

INSTITUTE OF APPLIED SCIENCES
THE UNIVERSITY OF THE SOUTH PACIFIC

BASELINE WATER QUALITY AND
CORAL REEF ASSESSMENT FOR
PAFCO - LEVUKA

PROGRESS REPORT NO. 1 - MAY 1995

IAS ENVIRONMENTAL REPORT NO. 78

by

Bale R. Tamata
Ed Lovell

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INTRODUCTION AND BACKGROUND

The Institute of Applied Sciences (IAS) of the University of the South Pacific (USP) has been commissioned by Sinclair Knight Merz of Brisbane, Australia to carry out an environmental impact assessment of the laying of new sections of the effluent outfall pipeline for the PAFCO plant at Levuka. The original effluent outfall pipeline was installed during the major expansion work at the plant in 1988. The expansion of the plant was funded by the government of Australia through its aid agency AIDAB. At the time, the IAS was also involved in an EIA of the whole works. This included the selection of quarry site and its rehabilitation, the rehabilitation of the wharf area and the monitoring of the water quality in the Levuka harbour before, during and after the completion of the expansion work. Part of the requirement of the aid package to PAFCO from AIDAB was the construction of the effluent outfall to transport waste from the factory to a discharge site in deeper waters near the barrier reefs. The IAS was commissioned by PAFCO to carry out the EIA in conjunction with the plant expansion (Green & Lovell, 1989, 1990, 1991, 1992).

The outfall pipeline was however subjected to various problems. Although the report by Green and Lovell (1992) had recommended that buoys be placed to mark the location of the outfall, the recommendation was not carried out. As a consequence, one of the main causes of damage to the outfall pipeline was due to anchors being dragged across the seabed and a lot of fishing boats do visit Levuka port.

Natural disasters can cause a great deal more destruction than is often appreciated. Cyclone Kina, one of the strongest cyclones to affect the Fiji islands in a long time caused massive destruction to the whole of the Fiji group in early January of 1993. The cyclone force winds and heavy rain and flooding caused a great deal of damage to the terrestrial as well as the marine ecosystems. Coral reefs around the islands were broken in many places. The PAFCO outfall pipeline was also damaged to some extent by cyclone Kina.

The reconstruction of the outfall pipeline at Levuka has been made possible with funding from AUSAID (formerly AIDAB). Sinclair Knight Merz (SKM) has been commissioned by AUSAID to provide consulting services for the design and supervision of the reconstruction work. The role of the IAS is to carry out an environmental impact assessment (EIA) of the reconstruction of the outfall as a sub-consultant to SKM. This report presents the results of the first component of the EIA, the baseline study.

WORK PROGRAMME

The proposed environmental work programme (EIA) would consist of a baseline study to establish conditions before reconstruction work begins, followed by a total of five monitoring periods spanning a period of about eighteen months (June 1995 - November 1996). The work involves water quality study and coral reef assessment at selected sites near the PAFCO plant and also offshore. The coral reef assessment involves the inspection of quadrats employed in previous studies (Green and Lovell, 1990, 1991, 1992), plus the implementation of additional sites.

Study sites

For water quality assessment, a total of six sites were selected. The sites were located as close as possible to the newly established coral reef study sites. Sites 1, 2 and 3 are close to the shore while sites 4, 5 and 6 are further out in the harbour. To distinguish between the water quality study sites and the coral reef sites, the water quality sites are identified by the letter 'w'.

Site 5 near the lighthouse is the furthest site from land and is in the very deep channel between the two reefs, *Balavu Reef* and *Lekaleka Reef*. Site 5 is the reference site, being least likely to be affected by the PAFCO plant operations. Site 6 located near the inner edge of the *Lekaleka Reef* is of particular interest in the assessment of long term effects of the effluent. It is envisaged that there is potential for the effluent to cause harm to the bountiful *Lekaleka reef* because of the combined effects of the South-East Trade Winds and tidal flow, dispersing the waste from the discharge site (deep waters between the two reefs) back onto the inner edges of the *Lekaleka reefs*. This potential problem can only be assessed after a long period of time, thus the proposed 18 month monitoring period. The location of the study/sampling sites are shown on Fig. 2 below. Table 1 below describes the six water quality sampling sites.

TABLE 1 - Description of Water Quality Study Sites

Site 1w	Near inshore reef site (1) & beacon
Site 2w	Near the discharge outlet for floor washing
Site 3w	Close to jetty and container yard, south of PAFCO
Site 4w	Offshore from site 3, near beacon and reef site (2)
Site 5w	Close to lighthouse at entrance to harbour
Site 6w	near inner edge of <i>Lekaleka Reef</i> & reef site (5)

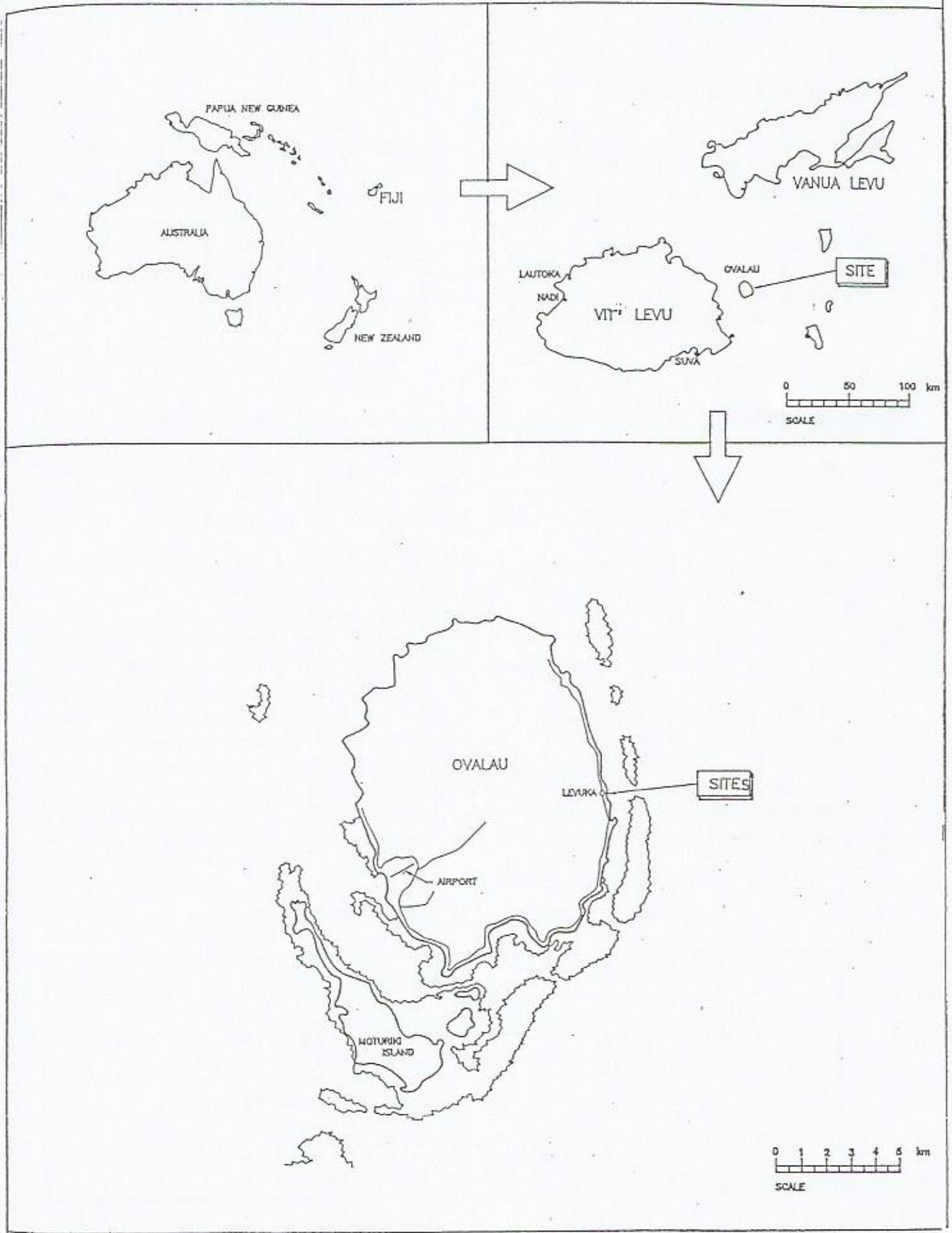


Figure 1: Map showing the location of the project.

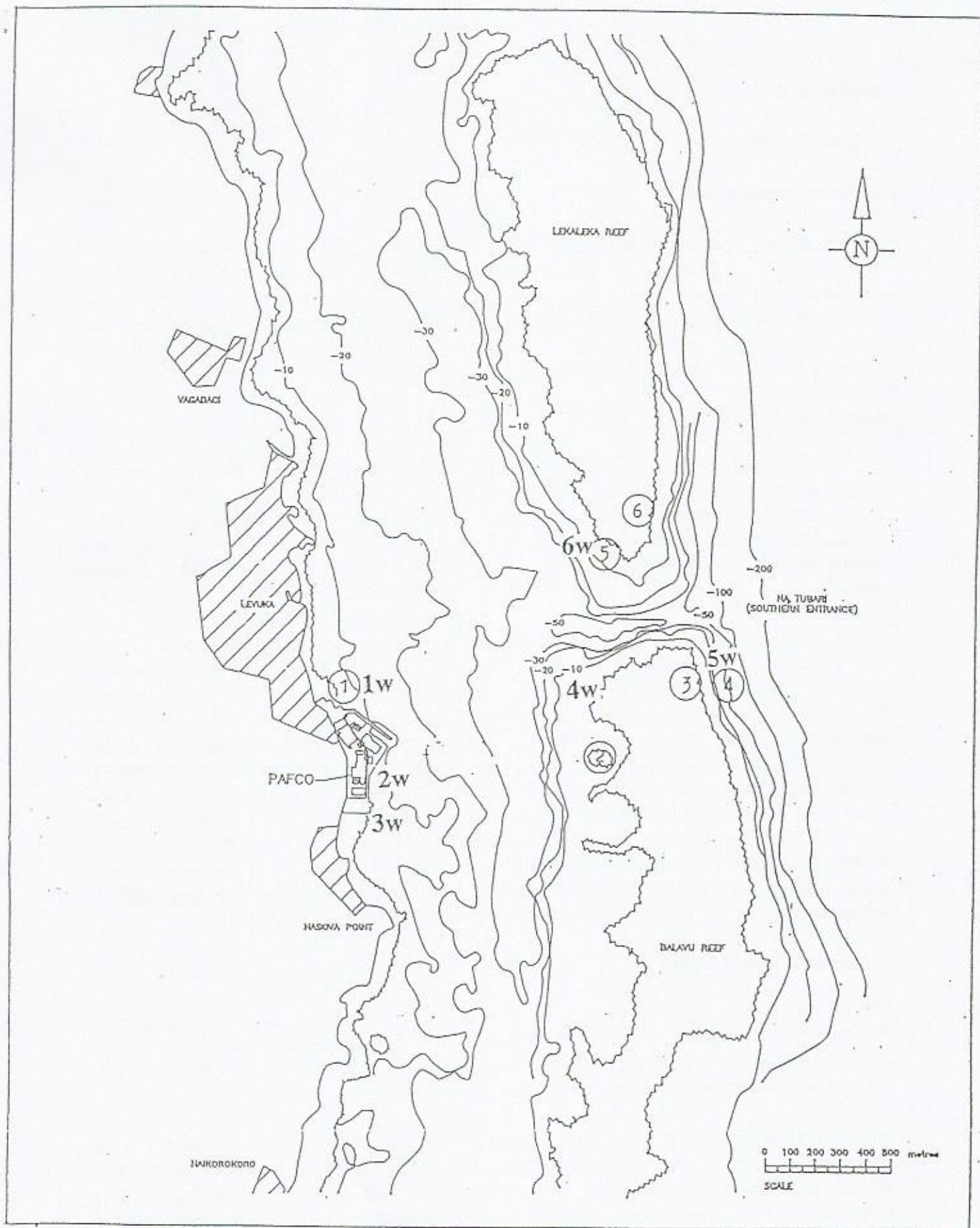


Fig. 2: Chart of Levuka Harbour showing study sites
 1w - 6w : Water quality sites; 1-6 : Coral reef sites
 adapted from Riedel & Byrne-Irwin Alsop Pacific

METHODS

Water Quality

On-site measurements

At each site, water temperature and dissolved oxygen concentrations at the surface and at 5 m depth were measured using a YSI Model 51B Dissolved oxygen (DO) meter. The meter was calibrated on site for altitude and water type. Clarity of the water was measured using a white secchi disc which was lowered into the water until the disc just disappears from site. Salinity at the surface and at 4 m depth was measured using the YSI Model 33 S-C-T Meter.

Laboratory analyses

Water samples were collected from the surface and at 5 m depth using the water depth sampler. The samples were stored in ice for analysis of biochemical oxygen demand (BOD), total suspended solids (TSS), the nutrients nitrates and orthophosphates, and faecal coliform concentrations. The samples for hydrocarbon concentrations were collected in large (1 L) Winchester bottles already filled with hexane.

Total suspended solids was measured for both surface and 5 m samples using the Filtration/Gravimetric method (APHA, 1981). The BOD was measured for surface samples only using the 5-Day incubation method (APHA, 1981). Levels of hydrocarbons in surface samples was measured using the Partition-Gravimetric Method (APHA, 1989). Faecal coliform levels in surface water samples were measured using Membrane-Filtration Method (APHA, 1981). Nitrate concentrations at the surface and at 5 m depth were measured using the Cadmium Reduction/Colorimetric Method and measurement of Absorbance on the UV Spectrophotometer (IAS Methods of Analysis of Water, May 1992). Orthophosphates concentrations for the surface and 5 m samples were measured using the Molybdenum blue-Colorimetric Method and measurement of Absorbance on the UV Spectrophotometer (IAS Methods, 1992).

Coral Reef Assessment

Monitoring sites were revisited or established, described and photographed. Photographs were taken in selected areas of the inshore reef and the offshore reefs of Lekaleka and Balavu Reefs. Site six has not been included in this write up but is subject to the same record as the other sites.

General assessment of the area is made by diving at each site or walking on it at extreme low tides. A set of three quadrats are established at each site. These are photographed for comparison in subsequent monitoring. The quadrats are of two sizes. The ones established in 1990 and monitored to 1993, are 2m² and those additional quadrats employed for this study are 1m².

RESULTS AND DISCUSSION

a) Water quality

The full results of the water quality assessment are tabulated below (Table 2).

Water Clarity :

There is a pronounced impact of the PAFCO cannery on clarity. The lowest clarity of 3 m was found for site 2, the site close to the discharge outlet for the plant floor washings (see photograph A in Appendix). Apparently, this waste outlet was highlighted by Green and Lovell (1992) as being a source of pollution in the harbour and should be connected up to the effluent outfall. The discharge going directly into the harbour was a very dirty brown colour, giving the water in the area very turbid and pale green appearance. There is a gradual improvement in water clarity as one moves away from the cannery. At site 1 to the north of the cannery, and at the offshore sites (sites 4, 5 and 6), the clarity values increase up to 13 m and possibly even higher.

Temperature and salinity :

Temperature and salinity were measured at the surface and at 4 m depth. No difference was found at the two depths indicating that the water was relatively well-mixed in the first few meters from the surface. At all sites, the salinity values were either 32 parts per thousand (ppt) or 33 ppt. Also at all sites (both surface and at 4 m depth), temperature of the water was very similar ranging from 27 to 28 °C. This mixing of the water would mean that any waste on the surface would be dispersed in the water column.

Dissolved oxygen :

The concentrations of dissolved oxygen indicate that no organic matter pollution was occurring at the time of sampling. The values of DO ranged from 4.0 (site 2 surface) to 5.9 mg/L (site 4 surface). In water where organic matter concentrations have exceeded the capacity of the decomposers to break down the waste to the simple, harmless compounds (carbon dioxide and water), the DO values would be greatly reduced to less than 2 mg/L.

Total suspended solids (TSS) :

The concentrations of TSS were very low and similar for all sites indicating a relatively clear water body. The TSS values varied from <1 - 2.7 mg/L. The distribution of TSS is uniform from the surface down to 5 m, the values for the surface and depth samples being almost identical for each site. The harbour is providing adequate dilution for the waste being discharged directly into the harbour near site 2. However whether the waste or floor washings conform to the Ports Authority of Fiji standard of 100 mg/L needs to be investigated.

Biochemical oxygen demand (BOD) :

The Biochemical oxygen demand was measured for the surface samples only. At site 2 close to the floor-washing discharge outlet, BOD concentration of 11 mg/L indicated gross pollution while the other sites with BOD of <2 mg/L indicated no pollution (Clark, 1986). This result confirms the fact that the discharge from floor washings (photograph A) is a point source of pollution in the harbour.

Hydrocarbons :

Hydrocarbon concentrations were generally low, up to 2 mg/L except at site 2 which had 10 mg/L. Any contamination or pollution due to hydrocarbons (oils and grease) would be fairly localised. The wharf area where fishing boats berth when in port would have significantly higher concentrations of oils and grease.

Nitrates and Orthophosphate :

If the cannery was discharging fish processing waste into the harbour, levels of the nutrients like nitrates and phosphates would be greatly increased and algal population would have increased. However, this does not seem to be the case with nitrates at least. The concentrations of nitrates in surface samples varied from 3.0 ug/L at site 6, to 88.7 ug/L at site 2. In all cases, there is an increase in NO₃ concentrations at 5 m depth. The most probable explanation here is that photosynthetic activity in the surface waters has resulted in greater uptake and use of nitrates. The exceptionally high nutrient levels at site 2 should be cause for concern. The orthophosphate concentration for the surface sample from site 2 (357 ug/L) is more than 10 times those of the other five surface samples. The floor washings with the expected high detergent components are a point source of phosphates in the harbour and this is very harmful to coral reefs in the area.

Faecal coliform :

Faecal coliform concentrations were measured in the surface samples only. While the other sites had reasonable faecal coliform counts which satisfy World Health Organisation recommended levels for bathing waters (<350 organisms/100ml), site 2 with 37000 org/100ml again exceeded this standard by more than 100 times. The discharge directly entering the harbour waters near site 2 must be diluted and treated prior to release into the harbour.

b) Coral reef assessment

Following are photographs of the quadrats and reef areas of interest. The quadrat positions are indicated in Figure 2. This area has been monitored since 1990 (Green and Lovell 1990). The rationale of including these previous quadrats is that they represent a known record of the variation during the period of the previous 5 years.

TABLE 2 : BASELINE WATER QUALITY ASSESSMENT RESULTS (May 1995)

Date received : 19/05/95

Parameter	Site 1	Site 1	Site 2	Site 2	Site 3	Site 3	Site 4	Site 4	Site 5	Site 5	Site 6	Site 6
	Surface	5m Depth	Surface	5m Depth	Surface	5m Depth	Surface	5m Depth	Surface	5m Depth	Surface	5m Depth
	95/690	95/708	95/691	95/709	95/692	95/710	95/693	95/711	95/694	95/712	95/695	95/713
Clarity (m)	9.0		3		4.5		6.5		13.0		12.0	
Temperature (deg °C)	28	27	27	27	27	25	27	27	27	27	27	27
Dissolved oxygen (mg/l)	4.8	4.9	4.0	5.0	5.2	5.8	5.9	5.8	5.8	5.4	5.4	5.2
Salinity (ppt)	32	32	33	33	33	33	33	33	32	33	32	33
Nitrate (ug/l)	25.3	119.2	88.7	152	15.1	58.3	4.6	105.8	40.2	107.2	3.0	128.1
Orthophosphate (ug/l)	<20	138.4	357	271.5	23.4	67.2	29.0	<20	<20	<20	<20	31.7
Faecal coliforms (/100 ml)	0		37000		20		500		160		12	
Total suspended solids (mg/l)	1.0	<1	1.4	1.8	1.4	1.3	2.1	2.0	1.3	1.5	2.7	2.2
Biochemical oxygen demand (mg/l)	<2		11		<2		<2		<2		<2	
Hydrocarbon (mg/l)	2		10		<2		<2		<2		<2	

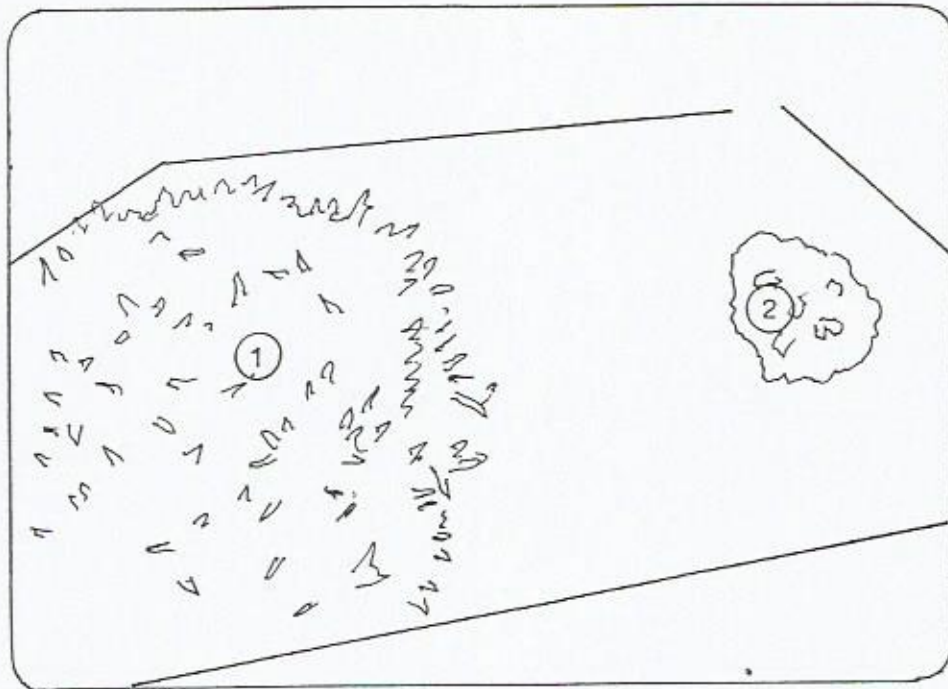
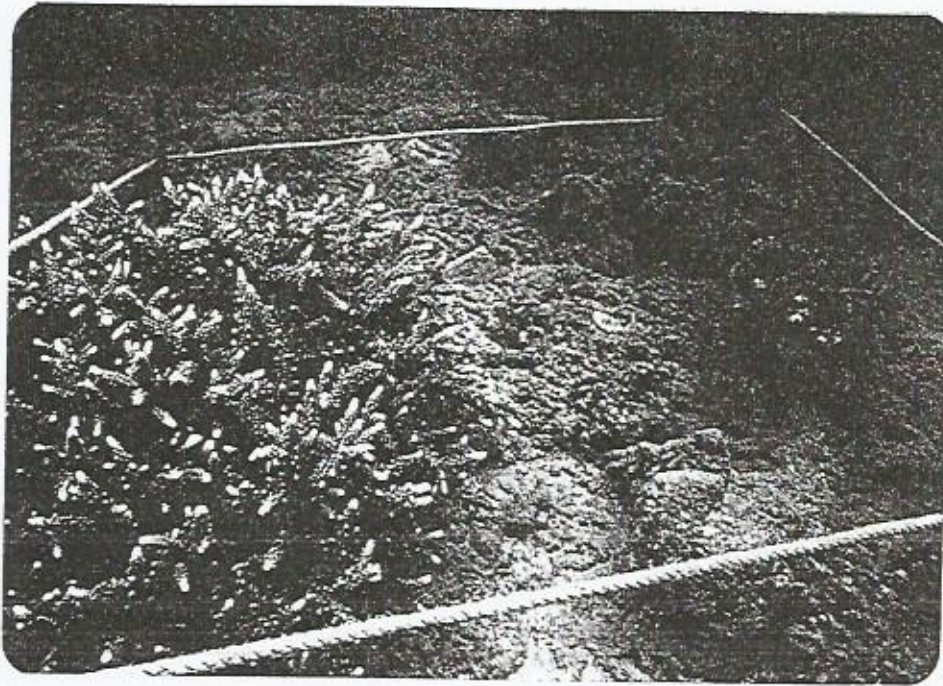
Site 1 : Inshore site offshore of Levuka

The inshore site is a good example of an inshore reef under stress. The coral assemblage exhibits less living cover. The area is often subject to the current flow which conveys effluent from the cannery. The high level of organic material evident in the water is manifested as a black ooze beneath a silty substrate in some areas. The high level of fine silt associated with the sand and the general lack of a consolidated reef structure, contrast this area with those on the offshore barrier. Comparisons with a coastal reef a kilometre to the north and evidence from anecdotal information, indicate that this reef assemblage has been degraded by the presence of its proximity to the cannery wharf or Levuka.

Figure 3a: An example of some of the best developed coral cover in the inshore area.



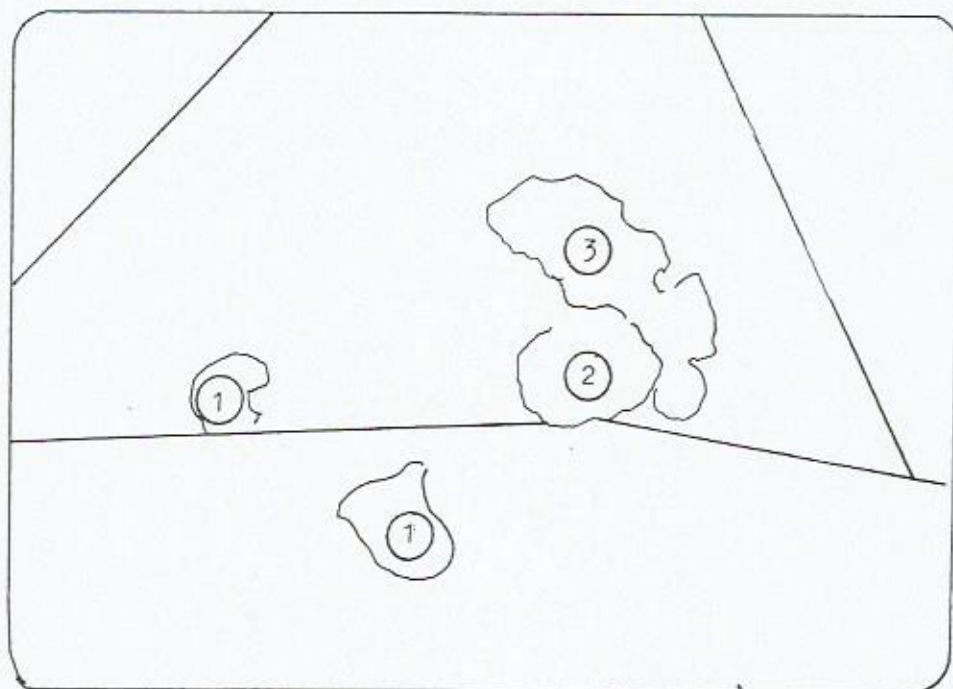
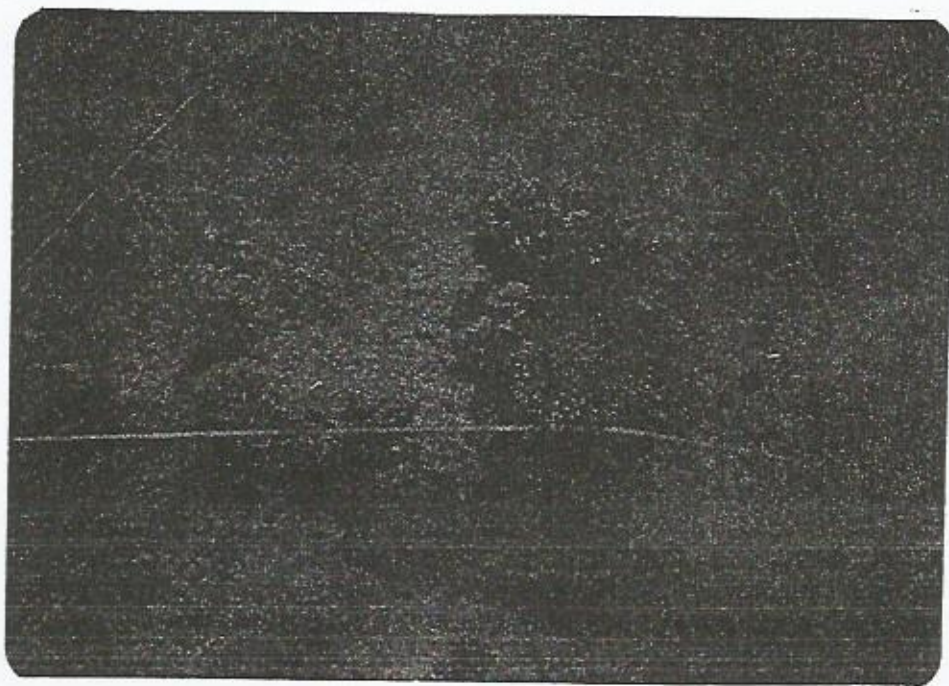
Figure 3b Quadrat 1: Inshore



Identifications:

1. *Acropora samoensis*
2. *Pocillopora verrucosa*

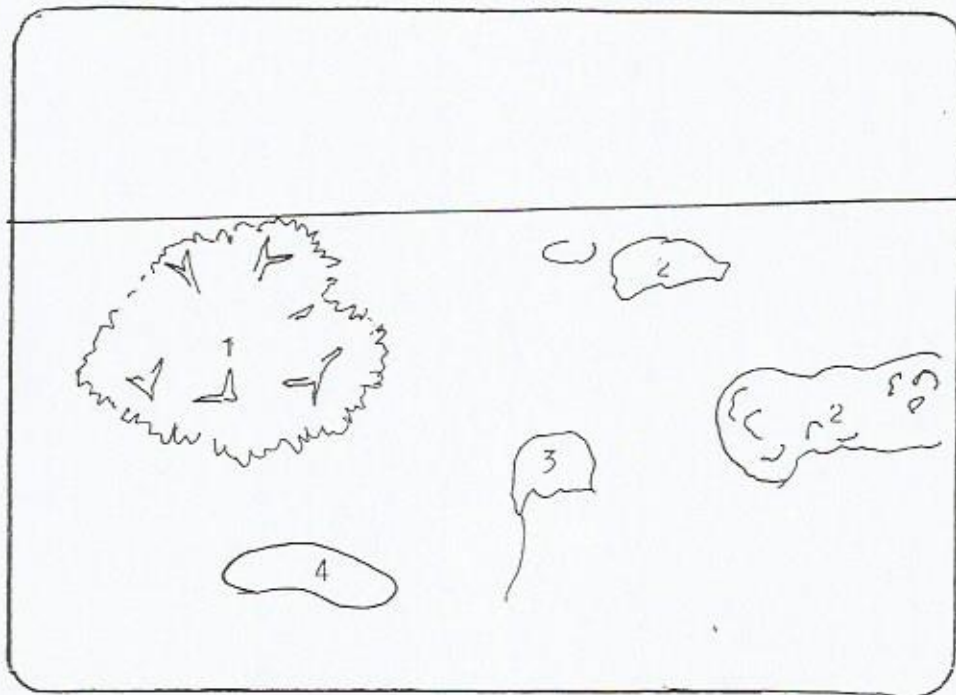
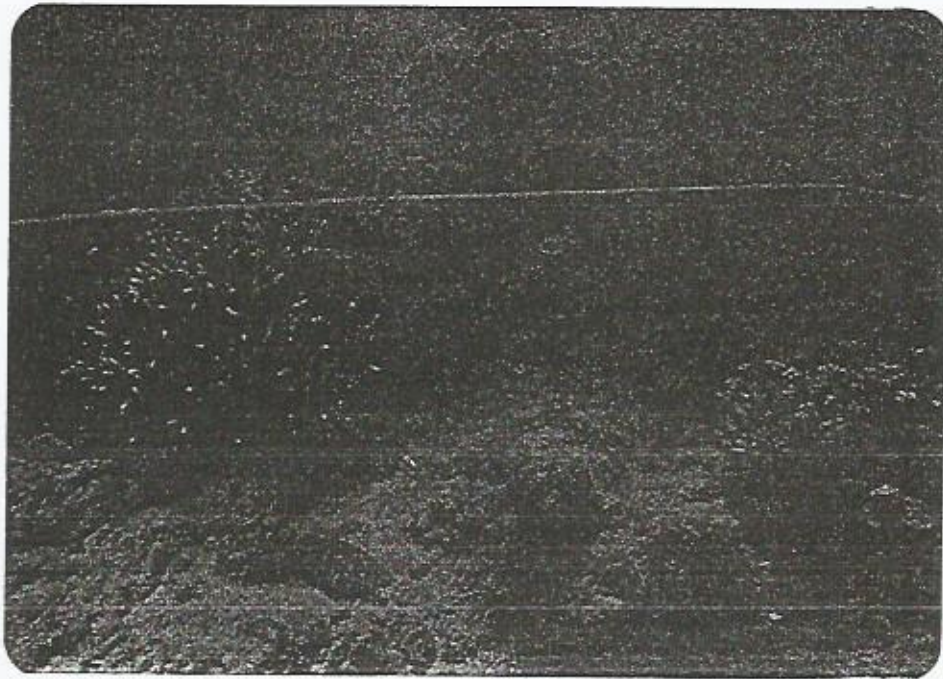
Figure 4: Quadrat 2: Inshore



Identifications:

1. *Porites* sp. 3. *Pocillopora verrucosa*
2. *Acropora* sp.

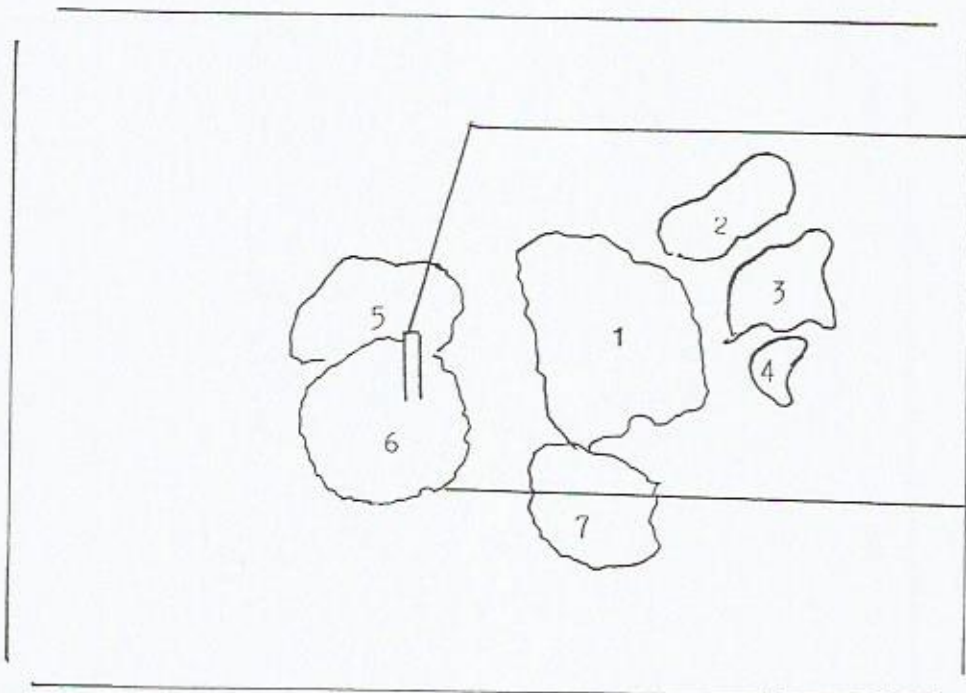
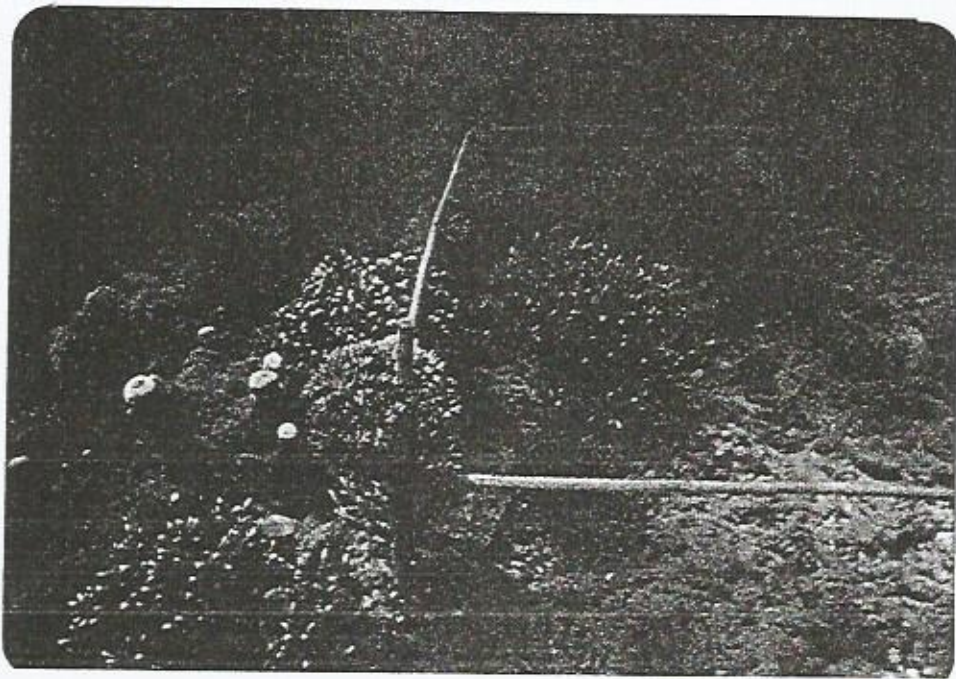
Figure 5: Quadrat 3: Inshore assemblage at northern perimeter of the quadrat.



Identifications:

1. *Acropora nobilis* 3. *Porites* sp.
2. *Pocillopora verrucosa* 4. *Herpolitha limax*

Figure 6: Quadrat 3 at right angle to previous photo.



Identifications:

- | | | |
|---------------------------------|----------------------------|--|
| 1. <i>Acropora nobilis</i> | 3. <i>Porites</i> sp. | 5. <i>Stylophora</i>
<i>pistillata</i> |
| 2. <i>Pocillopora verrucosa</i> | 4. <i>Herpolitha limax</i> | 6. <i>Pocillopora</i>
<i>damicornis</i> |
| 7. <i>Acropora</i> sp. | | |

SITE 2: Back reef coral knoll on Balavu Reef

This area is a small patch reef associated with the barrier reef system. Isolation from coastal influences by virtue of the shoreward channel provides contrast in terms of greater water clarity, a calcareous sandy substrate and a relatively constant salinity and temperature. The coral assemblage is luxuriant subtidally but has suffered substantial death in the intertidal area on the tops of the knolls.

Figure 7: General view of knoll opposite the quadrats



Figure 7a: Coral death evident intertidally on the reef top.

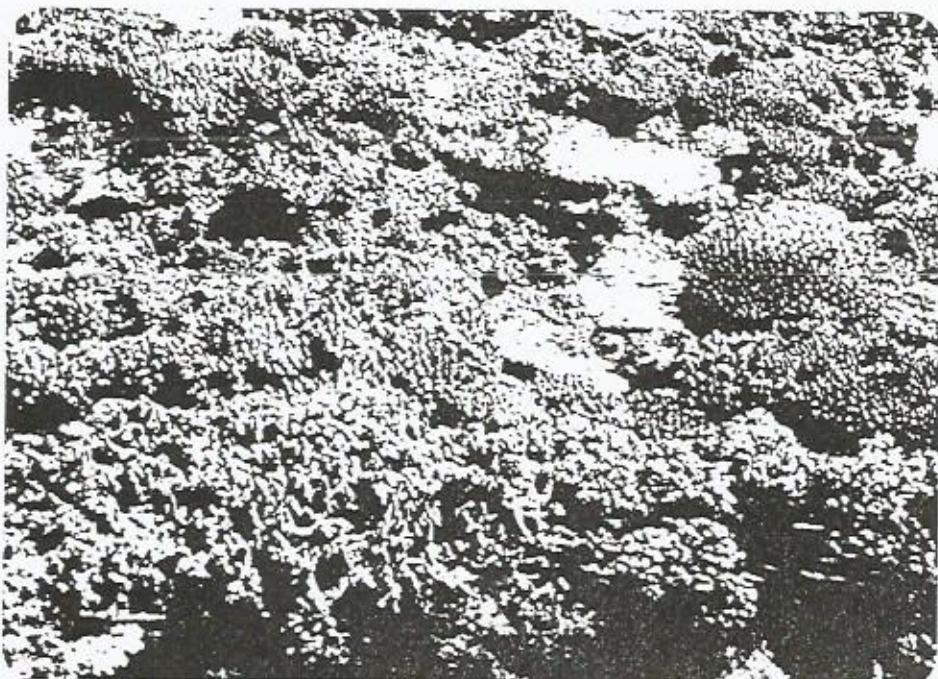
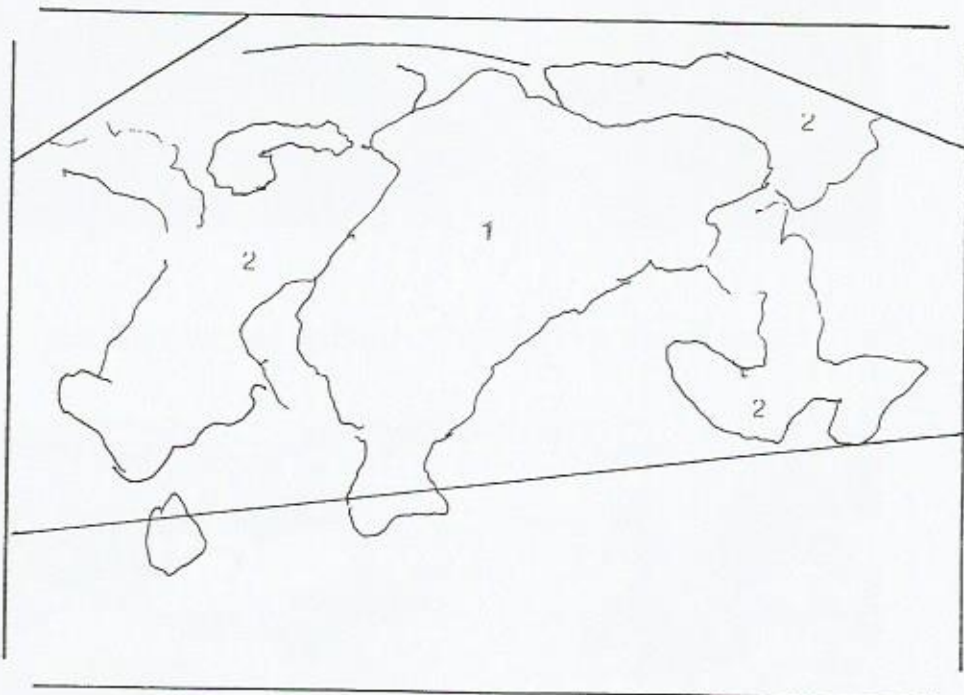
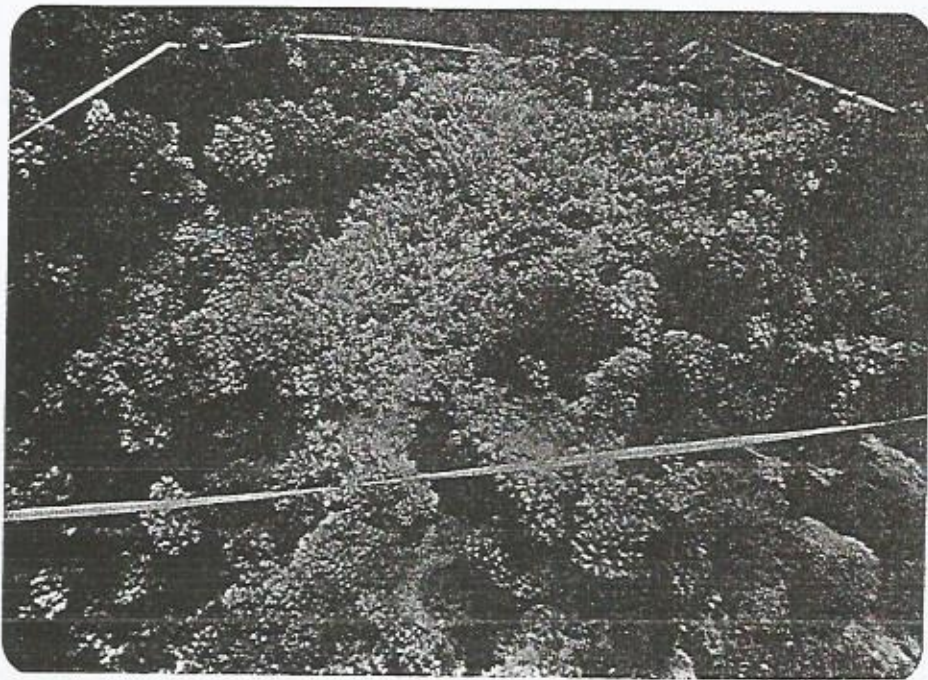


Figure 8: Quadrat 1: Back reef

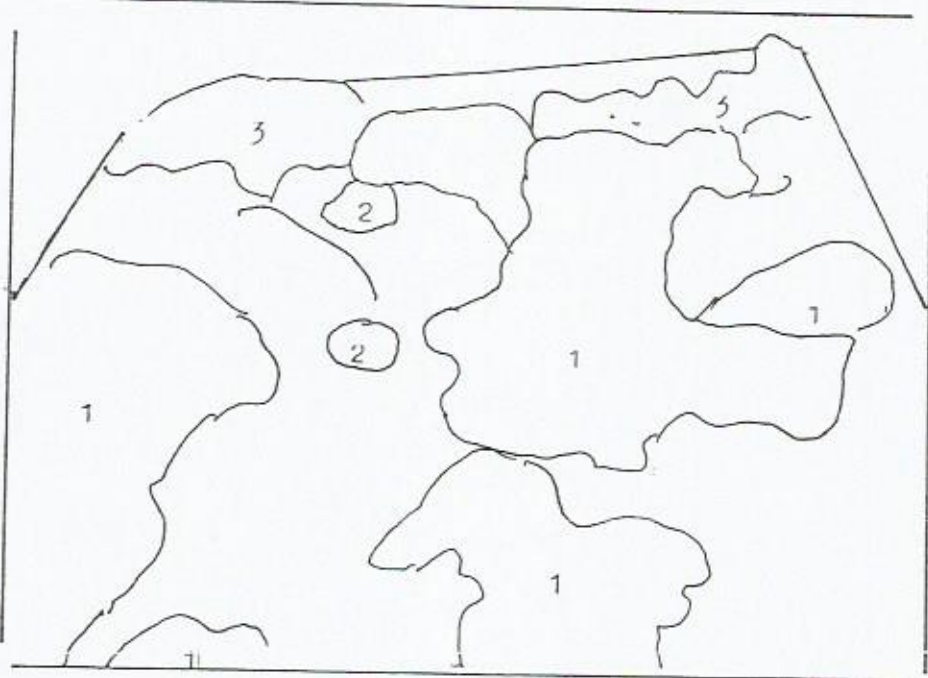
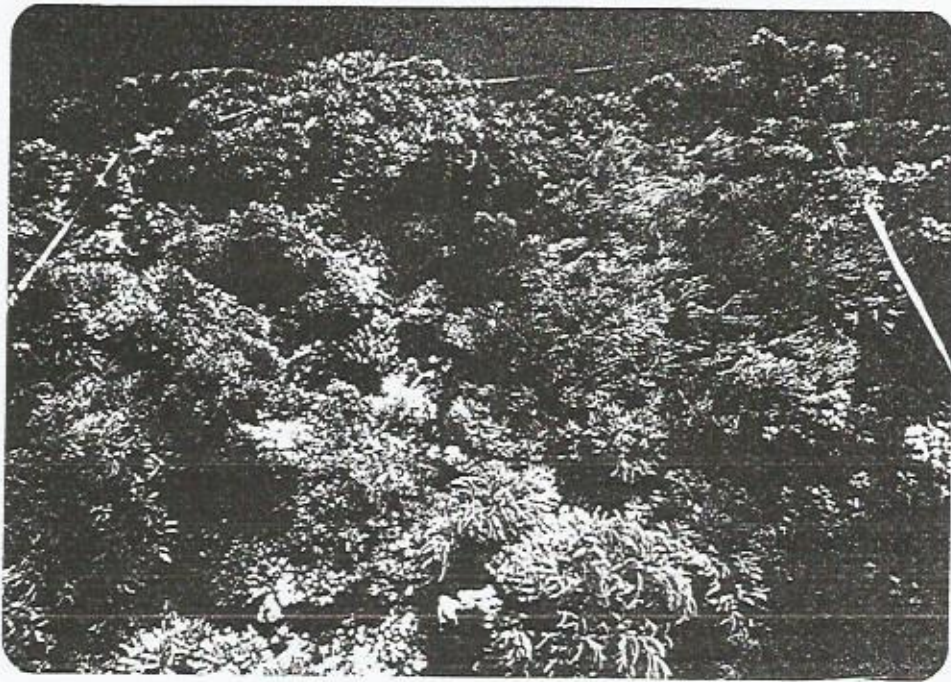


Identifications:

1. *Acropora elseyi*

2. *Pocillopora damicornis*

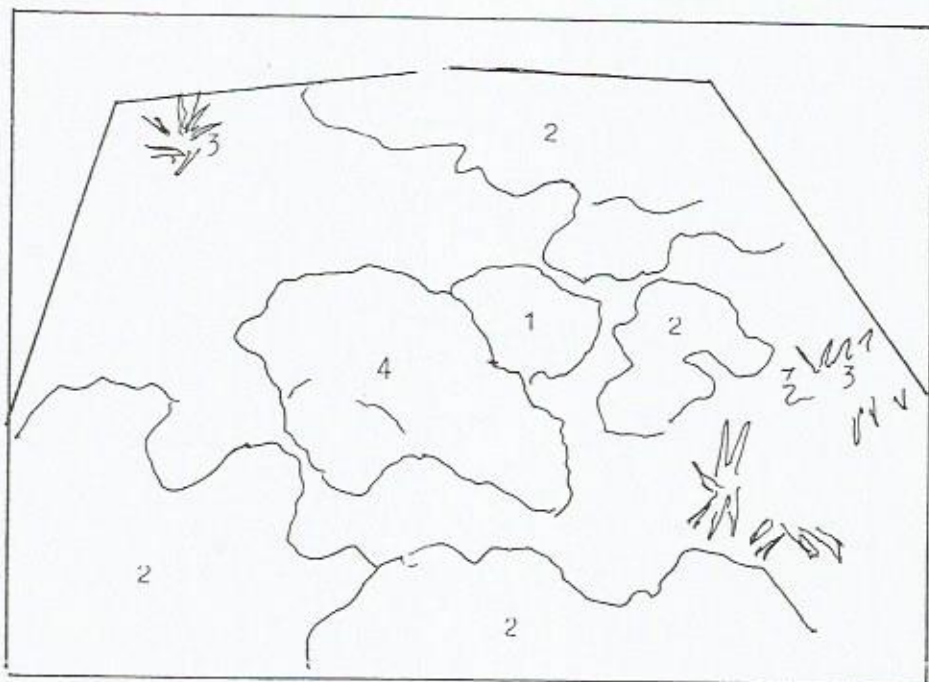
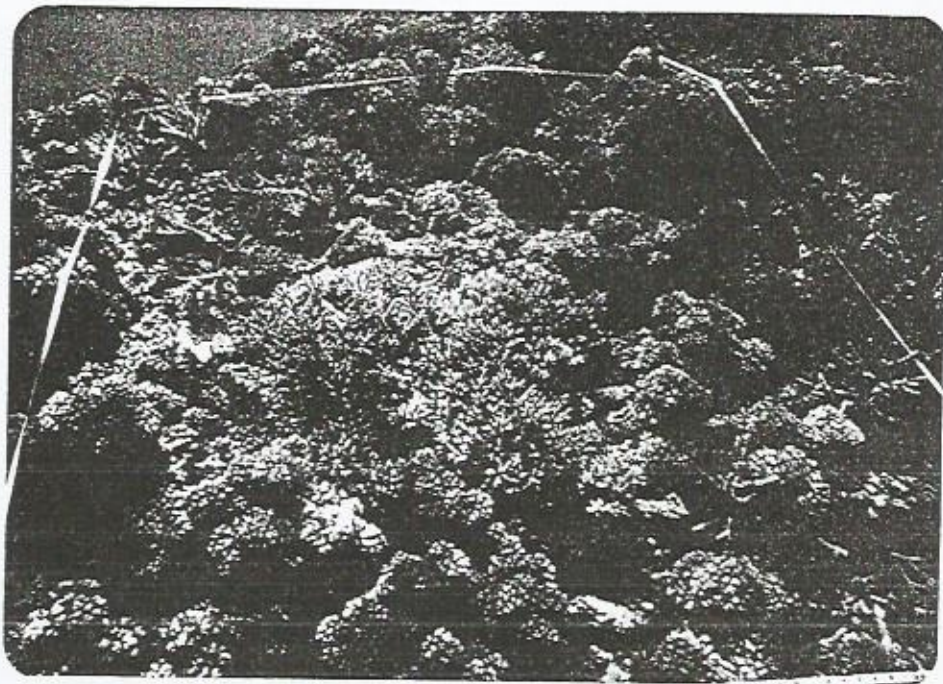
Figure 9: Quadrat 2: Back reef knoll



Species identifications:

1. *Sinularia* sp. (soft coral)
2. *Acropora digitifera*
3. *Pocilopora damicornis*

Figure 10: Quadrat 3: Back reef knoll



Species identifications:

1. *Acropora elseyi* 3. *Acropora formosa* 5. *Acropora* sp.
2. *Pocillopora damicornis* 4. *Acropora nobilis*

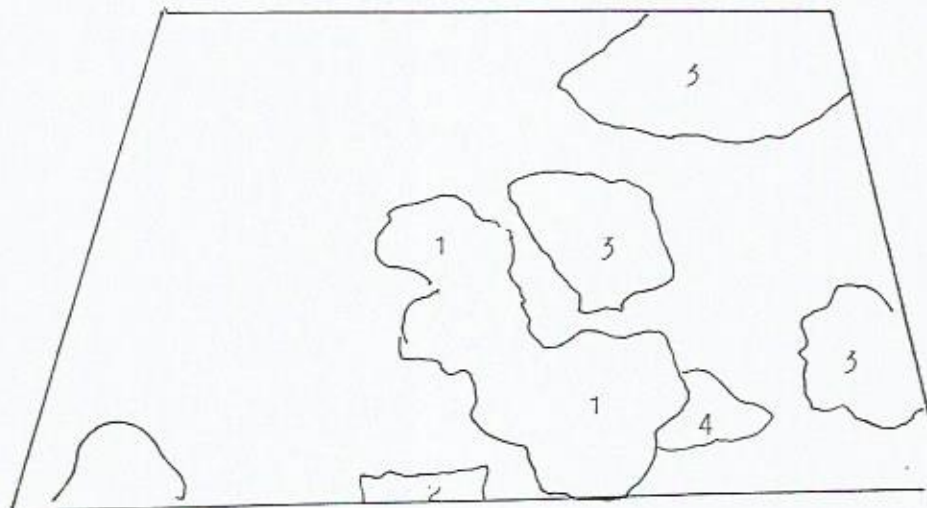
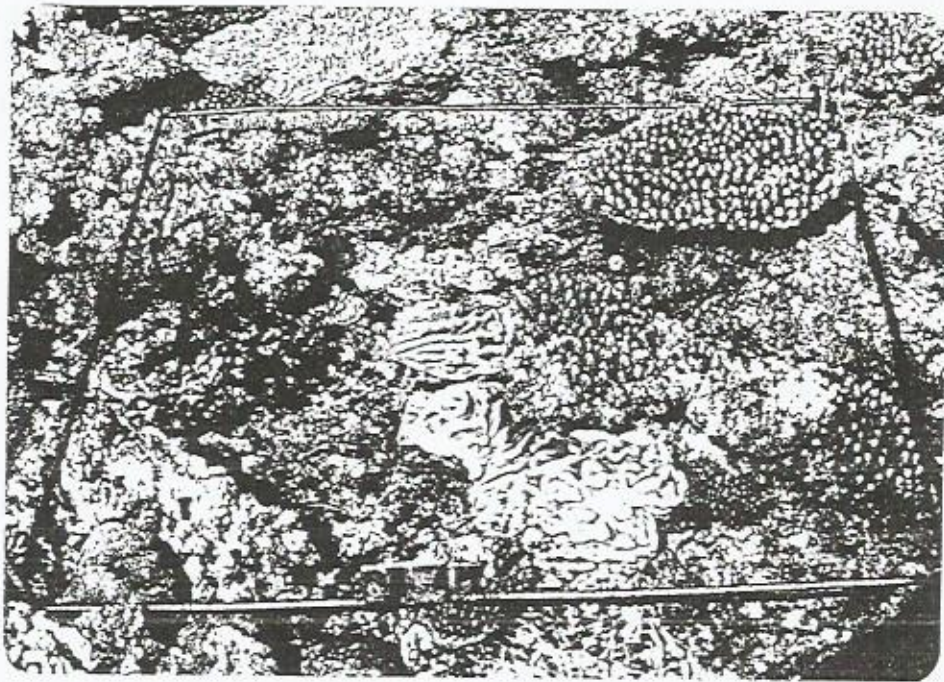
Six quadrats were established in an area adjacent the off-reef outfall. Three were intertidal on the reef flat and three are subtidal on the reef front, ranging from 2 to 8 metres.

SITE 3: Intertidal reef flat on the seaward margin of Balavu Reef

This site is characterised by the presence of an intertidal, wave washed assemblage located on the windward margin of Balavu Reef. The site is adjacent the proposed outfall site. The corals in this area are healthy but as is characteristic of this area, robust so as to be able to stand the wave action.

No unnatural coral death is evident here. The assemblage exhibits the type of diversity expected from this zone with the coral colonies encrusting or closely adhering to the reef substrate to avoid the wave action. The hard coral cover is estimated at 20% to 30% with soft corals monopolising some areas.

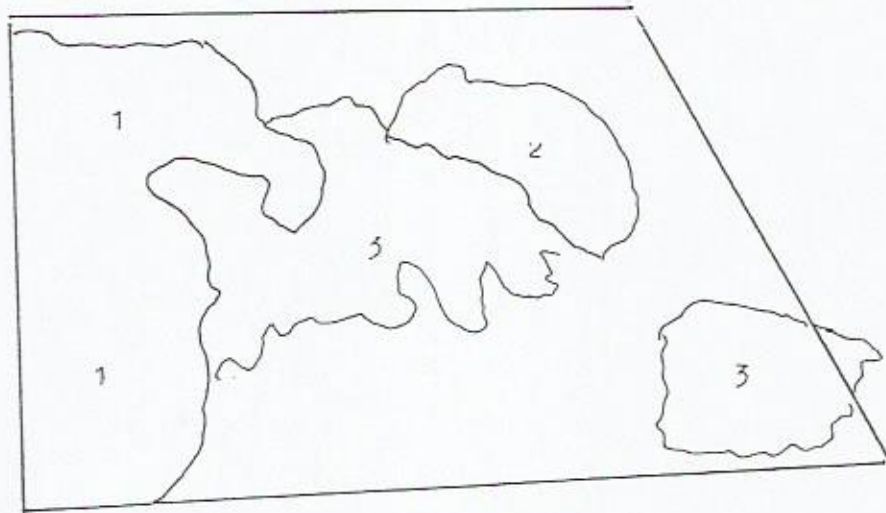
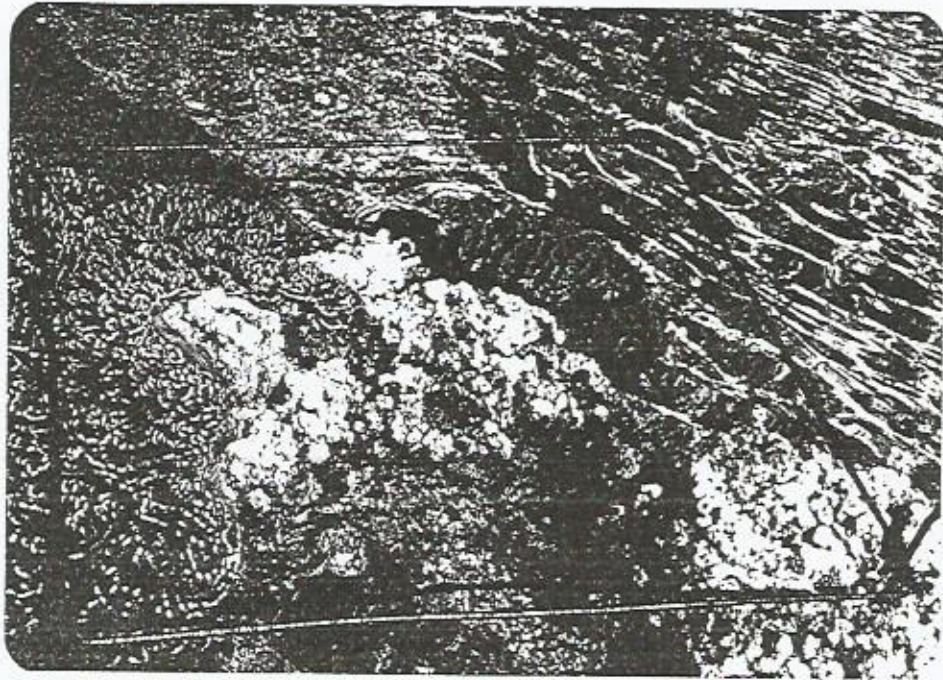
Figure 12: Quadrat 1: Intertidal Reef Flat



Species identifications:

- | | |
|--------------------------|----------------------------|
| 1. <i>Lobophytum</i> sp. | 3. <i>Acropora humulis</i> |
| 2. <i>Porites</i> sp. | 4. <i>Acropora</i> sp. |

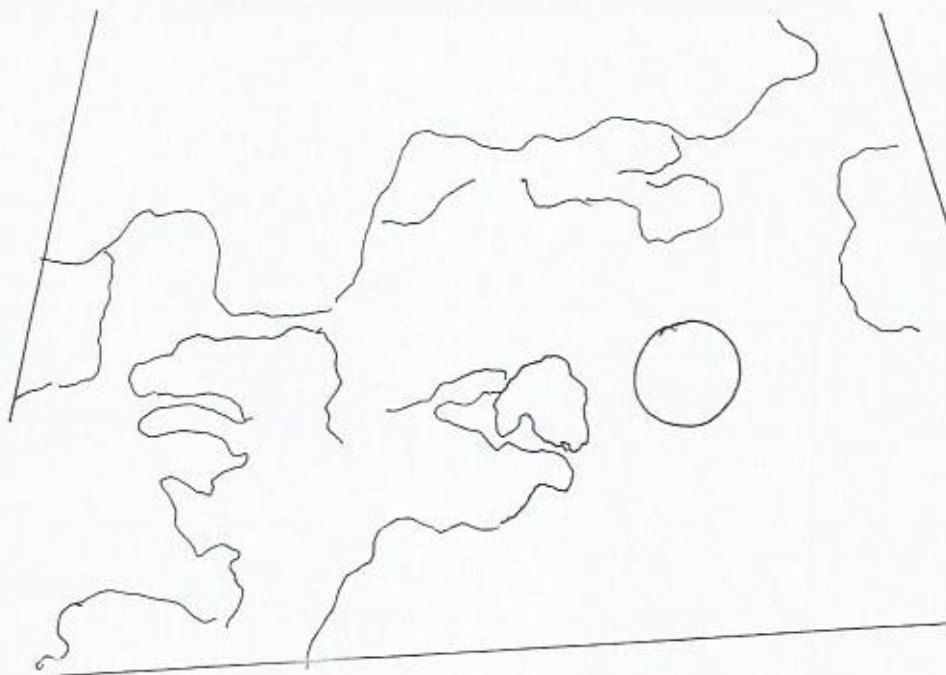
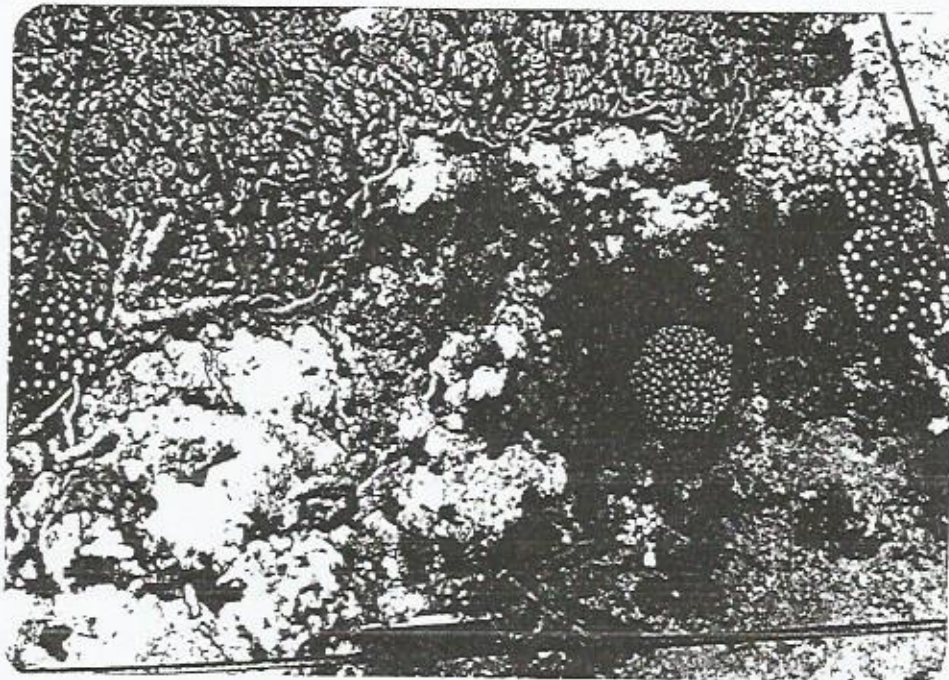
Figure 13: Quadrat 2: Intertidal Reef Flat



Species identifications:

- 1. *Lobophytum* sp.
- 2. *Porites* sp.
- 3. Coralline algae

Figure 14: Quadrat 3: Intertidal Reef Flat



Species identifications:

1. *Lobophytum sp.*
2. *Acropora humilus*
3. *Stylophora pistillata*
4. Coralline algae
5. *Acropora sp.*

General observation revealed an unusual coverage of *Sargassum sp.* on the reef flat. Though the growth of this algae is seasonal, such proliferation is an indication of elevated nutrients. The algal cover is limited to the north end of Balavu Reef. It is so dense that it has covered the reef, out competing nearly all of the hard coral on the reef flat.

Figure 15: The extensive mat of algae (*Sargassum sp.*).

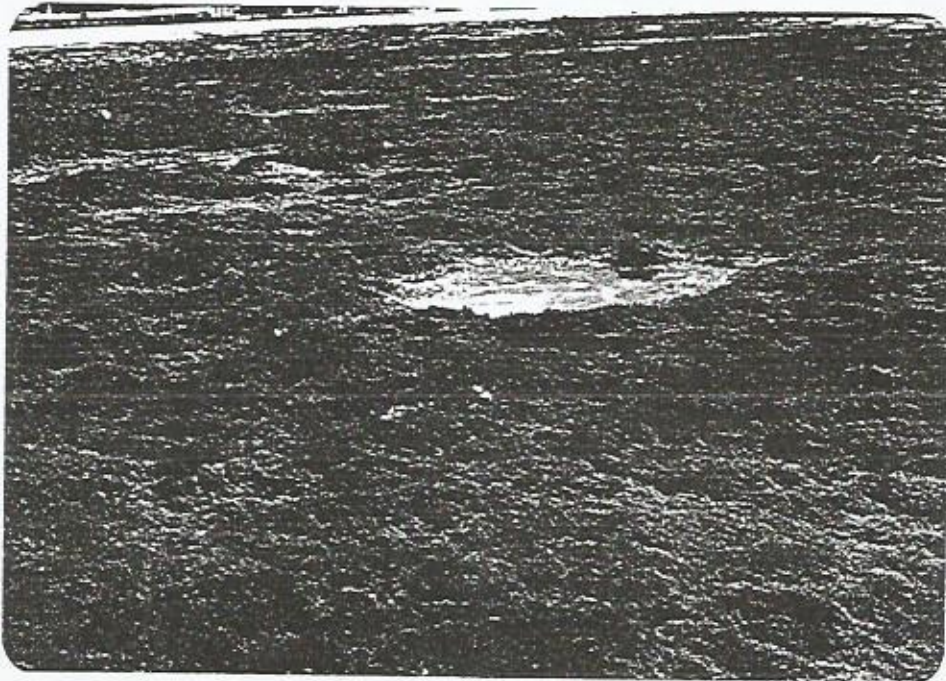


Figure 16: Abrasion and shading by the thick algal growth is responsible for the death of a large reef flat *Porites* colony.



SITE 4: Subtidal reef front on Balavu Reef

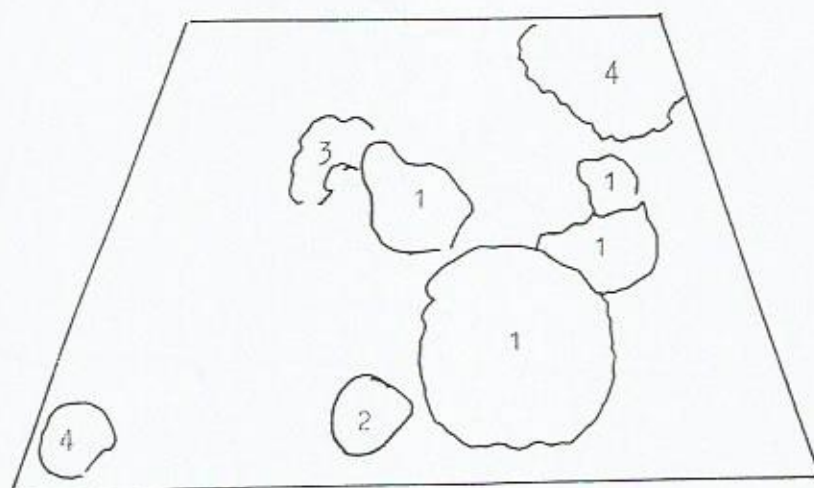
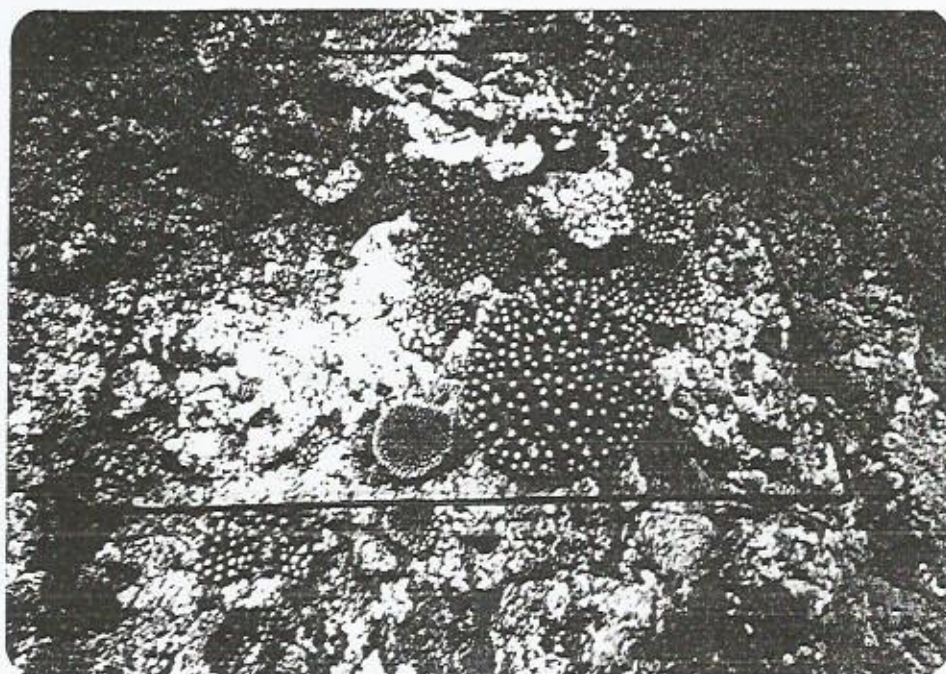
This area is the windward margin of Balavu Reef. The reef profile drops off steeply to a sandy margin at 15m. The reef front is often vertical with substantial undercutting in places. In the wave zone the profile is slightly sloping being dissected with an intermittent spur and groove system. The quadrat areas are located a the steep buttress slope of one of these features.

The percentage composition on the reef front was visually estimated at 50% coralline algae, 30% soft coral, 15% hard coral and 5% *Millepora sp.* On the wave washed slope, the hard coral cover is 60% with the sprawling plate-like colony forms of *Acropora hyacinthus* common.

Figure 17: The seaward margin of Balavu Reef adjacent the proposed waste water outfall.



Figure 18: Quadrat 1: Forereef slope at 2 metres depth



Species identifications:

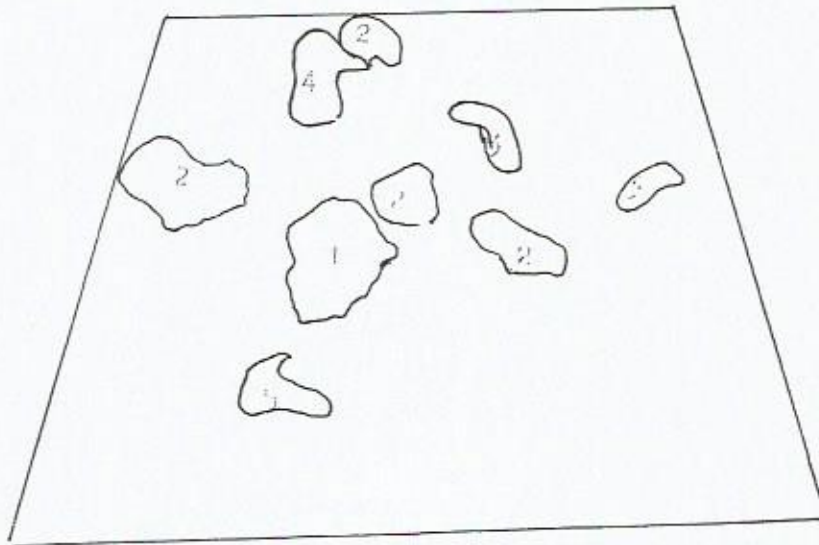
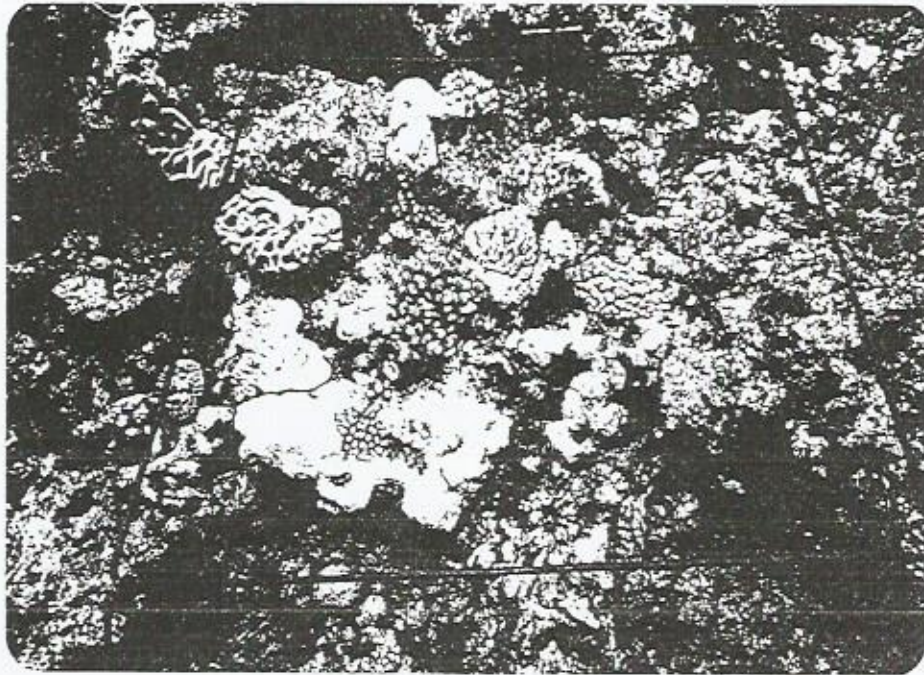
1. *Acropora humilis*

3. *Pocillopora eydouxi*

2. *Acropora hyacinthus*

4. *Pocillopora verrucosa*

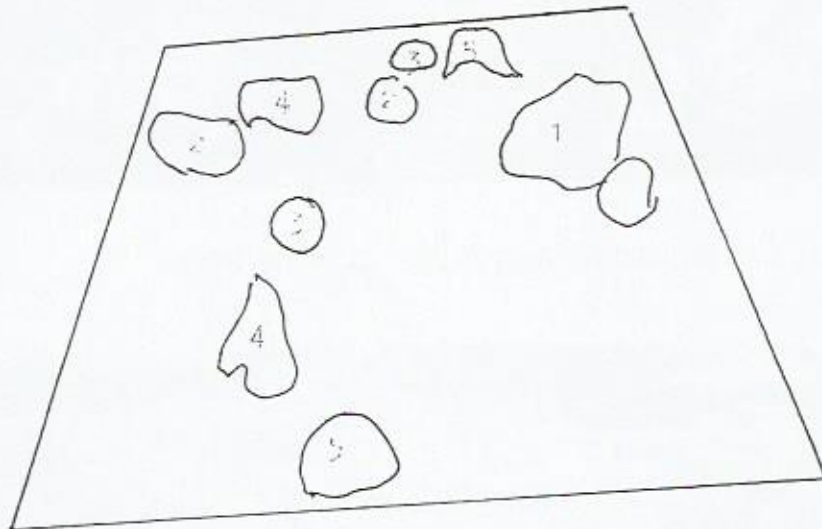
Figure 19: Quadrat 2: Forereef slope at 5 metres depth.



Species identifications:

1. *Pocillopora verrucosa* 3. *Porites* sp. 5. *Acropora* sp.
2. Soft coral 4. *Platygyra lamellina*

Figure 20: Quadrat 3: Forereef slope at a depth of 8 metres.



Species identifications:

1. *Pocillopora verrucosa* 3. *Acropora hyacinthus* 5. *Porites* sp.
2. Soft coral 4. *Montipora* sp.

SITE 5: Reef flat, channel margin on Lekaleka Reef

This site is located on the southwest corner of Lekaleka reef. It is represented by a series of bommies or knolls with a high degree of coral coverage on them. The luxuriance coral approaches maximum development attainable by a hard coral assemblage. This is due to proximity to the channel where oceanic water and limited wave action provide ideal conditions for coral growth. The quadrats are sited on the tops of the bommies.

Figure 21: General view of the southwest corner of the reef showing extensive coral cover.

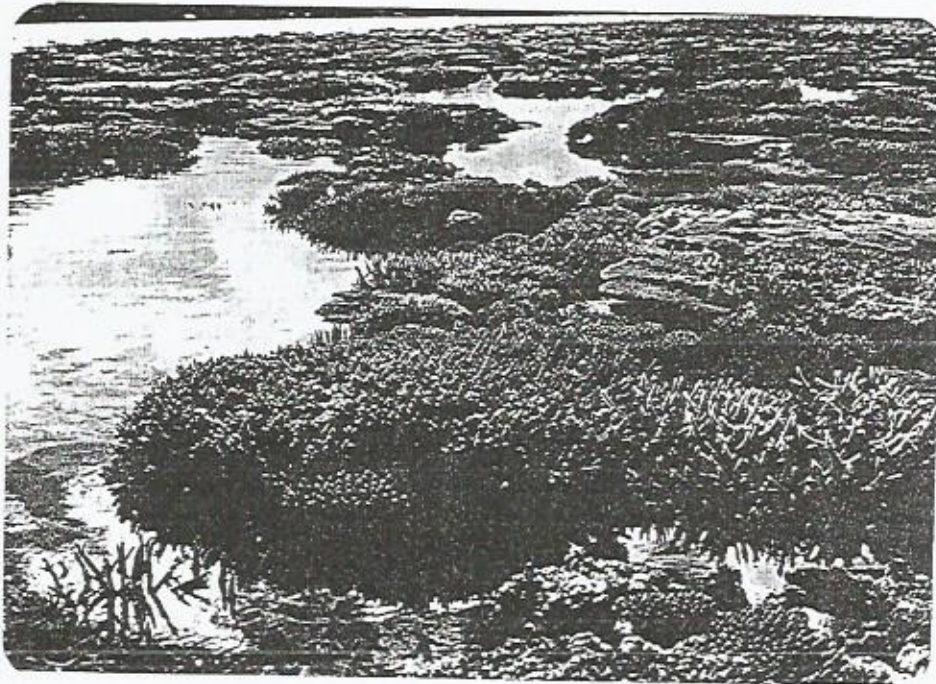


Figure 22: Coral assemblage in the quadrat area.

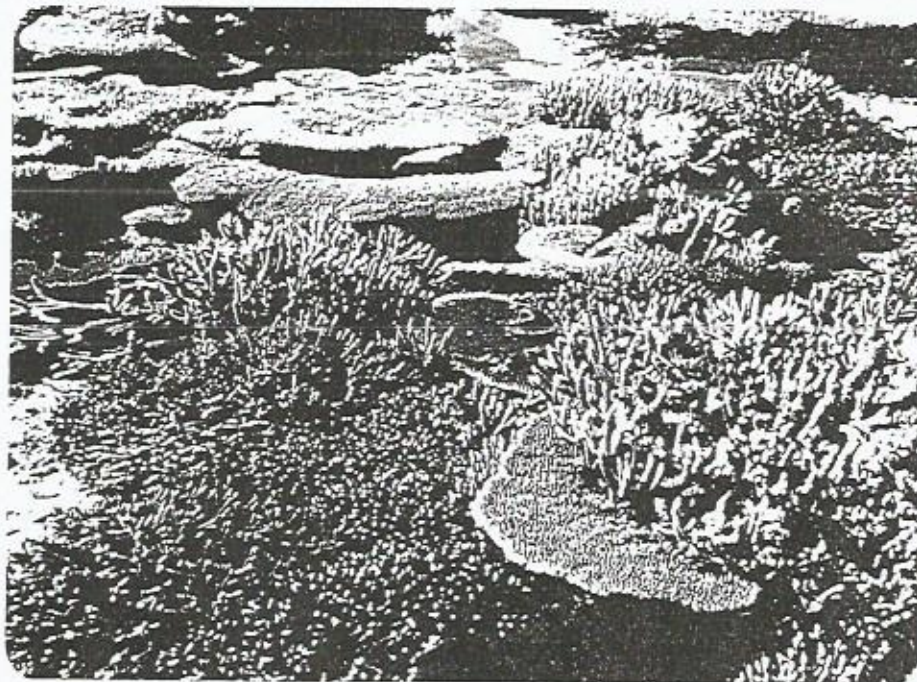
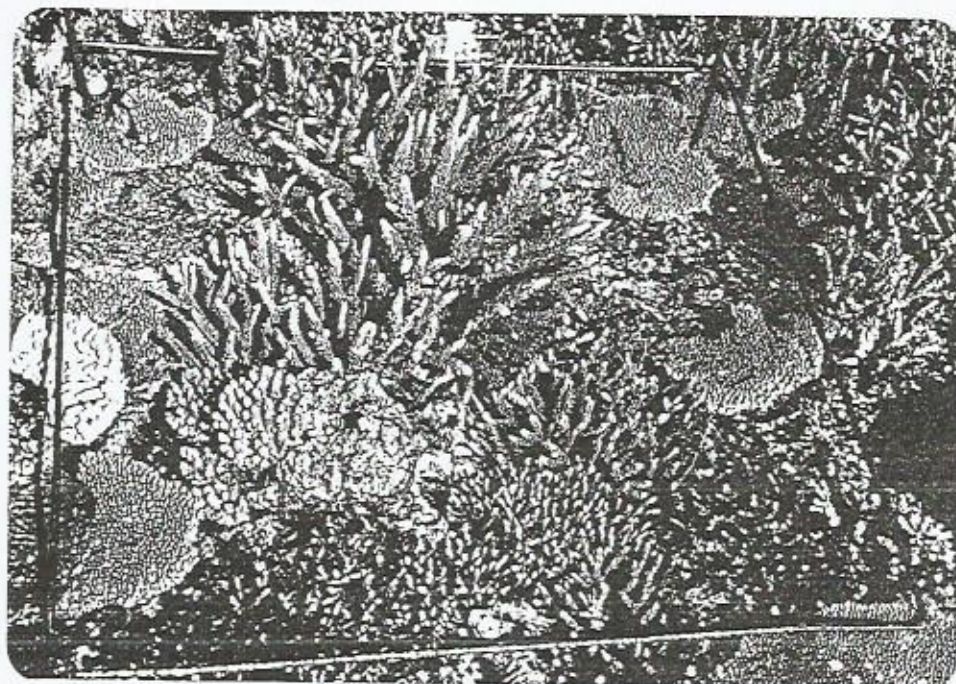


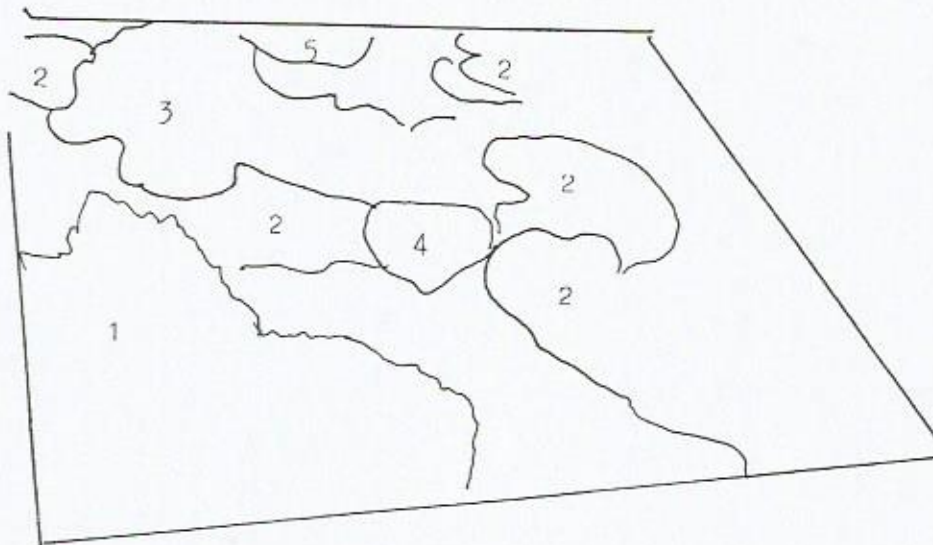
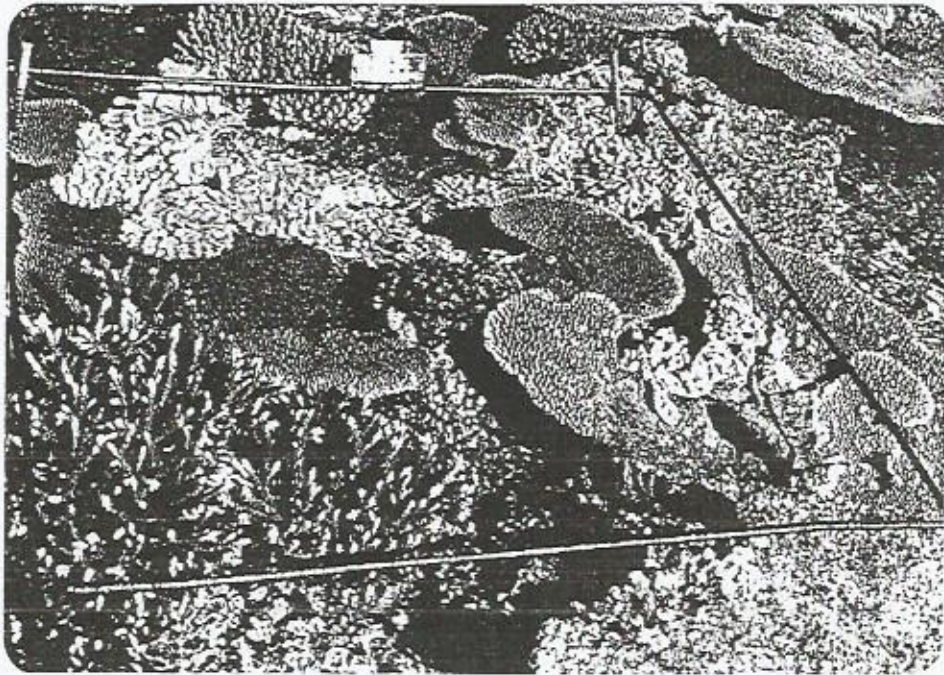
Figure 23: Quadrat 1: Reef Flat



Species identifications:

- | | | |
|-------------------------------|----------------------------------|------------------------|
| 1. <i>Acropora robusta</i> | 3. <i>Acropora microphthalma</i> | 5. soft coral |
| 2. <i>Acropora hyacinthus</i> | 4. <i>Acropora digitifera</i> | 6. <i>Acropora sp.</i> |

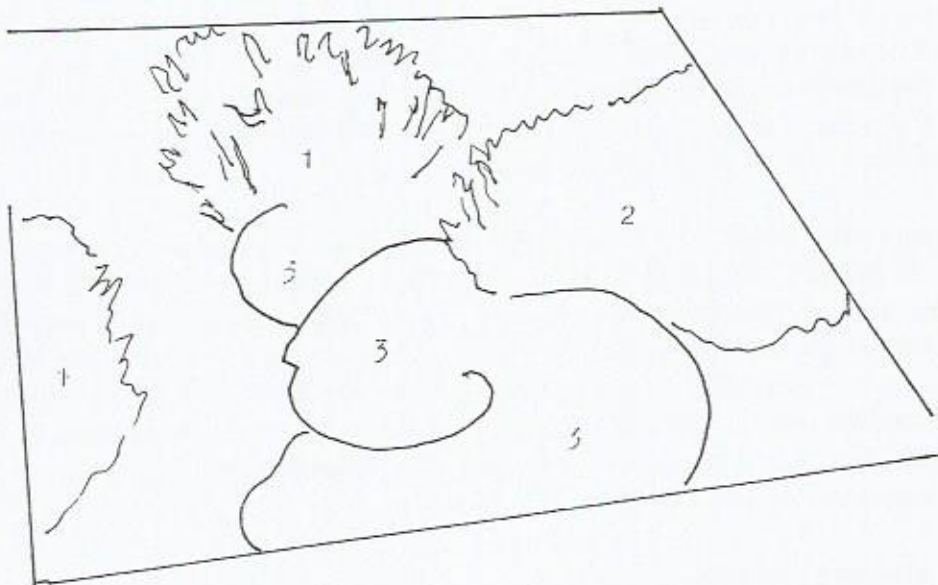
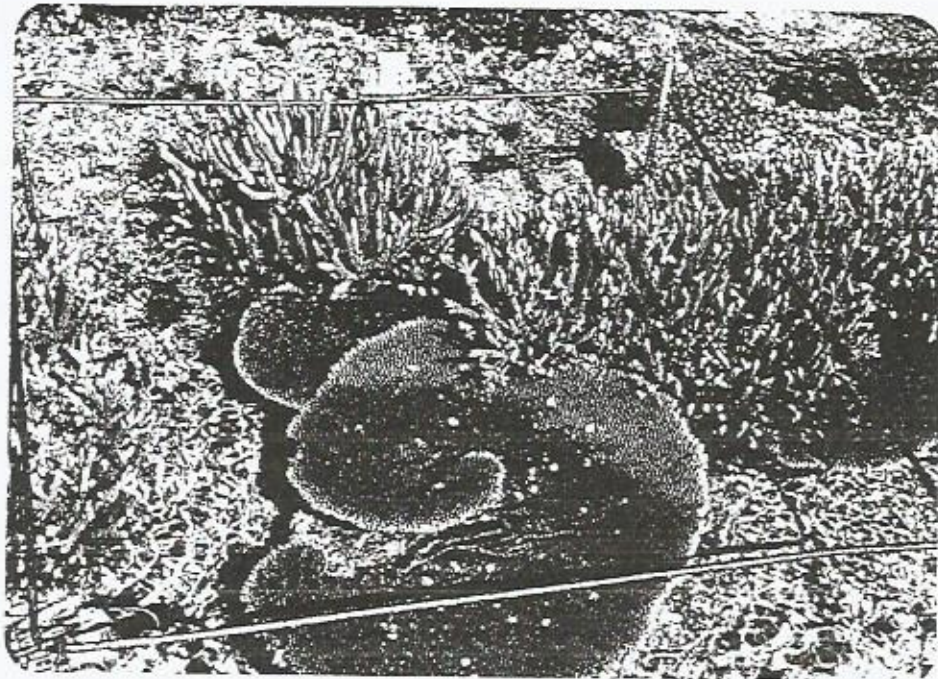
Figure 24: Quadrat 2: Lekaleka Reef Flat



Species identification:

1. *Acropora nobilis* 3. soft coral 5. *Acropora digitifera*
2. *Acropora hyacinthus* 4. *Pocillopora damicornis*

Figure 25: Quadrat 3: Lekaleka Reef Flat



Species identifications:

- 1. *Acropora robusta*
- 2. *Acropora nobilis*
- 3. *Acropora hyacinthus*

DISCUSSION OF CORAL REEF SURVEY RESULTS :

Summarising the general observations and the nature of the monitoring quadrats, the study sites represent a good deal of variability. This variability is expected due to the diverse physical environments in what results in the natural zonation on the reef. The occurrence of cyclone Kina presented another factor which affected the coral reef environment.

What is unusual is the contrast between the two reefs on either side of *Na Tubari* channel between *Balavu* and *Lekaleka* Reefs. The change which has occurred since the previous monitoring period on north Balavu Reef has been dramatic. It is now covered with *Sargassum*, intertidally, with substantial coral death on the tops of the coral bommies or knolls. Such vigorous growth of *Sargassum* could have been caused by high nutrient levels in the water in the area. In the channel and the adjacent intertidal reef areas on *Lekaleka* Reef, a luxuriant coral assemblage covers the tops of the coral knolls and fringe of the reef flat. Unfortunately, the nature of the coral being almost wholly dominated by the genus *Acropora* means that the reefs would be generally sensitive to environmental change.

Potential effluent impact

As the effluent will be less saline than the seawater, it will float to the surface, and would be carried rapidly and for some substantial distance, depending on the tidal currents and the effects of wind drift. The tidal current flows strongly in through the passage on the flooding tide (Lloyd and Peter, 1989) and is subject to prevailing wind drift. It is hoped that the dilution effect will prevent such contamination but this will depend on placing the outfall sufficiently far from the channel so that the wind drift will convey the surface effluent onto *Balavu Reef* which has already been affected.

The *Lekaleka* Reef is a source of food and is used by *Levuka* villagers for artisanal fishery. Judging from the numbers of people observed engaged in this activity during the low tide survey (40 - 50 people), it is responsible for a substantial contribution to the village food supply. With the altering of the nature of the reef flat to something similar to *Balavu Reef*, it will become less productive in terms of food products. Failure to observe caution in the siting of the pipe or to have a contingency plan in place if problems develop, may result in problems involving the local community.

Other effluent hazards

As well as the stimulation of algal growth, there is an adverse effect from the presence of elevated levels of phosphorous and nitrogen on the growth of corals, generally. Coral skeleton loose strength, becoming crumbly to the touch.

Contamination by industrial wastes and toxic bioaccumulation may present another hazard to the disposal of sewage and industrial effluent near an area where fishing and gleaning occur. This may cause degradation and the poisoning of the artisanal fishery. Seafood may become contaminated, swimmers and gleaners may be subjected to bacterial and viral diseases (Westman, 1974; Miller, 1978; Beder, 1989).

RECOMMENDATIONS:

It is recommended that the outlet to the pipe is placed as far to the south of the channel as is practicable because of potential problems outlined above.

Careful monitoring of the effects of the effluent on Lekaleka reef is essential.

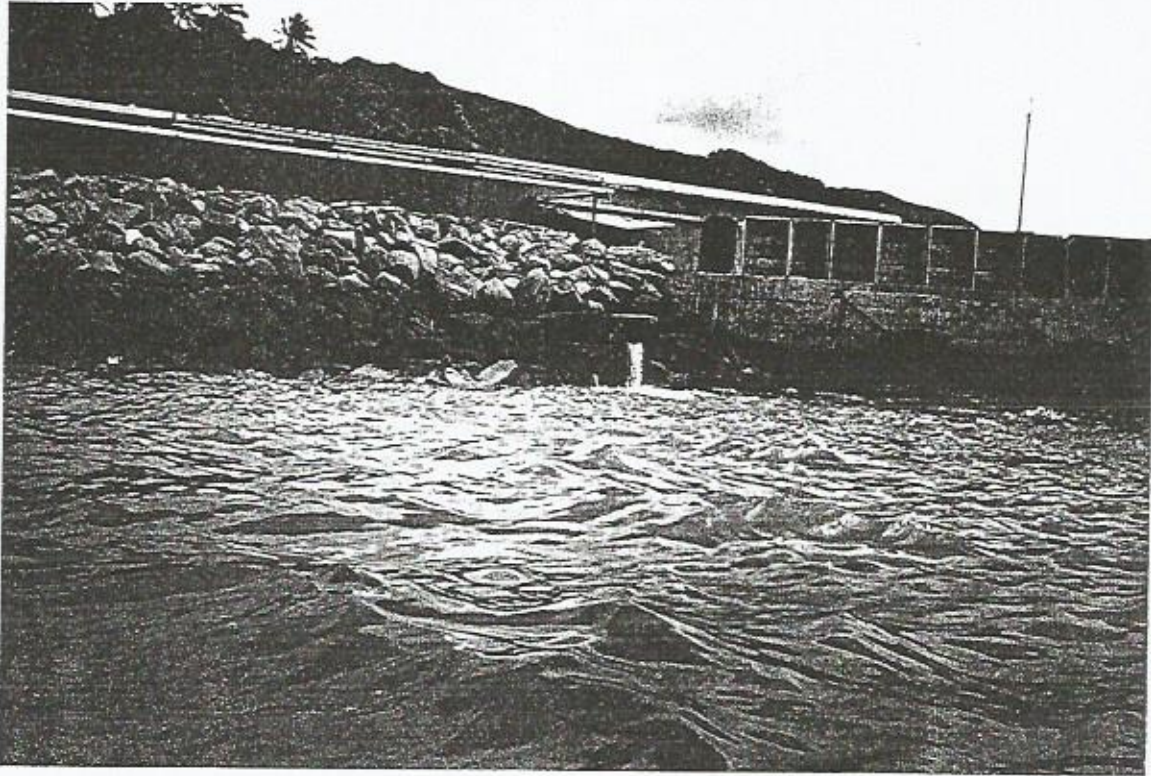
A contingency plan must be in place to divert the flow of effluent if a problem develops and to resite the outfall further away from the channel.

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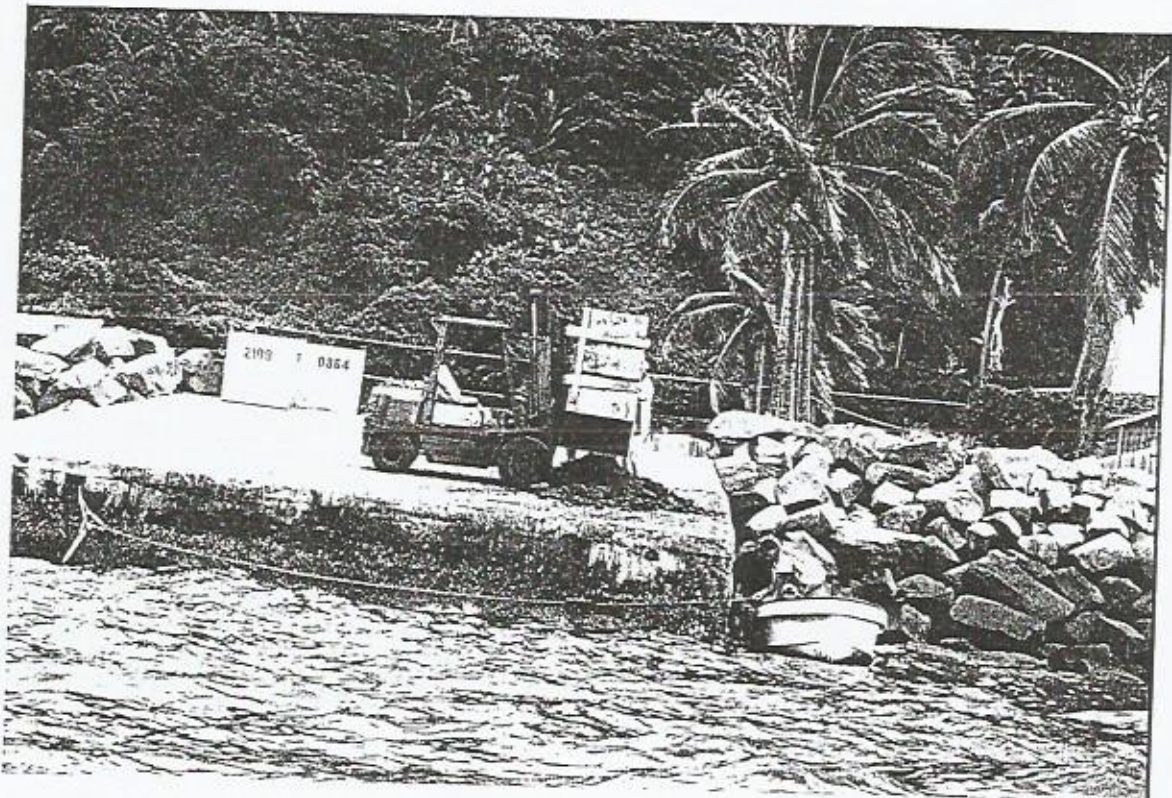
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APPENDIX

Photograph A - Water quality study site 2. Distinct turbidity of water near discharge outlet



Photograph B - Water quality study site 3. Fish meal on jetty near Container Yard.



Photograph C - Water quality site 4. Exposed reef flat on Balavu Reef showing mainly dead and bleached corals.



Photograph D - Fish meal floating on the surface of the water at Levuka harbour.

