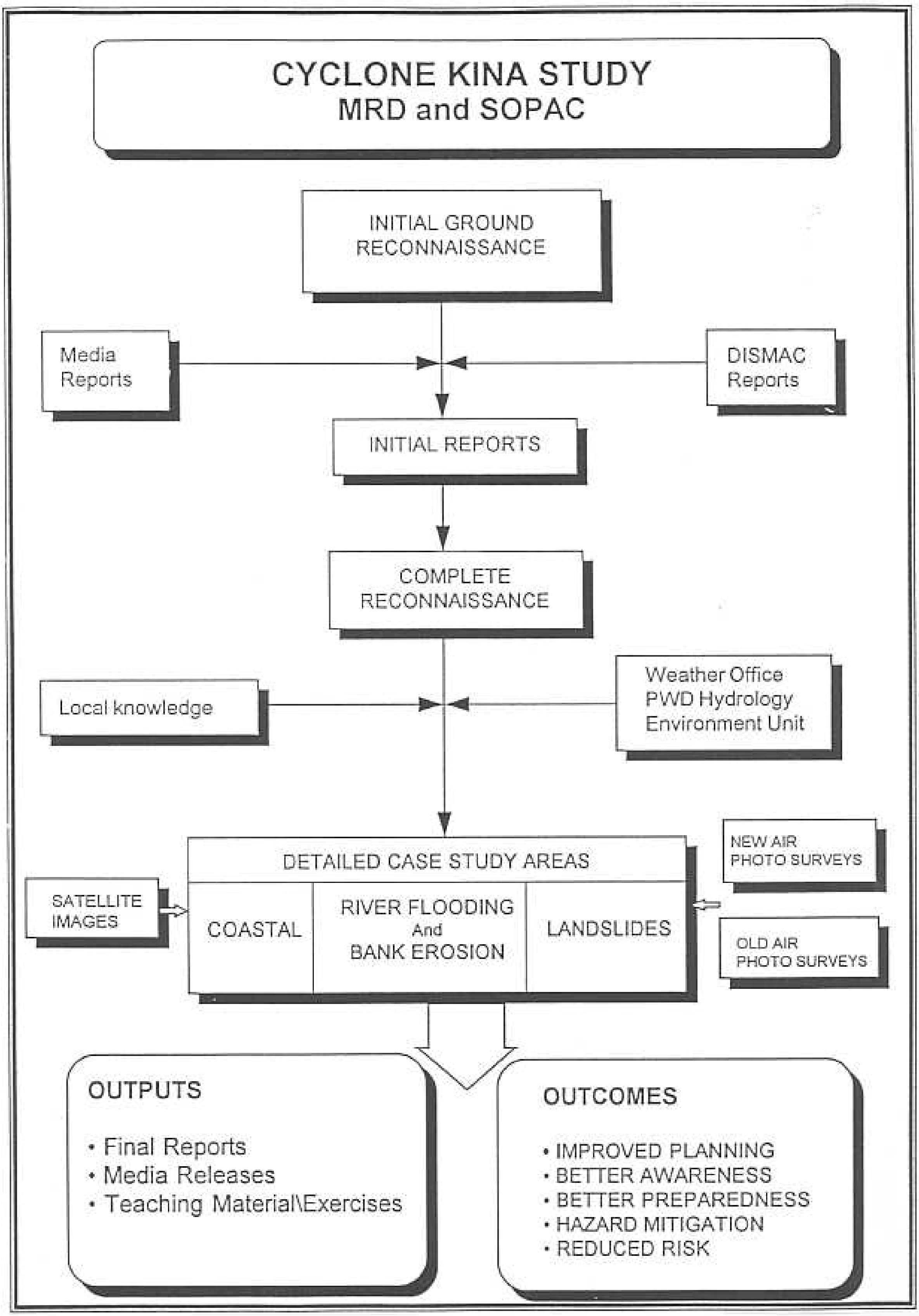


Figure 3. Flow chart for planned Cyclone Kina Study initiated by MRD and SOPAC.

The river normally occupies the most part of the channel base together with sand and gravel bars. At Vunidawa, in the vicinity of the Wainibuka-Wainimala-Rewa confluence the alluvial surface is extensively developed (Plate 2). At and downstream of Lutu in the lower reaches of the Wainibuka the channel is 15 m deep. Rodda (1990) reported an average depth of 10-12 m for this area (Plate 3).

As a result of the high rainfall associated with and proceeding Cyclone Kina, the rivers occupied the flood plain with average water depth of 2-3 m in the area close to Vunidawa (Figure 4). Indications are that water levels may have risen an average 14 m and perhaps by as much as 17-18 m in places.

At the same time the river banks around the meander loops were eroded and the main channel pattern were shifted downstream (Plate 4). This has yet to be documented, though Rodda (1990) reported up to 75 m shift in the Wainibuka-Wainimala-Rewa confluence in the period between 1928 and 1978 (Figure 5).

As water levels receded, substantive deposits of silt became evident on the flood plain, and new gravel bars appeared in the channels. As water levels fell to normal the undercut channel banks were left exposed, steep to vertical and unstable. These are now undergoing rotational slumping to re-establish equilibrium (Figure 6). Where the valley is narrow, for example in the middle reaches of the Wainibuka, this caused major damage to infrastructure such as roads and villages (Plate 5).

The Rewa Delta downstream from Kasavu (Plate 6) is a composite structure made up of at least five principal lobes (Figure 7). Each has been the major outlet for the Rewa River over recent geological time.

These lobes each have their own system of channels across the delta, many of which are abandoned during normal river flow conditions and are only occupied by water during floods. Much damage occurred where development has taken place which disregarded this natural and well-developed system of flood channels.

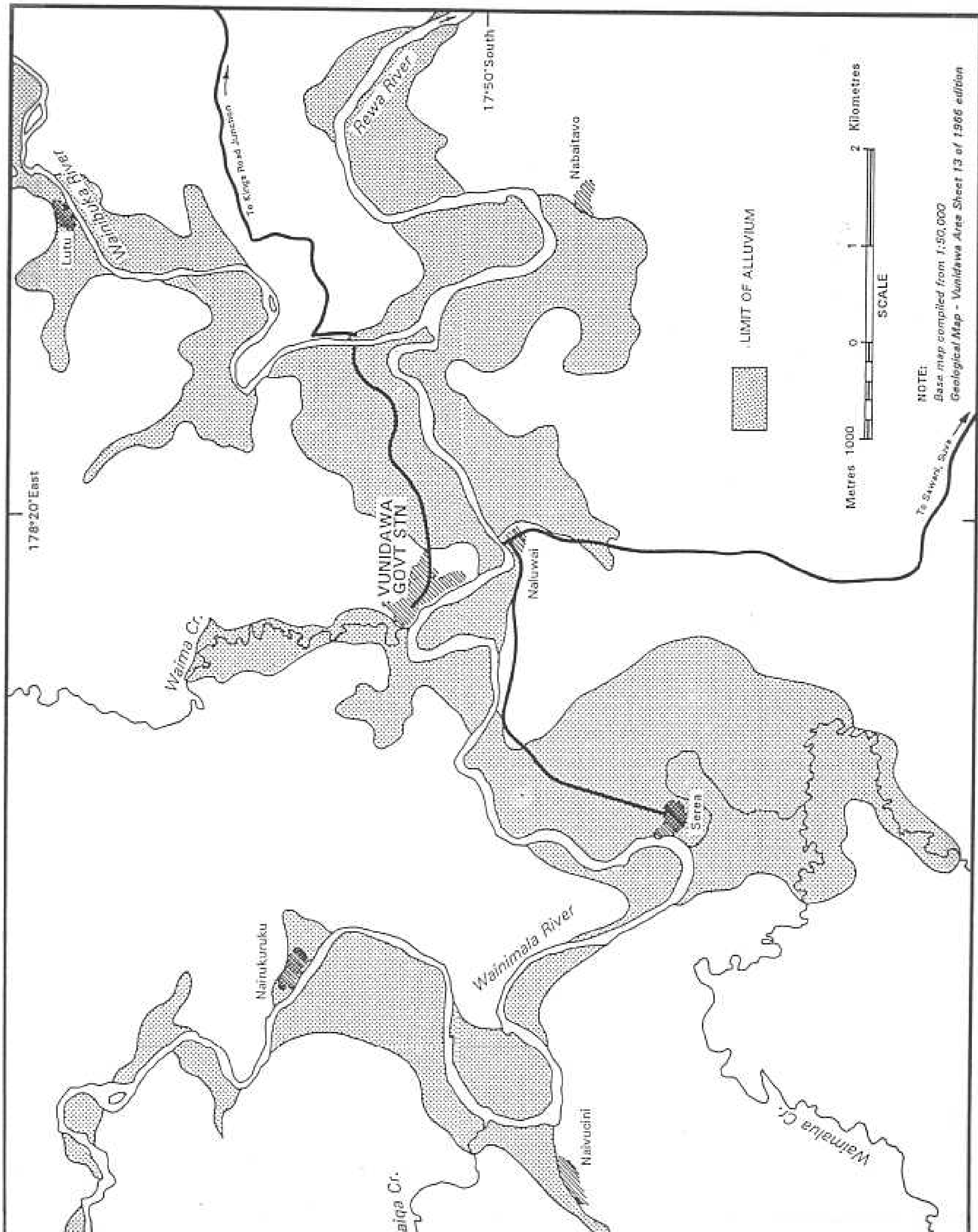


Figure 4. Map of the Wainimala, Wainibuka, Rewa rivers confluence near Vunidawa showing the extent of the alluvial flood plain, which was estimated to have been flooded to an average depth of 2-3 m as a result of rainfall associated with Cyclone Kina.

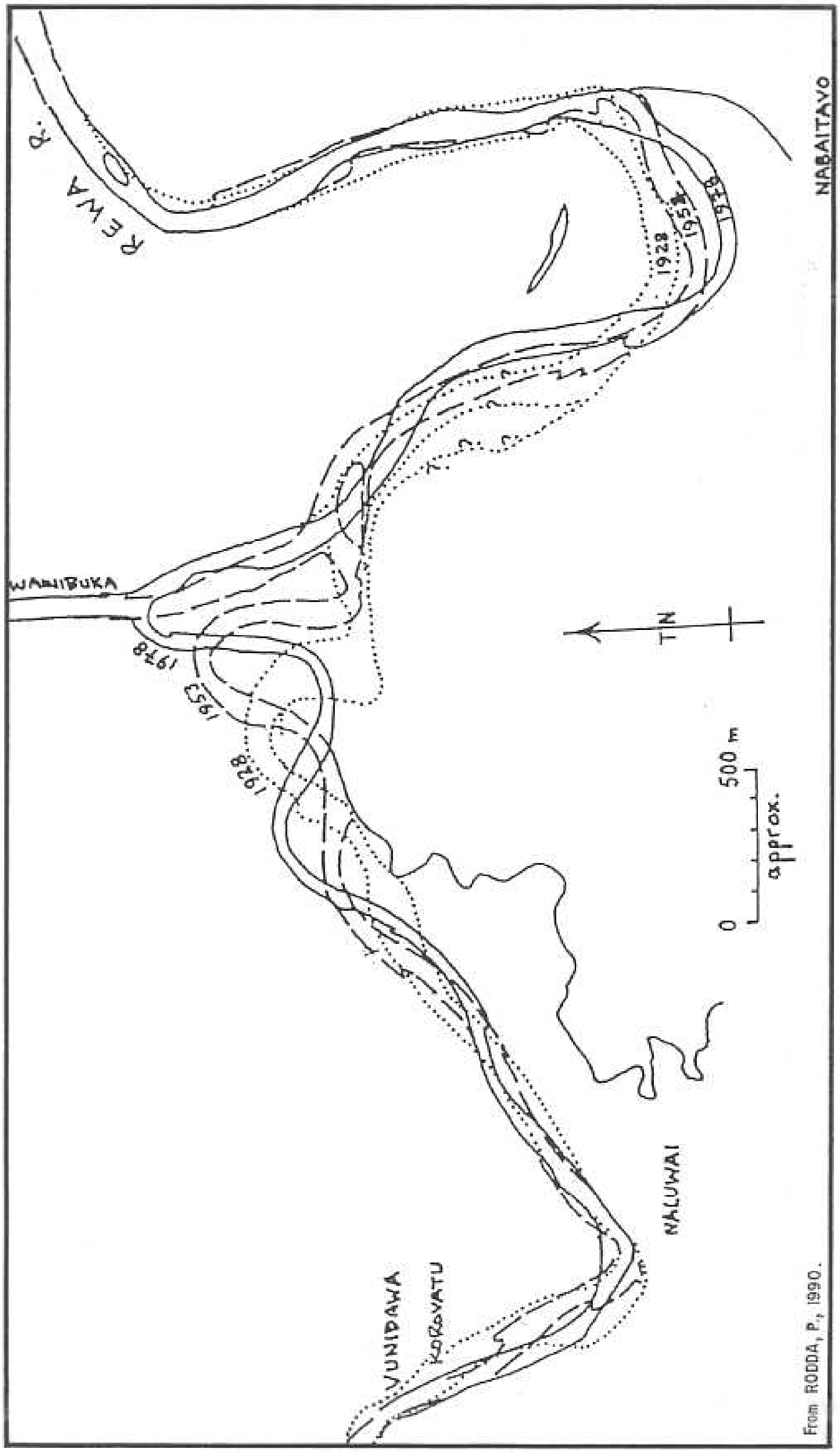
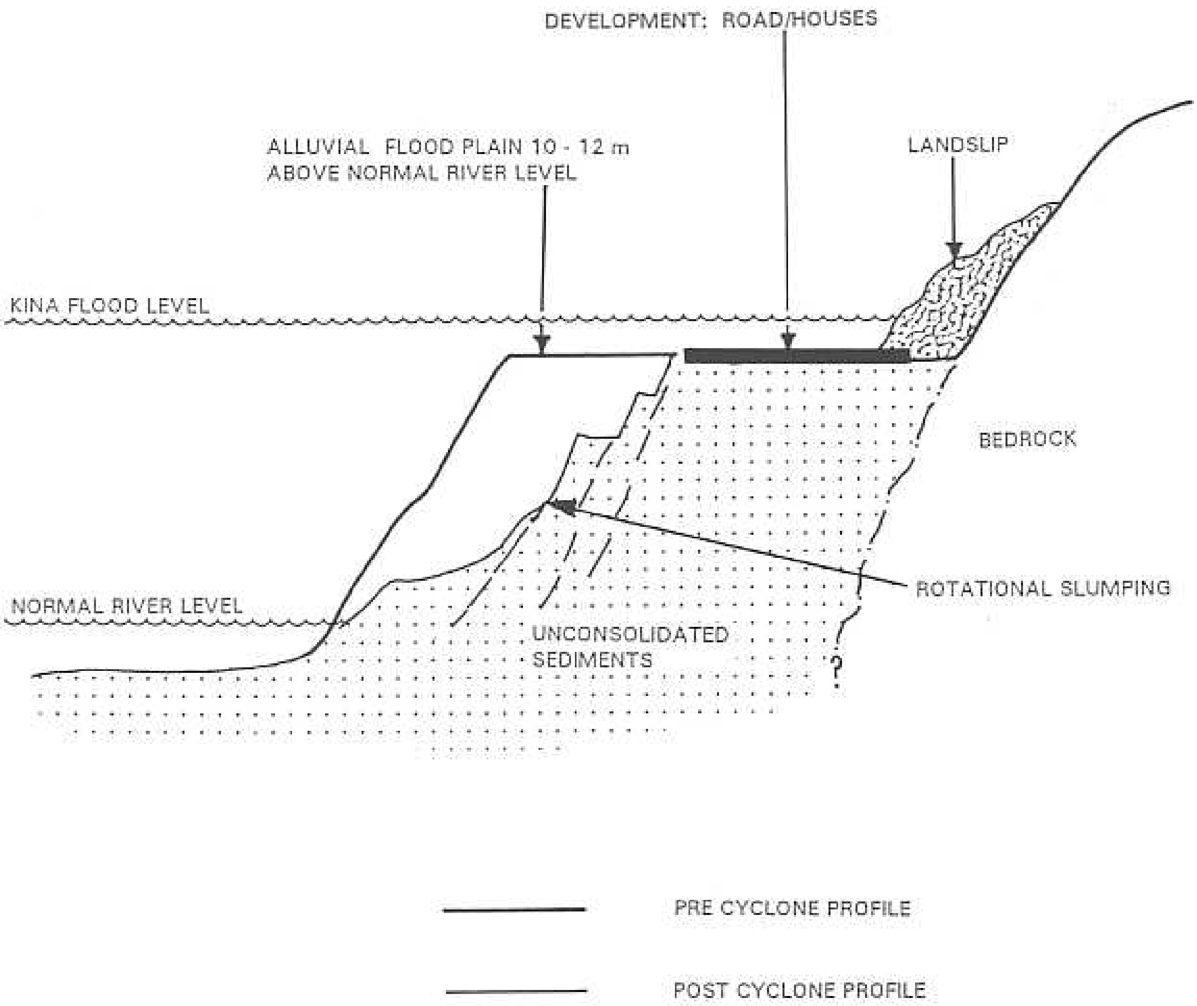


Figure 5. Sketch map reproduced from Rodda (1990) showing the movement over the 50-year period 1928-1978 of river meander channels at the Wainimala, Wainibuka, Rewa confluence.



COMPOSITE CROSS SECTION FOR WAINIMALA, WAINIBUKA AND REWA RIVERS

Figure 6. Composite cross-section for the Wainimala, Wainibuka and Rewa rivers showing effects of Cyclone Kina, in particular note the river bank failures now taking place as the eroded and oversteeped channel sides now attempt to stabilise by rotational slumping.

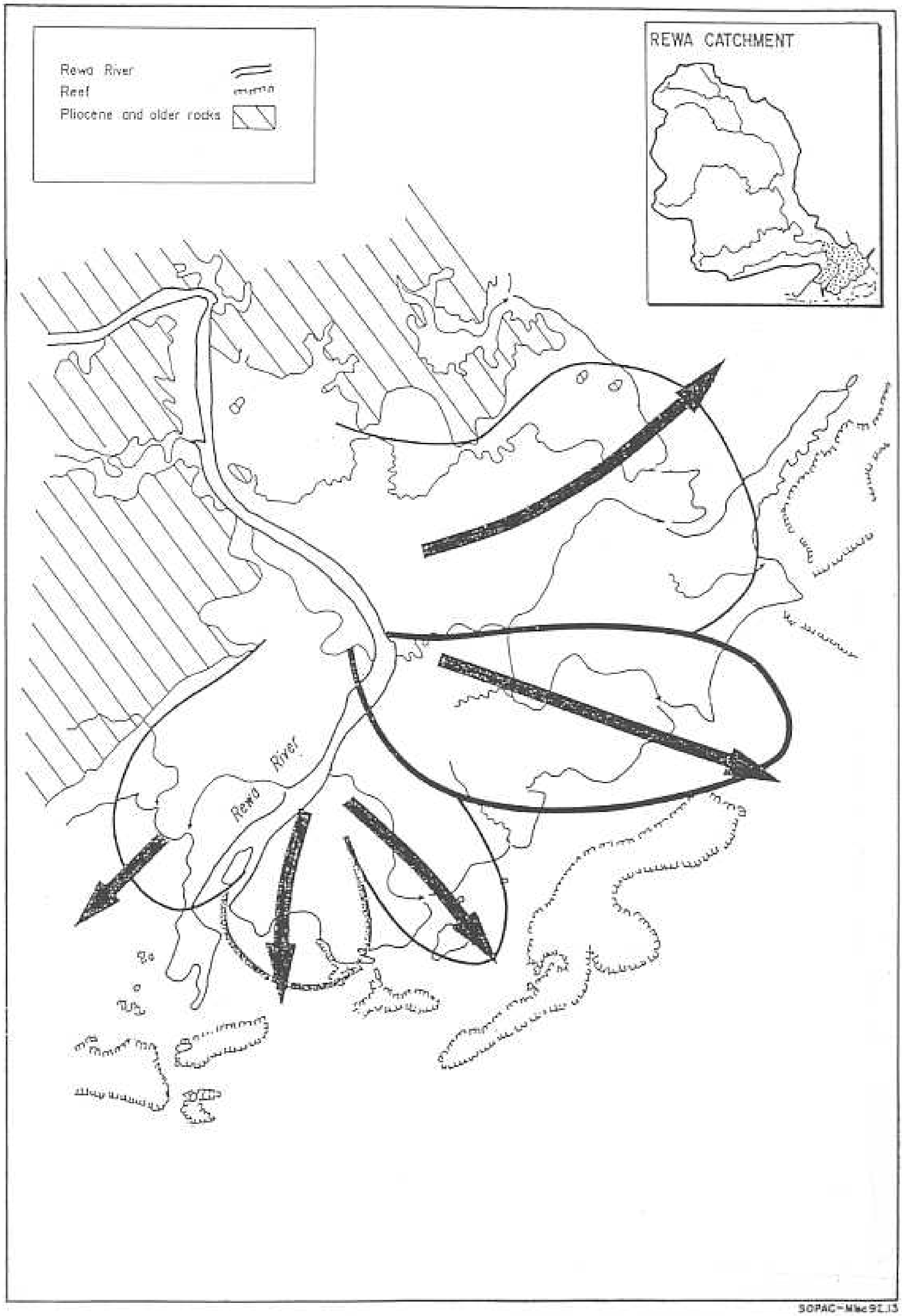


Figure 7. Map of the Rewa delta showing the principal lobes which constructed the present delta over the past 6000 years. Arrows indicate the main direction of discharge as each lobe was active. Note the position of present major channel and old channels, many of which are abandoned in normal flow conditions.

Navua River

No information is yet available for the upper Navua River and the comments below relate only to the delta area.

Inland from the shoreline seawall and road (see Coastal Section) are the rice paddies and drainage-irrigation network, the Suva-Nadi highway, and the dredged sand piles from the Navua River. All are man-made structures which produced water ponding.

Bordering each rice paddy is approximately 0.5 m of elevated ground (levee) meant to pond water within the lower lying rice paddy. Surrounding a group of rice paddies is a higher levee (approximately 1 m above the rice paddies) of the drainage-irrigation network. The Suva-Nadi highway, running in a east-west trend across the floodplain (Plate 7), is higher still than the drainage-irrigation levees. West of Navua town on either bank, and on the foreshore area of Vunibau village, sand and gravel dredged from the Navua River is stock piled to an average height of 3 m (Plate 8).

It is very obvious that a series of ponding effects took place within the rice paddies; within the levees of the drainage and irrigation network; north of the highway and adjacent to the dredge piles. These are all relatively recent structures and the surge of excess water, as one ponding system spilled over to another, took the public unaware and by surprise. Interviews with old residents confirmed that flood waters reached them from all directions, which had not been experienced by them in the past (Plate 9).

As with other occasional storms such as Kina, large quantities of sediment were eroded into the river and the estuary. This was deposited as sand bars at the river mouth and lower reaches of the main channel making it impossible to enter or leave the river mouth even at half tide.

Road embankment erosion was severe along Queens Road from Navua Bridge to Nasasa Road junction. The erosion was most severe in the vicinity of Vakabalea Road junction where the Suva-Nadi highway crosses an abandoned river channel (Figure 8). Erosion of this type was also very common in this area as a result of Cyclone Wally (Plates 10, 11). The

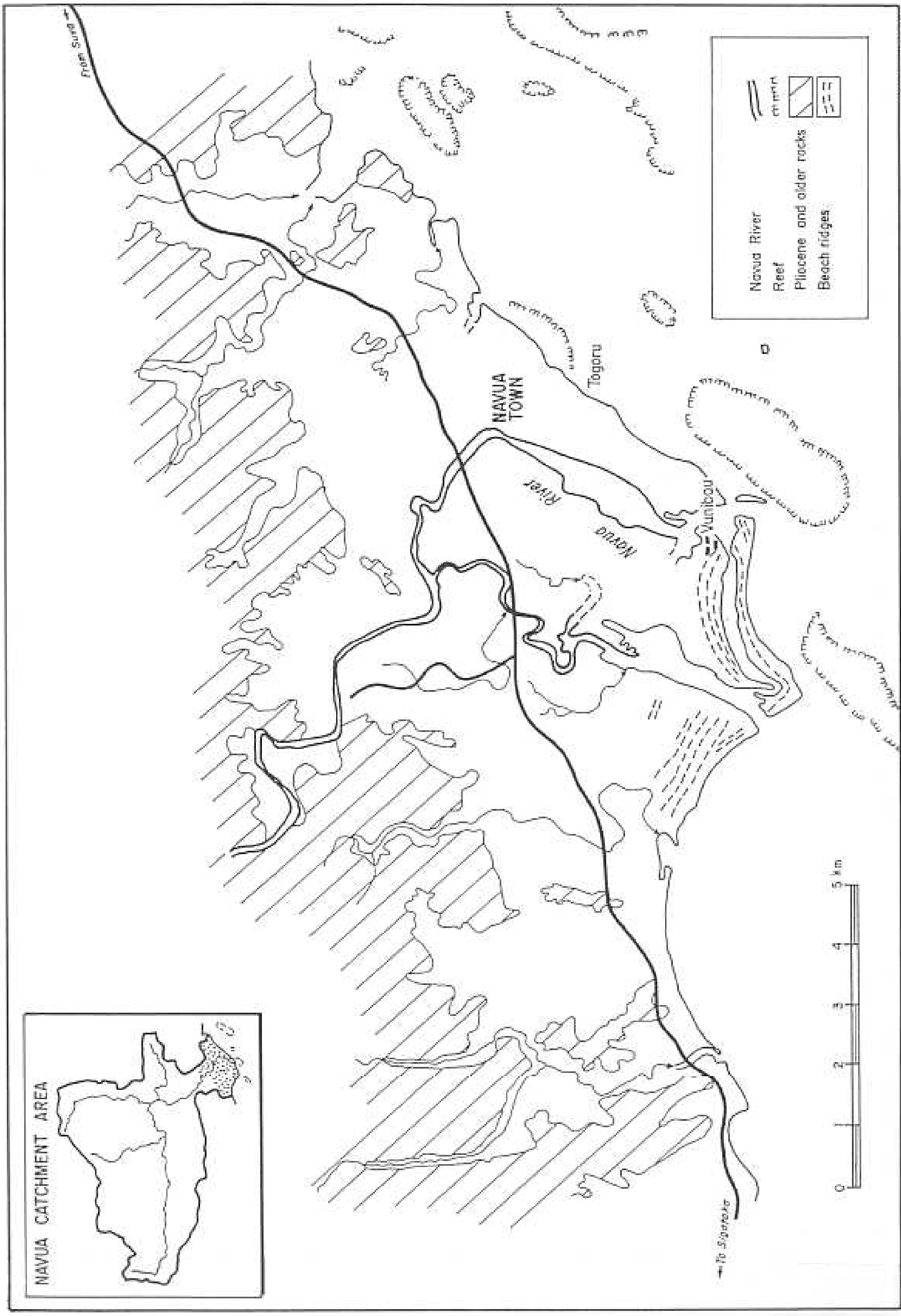


Figure 8. Map of the Navua delta, note position of Suva-Nadi highway in relation to abandoned river channels.

extensive gully of the road embankment on the coastal side was caused by strong currents and small water falls formed when water flowed over the road from north to south. A whole range from small potholes roughly 1 m in diameter to major scouring up to 2 m deep and 50 m in length are seen.

LANDSLIDES

A total of 160 landslides, excluding those failures along river banks, were recorded within the area surveyed (Figure 9). Of the total number of landslides, 30 were on natural slopes away from the roads and 130 on slopes associated with roads where a "cut-and-fill" method was used for road construction (Figure 10, Plate 12). A detailed list of these landslides and their locations is available from the Engineering Geology Section of MRD.

Within the area covered during this survey, no landsliding was observed on the scale that the Serua Hills were affected during Cyclone Wally (Howorth et al. 1981). However, it is possible that the upper Wainimala may show similar intensity of landscape failure.

Prior to Cyclone Kina there was heavy rainfall which caused saturation of soil layers over impermeable rock. The saturation of soils caused the pore water pressure to increase and the shear strength to decrease, which initiated failures. In addition, the excess water moving downslope between the soil and rock interface provided an excellent plane for the soil mass to move on.

Slope failures in excavations above the road level were typically debris slides over failure planes. The planes are inferred to be relict structures such as bedding, faults, and joints. Following displacement, the slide mass has disintegrated due to the very low strength material involved (Plate 13).

Slope failures below the road level have occurred at the heads of steep gullies and took the form of earth flows/mud flows which scoured the gullies for up to a hundred meters. The flows occurred within the red, lateritic soil and have involved the road fill placed on the natural ground surface.

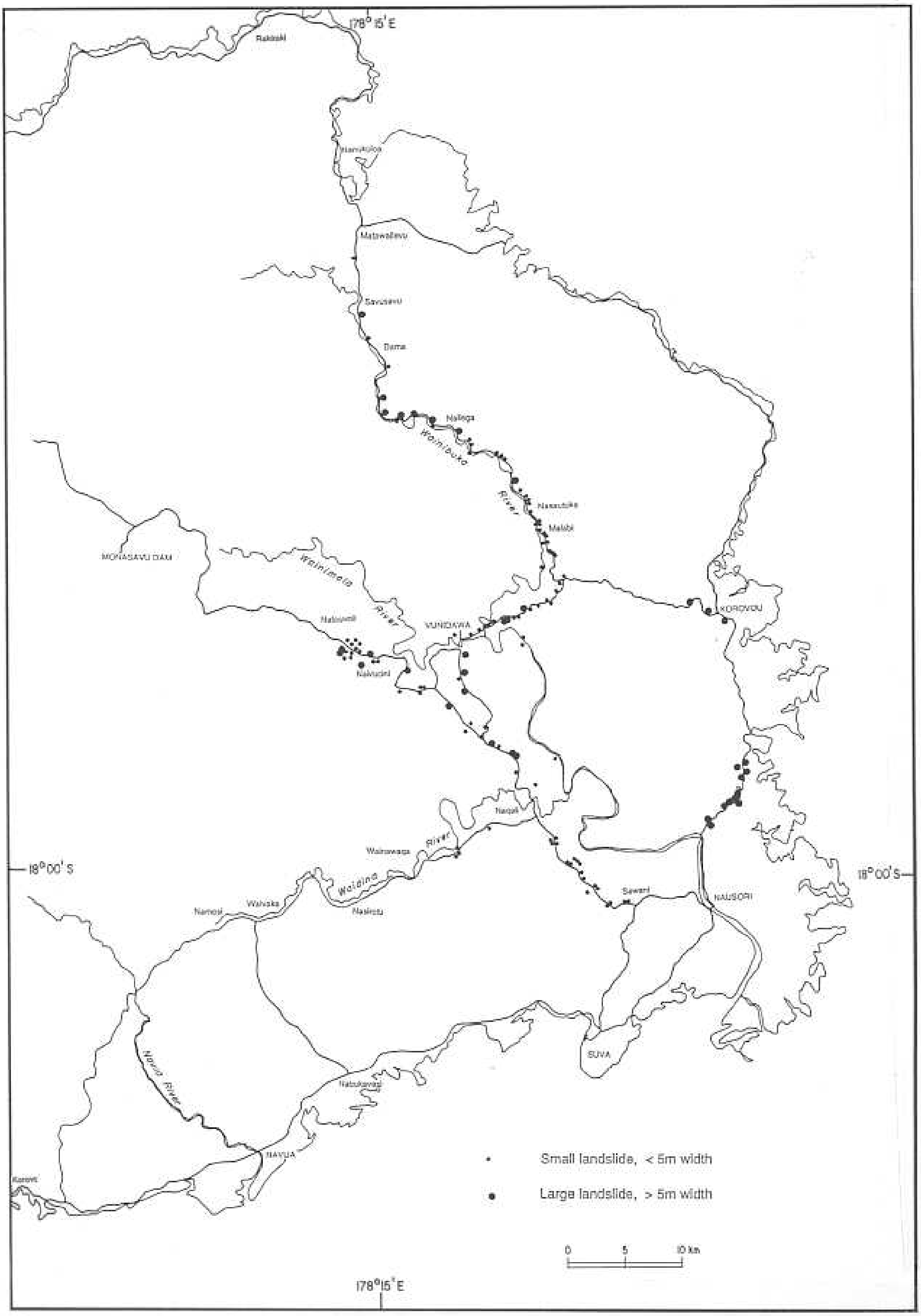


Figure 9. Approximate locations of landslides. The majority are immediately adjacent to the roads in areas of "cut-and-fill" construction.

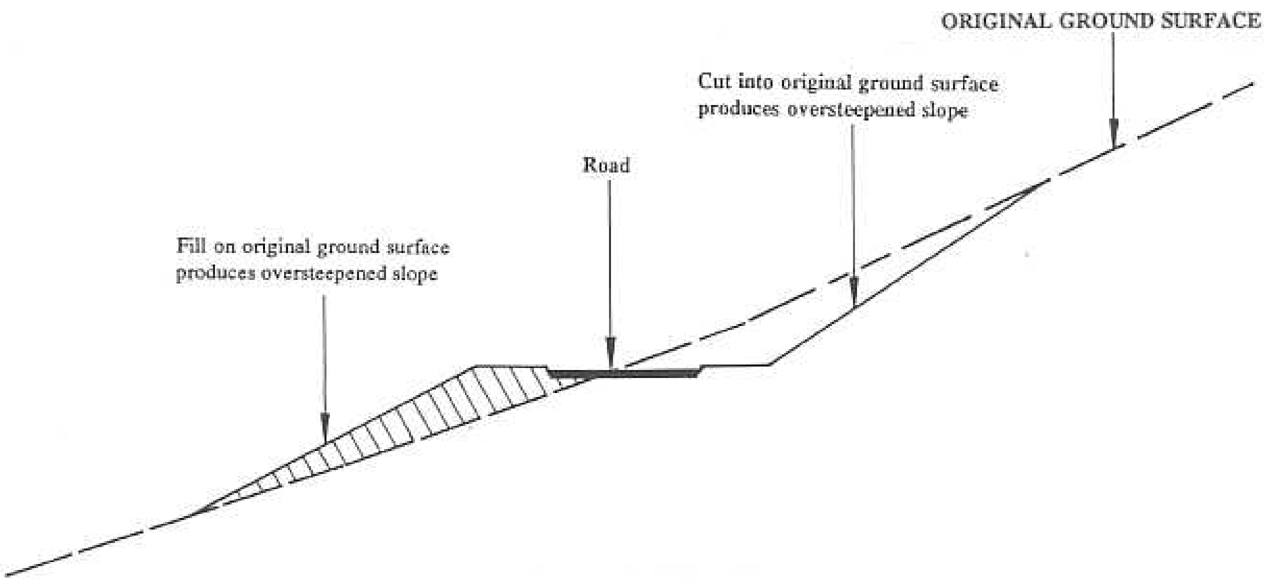


Figure 10. Sketch cross section of a typical hillslope "cut-and-fill" construction used for road development.

At several other localities, failures within the road surface also occurred (Plate 14). In some cases, these failures affect part of the road whereas in other cases, the whole width of the road is affected. The failures are generally characterised by presence of tension cracks ranging from a few centimetres to about 30 cm in width. The depth ranges from about 20 cm to about a metre.

These failures were mainly due to failed drainage system such as blocked drains and culverts; ponding of water above heads of gullies or at the sides of roads; and inadequate compaction of the roads.

COASTAL EFFECTS

South Coast From Suva to Galoa

For the most part, the southern coastal area of Viti Levu from Suva to Galoa was little affected by Cyclone Kina, except on the east side of the Navua delta.

Even before Cyclone Kina struck, erosion had been continually changing the coastline of the area from Togoru village westwards to the mouth of the Navua River. Kina caused severe erosion along this stretch of coastline, as has been true in previous cyclones. The shoreline receded about 5 m at some sites during Cyclone Kina.

The damage was caused by elevated sea levels (storm surge) resulting from the combination of onshore winds, storm waves and low barometric pressure that accompanied the cyclone. As witnessed by the residents in inundated areas, sea level was 3-4 m above normal. In areas close to an old seawall, boulders (up to 60 cm diameter) from the wall were uplifted and transported inland.

This stretch of low-lying coastline was exposed to the southerly winds that blew continuously throughout the duration of Cyclone Kina. This caused the storm waves driven shoreward by the strong winds not only to contribute to the elevated sea level, but also have damaging effects on the coast for they break on to the backshore, and beyond, to areas which are normally protected from wave attack and produce coastal flooding. Sea level rise is likely to have been greatest in this area not only because it is an exposed stretch of coastline, but also because Cyclone Kina approached perpendicular to the coast. The storm surge that affected the coastline during Kina was significantly more than what it can withstand and this is very evident on the Naitonitoni jetty which had lost all its wooden flooring.

Along edges of mangrove patches and across streams and creek channels, residual soils and coral and volcanic rock boulders have been used to form a 2-metre high seawall-cum-road overlying a sandy coast. This structure has been built in recent years to stop seawater entering the rice paddies (Plate 15). The natural channels have been replaced by a man-made drainage network comprising a series of flood gates (outfall) at the shoreline to allow excess water to drain into the sea. At low tide the water is about 70 cm below the top flange of each gate which is about 2.0 m wide. The five or six outfalls (floodgates) of this size definitely cannot cater for the total amount of excess water during occasional flooding or storms such as Kina (Plate 16).

Heavy rain had been falling continuously for about a fortnight before Cyclone Kina struck. It had caused water to be ponded behind the seawall allowing it to penetrate beyond the root zone of the top soil. The introduction of water into the unconsolidated, dry, low density, underlying sand had fully saturated the soil.

By using the residual soil as fill material for the seawall (Plate 17), the natural water channels, which were important for draining excess water overflowing from the Navua River, were also filled. The excess water then slowly undermined the fully saturated underlying unconsolidated soils. Hence the overlying residual fill material had collapsed and in one instance a squatter house was wholly lifted and drifted into the sea.

East Coast From Korovou to Namarai Bay

A reconnaissance survey of the coastline of eastern Viti Levu from the Waibula River (Korovou, Tailevu) north to Namarai Bay was carried out. The coast is dominated by a fringing reef, usually 200 m or less in width, with small patch reefs offshore. The continuity of the fringing reef is interrupted only by (i) river mouths of coastal catchments which may have deltas developed, the largest of which is Tavena Creek at Dawasamu; and (ii) three bays to the north (Figure 11).

For the most part the coast is fringed with mangroves, particularly close to the river mouths and heads of the bays. The presence of the mangroves and the shelter provided by the bays appear to have prevented extensive coastal erosion. Evidence of erosion was restricted to river/creek mouths and places were the mangroves were not present. Even in these places erosion could not be described as severe. This may indicate that at the time the cyclone passed by, it was not high tide.

As Cyclone Kina approached from tho northwest this coast of Viti Levu was subjected to sustained onshore easterly winds. Once the cyclone had passed this coast was largely sheltered from the southerly winds. During the period of easterly winds a "bank" of coral debris was deposited on the reef flat and close to the reef edge, discontinuously along the entire coast (Plate 18). The material was uplifted from the reef front by the wave action. An example of such a feature can be readily seen, close to the road north of Burelevu near Queen Victoria School (Figure 12, Plates 19, 20).

The shape of the bank is a wave form with a steep inland facing slope and gentle seaward facing slope, which would be expected from a dominant onshore flow direction. The dimensions of the bank were 10-15 m wide and up to 0.75 m high at the inland edge. Most of the debris was gravel size, dead, branching coral but included scattered boulders up to 2-3 cubic metres. On the larger boulders, some live coral (blue tips) were seen eight days after the event.

Similar banks have been produced by other cyclones, for example on the southeast side of Funafuti Atoll in Tuvalu by Cyclone Bebe in 1972, and on the north side of Upolu in Western Samoa by Cyclone Ofa in 1990 (Table 1). The bank produced by Cyclone Kina in northeast Viti Levu is small in comparison with these others. Also as with similar features it is very likely that the bank will be modified within a few months if not completely losing its identity.

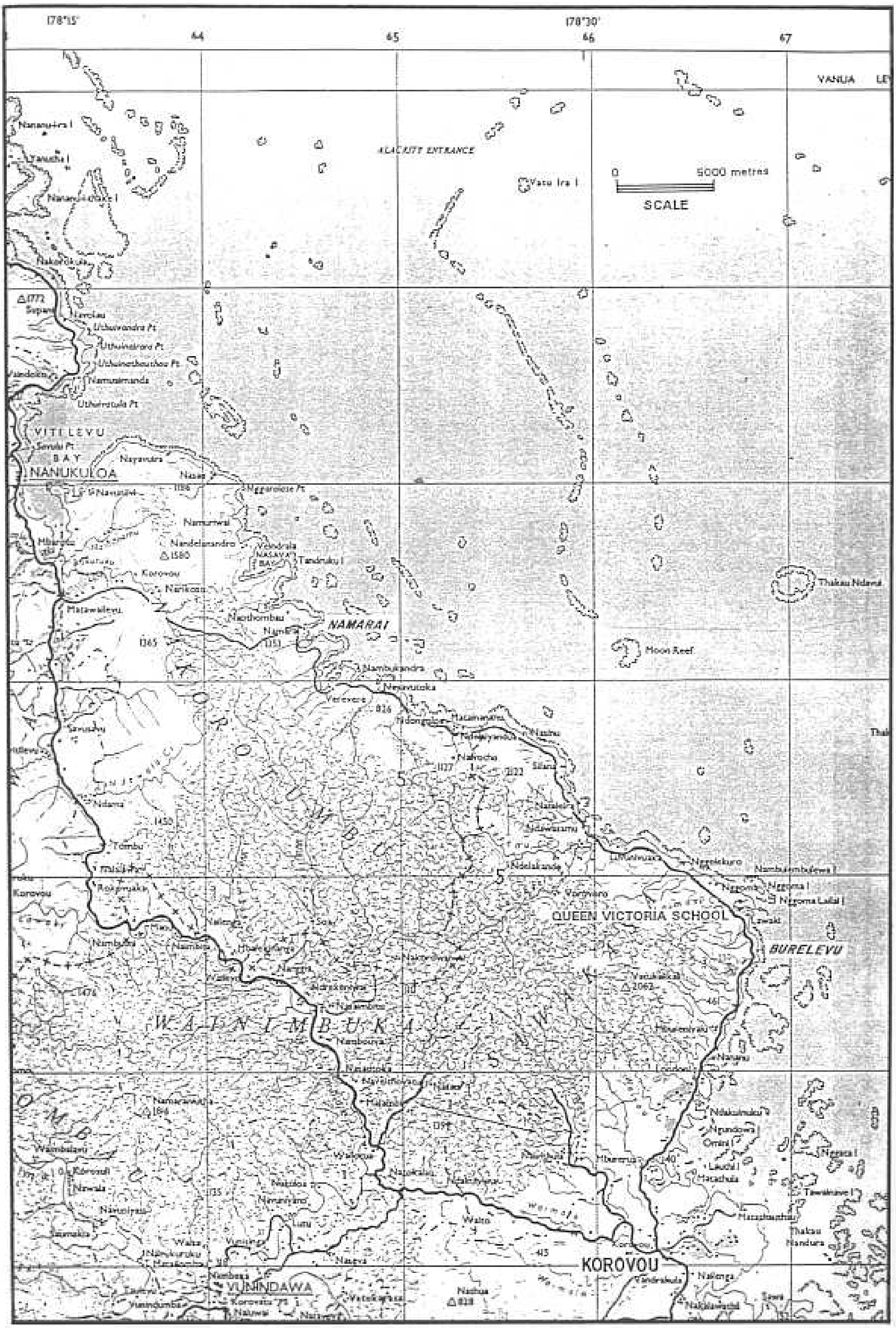
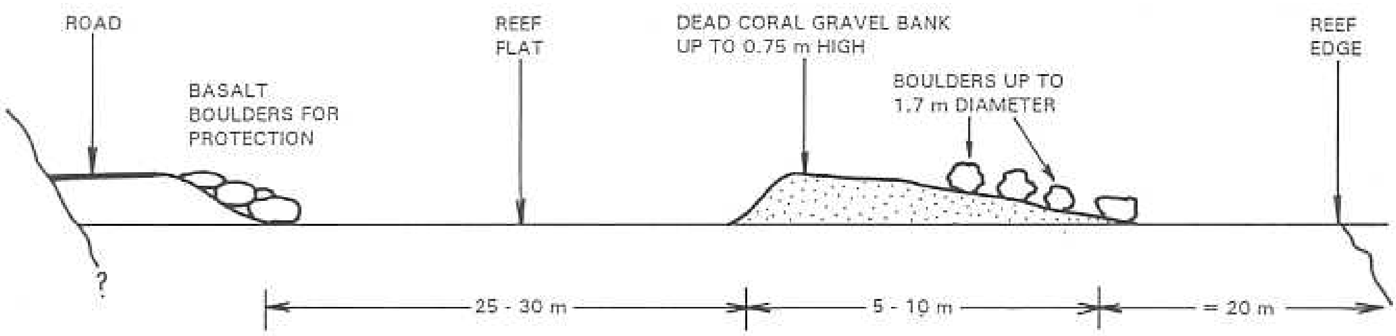


Figure 11. Map of northeast Viti Levu, note the proximity of the fringing reef to the coast, major bays and small area coastal catchments.



KINA CYCLONE BANK OF BURELEVU (NEAR QVS)

(Note: Mangrove protects road along most of this stretch of the coast).

Figure 12. Kina cyclone bank north of Burelevu near Queen Victoria School. Note that mangrove protects the road along most of this stretch of the coast.

Table 1. Comparison of banks formed by Cyclones Kina, Ofa and Bebe.

Cyclone:	KINA	OFA	BEBE
Country:	Fiji	Western Samoa	Tuvalu
Date:	January 1993	February 1990	October 1972
Bank Statistics			
Width:	5-10 m	15-50 m	37 m (average)
Height:	0.75 m	2-3 m	3.5 m
Distribution:	Northeast Viti Levu	North Upolu	Southeast Funafuti Atoll
	Series of banks up to 100 m long	Series of banks up to 250 m long, one bank 2 km long	Almost continuous for 18 km
Cyclone Statistics			
Minimum Pressure:	984 mb	986 mb	954 mb
Maximum Wind:	80-120 knots	70 knots	100 knots (?)
Rate of Movement:	10-15 knots	very slow	10 knots (?)

PRELIMINARY CONCLUSIONS AND RECOMMENDATIONS

Natural disasters, such as Cyclone Kina, ironically provide excellent opportunity for case study of natural processes. To carry out such a case study of Cyclone Kina is particularly important in view of the extent of the damage which it caused and its effects on peoples life.

1. Government should strongly support a fully integrated study of the effects of Cyclone Kina on the physical environment for the purpose of improved planning, better awareness and preparedness, hazard mitigation and risk reduction in the future.

   Immediate future work to be considered includes:

   - Complete ground reconnaissance into as yet inaccessible areas of the Central Division:
   - Reconnaissance work in other affected areas of the country;
   - Ground studies integrated with satellite image interpretation;
   - Case studies of select areas;
   - Airphoto surveys of selected case study areas, such as Wainibuka and Wainimala rivers, Rewa delta;
   - Analysis of historical data to better define magnitude and return period of the effects (eg. flooding).

   The preliminary conclusions and recommendations which follow are specific to problems recognised or areas affected.

2. Re-establishment of infrastructure, including roads, schools and houses in the narrow Wainibuka gorge area, needs to be carefully planned in view of the current instability of the slopes cut into the unconsolidated alluvial deposits.

3. Development of infrastructure on the Navua and Rewa deltas has to a large extent totally disregarded pre-existing abandoned river channels which act as natural floodways.

4. The natural floodways on major river deltas such as the Rewa and Navua need to be carefully mapped and their importance recognised and publicised.

5. Seawalls built in lowlying areas often cause more damage during storms and periods of flood than they are designed to prevent.

6. In reconstructing the Suva-Nadi highway across the Navua delta, adequate culverts should be provided to cope with at least the 20-year flood in areas where the road embankment crosses old channels.

7. Most slope failures have occurred along the roads where "cut-and-fill" construction was used for road development.

8. Slope failures are generally of two types: (i) rotational slumps/debbris flows in very low strength weathered bedrock; and, (ii) rapid mud flows/earth flows in road fill near the heads of steep gullies below the road level,

9. Consideration should be given io the design and effectiveness of the floodgates on the Navua irrigation project.

10. Mangroves proved, as they often do, to be effective at reducing coastal erosion. Any future development which requires removal of, or development on mangrove areas should be given serious environmental impact assessment before implementation.

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