LANDBANK

PROPOSED DEVELOPMENT AT McCABE STREET
MOSMAN PARK

PUBLIC ENVIRONMENTAL REPORT

MAUNSELL & PARTNERS PTY. LTD.

NOVEMBER 1987

VOLUME II

RESULTS OF TESTING GROUNDWATER QUALITY

NORTH FREMANTLE LOT 416 , Rockwater, 1980.

TABLE OF CONTENTS

UNIVERSITY OF WESTERN AUSTRALIA

MOSMAN PARK LAND

RESULTS OF TESTING GROUNDWATER QUALITY

NORTH FREMANTLE LOT 416

JUNE 1980

SUMMARY

Four test water bores were drilled on Lot 416, North Fremantle, to assess whether former industrial activities have affected the underlying groundwater. They were drilled to depths of up to 35 metres, that is about eight metres below the water table in superficial limestone and sand of the "Coastal Limestone" formation.

Analyses of groundwater samples taken during drilling and subsequent test-pumping indicated that above-background levels of certain contaminants are present at two of the four sites. At Site 3, nitrate concentration of up to 132 milligrams/litre far exceeds the recommended limit for drinking water i.e. 45 milligrams/litre. At Site 4, phosphate and mercury concentrations of 1.2 milligrams/litre and 0.07 milligrams/litre exceed recommended limits of 0.2 milligrams/litre and 0.02 milligrams/litre respectively. Concentrations of other deleterious constituents such as cyanide are not significantly high.

A production bore or bores located on the northern side of the property are unlikely to produce contaminated water, although monitoring and sampling would be desirable.

TABLE OF CONTENTS

1. INTRODUCTION

North Fremantle Lot 416 is the site of proposed residential development, lying on the northern bank of the Swan River in the Town of Mosman Park, Perth (Figs. 1 and 2). It was formerly occupied by a fertiliser manufacturing plant and ancillary works, and the ground might have been contaminated with chemicals stored, discharged, or dumped on site. In particular, there have been fears that cyanide, acids, and phosphate might be contaminating the shallow groundwater, and prove a hazard in the development of groundwater for lawn reticulation.

An investigation to sample the groundwater in reasonable detail was undertaken in March and April 1980. Four test bores were drilled at sites shown in Figure 2, using a cable-tool rig to give the most accurate samples of water and strata. Upon completion of drilling to some eight metres below the water table, a casing of 102 mm diameter PVC was inserted in the hole. The casing was slotted to allow the entry of groundwater, as shown in Figure 3. After cleaning out, each bore was pumped for 96 hours and sampled at 48-hour intervals. The rationale behind the procedure is that by creating a cone of depression in the aquifer water levels, the pumping will allow a fairly wide section of the aquifer to be sampled.

Information collected from the drilling and pumping of the bores comprised:

(1) aquifer types and lithologies

(2) depth to water table, its shape, and therefore groundwater flow direction

(3) groundwater salinity; in particular, variations with depth below the water table

(4) concentrations of selected constituents; variations with depth below the water table and variations with time over the 96 hours of pumping

Two existing production bores at Genders Park and Mosman Park Works Department (Fig. 1), were sampled to obtain control analyses. These bores are outside and up-gradient from the industrial site.

2. BORE STATISTICS

NAME: University of Western Australia, MPL 1.

LOCATION: North Fremantle, Lot 416.

ELEVATION: 24.09 metres above A.H.D.

STATUS: Completed, developed and pumped

DATE DRILLING COMMENCED: 19th April, 1980

DATE DRILLING COMPLETED: 20th April, 1980

DRILLER: Swan Boring Co.

DRILLING METHOD: Cable tool

DEPTH DRILLED: 33.0 metres

DEPTH COMPLETED: 33.0 metres

CASING: 1.5 m 150 mm steel protector/surface liner
0-24 m; 102 millimetre PVC class 9 casing
24-33 m; 102 millimetre slotted PVC class 9 casing

STATIC WATER LEVEL: 24.2 metres below surface level at 12.00 on 29/5/80

WATER SALINITY: 1,620 mg/l T.D.S. at 22.0 metres below surface level to:-
2,400 mg/l T.D.S. at 28.5 metres below surface level

PUMPING TESTS: 4 day constant rate pumping at 220.2 cubic metres/day (2000 gallons/hour)

CONSTRUCTION DIAGRAM: Figure 3 of this report

NAME: University of Western Australia MPL 2

LOCATION: North Fremantle, Lot 416

ELEVATION: 18.98 metres above A.H.D.

STATUS: Completed, developed and pumped

DATE DRILLING COMMENCED: 8th April, 1980

DATE DRILLING COMPLETED: 9th April, 1980

DRILLER: Swan Boring Co.

DRILLING METHOD: Cable tool

DEPTH DRILLED: 28.6 metres

DEPTH COMPLETED: 24.5 metres

CASING: 1.5 m, 150 millimetres steel protector/surface liner
0-19.5 m; 102 millimetre PVC class 9 casing
19.5-24.5 m, 102 millimetre slotted PVC class 9 casing

STATIC WATER LEVEL: 18.97 metres below surface level (at 12.00 on 29/5/1980).

WATER SALINITY: 1830 mg/l T.D.S. at 22 metres below surface level to
10,800 mg/l T.D.S. at 28.5 metres below surface level

PUMPING TEST: 4 day constant rate pumping at 220 cubic metres/day
(2000 gallons/hour)

CONSTRUCTION DIAGRAM: Figure 3 of this report

NAME: University of Western Australia, MPL 3

LOCATION: North Fremantle, Lot 416

ELEVATION: 22.31 metres above A.H.D.

STATUS: Completed, developed and pumped

DATE DRILLING COMMENCED: 25th March 1980

DATE DRILLING COMPLETED: 25th March 1980

DRILLER: Swan Boring Co.

DRILLING METHOD: Cable tool

DEPTH DRILLED: 30 metres

DEPTH COMPLETED: 30 metres

CASING: 1.5 m, 150 millimetre steel protector/surface liner
0-22 m; 102 millimetre PVC class 9 casing
22-30 m; 102 millimetre slotted PVC class 9 casing

STATIC WATER LEVEL: 21.895 metres below surface level (12.00 on
29/5/80)

WATER SALINITY: 2000 mg/l T.D.S.

PUMPING TEST: 4 day constant rate pumping at 220 cubic metres/day
(2000 gallons/hour)

CONSTRUCTION DIAGRAM: Figure 3 of this report

NAME: University of Western Australia, MPL 4

LOCATION: North Fremantle, Lot 416

ELEVATION: 24.57 m above A.H.D.

STATUS: Completed, developed and pumped

DATE DRILLING COMMENCED: 19th March, 1980

DATE DRILLING COMPLETED: 20th March, 1980

DRILLER: Swan Boring Co.

DRILLING METHOD: Cable tool

DEPTH DRILLED: 35 m

DEPTH COMPLETED: 33.5 m

CASING: 1.5 m, 150 millimetre steel protector/surface liner
0-24.5 m; 102 millimetre PVC class 9 casing
24.5-33.5 m; 102 millimetre slotted PVC class 9 casing

STATIC WATER LEVEL: 24.15 metres below surface level (at 12.00 on 29/5/80)

WATER SALINITY: 1,050 mg/l T.D.S. at 26 metres increasing to 1,560 mg/l T.D.S. at 33.5 metres

PUMPING TEST: 4 day constant rate pumping at 220 cubic metres/day (2000 gallons/hour)

CONSTRUCTION DIAGRAM: Figure 3 of this report

3. STRATA

Information on geological conditions has been available from two sources, namely :

(i) near-surface trenches excavated to depths of 3.0 m below ground surface and
(ii) drill samples from the four test bores

The locations of the trenches and test bores are shown in Figure 2.

The strata are interbedded sand and limestone in varying degrees of consolidation and cementation. They are of Quaternary age and are superficial deposits generally referred to as the "Coastal Limestone" formation. The unit extends to about 30 metres below sea level in the Perth coastal area, lying with unconformity on Cretaceous and older formations of the Perth Sedimentary Basin.

The material encountered during trenching operations consisted mainly of limestone in varying degrees of consolidation overlain by topsoil, overburden, rock and/or brick aggregate. Depths to the limestone range between 1.0 and 2.5 metres, maximum figures being attained at the southern extremities of the trenches. Only in the vicinity of Bore 4 was rubbish fill encountered, and this exceeded 3 metres in depth.

Detailed descriptions of drill samples collected during the field study are presented in Appendix 1, while the sequence of strata is shown in the details of bore completion in Figure 3.

The test bores encountered an upper limestone, generally buff coloured, lightly cemented in its upper horizons but becoming moderately to well cemented with depth. This upper unit ranged in thickness from 24 metres in Bore 4 to 10 metres in Bore 4, i.e. reducing from east to west. Bore 1 to the north encountered a little more than 10 metres of this lightly cemented limestone. The thickness of the limestone may relate to the elevation of the unit above the water table; at sites where the limestone is closer to the water table the lower units may be preferentially cemented by the deposition of a secondary calcareous matrix from the oscillating water table.

The limestone is underlain by a predominantly arenaceous sequence of yellow, fine to coarse sand, lightly cemented sandstone and sandy limestone. The sequence appears to thicken westwards towards Bore 2 where it is 12 metres thick.

In all bores, the arenaceous sequence overlies a yellow-buff limestone ranging from medium grained to very coarse, with varying degrees of cementation. Thicknesses range from 4 to 6 metres before Total Depth of the bores were reached.

4. AQUIFER

The superficial deposits constitute an unconfined aquifer with saturated thickness of about 30 metres. The groundwater is generally fresh in the upper part and saline in the lower part, as a result of the natural fresh/saline water interface associated with the estuary shoreline.

The depths to water table at the four sites ranged from 18.6 to 24.2 metres below ground surface, corresponding to reduced water-table levels of 0.408 to 0.429 metres above Australian Height Datum (mean sea level). Figure 4 shows that groundwater gradients are uniform under the study area with a downwards slope of 1 in 100 towards the south-south-west. This indicates that any contaminants reaching the water table would migrate towards the Swan River.

Values of aquifer porosity and permeability will be dependent on the different lithological types encountered. In limestones, porosity and permeability are afforded by solution cavities and rugs. In the arenaceous units, the porosity and permeability relate to interstitial pores, which tend to be finer and more uniform than solution cavities in limestone.

In the present study, pumping tests have been undertaken only to monitor the change in water quality with time, and not to determine values of aquifer transmissivity and storativity. Typical values of permeability (transmissivity divided by total saturated thickness) range between 200 and 430 metres/day for members of the Coastal Limestone Formation. That is, the formation is very permeable and transmits groundwater at a high volume of flow. Because of layering, however, the tendency for vertical percolation can be much less than the horizontal.

4.1 BORE CONSTRUCTION DETAILS

All four bores were drilled using a cable tool rig and completed with 102 millimetre class 9 PVC casing. In those bores in which saline or brackish groundwater was encountered (Nos. 2 & 4) a 3-4 metre cement plug was inserted at the base of the bore. The PVC casing was slotted and a gravel pack inserted below the water table to completed depths. Bore completion details are shown on Figure 3.

5.0 PUMPING TESTS

Following completion and development, each bore was pumped at a constant rate of approximately 220 cubic metres/day (2000 gallons/hour) for a period of four days. The purpose of these tests was to permit sampling of groundwater throughout the test period, to determine the variation in water quality induced into the cone of influence of the

Chemical analyses of bore water from Genders Park and Mosman Park Council Works Depot are also included in Appendix 3.

Salinity Analyses given in Appendix 2 indicate that brackish or saline groundwater was encountered in Bore 2 only at a depth of -4 metres AHD. Whereas this bore shows a maximum freshwater thickness of 4.5 metres, other completed bores show a freshwater zone between 6.5 and 10.5 metres. Conductivity levels during pumping for all bores tended to remain reasonably constant or decline in time suggesting a certain amount of bore development over the 4 day period. The measured values of conductivity from water in Bore 2 during pumping points to the inducement of brackish water into the cone of depression and reaffirms the shallow nature of the freshwater lens to the western limits of Lot 416.

The more comprehensive analyses in Appendix 3 show generally an uncontaminated fresh groundwater with a pH between 7 and 7.8 and conductivities between 1600 and 2200 µmhos/cm^2. Concentrations of heavy minerals and important cations analysed do not generally exceed the maximum permissible levels for potable water established by the World Health Organisation in 1971. Exceptions here include levels of nitrate in Bore 3 and mercury and phosphate in Bore 4.

To enable a comparison to be drawn with good quality water, Table 1 below shows typical concentrations of the parameters analysed allowable in potable water for domestic purposes and their ranges found in seawater.

TABLE 1

PARAMETER	Maximum desirable mg/ℓ	Maximum permissible mg/ℓ	Typical range of Concentration, mg/ℓ
iron (total)	0.1	1.0	0.002 - 0.2 (in suspension) 10-9 (in solution)
lead		0.1	0.004 - 0.005
copper	0.05	1.5	0.01 - 0.09
mercury		0.002	0.00003
sulphate	200	400	2210
nitrate		45	0.0044 - 3.1
phosphate		0.2	0.025 - 0.25
arsenic		0.05	
pH		6.5-9	-
TDS	1000	1500	16,000 - 20,000

pumping bore. Samples were taken after pumping periods of 30 minutes, 48 hours and 96 hours in each test respectively.

Discharge water was carried away from the borehole using "Layflat" plastic tubing, to preclude re-circulation during the test period.

5.1 TEST DATA

DATES TESTED: Bore 1 - April 21-25
Bore 2 - April 10-15
Bore 3 - March 21-25
Bore 4 - March 26-30
PUMP INLET SETTINGS: 3-4 metres below water table
CONSTANT RATE DISCHARGE: 220 cubic metres/day for 96 hours/bore
STATIC WATER LEVELS: Bore 1 - 23.7 metres below ground surface
Bore 2 - 18.6 " " " "
Bore 3 - 21.9 " " " "
Bore 4 - 24.2 " " " "
AVAILABLE DRAWDOWNS: 3-4 metres
CONTRACTOR: Swan Boring Co.
PUMP: Electrically driven, submersible turbine

6. WATER QUALITY

The main objective of the investigation was to determine the extent, if any, of the infiltration of leakages, spillages or discharges of industrial processing fluids or chemicals on Lot 416 to the water table, and the resultant effects on groundwater quality. To this end, water samples were taken with depth during drilling and with time during pumping as described in Section 5 above.

Water samples taken during drilling have been analysed for total dissolved solids (T.D.S.) and their vertical distribution is shown on Figure 3. Samples taken during pumping after suitable treatment in the field were analysed for the following parameters :- pH, conductivity, nitrate, phosphate, sulphate, cyanide, arsenic, copper, iron, mercury and lead. The results of analyses are shown in Appendices 2 and 3 respectively.

Nitrate levels in Bore 3 range from 87 to 132 mg/ℓ; they are markedly higher than the level of 45 mg/ℓ set by W.H.O. and the values found in the other bores. A possible source of the nitrate is septic tank installations (now unused) located to the north of Bore 3. Chemical decomposition and oxidation of effluent could give rise to the nitrate concentrations observed in the groundwater.

Bore 4 groundwater is characterised by an acidic pH and above-average concentrations of phosphate and mercury. Levels of nitrate, cyanide, arsenic, copper, iron, and lead are not abnormal.

Phosphate concentration in water from Bore 4 range from 0.02 to 4 milligrams/litre (mg/ℓ and appear to have stabilised at 1.2 mg/ℓ after four days of pumping. This may be compared with the recommended limit of 0.2 mg/ℓ for drinking water.

Mercury concentration increased during the pumping period from 0.05 to 0.07 mg/ℓ, and this level is substantially higher than the maximum permissible level of 0.002 mg/ℓ set by the W.H.O. for drinking water.

The high levels of phosphate and mercury, and the low pH, suggest the presence of a contaminating body within the area of influence of Bore 4. The source might be leachate from rubbish infill near the southern extremity of Trench No 1; residual material from phosphate bins previously located on site; and/or the dump of sulphide-rich material located to the east of the property.

If the groundwater is to be used for reticulation and not drinking, the above contamination levels may not be deleterious. However, additional information on build-up of say mercury in plants would be desirable. We suppose that in any case, no production bore would be located in the vicinity of Bore 4 as a result of the above findings.

7. CONCLUSIONS AND RECOMMENDATIONS

The sampling programme has indicated that the groundwater beneath Lot 416 uncontaminated at two of the sites (Nos 1 and 2). It contains high levels of nitrate only, at Site No 3, and high levels of phosphate and mercury at Site No 4.

We recommend that any production water bores be located in the northern part of the property (ref Bore 1) to reduce the likelihood of contaminated water being pumped. Under the natural groundwater gradient, flow is away from this site i.e. towards the Swan River (south-southwest). Under heavy pumping there is a small possibility of the cone of depression drawing water back from the contaminated area; evaluation of this would best be done by water-level measurements and sampling under production conditions.

A bore such as No 1 is capable of producing 220 cubic metres/day (2000 gallons/hour) of fresh groundwater for reticulation. Bores of higher production capability could be constructed, although the saline water interface will limit the total withdrawal from the locality. This facet has not been evaluated quantitatively in the present study.

8. REFERENCE

World Health Organisation, 1971. International Standards for Drinking Water, 3rd Edition, W.H.O. Geneva.

Passmore

ROCKWATER PTY. LTD.

S. Saunders,
Hydrogeologist.

J.R. Passmore,
Principal-Hydrogeologist.

Dated : July 3, 1980.

BORE 2

0-2m	sand	yellow, fine, uniform, subrounded - sub angular, plus limestone fine - medium grained, well cemented
2-4m	limestone	yellow, fine - medium, powdered, subrounded-angular, loosely cemented
4-6m	limestone	sandy, yellow/brown, fine-medium, uniform, sub angular - subrounded, loosely cemented
6-8m	limestone	arenaceous, cream, medium grained, sub angular, poorly to medium cemented
8-10m	limestone	arenaceous, yellow/brown, medium-coarse, sub angular - angular, poorly - moderately cemented
10-12m	sand	orange/brown, medium, uniform with limestone chips (0.2m) not cemented
12-14m	limestone	yellow/cream, fine grained, powdery, with some quartz angular, very loosely cemented
14-16m	limestone	buff/cream, very fine - fine grained, poorly to well cemented
16-18m	limestone	sandy, yellow, fine-medium grained with sands sub rounded, moderately-poorly cemented
18-29m	sandstone/ limestone	yellow/grey, medium-coarse grained, sub rounded - angular, poorly cemented
20-22m	limestone	white/grey, fine-medium, very well cemented vuggy in part, some shell debris
22-24m		as above
24-26m	limestone	sandy, yellow/grey, medium grained sub angular - rounded, loosely - well cemented
26-28m	limestone	more sandy, yellow/grey, fine to coarse, subrounded - rounded, poorly cemented
28-28.5m	sand	yellow/grey - from drillers log

APPENDIX 1

LITHOLOGICAL DESCRIPTIONS OF SAMPLES

BORE 1

0-2m	sand/limestone	yellow/buff, silty, medium grained, uniform, rounded, poorly to well cemented.
2-4m	limestone	yellow, fine-medium grained, rounded - sub-rounded
4-6m	limestone	yellow/buff, silty, fine-medium grained, rounded-sub angular, poorly-well cemented
6-8m	limestone	yellow, fine-medium, uniform, rounded
8-10m	limestone	yellow, medium, uniform, sub-rounded sub angular, well cemented, vuggy
10-12m	sand	brown/orange medium-coarse, sub-rounded, clean
12-13m	sand	brown/orange, fine-coarse, subrounded-sub angular with rounded felspar
13-14m	limestone	buff, fine-coarse grained, poorly sorted, very well cemented quartz, plus felspar
14-16m	limestone	buff/yellow, silty, very fine-medium grained, sub angular - sub rounded, poorly cemented
16-18m	limestone	buff, medium, uniform, sub-rounded, well-poorly cemented
18-20m	limestone	cream, silty, fine-medium grained, sub angular, medium - well cemented
20-22m	limestone	yellow/cream, silty, fine-medium grained, uniform, sub-rounded - sub angular, moderately cemented
22-24m	limestone	yellow/cream, fine-medium grained, uniform, angular - rounded, weakly - well cemented
24-26m	limestone	yellow/cream, medium - very coarse, breccia, subrounded - angular, poorly to well cemented
26-28m	limestone	yellow/cream fine-medium grained with sands and ubiquitous iron (0.1 mm) subrounded - subangular, poorly to very well cemented
28-30m	limestone	yellow, medium - very coarse, rounded-sub angular, very well cemented breccia
30-32m	limestone	grey/yellow, very fine-medium with abundant iron, very well cemented
33m	limestone	as above

BORE 3

0-2m	sand	light brown, silty and clayey, very fine to fine grained, sub angular very poorly sorted, calcareous
2-4m	limestone	buff, fine to medium grained, sub rounded, quartz grains 10% very poorly cemented
4-6m	limestone	as above
6-8m	limestone	buff to light yellow, grains of calcareous fragments (70%) and quarts (30%), quartz is fine to coarse grained, sub angular to subrounded, poorly sorted, poorly cemented
8-10m	limestone	as above, buff coloured and moderately cemented
10-12m	limestone	as 8-10m
12-14m	limestone	as 6-8m
14-16m	limestone	buff with calcareous (60%) and quartz (40%) fragments, quartz medium to coarse grained, subrounded, well sorted, moderately to well cemented
16-18m s	sandstone	buff to light yellow with 40% calcareous fragments quartz is medium to very coarse grained, sub rounded to rounded, poorly sorted, moderately cemented with calcareous cement
18-20m	sandstone	as 16-18m but moderately to poorly cemented
20-22m	sandstone	as 16-18m buff with 50% quartz
22-24m	sandstone	as 20-22m
24-26m	sand	light yellow, medium to coarse grained, subrounded,poorly sorted, very poorly cemented, with 20% calcareous fragments
26-28	limestone	light yellow to buff, 40% quartz, medium to very coarse, sub angular to sub rounded, very poorly sorted, poorly cemented
28-30m	limestone	as 26-28m

BORE 4

0-2m	limestone	grey, silty with 30% quartz, fine to medium grained, sub angular, very poorly sorted, with humus remains
2-4m	limestone	as 0-2m, light grey brown, slightly clayey, moderately cemented
4-6m	limestone	as 2-4m
6-8m	limestone	as 2-4m
8-10m	limestone	light red to brown, silty, with 20% quartz, very fine to fine grained, sub angular, poorly sorted, very poorly cemented
10-12m	limestone	as 2-4m poorly consolidated
12-14m	limestone	buff, with 40% quartz, fine to coarse grained, sub angular to sub rounded, poorly sorted, poorly cemented
14-16m	limestone	buff, with 40% quartz, medium to coarse grained, sub rounded, poorly sorted, moderately to well cemented
16-18m	limestone	as 12-14m but very fine to medium grained
18-20m	limestone	cream, with 20% quartz, very fine to fine grained, sub angular, poorly sorted, poorly cemented
20-22m	limestone	as 18-20m but very fine to medium
22-24m	limestone	as 20-22m moderately cemented
24-25m	sand	yellow, medium grained, sub angular, well sorted
25-26m	sand	as 24-25m fine to medium grained
26-28m	sandstone	yellow with 30% calcareous fragments, quartz is medium to very coarse grained, sub angular to sub rounded very poorly sorted, poorly cemented
28-30m	sandstone	as 28-30m
30-32m	limestone	yellow buff, with 40% quartz, medium to very coarse, sub angular, very poorly sorted, very well cemented
32-34m	limestone	as 30-32m

APPENDIX 2

WATER QUALITY DATA

SALINITY PROFILES

TDS concentrations milligrams/litre

BORE 1

Depth	24	25	26	28	29	30	31	metre
Salinity	1080	1120	1120	1420	1620	1680	1680	mg/ℓ

BORE 2

Depth	22	24	25	26	27	28.5	metre
Salinity	1830	2950	5250	7900	9600	10,800	mg/ℓ

BORE 3

Depth	25	26	27	28	29	metre
Salinity	1460	1270	1280	1350	1400	mg/ℓ

BORE 4

Depth	26	27	28	29	30	31	32	33	34	35	metre
Salinity	1050	1180	1160	1210	1050	1290	1500	1520	1560	2650	mg/ℓ

Depths measured below ground surface

APPENDIX 3

DETAILED WATER QUALITY ANALYSES

BORE 1

Date	Depth m	pH	Conductivity µmhos/cm^2	NO_3^- mg/ℓ	PO_4^{3-} mg/ℓ	SO_4^{2-} mg/ℓ	CN^- mg/ℓ	As mg/ℓ	Cu mg/ℓ	Fe mg/ℓ	Hg mg/ℓ	Pb mg/ℓ
20.4.80	24m	7.4	1621	16.9	< 0.05	74	NS	< 0.002	<0.05	< 0.05	<0.0005	< 0.05
20.4.80	31m	7.8	2400	2.87	"	84.5	NS	"	NA	NA	NA	NA
20.4.80	33m	7.4	2830	10.6	< 0.05	96.7	NS	< 0.002	<0.005	< 0.05	<0.0002	< 0.05
21.4.80	Bulk Sample	7.8	2040	10.9	< 0.05	69.5	NS	< 0.002	<0.05	< 0.05	<0.0005	< 0.05
23.4.80	"	7.6	2000	11.6	< 0.05	67.9	NS	"	"	< 0.05	<0.0005	< 0.05
25.4.80	"	7.7	1351	21.1	< 0.05	97.0	0.02	"	<0.05	1.00	<0.0005	< 0.05

BORE 2

Date	Depth m	pH	Conductivity µmhos/cm^2	NO_3^- mg/ℓ	PO_4^{3-} mg/ℓ	SO_4^{2-} mg/ℓ	CN^- mg/ℓ	AS mg/ℓ	Cu mg/ℓ	Fe mg/ℓ	Hg mg/ℓ	Pb mg/ℓ
9.4.80	19m	7.2	1748	21.3	< 0.05	133.3	NS	< 0.002	<0.05	3.20	<0.0005	< 0.05
9.4.80	28.5	7.0	1824	35.9	< 0.05	830.2	NS	< 0.002	"	3.10	"	"
10.4.80	Bulk Sample	7.1	4780	29.1	"	362.3	NS	"	"	0.05	"	"
12.4.80	"	7.2	3880	29.2	"	315.8	NS	"	"	0.05	"	"
15.4.80	"	7.8	3860	30.0	"	315.8	0.02	"	"	0.05	"	"

NS = Not Sampled: NA = Not Analysed: < = Less than.

APPENDIX 3

DETAILED WATER QUALITY ANALYSES

(cont)

BORE 3

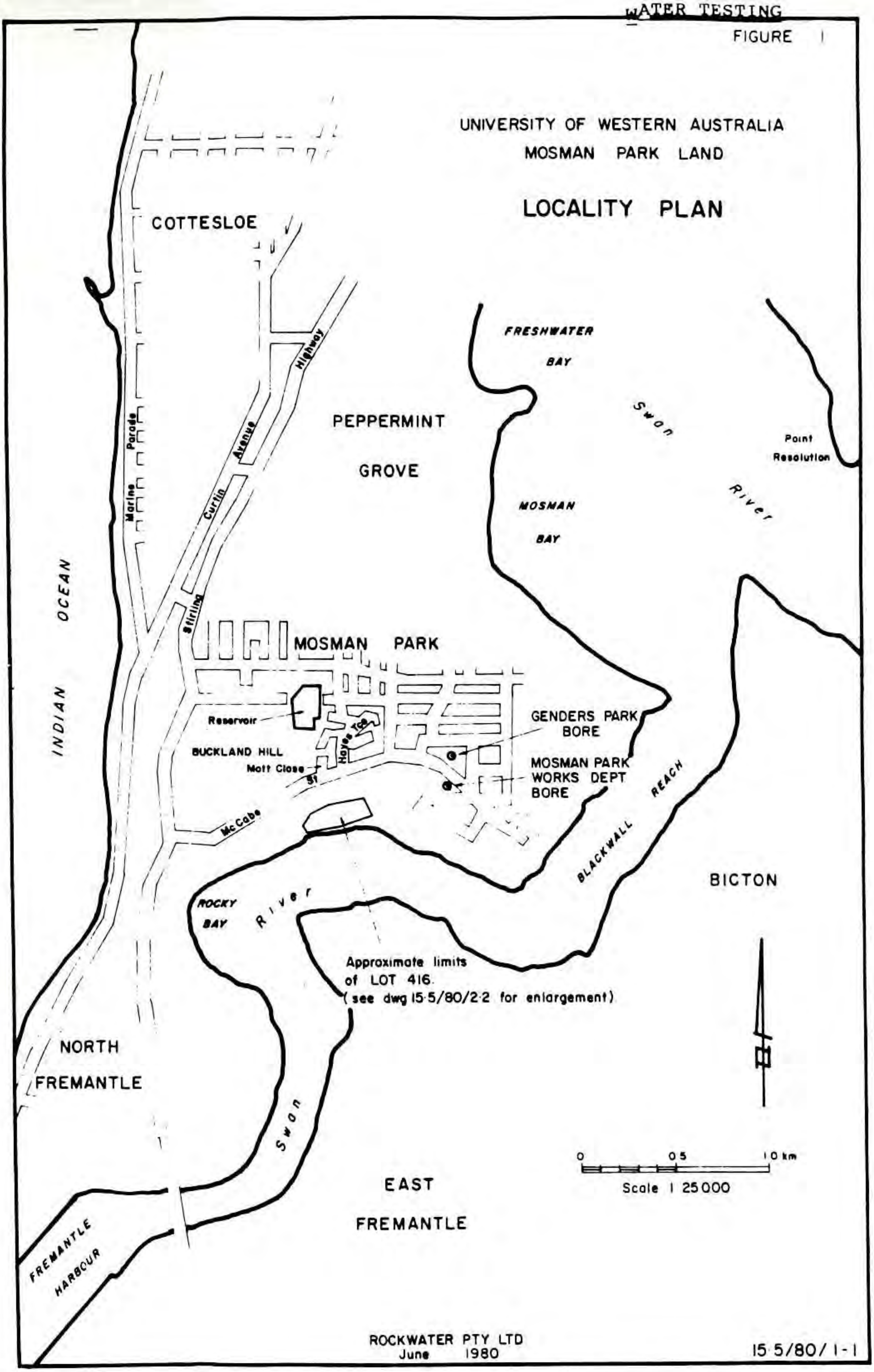
Date	Depth m	pH	Conductivity µmhos/cm^2	NO_3^- mg/ℓ	PO_4^{3-} mg/ℓ	SO_4^{2-} mg/ℓ	CN^- mg/ℓ	As mg/ℓ	Cu mg/ℓ	Fe mg/ℓ	Hg mg/ℓ	Pb mg/ℓ
25.3.80	24.5m	7.2	2850	79.3	0.02	276	NS	0.002	0.1	9	< 0.0002	< 0.05
25.3.80	30.0m	7.6	2059	132.3	"	100	NS	"	< 0.05	0.3	"	"
26.3.80	Bulk sample	7.6	2000	129.6	"	92	NS	"	"	0.25	"	"
28.3.80	"	7.5	2041	125.4	"	100	NS	"	"	< 0.05	"	"
30.3.80	"	7.4	2070	87.3	"	96	< 0.02	"	"	< 0.05	"	"

BORE 4

Date	Depth m	pH	Conductivity µmhos/cm^2	NO_3^- mg/ℓ	PO_4^{3-} mg/ℓ	SO_4^{2-} mg/ℓ	CN^- mg/ℓ	As mg/ℓ	Cu mg/ℓ	Fe mg/ℓ	Hg mg/ℓ	Pb mg/ℓ
20.3.80	26.5	6.9	1900	34.5	0.7	146	NS	<0.002	< 0.05	16	0.06	< 0.05
20.3.80	29.0	7.6	2009	30.3	0.02	131	NS	"	"	11.5	0.047	"
21.3.80	Bulk sample	6.7	2230	21.6	< 4.0	146	NS	"	"	0.3	0.05	"
23.3.80	"	6.5	2190	28.9	< 1.3	154	NS	"	"	0.1	0.058	"
25.3.80	"	6.4	2200	22.3	< 1.2	154	0.02	"	"	<0.05	0.069	"
MOSMAN PARK BOREHOLE		7.2	2480	23.3	< 0.02	90	0.02	< 0.002	<0.05	0.3	< 0.0005	< 0.05
GENDERS PARK BOREHOLE		7.2	2220	28.7	< 0.02	82	0.02	< 0.002	<0.05	0.2	< 0.0005	< 0.05

NS = Not Sampled. = Less than.

FIGURE 1



UNIVERSITY OF WESTERN AUSTRALIA
MOSMAN PARK LAND

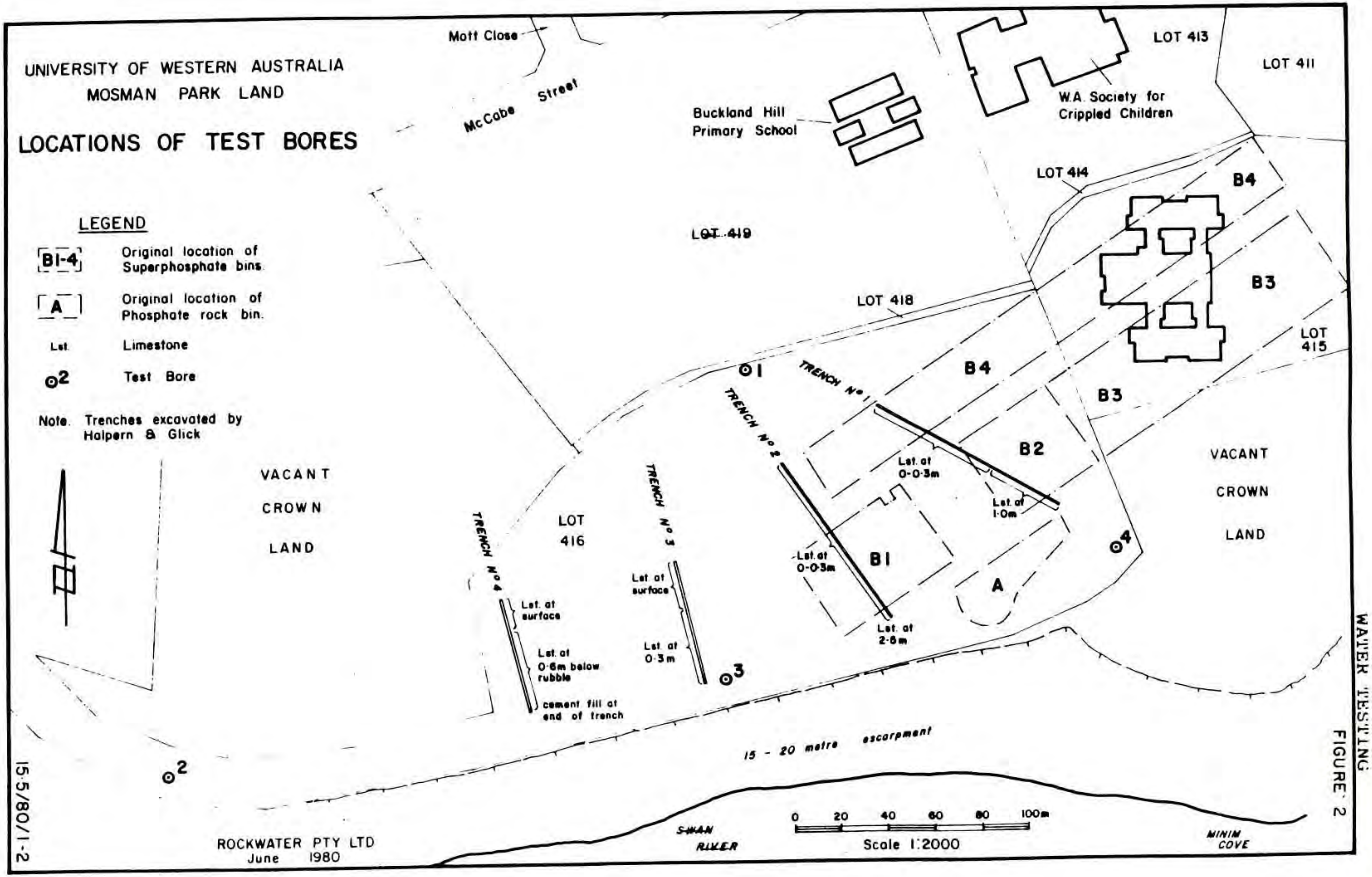
LOCALITY PLAN

ROCKWATER PTY LTD
June 1980

15·5/80/1-1

UNIVERSITY OF WESTERN AUSTRALIA
MOSMAN PARK LAND

LOCATIONS OF TEST BORES



ROCKWATER PTY LTD
June 1980

15/5/80/1-2

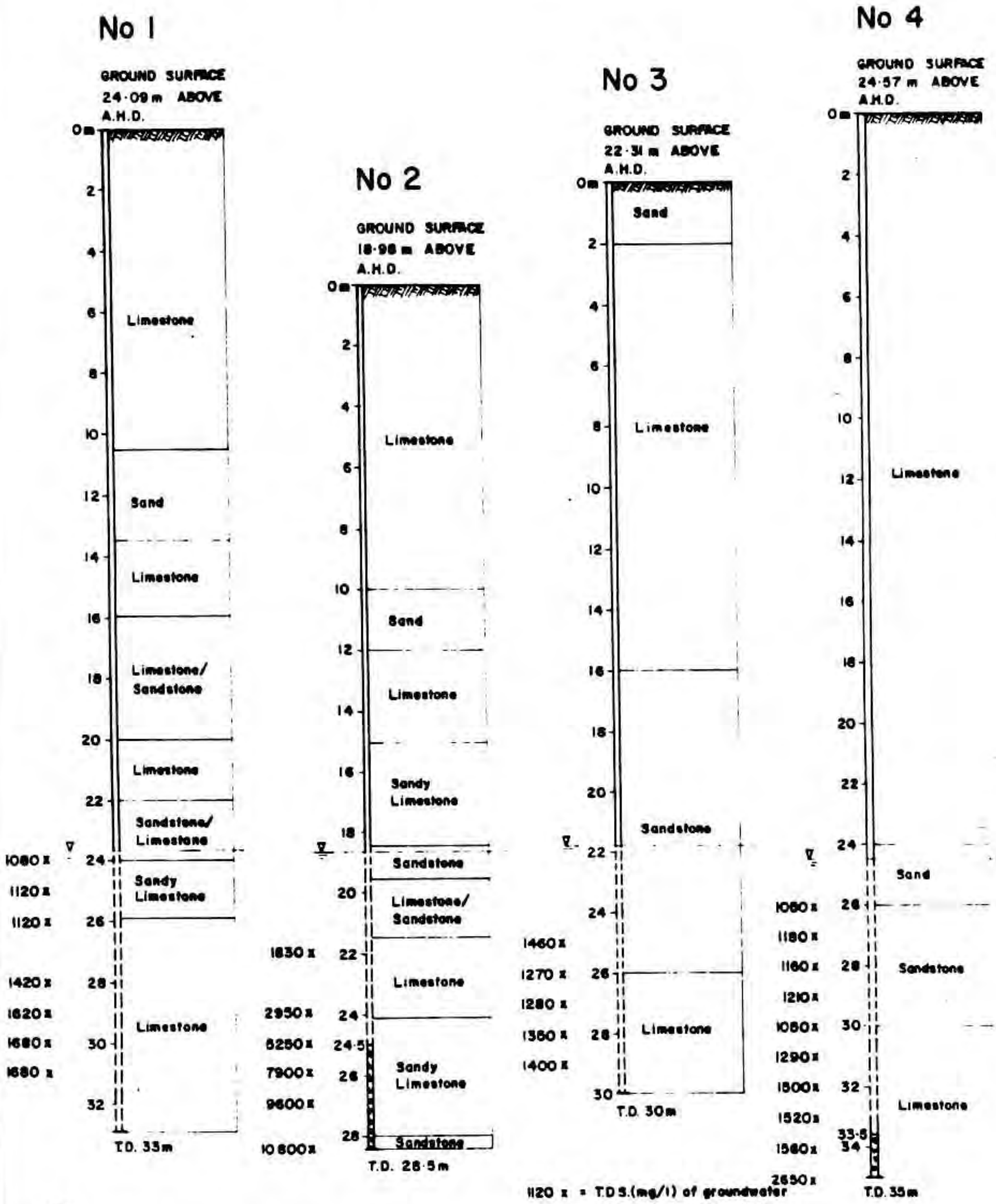
WATER TESTING

FIGURE 2

FIGURE 3

UNIVERSITY OF WESTERN AUSTRALIA
MOSMAN PARK LAND

DETAILS OF TEST BORE COMPLETION & GENERALISED BORE LOGS



1120 x = T.D.S.(mg/l) of groundwater sampled during drilling.

Note

Bore surface liner of 150mm steel casing 1·5 m length with 0·5 m above surface level. All bores completed with 102 mm PVC casing & slotted over sections as shown.

▽ = WATER TABLE

▨ = GROUTED SECTION

ROCKWATER PTY LTD
May 1980

15·5/80/1-3

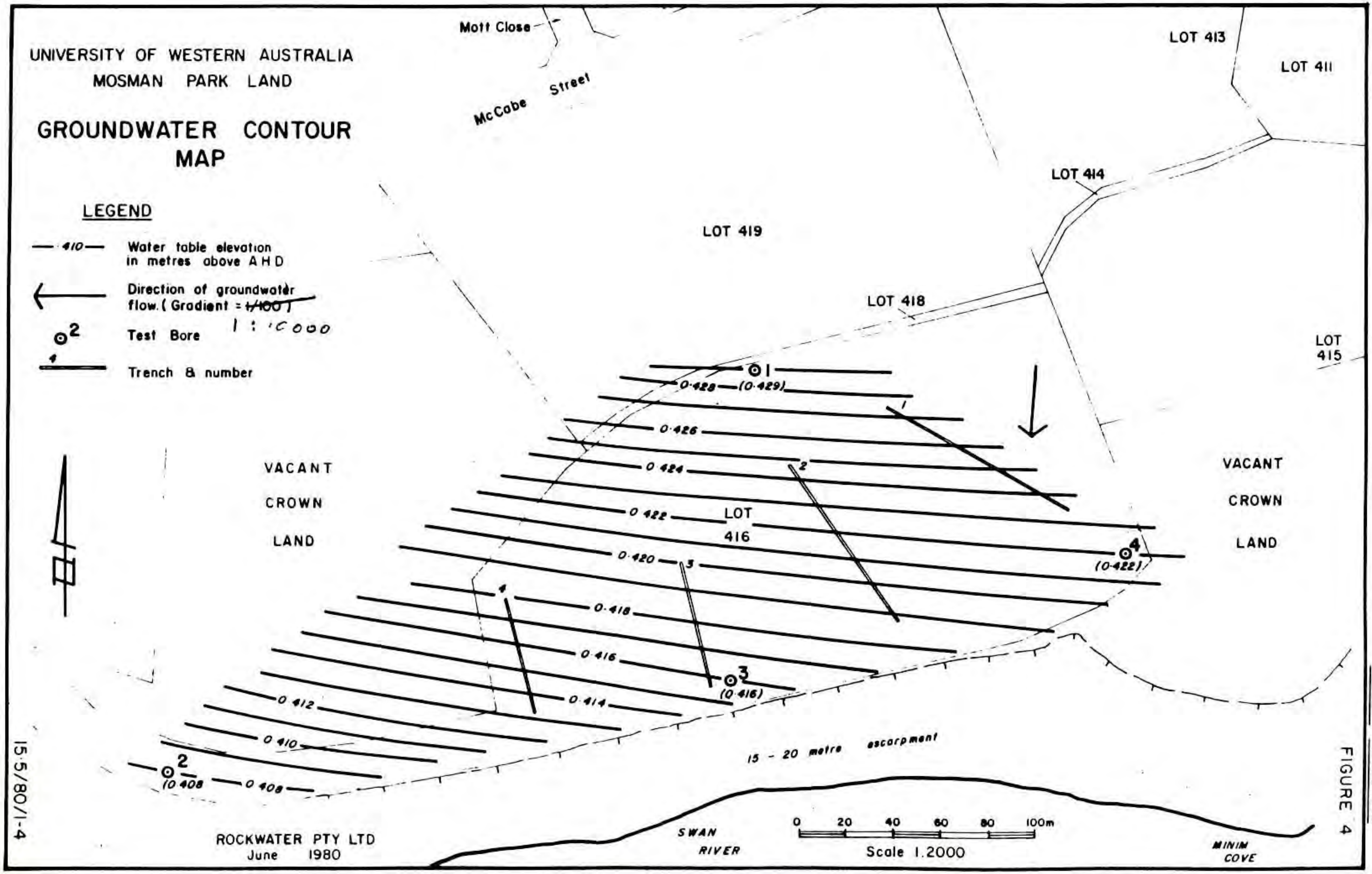


FIGURE 4

WATER TESTING

RESULTS OF TESTING SOIL FOR HEAVY METALS AT NORTH FREMANTLE LOT 416 , Analabs, 1981.

UNIVERSITY OF WESTERN AUSTRALIA

MOSMAN PARK LAND

RESULTS OF TESTING SOIL FOR HEAVY METALS AT NORTH FREMANTLE LOT 416

NOVEMBER 1981

TABLE OF CONTENTS

MOSMAN PARK RESIDENTIAL DEVELOPMENT

1. Introduction

At the request of the Estate Department of the University of Western Australia detailed sampling of a potential residential development site as Mosman Park Western Australia (Lot 416 North Fremantle) was undertaken to ascertain the degree of industrial contamination from industry previously operating on the site, and in order that recommendations to develop the site with minimum risk of environmental pollution could be made.

The land to be sampled was previously used by two noxious industries.

1. Superphosphate works.
2. Gold smelting and mercury distillation for gold recovery.

Likely contaminants would be bismuth, arsenic, copper, lead, cadmium, mercury and zinc.

2. Procedure

2.1 Field Sampling

Systematic sampling of the area was carried out on 30th November and 1st December along side but not in trenches previously excavated by Halpern Glick and Lewis at an approximate distance between samples of 10 metres. Position detail of sampling is contained in Appendix 1 .

Areas covered with bitumen or concrete and area near borehole 4 where fertilizer dumping was evident were avoided in the systematic sampling but the extremities of these areas were sampled.

The area near borehole 4 (Appendix 1) was not sampled because of visual evidence of copper contamination and the difficulty of obtaining a representative sample.

Each sample core was taken to a depth of 30cm using a 50cm diameter hand auger except when limestone was intercepted where a pneumatic sampler was utilized. With these samples the 30cm core was divided into two sub samples; one of the soil and the other of underlying limestone (Ryall 1979).

2.2 Sample Preparation and Analysis

At the laboratory the samples were dried and pulverised in a Sieb Tech ring pulveriser to nominal 100 micron particle size.

The pulverised samples were then analysed for copper, lead, zinc, cadmium, bismuth and iron by total acid digestion, atomic absorption spectrophotometric determination utilizing a Varian Techtron 575 machine. Arsenic was determined using the same digestion and vapour hydride atomic absorption spectrophotometric determination. Mercury was analysed using a nitric / perchloric acid digestion and non flame atomic absorption spectrophotometry using stannous chloride reduction. Results of these analyses are contained in Appendix 2.

3. Discussion

The coastal limestone or "Cottosloe stone" on this site is of Pleistocene age and is termed "aeolianite" (McArthur and Bettenay 1960). It is sometimes exposed due to wind action but usually covered by shallow yellow and brown neutral soils which have been extensively leached and are deficient in trace elements essential to plant growth.

Although no data is available it could be assumed due to similarity in chemical reaction, it would be very low in hazadous elements such as arsenic, cadmium, bismuth, lead and mercury in its natural state. Supporting this assumption is the fact that there are no reported accumulations of these elements in vegetables grown extensively on this dune system.

The area of dumping on the site near borehole 4 will be considered separately for discussion.

The mean element concentrations indicate contamination of the site with all elements measured. Definite patterns of accumulation within soil or aeolianite are not present. Correlations between elements are presented in Table 1.

<u>Table 1</u> Correlation between elements concentration.

Job No: 82.0 01 22117

	Fe	Cu	Zn	As	Cd	Hg	Pb	Bi
Fe	1.0000	.4249	.3233	.6985	.1987	.0565	.1145	.2609
Cu	.4249	1.0000	.8731	.4515	.8004	.1445	.0403	.8008
Zn	.3233	.8731	1.0000	.3104	.8846	.2653	.0283	.7986
As	.6958	.4515	.3104	1.0000	.2347	.1445	.1207	.2741
Cd	.1987	.8004	.8846	.2347	1.0000	.2791	.0516-	.7013
Hg	.0565	.1445	.2653	.1445	.2791	1.0000	.0647	.1442
Pb	.1145	.0403	.0283	.1207	.0516-	.0647	1.0000	.0944
Bi	.2609	.7986	.7986	.2741	.7013	.1442	.0944	1.0000

The copper zinc cadmium and bismuth are highly correlated and are probably from the same source. Possibly fertilizer trace element additives.

The lead is not correlated to any other element and may be the result of a smelting process.

Iron and arsenic are correlated which may be the result of arseno pyrite material containing gold; from a smelting process.

The average content of heavy metals in the samples analysed from the site are compared with trace element levels in normal carbonate rocks in table 2. and with allowable limits.

Table 2. Heavy metal levels in 0-30cm soil layer.

		Average from site	Content of carbonate rocks (Turekin & Wedepohl 1961)
Iron	Fe	3.06%	-
Copper	Cu	99PPM	4PPM
Zinc	Zn	224PPM	20PPM
Arsenic	As	15PPM	1PPM
Cadmium	Cd	1.55PPM	0.035PPM
Mercury	Hg	0.34PPM	0.04PPM
Lead	Pb	943PPM	9PPM
Bismuth	Bi	0.9PPM	-

	Maximum Allowable in agricultural soils (Ontario) (Seto & Deangelis 1978)	Maximum added to soil allowable
Cu	100 PPM	168 PPM
Zn	216 PPM	363 PPM
As	13 PPM	15 PPM
Cd	1.4 PPM	1.6 PPM
Hg	0.5 PPM	0.9 PPM
Pb	56 PPM	94 PPM
Bi	-	-

Visual evidence indicates the presence of sulphides and oxidation products of sulphides as the contamination source of copper. It would be expected that continual oxidation would result in the contaminants being leached out of the surface soil system but a time estimate on that process is not possible.

In this environment mechanisms of heavy metal bonding are:

1. pH dependent
   - physico - sorption
   - pseudomorphosis (dependent on supply and time)
2. Co-precipitation (incorporation by exceeding the solubility product)

If the alkaline water body from the leached "Cottosloe Stone" comes in contact with river water with normal Ca+ and HCO3- levels at neutral pH the pH will increase, the solubility product of CaCO3 is reduced and CaCO3 is precipitated in the mixing zone carrying the toxic metals with it. However co-precipitation of the heavy metals with calcium carbonate would occur and in the limestone profile before reaching the river water. This was confirmed by scanning electron microscopy of two surface samples.

Elements present were calcium, phosphorus, copper, sulphur. Leaching into the carbonate layer was not marked. (Appendix 4).

Each heavy metal should be considered separately with a view to its chemcial properties.

3.1 Bismuth, Copper, Zinc

Would not be considered a hazard to the marine environment of the river. Nor can they be considered toxic to plants at the levels encountered. It does not pose a threat to human health in the food chain system if plants grown on the soil were to be consumed.

Limits for consumption - Maximum permitted concentration in food. Regulation A 08 001. Bismuth - not listed. Copper 10.0 ppm. Zinc 150.0 PPM.

3.2 Lead

Would not be considered a hazard to the marine environment of the river. It can not be considered toxic to plants grown on the soil. (Judel & Stelte 1977) It does pose a threat to human health in the food chain if vegetables or fruit trees were grown on the soil and consumed.

However this has to be qualified by the knowledge that uptake of lead in this environment would be minimal and there are no published figures for toxicity in humans from consumption of fruit or vegetables grown on lead contaminated soils. There are documented deaths of horses grazing in lead contaminated roadside areas (Rabinowitz & Wetherill 1972) but lead levels in these areas are up to 3000 PPM in dry weight of plant matter.

Limits for consumption - Maximum permitted concentration in food Regulation A 08 001.

Fruit juices and fruit juice drinks	0.5 PPM
Milk	0.3 PPM
Vegetables	2.0 PPM
All other foods	1.5 PPM

3.3 Cadmium

Would not be considered a hazard to the marine environment of the river. It cannot be considered toxic to plants grown on the soil and uptake by plants at neutral pH would be approximately a third of that at pH 4.6. Fruit trees are particularly susceptible to cadmium uptake. It does pose a threat to human health in the food chain system if vegetables or fruit trees were grown on the soil and consumed. However, although the average soil content is below the sum of recommended and additive cadmium allowable in Ontatio for agricultural soils, individual areas are grossly in excess of the figure.

Limits for consumption - maximum permitted concentration in food Regulation A.08.001 0.05 PPM.

3.4 Arsenic

Would not be considered a hazard to the marine environment of the river in its current association with iron. It cannot be considered toxic to plants grown on the soil. It does pose a threat to human health in the food chain system if vegetables or fruit were grown on the soil where there are areas of high arsenic content.

Limits for consumption - maximum permitted concentration in food Regulation A.08.001 is 1.0 PPM.

3.5 Mercury

Is considered a hazard to the marine environment as it is a very mobile element and would dissolve into the water aquifer and presumably eventually drain into the river. It cannot be considered toxic to plants. In some instances levels exceed those accepted for agricultural purposes.

Limits for consumption - maximum permitted concentration in food Regulation A.08.001.

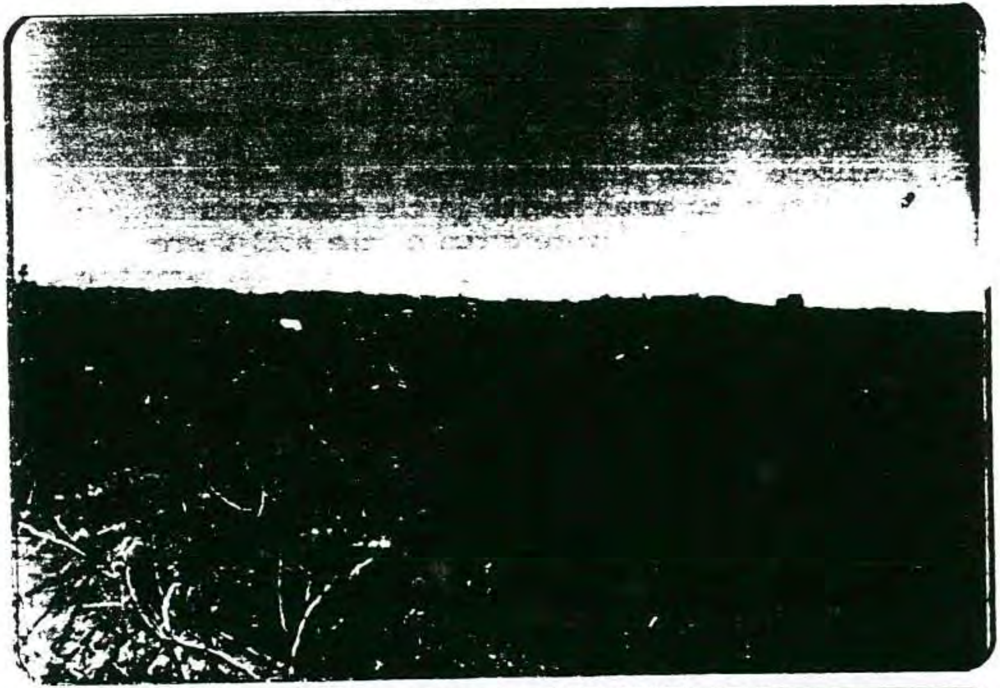
Fish and fish products	0.5 PPM
Other foods	0.03PPM

3.6 Area near Borehole 4.

This area of fill and dump is considered separately because of its heterogenuity and sampling difficulty and because it has been obviously used as a dumping area for superphosphate, copper and zinc minerals along with various other items of refuse.

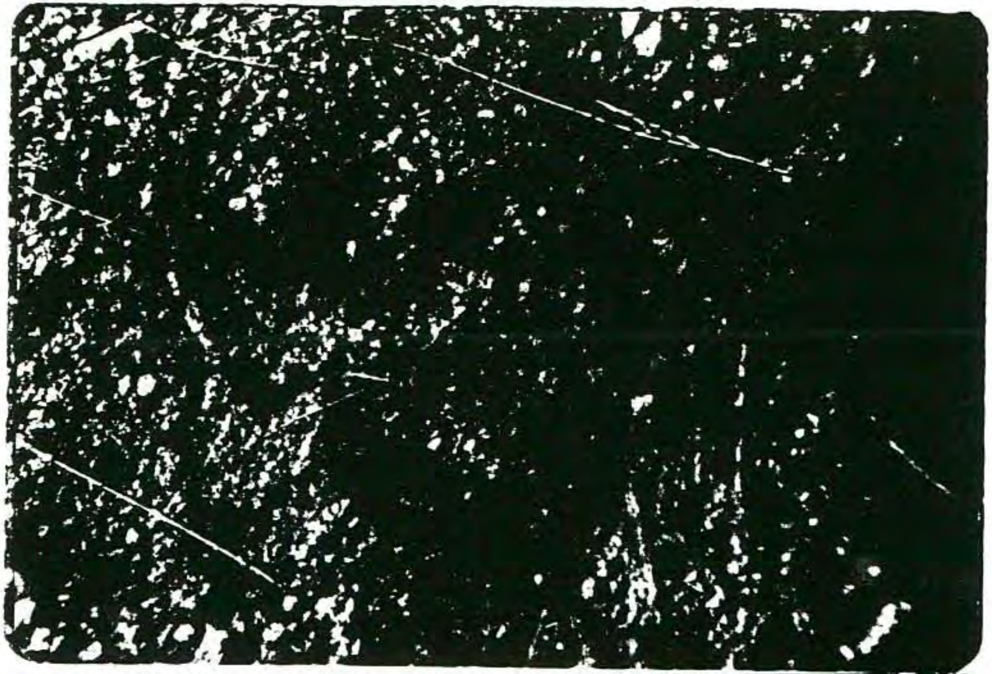
Visual evidence indicates copper contamination and because of the correlation between copper, cadmium, zinc and bismuth infers contamination by the other metals. The minerals are obviously present at a much higher concentration than elsewhere in the site and would be toxic to plants. Although this could be further filled with sand, tree roots would still accumulate nutrients from this zone because of its high phosphate content.

See photographs 1 - 5 below:



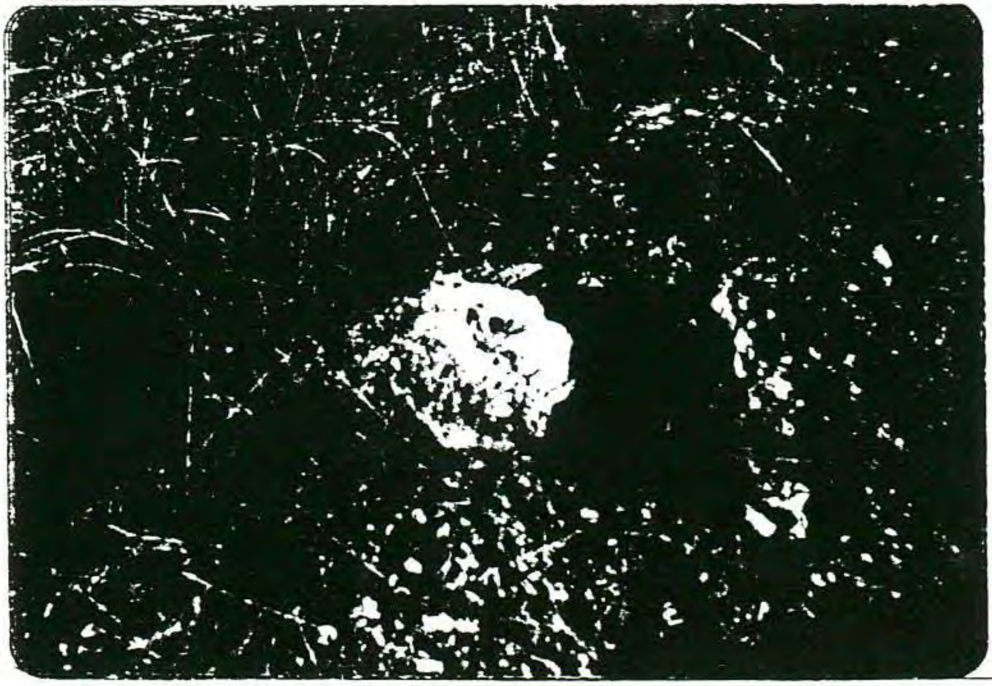
Dump site near borehole 4

Fertilizer waste



Magnified area of
fertilizer waste.

Phosphate and
copper waste 1.



Phosphate and
copper waste 2.

Analysis of a portion of contaminated soil from photograph 5 gave the following results.

Copper	6950 PPM
Lead	90 PPM
Zinc	635 PPM
Bismuth	10 PPM
Cadmium	20 PPM
Iron	6000 PPM
Mercury	0.27 PPM
Arsenic	29 PPM

Copper is in excess of that which would cause toxicity to plants (25 PPM E.D.T.A. soluble Cu is maximum most plants can tolerate).

Lead is not at a sufficiently high level to cause concern.

Zinc is in excess of that which would cause toxicity to plant (25 PPM E.D.T.A. Zn is maximum most plants can tolerate).

Cadmium is in excess of the maximum allowable for agricultural purposes.

Bismuth content is high but unfortunately data is not available to comment on its toxicity to plants or humans.

Mercury is within the limits acceptable for agriculture.

Arsenic level is in excess of that which is considered acceptable for agriculture however is not sufficiently high to be of concern.

4. Conclusions and Recommendations

1. Industrial contamination with noxious metals has taken place at the site examined at lot 416 North Fremantle.
2. Contamination is not discretely isolated and has been dispersed by wind erosion, leaching and diffusion laterally and vertically downwards from dumps and stockpiles into the calcareous limestone base rock and around the site.
3. A good correlation exists between copper, zinc, cadmium and bismuth found in the soil indicating all elements to be from one source.
4. A good correlation exists between iron and arsenic indicating these may also be from a single source.

5. No danger exists to the marine environment of the river from copper, lead, cadmium, zinc, bismuth or arsenic.

6. There is danger to the marine environment from mercury but this danger is minimal. There is nothing can be done to eliminate the problem except to remove all top soil from the site.

7. Lead levels on lines 1,3 and 4 usually exceed those accepted for agriculture. An acceptable level is 150 PPM. It is not known what form the lead is in but it can be assumed it will eventually become a carbonate and become available to plants where it may substitute for phosphorus in some processes if phosphorus is deficient. This could be a hazard in the food chain system.

8. Some cadmium levels on lines 1 and 2 are higher than acceptable for agriculture.

9. Some mercury levels on lines 1 and 3 are higher than acceptable for agriculture.

Uptake of heavy metals by plants in this environment of low cation exchange capacity soils at neutral pH is likely to be much lower than in soils of higher cation exchange capacity and lower pH on which recommended levels of acceptable limits of heavy metals are based.

It could well be that foods grown on this soil will not reach the maximum permitted concentrations for consumption as outlined by Regulation A.08.001 by the Western Australian Government.

A detailed plant uptake study of heavy metals would not be cost effective in an attempt to gather sufficient information to decide on the safety or not of growing consumable plants on the soil. A more realistic approach would be to excavate the surface soil and replace it with clean top soil to a depth of 25 - 50cm where food gardens are likely to be grown. To prevent wind erosion a cover such as bitumen spray, cement addition or plastic sheet should be used over the new top soil and the soil planted with vegetation.

Contaminated soil should be mixed as homogeneously as possible and either dumped at a site with little precipitation, large distance between ground surface and groundwater table, with aquifers of good self purification capacity, poor groundwater quality and low groundwater velocity or the contaminated soil could be used as fill in areas of public open space, under buildings or roadworks at this site.

REFERENCES

5.

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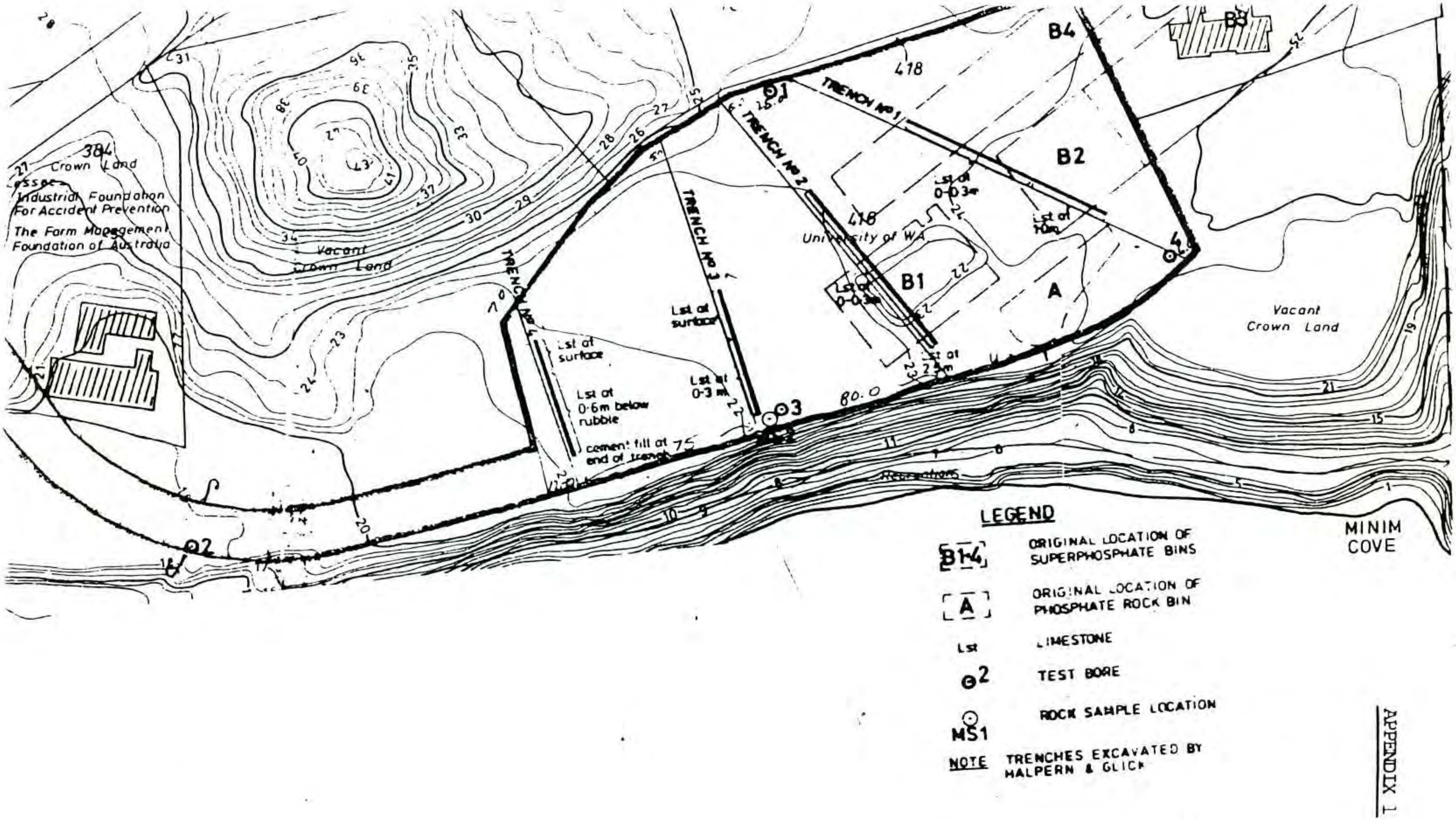
Ryall W.R. 1979 "Guidelines for collection, preparation and storage of geochemical samples for mercury analyses," C.S.I.R.O. Institute of Earth Resources Technical Communication 67.

Seto P, Deangelis P "Concepts of sludge utilization on agricultural land" : Sludge Utilization and Disposal Conference Proceedings No 6 Environment Canada Ottawa PP 138 - 155.


Crown Land
Lessee
Industrial Foundation For Accident Prevention
The Farm Management Foundation of Australia
384
Vacant Crown Land
TRENCH No 1
TRENCH No 2
TRENCH No 3
TRENCH No 4
418
University of WA
B1
B2
B3
B4
A
Lst at 0-0.3m
Lst at 1.0m
Lst at 0-0.3m
Lst at 2.5m
Lst at surface
Lst at surface
Lst at 0-3 m
Lst at 0.6m below rubble
cement fill at end of trench
80.0
Vacant Crown Land
Recreation
MINIM COVE
LEGEND
B1-4 ORIGINAL LOCATION OF SUPERPHOSPHATE BINS
A ORIGINAL LOCATION OF PHOSPHATE ROCK BIN
Lst LIMESTONE
⊖2 TEST BORE
⊙ MS1 ROCK SAMPLE LOCATION
NOTE TRENCHES EXCAVATED BY HALPERN & GLICK

APPENDIX 1

APPENDIX 2

ANALABS

A division of MacDonald Hamilton & Co. Pty. Ltd.

ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No
	82.0 01 22117	5.2.82	

TUBE No	SAMPLE No	Fe	Cu	Zn	As	Cd	Hg	Pb	Bi
1	1	8700	21	129	6	0.5	0.030	58	x
2	2	20.0%	138	161	120	1.3	0.13	39	x
3	3	7300	31	158	9	1.7	0.020	41	x
4	4	13.0%	950	2600	48	16.0	0.46	620	11
5	5	1.49%	100	663	8	3.5	3.7	1586	x
6	6	4567	30	118	9	1.0	1.5	55	x
7	7	1.55%	63	194	11	3.9	2.7	84	2
8	8	1.26%	61	343	7	4.2	1.27	237	x
9	9	7000	61	212	5	3.2	0.71	92	x
10	10	18.0%	82	63	28	x	0.36	56	x
11	11	3200	11	18	4	0.6	0.070	7	x
12	12	2700	22	69	2	1.2	0.010	26	x
13	13	1.08%	77	234	6	4.6	0.05	124	x
14	14	3800	29	125	4	4.8	0.03	15	x
15	15	3300	22	128	4	.9	0.02	152	x
16	16	4525	22	425	5	.7	0.02	820	x
17	17	2950	14	35	3	x	0.025	35	x
18	18	3933	15	99	x	.1	0.028	127	x
19	19	1.70%	300	395	58	5.5	1.2	260	x
20	20	2.60%	440	1000	5	6.9	0.050	270	8
21	21	1.81%	142	250	x	3.5	0.05	88	1
22	22	2.90%	55	200	4	0.2	0.020	123	x
23	23	7.1%	200	377	19	.8	0.07	265	x
24	24	13.1%	131	135	26	.8	0.13	114	x
25	25	3.10%	30	53	10	0.5	0.030	133	x

Results in ppm unless otherwise specified

T = element present; but concentration too low to measure

X element concentration is below detection limit

\- element not determined

AUTHORISED OFFICER

APPENDIX 2 .

ANALABS

ANALYTICAL DATA

REPORT NUMBER 82.0 01 22117

REPORT DATE 5.2.82

[illegible]	[illegible]	Fe	Cu	Zn	As	Cd	Hg	Pb	U	
1	26	2.43%	15.5	27.5	9	x	0.025	15		
2	27	1.42%	21	44	6	.3	0.025	170	2	
3	28	3033	6	11	5	x	x	11	x	
4	29	3067	8	17	4	x	0.010	19	x	
5	30	4167	16	113	3	.3	x	137	x	
6	31	2733	10	25	4	.2	x	22	x	
7	32	2533	14	32	3	.3	0.005	38	1	
8	33	1.10%	112	131	12	.9	0.040	138	x	
9	34	4.60%	260	730	55	1.9	1.3	550	3	
10	35	9.25%	195	500	35	1.3	2.0	2.10%	5	
11	36	4.08%	85	166	17	.4	0.19	4300	x	
12	37	6.2%	61	74	18	x	0.23	8608	x	
13	38	6.9%	42	114	11	.3	0.14	269	x	
14	39	3333	9	13	4	x	0.012	15	x	
15	40	6367	40	107	8	.3	0.04	455	x	
16	41	4167	18	57	5	.2	0.03	36	1	
17	42	4100	22	180	5	.5	0.03	54	x	
18	43	5667	33	32	8	.3	0.03	31	x	
19	44	4.50%	550	255	30	2.0	0.27	350	3	
20	45	4.45%	66	54	14	x	0.12	1500	x	
21	46	3.6%	151	250	59	0.6	0.050	460	x	
22	47	5.95%	57	39	9	x	0.06	122	x	
23	48	2.57%	131	197	45	1.3	0.16	3800	6	
24	49	4500	14	31	4	.2	0.02	523	1	
25	50	5933	13	29	4	.4	0.02	42	x	

Results in ppm unless otherwise specified
T = element present, but concentration too low to measure
X = element concentration is below detection limit
— = element not determined

AUTHORISED OFFICER

APPENDIX 2.

ANALABS

A division of MacDonald Hamilton & Co. Pty. Ltd.

ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No
	82.0 01 22117	5.2.82	

LINE No	SAMPLE No	Fe	Cu	Zn	As	Cd	Hg	Pb	Bi
1	51	3225	12	22	4	x	0.02	20	x
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23	DETECTION	1	1	1	1	0.1	0.005	1	1
24	DIGESTION	A6	A6	A6	A1	A6	A1	A6	A6
25	METHOD	A6/2	A6/2	A6/2	A1/3	A6/2	A1/5	A6/2	A6/2

Results in ppm unless otherwise specified
T = element present; but concentration too low to measure
x element concentration is below detection limit
– element not determined.

AUTHORISED OFFICER

APPENDIX 2.

ANALABS

A division of MacDonald Hamilton & Co. Pty. Ltd.

ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	[illegible]	PAGE
	82.0.01.22117	24.12.81		1 OF 4

TUBE No.	SAMPLE No.	Fe	Cu	Zn	Pb	Cd	Hg	[illegible]	[illegible]	
1	1/1	8700	21	129	6	0.5	0.030	58	×	
2	2/1	20.0%	138	161	120	1.3	0.13	39	×	
3	3/1	7300	31	158	9	1.7	0.020	41	×	
4	4/1	13.0%	350	2600	48	16.0	0.46	620	11	
5	5/1	1.36%	144	900	10	1.8	1.6	760	×	
6	5/2	1.55%	79	545	7	2.8	5.0	2000	×	
7	6/1	8400	58	315	13	2.2	3.0	146	×	
8	6/2	3300	24	78	8	0.8	1.2	37	×	
9	7/1	3.36%	98	280	10	4.0	3.0	113	×	
10	7/2	1.20%	56	177	11	3.8	2.6	78	2	
11	8/1	5900	53	310	6	4.4	0.10	215	×	
12	8/2	2.60%	78	410	8	3.9	3.6	280	×	
13	9/1	5600	44	195	4	3.2	0.16	96	×	
14	9/2	9800	95	245	6	3.2	1.8	85	×	
15	10/1	18.0%	82	63	28	×	0.36	56	×	
16.	11/1	3200	11	18	4	0.6	0.070	7	×	
17	12/1	2700	22	69	2	1.2	0.010	26	×	
18	13/1	7600	68	330	4	7.3	0.060	235	×	
19	13/2	1.14%	79	215	6	4.1	0.050	102	×	
20	14/1	6300	74	325	4	14.0	0.070	28	2	
21	14/2	3300	20	85	4	2.9	0.025	12	×	
22	15/1	3900	28	160	3	1.2	0.020	230	×	
23	15/2	2700	16	95	4	0.5	0.020	74	×	
24	16/1	6100	29	630	5	1.2	0.030	1230	×	
25	16/2	7950	14	270	4	0.2	0.010	410	×	

Results in ppm unless otherwise specified
T = element present; but concentration too low to measure
X = element concentration is below detection limit
— = element not determined

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ANALABS

A Division of MacDonald Hamilton & Co. Pty. Ltd.

APPENDIX 2

ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	DATE	CLIENT ORDER No.	PAGE
	82.0.01.22117	24.12.81		2 OF 4

TUBE No.	SAMPLE No.	Fe	Cu	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
1	17/1	3300	17	50	3	x	0.020	53	x	
2	17/2	2600	10	21	2	x	0.030	16	x	
3	18/1	5200	22	200 !	1	0.3 ✓	0.025 ✓	260	x	
4	18/2	3300	12	48	x	x	0.030	61	x	
5	19/1	1.70%	300	395	58	5.5	1.2	260	x	
6	20/1	2.60%	440	1000	5	6.9	0.050	270	8	
7	21/1	2.00%	141	250	x	2.9	0.050	95	1	
8	21/2	1.43%	145	250	2	4.6	0.050	74	2	
9	22/1	2.90%	55	200	4	0.2	0.020	123	x	
10	23/1	7.90%	170	245	17	0.6	0.050	127	x	
11	23/2	5.50%	260	640	22	1.1	0.10	540	x	
12	24/1	14.0%	146	150	28	0.9	0.15	128	x	
13	24/2	8.60%	54	62	15	0.1	0.050	46	x	
14	25/1	3.10%	30	53	10	0.5	0.030	133	x	
15	26/1	4.00%	21	42	11	x	0.040	25	x	
16	26/2	8600	10	13	6	x	0.010	5	x	
17	27/1	1.60%	24	54	7	0.2	0.020	119	x	
18	27/2	1.23%	18	34	5	0.3	0.030	220	4	
19	28/1	3700	7	13	5	x	x	14	x	
20	28/2	2900	6	10	5	x	x	10	x	
21	29/1	3300	8	19	5	x	0.010	24	x	
22	29/2	2950	8	16	4	x	0.010	16	x	
23	30/1	6500	32	280	4	0.9	x	340	x	
24	30/2	3000.	9	30	3	x	x	35	x	
25	31/1	3400	16	44	3	0.6	x	29	x	

Results in ppm unless otherwise specified

T = element present; but concentration too low to measure

X = element concentration is below detection limit

— = element not determined

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APPENDIX 2

ANALYTICAL DATA

SAMPLE PREFIX	[illegible]	REPORT DATE	[illegible]	PAGE
	82.0.01.22117	24.12.81		3 OF 4

TUBE No.	SAMPLE No.	Fe	Cu	Zn	As	Cd	Hg	Pb	Bi	
1	31/2	2400	7	16	5	x	x	18	x	
2	32/1	4000	22	67	3	0.5	0.015	79	3	
3	32/2	1800	10	14	3	0.2	x	18	x	
4	33/1	1.10%	112	131	12	0.9	0.040	138	x	
5	34/1	4.60%	260	730	55	1.9	1.3	550	3	
6	35/1	9.25%	195	500	35	1.3	2.0	2.10%	5	
7	36/1	5.00%	67	146	17	0.7	0.22	7300	2	
8	36/2	3.90%	89	170	17	0.3	0.18	3700	x	
9	37/1	10.0%	34	26	21	x	0.12	225	x	
10	37/2	4.30%	74	98	17	x	0.28	1.28%	x	
11	38/1	3.90%	23	58	10	x	0.090	128	x	
12	38/2	8.40%	52	142	11	0.5	0.16	340	x	
13	39/1	4500	14	18	4	0.1	0.020	22	x	
14	39/2	3100	8	12	4	x	0.010	14	x	
15	40/1	1.01%	63	215	9	0.8	0.040	880	x	
16	40/2	6100	38	99	8	0.3	0.040	425	x	
17	41/2	3100	13	82	4	0.1	0.025	34	x	
18	42/1A	4600	31	335	6	0.9	0.040	83	x	
19	42/1B	4700	21	44	6	0.2	0.030	37	2	
20	42/2	3600	14	26	4	x	0.015	25	x	
21	43/1	7000	36	37	9	0.2	0.030	34	x	
22	43/2	5000	32	30	7	0.3	0.035	30	x	
23	44/1	4.50%	550	255	30	2.0	0.27	350	3	
24	45/1	8.35%	103	69	19	x	0.19	3400	2	
25	45/2	2.50%	47	46	12	x	0.080	550	x	

Results in ppm unless otherwise specified

T = element present; but concentration too low to measure

X = element concentration is below detection limit

— = element not determined

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APPENDIX 2

ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	[illegible]	PAGE
	82.0.01.22117	24.12.81		4 OF 4

TUBE No.	SAMPLE No.	Fe	Cu	Zn	As	Cd	[illegible]	[illegible]	Bi	[illegible]
1	46/1	3.60%	151	250	59	0.6	0.050	460	×	
2	47/1	8.60%	60	43	10	×	0.075	98	×	
3	47/2	3.30%	54	34	7	×	0.050	146	×	
4	48/1	3.20%	133	200	32	1.7	0.18	4000	5	
5	48/2	2.25%	130	195	31	1.1	0.15	3700	6	
6	49/1	4700	15	30	4	0.1	0.020	590	3	
7	49/2	4400	14	31	4	0.3	0.020	490	×	
8	50/1	6600	14	26	3	0.3	0.015	46	×	
9	50/2	5800	13	29	4	0.4	0.025	41	[illegible]	
10	51/1	3850	16	29	6	0.3	0.020	37	×	
11	51/2	3100	11	21	3	×	0.020	16	×	
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23	DETECTION	1	1	1	1	0.1	0.005	1	1	
24	DIGESTION	A6	A6	A6	A1	A6	A1	A6	A6	
25	METHOD	A6/2	A6/2	A6/2	A1/3	A6/2	A1/5	A6/2	A6/2	

Results in ppm unless otherwise specified
T = element present; but concentration too low to measure
X = element concentration is below detection limit
— = element not determined

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APPENDIX 3

Several peices of loosely consolidated "rock" samples were received for determination of the copper mineral.

Examined microscopically in oils, it appeared to be very fine grained, more of a stain on other species. A number of specks of concentrated blue mineral were examined with the C.S.I.R.O. electron scanner.

These gave rather variable concentrations for various elements. These were calcium, phosphorus, sulphur and copper. No zinc was detected. Most had high calcium and copper was sometimes low.

The analysis was repeated later and a selection of non copper bearing (white) fragments were also examined with the scanner.

This time the examination was made in two ways, a field of view by scanning, and a point analysis of the same area.

This did not give significantly different results for the two methods used. The same elements were detected as before in the blue material. The white fragments gave calcium and phosphorus and a little iron.

The above seems to suggest that some of the copper is associated with sulphur, presumably in the oxidised form. Exact determination of the nature of the cryptocrystalline copper minerals requires X-ray diffraction.

CSBP FERTILISER WORKS SITE MOSMAN PARK ,

Technical Assessment Group, 1984.

CONTENTS

Section 1 INTRODUCTION

In December 1982 the Under Secretary for Lands approached the Department of Conservation and Environment with a view to setting up a working group to investigate the extent and type of industrial contamination of the site previously occupied by CSBP and Farmers Fertiliser Works in McCabe Street, Mosman Park, see Figure 1.

The Under Secretary for Lands became aware of the potential contamination of the site following investigations by the University of Western Australia of a portion of the site which had been procured during a land exchange with the Crown by the University three years previously. The University had commissioned two consultants to investigate the contamination of the soil and groundwater of its portion of the site.

The results of the consultants' investigations gave sufficient evidence of contamination of the site by industrial activity to justify the investigation of the whole site and an intensification of the investigation of the University's portion of the site.

The working group, or as it became known, the Technical Assessment Group has investigated the site and presents this report to the Under-Secretary for Lands and the University of Western Australia on the state of the site for their consideration.

The Members of the Technical Assessment Group are:

Mr D Viol (Chairman)	Department of Conservation and Environment
Mr R Atkins	Waterways Commission
Mr S Baseden	Government Chemical Laboratories
Mr T Bestow	Geological Survey, Department of Mines
Mr R Davis	University of Western Australia
Mr G Dellar	Government Chemical Laboratories
Mr D Galloway	Department of Conservation and Environment
Mr B Hand	University of Western Australia
Dr K Hirschberg	Geological Survey, Department of Mines
Mr J Jago	Government Chemical Laboratories
Mr R Mickle	Department of Lands & Surveys
Dr P Psaila-Savona	Public Health Department
Mr P Wilson	Government Chemical Laboratories

Section 2 SUMMARY OF THE STATE OF THE SITE

The soil on the site is contaminated with various levels of heavy metals with lead being the major contaminant. The contamination is not uniform across the site and largely correlates with the location of buildings on the site.

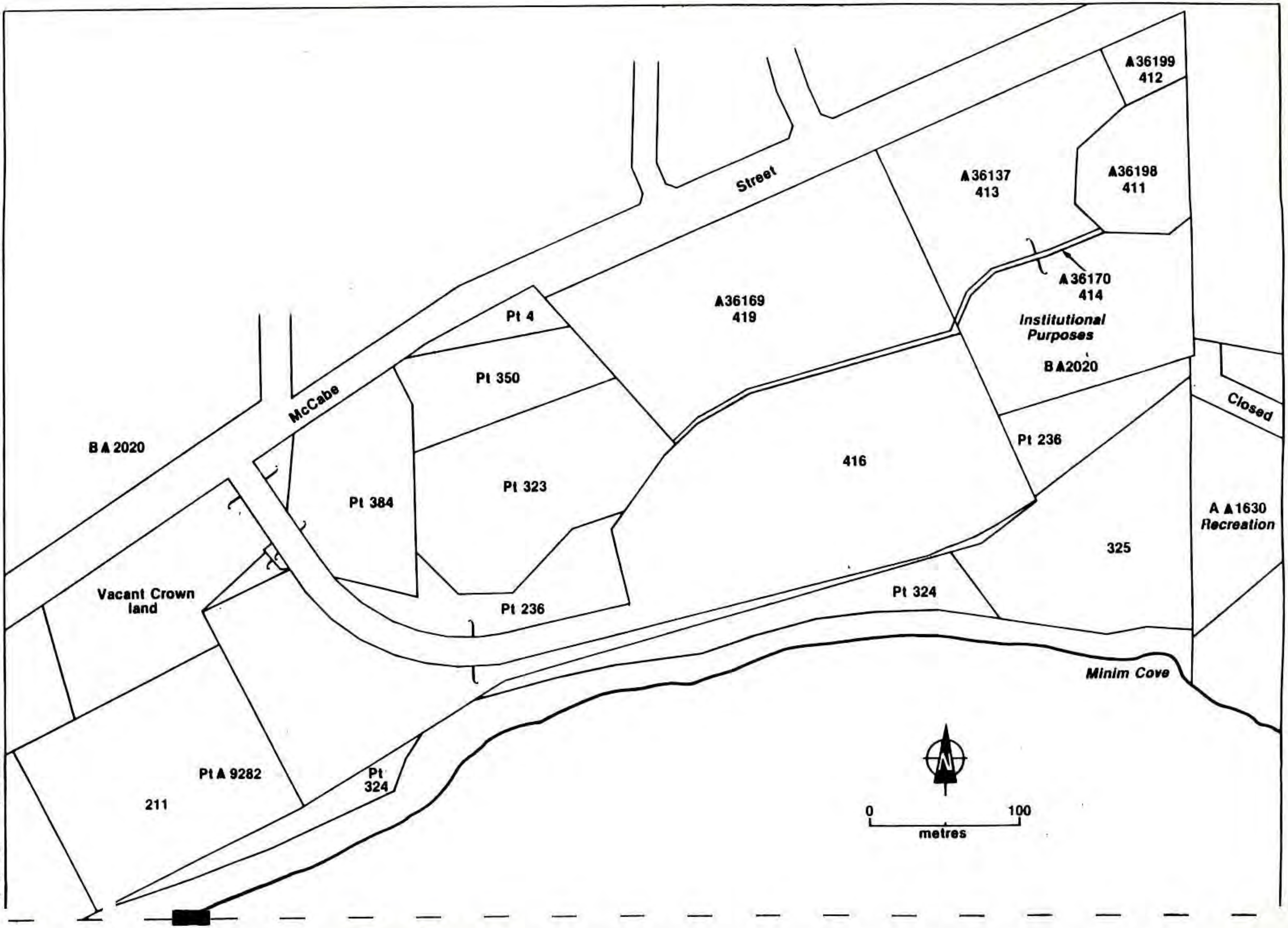


Figure 1 Study Ar

In general terms the site can be described as stable with some possible on-going minor addition of heavy metals, particularly lead, copper, zinc and arsenic to the river adjacent to the site from storm water run-off.

There are two major dumps of pyrites residue on the site. The smaller one is relatively inert, containing some sulphate salts. The other contains heavy metals and cyanide; this dump is mostly covered with soil and appears to be self-sealing. There are many minor dumps of pyrites residue eg under roadways and on the upper river embankment. These residues are similar in nature to the residues contained within the smaller residue dump.

There does not appear to be any contamination of the groundwater below the site which is a consequence of the surface contamination.

There does not appear to be any contaminated dust being blown from this site onto surrounding residential areas.

The Rocky Bay Village which is situated on Loc.413 (see Figure 1) is affected by dust blown from the site however the levels of lead and cadmium are well below the levels set by the NH & MRC as unsafe for a residential environment. The soil surrounding the Village do contain some contaminants from the industrial activity which occurred on the site however it is unlikely that any of these soils will interact with the operations of the Village.

The quality of the bore water used on the gardens of the Village is within the limits set for potable water except for a high salt content which while making the water unsuitable for drinking does not constitute any hazard to the users of the Village.

Section 3 THE INDUSTRIAL HISTORY OF THE SITE

The plant works on the site were constructed in two major phases. The No 1 and 2 acid plants on the upper eastern end of the site were built sometime after 1910. The No 3 acid plant on the lower western end of the site which was subsequently used to process flotation concentrates from gold mining operations, was built in the 1930's.

The No 1 and 2 Acid Plants and Superphosphate Works

The first acid plants were built sometime after 1910. These consisted of two groups of Herreshoff furnaces (or roasters) each group consisting of six furnaces which supplied sulphur dioxide to a lead chamber sulphuric acid plant. The sulphuric acid was then in turn used to make superphosphate.

The Herreshoff roasters were cylindrical multi staged vertical furnaces which burnt a variety of materials to provide sulphur dioxide to the lead chamber acid process. See Figure (2).

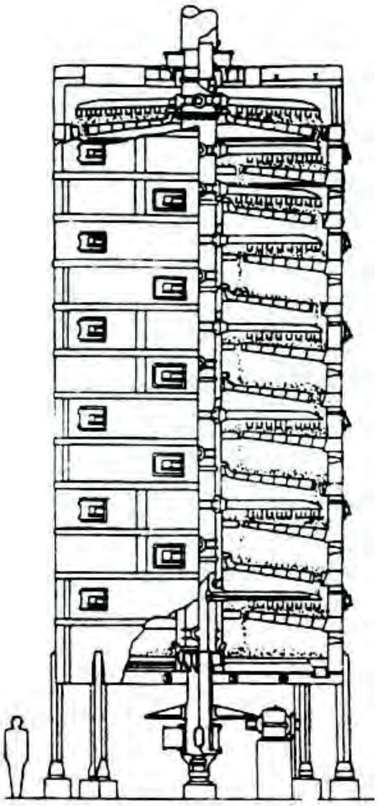


Figure 2 Herreshoff Furnace Ref 1

The materials burned were

- (i) iron pyrite (FeS_2 from Norseman)
- (ii) chalcopyrite (from Tasmania $CuFeS_2$)
- (iii) Spanish pyrite (FeS_2 possibly with associated cinnabar HgS)
- (iv) Norseman pyrite concentrate
- (v) Kalgoorlie pyritic flotation concentrate from Gold Mines of Kalgoorlie.

The pyrites contained many small amounts of other minerals as can be seen from Table 1.

Table 1 Analysis of a Kalgoorlie Pyritic Concentrate Ref 2.

Major constituents		percent
Sulphur as sulphide	S	37.09
Iron as pyrite	Fe	32.31

Minor and trace constituents	parts per million
Arsenic	1280
Copper	1120
Zinc	622
Nickel	301
Cobalt	202
Tellarium	132
Gold	103
Antimony	40
Silver	25
Mercury	22
Lead	20
Germanium	19
Bismuth	18
Selenium	13
Platinum	<0.1

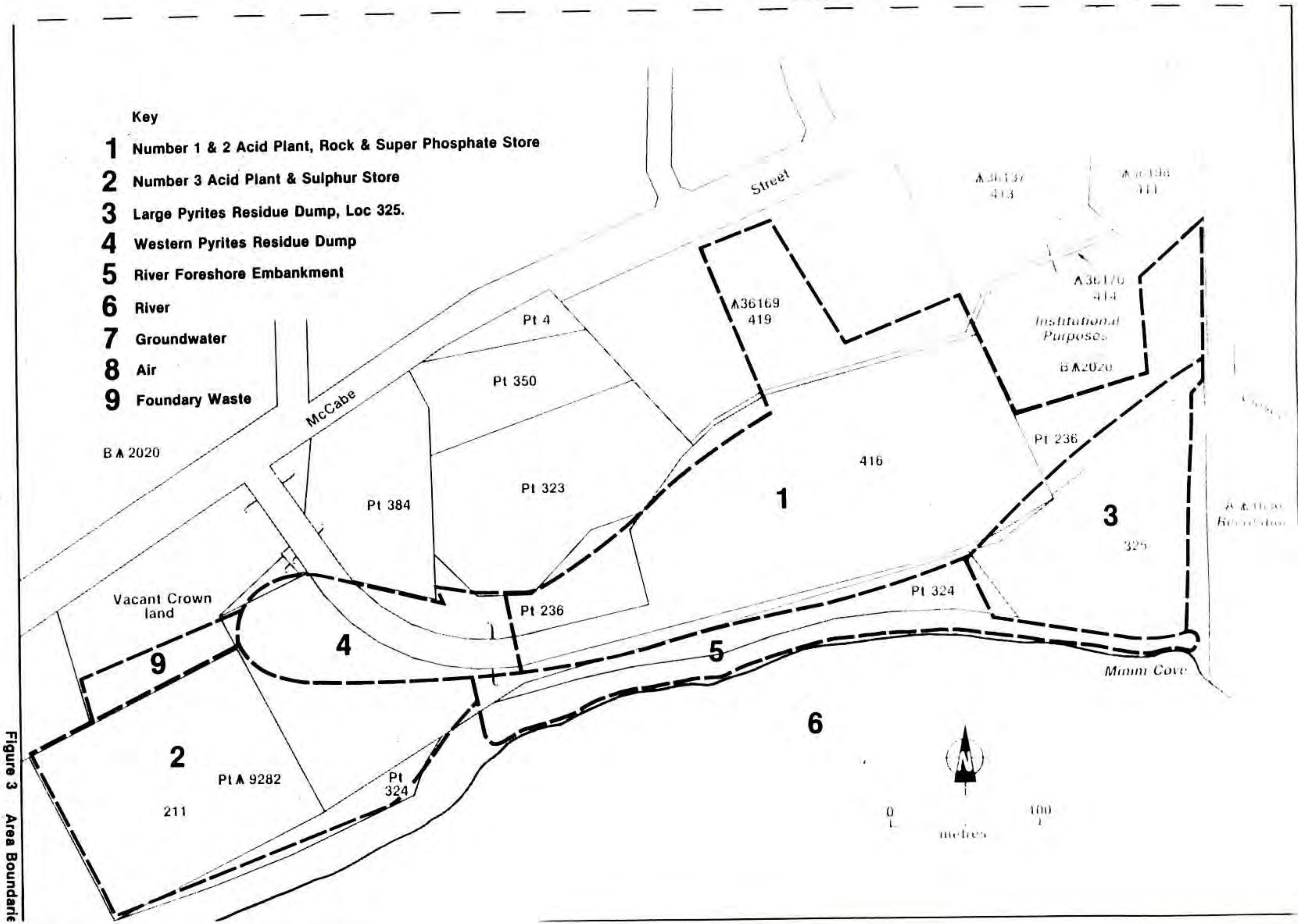


Figure 3 Area Boundarie

Very little is known about what, or how much of these materials were burnt in the roasters before 1952. It appears that economics determined what type of material was used to produce the sulphur dioxide for the acid plant.

The Herreshoff roasters operated at approximately 580^0C and produced a cinder containing 1-4% sulphur with a particle size of generally less than 9mm diameter. The operating conditions in the Herreshoff roasters gave good sulphur removal (as SO_2 gases) from the pyrites. The low levels of metals in the cinders from these roasters appear to indicate that metals were also removed from the pyrites leaving a cinder comparatively free of metals,see Table 3, Section 6.

The cinders from these roasters were dumped at various places around the site. The major dumps were along the river embankment in Lot 324, see Figure 3; in the western pyrites residue dump, Area 4 in Figure 3; and along the northern edge of Lot 325. Area 4 contains approximately 10 x 10^3m3 of pyrite residue. These cinders were also used as road base material around the site. Some were also used in a similar manner by the Mosman Park Roads Board, however, this practice was abandoned as the rising salt from the residue led to the rapid degradation of the road surfaces. An unknown amount of the cinders were exported to Japan and other overseas markets as a basis for pigment manufacture and as a raw material for iron production.

The raw pyrite was brought onto the site as it was required and consequently only small stockpiles were present on the site at any one time. However, the locations and types of these stockpiles are unknown.

To provide a clean gas to the acid plant the sulphur dioxide and dust from the roasters were passed through a battery of cyclones to remove the dust. The dust collected is thought to have contained a high concentration of a large number of metal oxides. Some of the metals were arsenic, copper, lead, mercury, selenium and zinc. It is thought that the dust was either sold or dumped at various locations around the site, particularly on the northern edge of lot 325.

Despite the efficient removal of dust the gas which entered the acid plant still contained some metals volatilized by the high furnace temperatures. These ended up in the acid which in turn was incorporated into the superphosphate thereby passing out of the works.

The acid plant was a standard lead chamber sulphuric acid plant, see Figure 4 over.

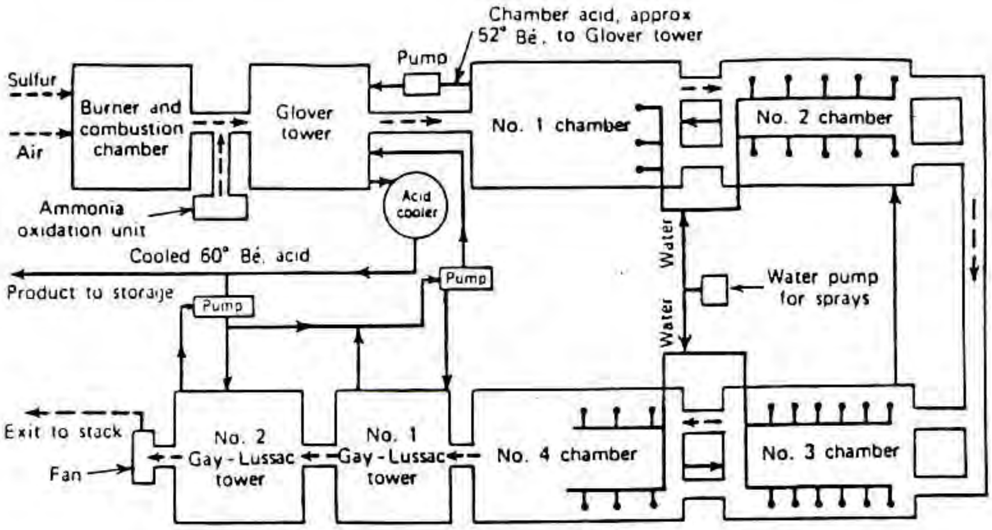


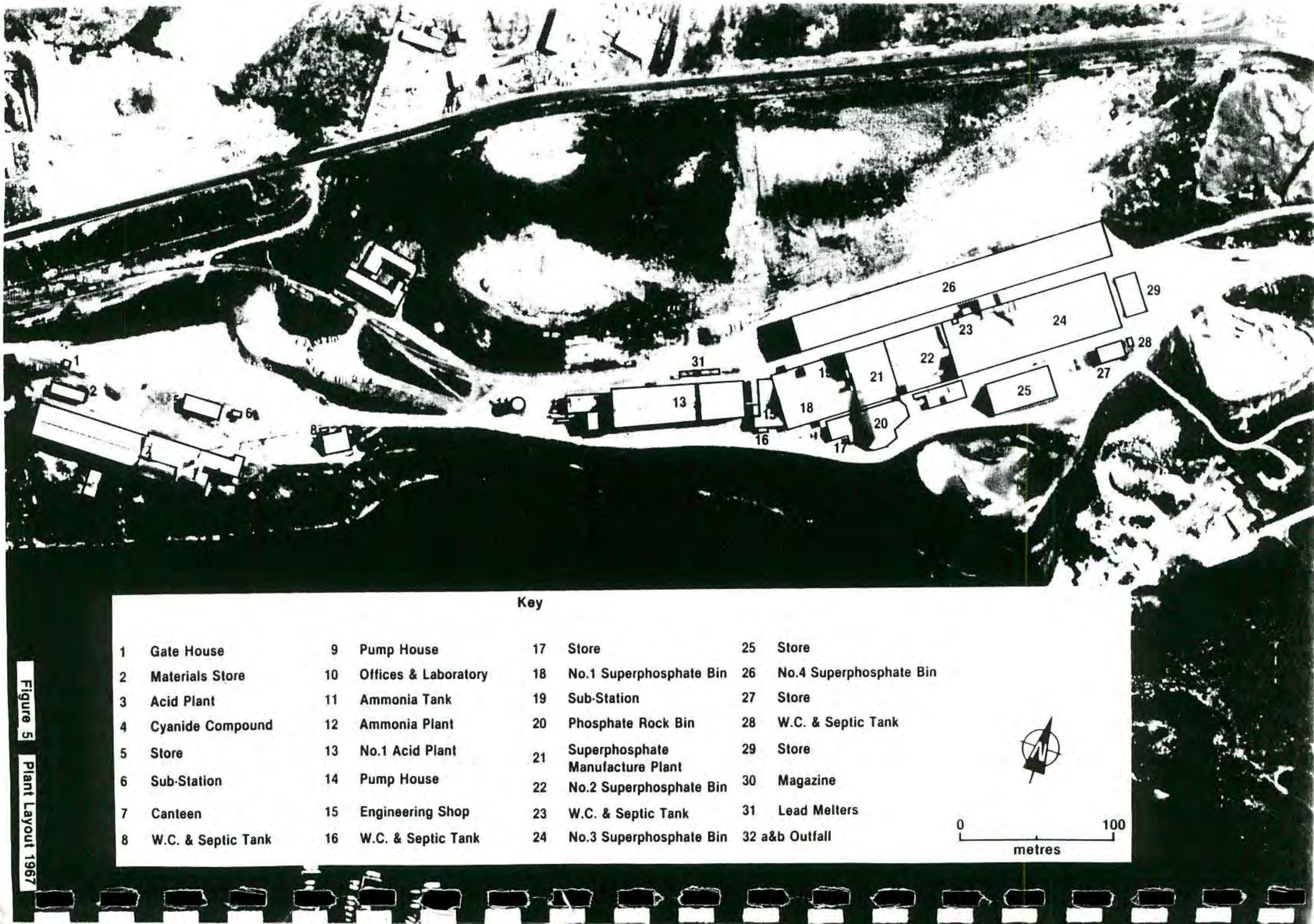
Figure 4 Lead chamber Sulphuric Acid plant Ref 3

Over a period of time the inside of lead chambers corroded and became coated with lead sulphate. Periodically the lead sulphate was removed from the tanks and dumped around the site. When the tanks became highly corroded they were replaced and the old tanks melted down on site, see Figure 5, and the recovered lead sold. Pieces of elemental lead can still be found on the site of the lead melters.

Superphosphate was manufactured by mixing sulphuric acid and crushed phosphate rock to form a slurry. This slurry was fed into large concrete 'dens'. The dens were large boxes with one vertical wall made of wood which could be removed once the rock had reacted and the superphosphate removed. In the later years of operation the dens were equipped with scrubbers to control the release of hydrogen fluoride and other fluoride compounds to the atmosphere. The scrubbers also removed mercury compounds which had been liberated from the phosphate rock during the reaction with the sulphuric acid. Initially the liquor from these scrubbers was allowed to flow onto the site in the vicinity of the dens but with the introduction of higher flourine rocks the effluent was discharged into the cinders residue dump.

Once the acid had sufficiently reacted with the phosphate rock the superphosphate was removed from the dens and placed in the superphosphate storage sheds to cure. Superphosphate Store No 1 had a large depression in the floor from which the superphosphate was extracted for packaging and sale. This depression is still present today. Other sheds had tunnels with conveyors so the superphosphate could be removed. Some trace elements were mixed in with the superphosphate one of them being copper (as copper or copper sulphate) the copper pyrites roasted. For a limited period of time copper oxide from the copper pyrites roasting was added to the superphosphate.

The Herreshoff roasters burnt various pyrites until 1958. Between 1958 and 1964 sulphur replaced pyrites as the source of the sulphur dioxide.



Key

1	Gate House	9	Pump House	17	Store	25	Store
2	Materials Store	10	Offices & Laboratory	18	No.1 Superphosphate Bin	26	No.4 Superphosphate Bin
3	Acid Plant	11	Ammonia Tank	19	Sub-Station	27	Store
4	Cyanide Compound	12	Ammonia Plant	20	Phosphate Rock Bin	28	W.C. & Septic Tank
5	Store	13	No.1 Acid Plant	21	Superphosphate Manufacture Plant	29	Store
6	Sub-Station	14	Pump House	22	No.2 Superphosphate Bin	30	Magazine
7	Canteen	15	Engineering Shop	23	W.C. & Septic Tank	31	Lead Melters
8	W.C. & Septic Tank	16	W.C. & Septic Tank	24	No.3 Superphosphate Bin	32 a&b	Outfall

Figure 5 Plant Layout 1967

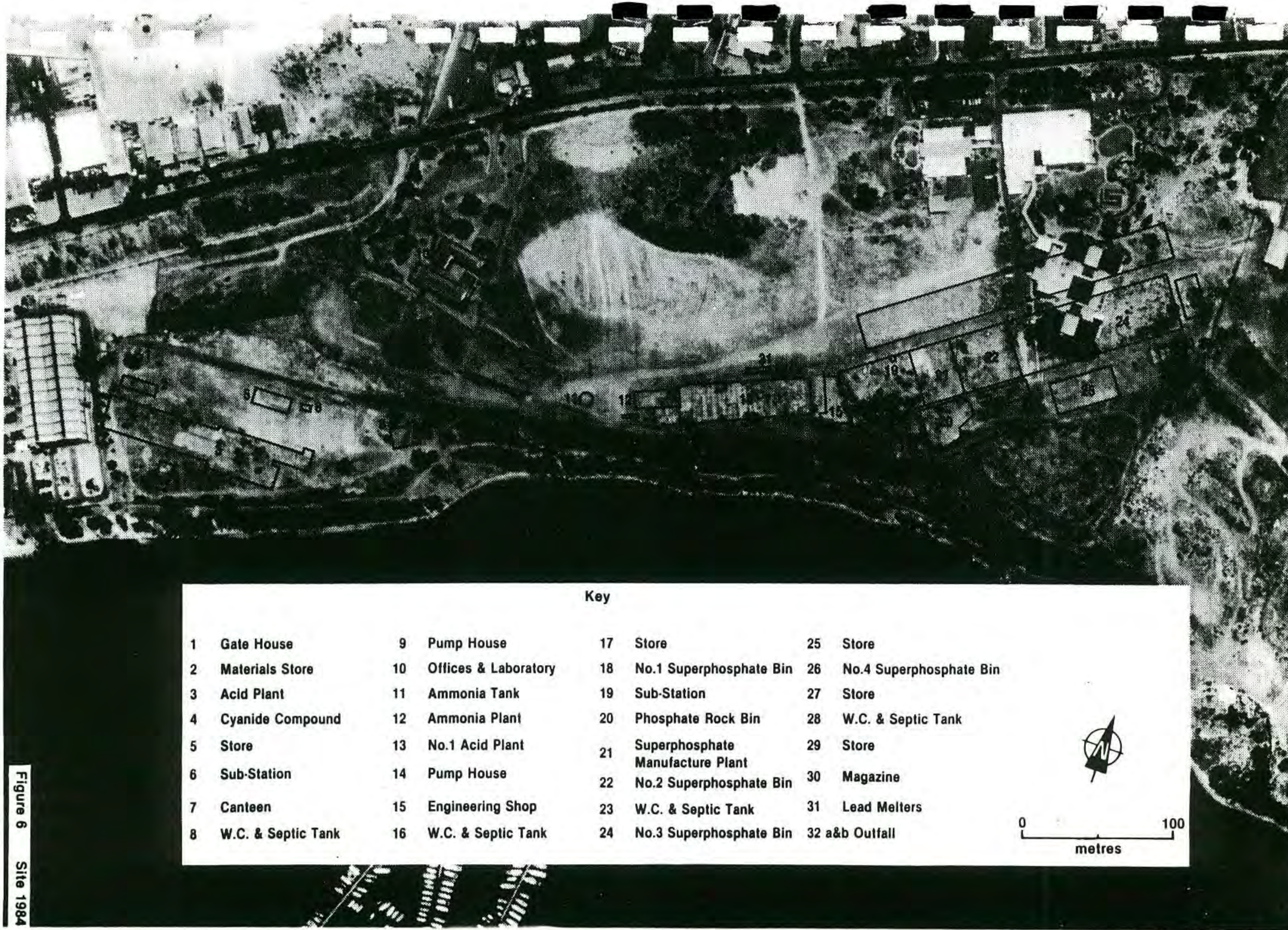


Figure 6 Site 1984

Key

1	Gate House	9	Pump House	17	Store	25	Store
2	Materials Store	10	Offices & Laboratory	18	No.1 Superphosphate Bin	26	No.4 Superphosphate Bin
3	Acid Plant	11	Ammonia Tank	19	Sub-Station	27	Store
4	Cyanide Compound	12	Ammonia Plant	20	Phosphate Rock Bin	28	W.C. & Septic Tank
5	Store	13	No.1 Acid Plant	21	Superphosphate Manufacture Plant	29	Store
6	Sub-Station	14	Pump House	22	No.2 Superphosphate Bin	30	Magazine
7	Canteen	15	Engineering Shop	23	W.C. & Septic Tank	31	Lead Melters
8	W.C. & Septic Tank	16	W.C. & Septic Tank	24	No.3 Superphosphate Bin	32 a&b	Outfall

There were several stormwater drains on the site consequently a considerable amount of water drained off the site into the river through the open launder cooling water returning, see the outfall pipe Figure 5(32A).

The No. 3 Acid Plant and Gold Extraction Works

The No.3 acid plant which was built in the 1930's was situated on the lower western end of the site and between 1930 and 1952 it burnt sulphur to produce sulphur dioxide. The sulphur was stockpiled adjacent to the plant as shown in Figure 3.

In 1953/54, a flash roaster was used to burn Norseman pyrite concentrate in this plant.

In 1955 a small fluidised bed furnace or roaster, see Figure 7 below, was built to utilise gold flotation concentrates from Western Mining Company's Kalgoorlie mines. These concentrates were stockpiled alongside the plant while the fluidised bed roaster was constructed. In 1956 following the successful operation of the small fluidised bed roaster a much larger fluidised bed roaster was constructed. The purpose of using fluidised bed roasters and gold mining concentrates was not only to provide sulphur dioxide for the acid plant but also to breakdown the sulphide minerals and gold compounds in the concentrate thereby making the gold available for extraction by cyanidation. Unlike the Herreshoff roasters which produced a granular cinder residue the fluidised bed roaster produced a very finely divided powder residue enabling it to be slurried with water.

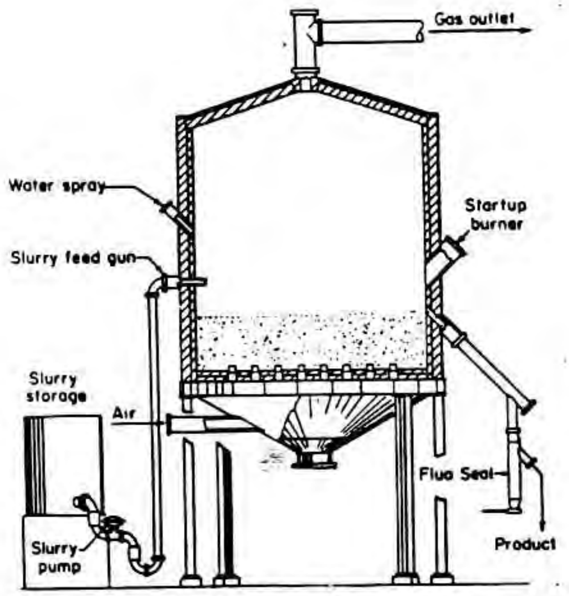


Figure 7 Fluidised Bed Furnace Ref 4

This slurry was limed, to make the slurry alkaline, and then reacted with cyanide, (mostly in the form of sodium cyanide) for a period of 24 hours. The slurry was then filtered and the filter cake washed with water. The gold was then removed from the cyanide filtrate and wash water and the gold free water then returned to the process. Some of this water was bled off the return process water stream, and then mixed with the filter cake to reform a 50% slurry. Following this the slurry was chlorinated to destroy the cyanide until it had free cyanide content equivalent of 0.001% KCN. This slurry was then pumped to a slurry dump on Lot 325.

Apart from a certain amount of copper oxide incorporated in the Superphosphate, all the residues of the materials burnt in the fluidised bed roasters ended up in the dump of Lot 325. When Lot 325 was filled, a disused quarry under what is now the carpark adjacent to the sports oval on Reserve No.36788 was filled.

The dump of Lot 325 contains approximately 70 x 10^3 m^3 of pyritic residue contained within progressively higher limestone bunds producing a total residue thickness of 9-10m.

When burning pyrites the operating conditions of the fluidised bed roaster produced a residue containing higher levels of metals than in the residue from the Herreshoff roasters. The high levels of metal compounds found in the dump on Lot 325 would indicate that, other metal compounds were retained in the dump, see Table 2, Section 6.

The gas passing out of the roaster was treated in a similar manner to that employed in the No. 1 & 2 acid plants, with an additional electrostatic precipitation being used to clean the gas. The acid was then used to make superphosphate. The disposal of other wastes from the process occurred in a similar manner to that employed in the No. 1 & 2 acid plants, ie. discharged onto the ground at various locations around the site.

In Summary the major sources of contamination of the site were

- lead sulphate from the lead acid chambers.
- lead from the lead melters
- the dust from the gas cleaning equipment
- raw pyrites dumps at unknown locations around the site.
- the fluoride scrubber liquor
- pyritic reside and the metal compounds contained within these residues in various dumps around the site.
- fall out and leakages from the processes that operate on the site.
- contaminants in rainwater runoff from the sheds and equipment

Section 4 HISTORY OF LAND TENURE

The site which is now made up of land occupied by the Western Australian Society for Cripple Children's Rocky Bay Village, the University of Western Australia and vacant Crown land was originally part of the river foreshore embankment. The site was overlain with top soil supporting typical Coastal Limestone Ridge vegetation.

Around 1895 the Public Works Department quarried limestone on this site to obtain rock to build the north and south moles at Fremantle. This quarry was serviced by a railway, the route of the lower railway line still being present today as a walk trail halfway down the river embankment.

The original lease of approximately 17 acres was issued in 1909 by the Minister for Works to the Mt Lyell Mining and Railway Company Ltd., see Figure 8. The lease was for the establishment of works for the manufacture of acids and superphosphates and other agricultural fertilisers. This lease was over a portion of Reserve No. B 2020 later surveyed as North Fremantle Lot 236.

In 1916 the company sought additional land from Reserve No.B 7133 for extension of its works railway siding. This lease was issued over North Fremantle Lots 236 and 210.

The company sought additional land to the south west of Lot 236 in 1924. This land was held under sub lease from the Minister for Works by Westralia Iron Works Co. Ltd. being Reserve No.8292. Westralia agreed to subdivide its holding which was then transferred to the Mt. Lyell Mining and Railway Co. as North Fremantle Lot 211.

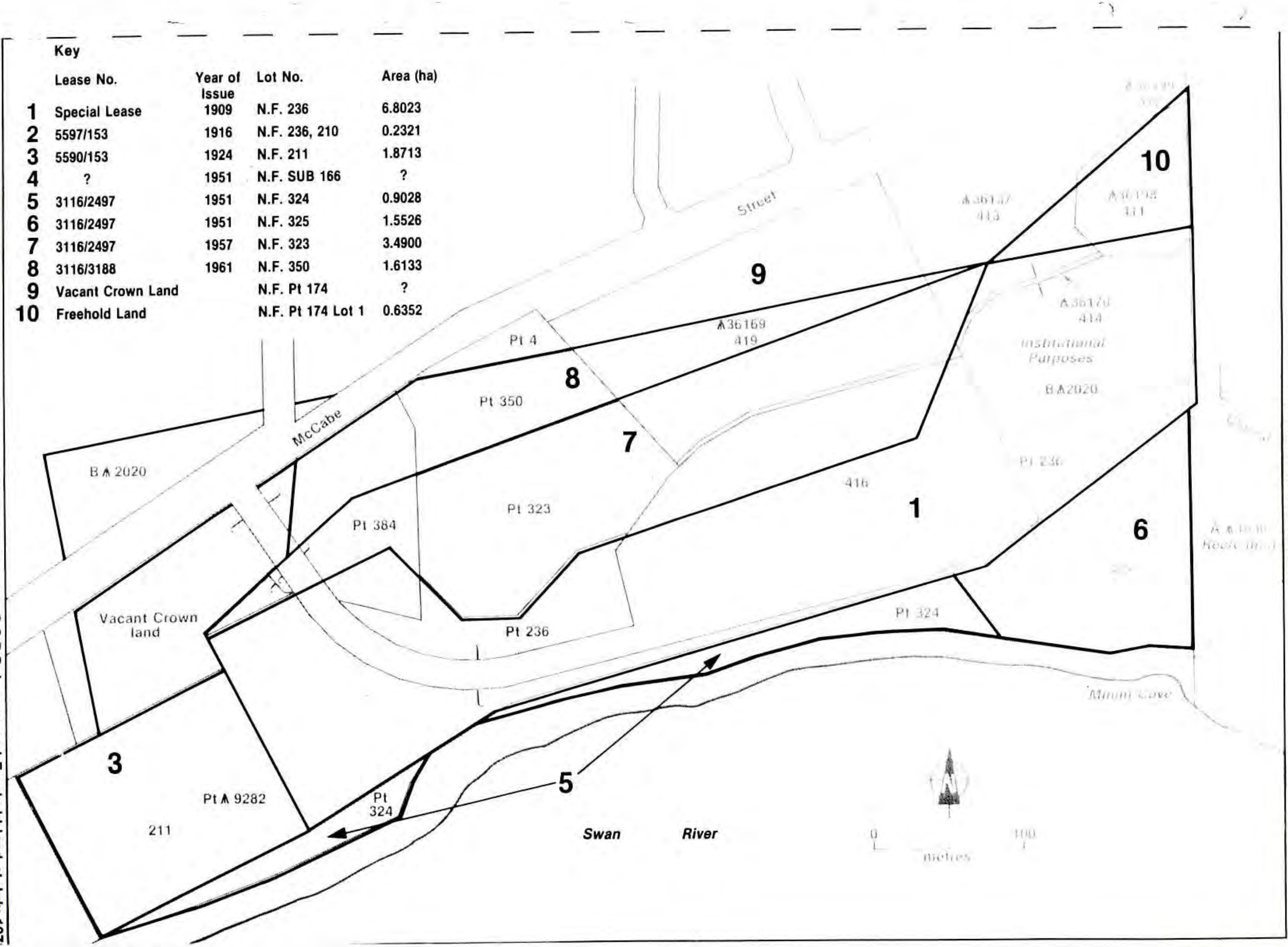
In 1929 the Mt Lyell company was restructured as Cuming Smith Mt. Lyell Farmers Fertilisers.

In 1951 permission was granted for pyrites residue to be deposited on

i. Reserve No. 17102 Mosman Park Sub Lot 166
ii. Portion of Reserve No. B.2020 distinguished as North Fremantle Lot 325.
iii. Portion of Reserve No. B.2020 distinguished as North Fremantle Lot 324.

In 1953 formal leases were issued over these sites for the purpose of disposal of pyrites on a year to year tenancy. Deposits were to be placed in existing borrow pits with a view to the eventual restoration of ground levels. A lease over North Fremantle Lot 323 was granted to the company in 1957 for the manufacture of acids, superphosphate and other agricultural fertilisers.

Further land was leased by the company in 1961. This was identified as North Fremantle Lot 350 and was used to rationalise the boundaries of the works, provision of internal road, offices, superphosphate storage and staff amenities.



Key

Lease No.		Year of Issue	Lot No.	Area (ha)
1	Special Lease	1909	N.F. 236	6.8023
2	5597/153	1916	N.F. 236, 210	0.2321
3	5590/153	1924	N.F. 211	1.8713
4	?	1951	N.F. SUB 166	?
5	3116/2497	1951	N.F. 324	0.9028
6	3116/2497	1951	N.F. 325	1.5526
7	3116/2497	1957	N.F. 323	3.4900
8	3116/3188	1961	N.F. 350	1.6133
9	Vacant Crown Land		N.F. Pt 174	?
10	Freehold Land		N.F. Pt 174 Lot 1	0.6352

Continued on next map

Figure 8 C.S.B.P. Leases and Freehold land at July 197

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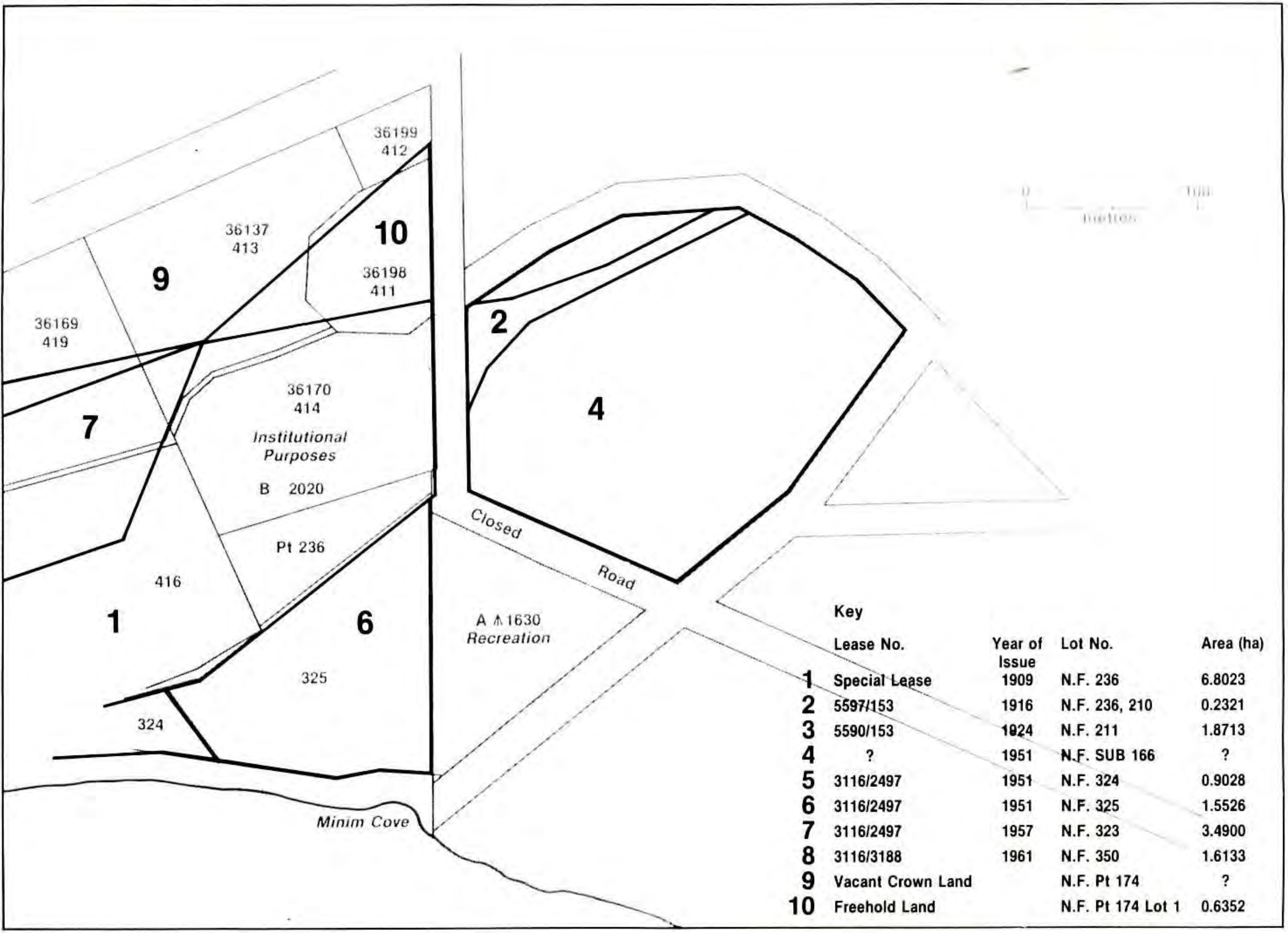


Figure 8 CSBP Leases & Freehold Land at July 1973

Key

	Lease No.	Year of Issue	Lot No.	Area (ha)
1	Special Lease	1909	N.F. 236	6.8023
2	5597/153	1916	N.F. 236, 210	0.2321
3	5590/153	1924	N.F. 211	1.8713
4	?	1951	N.F. SUB 166	?
5	3116/2497	1951	N.F. 324	0.9028
6	3116/2497	1951	N.F. 325	1.5526
7	3116/2497	1957	N.F. 323	3.4900
8	3116/3188	1961	N.F. 350	1.6133
9	Vacant Crown Land		N.F. Pt 174	?
10	Freehold Land		N.F. Pt 174 Lot 1	0.6352

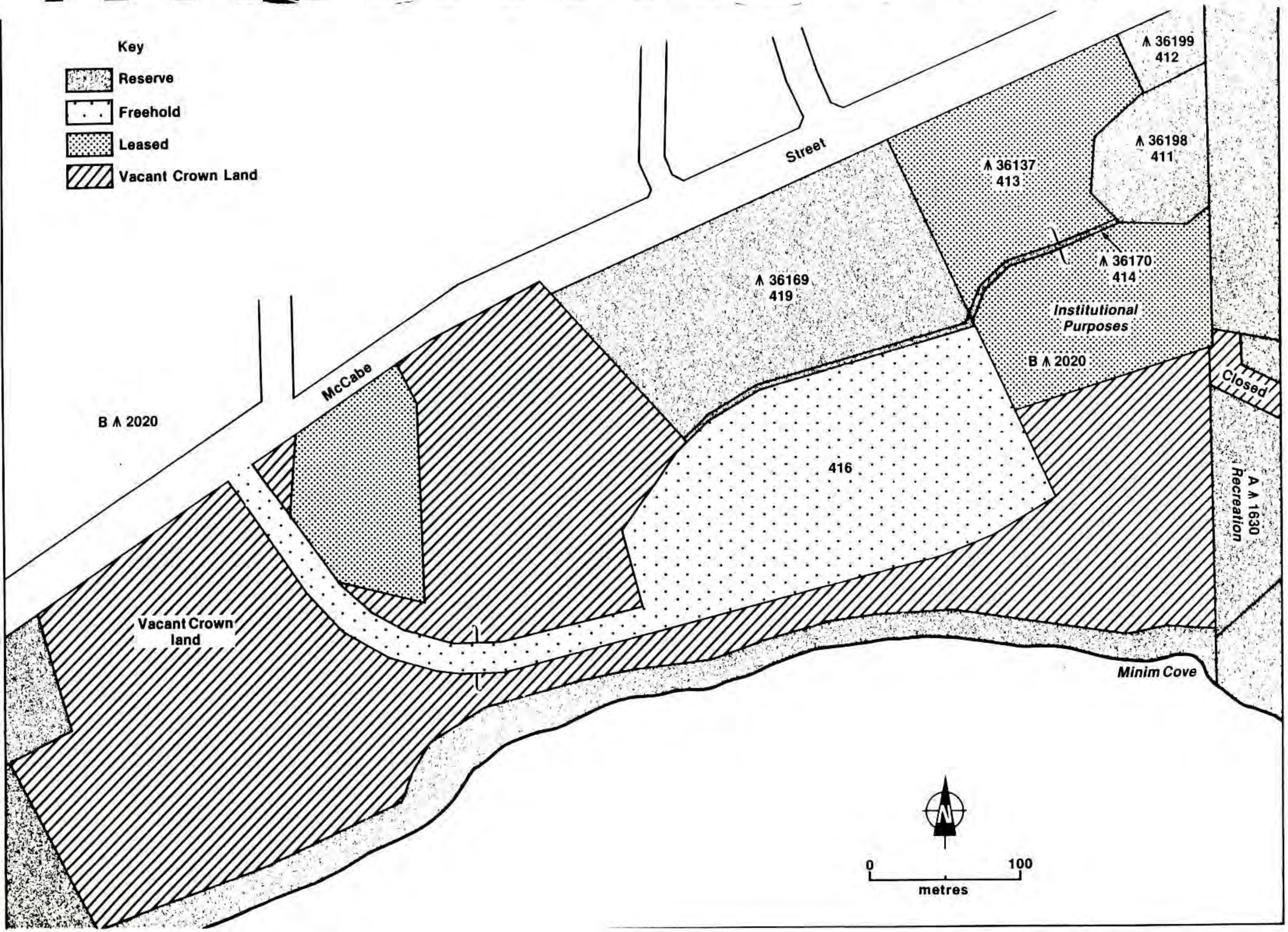


Figure 9 Cadastral Boundaries at July 198

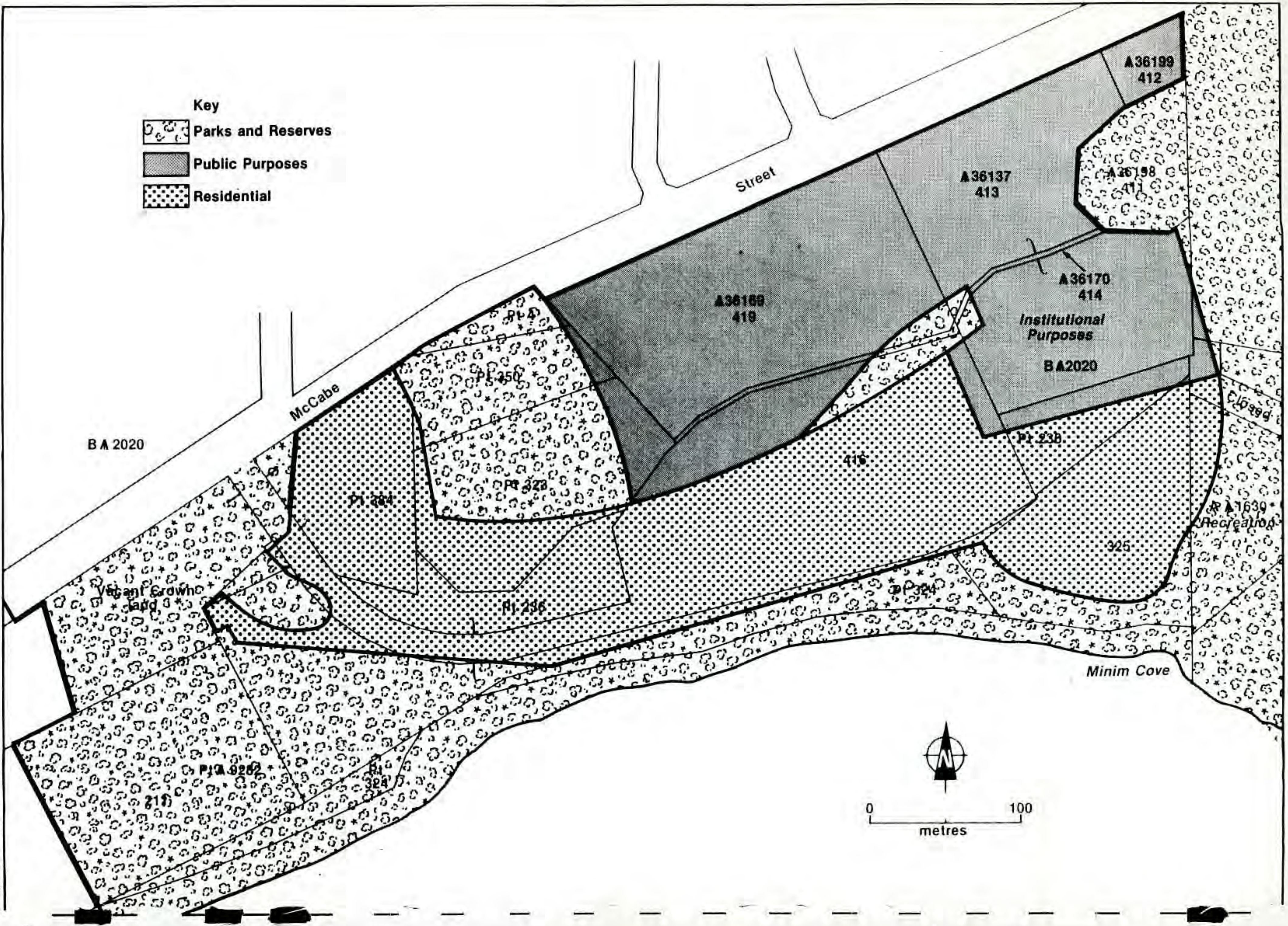


Figure 10 Zonings

In 1966 Cuming Smith and Mt Lyell Farmers Ferilisers Ltd became CSBP Farmers Ltd. The company ceased operations on this site 1969 and terminated the leases in July 1973. The Government of the day was satisfied that the conditions of the leases with respect to the restoration of the site had been complied with by the company

In June 1979 the University of Western Australia exchanged the land now occupied by the Rocky Bay Village for a portion of land in the middle of the site, now designated Location 416, see Figure 9. The current MRPA zonings for the site are shown in Figure 10.

Section 5 INVESTIGATIVE PROCEDURES

Before site investigations began all the information available on the raw materials used, the processes which operated and wastes produced by the fertiliser works was assembled. From this information it was deduced that the most likely contaminants of the site would be heavy metals, cyanide and pyrites residue. These investigations were followed by investigations of old aerial photographs of the site, several site visits and a study of the reports of the previous work done on the site commissioned by the University and carried out in 1981 by Rockwater Pty Ltd and Analabs Analytical Chemists.

Rockwater installed four bores on loc 416, determined the hydraulic gradient of the water and sampled the water for iron, lead, copper, mercury, sulphate, nitrate, phosphate, arsenic, pH and TDS. Analabs sampled the surface of part of Loc 416 and analysed the samples for heavy metals - iron, copper, zinc, arsenic, cadmium, mercury, lead and bismuth. The University made the reports of these investigations available to the Group. These reports provided preliminary information about the site and gave useful leads on which contaminants should be investigated.

The primary concern of the Group was to establish whether the health and well-being of the children in the Rocky Bay Crippled Children's Home was being affected in any way by the contaminants of the site. The potential health risk to the children was determined by

- analysing the soil in close proximity to the home for iron, copper, lead, cadmium, zinc and arsenic.
- setting up a high volume air sampler in the vicinity of the home to sample the windbourne dust. This dust was then analysed for lead and mercury.
- sampling the bore water used on the gardens of the home for chloride, sulphate, cyanide, nitrogen, phosphorus, cadmium, copper, iron, lead, manganese, mercury and zinc.

For a full investigation the site was divided into nine Areas as shown in Figure 3. These areas were;

Area 1 Number 1 & 2 Acid Plant, Rock & Superphosphate Store
2 Number 3 Acid Plant and Sulphur Store
3 Large Pyrites Residue Dump Loc 325
4 Western Pyrites Residue Dump
5 River Foreshore Embankment
6 River
7 Groundwater
8 Air
9 Foundry Waste.

Area 1 & 2 Soil Investigations

Area 1 is predominantly made up of Loc 416 which was investigated by Analabs.

The soil in Area 1 was investigated in two stages. Firstly the surface and subsoil in the vicinity of the Rocky Bay Village was sampled on a grid basis. Later trenches were dug to bed rock across both Areas 1 and 2 and the surface soil and bed rock of both these Areas was sampled, see Figure 11. In some locations building foundations or roadways precluded the digging of trenches.

These samples were analysed for heavy metals specifically lead, copper,cadmium, zinc, arsenic in the vicinity of Loc 416 (Area 1) and copper, lead and zinc in the vicinity of the No 3 Acid plant (Area 2). Mercury was tested for using a screening procedure with a detection limit of 0.5ppm.

All of the samples tested in Area 1 had mercury levels of less than the detection limit. The processes which operated on Area 2 made it unlikely that significant mercury would be found in Area 2.

Area 3 & 4 Pyrites Residue Dumps

These dumps were sampled by a combination of grab samples from the trenching and a bore hole through each dump, see Figure 11. Each bore hole extended below the dump into the bed rock. The bore on Loc 325 was drilled to below the water table. This was then lined and capped for future access for water sampling.

The cores from the bores were analysed for heavy metals - iron, arsenic, gold, copper, mercury, lead and zinc. The core from the bore on Loc 325 was also analysed for free, complexed and total cyanide.

Area 5 River Foreshore Embankment

As stated in Section 3 the foreshore embankment was used as a dumping area for pyrites residue. The upper edge of the embankment was cut as part of the trenching procedure to determine the thickness of the residue. This residue was grab sampled and analysed for chloride, copper, iron, phosphorus, sulphur (as total and sulphate) and zinc, lead, cadmium, mercury and arsenic.

Area 6 River

Because of various discharges from the works that entered in the river both the sediments molluscs and alga along the foreshore below the site were sampled. The sediments were sampled at seven sites and analysed for arsenic, cadmium, copper, lead, mercury, nickel and zinc. Molluscs (Antigona chemnitzi) from two of the sites adjacent to an outfall pipe, see Figure 4 (No 32A) were also analysed for these metals.

Area 7 Groundwater

The groundwater was sampled from the following bores,

- the four bores installed by Rockwater on Loc 416; See Figure 11
- the Geological Surveys multiport bore; See Figure 11
- the bore installed in the residue dump on Loc 325;See Figure 11
- six privately owned reticulation bores located in the vicinity of the site between Mott Close and Briggs Street.

The depth of water was measured in the bores to which access could be gained. Water from all the bores was sampled. The samples were analysed for pH, conductivity, chloride, orthophosphate, total phosphorus, ammonia, nitrate , sulphate, cyanide, zinc, cadmium, arsenic, copper, iron, mercury, lead, and manganese.

Area 8 Air

The degree of air pollution resulting from windblown dust from the site was investigated by installing two high volume air samplers. One in the vicinity of the Rocky Bay Village, the other in the grounds of the old CSBP offices, now occupied by IFAP. This second sampler was used to determine background dust levels. These samples operated for a period of three months over summer 1983/84 when the possibility of windblown dust was the greatest.

Area 9 Foundry Waste

The Foundry Waste dump was not part of the original CSBP lease or freehold area. The waste dump was inspected during other site inspections. It was not sampled or analysed.

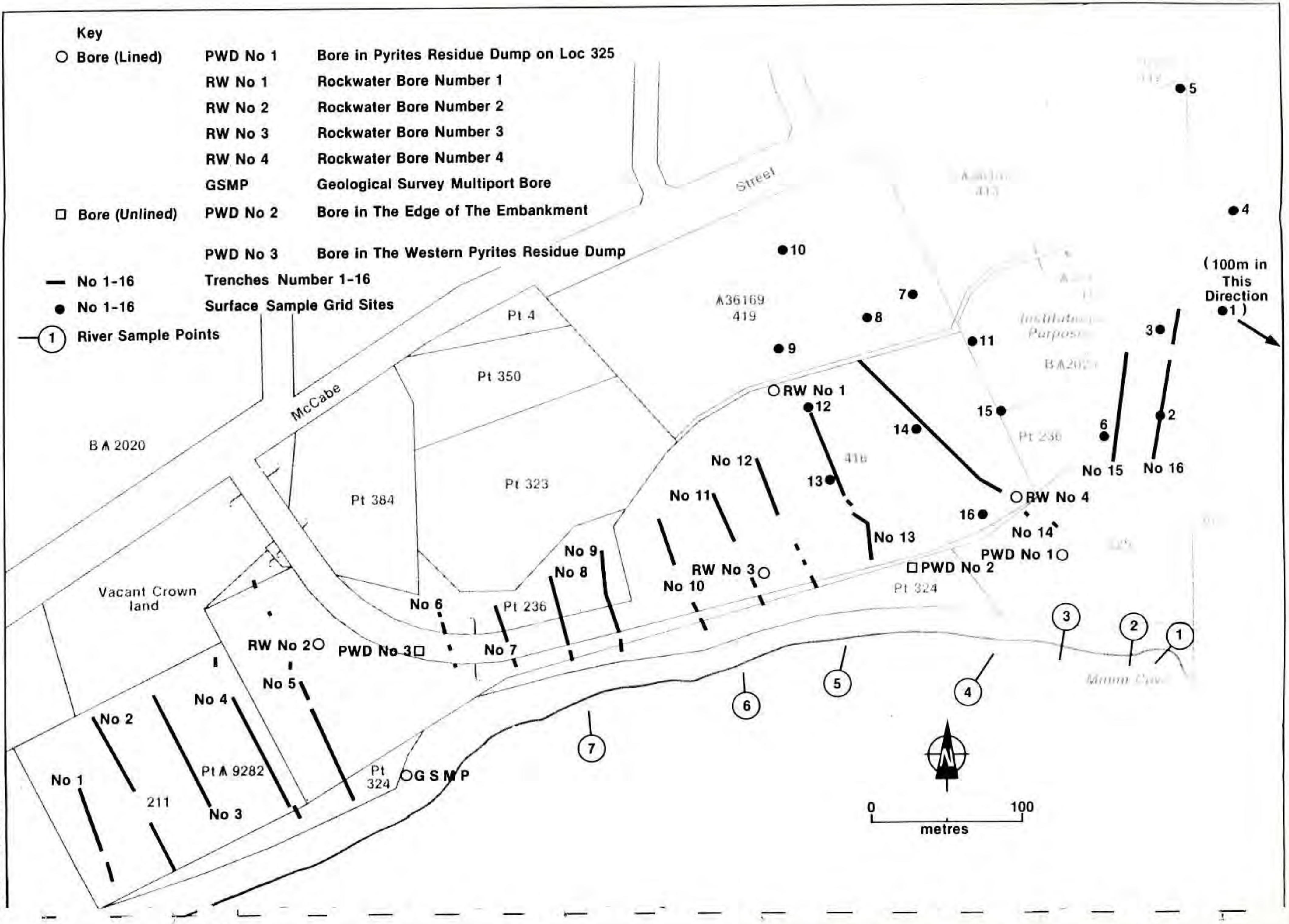


Figure 11 Sample Collection Points

Responsible Agencies

The sampling and analysis of the soil and pyrites residue dumps were conducted by the Government Chemical Laboratories and the Department of Conservation and Environment.

The Public Works Department installed the bore holes through the pyrites residue dumps.

The Waterways Commission sampled the river sediments and biota. Analysis of these samples was by the Government Chemical Laboratories.
The Clean Air Section of the Public Health Department set up high volume air samplers in the vicinity of the Rocky Bay Village. The samples collected were analysed by WAIT.
The Geological Survey of the Department of Mines sampled the ground water. These samples were analysed by the Government Chemical Laboratories.

The Department of Lands and Surveys supplied aerial photographs, cadastral information and surveyed the site locating the trenches and boreholes.

The Department of Conservation and Environment prepared the conceptual plan of the study and administered the investigations.

The results of the various analyses are contained within the Technical Appendix entitled 'Results of Analyses".

To enable comparisons of results with other published data, where possible, sampling and analyses followed established and recognised procedures. In cases where it was not possible to follow established procedures the methods employed were those which produced the most useful data.

Section 6 RESULTS OF THE INVESTIGATIONS

This section is a summary of the results contained within the Technical Appendix - Results of Analyses.

Pyrites Residue - Areas 3 & 4, under roadways and Area 5

As stated in section 3 the composition of the pyrites residue is dependent upon the furnace in which the pyrites was burnt. The large dump on Loc 325 which resulted from the operation of the fluidised bed furnace which operated in Acid Plant No 3 contains both heavy metals and cyanide (in free and complexed forms).

The results of the analysis of the bore core from the dump on Loc 325 is shown over in Table 2.

Table 2 Results of analyses of core from pyrites residue dump in Area 3.

Core No	Depth m	Material	Fe	As	Cu	Hg	Pb	Zn	TSS	NH3	CN free	CN total
							........ppm........					
2		s							9770	0.69	0.039	0.78
4		p/r			730	0.1	390	350	9420	2.0	0.67	98
6		p/r			-				10800	190	0.26	
7		p/r			540	2.0	280	750	10300	185	5.4	420
8		p/r							8940	18	7.8	
10		p/r							7390	3.1	15.0	350
11		p/r			740	0.9	320	760				
12		p/r							8730	8.2	69	
15		p/r			1100	4.2	460	1600				
16		p/r							8740	21	70	180
17		p/r-s	12500	110	160	0.1	15	40	2560	1.2	1.4	41
19		s	4400	9	150	<0.1	10	16	950	2.1	0.40	
22		s-lst							740	2.8	0.096	2.6
23		lst	5200	6	120	<0.1	26	12				
28		lst							1330	3.6	0.020	
31		lst	3100	5	50	0.1	48	12	7220	0.14	0.027	

p/r - pyrite residue, s - sand, lst-limestone
TSS - total soluble salts.

The levels of heavy metals in the dump show some elevation above the levels in the soil below the dump. The results in Table 2 indicate that after 20 years exposure to leaching and biodegradation there is still a large store of cyanide in the residue profile. The cyanide is essentially contained in the pyrites layer and exists in the 'free' as well as the complex form, probably as one or more of the possible metal cyanide complexes.

The ground water in the bore below the dump was sampled. The cyanide level in this sample was less than 0.05mg/l which is within the NH & MRC limit. However, this bore had not been properly developed and the sample taken may not be representative of the state of the groundwater below the dump.
The pyrite residue in Area 4, underlying the roadways and on the river embankment (Area 5) is thought to have come from the Herreshoff furnaces which operated in the No 1 & 2 Acid Plants. This residue contains much lower heavy metal contamination than that from Acid Plant No 3. As this residue was not treated with cyanide to recover gold there should be no cyanide in these dumps. Levels of heavy metals in these residues is shown in Table 3 below.

Table 3. Results of analyses from the pyrites residue dump in Area 4, under roadways & Area 5.

Material	Depth m	Cu	Hg	Pb	Zn
		.......ppm........			
p/r	2.25-3.00	200	0.1	79	400
p/r	3.75-4.50	130	<0.1	42	56
p/r	6.00-6.75	360	0.1	53	120
p/r - s	7.50-8.25	18	0.1	36	76
S	9.00-9.75	2	<0.1	17	12

The residues in these areas are largely inert and do not appear to be adding any heavy metals to the surrounding environment. Some sulphate salts are leaching out of these residues and causing small salt crystal formations at the base of Area 4 and degradation of the bitumen roadways under which the pyrites residue was used as a road base.

The two types of pyrites residue were analysed for cadmium and it was found that the residue contained less than 1ppm cadmium.

There is a small amount of gold (1.0ppm) in the residue in Area 4. However, this gold is in a form which would make it uneconomical to recover by presently available methods.

<u>Soil</u> - Area 1

Two sampling operations were carried out on this Area. The first in the vicinity of the Rocky Bay Village, the second in the trenches dug across the site. The first sampling operation consisted of selecting sixteen sampling points using a 100m grid, see Figure 11. At each site samples of the 0-10mm and 140-150mm depth were taken. Five surface samples were taken for each sample point on the grid to provide a bulk sample for that point.

The 0-10mm surface sample was considered to represent the most likely sources of respirable dust. The 140-150mm sample was taken to establish the extent of penetration of any contamination into the subsoil.

The samples were analysed for heavy metals - iron, arsenic, cadmium, copper, lead and zinc. The summary of results of these analyses are shown below in Table 4.

Table 4. Summary of results from grid soil sampling near the Rocky Bay Village.

	SUBSOIL 140-150mm		
	Range	Mean	SD
	...............ppm.............		
Iron	3000-12000	5000	3000
Arsenic	2.4-13	6.1	3.6
Cadmium	<0.2-3.1	<1	-
Copper	3-200	40	60
Lead	10-120	38	31
Zinc	11-280	76	82

	TOP SOIL 0-10mm		
	Range	Mean	SD
	............ppm...........		
Iron	2000-51000	10000	9000
Arsenic	2.1-19	6.8	3.9
Cadmium	<0.2-14	-	-
Copper	5-950	76	130
Lead	20-740	194	197
Zinc	19-2810	380	488

The mean value for lead in the subsoil samples is weighted by the result for Site 14 (120ppm) which is located near a rubbish pit area. Exclusion of this value gives a range 10-51 ppm, mean 29ppm, for lead in the subsoil. The mean of 29 ppm for lead is only marginally higher than the 16ppm lead content found in coastal limestone remote from the site.

The second sampling operation consisted of taking samples of the surface, bedrock and other features in the trenches dug across Areas 1, 2 & 4.

These samples were analysed for copper and lead.

High levels of lead 460 - 68000ppm (mean 7430ppm SD 18350ppm) were found in the surface samples taken from the northern edge of the No 1 Acid plant in the vicinity of the location of the lead melters.

The lead results for the areas near the Rockey Bay Village are much lower than the above figures and are in most cases consistent with the results obtained from the grid sampling conducted around the Village.

Leaf samples were taken from castor oil trees growing between Trenches 13 and 14 and analysed for copper and lead. These results show a low uptake of copper and lead by this plant when compared with levels in control plants growing near McCabe Street.

Soil - Area 2

Because no previous investigation had been conducted on Area 2, the location of the No.3 Acid Plant, the trenches were sampled more extensively than those in Area 1.

Samples were taken of the surface 0-50mm and the bedrock at 10m intervals along each trench. Between each 10m point five grab samples were taken of the surface soil. These were mixed to provide a bulked composite. These samples were analysed for copper, lead and zinc.

Bedrock samples in the main showed very little penetration of copper, lead or zinc into the profile. There were some elevated levels of these metals in areas associated with the foundations of the plant or in the presence of pyrites residue. These values were excluded from the calculation of mean values listed in Table 5 below. The surface samples show a wide range of levels of contamination. These are listed below in Table 5. The degree of variability is a characteristic of industrially contaminated sites. The values for copper and zinc are high, those for lead are particularly high.

Table 5 Summary of Results from soil sampling in Area 2.

	Bedrock Samples			Top Soil Samples		
	Range	Mean	SD	Range	Mean	SD
....	ppm	....	....	....	.... ppm	.....
Copper	-	17	0.7	19-2000	185	322
Lead	-	45	36	56-5700	1191	1254
Zinc	-	23	20	29-800	240	199

Samples of couch grass and castor oil tree were analysed to determine lead uptake. The results indicate that lead levels are abnormally high reflecting elevated levels of lead in the soils.

Groundwater

The study of the groundwater consisted of a bore census over the area, and a sampling program of all the bores located.

The residential area covered by the census is bounded by Mott Close in the north west, Read Ave. in the north and eastward from there to Briggs St. Six bores were located in this area. An additional six bores were sampled on the study area. See Figure 11. Four of these bores had been installed by Rockwater for the University, the other two were the Geological Survey's multiport bore on Loc.324 and the bore installed below the pyrites residue dump on Loc.325.

Because of the difficulty of determining the hydraulic paramaters of the Tamala Limestone sequence which underlies the site only a generalised hydraulic gradient and water table contour plan were determined. This showed the direction of groundwater flow to be from 10^0-15^0 west of north toward the river. The hydraulic gradient was approximately 0.0001.

The samples taken from the bores were analysed for numerous parameters as listed in Section 5. The majority of the bores have water in which levels of organic contaminants are within the levels set for potable water supplies. It appears that contaminants in the bores which contain elevated levels of organic contaminants are from sources outside the fertiliser works site.

The samples were also analysed for heavy metals and apart from the occasional raised iron value, all other metal levels are well below the maximum allowable level for potable water supplies.

These ground water samples would require only a 10 times dilution with the Swan River to meet the marine and estuarine water quality criteria. The dilution would be expected to be well in excess of 10 times even under low flow summer conditions.

Air

The air was sampled using high volume air samples as described in Section 5. The results indicated slightly elevated lead levels in the airborne dust near the Village. The lead in these samples is essentially of vehicular origin. The levels are well below the National Health and Medical Research Council goal of 1.5ugm. Mercury was not detected in any of the samples.

River

The river was sampled as described in Section 5. The results of the analyses of the sediments and biota indicate that there is or has been contamination of the river from an outfall pipe, see Figure 5. It is possible that runoff from the site is still carrying contaminants into the river. The results of the analyses are listed in Table 6 below.

The 'mean' values listed below are the mean of the results from the sample sites excluding the values for the samples taken in the vicinity of the outfall pipe. These are listed in a separate column.

Table 6 Heavy metals in sediments and mollusc adjacent to the site and in the vicinity of an outfall pipe. All values are for dry weight.

	Sediments		Molluscs	
	Mean	Outfall pipe	Mean	Outfall pipe
	.......mg/kg.......		......mg/kg.......	
Arsenic	6.7	310	0.69	0.35
Cadmium	<3.3	7.1	0.78	6.15
Copper	30.7	2600	3.2	2.5
Lead	45.3	1900	1.1	19.0
Mercury	<1.2	1.4	0.05	0.09
Nickel	<2.7	2.8	0.62	2.2
Zinc	76.2	2400	13	9.9

Comparing the results of analyses for this site with other data available for the Swan River reveals that adjacent to the outfall pipe levels of arsenic, copper, lead and zinc were considerably higher than other locations in the Swan River.

No investigation of storm water runoff was undertaken. It is possible that in heavy rainfall episodes a 'slug' flow of water with heavy metal contaminants could be added to the river.

Section 7 CONCLUSIONS

The majority of the site is contaminated to varying degrees by a variety of substances.

The major contaminants of the site are

Pyrites Residue

Pyrites residue which resulted from the roasting of various types of pyrites to produce sulphur dioxide which was used in the manufacture of sulphuric acid. The pyrites residue contained metal compounds which were constituent as trace elements in the parent pyrite and were retained in the residue after roasting. The pyrites residue is contained in two major dumps and in scattered locations around the site eg under roadways.

The residue in the dump on Lot 325 contains some heavy metals and cyanide. The cyanide in the dump on Lot 325 is the residue of cyanidation of the pyrites residue to extract gold. There are some indications of possible mobility of the cyanide and heavy metals down through this dump. However further investigations are required to determine if this is occurring. The dump appears to be self sealing as there is no evidence of heavy metals or cyanide leaching into the limestone below the dump. Because of a different pyrites roasting technique and no gold extraction the residue in the other dumps around the site contains much lower levels of heavy metals and cyanide than the residue on Lot 325. As a consequence this residue is largely inert and does not appear to be adding heavy metals to the surrounding environment. Some sulphate salts are leaching out of these residues causing small salt crystal formations in various locations.

Heavy metals in the soil

The soils around both the No 1 and 2 and No 3 acid plants contain elevated levels of heavy metals. The sources of these heavy metals were

- lead sulphate from the lead acid chambers
- lead from the lead melters
- the dust from the gas cleaning equipment
- the contaminants in the liquor from the fluoride scrubber.
- the general fallout and leakages from the processes
- contaminants in rainwater runoff from the sheds and equipment.

The most significant heavy metal contaminants are lead, cadmium, copper and zinc. Concentrations are higher near the former factory. The distribution of the contamination does not follow any set pattern.

Of the contaminants lead is the most significant occurring at various locations in very high levels in the top 0-1cm of soil. The soils adjacent to the Rocky Bay Village show some elevation in levels of heavy metals however these are lower than on other parts of the site.

Groundwater Contamination

The majority of the bores analysed for organic contaminants have levels of contaminants within the levels set for potable watersupply. It appears that the contaminants in the bores which contain elevated levels of organic contaminants are from sources outside the fertiliser works site.

Apart from the occasional raised iron value all heavy metal levels are well below the maximum allowable levels for potable water supplies.

Airborne Dust

The air sampled in the vicinity of the Village shows slightly elevated levels of lead relative to that sampled in the grounds of IFAP. The lead in these samples appears to be of vehicular origin and well below the National Health and Medical Research Council's goal for airbourne lead in residential areas.

River Contamination

The sediments and biota in the river adjacent to the site show that the levels of heavy metals in the sample sites, except for one sample site adjacent to an outfall pipe, are within the same order of magnitude with levels measured in other parts of the Swan River.

The sediments and biota in the vicinity of the outfall pipe show levels of heavy metals up to two orders of magnitude above other levels found elsewhere in the river.

Within this report no description has been given of the options available for the type and extent of measures to ameliorate the contamination of the site. The Technical Assessment Group considers that this activity should be planned in conjunction with the planning for the final use of the area.

McCABE STREET DEVELOPMENT STUDY

FINAL REPORT , Maunsell, 1986.

TABLE OF CONTENTS

SECTION 1

EXECUTIVE SUMMARY

1. EXECUTIVE SUMMARY

1.1 BACKGROUND

Maunsell & Partners Pty. Ltd. was jointly commissioned by the University of Western Australia and the Lands and Surveys Department to investigate the feasibility of developing all or part of an area of land lying between McCabe Street and the Swan River in Mosman Park. A large part of the land under consideration was leased for the establishment and running of a Fertilizer Works. Various leases were taken out between 1909 and 1969 to progressively increase the area of land taken up by the Fertilizer Works.

The land subject to investigation in this report is a combination of part of the former Fertilizer Works leases, adjacent Vacant Crown Land and land presently reserved for Institutional Purposes. It is, however, noted that land presently occupied or used by both the Crippled Children's Society's Rocky Bay Village and the Buckland Hill Primary School has been specifically excluded from consideration in this investigation and therefore no reference is made or conclusions drawn in regard to either of these institutions.

Previous investigations have been carried out on parts of the site known to have been affected by the Fertilizer Works and these have shown various levels of contamination by a number of heavy metals. Conclusions drawn from the most recent of these investigations have suggested that the area is suitable for residential development provided measures are taken to bury contaminated soils.

1.2 INVESTIGATIONS

The present investigation has been carried out as a staged programme using the results of the previous reports as a basis for formulating appropriate and workable development strategies. The particular stages followed may be summarised as:

Stage I - Desk study of previous investigation reports, site records, aerial photography, historical plans and lease details of the area. Expert opinion was sought on the industrial site clean-up and toxicological aspects of the project. Also research was carried out to establish guidelines for assessing the various levels of contamination identified.

Stage II - The results of Stage I were used to formulate a preliminary development proposal together with a preliminary strategy for cleaning up the various contaminated areas of the site. This work was seen as a necessary prerequisite to subsequent stages with all preliminary proposals developed in Stage II subject to review as a result of these subsequent stages.

Stage III - Additional site investigations, samplings and analyses were performed to verify information reported and used in Stages I and II respectively.

Stage IV - Results of the work conducted in Stage III were compiled and analysed in order to revise and refine the preliminary development proposals outlined in Stage II.

1.3 CONCLUSIONS

In considering the various stages of the investigation and in formulating recommendations for site treatment consideration has been given to the need to ensure that economical and practical clean-up measures can provide a substantially risk-free environment for future landowners. It has been considered unacceptable to suggest establishment of residential properties on any part of the site where such a risk-free environment cannot be achieved.

The results of the site investigations may be summarised as follows:

. Heavy metal contamination of the river foreshore is evident as is contamination of molluscs in the section of the river adjacent to the embankment pyrites cinders dump.

. Mineralogical investigations and site observations have confirmed the presence of oxidation of the pyrites cinders giving rise to the production of sulphuric acid and the associated release of soluble heavy metal compounds.

. These investigations and observations indicate that leaching has occurred from this dump and there is potential for continued leaching associated with the present active oxidation of the materials.

. Toxicological opinion confirms that the levels of contamination identified on the river foreshore can be considered high for a beach frequented by children and that the heavy metal levels contained in the pyrites cinders warrants burial to avoid human contact with this material.

- The previously uninvestigated northern areas of the site along McCabe Street and west of the Primary School, preliminarily defined as being suitable for development, are relatively free of contamination.

- The discovery of a deposit of amosite (asbestos fibre) in a trench excavated in this northern area confirms the generally acknowledged characteristic of industrial sites that contamination is unpredictable both in type and distribution.

- Whilst evidence of pollution has been identified, little is yet known about the possible transport mechanisms that have led to and may still be actively causing such pollutions, and further investigation is required before firm conclusions can be drawn in respect of the potential for and extent of future pollution levels.

- The evidence obtained regarding active weathering (oxidation) of the pyrites cinders and leaching, particularly from the embankment dump, raise concerns regarding contamination of groundwater beneath the site.

1.4 RECOMMENDATIONS

In formulating the recommendations for treatment of the site two options were considered, the first being based on no immediate development of any part of the site and the second being limited residential development with associated passive recreation on undeveloped areas of the site.

It must be emphasised that the recommendations given for the first option are seen as necessary treatments that should be carried out as a matter of some urgency to clean up identified contamination in areas readily accessible and currently used by the public. However, it should be recognised that regardless of the land use chosen for the site, the Option II measures may ultimately be required to ensure that public health is safeguarded and that interests of adjacent landowners and users are protected.

The recommended site treatments may be summarised as follows:

<u>Option I</u> - No site development, immediate clean-up requirements.

- install security fencing to limit public access to the site and the embankment area

- realign the cycleway to the upper, main site level

- remove all stormwater drainage collection systems and outfalls
- remove contamination and molluscs from the river foreshore and adjacent banks and reconstruct the beach and banks as necessary with materials designed to limit future leaching onto the foreshore
- instigate and carry out a regular monitoring programme to detect any renewed beach contamination
- instigate and carry out a leachate-waste stability test to enable the prediction of contaminant migration potential from the waste dumps
- the budget estimate of costs associated with this work excluding costs associated with the monitoring programme and leachate-waste stability test is $330,000.

Option II - limited site development for residential purposes with development of the remaining area for passive recreation.

- remove minimum of 300mm of topsoil from the area to be developed for residential use together with any other isolated deposits of contaminant materials.
- cover this stripped area with 1.2m depth of clean fill and spread the stripped topsoil on the lower, western area of the site.
- treat the top of the pyrites slurry dump by covering with an impermeable membrane and 1m of clean fill, constructing walls and fences to restrict public access from the front slopes and landscaping these slopes.
- treat the river foreshore and adjacent banks as for Option I.
- realign the cycleway as for Option I
- treat the stormwater collection systems and outfalls as for Option I
- remove all material in the embankment pyrites cinders dump and stockpile adjacent to the western pyrites cinders dump
- grade the upper embankment to a shallow slope and landscape it
- strip all material from the former lead melters site and dispose at an approved toxic landfill site.
- cover the western pyrites cinders dump, the removed cinders from the embankment and the foundry waste dump with 300mm of crushed limestone and 700mm of clean fill to form part of the passive recreation area

- cover the entire remaining part of the site with 1000mm of clean fill for use as a passive recreation area
- landscape and grass the passive recreation areas as appropriate
- the budget estimate of costs associated with this work but excluding any residential development costs other than placing clean fill is $1,320,000.

Finally, it is recommended that additional and comprehensive investigations be carried out to determine the presence or otherwise of groundwater contamination beneath the site. In particular, areas beneath the pyrites slurry dump and the southern edge of the site generally should be examined. It is recommended that a suitably qualified and experienced Groundwater Consultant be commissioned to undertake this work at the earliest opportunity. In addition, a leachate-waste stability test for the assessment of long term contaminant mobility from the site is recommended. An appropriate procedure, such as the TCLP adopted by the NSW State Pollution Control Commission, would enable prediction of future contaminant migration.

SECTION 2

INTRODUCTION

2. INTRODUCTION

2.1 SCOPE

Maunsell & Partners Pty. Ltd. was commissioned in September 1985 jointly by the University of Western Australia (UWA) and the Lands & Surveys Department to investigate the feasibility of developing all or part of an area of land in Mosman Park which was previously the site of the CSBP & Farmers Fertilizer Works.

The principal aims of this study were to investigate the feasibility of establishing a residential development on all or part of the site using the results of the previous studies and also any additional site investigation work considered necessary.

2.2 PRELIMINARY CONSIDERATIONS

Earlier investigations carried out by both private consultants and by a Government appointed Technical Assessment Group have shown that a significant proportion of that part of the site previously leased by CSBP & Farmers has been contaminated to varying degrees by heavy metals.

As a preliminary step in defining the extent of this investigation, consideration was given to the serious implications of developing residential property on land known to contain substances that are a potential health risk. Recognition of these implications prompted the seeking of comment from Dr. S. Hrudy, an internationally recognised expert in hazardous waste treatment from the University of Alberta, Edmonton, Canada. On the basis of his recent experience of former industrial site clean-up programmes in North America, Dr. Hrudy advised strongly against development of areas identified as being contaminated. The reasons quoted in support of this advice are:

(a) The inability to give reasonable assurance that any "economically feasible" clean-up action or monitoring programme has removed all chance of future residents coming into contact with toxic materials.

(b) The possibility that future residents may develop allergic or sensitisation reactions to toxic metal wastes, such reactions not necessarily being predictable by the application of average criteria on chronic metal toxicity.

(c) The legal implications associated with development of a contaminated site. A warning was given regarding liability under retrospective legislation which is a recent phenomenon of the legal system in North America but which is, at the present time, not mirrored in Australia.

(d) In relation to liability it is advised that a full disclosure of all details of the past use and present condition of the land would be mandatory. It is considered highly probable that such a disclosure would have a significant and negative effect on land values even to the extent that any proposed development and associated clean-up programme would become uneconomic.

(e) Experience on sites similarly used for industrial purposes indicates a high probability that contamination will be widespread and unpredictable. This unpredictable nature of industrial contamination indicates the need for extreme caution in presenting "averaged" analysis results without consideration of peak values in isolated areas.

Consideration of this advice gave rise to some initial concern as to the feasibility for any development. It was, however, noted that the boundaries of the site to be considered in this present work were expanded beyond the limits defined in the earlier site studies. As a result it was decided that some scope exists for residential development over a limited section of the overall area.

2.3 PROGRAMME OF WORK

The following programme of activities was developed for this study having in mind the advice received from Dr. Hrudy.

2.3.1 Review historical site records, available plans and aerial photography and previous site investigation reports in order to define areas of the site most likely to be free from contamination.

2.3.2 Develop preliminary development proposals.

2.3.3 Define an additional site investigation programme of sufficient scope to confirm the feasibility of the development proposals.

2.3.4 Collate and analyse results of the site investigations. Review and refine the preliminary development proposals in light of these results.

2.4 REPORT PRESENTATION

At the expense of brevity this report is presented as a detailed account of the various phases of work as outlined in Section 2.3. It was not considered possible or appropriate to present a brief and concise account of the work undertaken when each successive stage of the work was necessarily developed from the results of the previous investigations.

In addition, development of the work programme and of final recommendations for site development have been influenced to a significant degree by the implications of the independent advice received on the project. On this basis full discussion of these implications at each stage of the work was considered to be warranted.

2.5 LIABILITY

Reference is made to the advice provided to us by Dr. Hrudy in respect of our professional standard of care and the professional legal liability which attached to our advice. In undertaking this commission Maunsell & Partners Pty. Ltd. has exercised reasonable skill, care and diligence in the performance of its services in accordance with the ethics of the engineering profession. Our liability arising out of the performance or non-performance of our services whether under the law of contract, tort or otherwise, shall be limited to those damages which are directly caused by us, and the amount of our liability shall not exceed $300,000.

Although it is recognised that the potential for future serious contamination and adverse effects on public health may be very slight the possibility, however remote, will continue to exist. Therefore Maunsell & Partners Pty. Ltd., in providing this report does not accept any liability related to any aspects of the site not directly related to the recommendations and treatment options contained therein. Similarly, the firm can accept no liability for any clean-up work performed by others unless such work is carried out under its direct supervision and to its complete satisfaction.

In conclusion and in recognition of the risks associated with this type of situation it is noted that a monitoring programme has been included as part of both the site treatment options. It must be recognised that neither of the options outlined calls for complete removal of all contaminants from the site. However, the treatments recommended are designed to minimise risks of any future contamination while maintaining practical and economical development options. The monitoring programmes given are designed to further reduce these risks but again Maunsell & Partners Pty. Ltd. can accept no liability for consequences related in any way to failure to observe and maintain these recommendations in their entirety.

SECTION 3

SITE DESCRIPTION

3. SITE DESCRIPTION

The land under consideration in this study is situated within the Town of Mosman Park. It is bounded to the north by McCabe Street, to the south by the Swan River and to the east and west by vacant recreational land and the State Engineering Works respectively.

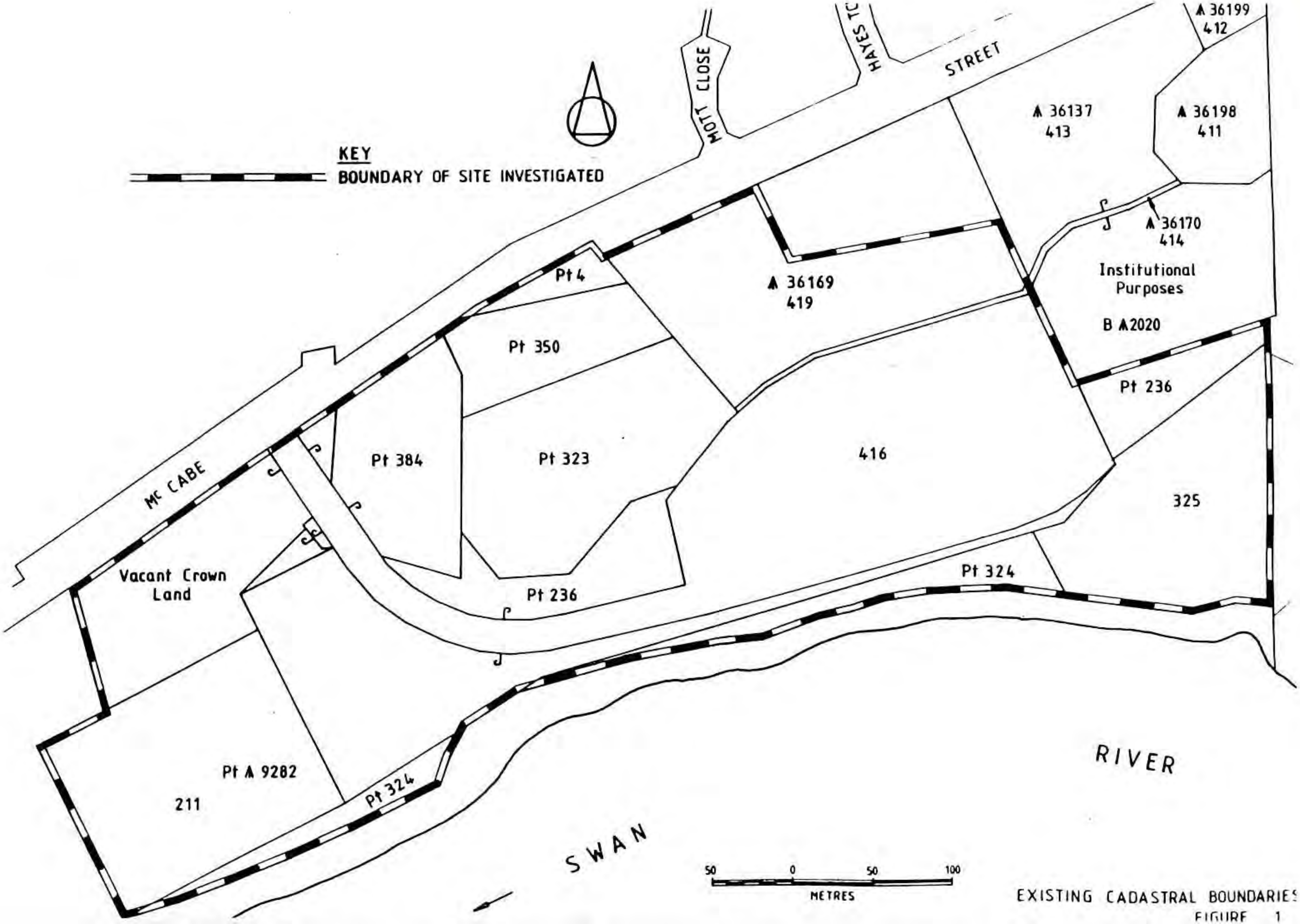
Details of the present cadastral boundaries within and adjoining the site are shown in Figure 1 with associated zonings shown in Figure 2. The extent of the CSBP & Farmers Fertilizer Works leases are shown in Figure 3 together with a tabulation of the dates of issue for each of the leases.

It will be noted that the boundaries of the site under consideration as shown in Figure 1 across Reserve 36169, Lot 419 coincide in part with the boundary of Lease No. 3116/3188, Lot No. NF350. At the present time the entire area of Reserve 36169 is for use by the Education Department for the Buckland Hill Primary School. However, under the terms of reference given for this study it has been indicated that the site boundaries will be approximately as shown in Figure 1 with final confirmation subject to detailed negotiations with the Education Department.

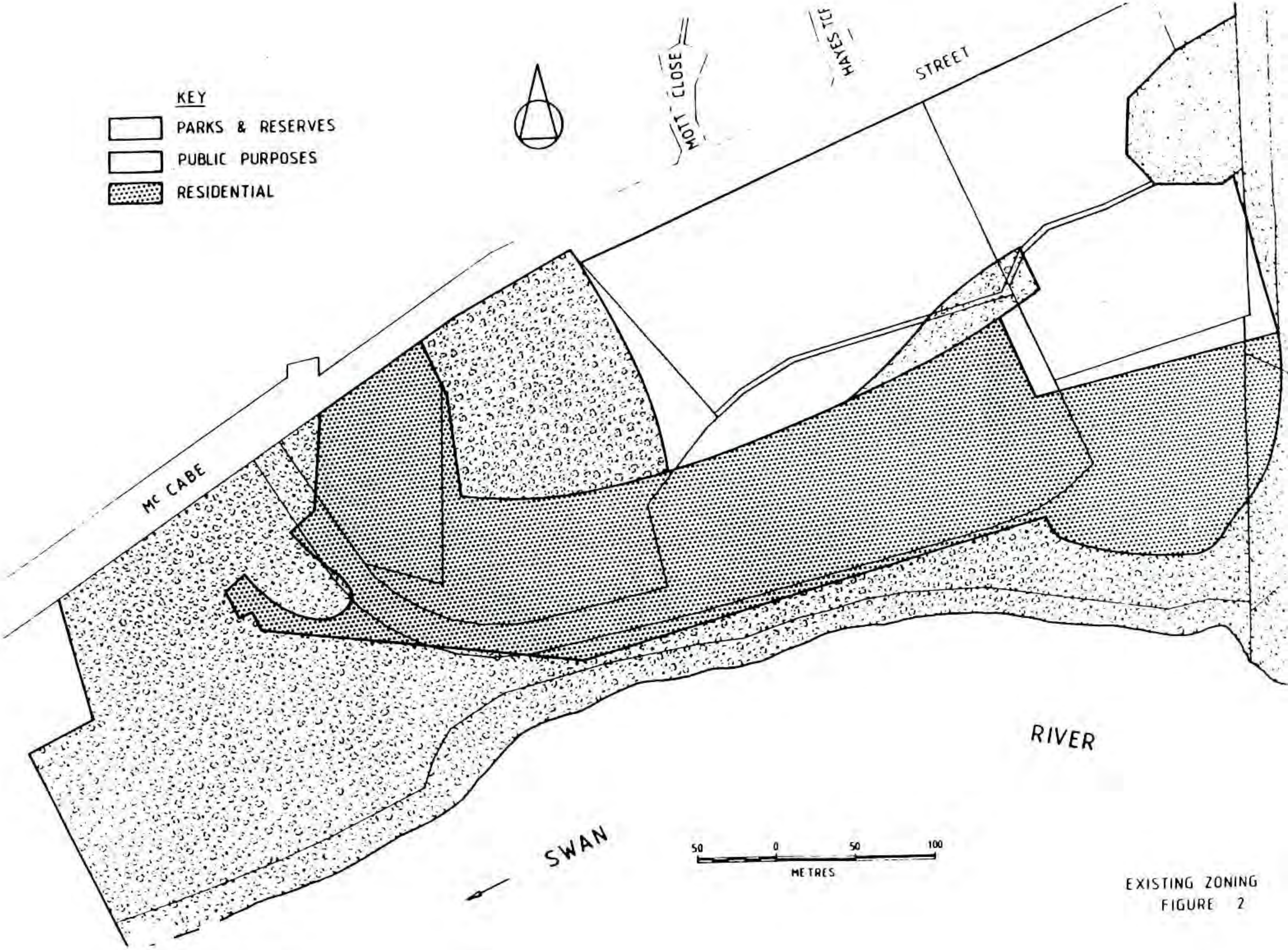
Parts of the former Fertilizer Works lease areas are presently used for other purposes. Lot 413 and Lot Pt. 414 (Reserves 36137, 36170 and B 2020) form the site of the Crippled Children's Society Rocky Bay Village. As stated above part of Lot 419 (Reserve 36169) is occupied by the Buckland Hill Primary School. Although these two institutions lie within the bounds of the original Fertilizer Works consideration of them was excluded from the scope of this investigation. As a result no specific investigations or comments have been made with regard to these areas.

Finally Lot Pt. 384 is leased by the Industrial Foundation for Accident Prevention (IFAP) and the Farm Management Foundation of Australia. This lease is from the Crown and is due to expire in the near future without renewal.

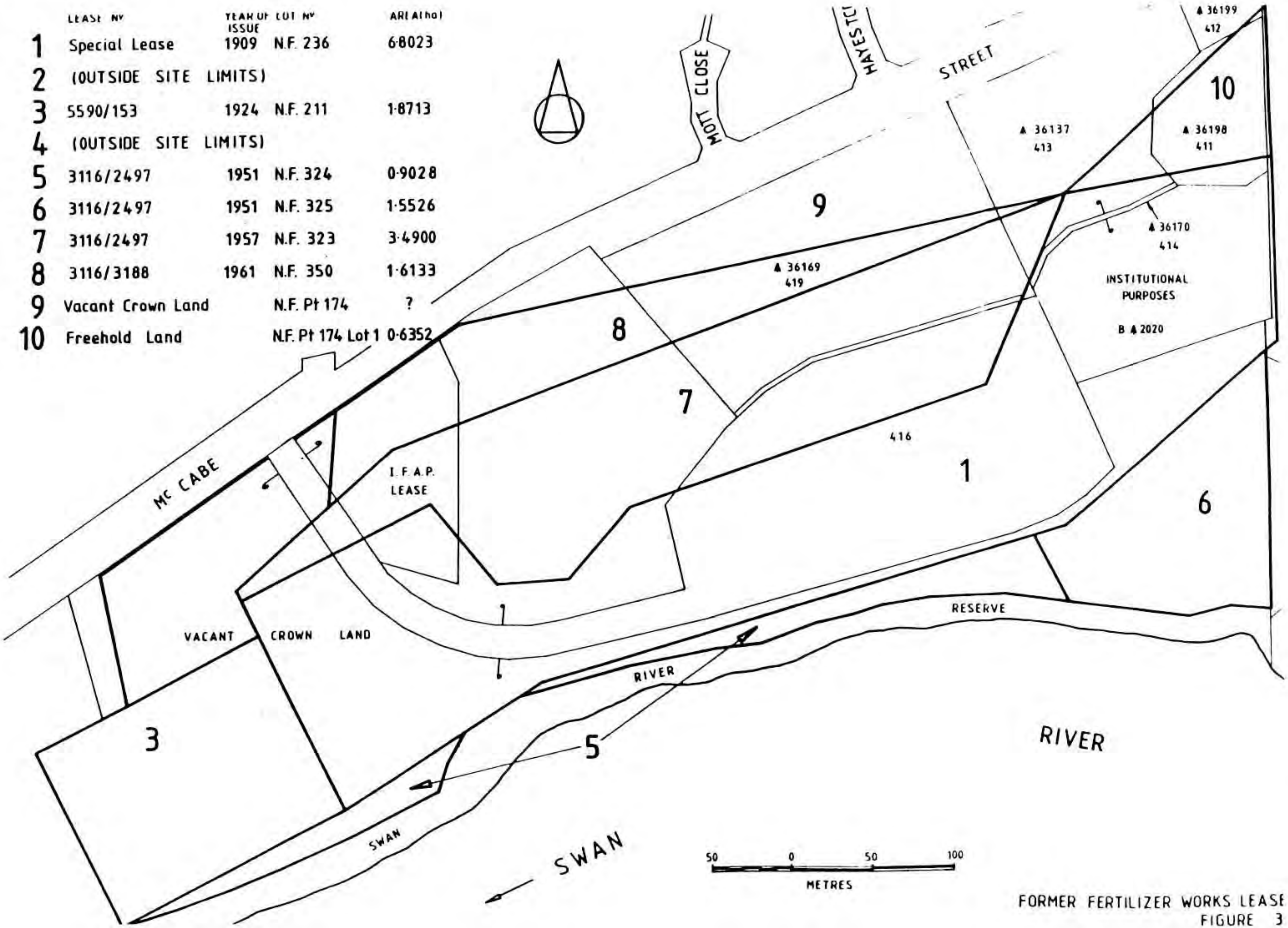
The remaining and largest part of the site is in an undeveloped state as left by CSBP & Farmers when their leases were terminated. The only signs of the previous industrial development on the site are a variety of concrete footings and building slabs, a bitumen parking area, a number of bitumen and gravel roads and some isolated miscellaneous items such as steps, drainage outfalls and manholes.



EXISTING CADASTRAL BOUNDARIES
FIGURE 1



EXISTING ZONING
FIGURE 2



A very recent development in the area has been the construction by the Town of Mosman Park of a cycleway running along the river embankment from the east and terminating at the western boundary of the site. It is understood that negotiations are underway to resume part of the State Engineering Works land to permit the westerly extension of the cycleway to form part of the overall Swan River cycleway system.

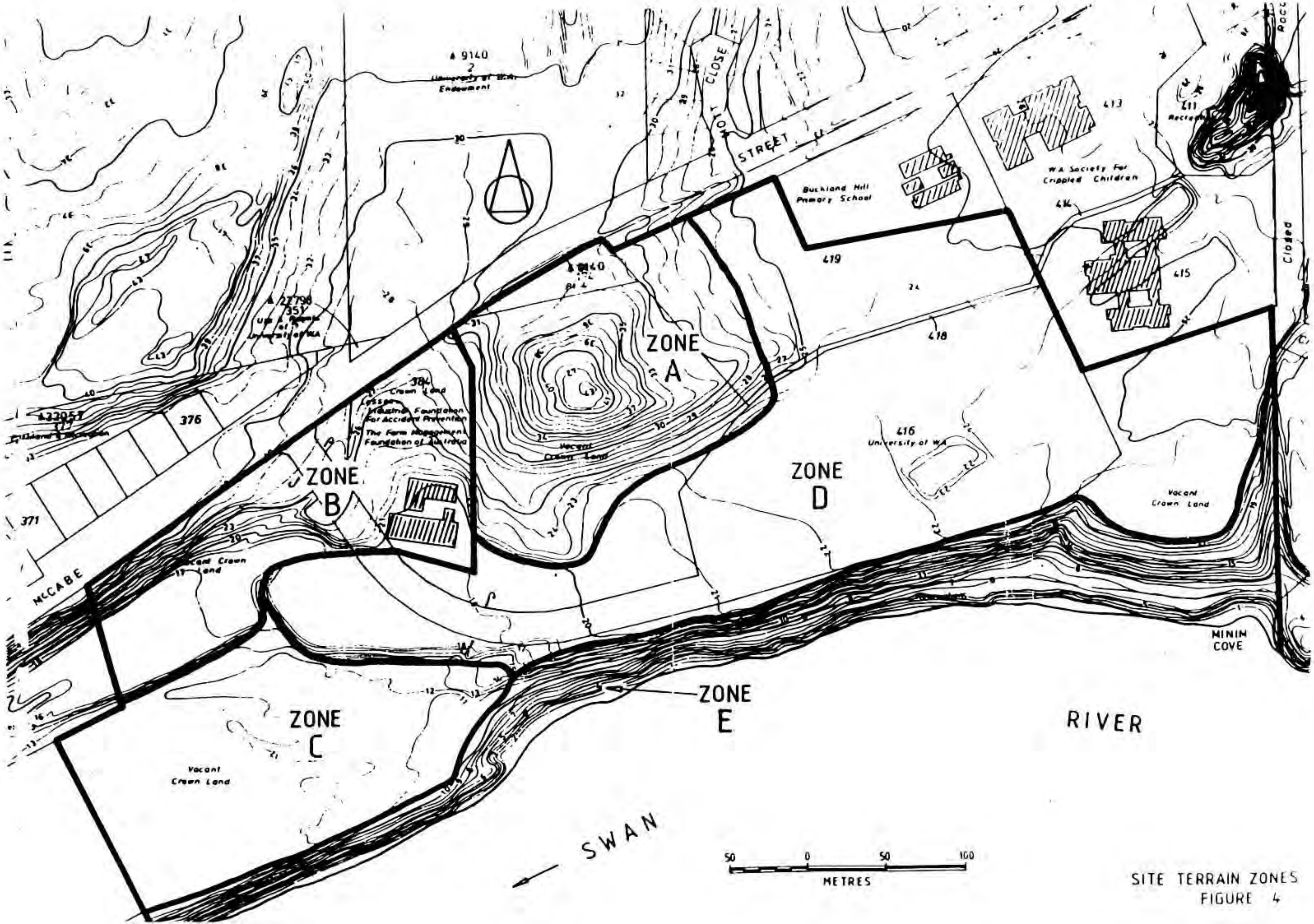
The site can be divided into five main terrain zones as shown in Figure 4.

Zone A:

This Zone is dominated by a steeply sided limestone hill rising approximately 20m above the main site and up to 42m above river level. Early contour plans of the site show that this limestone hill is the remnant of a much larger ridge that extended south towards the river bank. However, the section of this ridge closest to the river was apparently excavated before or at the time of the original site development to provide room for the Fertilizer Works and associated rail link. This is supported by railway plans dated as early as 1925 which show a limestone cutting immediately to the north of the main plant buildings of the time. A search of aerial photography covering the site indicates that further quarrying of the remaining limestone ridge commenced sometime between 1961 and 1964. The reasons for this quarrying are unknown although it is not considered likely that the limestone would have been used in the Fertilizer Works.

Zone B:

This Zone lies to the west of Zone A and adjacent to McCabe Street. It contains a steep limestone cut of approximately 12m depth between McCabe Street and the lower level of the western end of the main Works site. There is also a limestone outcrop located immediately west of the IFAP building with a narrow cut that was originally occupied by an early railway link to the Works. At the toe of the cut there is a dump reportedly containing foundry waste. This dump is in an area that was never part of the CSBP leases but the adjacent part of the site was taken over by CSBP from Westralian Ironworks and it is considered likely that the dump was created by that Company prior to the time of takeover. The IFAP building, part of which formed the laboratory and administration block for the Fertilizer Works, is also contained within Zone B.



SITE TERRAIN ZONES
FIGURE 4

Zone C:

This Zone occupies the south-western end of the site and is approximately 12m above river level. Land in this Zone is relatively level dropping only slightly to the south-east by up to 1.5m. This is the site of Acid Plant No. 3 and contains the remnants of the building associated with this part of the plant. There is a shallow cover of sandy soil overlying limestone bedrock. The soil depth varies from approximately 0.3m on the north to in excess of 1.5m on the south side of the Zone.

Zone D:

This Zone forms the largest section of the site and is on average approximately 22m above river level. It rises from 20m above river level at the western end to 25m at the north and eastern ends. Similarly to Zone C, it has little relief except where it adjoins the southern and eastern edges of the limestone hill in Zone A. Here again there is a thin layer of sand overlying limestone bedrock. The soil depths vary from over 2m adjacent to McCabe Street to only a nominal surface layer towards the centre of the Zone and then increasing to over 1m closer to the river embankment. At the western end of Zone D immediately south of the IFAP building is a large dump of pyrites cinders reportedly containing approximately 10,000m^3 of the material (refer Reference 1). The extent of the dump is outlined in Figure 8. At the south-eastern end of Zone D is a large dump of slurried pyrites cinders generated by fluidised bed roasters in Acid Plant No. 3 (Zone C). The dump has been estimated to contain approximately 70,000m^3 of material (refer Reference 1).

Zone E:

This Zone contains the river embankment which runs along the entire length of the southern boundary of the site. There is clear evidence to show that the original form of this embankment was one of rugged limestone cliffs similar to those both upstream and downstream of the site. However, development activities on the site above have resulted in a somewhat more regular embankment that may be divided into three sections. The first and most easterly section covering approximately 140m length contains Minim Cove and consists of what could substantially be considered the natural embankment to approximately 5m above river level. Above this the embankment forms the southern edge of the pyrites slurry dump referred to in Zone D. The embankment consists of a series of crushed limestone bunds built to contain the slurried pyrites waste generated by Acid Plant No. 3. The extent of the dump is outlined in Figure 4. The next section to the west and covering approximately 340m length consists of an upper embankment formed by dumping of pyrites cinders waste from the Fertilizer Works and being approximately 15m in height. At the foot of this steep embankment there is a 2-3m wide berm that falls away 5-6m to the river. This lower embankment consists partly of the natural limestone cliffs and partly of overspilt dumped material from the embankment above. The source of the overspilt material can be confirmed by colouration of the sand on the lower embankment and observation of larger pieces of pyrites cinders on the beach. The cycleway recently constructed by the Town of Mosman Park is constructed along the berm.

The third section of embankment adjoins the western end of the site and is approximately 400m in length. In this section the embankment is approximately 12m in height and is evenly graded on a relatively steep but well vegetated slope. It appears that this section of the embankment consists of crushed limestone with no evidence of pyrites cinders on the beach or on the slope faces. The above mentioned cycleway runs inside the site fenceline some 5-10m north of the embankment crest.

SECTION 4

BACKGROUND INFORMATION

4. BACKGROUND INFORMATION

The majority of the land under investigation was previously leased from the Crown by CSBP & Farmers for the purposes of manufacturing fertilizers. The full area of land was leased progressively between 1909 and 1961 until 1973 when all leases were terminated. A detailed history of the Company's leases is presented in Reference 1.

Part of the land relinquished by the Company became University Endowment Land. However, in 1979 the land presently occupied by the Rocky Bay Village was exchanged by the UWA for land within a newly created Lot 416 (refer Figure 1).

In considering potential development of the site and having in mind its prior use the UWA commissioned an investigation to determine the presence and extent of any industrial pollution within Lot 416. This work was carried out and reported by Analabs and Rockwater Pty. Ltd. (References 2 & 3) in 1981.

It was established by Analabs that the shallow surface soils within Lot 416 were contaminated to varying degrees by a number of heavy metals. One of the recommendations in the report was that, prior to any development, topsoil should be stripped and replaced with up to 0.5m of clean fill particularly where food gardens could be located over contaminated areas.

The Rockwater report identified a very small groundwater gradient (0.0001) across the site towards the Swan River with potential contamination of groundwater on the southern and south-eastern edges of the site. In particular nitrate, phosphate and mercury levels were found to be in excess of levels recommended for potable water supplies. Groundwater to the north of the site was found to be of potable quality.

Following submission of the above reports agreement was reached between the UWA and the Lands & Surveys Department to undertake further investigations in an effort to determine the full extent and degree of contamination over the entire area of the former CSBP & Farmers leases.

Particular attention was paid to evaluation of any risks that may be associated with the location of the Rocky Bay Village and the Buckland Hill Primary School.

These further investigations were undertaken by a Government appointed Technical Assessment Group (TAG) consisting of senior members of several relevant Government Authorities. The report of these investigations (Reference 1) confirmed that the "majority of the site is contaminated to varying degrees by a variety of substances". The most significant contaminant in the surface soils was identified as lead with high levels of copper, zinc and cadmium found particularly in areas close to the former buildings. Additionally, it was concluded that the groundwater was not contaminated and there was no significant contamination of the atmosphere.

There was some evidence to indicate that stormwater outfalls from the site were acting to concentrate heavy metal accumulations in the river sediments but that in general contamination of these sediments was not high.

The text of the TAG report was reviewed by the Health Department of Western Australia. As a result of this review the Department stated in correspondence (Reference 4) that the site could be used for residential development provided at least 1m of clean fill was added to all areas affected by contamination and that use of groundwater from beneath the site was prohibited.

As a result of the above detailed investigations, reports and correspondence agreement was reached between the UWA and the Lands & Surveys Department to rationalise site boundaries and to investigate the possible development of all land bounded by McCabe Street, the Rocky Bay Village, the Swan River and the State Engineering Works. This study is the outcome of that decision.

SECTION 5

INVESTIGATION SUMMARY

5. INVESTIGATION SUMMARY

As stated previously the principal aim of this study has been to establish the feasibility of developing all or part of the site under consideration for residential purposes.

In order to assess the feasibility of such development the investigations have been carried out in the following stages:

Stage I - Desk Study

The results of the previous investigations were examined and additional research carried out to permit judgment to be made on the practicability of developing the site.

Stage II - Preliminary Development Proposals

Based on information gained in Stage I a preliminary development proposal was formulated together with a strategy for cleaning up the site.

Stage III - Site Investigations

To verify the preliminary proposals and strategies formulated in Stage II a number of further site investigations were carried out particularly on areas of the site not included in previous work.

Stage IV - Compilation and Analysis of Site Investigation Results

Following completion of the site investigations selected samples were analysed for heavy metal content and the resulting data compiled and analysed with respect to the proposed site development strategy.

5.1 STAGE I - DESK STUDY

5.1.1 Contamination Criteria

To allow an objective review of the results reported in the previous two investigations of the site and in order to form a basis for planning work associated with this report steps were taken to identify normal, or "background" levels of heavy metal concentrations in soils and also "allowable" concentrations for various land uses. In the absence of clear and specific guidelines on such values a range of values identified from the literature or from other sources have been listed in Tables I and II below:

TABLE I

NORMAL BACKGROUND HEAVY METAL CONCENTRATIONS IN SOIL (PPM)

Source	Fe	Cu	Zn	As	Cd	Hg	Pb	Bi
1. Content of Carbonate Rocks (Ref. 2)	-	4	20	1	0.035	0.04	9	-
2. Accumulation of copper, lead and arsenic in some Australian Orchard Soils - Merry et al (Ref. 5) - Background levels in								
(a) S.E. Australia	-	16	-	4	-	-	20	-
(b) N. America	-	22	-	6.5	-	-	20	-
(c) Ontario	-	25	-	6.3	-	-	14	-
3. Data from NSW State Pollution Control Commission (refer Appendix C) - uncontaminated, normal range	-	0-100	0-250	0-30	0-1	0-1	0-500	-

TABLE II

RECOMMENDED HEAVY METAL CONCENTRATIONS IN SOIL
BY LAND USE (PPM)

Source	Fe	Cu	Zn	As	Cd	Hg	Pb	Bi
1. Max. allowable in Agricultural Soils, Ontario (Ref. 2)	-	100	216	13	1.4	0.5	56	-
2. Re-Use of Sludges and Treated Waste Water in Agriculture, Germany (Ref. 6) Guidelines for Tolerable Limits in Arable Land	-	100	300	20	3	2	100	-
3. Recommended soil levels from NSW State Pollution Control Commission (refer Appendix C)								
a. Public Open Space, Formal Playing Fields	-	1000	-	40	15	20	2000	-
b. Amenities playing fields, parks, playgrounds, small children - adopted for use in NSW	-	1000	130	40	12	4	1500	-

It will be seen from Table II that a considerable range of heavy metal concentrations are listed. The levels of contamination are generally much lower where vegetables and other edible plants are to be grown. Similarly, in areas where extensive, rather than intensive human activities are involved and where a low probability of soil or vegetable matter ingestion can be anticipated the allowable levels are higher. However, it is important to note that soils with contaminant levels listed in 3a) and b) of Table II would have to be covered with a minimum of 500mm of clean, uncontaminated soil to allow adequate growth of grass since zinc and copper are phytotoxic and at the levels quoted would inhibit growth of covering vegetation.

In assessing the significance of contamination levels obtained from both past and present analyses the values listed in Table II, Item 1, Maximum Allowable in Agricultural Soils, Ontario and in Table II, Item 3b, Amenities Playing Fields, Parks, Playgrounds, Small Children have generally been used for residential areas and passive recreation areas respectively.

5.1.2 Assessment of Previous Investigations

As summarised in Section 4 above two previous site investigations and reports have been prepared on the majority of the site under present consideration. It is noted in both the Analabs and the TAG reports that lead is the principal contaminant in the soil over a large part of the site but particularly in close proximity to the former building slabs and footings. It is also noted that the level of lead contamination is highest at the soil surface and that levels drop markedly with depth below 150 to 200mm from the surface.

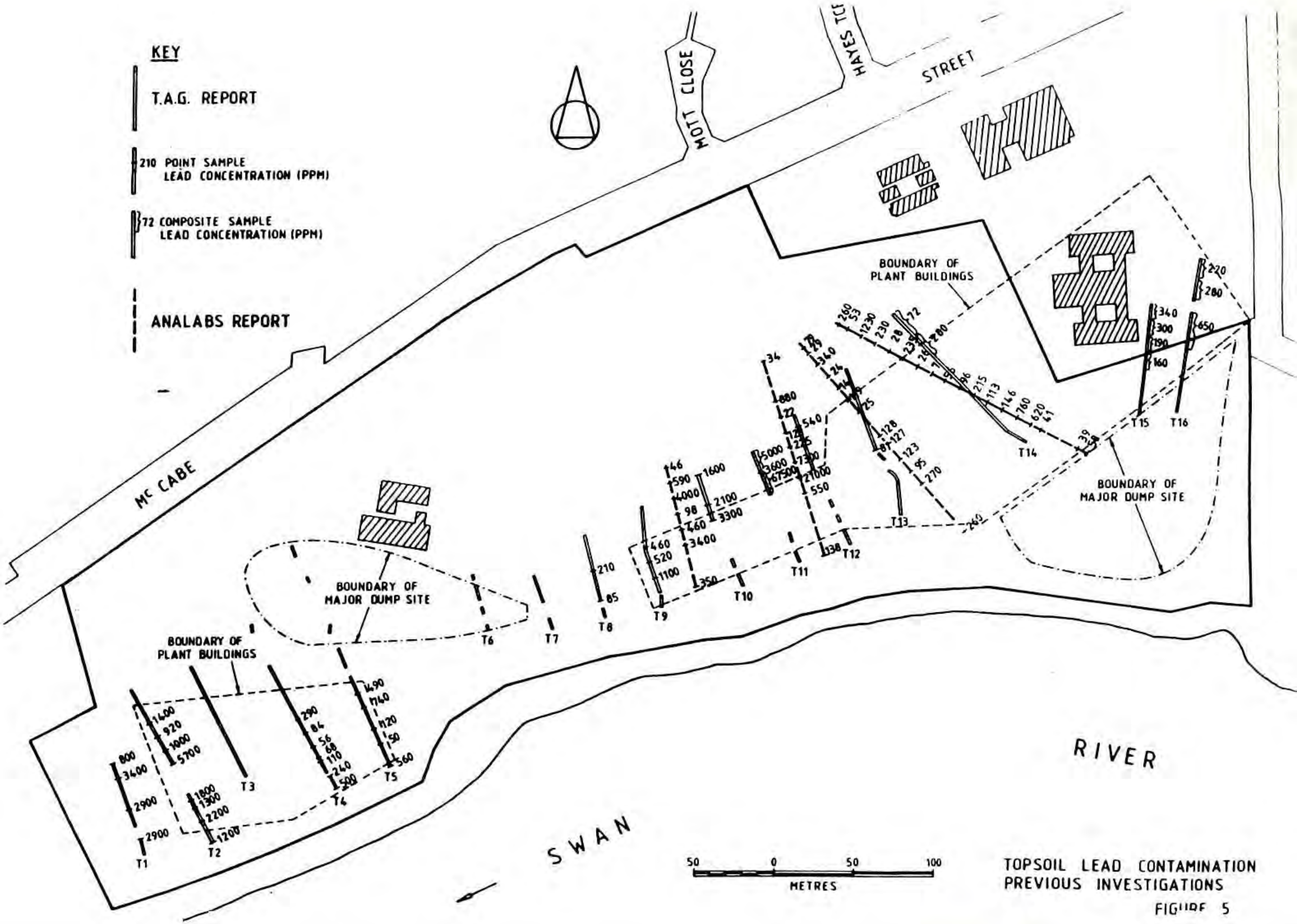
In order to assess the significance of the lead contamination levels, results from both the Analabs and the TAG reports were plotted firstly for topsoil (refer Figure 5) and secondly at bedrock level (refer Figure 6). To assist in interpretation of the bedrock values the depth below surface of each result was also plotted.

Comparison of the lead concentrations for topsoil plotted in Figure 5 with a background level of 9 to 500ppm (Table I) in soils indicates that a significant proportion of the area investigated contains an unacceptably high level of surface contamination.

In addition, comparison of the plotted values with the allowable lead concentration for agricultural soils of 56-100ppm (Table II) illustrates the restrictions associated with production of food on such soils.

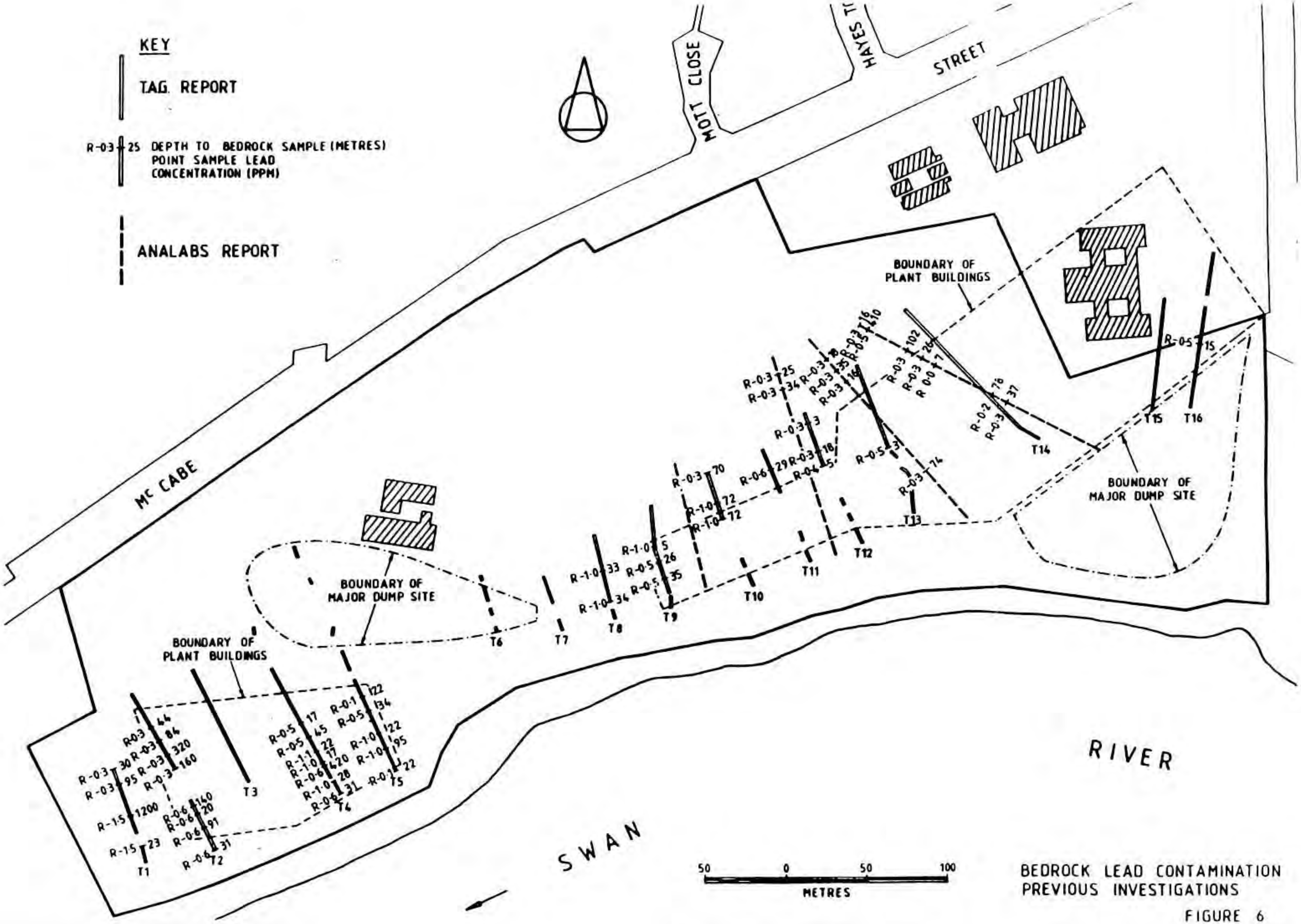
However similar comparisons with lead levels plotted for bedrock samples as plotted in Figure 6 show that only a few isolated areas are contaminated to unacceptably high levels.

In addition to the trench sampling work carried out by the TAG a series of isolated sampling points were analysed. These sampling points were sited on a 100m grid in close vicinity to the Rocky Bay Village. A summary of results from this analysis programme together with sampling point locations are plotted in Figure 7. The analysis figures shown are for bulk topsoil and subsoil samples where levels exceed the highest allowable concentrations listed in Table II for agricultural soils. It can be seen that although lead has been



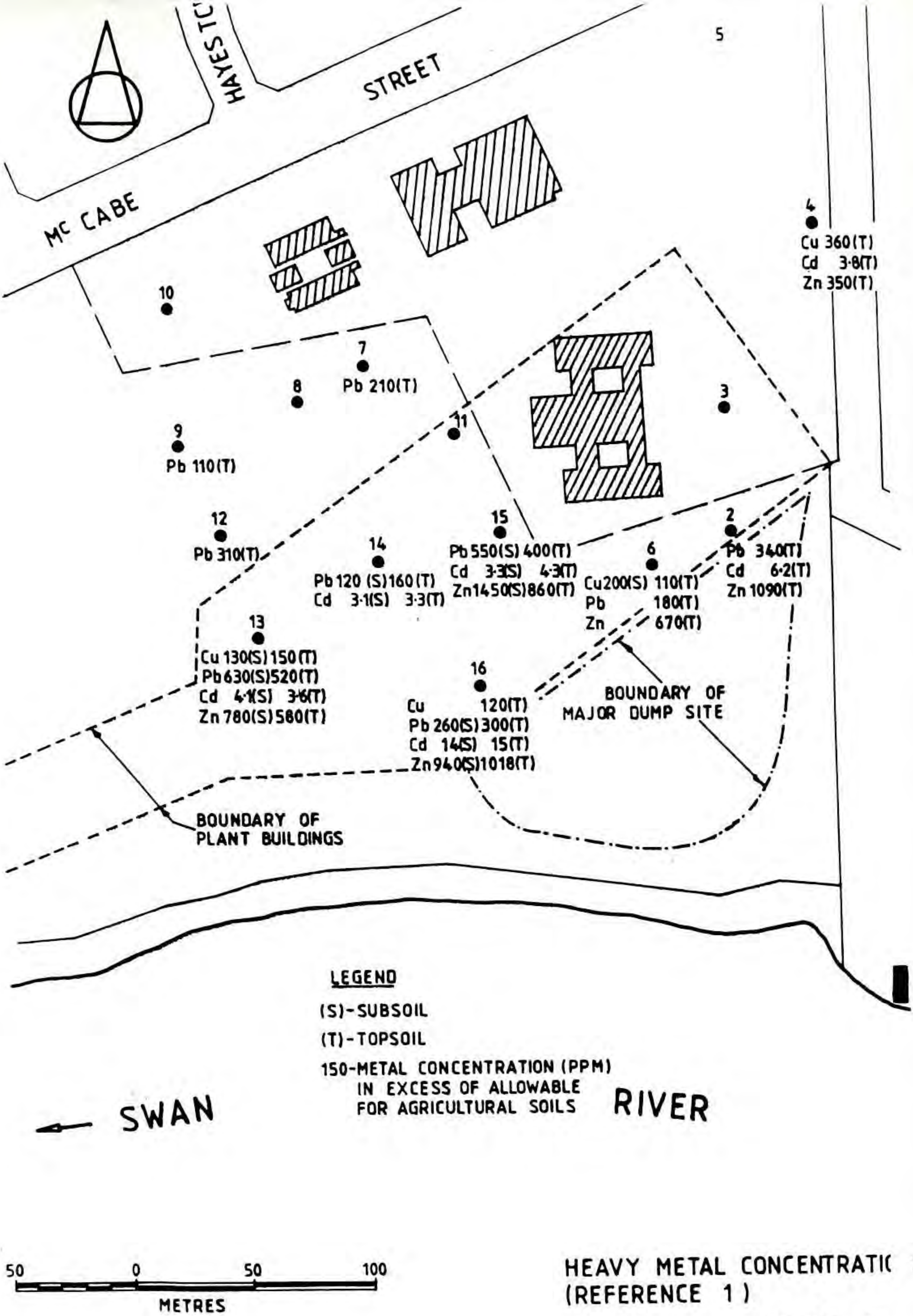
TOPSOIL LEAD CONTAMINATION
PREVIOUS INVESTIGATIONS

FIGURE 5



BEDROCK LEAD CONTAMINATION
PREVIOUS INVESTIGATIONS

FIGURE 6



HEAVY METAL CONCENTRATI
(REFERENCE 1)

FIGURE 7

identified as a principal contaminant, concentrations of other heavy metals are also unacceptably high in areas primarily in close proximity to the original plant buildings and associated facilities. These results are also confirmed by sample analyses from the Analabs report although these results are not plotted here.

In the TAG report samples of the pyrites cinders residue were analysed and found to contain levels of copper and zinc in excess of those allowable for agricultural soils.

From discussions with various persons competent in the chemical and toxicological fields it is apparent that the heavy metals are most stable in an alkaline environment. It is only in an acidic environment that metals such as arsenic and cadmium form soluble compounds that are highly mobile and known to be highly toxic. It is considered that the alkaline nature of the soils and underlying bedrock has resulted in the general confinement of the majority of heavy metal contamination to the surface and near-surface soils.

5.1.3 Implications of Contamination on Residential Development

Prior to the formulation of any development proposals for the site consideration was given to the possible implications of establishing residential freehold properties over areas of contamination. Reference should be made to Section 2.2 for further discussion of this aspect of the development.

Reference has been made in Section 4 to correspondence from the Health Department (Reference 4) in which a recommendation is made to cover the site with at least 1m of clean fill to allow residential development. A similar recommendation is also made in the earlier Analabs report which specifically dealt only with Lot 416.

Based on this form of pretreatment the following practical aspects of low to medium density residential development subject only to normal building by-laws were considered with respect to the underlying heavy metal contamination:

(1) The 1m of sand cover would effectively act to separate root systems of vegetable crops and small garden shrubs from the contaminated ground. However the root systems of larger trees, including fruit trees would penetrate into the contaminated soils. As well as the possible contamination of the fruit by uptake of the heavy metals there is also a remote but identifiable risk that such a tree could be blown over and bring the contaminated soil to the surface.

(2) Under normal conditions of freehold land ownership, excavation to, or in excess, of 1m depth can be foreseen for swimming pool installation, landscaping, cellar construction, soak well installation etc. Such activity unless closely monitored and controlled could result in contaminated soil being brought to the surface.

(3) Although neither the Rockwater nor the TAG reports indicate serious groundwater pollution (refer Section 6.4) recommendations are made, and reiterated by the Health Department, that groundwater use, particularly towards the southern side of the site, should not be permitted. Although it is recognised that a caveat or licence system can control bore installation such restrictions could be viewed as undesirable by potential land buyers.

(4) Installation of the majority of services other than sewerage and drainage in a normal subdivisional development is carried out after completion of roadworks and immediately prior to commencement of building construction. It is recognised that special precautions can be taken during initial construction of such services but it is far more difficult to control later maintenance and/or upgrading works where large excavations are a real possibility. The risks in such activities are seen to be from the dust that may be generated during excavation and from spoil stockpiles and also from the raising of contaminated soil to the surface.

As can be seen, three of the above postulated situations have the potential to cause contaminated soil to be brought to the surface at some time in the future. The prime risk associated with such an occurrence is that the contaminated soil can then be ingested directly, particularly by children, or be absorbed by vegetables or other food plants. In our opinion there is, in a normal residential development, a real and significant risk of any one of the above situations leading to contamination of surface soils.

In view of the high land values that have recently been achieved in this area and that are predicted for any development on this site it is seen as unacceptable to establish residential properties on an area where risks as identified above exist. If however a development on the heavily contaminated areas was to proceed, it would, in our opinion, be an essential prerequisite to sale that a full disclosure of the history of the land and complete details of all remedial works undertaken be released to potential landowners. Further, it is our opinion that release of such information would have a significant and detrimental effect on land values to the extent that the viability of the entire development could be placed at risk.

On the basis of the points raised above and the advice received from Dr. S. Hrudy (refer Section 2.3) it is, in our opinion, impracticable to develop any part of the site that is heavily contaminated to the extent that economical and practical clean-up measures could not be expected to provide a substantially risk-free environment for future landowners.

Data compiled from the previous reports and summarised in Section 5.1.2, Figures 5, 6 and 7 were used to identify potential areas of the site where the above minimum risk criteria could be applied. In addition, searches were carried out of the aerial photography archives of the Lands & Surveys Department and also the plan archives of Westrail. Information gathered from these sources was used largely to confirm aspects of the recorded history of the site and particularly in identifying areas of the site used to dump waste material.

5.2 STAGE II - PRELIMINARY DEVELOPMENT PROPOSALS

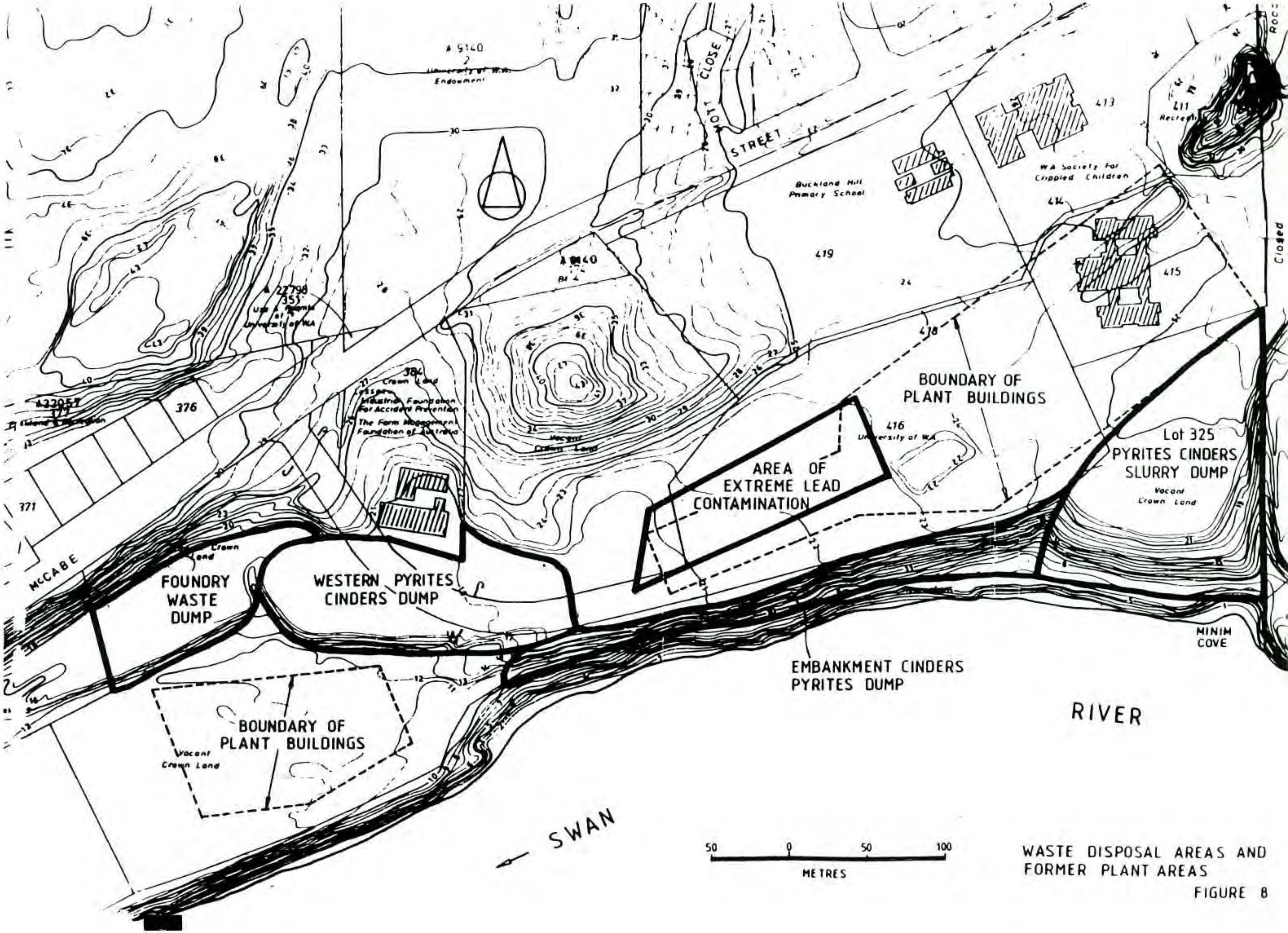
The principal criteria for deciding the area of the site that is suitable for residential development have been outlined in Section 5.1.3. To reiterate, any area of the overall site that cannot be economically and practically cleaned up to a standard sufficient to ensure no risk of contact with contaminated soil by future landowners is to be considered unsuitable for residential development.

The report of the TAG investigations on the site outlines a number of areas where waste products from the Fertilizer Works have been dumped. These waste products have been identified as containing raised levels of heavy metal contaminants and the dump areas can therefore be considered, under the above criteria, as unacceptable for development unless pretreated in some manner. Areas of the site identified as being used for major waste dumping activities are shown in Figure 8 together with the areas occupied by the major plant buildings and associated structures. The bulk of this plotted information has been derived from diagrams in the TAG report (Reference 1).

Dealt with individually the main waste dump areas are:

Pyrites Cinders Slurry Dump - Lot 325:

This is the site of a large capacity slurry dump. Waste pyrites cinders from the fluidised bed furnaces installed on the site in 1955 were treated by cyanidation to extract gold, neutralised and then pumped as a slurry into this dump. The slurry is retained by a series of crushed limestone bunds to a maximum depth in excess of 10m. TAG investigations reveal a significant heavy metal and cyanide content within the dump. Development over this dump was considered to be unacceptable.



WASTE DISPOSAL AREAS AND FORMER PLANT AREAS

FIGURE 8

Western Pyrites Cinders Dump:

This is the site of a pyrites cinders dump. The pyrites cinders were generated by the Herreshoff furnaces from approximately 1910 onwards. The material is presumably stockpiled on the limestone subgrade and has a bitumen sealed carpark constructed over part of its surface. The carpark was established by CSBP to cater for workforce parking adjacent to the laboratory and administration building (now leased by IFAP). The pyrites cinders are identified in the TAG report as being "largely inert" and as not appearing to be "adding any heavy metals to the environment". Limited testing of this material, as reported by the TAG, reveal some elevated copper and zinc concentrations.

In addition to this contamination potential, it is questionable whether stockpiled waste would form a suitable foundation material for conventional urban building construction purposes. For these reasons it was decided that the stockpiled material should be removed and the underlying land covered with clean fill for residential use.

Embankment Pyrites Cinders Dump:

This is a second area of pyrites cinders dumping. However it is located along the main river bank and has been left at or close to its natural angle of repose to form a steep and potentially unstable slope. The pyrites cinders are covered in places by crushed limestone material but in others are completely exposed. The embankment falls approximately 15m from nominal site level to a 2-3m wide berm located 5-6m above river level. The quantity of material involved and its potential instability render it unacceptable for development.

Foundry Waste Dump:

According to the TAG report this is a stockpile of foundry waste located in an area that was not part of the CSBP leases. Again it can be assumed that this stockpile was established directly on the limestone subgrade. It is noted that the adjacent part of the CSBP plant was previously occupied by Westralian Ironworks. The lease was taken up by CSBP in 1924 and it is therefore highly probable that the Ironworks was the source for this material.

Again the TAG report treats this as a stockpile of relatively inert material. On this basis use of the area occupied by at least part of this stockpile was considered to be acceptable following removal of the waste material.

In addition to these known areas of waste dumping, sections of the site that have been identified in the Analabs and TAG reports as being most heavily contaminated were also considered to be unsuitable for development purposes. Difficulties associated with clean-up of these areas relate to the extent and depth of contamination in proximity to building slabs and foundations, the presence of pyrites cinders for road base material and the possibility of locating previously unidentified but localised dumps of contaminated materials. Of particular concern is the area of extremely high lead concentrations on the former site of the lead melters and also the significant levels of cadmium and arsenic identified in isolated sample analyses close to the plant buildings.

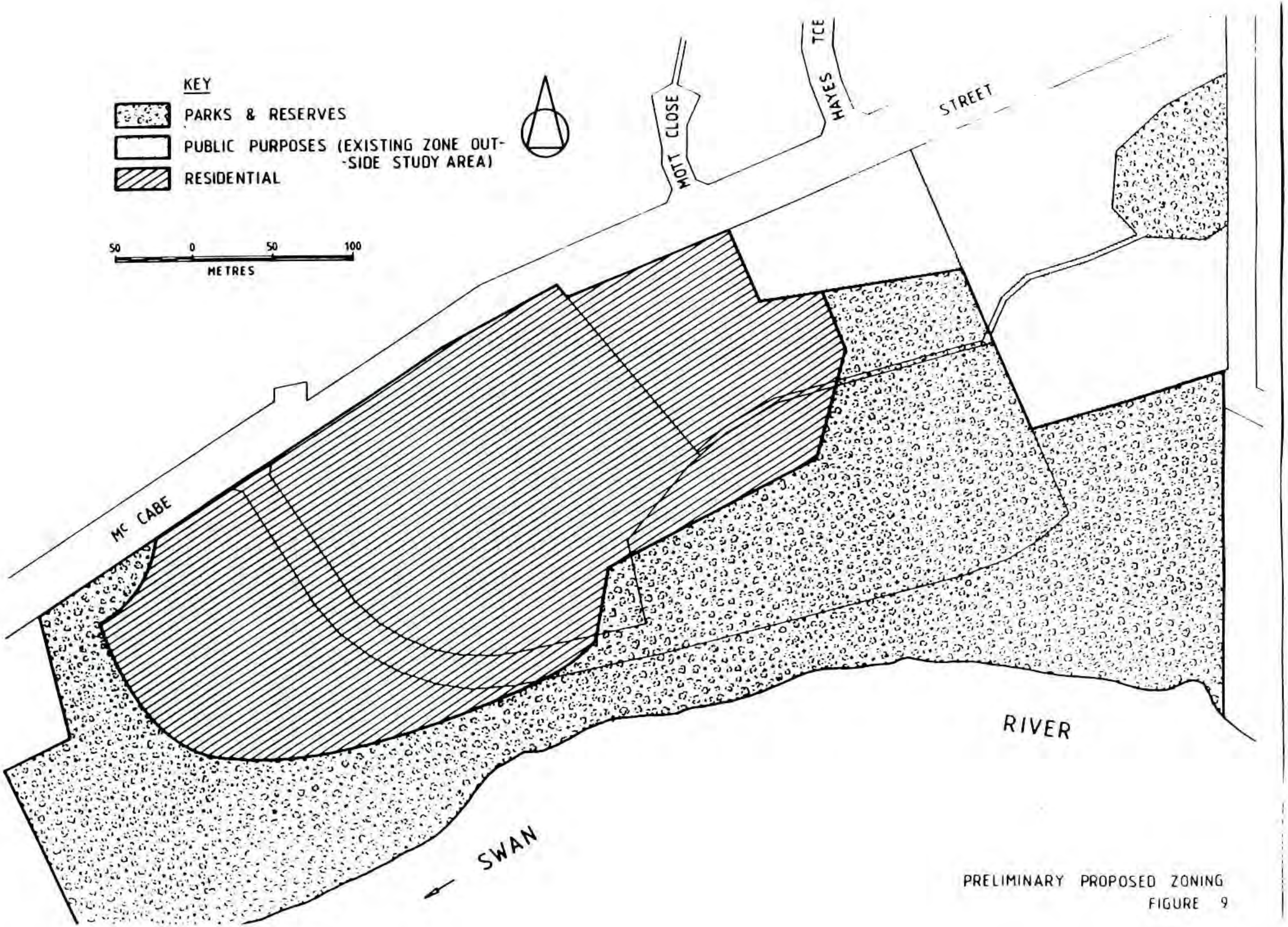
Results contained in both the Rockwater and TAG reports related to groundwater quality also gave cause for concern. The matter of groundwater contamination is discussed more fully in Section 6.4, however in overall terms it is considered that there is a significant risk of groundwater contamination on the southern and, in particular, the south-eastern areas of the site.

Combination of all these points (as illustrated in Figures 5, 6 and 7) led to the division of the site into an area that is, or can be made, suitable for residential development and a second area that can be used for passive recreation purposes. The preliminary proposed zoning is shown in Figure 9 and it will be noted that all of the Western Pyrites Dump and a significant part of the Foundry Waste Dump have been included within the area proposed for development.

Comparison of Figure 9 with the plotted lead contamination levels in Figures 5 and 6 shows that part of the area proposed for residential use contains shallow surface soils containing raised levels of lead. It is also apparent that the northern part of the site has not been previously tested for heavy metal contamination although in fact parts of this area were never included in the CSBP leases. In addition, research into details of the CSBP leases shows that the lease over Lot No. NF350 which encompassed part of this section of the site was granted subject to there being minimum disturbance to the limestone hill and to there being no dumping of pyrites residue on this area. Based on these two facts it was considered highly probable that any contamination to be found in this area would be close to the surface and due to wind blown deposits of fine material or localised and unauthorised dumping of waste materials from the Fertilizer Works.

In order to ensure, as far as possible, the complete clean-up of areas to be used for residential purposes and to therefore minimise the risks of contact with contaminated materials the following strategy was proposed for treatment of relevant sections of the site:

(a) All vegetation within the entire site shall be stripped, stockpiled and burnt.



PRELIMINARY PROPOSED ZONING
FIGURE 9

(b) Within the area to be developed for residential use all soil to bedrock or, where appropriate, soils to a minimum depth of 300mm shall be removed.

(c) All isolated dumps of suspect materials located under item (b) above shall be removed.

(d) All pyrites cinders within the western pyrites cinders dump shall be removed.

(e) Material within the foundry waste dump affected by future residential development shall be removed.

(f) All removed material from items (b) to (e) above shall, subject to testing for excessive contamination, be spread to an even depth over the south-western section of the site (Zone C, Figure 4) beneath the area proposed for recreation.

(g) The area for recreation shall be smoothly contoured and the entire area covered with at least 1m depth of clean filling.

(h) The area for residential use shall be smoothly contoured and covered to a minimum depth of 1.2m of clean filling.

It should be recognised that the above preliminary proposed strategy and the associated preliminary proposed zoning shown in Figure 9 are a result of consideration and analysis of the recorded history and investigation reports available at the time of commencement of this investigation. It was found necessary to formulate these proposals in order to adequately plan the subsequent supplementary and additional site investigations. However, it will be seen by reference to Section 8 that a number of the above proposals require amendment as a result of these further investigations. The reasons for and extent of these changes are discussed in Sections 6 and 7.

5.3 STAGE III - SITE INVESTIGATIONS

As stated in Section 5.2 the proposals for site development were based on evidence gathered from site records and from the results of previous investigations. However, virtually no detailed information was available on the condition of a large proportion of the area proposed for full clean-up and subsequent residential use.

Documented case histories of investigations into other existing and former industrial sites around the world reveal that levels and extent of contamination are often unpredictable. This point combined with the fact that clean-up of areas other than minor surface contamination could well involve considerable expense led to the proposal to extend the previous investigations to cover the full site area.

The location and extent of the investigations are as shown on Figure 10 and comparison with Figures 5 and 6 show the relationship of this new work to the previous investigations. The details of the investigations undertaken are as follows:

(a) Trench MT1:

This trench was aligned to approximately extend the work done by both Analabs and the TAG to the northern site boundary on McCabe Street. Sampling of topsoil, subsoil and bedrock was carried out in similar fashion to the methods used for the TAG report (refer Reference 1). In order to ensure uniformity of procedures as far as possible two representatives of the Government Chemical Laboratories provided on-site practical advice on sampling techniques.

(b) Trench MT2:

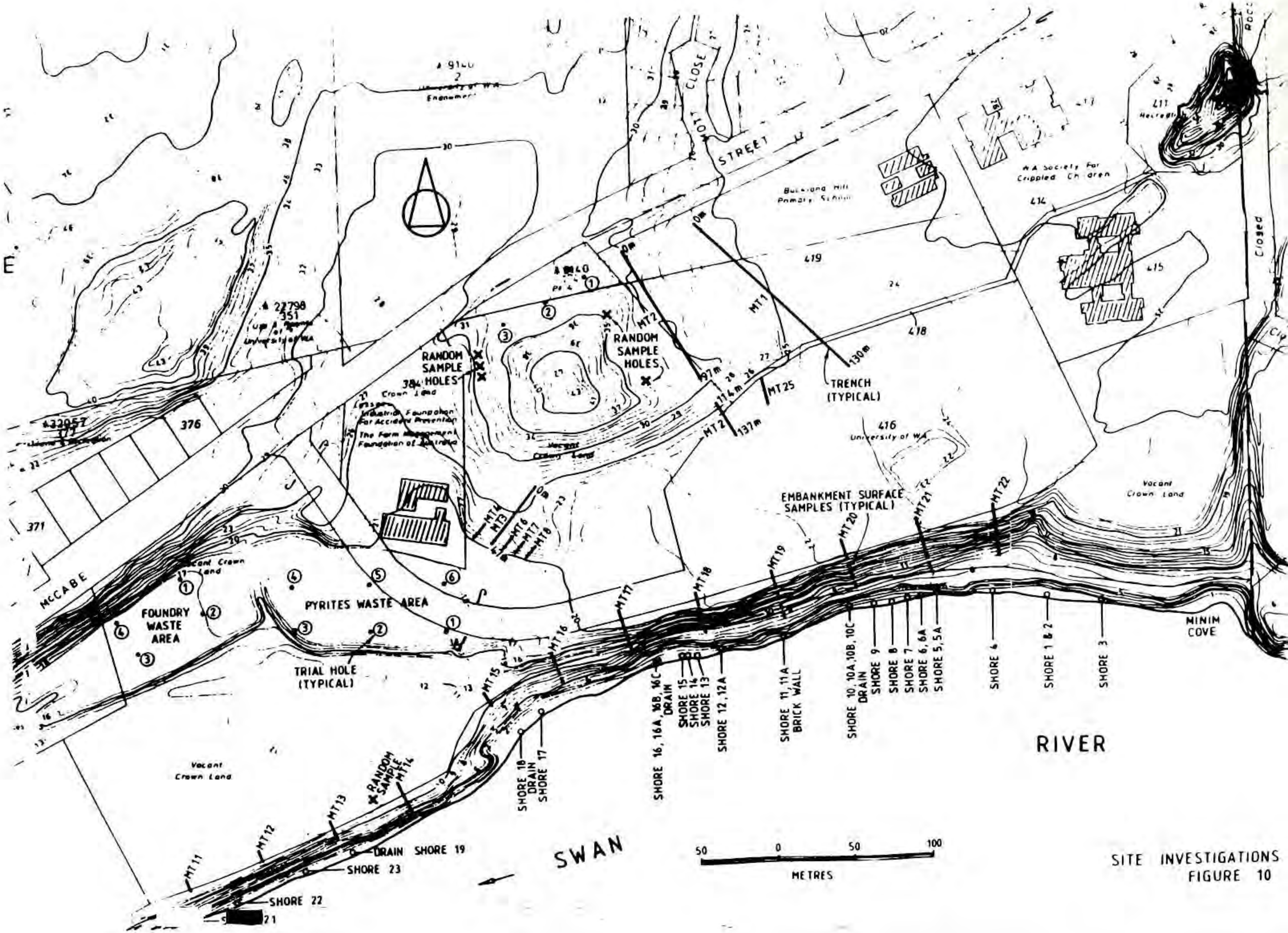
This trench was similarly located to cover previously unexplored areas of the site. It was located further up the lower slopes of the limestone hill to assess the depth of soil cover in this area and also with a view to intercepting any previously unknown dumps of waste material. It was found necessary to interrupt the trench over a section of limestone ridge due to access problems and in order to avoid disturbance to dense vegetation. Sampling was undertaken as for Trench MT1.

(c) Trench MT3:

This trench was located across an apparent area of pyrites cinders dump behind a low limestone retaining wall on the eastern side of the IFAP building. Westrail plans inspected and dated 1925 showed that this retaining wall had existed since at least that time and was apparently originally built to allow construction of the rail link into the site after earlier limestone quarrying was terminated. Sampling was undertaken as for Trench MT1.

(d) Trenches MT4-MT7:

These trenches were excavated parallel to and on each side of Trench MT3 in order to provide a clearer picture of the nature and extent of any stockpiled waste material behind the limestone retaining wall. Sampling of these trenches was only undertaken as considered appropriate by inspection and comparison of soils with those identified in Trench MT3.



SITE INVESTIGATIONS
FIGURE 10

(e) Trenches MT11-MT15:

These trenches were excavated to determine whether or not pyrites cinders had been dumped to form all or part of the river embankment adjacent to Zone C of the site. Prior inspection of this area had shown that at least a thin surface layer of deep reddish-brown material existed over parts of the site and extending to the top edge of the embankment. In the event access to the top edge of the embankment was restricted by vegetation and fencing but the final trench locations were the best practically available subject to such site restrictions. Random grab sampling of these trenches was undertaken.

(f) Trenches MT16-MT22:

These trenches were excavated primarily to assess the extent of the pyrites cinders that are known to have been dumped on the upper embankment. Sampling of material in these trenches was undertaken as considered appropriate by inspection to add further information on the nature of the various materials excavated.

(g) Pyrites Holes 1-6:

These holes were excavated on a grid pattern in the Western Pyrites Cinders Dump. The holes were sampled at regular depth intervals, the aim being to assess heavy metal levels in this material and to provide additional data on the nature of the cinders. Excavation of pyrites hole No. 5 was not possible due to the presence of a limestone outcrop.

(h) Foundry Grid 1-4:

These holes were excavated at selected locations on the foundry waste dump with sampling at regular depth intervals. The purpose of these trial holes was to assess the nature and depth of this material which had to date not been fully investigated.

(i) Random Sample Holes:

These sample holes were excavated in locations adjacent to the IFAP building and McCabe Street to confirm that no unforeseen dumping had occurred in these areas. Sampling was carried out of the topsoil and subsoil strata in these holes.

(j) Trial Holes Foreshore 1, 1A and 2:

These trial holes were excavated on the berm of the river embankment with the aim of intercepting any lateral leaching of materials from the pyrites cinders slurry dump and from the embankment pyrites dump.

(k) Embankment Sampling

Grab samples were taken at regular intervals down the face of the embankment on the line of Trenches MT16-MT22 in order to assess the nature of this surface material.

(l) River Beach Sampling

Grab samples were also taken on the beach along the entire length of the site. Inspection revealed a number of areas where staining or discolouration was evident on the beach or embankment. Grab samples were taken specifically from these areas. The intention of this work was to verify the comments contained in the TAG report concerning the low level of river sediment contamination.

(m) Mollusc Sampling

As a supplementary exercise, in light of soil analysis results on the beach samples, a number of individual mollusc samples were taken for analysis in areas of high soil contamination. Again, confirmation of the conclusions drawn in the TAG report was the principal aim of this work.

As stated at the beginning of this Section the prime aim of the site investigations was to confirm details and strategies for the site development proposals outlined in Section 5.2. Trenches MT1, MT2 and MT3 as shown in Figure 10 were located specifically to achieve this aim since this northern part of the site is the only section not previously subject to any form of investigation. The systematic sampling system employed by the TAG was applied in these trenches.

The primary aim of the following site investigations was to allow some quantification of the various treatment proposals outlined in Section 5.2. In particular, Trenches MT4 to MT7 were excavated to determine the quantity of pyrites cinders in the suspected dump area. Trenches MT11 to MT15 were excavated principally to confirm that the river embankment in this area has not been used as a pyrites cinders dumping zone. Trenches MT16 to MT22 were excavated to assess the extent of the embankment pyrites cinders dump. Sampling of these excavations was carried out in a comparatively random manner as determined by inspection. It was not considered necessary for systematic sampling of these excavations because the areas to be covered had been or were being sampled and analysed to a satisfactory and practical extent. The holes in the western pyrites cinders dump and the foundry waste dump were located on a regular grid and sampled systematically to achieve better appreciation of the nature of the materials involved.

The random sample holes were located by inspection to widen the area of investigation where contamination levels were expected to be low. The location of these holes was largely controlled by the proximity of limestone to the surface. They were excavated only in areas where soil or very weakly cemented limestone occurred to sufficient depth to allow excavation. Sampling was carried out in a systematic manner similar to the methods adopted in the TAG report but only selected samples were analysed. The proposal to strip topsoil to at least 300mm depth in these areas was considered to preclude the need for intensive sampling.

During the course of the originally planned work a number of observations prompted re-assessment of the original programme. The relevant observations and details of resultant actions are as follows:

(1) The observation of surface staining at the toe of the embankment pyrites cinders dump was suspected to be evidence of leaching from this material. As a result trial holes Foreshore 1, 1A and 2 were excavated and extensively sampled. Based on site observations and access restrictions it was not considered appropriate to extend these investigations along the berm. This is summarised in (j) above.

(2) The depth of pyrites cinders encountered in Trenches MT17 to MT22 was not in excess of 1m on the horizontal plane behind the top edge of the embankment. From previous records and aerial photography it had been assumed that the cinders material was dumped to a uniform thickness over a prepared limestone face. In an effort to more accurately define the quantity of material dumped it was decided to take grab samples down the embankment face on the line of Trenches MT16 to MT22. This is summarised in Item (k) above.

(2) The results of river sediment sampling undertaken as part of the TAG investigations had shown relatively low levels of contamination except at a drainage outfall. A thorough investigation of the river beach line and immediate embankment revealed a number of areas where staining of the sand and rock was apparent. A number of other drainage outlets and possible

seepage paths were also identified and it was therefore decided to sample the most obviously affected areas to determine the extent, if any, of heavy metal contamination. This is summarised in Item (l) above.

(4) Following receipt of the soil analyses from (2) above it was considered that sufficient justification existed for the taking of additional mollusc samples at the approximate locations of the tested beach samples. This is summarised in item (m) above.

5.4 STAGE IV - SITE INVESTIGATION RESULTS

Following completion of the site investigations selected samples were analysed for heavy metal content. Results of these analyses were then compiled and plotted for the prime purpose of assessing the practicability and economic viability of the site development proposals as outlined in Section 5.2.

Preparation and analysis of the samples was carried out in similar fashion to the methods used by the Government Chemical Laboratories during work for the TAG report. Briefly, the samples were air dried (to facilitate mercury detection) and sieved to separate the minus 2mm fraction. Where little or no material in a particular sample was less than 2mm size the material was pulverised in a disc mill. In all cases, the minus 2mm fraction was ground in a disc mill to less than 150 micron. Heavy metal concentrations were then determined by digestion of a 1 gramme sample with perchloric acid followed by atomic absorption spectrophotometry.

The results of the sample testing are presented in tabulated form as supplied by the Analabs laboratory in Appendix A.

To assist in interpretation of the results the following sub-sections are presented as a summary of observations from each area of investigation with diagrammatic presentation of relevant test results. More detailed notes on each of the excavations or sampling lines are presented in Appendix B.

5.4.1 Trench MT1

Material excavated in this trench consisted mainly of fine yellow sand overlain by a thin layer of topsoil or crushed limestone. Limestone bedrock was found to vary in depth from very shallow (less than 500mm) at the south end to approximately 2m near a disused sand borrow pit. The limestone surface exhibited the characteristics of a pinnacle formation.

Of the metals analysed lead and zinc were the only metals detected at concentrations in excess of recommended levels for agricultural soils. A plot of lead and zinc concentrations along the trenchline is shown in Figures 11 and 12 respectively.

Values plotted are for topsoil and subsoil samples and it will be noted that levels for the subsoil samples which varied in depth between 150mm and 400mm are, for practical purposes, within expected background levels. The concentrations of lead and zinc show an increase at the southern end of the trench. This is in conformance with results quoted by TAG and Analabs during their respective testing in this same area.

5.4.2 Trench MT2

Material excavated in this trench consisted mainly of fine brown sand and limestone gravel beneath a layer of fine black topsoil. The section of trench north of the limestone ridge ran across a number of stockpiles of material. This material was found to be of similar appearance to the natural topsoil and it is considered highly probable that the stockpiles were a result of clearing and stripping in the disused borrow pit in the same vicinity.

The underlying limestone rock again consisted of pinnacles north of the limestone ridge. South of this ridge the limestone rock was found virtually at surface level being the line of cut of the limestone quarry (refer Section 5.1).

Plotted concentrations in topsoil and subsoil for lead, zinc, copper and arsenic are presented graphically in Figures 13, 14, 15 and 16 respectively. It will be noted that all plots peak in the zone between approximately 85m and 97m in both the topsoil and subsoil readings. This would seem to indicate the possibility that some unrecorded dumping occurred in this area. Zinc and arsenic levels show a more mild peak at approximately 60m to 70m chainage. Also copper and arsenic show a mild peak at approximately 50m chainage. The levels recorded for all these peaks in subsoil samples are below acceptable levels for agricultural soils.

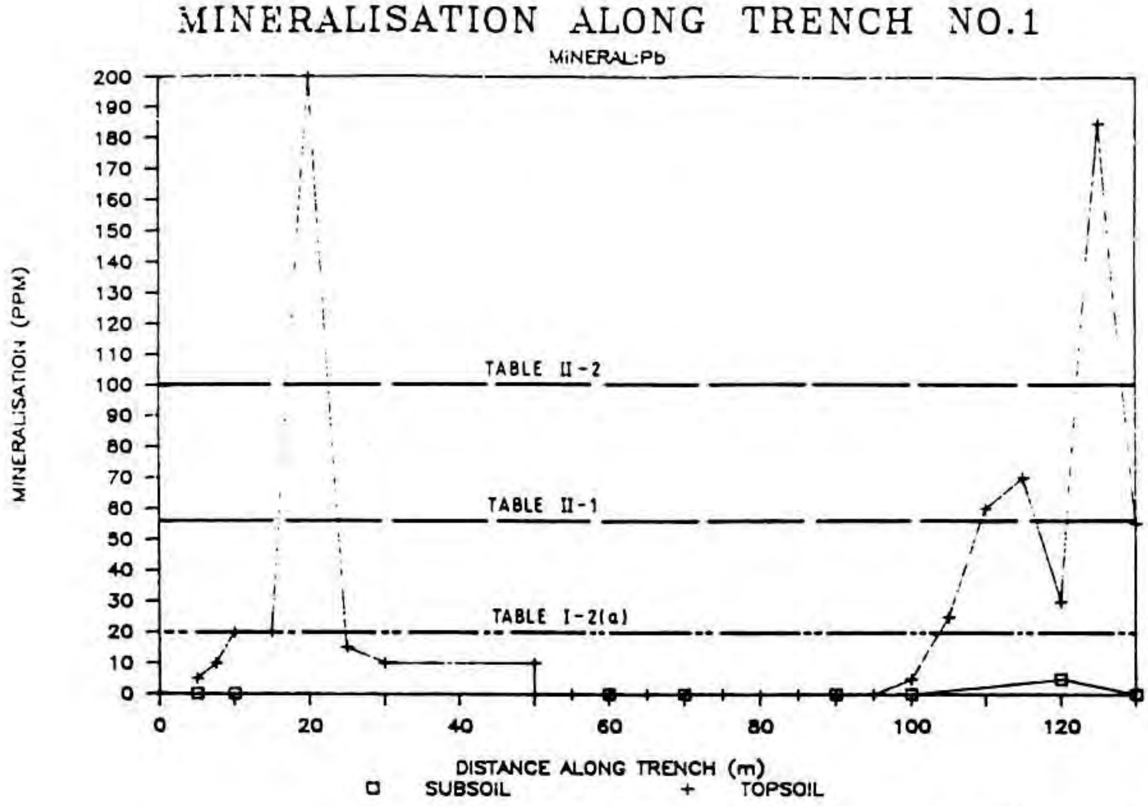


FIGURE 11

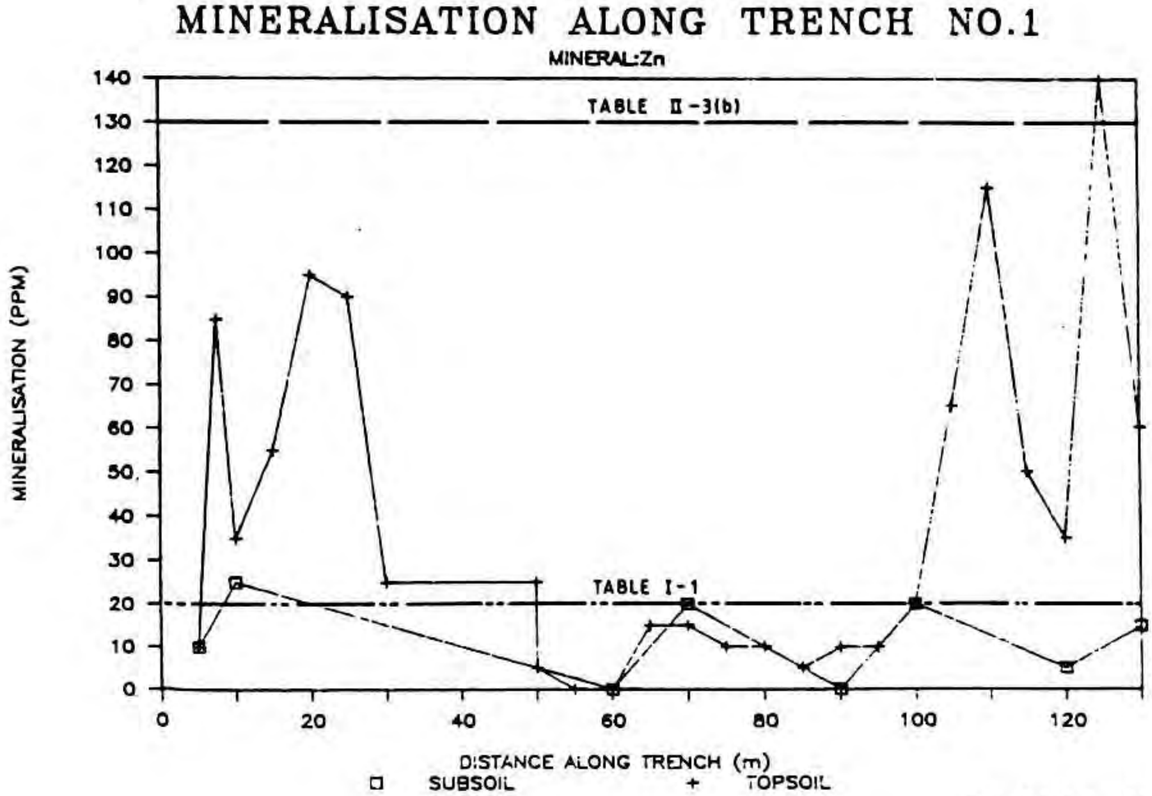


FIGURE 12

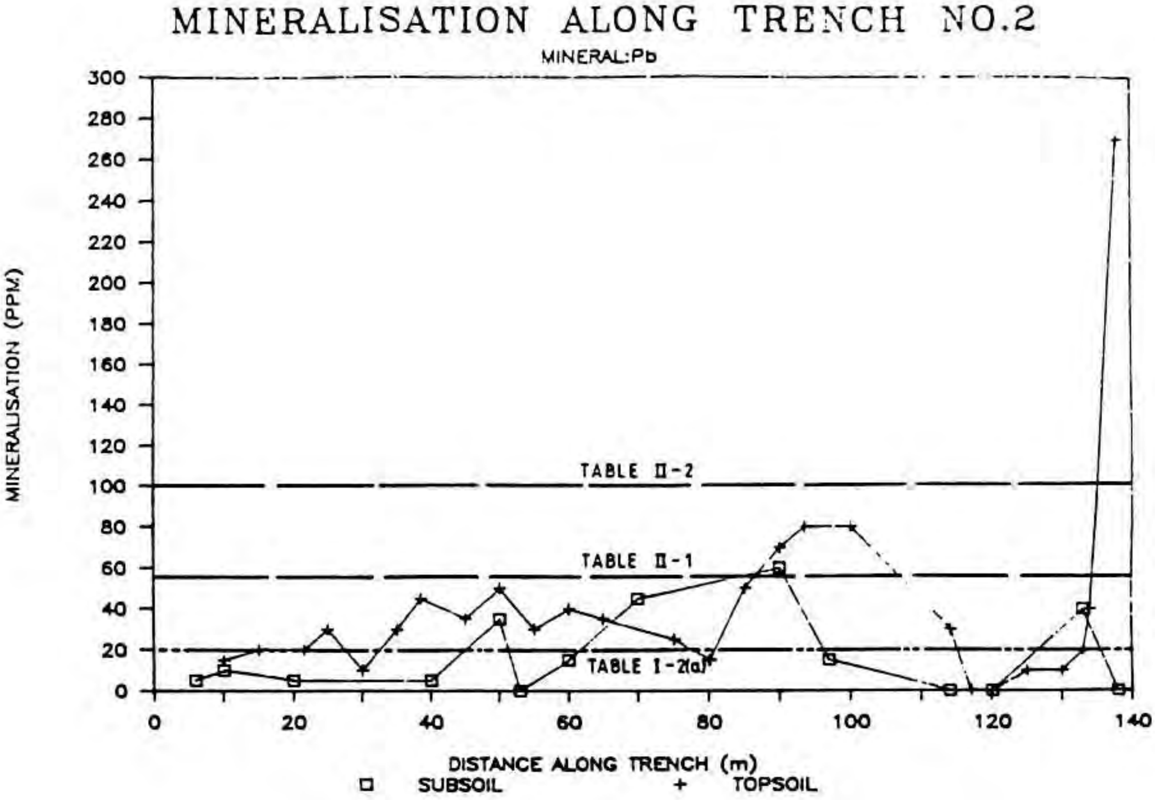


FIGURE 13

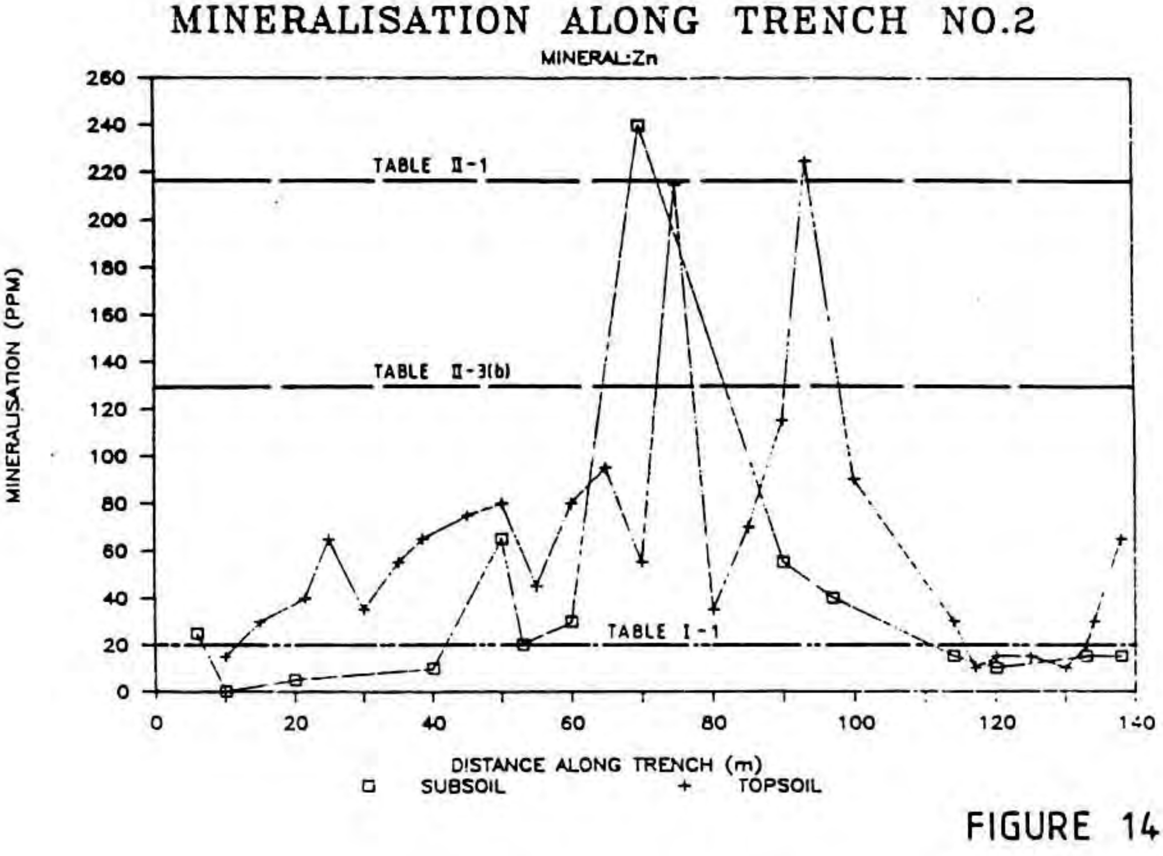


FIGURE 14

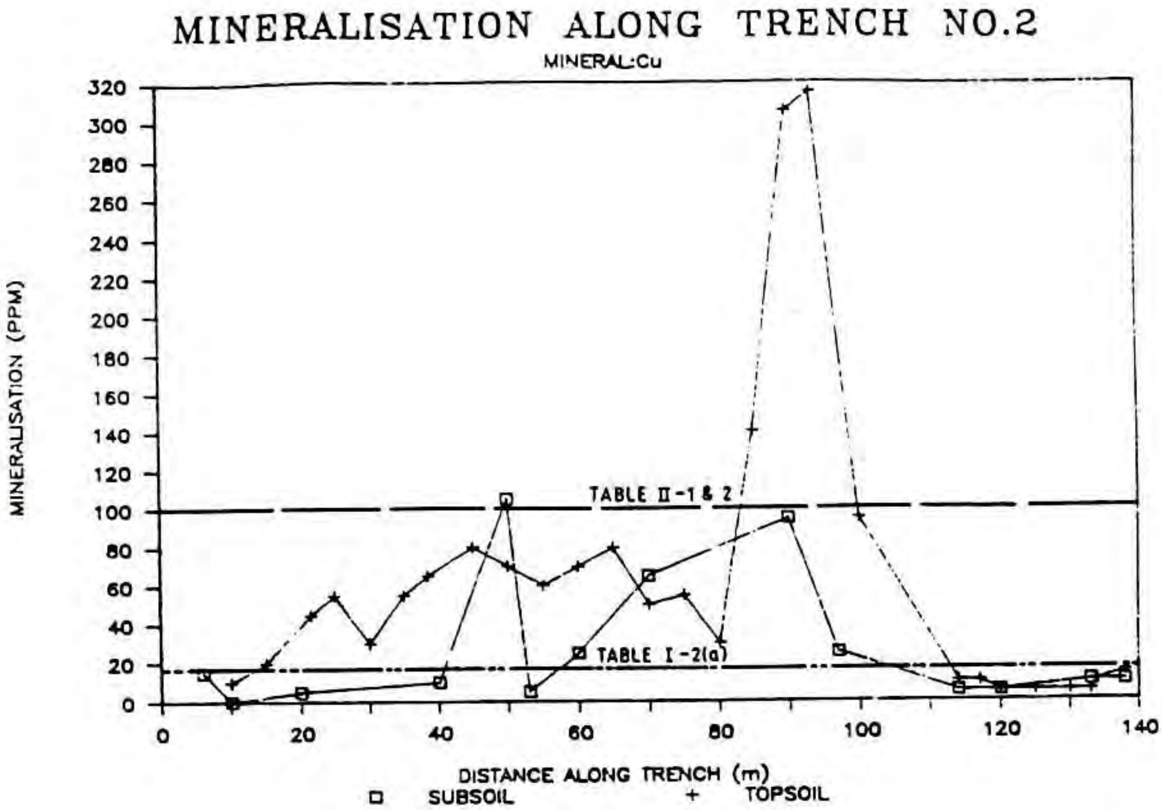


FIGURE 15

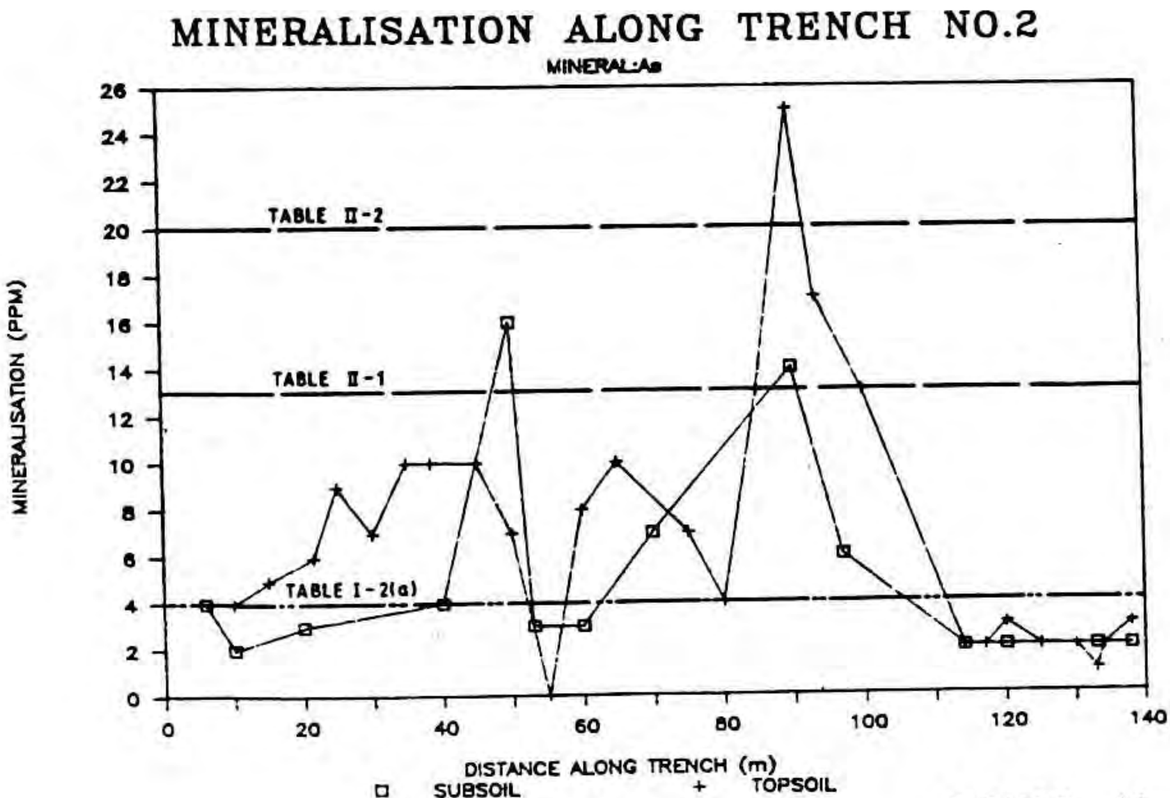


FIGURE 16

5.4.3 Trench MT3

Material excavated in this trench varied from a very weakly cemented sandstone at the north-eastern end to a fine brown sand at the south-western end beneath a thin layer of grey-brown topsoil. At the extreme south-western end of the trench the top layer of material to a depth of 200mm to 300mm was identified as pyrites cinders waste. Evidence of hard limestone pinnacles was found in the trench beneath the sandy subsoil.

Plotted concentrations of lead, zinc, copper and arsenic are presented graphically in Figures 17,18,19 and 20 respectively. The analyses indicate a marked increase in heavy metal content at chainage 47m at the surface where the pyrites cinders was identified. It is also noted that lead, zinc, copper and arsenic values in the subsoil at chainage 20m show elevated levels close to or above levels acceptable for agriculture.

5.4.4 Trenches MT4 to MT7

These trenches were excavated to determine the extent and depth of pyrites cinders material that may be dumped in this area. In the event it was found that the cinders formed only a thin surface layer behind the limestone retaining wall. Of particular note, however, was the discovery of a deposit of amosite (a form of asbestos fibre) in Trench MT4 which was located approximately 10m west of Trench MT3. The material was buried at approximately 500mm depth but was not located in any other trenches in this area.

5.4.5 Trenches MT11 to MT15

Materials excavated in these trenches generally consisted of crushed limestone under a thin (150mm to 300mm) layer of reddish-brown material that is thought to be sand contaminated with pyrites cinders. The prime purpose of these trenches was to establish the depth of any pyrites waste on this part of the river embankment. Since no deep deposits of such material were located extensive sampling was not carried out in these trenches.

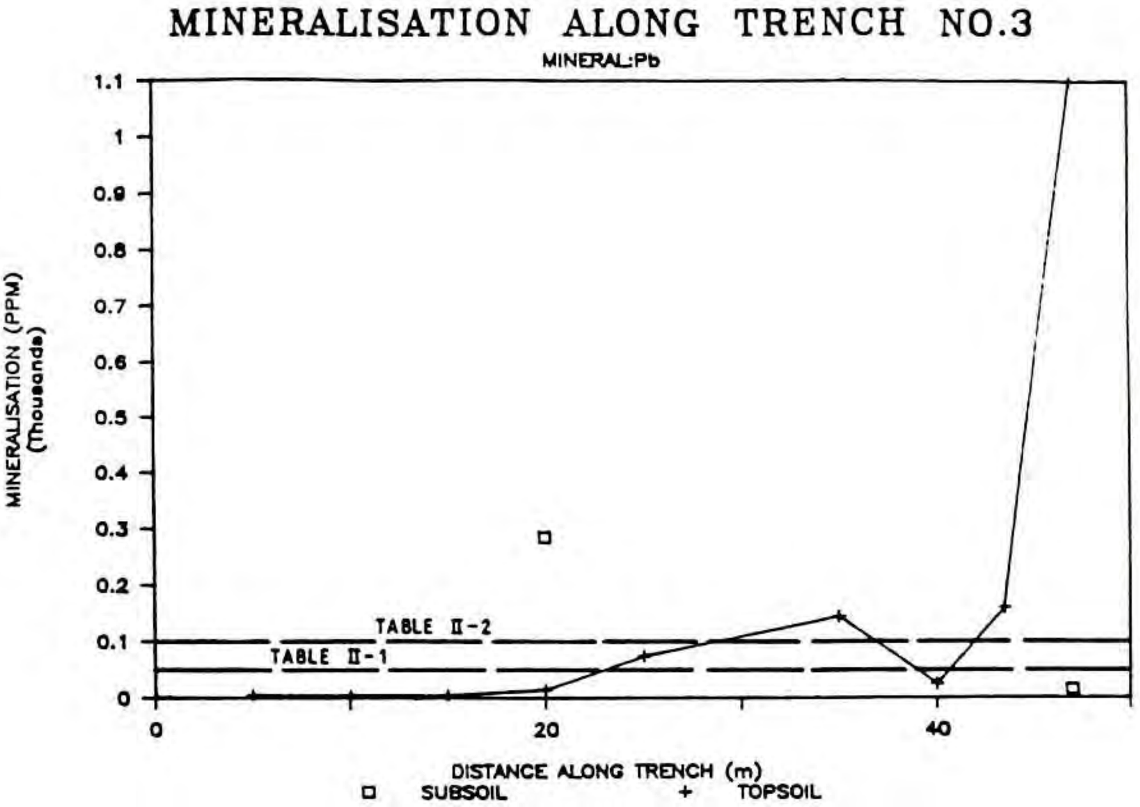

MINERALISATION ALONG TRENCH NO.3

FIGURE 17

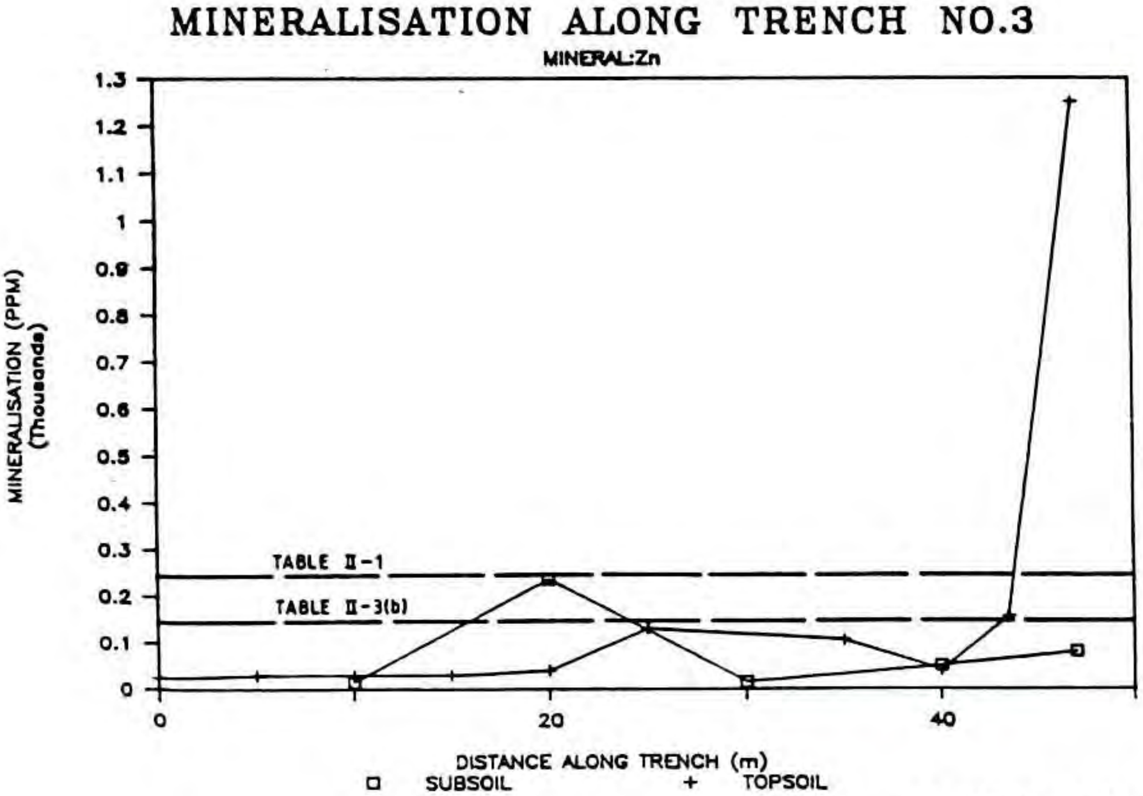

MINERALISATION ALONG TRENCH NO.3

FIGURE 18

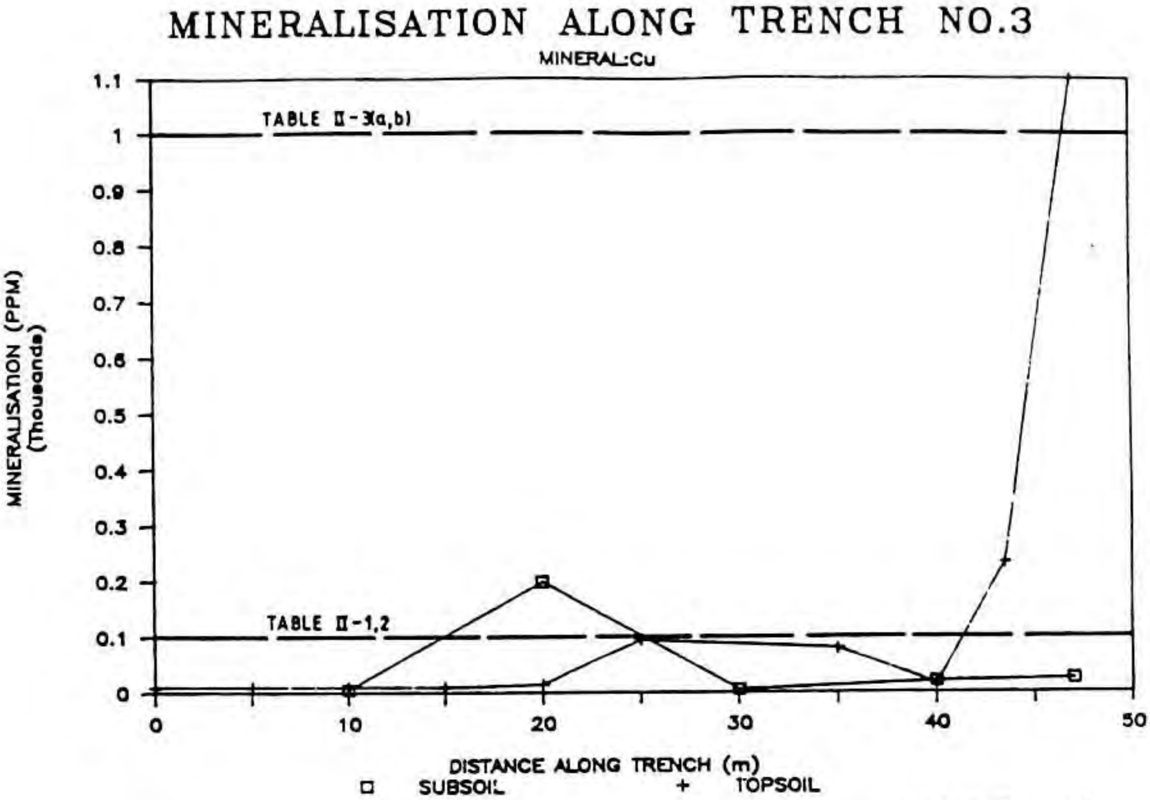


FIGURE 19

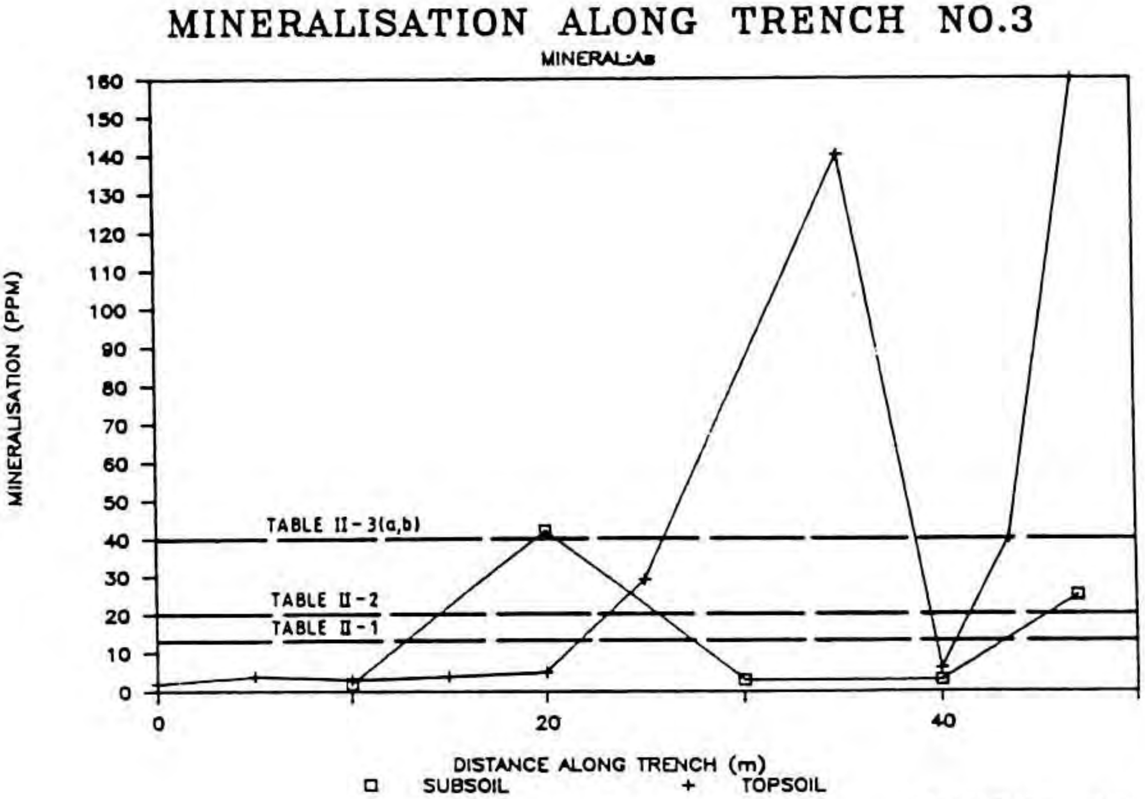


FIGURE 20

5.4.6 Trenches MT16 to MT22

Material excavated in these trenches varied considerably and for ease of description the relevant information is plotted in Figures B1 to B7 in Appendix B. In plotting these sketches the measured strata in the excavated trenches was extrapolated down the embankment. In general the measurable slopes of the strata close to the face of the embankment in the trenches were found to be approximately 1:1.5. Embankment face slopes were plotted from a 1:2000 scale contour plan of the area. Reference is made also to Section 5.4.11 which deals with the embankment sampling programme that was carried out, the results of which were also used to plot Figures B1 to B7.

A number of samples were taken from these trenches and a selected few analysed. The results of these analyses are listed in Table III for samples taken specifically from the pyrites cinders material. The only exception to this is the sample identified as MT18-7-0.4 which was taken from a thin vein of blue coloured material located immediately beneath the pyrites cinders. However, even if the concentrations given for this sample are omitted, the concentrations of the various metals listed for the remaining samples are well above acceptable levels. It is possible that the bright blue material is ferric ferrocyanide or "Prussian Blue", a product of the reaction of cyanides (perhaps from the gold extraction wastes in the pyrites cinders slurry dump) and iron.

It should be noted that the bright blue colour associated with sample MT18-7-0.4 is considered to be cause for concern because of the natural attraction of young children to such material found lying on, or exposed in, the ground. The metal concentrations and, in particular, the level of cadmium given for this sample are extremely high and potentially toxic if ingested (e.g. by sucking on a small piece of such a brightly coloured specimen).

TABLE III

EMBANKMENT TRENCHES

Sample	Fe	Cu	Zn	As	Cd	Hg	Pb
MT15 Gen Sample	352,000	230	365	260	2.0	0.1	120
MT15 7/2.1	10,000	500	1,800	2	3.3	x	x
MT16 Gen Sample	484,000	260	230	200	2.1	0.145	950
MT17 4/1.0	459,000	850	950	1,100	6.1	8.8	2250
MT17 6/0.45	152,000	900	1,100	110	4.5	0.54	775
MT18 7/0.4*	19,000	34,000	60,500	110	240	0.26	105
Arithmetic Mean (MT18 7/0.4 omitted)	291,400	548	889	334	3.6	1.9	819

Key to sample description:

MT15	Trench 15
7	Distance of sample location from reference point
2.1	Depth below ground level of sample location
*	Sample from thin blue vein of material located immediately beneath pyrites cinders waste

5.4.7 Pyrites Cinders Holes 1-6

Material excavated in the majority of these holes was, as expected, pyrites cinders with the exception of PH1 (refer Figure 10) and PH6 which appear to lie on the edge of the main dump area.

Samples were taken from each of the holes at various depths to ascertain heavy metal content. Selected samples were also tested for the level of acidity. The results are summarised in Table IV.

Comparison of values listed in Table IV with allowable levels for agricultural purposes and in soil beneath clean fill in a playground situation indicates that arsenic levels in particular are high and to a lesser degree zinc levels are higher than acceptable. As noted in earlier work by Analabs results of this investigation generally reveal a high degree of correlation between iron and arsenic and it is therefore possible that the arsenic is chemically combined with iron as an arseno-pyrites which is relatively insoluble and therefore not mobile. However, there is also a possibility that the arsenic is present as arsenic oxide or some other arsenate generated during the roasting process. Under favourable conditions some of these compounds can be soluble and therefore potentially very mobile.

It is also noted that samples taken during the TAG investigations did not reveal cadmium levels above 1ppm. However, nine of the samples taken in this investigation gave levels of 1.0ppm or greater with a maximum level in a sample taken from only 0.4m depth of 4.7ppm. Although testing of pH levels has not been exhaustive the results shown in Table IV indicate the possibility of acidic environments being present within the stockpile and the formation of highly toxic cadmium sulphate or other cadmium compounds should therefore not be ignored. This matter is discussed further in Section 6.2.

Conversely, the total heavy metal concentration levels are comparatively low and calculations carried out by a representative of the NSW State Pollution Control Commission on the heavy metal concentrations listed for Sample PH1 at 0.7m indicate that as much as 2kg of this material would have to be ingested by a child at a single sitting for there to be any detrimental effect.

5.4.8 Foundry Grid 1-4

Material excavated from these holes indicated the presence of large quantities of scrap metal interspersed with fine granular material, brown in colour with the exception of Hole 4 where limestone only was intersected below a thin layer of topsoil.

TABLE IV

WESTERN PYRITES CINDERS DUMP

		Metal Concentrations (ppm)							
Sample	Description	Fe	Cu	Zn	As	Cd	Hg	Pb	pH
PH1 0.7m	Pyrites Cinders	476,000	400	405	420	2.3	0.96	1100	
PH1 1.0m	Limestone, rubble	10,000	170	540	42	2.4	0.08	45	
PH1 2.0m	Foundry waste	27,000	35	25	3	0.6	0.10	15	
PH2 1.0m	Light pyrites Cinders	468,000	180	115	240	1.0	x	15	8.8
PH2 2.0m	Pyrites Cinders	420,000	165	80	350	1.3	x	25	4.3
PH2 3.0m	Pyrites Cinders	429,000	105	60	490	1.2	x	x	7.9
PH3 1.0m	Pyrites Cinders	484,000	275	150	220	1.1	x	x	
PH3 2.0m	Pyrites Cinders	469,000	55	105	280	1.1	x	x	
PH3 3.0m	Pyrites Cinders	450,000	80	105	240	0.8	x	x	
PH4 2.0m	Pyrites Cinders	470,000	130	155	210	0.8	x	x	
PH4 3.0m	Pyrites Cinders	504,000	105	135	240	1.0	x	x	
PH6 0.15m	Topsoil	9,000	20	20	5	0.5	0.04	x	
PH6 0.4m	Pyrites Cinders & limestone	86,000	120	1950	63	4.7	0.25	315	
Arithmetic Mean		349,620	142	296	216	1.4	0.11	115	
Allowable in Agricultural Soils - Ontario		-	100	216	13	1.4	0.5	56	
Playgrounds small children NSW		-	1000	130	40	12	4	1500	

Key to sample description: PH1 - pyrites cinder stockpile hole No.1
0.7m - depth below ground level of sample location

Samples taken from Hole 2 indicated elevated levels of copper and zinc, in particular, with levels of cadmium and lead being slightly higher than acceptable (refer Table II). It should be noted that the samples tested contained a large proportion of metal turnings and pieces of metal. The samples were therefore screened to remove these larger constituents and the analysis performed on the fraction passing the 2mm screen.

5.4.9 Miscellaneous Trial Holes

Excavation of these trial holes revealed no materials that by inspection could be considered foreign to the site and samples tested revealed no elevated levels of heavy metal concentrations.

5.4.10 Foreshore Holes

A series of holes were excavated adjacent to the cycleway on the embankment berm where access was available for the backhoe. The following results are of note but a full description of all excavations is given in Appendix B.

Foreshore Hole No.1 was excavated at the toe of the embankment pyrites cinders dump in an area where the berm is approximately 10m wide and 5m above river level. This location was chosen because of the yellowish-brown crystalline staining on the surface soils with associated lack of vegetative cover.

Excavation revealed the presence of an earthernware agricultural drain located beneath the stained area running parallel with and adjacent to the toe of the embankment. Close inspection showed a slight surface depression running along the line of the drain for approximately 30m west of the excavation. The drain was found to be partly full of a yellow coloured, fine slurry material and the limestone and sand above and beneath the drain was stained brown and had apparently been chemically bound to form a very hard cemented material that was extremely difficult to dig with the backhoe. Extensive sampling within and around the drain was undertaken. Also a second excavation (Foreshore 1A) approximately 4m closer to the river was made and samples taken in order to establish whether or not lateral seepage was occurring from the blocked drain.

Investigation of the lower river embankment revealed a significant area of staining on the steep, rocky face close to the position of the drain. Samples were also taken in this area (Foreshore 2). Table V summarises the results of sample analyses from these holes.

TABLE V

FORESHORE EXCAVATIONS

Sample	Fe	Cu	Zn	As	Cd	Hg	Pb
Fshore 1 0.15m	151,000	40	35	100	0.5	0.06	30
Fshore 1 0.3m A	4,000	5	10	3	0.4	x	5
Fshore 1 0.3m B	162,000	45	35	120	0.6	0.10	110
Fshore 1 0.8m	3,000	5	10	2	0.5	x	x
Fshore 1 200mm above drain	59,000	45	20	79	0.4	0.05	20
Fshore 1 in pipe	163,000	35	15	100	0.3	0.05	10
Fshore 1 250-300mm below drain	20,000	55	75	5	0.9	x	5
Fshore 1 below drain	150,000	90	20	100	0.6	0.04	x
Fshore 1 rock below drain	780,000	80	30	16	0.6	0.32	x
Fshore 1A 0.5m	49,000	50	65	20	0.6	0.04	10
Fshore 1A 1m	5,000	x	5	2	0.4	0.01	x
Fshore 1A 0.4m	4,000	x	5	6	0.5	0.04	x
Fshore 2 0.05m	17,000	10	85	5	0.8	0.1	20
Fshore 2 0.15m	49,000	10	25	5	0.4	x	10
Fshore 2 1.5m	5,000	x	5	3	x	x	x
Arithmetic Mean	67,930	31	29	38	0.5	0.05	15

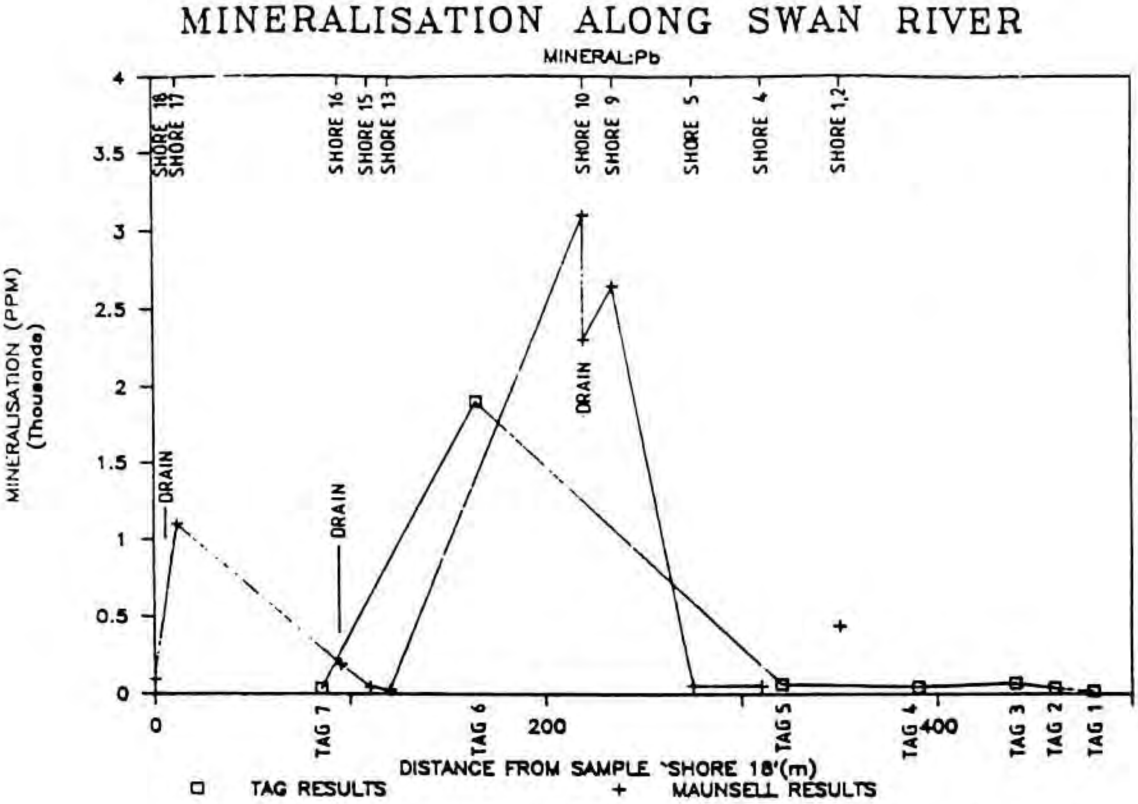


FIGURE 21

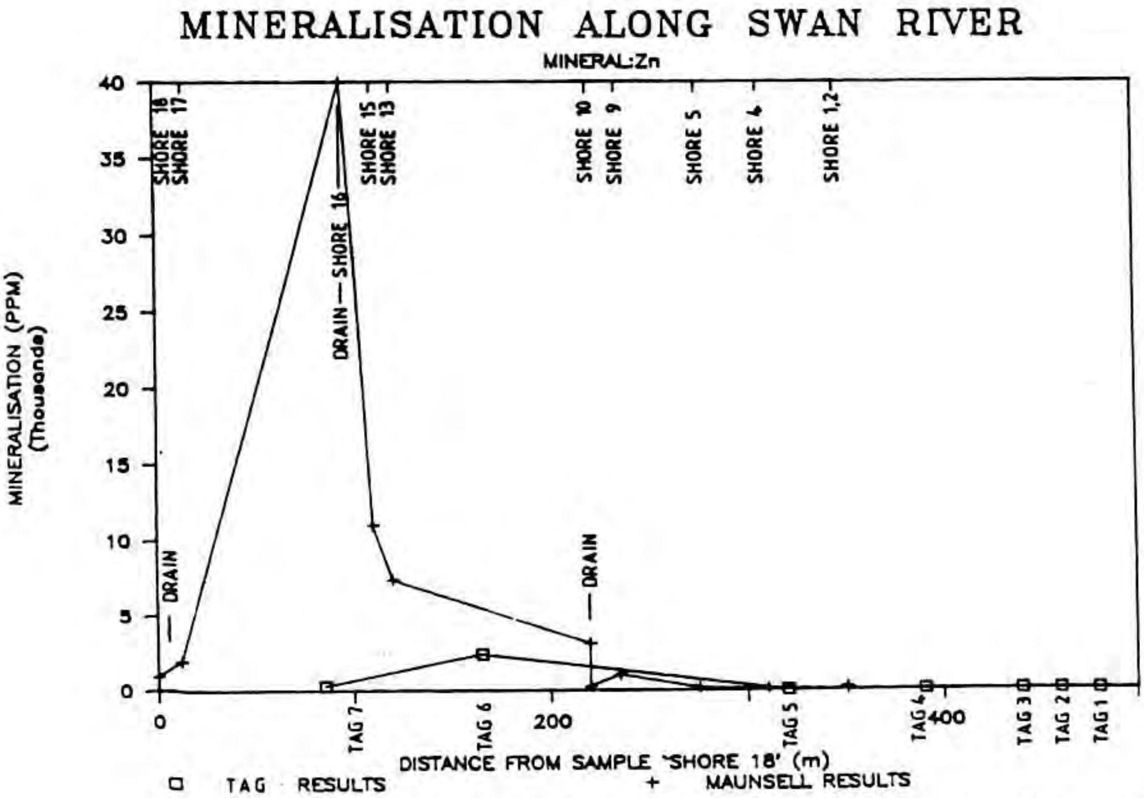


FIGURE 22

MINERALISTION ALONG SWAN RIVER

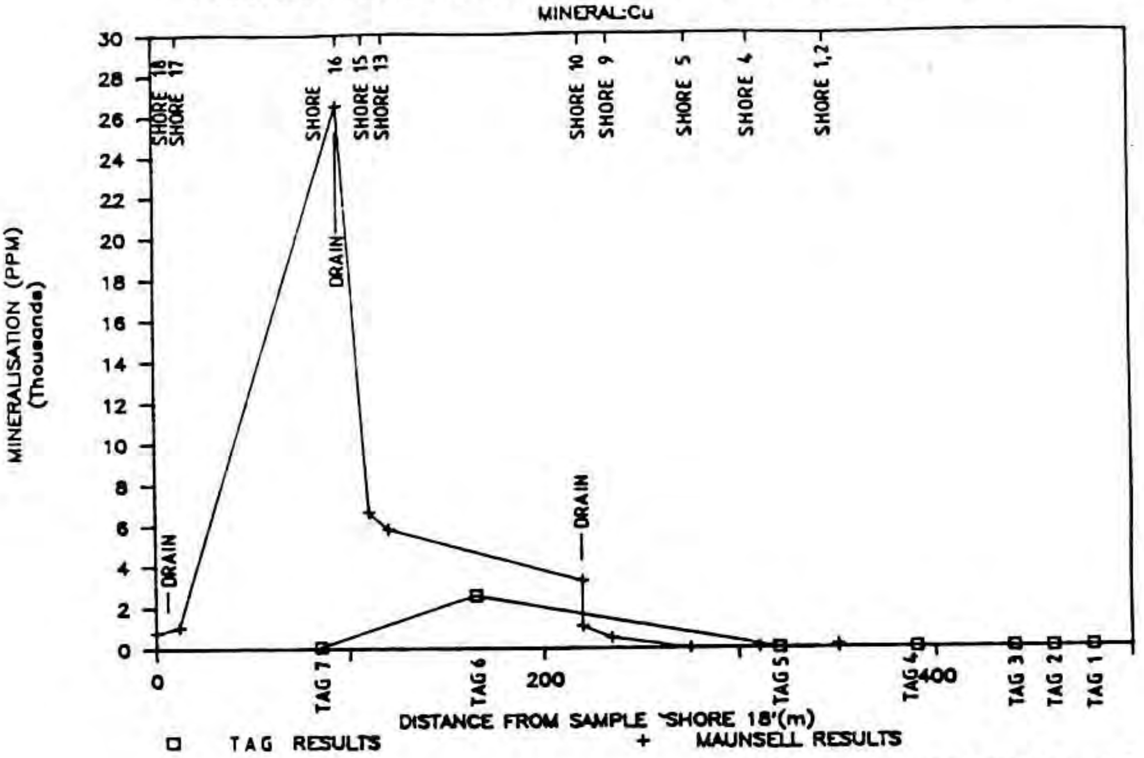


FIGURE 23

MINERALISATION ALONG SWAN RIVER

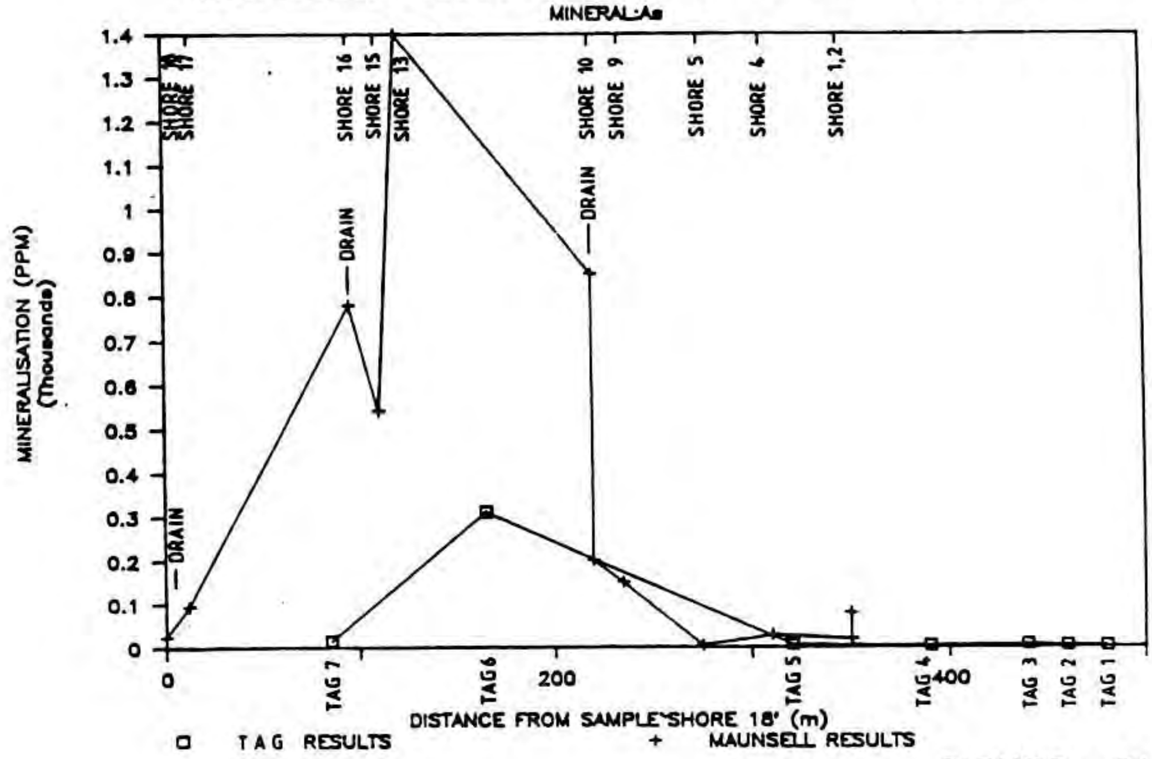


FIGURE 24

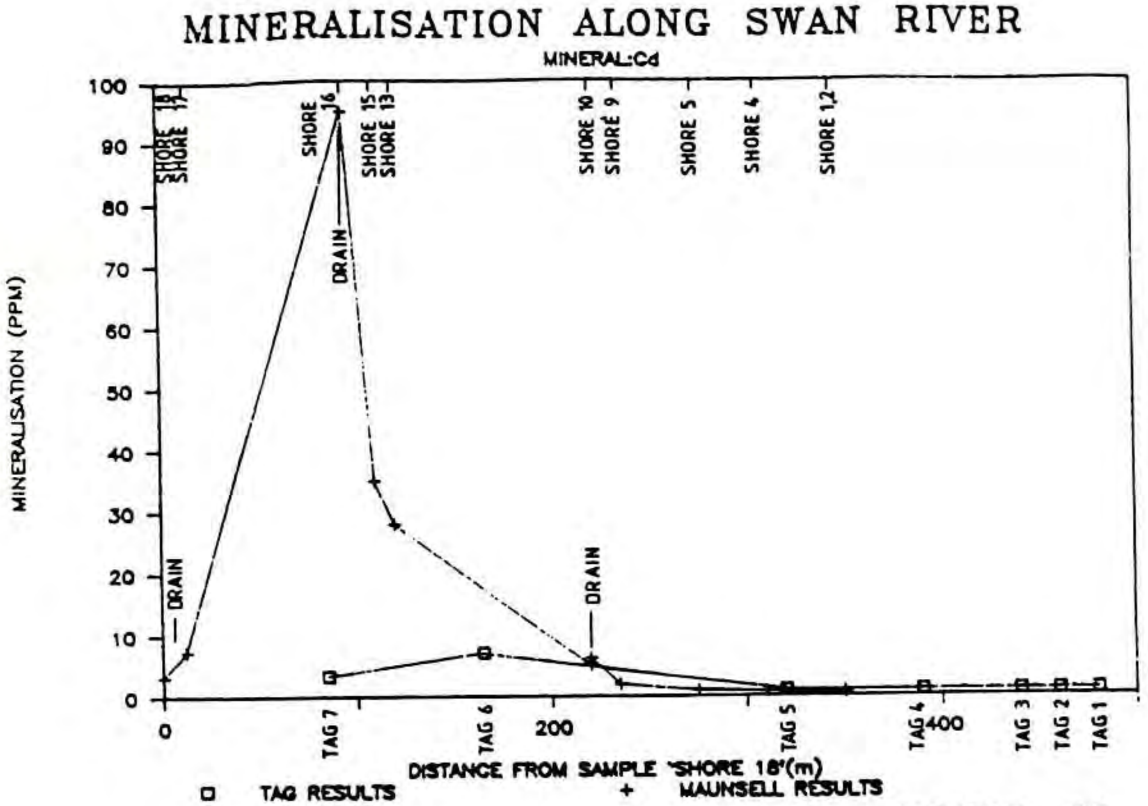

MINERALISATION ALONG SWAN RIVER
MINERAL:Cd
MINERALISATION (PPM)
100
90
80
70
60
50
40
30
20
10
0
SHORE 18
SHORE 17
SHORE 16
SHORE 15
SHORE 13
SHORE 10
SHORE 9
SHORE 5
SHORE 4
SHORE 1,2
DRAIN
DRAIN
DRAIN
0
TAG 7
TAG 6
200
TAG 5
TAG 4
400
TAG 3
TAG 2
TAG 1
DISTANCE FROM SAMPLE 'SHORE 18'(m)
□ TAG RESULTS
+ MAUNSELL RESULTS

FIGURE 25

As can be seen none of the arithmetic mean values of heavy metal concentrations are above allowable levels for agriculture (refer Table II) except for arsenic. However, as stated in Section 5.4.7 above there is, by inspection a good correlation between iron and arsenic levels indicating the probable presence of arseno-pyrites.

To clarify the situation with regard to the slurry contained within the agricultural drain further chemical analysis was performed on the relevant sample. It was reported by Analabs to be primarily a compound known as jarosite $(KFe_3(SO_4)_2\ OH_6)$. This is an essentially harmless compound but is formed in an acidic environment by the combination of iron and potassium.

The reason for the agricultural drain being at this location and the original method of disposal of the jarosite is unknown. The generally low levels of heavy metal contamination found in the slurry itself do not appear to give reason for great concern. However, the fact that this material has been formed and is evidently continuing to be formed in acidic conditions is of significance with respect to the possibility of leaching of other heavy metals from the dump (refer Section 6.2).

5.4.11 Embankment Sampling

Samples taken from the embankment and actually analysed were limited to those showing presence of pyrites cinders, bearing in mind the possibility of public access to this exposed material. The results of these analyses are presented in Table VI.

TABLE VI

EMBANKMENT SAMPLES

		Heavy Metal Concentrations (ppm)					
Sample	**Fe**	**Cu**	**Zn**	**As**	**Cd**	**Hg**	**Pb**
MT15 - E1	267,000	125	160	270	0.8	0.04	x
MT17 - E4	18,000	180	280	26	1.3	0.12	375
MT18 - E4	327,000	745	600	140	2.5	0.74	1250
MT21 - E2	423,000	105	115	200	0.7	0.04	x
MT22 - E1	58,000	245	215	21	2.0	0.14	950
MT22 - E3a	356,000	70	75	150	0.5	0.01	x
Arithmetic Mean	241,500	245	240	134	1.3	0.18	429

Comparison of these individual and mean concentrations with the levels given for Sample PH1 0.7m in Table IV indicates that unrealistically large quantities would generally have to be ingested to cause serious health problems (refer Section 5.4.7). However, isolated concentrations are high (Pb-1250ppm, Cd-2.5ppm, Cu-745ppm) as with samples analysed from other parts of the site.

5.4.12 River Beach Sampling

Samples obtained and analysed from the river beachline were specifically taken from areas showing clear signs of staining, or foreign deposits or in the immediate vicinity of drainage outfalls from the site above.

Reference to results given in Appendix B show a wide variation in concentration levels. However, particular concern is raised by the series of results for Samples Shore 09 to Shore 18.

Reference to Figure 10 indicates the extent of beach covered by these sample points and Table VII summarises the results of the analyses.

To assist in the interpretation of these results metal concentrations have been plotted against beach location with approximate locations of the TAG report samples also plotted. Figures 21, 22, 23, 24 and 25 show plotted results for lead, copper, zinc, arsenic and cadmium.

5.4.13 Mollusc Sampling

The samples of molluscs (Venus chemnitzii) were stored on ice and the flesh was analysed for heavy metal content. The results appear in Appendix A and are listed in Table VIII.

It can be seen that one of the sampled molluscs contained a heavy metal concentration above allowable Food & Drug Regulation levels, that being Sample Shore 12 with a mercury level of 1.7ppm (wet weight). This is over three times the allowable concentration for mercury. It is also relevant to note that one of the two mollusc samples analysed in the TAG report contained a lead concentration of 19ppm (wet weight), this being over seven times the allowable concentration for lead.

TABLE VII

RIVER BEACH SAMPLES

Sample	Location	Fe	Cu	Zn	As	Cd	Hg	Pb	pH
Shore 09	beach	204,000	530	1,050	150	2.0	0.43	2,650	
Shore 10B	mid-height of river bank	160,000	1,100	270	200	6.3	0.75	2,300	
Shore 10C	toe of river bank	176,000	3,300	3,100	850	5.1	0.80	3,100	
Shore 13	beach	53,000	5,850	7,400	1,400	28.0	0.08	25	7.4
Shore 15	beach	66,000	6,650	11,000	540	35.0	0.62	45	8.2
Shore 16C	toe of river bank	60,000	26,500	40,000	780	95.0	0.78	190	8.0
Shore 17	beach	66,000	1,050	1,950	95	7.3	1.8	1,100	
Shore 18	beach	43,000	780	950	25	3.2	0.03	95	
Arithmetic Mean		103,500	5,270	8,215	505	22.7	0.66	1,188	
TAG Report River Sediment - Sample No.6		-	2,600	2,400	310	7.1	1.40	1,900	

TABLE VIII

MOLLUSC SAMPLES

	Metal Concentrations (wet wt. mg/kg)			
Sample	As	Cd	Hg	Pb
Shore 5	0.3	0.1	0.07	1.0
Shore 8	<0.1	0.1	0.02	<1.0
Shore 12	0.3	0.1	1.70*	<1.0
Shore 13	<0.1	0.2	0.01	2.0
Shore 14-15	<0.1	<0.1	<0.01	<1.0
Shore 16	0.3	0.5	0.07	1.0
Shore 17-18	<0.1	0.4	0.04	2.0
Shore 19	0.2	0.1	0.05	1.0
Shore 21	0.1	0.1	0.01	1.0
Shore 23	0.1	<0.1	0.01	2.0
Allowable (Subreg.A.08.002 Food & Drug Regulations - Wet Weight)	1.0	2.0	0.5	2.5
Cockburn Sound Study 19.12.78 (Ref. 7) Mytilus edulis			0.06-0.41	
Derwent River Estuary Tasmania 1976 (Ref. 7) Mytilus edulis		0.7-6.3	0.07-2.16	0.5-88.3
Western Port Bay Victoria 1976 (Ref. 7) Mytilus edulis		0.1-4.0		<0.1-1.9
TAG Report (Ref. 1)				
Site 1	0.69	0.78	0.05	2.2
Site 6	0.35	0.15	0.09	19.0*
Venus chemnitzii				

* concentrations in excess of Sub-reg.A.08.002 Food & Drug Regulations

SECTION 6

DISCUSSION OF INVESTIGATION RESULTS

6. DISCUSSION OF INVESTIGATION RESULTS

6.1 GENERAL

Site development proposals as described in Section 5.2 were formulated as a necessary prerequisite to the definition and planning for the site investigations described in Section 5.3. The basis for establishing these proposals was the information gathered from reports on previous investigations and historical records.

In reviewing the results of these latest investigations it is considered that while the majority of assumed criteria used in developing the proposals have been confirmed there are a number of points where the more recent investigation results do not agree with conclusions drawn from the past work. There is significant potential for these differences to have a marked influence on the final development and treatment recommendations for the site.

6.2 PYRITES CINDERS

The pyrites cinders were generated by roasting of the pyrites in Herreshoff Furnaces used to produce sulphur for the fertiliser works (refer Reference 1). They are described in the TAG report as being "largely inert" and as not appearing "to be adding any heavy metals to the surrounding environment". It was also stated that the material contained less than 1ppm cadmium.

Results from a number of tests carried out in this latest investigation indicate that cadmium levels in excess of 1ppm can be identified with levels as high as 6.1ppm being reported. Although calculations referred to in Section 5.4.7 show that, in general ingestion of only ridiculously high quantities of this material would be likely to cause detrimental effects on health, isolated samples show much higher levels of contamination.

It will be noted from Appendix A that pH levels were tested in two series of samples taken from excavations through pyrites cinders. The relevant values are listed in Table IX.

TABLE IX

PYRITES CINDERS - pH LEVELS

Sample	Description	pH
PH2 1m	Light coloured pyrites cinders	8.8
PH2 2m	Pyrites cinders	4.3
PH2 3m	Pyrites cinders	7.9
MT17-4-1.0	Pyrites cinders	3.9
MT17-4-2.0	Crushed limestone	8.9

The formation of soluble heavy metal compounds can be expected to occur in an acidic environment that is generated by oxidation of sulphide constituents of the pyrites cinders and more particularly by any remaining pyrites in the roasted cinders. The possibility of such soluble compounds forming within the pyrites cinders is apparent in view of the acidity encountered in at least two of the samples as shown in Table IX. The associated possibility of leaching of these soluble compounds into the groundwater or onto the beach and into the river likewise cannot be discounted. The observation in a number of the trenches MT15 to MT22 of thin layers of variously coloured, generally hard materials at the interface between the crushed limestone and the pyrites cinders also indicates the possibility of active leaching. In particular, the blue vein in trench MT18 (3.4% Cu, 6.05% Zn, 240ppm Cd), the hard white vein encountered in trench MT15 (500ppm Cu, 1800ppm Zn) and the orange band of material in trench MT17 (possibly goethite Fe.O.OH) are considered to be indicative of deposits of heavy metal compounds precipitated as a result of contact with the alkaline limestone material beneath the cinders, or of the presence of ferric ferrocyanide. These materials are observed to be crystalline and would, where located, be expected to form an impermeable barrier to further downward moisture flows and consequent penetration of heavy metals.

It is possible that a thin layer of precipitated material has formed at the underside interface between the pyrites cinders on the embankment and the crushed limestone. This could result in the effective confinement of further leachate products to within the cinders but above this layer of precipitate. Such a process would result in leaching of soluble heavy metal compounds down the embankment through the pyrites cinders towards the river at times of heavy run-off. The observed staining along sections of the lower beach embankment (chosen as sampling points) gives further support to the above.

Testing and observations have not been specifically carried out to confirm the presence of such an impermeable layer but the lack of penetration of heavy metals, and in particular iron, into the limestone can be demonstrated by sample analyses given in Table X.

TABLE X

EMBANKMENT TRENCH ANALYSES

Sample	Material	Fe	Cu	Zn	As	Cd	Hg	Ph
MT17-4-1.0	Pyrites cinders	459,000	850	950	1100	6.1	8.80	2250
MT17-4-2.0	Crushed limestone	3,000	5	20	2	0.2	0.03	x
MT17-6-0.45	Pyrites cinders	152,000	900	1100	110	4.5	0.54	775
MT17-6-1.0	Crushed limestone	3,000	5	20	2	0.2	0.02	x
MT17-6-1.5	Crushed limestone	2,000	5	20	2	x	0.01	x

As detailed in Section 5.4.10 the yellow slurry discovered in the earthenware agricultural drain at the toe of the pyrites cinders dump on the river embankment has been identified as jarosite, a potassium iron sulphate that is not considered dangerous. The formation of jarosite results from the combination of iron (in this case from the pyrites cinders) with available potassium. This occurs in an acidic environment (pH<4).

Also as stated in Section 5.4.10 the reason for installing the agricultural drain at the base of the embankment pyrites cinders dump is not known. However, mention is made in a "Draft Background Paper" produced for the TAG investigation that in 1955 complaints were made regarding discoloured water identified as emanating from the Fertilizer Works and reaching the river. CSBP is reported to have advised that the discolouration was caused by seepage in periods of heavy rain. In view of this statement it is not considered unreasonable to conclude that the agricultural drain was installed about this time to intercept such seepage.

Jarosite is associated with weathering (oxidation) processes in stockpiles of iron-based materials and it is therefore considered possible that it is being formed within the embankment pyrites cinders dump. The surface staining at the embankment toe and the staining of the lower embankment limestone rock indicate that production and leaching of this material is continuing. This provides further evidence that active leaching processes are present within the embankment pyrites cinders dump.

It should be noted that none of the samples tested from the excavations Foreshore 1, 1A and 2 indicate excessively high levels of metal contamination (refer Table V). However, in view of the solubility and consequent mobility of other heavy metal compounds combined with the permeability of the underlying soil and rock these analyses do not necessarily mean that such compounds are not being formed or being carried down the embankment at a deeper level.

To provide further information regarding the potential for continued oxidation of the stockpiled pyrites cinders and the possible leaching of soluble heavy metal compounds Dr. J. Just, a consultant mineralogist, was requested to investigate the mineralogy of the dumped material. A copy of this report is included in Appendix F.

The relevant conclusions of the report may be summarised as:

(a) The mineralogical composition of the material is

- dominant : haematite
- subordinate : quartz, gypsum
- minor : barite, potassium feldspar
- trace : magnetite, calcite?, plumbojarosite

(b) Detected heavy metal minerals

- zincian brochantite
- azurite
- plumbojarosite
- cerussite??
- hydrated hydroxysulphates of iron and aluminium with small content of copper and zinc

(c) No sulphides were detected in the investigated samples, but the presence of ephemeral iron sulphates indicates that oxidation of sulphides to sulphuric acid is still taking place in the dump material (refer to Appendix A for results of sulphur analyses of selected samples).

(d) Copper, zinc and lead appear to be well contained within the dump material by the neutralising action of the limestone under low water flow conditions but copper and zinc could escape into the wider environment under conditions of increased water flow.

6.3 RIVER AND BEACH CONTAMINATION

In the TAG report definite conclusions are not drawn on the significance of levels of contamination to the river and adjacent beaches. The results presented do not indicate significant levels of contamination except in the vicinity of a drainage outfall.

Results of current inspection, sampling and analysis work strongly suggest that there is a significant length of beach that is relatively heavily contaminated. The analysis results presented in Table VII show very high levels of cadmium, arsenic, copper and zinc. There is some evidence to suggest that levels of contamination are related to the continued presence of drainage outfalls along this section. However, observations of staining on the face of the lower river bank tend to indicate the possibility of leachate seepage in some areas.

It is probable that the heavy metal contaminants present on the foreshore are in an insoluble form (e.g. carbonates) having been precipitated by contact with the alkaline limestone and sand on the lower embankment and beach. However, the presence of such compounds on the beachline indicate the possibility of the more soluble and toxic heavy metal compounds reaching the river during and after periods of heavy rainfall.

While the heavy metal concentration in the mollusc samples analysed are generally within acceptable limits, one mollusc collected from location Shore 16C (refer Figure 10) has unacceptably high levels of mercury. Correlation between shoreline contamination and mollusc contamination has not been attempted. Nevertheless the result of these analyses suggests that uncontrolled harvesting of molluscs in the area, in the absence of any orderly, longer-term monitoring programme, should be discouraged.

It is also noted that along much of the beachline individual pieces of pyrites cinders can be identified in the sand although the potential danger from this material is unlikely to be significant due to its apparent insolubility.

6.4 GROUNDWATER

Specific investigation of groundwater contamination has not been undertaken in the work associated with this report. The time and costs involved in drilling, core sampling, pumping and sampling groundwater were considered to be outside the scope of this investigation.

Consideration has, however, been given to the previous investigations carried out firstly by Rockwater Pty. Ltd. and secondly by the TAG. It is noted that the Rockwater investigations dealt specifically with the UWA land within Lot 416.

The following points are considered to be relevant with regard to the possibility of groundwater contamination beneath the site:

(a) The Rockwater report concludes that the groundwater beneath the southern and south-eastern ends of Lot 416 is contaminated with nitrate, and phosphate together with mercury. Samples were obtained at intervals during approximately 4 days of continuous pumping with precautions taken to avoid recirculation of pumped water.

(b) Criticism of the Rockwater investigation is made in the TAG report particularly with regard to the depth of the bores used. The bores extend to 8-10m below groundwater level but the Geological Survey of WA suggests that the bores should extend to the base of the aquifer at 28-30m below groundwater level. This may be a valid comment due to the possible downward migration of metal contaminants as a result of density differences.

(c) With reference to groundwater quality beneath the slurry dump the TAG report concludes that "apart from the occasional raised iron value all heavy metal levels are well below the maximum allowable ......". However, in an earlier reference to the bore from which samples were taken the comment is made that "...... this bore had not been properly developed and the sample taken may not be representative of the state of the groundwater below the dump". It is also noted that all groundwater samples from bores within the site were obtained by bailing and that prolonged pumping with sampling at intervals was not undertaken. On this basis it is considered that results quoted with regard to water quality must be of questionable reliability.

To summarise, it would appear that the Rockwater tests indicate the possible contamination of groundwater beneath the more heavily contaminated areas of Lot 416. The apparent lack of contamination of groundwater samples reported by the TAG may be due to poor sampling techniques.

Reference to Sections 6.2 and 6.3 indicates that there is potential for the development of soluble heavy metal compounds, particularly within the pyrites cinders dumps.

There is also evidence to support the fact that these compounds are mobile within an acidic environment. Surface staining and sample analyses again provide evidence that heavy metals are being carried down and accumulating on the beach below the site either by direct leaching or by mechanical means associated with stormwater runoff.

The presence and apparent continued leaching of jarosite is a further indication of the downward movement of contaminated water. There is considered to be the possibility of downward migration of heavy metals within the slurry dump as reflected in the significantly higher concentrations near the base of the dump (refer Table 2 in the TAG report, Reference 1). Although the metal concentrations within the limestone underlying the slurry dump are markedly lower than those within the dump the permeable nature of the limestone is considered to provide some concern for groundwater contamination remembering that the results of early groundwater testing was referred to as inconclusive in the TAG report.

6.5 ISOLATED CONTAMINATION

The detection of amosite in the trench survey MT4 is an explicit example of isolated contamination, commonly experienced in the development of contaminated sites. Although in the case of asbestos fibre the environmental hazard arises from inhalation of airborne fibres there is no risk from external contact, nor to water pollution. This example clarifies the need for some flexibility in subsequent site treatment. To this effect, the recommendations for site development (Section 8.3) include individual assessment of isolated contamination areas should they occur.

SECTION 7

REVIEW OF DEVELOPMENT PROPOSALS

7. REVIEW OF DEVELOPMENT PROPOSALS

In Section 5.2 preliminary development proposals for part of the site were formulated to allow adequate planning of subsequent site investigations. Formulation of these proposals was based on a review of previous site investigations and other historical records.

As discussed in Section 6 the results of the site investigations carried out as part of the present work point to a number of potential problems associated with various aspects of the preliminary proposals. In this Section, these potential problems are identified and their impact on the development proposals are discussed.

7.1 RIVER FORESHORE

Earlier comments in the TAG report concerning the extent and degree of sediment and biota contamination in the river tend to indicate that a serious problem does not exist in this regard. Mention is, however, made of the increased level of contamination (by up to two orders of magnitude) in a sediment sample taken in close proximity to a stormwater outfall.

Evidence gained from the analysis of soil and mollusc samples taken at relatively close intervals along the entire beachline adjacent to the site in this investigation indicates a more significant level of soil contamination over a stretch of approximately 250m of beachline. Details of these results are given in Section 6.3. Samples were taken from identifiable areas of contamination and although there are some indications of a correlation between drainage outfalls and high contamination levels there is the possibility that leaching is also causing accumulation of heavy metals at the embankment toe and on the beach.

Expert toxicological advice received on the basis of the maximum contamination levels discovered on the beach (refer Appendix C) is that they can be considered high for a beach frequented by children. In addition, it is noted that one of the mollusc samples obtained from the area of maximum soil contamination contained mercury levels over three times the maximum permitted metal concentrations in molluscs as defined in the Food and Drug Regulations (Subregulation A.08.002). Tabulated values of mercury concentrations in molluscs found in the Cockburn Sound study and from other areas are given in Appendix D.

In view of these results it is considered that this section of the beachline requires clean-up by removal of contaminated material from the beach and lower embankment and with replacement of this contaminated material with crushed limestone in order to immobilise, as far as possible, any heavy metal leachates. Suitable limestone rip-rap should be placed at the lower embankment toe to control erosion.

7.2 EMBANKMENT PYRITES CINDERS DUMP

The pyrites cinders dumped over the river embankment from approximately 1951 is described in the TAG report as "largely inert". Further, excavations made during this present investigation have revealed the presence not only of pyrites cinders but also isolated bands of other materials within the dump. In addition, the discovery of apparently active leaching of jarosite from the eastern end of this dump and conditions suitable to produce soluble heavy metal compounds indicates the possibility of leaching of such compounds from the dump as discussed in Section 6.2

Although the average heavy metal concentrations found in this material are not exceptionally high they are above levels recommended for agriculture and in some cases close to or in excess of levels set in NSW for use beneath playground areas (refer Table II). Results obtained for samples taken from within the pyrites cinders have been referred to a toxicologist for review. It has been deduced that ingestion of the cinders is unlikely to be a problem due to the large quantities required to cause health problems (refer Appendix C). However, a recommendation has been made to cover the material to minimise the risks of ingestion of particularly heavily contaminated material that may exist, to protect the bank from erosion and consequent spillage into the river and to seal the cinders from ingress of moisture.

In view of the results obtained and the independent advice summarised above it is considered that action needs to be taken to effectively treat this embankment material. The alternatives are to remove the pyrites cinders entirely to a more stable location or to cover the material in-situ with suitable material. The most appropriate covering is considered to be approximately 300mm of crushed limestone topped with approximately 700mm of clean fill. The limestone would assist in creating an alkaline environment as it acts upon any groundwater seepage and thereby tending to immobilise heavy metals within the pyrites cinders. Although this alkaline environment may enhance the migration of the arsenic contamination, it is highly likely that the excess concentration of iron in the pyrites cinders would react with arsenic to form low solubility arseno-pyrites and thereby immobilise the arsenic. The sand would permit landscaping of the area thus restricting public access to the slopes. As discussed in Section 8.3.5 there are major problems associated with stabilising cover material and this, together with the potential for continued leaching is considered to warrant complete removal of this material.

7.3 DISPOSAL OF CONTAMINATED MATERIALS

As detailed in Section 5.2 it was originally proposed to excavate the western pyrites cinders dump, the foundry waste dump and other areas of surface contamination within the residential area and to spread the material evenly over the lower, western end of the site.

Results obtained from the present investigations, particularly with regard to the possible leaching along the beachline and from beneath the embankment pyrites cinders dump are considered to indicate that adoption of the above proposals would be unwise. Even with a relatively thin layer of material spread over the area concerned there would be an attendant risk of contaminated leachates and water borne particles reaching the adjacent river and beachline or the underlying groundwater. The only effective means of controlling such processes are to either place all such material in a disposal area on the site and to cover it with suitable soil (limestone and sand) or to remove the material to an approved toxic waste landfill disposal site.

Alternatively, it may be appropriate to leave the dumps in their present positions and to similarly cover them. This will ensure any surface moisture ingress is alkaline and therefore will minimise the risk of formation and subsequent downward movement of soluble heavy metal contaminants. These options would necessitate the exclusion of both the western pyrites cinders dump and the foundry waste dump from the area potentially suitable for residential development.

In addition to the above mentioned major stockpile of contaminated materials the original site development proposals called for the spreading of stripped topsoil and subsoil from areas to be used for residential development on the lower, western end of the site (Zone C in Figure 4). In general, the new investigations have confirmed the lack of substantial contamination in these northern parts of the site. The need to carry out such stripping work is still seen as being necessary to remove all risks of encountering otherwise unidentified areas of contamination in the area proposed for development. However, the generally low levels of heavy metal content identified in trenches MT1 and MT2 and as previously reported in the other investigations are not seen as representing a significant risk of ongoing contamination if treated as originally proposed.

Reference is made in Section 5.4.4 to the discovery of a deposit of amosite in trench MT4 together with a surface screed of pyrites cinders in trenches MT3 to MT7.

In view of the above discussion and the hazardous nature of amosite it is considered that these and other such deposits that may be discovered during further site clean-up works should be disposed of by either of the two methods described above, namely by burial on site or by removal to an approved toxic waste landfill site (refer Section 8.3.1).

Finally, reference is made to Table II Item 3 (b) which lists the allowable levels for contaminated soil beneath playground areas as adopted in NSW. Consideration of the levels of contamination identified in the Analabs and TAG reports indicate that the area of the site occupied by the lead melters exhibits very high values of lead contamination.

In view of the criteria used in NSW it is considered inappropriate to recommend covering of this material with clean fill without some form of prior clean-up. It is therefore considered necessary for soil contained within this area to be removed from the site and buried deep within an approved toxic waste landfill site.

SECTION 8

RECOMMENDATIONS FOR SITE TREATMENT

8. RECOMMENDATIONS FOR SITE TREATMENT

8.1 INTRODUCTION

The scope of work to be covered by this report, as initially defined, related specifically to assessment of the potential for development of all or part of the site for residential purposes.

The evidence presented showing varying degrees of contamination over the site both from previous investigations and from the present work has revealed the need to consider the much wider implications of any such development on the site and adjacent areas. In particular, use of all, or even part, of the site for residential purposes will lead inevitably to increased public access to, and use of, the river foreshore. To some extent such increased usage may already be occurring due to the recent construction of a cycleway along the length of river embankment under study.

The recommendations for site treatment are presented as two separate options, each option providing for an increased level of site development. However, it should be noted that there is considered to be sufficient justification, particularly with respect to the foreshore soil and and mollusc analyses, for the recommended treatments under Option I to be adopted as immediate clean-up measures. As discussed, the Option I treatment can also be adopted in the long-term if it is decided not to develop any part of the site for some time. Residential development as initially envisaged in Section 5.2 of this report and as later modified in Section 7 will require the treatment recommendations outlined in Option II.

As discussed in Section 5.1.3 any attempt to develop the land must, in our opinion, be accompanied by a completely open statement concerning the past history of the Fertilizer Works and of the remedial works undertaken to ensure adequate clean-up of the site. Sale of freehold land under anything but this condition could not be supported. Whilst it is recognised that adoption of this course of action will undoubtedly have a negative effect on land values in any proposed development no attempt has been made to quantify such an effect. However, the recommendations contained herewith are considered to satisfy the need for minimising any risks associated with public ownership or use of the site and the adjacent river and its environs.

It is important to note that although adoption of Option I is seen as necessary immediately, whether or not residential development is planned, the recommended treatments may not preclude the possible future build-up of contamination particularly on the river foreshore since the prime sources of contamination are not being disturbed. The monitoring programme outlined for Option I is designed to give early warning of developing contamination and should this be observed then further treatment will be necessary. This applies in particular to the embankment pyrites cinders dump. Some consideration should also be given to the possible adverse reaction of local residents and users of the river foreshore to adoption of this option because of these longer term contamination risks.

To assist in comparison of Options I and II an attempt has been made to quantify the amount of work covered by each recommendation and to arrive at a budget estimate of associated costs. The estimated costs are given for each individual recommendation with full details of assumptions, rates and quantities given in Appendix E.

8.2 OPTION I - MINIMAL SITE DEVELOPMENT

Should it be decided not to develop any part of the site under consideration there are a number of clean-up activities that, in our opinion, require immediate attention.

There are clear signs of increasing public pressure on this section of the river and its immediate environs. Residential development within this part of Mosman Park is increasing with the close association of these developments to the river being a major factor in their popularity.

The results of the present investigations and, to some degree, of past investigations provide clear evidence to show that parts of the site and the adjacent river foreshore have undesirably high levels of heavy metal contamination.

It is considered to be unreasonable to subject users of the river or the site unknowingly to risks associated with such contamination of soils and biota.

The recommendations given are intended to prevent human contact with identified areas of contamination either by appropriate means of clean-up or by restriction of public access.

Control or restriction of public access is most difficult in the river foreshore area and for this reason the recommended clean-up treatments concentrate on this particular section of the site. Restriction of public access to the remainder of the site is relatively easy and therefore minimal treatment is recommended in these areas.

However, in leaving the bulk of the material that represents the source of contamination in its existing state there is a need to monitor conditions in areas where public access is maintained to ensure contamination does not exceed acceptable levels at some time in the future. In the event that recurrence of contamination does occur more stringent clean-up of the site will be necessary at least to the extent outlined for Option II with regard to the embankment pyrites cinders dump.

Briefly, the recommendations require security fencing of the main site and the river embankment to effectively restrict public access to areas of surface or near-surface contamination.

To maintain the river cycleway link it is recommended that the existing pathway be moved to the top of the embankment with additional security fencing to restrict access to each side.

Finally, as stated above, the principal clean-up effort is to be concentrated on the river foreshore and immediate embankment as effective restriction of public access to these areas is impracticable.

The basic features of the recommended site treatments are illustrated in Figure 26.

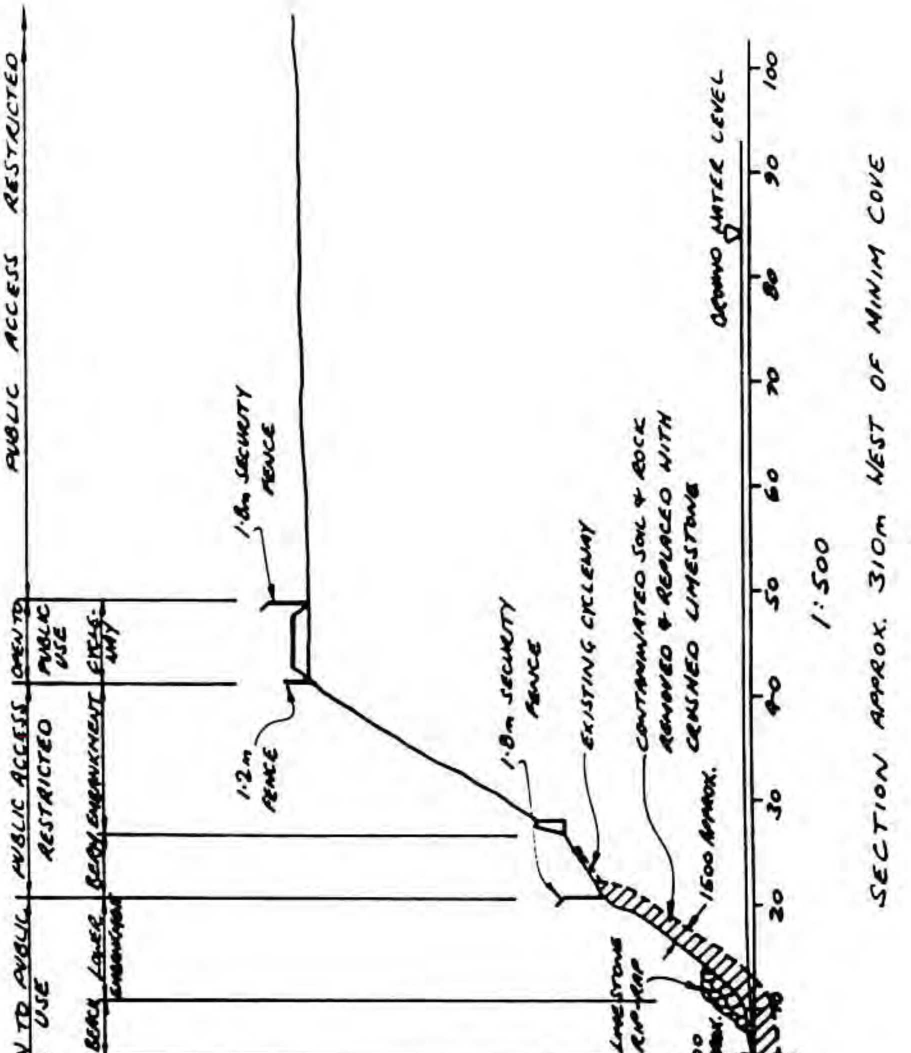
8.2.1 Site Fencing

It is recommended that the entire site and adjacent embankment be fully enclosed with chainlink security fencing topped with barbed wire. The fence alignment should follow the site boundaries as shown on Figure 1, with the following exceptions

(a) The security fence should run on the northern side of the realigned cycleway to prevent access to the main site area.

(b) Extension of the security fence as close as practicable to the edge of the river should be adopted with suitable openings allowed at each end of the site to accommodate the cycleway.

(c) Within the limits of the site a 1.2 to 1.5m fence should be installed on the south side of the realigned cycleway to maintain river views but to discourage public access to the steep and potentially unstable embankment slopes.



SECTION APPROX. 310m WEST OF MINIM COVE

PROPOSED TREATMENT OF RIVER
EMBANKMENT – OPTION I

FIGURE 26

(d) A full height security fence should be installed along the outer edge of the embankment berm to prevent public access to the site from the river.

(e) Gates should be provided in at least three locations to allow authorised access for maintenance of firebreaks, firefighting and site monitoring.

(f) Consideration should also be given to a fenced accessway between the cycleway and the Rocky Bay Village to preserve existing wheelchair and pedestrian movements.

A budget estimate of costs for this work is $37,000.

8.2.2 Cycleway

It is recommended that the recently constructed cycleway be relocated from its present alignment along the embankment berm to the top of the embankment. The new cycleway should be constructed on a minimum of 1m of clean fill placed over the existing ground level. It is noted that at the western end of the site the cycleway is presently aligned along the top of the embankment. It is recommended that the current alignment be maintained in this area but that the cycleway be re-constructed on 1m of clean fill as for the more easterly section.

A budget estimate of costs for this work is $43,000.

8.2.3 Stormwater Collection Systems and Outfalls

It is recommended that all existing stormwater collection systems and outfalls on the site be fully excavated and removed. Disposal of rubble and other debris shall be to an approved toxic waste landfill site because of the possibility of pipes containing contaminated silts. It is recommended that all trench excavations in the embankment necessary to remove the outfalls be fully backfilled with at least two impermeable barriers across each trenchline to prevent continued preferential drainage through the backfill.

A budget estimate of costs for this work is $8,000.

8.2.4 River Bank and Beaches

It is recommended that the section of the lower river bank and adjacent beachline that has been identified as being particularly contaminated between sampling points Shore 9 and Shore 18 (refer Section 5.4.12) should be cleaned up. Such action should include:

(a) Excavation and removal of beach sand together with loose rock and soil from the lower embankment. The initial extent of such excavation should be guided by visual inspection but finally determined by further sampling and testing.

(b) Re-establishment of the bank profile and beachline with crushed limestone filling and including replanting of the lower embankment slopes and placement of limestone rip-rap to prevent scour of the rebuilt slopes.

(c) Collection and destruction of all molluscs along the entire stretch of beachline adjacent to the site. The opportunity may also be taken to analyse additional mollusc samples to confirm the extent of contamination.

(d) Placement of contaminated material removed from the beach in a discrete stockpile not exceeding 1.5m in height adjacent to the toe of the western pyrites cinders dump and covering of this stockpile with crushed limestone to a depth of not less than 0.5m.

A budget estimate of costs for this work is $180,000.

The costs of excavation are based on the use of a hydraulic excavator loading into off-highway dump trucks with minor hand excavation necessary to clean out crevices within the underlying limestone rock.

Reconstruction of the embankment would also be achieved using a hydraulic excavator.

8.2.5 Monitoring Programme

Recommended site treatments outlined for Option I are designed to minimise the chances of contact by the public with contaminated soil on the site itself and to remove surface contamination from the river foreshore and immediate embankment areas. The following monitoring programme is designed to confirm the effectiveness and integrity of these restrictions and to monitor any recurrence of contamination on the beaches and lower embankments.

(i) The integrity of all security fencing and other miscellaneous fencing should be checked by inspection at six monthly intervals. All necessary repairs should be carried out promptly (within one week) and action taken to restrict unauthorised access, for instance by burrowing under fencing or due to damaged gates.

(ii) The restored river beachline and adjacent embankment should be inspected for scour and erosion initially at six month intervals for at least two years. Inspection may be reduced to yearly intervals thereafter subject to satisfactory stability being achieved in the first two years. Any damage noted in these inspections should be repaired promptly.

(iii) Inspections should be carried out at least twice during each winter period and preferably immediately after heavy rainfall events to identify and analyse any leaching that may occur either from the slurry dump, the embankment pyrites cinders dump or the backfilled drainage outfall points. Additionally, such inspections should also be carried out immediately after any unseasonal rainfall events. The extent and frequency of such inspections should be varied according to results and experience gained over an initial five year period. The inspections should initially include the entire length of the river foreshore adjacent to the site.

(iv) A network of slotted PVC groundwater monitoring bores should be installed either along the upper beachline or on the embankment berm. The bores should be used to monitor the quality of the shallow groundwater at yearly intervals. The bores should penetrate to different levels in the aquifer up to approximately 3m depth. Each bore should be designed to sample from a small depth range (300mm) of the aquifer by selective slotting. Samples should only be taken after at least 3 volumes of each bore's contents have been pumped and discarded. Analyses should test for heavy metals and also pH (measured on site) since a drop in pH will indicate the possible presence of soluble, heavy metal compounds.

(v) Samples shall be taken and analysed at preselected locations along the foreshore adjacent to the entire site at six monthly intervals for a period of five years. Particular attention should be applied to the area identified as being heavily contaminated in this report (i.e. location Shore 9 to location Shore 18, Figure 10). In addition, and as necessary in light of the soil analysis results, any molluscs appearing on the foreshore should be representatively sampled and analysed.

From the initial five year period sampling frequency may be reduced to twelve monthly intervals provided previous results show no signs of increasing contamination.

(vi) Subject to any further groundwater investigation work that may be carried out (refer Section 8.5) it is recommended that all permanent bores on the site and particularly those close to or along the river embankment should be sampled and analysed at six monthly intervals for two years and at yearly intervals thereafter. Sampling frequency after the first five years may be varied to suit previous analysis results.

Samples should be taken from water pumped at a set rate to the surface and at time intervals all as recommended by a qualified Groundwater Consultant.

(vii) In order to assess the long term stability of the contaminants within the various waste dumps, an investigation of the leachate generation potential of the various contaminated soils is strongly recommended. Such an investigation would enable long term prediction of contaminant migration under the alkaline sub-surface conditions designed.

8.3 OPTION II - SITE DEVELOPMENT

A decision to develop part of the site for residential purposes as detailed in Section 5.2 and modified in Section 7 significantly alters the criteria under which treatment recommendations are formulated. To reiterate previous statements it is seen as essential to ensure that land subject to sale as freehold property is free of contamination. It should also be recognised that moves to develop part of the site will result in additional public pressure on the river and its immediate environs. In view of the stated close relationship between land values and proximity to the river moves to restrict access to any part of the site adjacent to the proposed residential area or to the river and the embankments will seriously detract from the perceived quality of land available. It is therefore seen as essential that any proposal to develop the site be accompanied by sufficient treatment to ensure free public access to all parts of the site such that there is no direct contact with contaminants and minimal risks for development of future contamination.

Essentially the following recommendations are designed to make available for residential development an area of the site that is relatively free of existing contamination but which will be subject to minor surface clean-up to ensure any unidentified sources of contamination are removed. The remaining area of the site will be covered to form a passive recreation area with additional treatment of the river foreshore and the embankment pyrites cinders dump recommended to meet the public access and land use criteria stated above.

The basic features of the recommended site treatments are illustrated in Figures 27, 28 and 29, each sketch showing different aspects of the treatments.

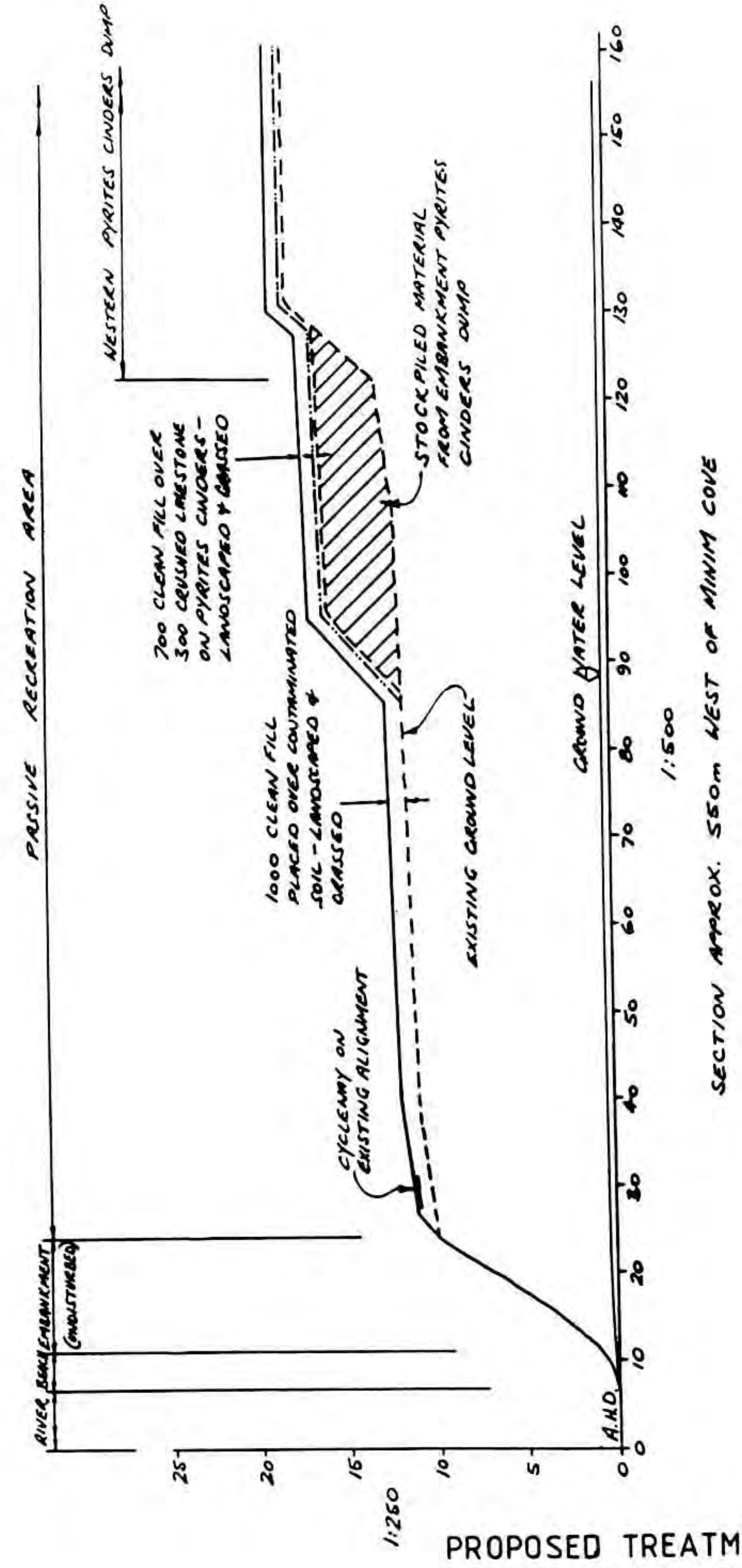
8.3.1 Area for Residential Development

It is recommended to confine the extent of any residential development to the area shown in Figure 30. It is considered to be a practicable and economical solution to remove all but minor traces of contamination from the area identified and therefore permit normal residential development to proceed without restriction. The only exception to this being the limit on groundwater usage which should remain until more exhaustive and definitive studies can be completed on this aspect of contamination.

It is recommended that soil to a depth of not less than 300mm be removed from the area concerned unless solid bedrock is found at lesser depth in which case all loose material should be stripped. Caution will be required when handling stripped materials to ensure minimal dust generation. The work should therefore be programmed for winter with strict requirements related to watering for dust control purposes. Inspection by a qualified chemist and supplementary soils testing should be employed to ensure removal of all contaminated ground. It is envisaged that bulk earthmoving equipment and techniques will be suitable for the work subject to adequate dust control measures.

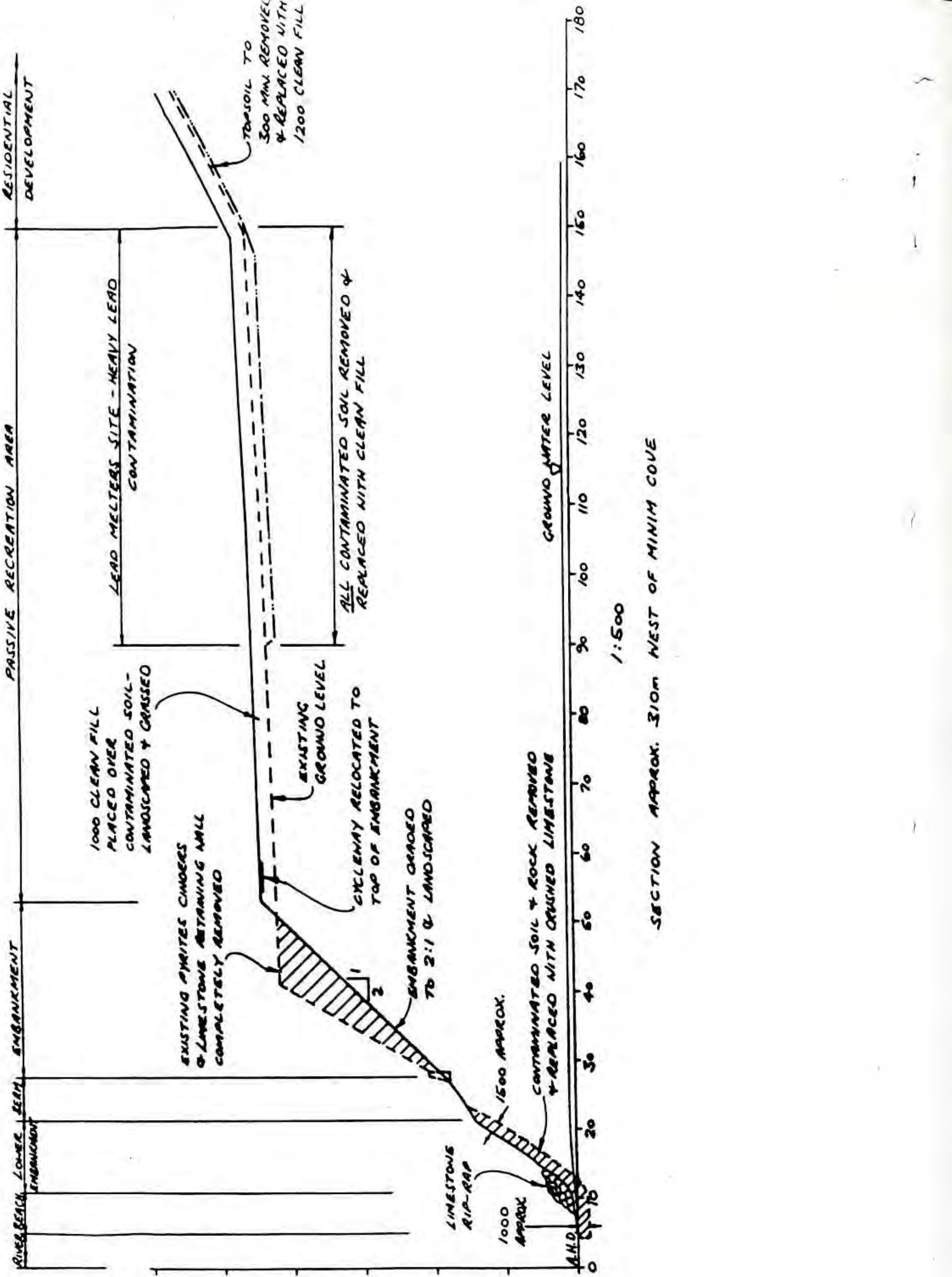
The area for development should then be covered with a minimum of 1.2m of clean fill.

Stripped material, with the exception of identifiable pyrites cinders or other deposits of foreign material should be placed over the lower western end of the site. Pyrites cinders from the area to be cleaned



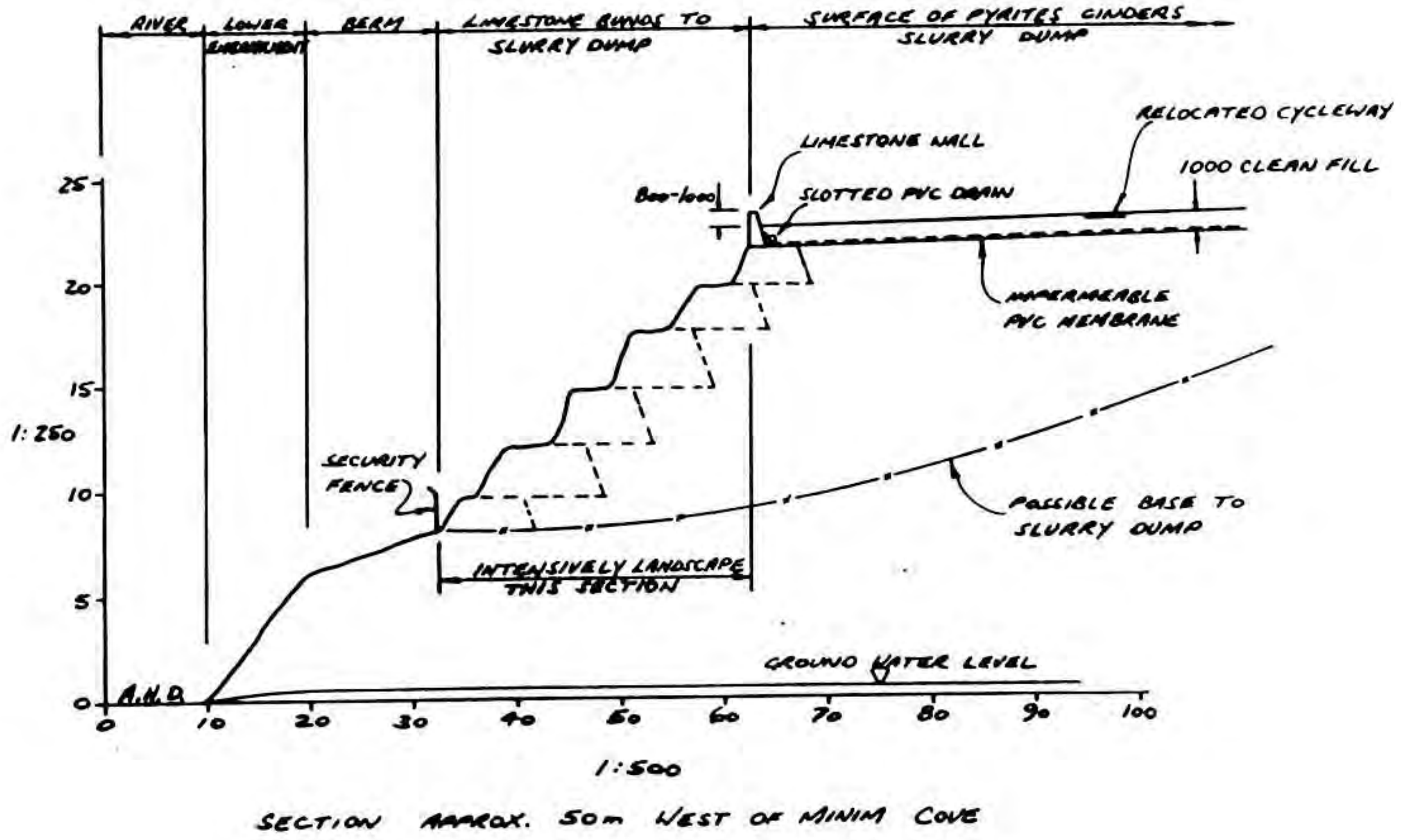
PROPOSED TREATMENT OF GENERAL SITE – OPTION II

FIGURE 27



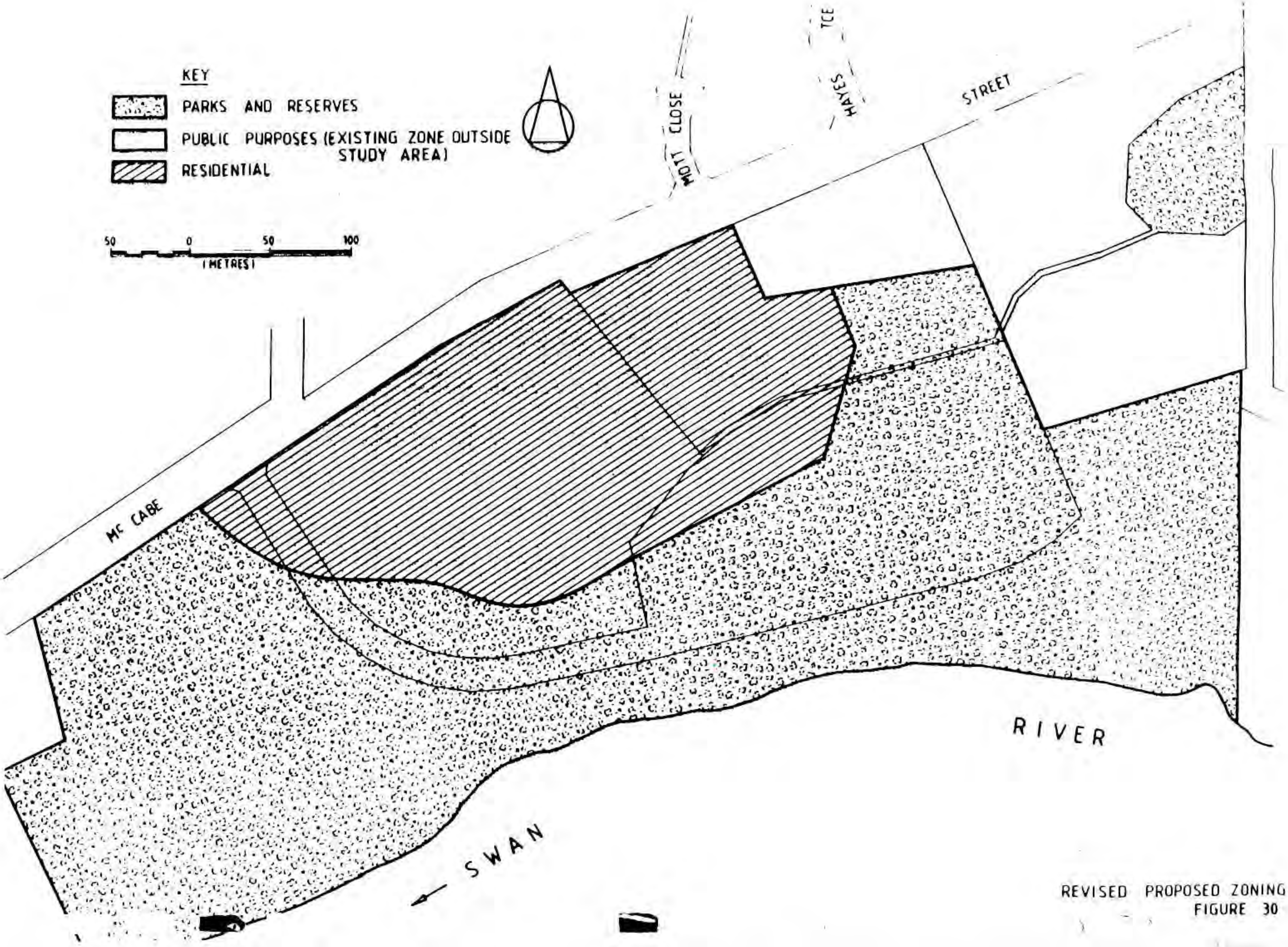
PROPOSED TREATMENT OF RIVER EMBANKMENT & SITE – OPTION II

FIGURE 28



PROPOSED TREATMENT OF
PYRITES CINDERS SLURRY
DUMP – OPTION II

FIGURE 2



REVISED PROPOSED ZONING
FIGURE 30

up should be added to the surface of the western pyrites cinders dump. Any deposits of foreign material encountered should be identified and either treated similarly to the pyrites cinders or, if this is judged to be inappropriate, removed from site to an approved landfill site (e.g. amosite found in trench MT4). Due to the anticipated minimal degree of contamination in the stripped material that is to be placed on-site, the various stabilisation-solidification and chemical fixation technologies available for heavily contaminated materials are not believed to be warranted. However, random assessment of the "uncontaminated" material for total and mobile contaminant concentrations is recommended.

A budget estimate of costs for this work is $121,000.

8.3.2 Pyrites Slurry Dump

It is recommended that the surface of this dump be covered with an impermeable membrane to prevent moisture ingress and that steps be taken to restrict public access to the front slope. Although there is no clear evidence to suggest leakage of hazardous material (e.g. soluble heavy metal compounds, cyanides, etc) from this dump it is considered unlikely that the permeable limestone will have sealed entirely and may therefore be allowing leachate to enter the groundwater or otherwise seep towards the river. The Rockwater bore No.4 encountered elevated levels of phosphate and mercury indicating the possibility of leaching.

In the absence of further, more exhaustive testing to confirm the occurrence of leaching it is considered appropriate to seal the surface and thereby prevent ingress of moisture to the already heavily moistened slurry. It is recommended that a PVC membrane (Canvacon 16SS or similar) be spread over the dump area on a 150mm thick layer of clean sand and this then be covered with 1m of clean fill.

Restriction of public access to the front slopes of the dump is necessary to avoid disturbance and consequent erosion of these steep faces. It is recommended that this restriction be achieved by the construction of a low (800-1000mm) limestone wall along the top edge of the dump. Use of this wall to retain the 1m of clean fill over the dump will create a 1.8 to 2.0m drop to the steeply sloping bunds on the river side of the wall and should therefore effectively discourage public access. The bottom of the bundwall slope should be security fenced and returned as necessary to meet the limestone wall to isolate the slope area. The slopes should then be intensively landscaped to further dissuade public access (refer Section 8.3.10.) It will be necessary to install a leach drain immediately behind the limestone wall to intercept and remove groundwater seepage above the membrane and to carry it to a suitable sump.

The advantage of treating the slurry dump in this way is that it forms a high point along this stretch of the river and therefore offers the possibility of development as a viewing area. Also consideration should be given to the possible use of this area by the Rocky Bay Village for additional parking or recreational purposes.

A budget estimate of costs for this work is $92,000.

8.3.3 Riverbank and Beaches

It is recommended that the treatment of these areas outlined in Section 8.2.5 for Option I also be applied for Option II.

As previously, the budget estimate of costs for this work is $180,000.

8.3.4 Cycleway

In order to complete embankment works as detailed in Section 8.3.5 it will be necessary to remove the existing cycleway at least in the area adjacent to the embankment pyrites cinders dump. It is therefore considered appropriate to relocate the cycleway to the top of the embankment as detailed in Section 8.2.2. However, with the more elaborate embankment treatment recommended below the need for fencing will be obviated and placement of fill will be provided for in the overall recreation area development.

A budget cost estimate for relocation only of the cycleway is $35,000.

8.3.5 Embankment Pyrites Cinders Dump

To achieve an acceptable level of protection for future users of the site and, in particular, of the river foreshore and embankment area it is considered necessary to remove the dumped pyrites cinders material. Assessment has been made of alternative treatments such as covering and sealing the dump (as recommended by the toxicological report, Appendix C) but the costs associated with such treatment, particularly in relation to the need to retain such covering material on the steep slopes, are prohibitive. Partial treatment with a covering of crushed limestone and sand would offset the cost of sealing but such treatment would not eliminate the possibility of future leaching with consequent recontamination of the beaches and

biota. Further, indicative costs of such partial treatment are similar to the estimated costs for removal of the material due to the need for retaining structures and therefore little advantage is seen in pursuing these alternative courses of action.

It is considered practicable to excavate the material with a large hydraulic excavator loading into dump trucks although scope exists for alternative methods of excavation. Again, dust control would be of paramount importance with the work programmed for the winter months and water spray application as necessary. The material should be removed to form an extension of the western pyrites cinders dump.

Following removal of all the pyrites cinders and any other foreign materials encountered the embankment slope above the existing berm should be flattened to a slope not exceeding 26^{o} (approximately 1:2). The slope should then be covered with 1m of clean fill and intensively landscaped (refer Section 8.3) with discrete paths provided at selected locations to facilitate public access to the river.

8.3.6 Former Lead Melters Site

It is recommended that all soil within this heavily contaminated area be excavated and removed from the site and deeply buried in an approved toxic waste landfill site. The levels of lead contamination in this area are well above even the 2000ppm level recommended by the NSW State Pollution Control Commission for use beneath clean fill on recreational areas (refer Table II). It is therefore considered inappropriate to allow this material to remain at the site even under a clean soil covering.

A budget estimate of costs for this work is $32,000.

8.3.7 Western Pyrites Cinders Dump and Foundry Waste Dump

It is recommended that these dumps be left undisturbed. However, in order to minimise the chances of leaching, particularly of soluble heavy metal compounds, it is recommended that the surface of each dump be covered with 300mm of crushed limestone topped with 700mm of clean fill. This treatment also applies to the stockpiled pyrites cinders from the embankment dump.

A budget estimate of costs for this work is $216,000.

8.3.8 Passive Recreation Area

It is recommended that all areas of the site not identified in Figure 26 as being suitable for residential development be reserved for passive recreation purposes. The area should be covered with a minimum of 1m of clean fill. It is also recommended that all Local and State Government authorities be made fully aware of the underlying nature of the site to ensure no future uncontrolled excavations or development is allowed to take place.

A budget estimate of costs for this work is $110,000.

8.3.9 Stormwater Collection Systems and Outfalls

The recommendations in Section 8.2.4 for Option I should also be followed for Option II.

The budget estimate of costs for this work is $8,000.

8.3.10 Landscaping

It is recommended that the passive recreation area, the river embankment and the pyrites slurry dump slopes be planted with grass and shallow rooted shrubs and plants. Reticulation of the area should only be implemented if absolutely necessary and where a bore can be located at a point as far remote from the surface contamination as possible. In the event that such a bore is installed regular monitoring of water quality is recommended as being essential (refer Section 8.5).

A budget estimate of costs for this work without allowance for reticulation is $150,000.

8.3.11 Monitoring Programme

Due to more stringent and widespread measures recommended for Option II the need for a large scale monitoring programme is obviated. However, potential for contamination of the groundwater remains and in conjunction with any additional groundwater studies it is recommended that ongoing sampling and analysis be undertaken to monitor groundwater quality if Option II is adopted.

Also a local authority monitoring programme should be developed to ensure the integrity of the covering of clean fill over the various dump sites and the passive recreation area is maintained. The slopes of the slurry dump should be regularly checked (six monthly) for erosion or other disturbance.

8.4 BUDGET ESTIMATE SUMMARY

The following is a budget estimate summary of the costs likely to be associated with each of the options for site treatment. As previously discussed the estimates have been based on the best information available but their accuracy is necessarily open to question due to the unpredictable extent and nature of contamination in areas not already fully investigated. In order to provide for this uncertainty final total costs given below have a contingency allowance of 10% added to the estimate. It is noted that the estimates have also been adjusted from the individual item estimates to include for design documentation and supervision fees.

Option I - Minimal Site Development

Estimated Cost	$ 300,000
10% Contingency	$ 30,000
Total Budget Estimate	$ 330,000

Option II - Residential Development

Estimated Cost	$ 1,200,000
10% Contingency	$ 120,000
Total Budget Estimate	$ 1,320,000

8.5 ADDITIONAL GROUNDWATER INVESTIGATIONS

As discussed at length in Section 6.4 and in various other sections the extent of the investigations into the possible contamination of groundwater beneath the site are not considered adequate. No further work has been carried out in this regard as part of this present study because of timing and funding limits. Also, it is only since the results of this latest investigation have become available that the implications of those results with regard to groundwater contamination have become apparent. In particular, the discovery of the leach drain at the toe of the pyrites cinders embankment dump, signs of leaching in other areas of that dump and the observed signs of leaching at the beachline indicate a potential for groundwater pollution.

The recommendations outlined for Option II of the site treatment with respect to the pyrites slurry dump are designed to minimise the further passage, if any, of contaminants into the groundwater. Although the limestone and sand underlying the slurry shows little sign of heavy metal contamination it is possible that soluble and therefore highly mobile heavy metal compounds are present and are being carried through these formations and directly into the groundwater. It is not considered that work to date has been sufficiently thorough to show that no problem exists and that the base of the dump has actually "sealed" itself. Increasing pressures of residential and recreational uses in and around the area will continue to place increasing demands on water from this aquifer.

The cost implications related to the need for treatment of the pyrites slurry dump over and above the recommendations given in Option II (Section 8.3.2) are such that it is considered justifiable to undertake a complete and thorough investigation of groundwater contamination beneath the entire site.

To formulate and instigate such an investigation it is recommended that a suitably qualified and experienced Groundwater Consultant be commissioned at the earliest opportunity.

In addition, a predictive understanding of future leachate mobilisation of contaminants from the dumps may be achieved through appropriate leachate testing procedures such as the US Environmental Protection Agency's Toxicity Concentration Leachate Procedure (TCLP). This procedure has recently been tentatively adopted by the NSW State Pollution Control Commission. Such testing would enable an assessment of the long term mobilisation potential of the contaminants and would thereby enable the development of strategies to obviate the future contamination risks.

APPENDIX A

ANALYSIS RESULTS

APPENDIX A

ANALYSIS RESULTS

The results presented herein are in the form of test certificates and reports prepared and authorised by Analabs. The samples analysed were collected by Maunsell & Partners Pty. Ltd. and submitted to the laboratory for testing.

ANALABS

A division of MacDonald Hamilton & Co. Pty. Ltd.

Phone (09) 458 7999
52 Murray Road, Welshpool, W.A. 6106
Telex AA92560

ANALYTICAL REPORT No. 1000.0.01.41869

THIS REPORT MUST BE READ IN CONJUNCTION WITH THE ACCOMPANYING ANALYTICAL DATA

Maunsell & Partners Pty Ltd
PO Box 7190
Cloisyters Square
Perth
WA 6000

ORDER No. 118289
PROJECT
DATE RECEIVED 09/12/85
RESULTS REQUIRED ASAP

No. OF PAGES OF RESULTS 12
DATE REPORTED 13/12/85
No. OF COPIES 1
TOTAL No. OF SAMPLES 146

STATE OF SAMPLES		PRE-TREATMENT							ANALYSIS		
REFER BELOW	SAMPLE NUMBERS	DRY	CRUSH	SPLIT	PUL-VERISE	SIEVE	OTHER SEE REMARKS	NONE	REFER TO ANALYSIS SECTION	PREPARATION	METH
	Pret:MT01										
	various				1				Cu,Pb,Zn,Fe		101
									As		114
									Cd,Bi		102
									Hg		122
B	various										
	Pret:MT01										
	various				1				Cu,Pb,Zn,Fe		10
									As		114
									Cd,Bi		10
									Hg		12

RESULTS TO

as above

RESULTS TO

REMARKS

This Laboratory is registered by the National Association of Testing Authorities, Australia. The test(s) reported herein have been performed in accordance with its terms of registration. This document shall not be reproduced except in full.

STATE OF SAMPLES	
whole core	WC
split core	SC
cutting	CU
rock	Ro
soil	SO
pulp	PU
water	WA
tissue	TI
stream sediment	SS
heavy mineral	HM

ANALYSIS — PREPARATION			
perchloric acid	A1	cold acid	CA
hydrochloric acid	A2	specific sulphide	SS
nitric acid	A3	other mixed acids	Ma
aqua regia	A4	alkaline attack	AA
nitric-perchloric	A5	volatilization	VO
HF mixture	A6	ignition	IG
HF under pressure	A7	pressed powder (XRF)	PP
fusion	A8	glass fusion (XRF)	GF

ANALYSIS — METHOD	
atomic absorbtion	AAS
x-ray fluorescence	XRF
spectrophotometry	SPEC
colorimetry	COL
chromatography	CHR
titration	TTN
other chemicals means	CHEM
miscellaneous	MISC
fluorescence	FLUO
inductively coupled plasma	ICP

AUTHORISED OFFICER

ANALABS

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ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	1000.0.01.41869	13/12/85	118289	1 OF 12

TUBE No.	SAMPLE No.			Fe%	Cu	Zn	As	Cd	Hg	Pb
1	Fndry 4 Grid 2 1m			2.5	1900	520	2	1.6	0.100	355
2	Fndry 4 Grid 2 2m			3.2	2750	1500	7	3.7	0.110	315
3	Fshore 1 0.15m			15.1	40	35	100	0.5	0.060	30
4	Fshore 1 0.3mA			0.4	5	10	3	0.4	x	5
5	Fshore 1 0.3mB			16.2	45	35	120	0.6	0.100	110
6	Fshore 1 0.8m			0.3	5	10	2	0.5	x	x
7	Fshore 1 200mm Above Drain			5.9	45	20	79	0.4	0.050	20
8	Fshore 1 200mm In Pipe			16.3	35	15	100	0.3	0.050	10
9	Fshore 1 250-300mm below			2.0	55	75	5	0.9	x	5
10	Fshore 1 Below drain			15.0	90	20	100	0.6	0.040	x
11	Fshore 1 Rock below drain			7.8	80	30	16	0.6	0.320	x
12	Fshore 1A 0.5m below gnd			4.9	50	65	20	0.6	0.040	10
13	Fshore 1A 1m			0.5	x	5	2	0.4	0.010	x
14	Fshore 1A 400mm			0.4	x	5	6	0.5	0.040	x
15	Fshore 2 0.05m			1.7	10	85	5	0.8	0.100	20
16	Fshore 2 0.15m			4.9	10	25	5	0.4	x	10
17	Fshore 2 1.5m			0.5	x	5	3	x	x	x
18	MT01 005 0.05			0.7	15	10	3	0.5	x	5
19	MT01 005 0.4			0.5	5	10	3	0.5	x	[illegible]
20	MT01 005 10 0.05			0.6	20	85	4	0.6	0.040	10
21	MT01 010 0.05			0.7	15	35	3	0.3	0.040	2
22	MT01 010 0.3			0.9	5	25	3	x	x	[illegible]
23	MT01 010 20 0.05			0.9	35	55	5	0.6	0.060	20
24	MT01 020 0.05A			0.8	30	95	4	0.5	0.040	20
25	MT01 020 0.05B			0.7	35	35	6	0.1	0.040	10

Results in ppm unless otherwise specified
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ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	1000.0.01.41869	13/12/85	118289	2 OF 12

TUBE No.	SAMPLE No.			Fe%	Cu	Zn	As	Cd	Hg	Pb
1	MT01 020 30 0.05			0.9	30	90	5	0.5	0.040	15
2	MT01 030 0.05			0.7	15	25	3	0.2	0.020	1
3	MT01 030 35 0.05			0.8	30	25	6	0.2	0.030	1
4	MT01 050 0.05			0.3	x	5	2	0.1	x	x
5	MT01 050 60 0.05			0.6	x	x	1	x	x	x
6	MT01 060 0.05			0.6	x	x	2	x	x	x
7	MT01 060 0.4			0.4	x	x	2	x	0.010	x
8	MT01 060 70 0.05			0.5	10	15	2	x	x	x
9	MT01 070 0.05			0.5	10	15	3	x	0.010	x
10	MT01 070 0.2			0.5	15	20	3	0.6	0.030	x
11	MT01 070 80 0.05			0.5	10	10	2	x	x	x
12	MT01 080 0.05			0.5	5	10	2	x	x	x
13	MT01 080 90 0.05			0.6	5	5	2	x	x	x
14	MT01 090 0.05			0.6	5	10	2	x	x	x
15	MT01 090 0.2			0.5	x	x	1	x	x	x
16	MT01 090 100 0.05			0.6	5	10	2	x	x	
17	MT01 100 0.05			0.7	10	20	2	x	x	
18	MT01 100 0.15			0.8	15	20	3	x	0.030	
19	MT01 100 110 0.05			3.3	40	65	8	0.3	0.040	2
20	MT01 110 0.05			1.0	30	115	3	0.3	0.010	6
21	MT01 110 0.15			0.6	5	10	2	x	x	
22	MT01 110 120 0.05			0.6	20	50	2	0.3	0.020	7
23	MT01 120 0.05			0.6	20	35	2	0.2	0.030	3
24	MT01 120 0.15			0.7	5	5	2	0.1	0.010	
25	MT01 120 130 0.05			0.5	25	140	2	0.7	0.040	18

Results in ppm unless otherwise specified
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ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	1000.0.01.41869	13/12/85	118289	3 OF 12

TUBE No.	SAMPLE No.				Fe%	Cu	Zn	As	Cd	Hg	Pb
1	MT01 130 0.05				0.4	20	60	2	0.4	0.020	55
2	MT01 130 0.15				0.5	15	15	x	0.2	0.040	x
3	MT02 002 10 0.15				0.7	15	25	4	0.2	0.120	5
4	MT02 003.4 0.3				1.2	25	30	6	0.5	0.050	105
5	MT02 010 0.05				0.9	10	15	4	x	0.040	15
6	MT02 010 0.3				0.7	x	x	2	x	x	10
7	MT02 010 20 0.05				0.9	20	30	5	0.4	0.160	20
8	MT02 020 0.2				0.6	5	5	3	x	0.050	5
9	MT02 020 30 0.05				0.9	55	65	9	0.5	0.180	30
10	MT02 021.5 0.05				0.9	45	40	6	0.3	0.230	20
11	MT02 030 0.05				0.8	30	35	7	0.4	0.170	10
12	MT02 030 40 0.05				0.9	55	55	10	0.5	0.180	30
13	MT02 038.5 0.05				1.1	65	65	10	0.7	0.110	45
14	MT02 040 0.15				0.6	10	10	4	0.1	0.040	5
15	MT02 040 50 0.05				1.0	80	75	10	0.7	0.180	35
16	MT02 050 0.05				1.0	70	80	7	0.6	0.060	50
17	MT02 050 0.2				1.7	105	65	16	0.4	0.090	35
18	MT02 050 60 0.05				1.3	60	45	9	0.6	0.090	30
19	MT02 053 0.2				0.5	5	20	3	0.2	0.140	x
20	MT02 060 0.05				0.9	70	80	8	0.9	0.120	40
21	MT02 060 0.15				0.6	25	30	3	0.3	0.060	15
22	MT02 060 70 0.05				1.1	80	95	10	0.6	0.180	35
23	MT02 070 0.05				1.1	50	55	8	0.5	0.090	30
24	MT02 070 0.15				1.3	65	240	7	0.8	0.180	45
25	MT02 070 80 0.05				1.0	55	215	7	0.7	0.110	25

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ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	1000.0.01.41869	13/12/85	118289	4 OF 12

TUBE No.	SAMPLE No.			Fe%	Cu	Zn	As	Cd	Hg	Pb
1	MT02 080 0.05			0.9	30	35	4	0.5	0.080	15
2	MT02 080 0.15			0.6	5	5	3	0.1	x	x
3	MT02 080 90 0.05			1.7	140	70	13	0.3	0.120	5
4	MT02 090 0.05			2.5	305	115	25	0.7	0.350	7
5	MT02 090 0.15			1.4	95	55	14	0.4	0.090	6
6	MT02 090 97 0.05			1.8	315	225	17	1.1	0.240	8
7	MT02 097 0.15			1.0	25	40	6	0.2	0.030	15
8	MT02 100 0.05			1.3	95	90	13	0.6	0.160	8
9	MT02 114 0.05			0.9	10	30	2	0.5	x	3
10	MT02 114 0.15			0.7	5	15	2	0.3	x	x
11	MT02 114 120 0.05			0.6	10	10	2	0.3	x	
12	MT02 120 0.05			0.5	5	15	3	0.3	x	
13	MT02 120 0.3			0.5	5	10	2	0.2	x	
14	MT02 120 130 0.05			0.6	5	15	2	0.7	x	1
15	MT02 130 0.05			0.5	5	10	2	0.2	x	1
16	MT02 130 138 0.05			0.6	10	30	2	0.5	x	4
17	MT02 133 0.05			0.5	5	20	1	0.3	x	2
18	MT02 133 0.3			0.3	10	15	2	0.3	x	
19	MT02 138 0.05			0.5	15	65	3	0.7	0.020	27
20	MT02 138 0.3			0.3	10	15	2	0.3	x	
21	MT03 00 0.05			0.3	10	25	2	0.3	x	
22	MT03 00 10 0.05			0.3	10	30	4	0.4	0.030	
23	MT03 10 0.05			0.3	10	30	3	0.1	0.200	
24	MT03 10 0.3			0.4	5	15	3	0.1	0.010	
25	MT03 10 20 0.05			0.3	10	30	4	0.1	0.220	

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ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	1000.0.01.41869	13/12/85	118289	5 OF 12

TUBE No.	SAMPLE No.			Fe%	Cu	Zn	As	Cd	Hg	Pb
1	MT03 20 0.05			0.3	15	40	5	x	0.120	1
2	MT03 20 0.3			2.9	200	235	42	1.3	0.400	28
3	MT03 20 30 0.05			4.9	95	130	29	0.6	0.370	7
4	MT03 30 0.05			2.6	150	170	110	0.4	0.900	14
5	MT03 30 0.2			0.8	25	80	25	x	0.190	1
6	MT03 30 40 0.05			1.0	80	105	140	0.7	1.570	14
7	MT03 40 0.05			0.4	15	40	6	0.5	0.040	2
8	MT03 40 0.3			0.2	5	15	2	0.4	x	
9	MT03 40 47 0.05			3.0	235	155	40	0.4	0.290	16
10	MT03 47 0.05			13.4	1100	1250	160	5.6	0.640	110
11	MT03 47 0.3			0.6	20	50	3	0.3	x	
12	MT04 7 1.4			4.9	50	65	20	0.6	0.040	1
13	MT13 3.5 1.0			0.8	15	15	60	x	x	
14	MT13 6.8 0.3			1.9	125	55	30	0.5	0.380	57
15	MT14 03 1.0			0.5	5	15	4	x	x	
16	MT14 14 0.5			33.4	185	160	230	0.3	0.060	2
17	MT15 7 2.1 GS			1.0	500	1800	2	3.3	x	
18	MT15 Gen Sple			35.2	230	365	260	2.0	0.100	12
19	MT16 Gen Sple			48.4	260	230	200	2.1	0.145	9
20	MT17 17 4 1.0			45.9	850	950	1100	6.1	8.800	22
21	MT17 4 2.0			0.3	5	20	2	0.2	0.030	
22	MT17 6 0.45			15.2	900	1100	110	4.5	0.540	7
23	MT17 6 1.0			0.3	5	20	2	0.2	0.020	
24	MT17 6 1.5			0.2	5	20	2	x	0.010	
25	MT18 7 0.4			1.9	3.40%	6.05%	110	240.0	0.260	10

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ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	1000.0.01.41869	13/12/85	118289	6 OF 12

TUBE No.	SAMPLE No.			Fe%	Cu	Zn	As	Cd	Hg	Pb
1	MT21 3.4 0.9			0.4	25	100	10	1.4	0.180	4
2	MT25 5 0.05			0.4	45	65	5	0.4	0.060	2
3	MT25 5 0.15			0.3	25	25	5	0.2	0.030	
4	McCabe St 1 0.05			0.2	10	30	2	0.4	x	
5	McCabe St 2 0.05			0.2	15	30	2	0.4	x	
6	McCabe St 3 0.05			0.2	10	30	2	0.4	0.010	
7	Nth West 3 Random			0.9	35	60	11	0.2	0.140	4
8	Pyrites Hole 1 0.7m			47.6	400	405	420	2.3	0.960	110
9	Pyrites Hole 1 1m			1.0	170	540	42	2.4	0.080	4
10	Pyrites Hole 1 2m			2.7	35	25	3	0.6	0.100	1
11	Pyrites Hole 2 1m			46.8	180	115	240	1.0	x	1
12	Pyrites Hole 2 2m			42.0	165	80	350	1.3	x	2
13	Pyrites Hole 2 3m			42.9	105	60	490	1.2	x	2
14	Pyrites Hole 3 1m			48.4	275	150	220	1.1	x	
15	Pyrites Hole 3 2m			46.9	55	105	280	1.1	x	
16	Pyrites Hole 3 3m			45.0	80	105	240	0.8	x	
17	Pyrites Hole 4 2m			47.0	130	155	210	0.8	x	
18	Pyrites Hole 4 3m			50.4	105	135	240	1.0	x	
19	Pyrites Hole 6 0.15m			0.9	20	20	5	0.5	0.040	
20	Pyrites Hole 6 0.4m			8.6	120	1950	63	4.7	0.250	3
21	sMT01 110 0.15			0.6	15	70	5	0.7	0.050	
22										
23	DETECTION			0.1	5	5	1	0.1	0.005	
24	DIGESTION									
25	METHOD			101	101	101	114	102	122	1

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ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	1000.0.01.41869	13/12/85	118289	7 OF 12

TUBE No.	SAMPLE No.			Bi						
1	Fndry 4 Grid 2 1m				x					
2	Fndry 4 Grid 2 2m				x					
3	Fshore 1 0.15m				x					
4	Fshore 1 0.3mA				x					
5	Fshore 1 0.3mB				x					
6	Fshore 1 0.8m				x					
7	Fshore 1 200mm Above Drain				x					
8	Fshore 1 200mm In Pipe				x					
9	Fshore 1 250-300mm below				x					
10	Fshore 1 Below drain				x					
11	Fshore 1 Rock below drain				x					
12	Fshore 1A 0.5m below gnd				x					
13	Fshore 1A 1m				x					
14	Fshore 1A 400mm				x					
15	Fshore 2 0.05m				x					
16	Fshore 2 0.15m				x					
17	Fshore 2 1.5m				x					
18	MT01 005 0.05				x					
19	MT01 005 0.4				x					
20	MT01 005 10 0.05				x					
21	MT01 010 0.05				x					
22	MT01 010 0.3				x					
23	MT01 010 20 0.05				x					
24	MT01 020 0.05A				x					
25	MT01 020 0.05B				x					

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ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	1000.0.01.41869	13/12/85	118289	8 OF 12

TUBE No.	SAMPLE No.			Bi						
1	MT01 020	30 0.05			×					
2	MT01 030	0.05			×					
3	MT01 030	35 0.05			×					
4	MT01 050	0.05			×					
5	MT01 050	60 0.05			×					
6	MT01 060	0.05			×					
7	MT01 060	0.4			×					
8	MT01 060	70 0.05			×					
9	MT01 070	0.05			×					
10	MT01 070	0.2			×					
11	MT01 070	80 0.05			×					
12	MT01 080	0.05			×					
13	MT01 080	90 0.05			×					
14	MT01 090	0.05			×					
15	MT01 090	0.2			×					
16	MT01 090	100 0.05			×					
17	MT01 100	0.05			×					
18	MT01 100	0.15			×					
19	MT01 100	110 0.05			×					
20	MT01 110	0.05			×					
21	MT01 110	0.15			×					
22	MT01 110	120 0.05			×					
23	MT01 120	0.05			×					
24	MT01 120	0.15			×					
25	MT01 120	130 0.05			×					

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ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	1000.0.01.41869	13/12/85	118289	9 OF 12

TUBE No.	SAMPLE No.			Bi						
1	MT01 130 0.05				x					
2	MT01 130 0.15				x					
3	MT02 002 10 0.15				x					
4	MT02 003.4 0.3				x					
5	MT02 010 0.05				x					
6	MT02 010 0.3				x					
7	MT02 010 20 0.05				x					
8	MT02 020 0.2				x					
9	MT02 020 30 0.05				x					
10	MT02 021.5 0.05				x					
11	MT02 030 0.05				x					
12	MT02 030 40 0.05				x					
13	MT02 038.5 0.05				x					
14	MT02 040 0.15				x					
15	MT02 040 50 0.05				x					
16	MT02 050 0.05				x					
17	MT02 050 0.2				x					
18	MT02 050 60 0.05				x					
19	MT02 053 0.2				x					
20	MT02 060 0.05				x					
21	MT02 060 0.15				x					
22	MT02 060 70 0.05				x					
23	MT02 070 0.05				x					
24	MT02 070 0.15				x					
25	MT02 070 80 0.05				x					

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ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	1000.0.01.41869	13/12/85	118289	10 OF 12

TUBE No.	SAMPLE No.			Bi						
1	MT02 080 0.05				x					
2	MT02 080 0.15				x					
3	MT02 080 90 0.05				x					
4	MT02 090 0.05				x					
5	MT02 090 0.15				x					
6	MT02 090 97 0.05				x					
7	MT02 097 0.15				x					
8	MT02 100 0.05				x					
9	MT02 114 0.05				x					
10	MT02 114 0.15				x					
11	MT02 114 120 0.05				x					
12	MT02 120 0.05				x					
13	MT02 120 0.3				x					
14	MT02 120 130 0.05				x					
15	MT02 130 0.05				x					
16	MT02 130 138 0.05				x					
17	MT02 133 0.05				x					
18	MT02 133 0.3				x					
19	MT02 138 0.05				x					
20	MT02 138 0.3				x					
21	MT03 00 0.05				x					
22	MT03 00 10 0.05				x					
23	MT03 10 0.05				x					
24	MT03 10 0.3				x					
25	MT03 10 20 0.05				x					

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ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	1000.0.01.41869	13/12/85	118289	11 OF 12

TUBE No.	SAMPLE No.	Bi
1	MT03 20 0.05	x
2	MT03 20 0.3	x
3	MT03 20 30 0.05	x
4	MT03 30 0.05	x
5	MT03 30 0.2	x
6	MT03 30 40 0.05	x
7	MT03 40 0.05	x
8	MT03 40 0.3	x
9	MT03 40 47 0.05	x
10	MT03 47 0.05	x
11	MT03 47 0.3	x
12	MT04 7 1.4	x
13	MT13 3.5 1.0	x
14	MT13 6.8 0.3	x
15	MT14 03 1.0	x
16	MT14 14 0.5	x
17	MT15 7 2.1 GS	x
18	MT15 Gen Sple	x
19	MT16 Gen Sple	x
20	MT17 17 4 1.0	x
21	MT17 4 2.0	x
22	MT17 6 0.45	x
23	MT17 6 1.0	x
24	MT17 6 1.5	x
25	MT18 7 0.4	x

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ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	1000.0.01.41869	13/12/85	118289	12 OF 12

TUBE No.	SAMPLE No.			Bi
1	MT21 3.4 0.9			x
2	MT25 5 0.05			x
3	MT25 5 0.15			x
4	McCabe St 1 0.05			x
5	McCabe St 2 0.05			x
6	McCabe St 3 0.05			x
7	Nth West 3 Random			x
8	Pyrites Hole 1 0.7m			x
9	Pyrites Hole 1 1m			x
10	Pyrites Hole 1 2m			x
11	Pyrites Hole 2 1m			x
12	Pyrites Hole 2 2m			x
13	Pyrites Hole 2 3m			x
14	Pyrites Hole 3 1m			x
15	Pyrites Hole 3 2m			x
16	Pyrites Hole 3 3m			x
17	Pyrites Hole 4 2m			x
18	Pyrites Hole 4 3m			x
19	Pyrites Hole 6 0.15m			x
20	Pyrites Hole 6 0.4m			x
21	sMT01 110 0.15			x
22				
23	DETECTION			1
24	DIGESTION			
25	METHOD			102

PLEASE NOTE :

1. Samples air dried before preparation.
2. Sample MT4-7-1.4 is fibrous in appearance.
3. Foundry 4 Hole 2-1M and 2M - Iron turnings removed prior to analysis.

Results in ppm unless otherwise specified
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Telex AA92560

ANALYTICAL REPORT No. [illegible]

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Maunsell & Partners Pty Ltd
PO Box 7190
Cloisters Square
Perth
WA 6000

ORDER No.	PROJECT
118291	

DATE RECEIVED	RESULTS REQUIRED
16/12/85	ASAP

No. OF PAGES OF RESULTS	DATE REPORTED	No. OF COPIES	TOTAL No. OF SAMPLES
4	24/12/85	1	9

STATE OF SAMPLES REFER BELOW	SAMPLE NUMBERS	PRE-TREATMENT DRY	CRUSH	SPLIT	PUL-VERISE	SIEVE	OTHER SEE REMARKS	NONE	ANALYSIS REFER TO ANALYSIS SECTION	PREPARATION	MET
	various				1				Cu,Pb,Zn,Fe Cd,Bi As Hg		1 10. 11 1

RTM
PR
2 JAN 1986

RESULTS TO

as above

RESULTS TO

REMARKS

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STATE OF SAMPLES	
whole core	WC
split core	SC
cutting	CU
rock	Ro
soil	SO
pulp	PU
water	WA
tissue	TI
stream sediment	SS
heavy mineral	HM

ANALYSIS — PREPARATION			
perchloric acid	A1	cold acid	CA
hydrochloric acid	A2	specific sulphide	SS
nitric acid	A3	other mixed acids	Ma
aqua regia	A4	alkaline attack	AA
nitric-perchloric	A5	volatilization	VO
HF mixture	A6	ignition	IG
HF under pressure	A7	pressed powder (XRF)	PP
fusion	A8	glass fusion (XRF)	GF

ANALYSIS — METHOD	
atomic absorbtion	AAS
x-ray fluorescence	XRF
spectrophotometry	SPEC
colorimetry	COL
chromatography	CHR
titration	TTN
other chemicals means	CHEJ
miscellaneous	MISC
fluorescence	FLUOR
inductively coupled plasma	ICP

AUTHORISED OFFICER

ANALABS

A division of MacDonald Hamilton & Co. Pty. Ltd.

ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	1000.0.01.42013	24/12/85	118291	1 OF 4

TUBE No.	SAMPLE No.			Fe%	Cu	Cu	Zn	Zn	As	Cd
1	MT15-E1			26.7	125	–	160	–	270	0.
2	MT17-E4			1.8	180	–	280	–	26	1.
3	MT18-E4			32.7	745	–	600	–	140	2.
4	MT21-E2			42.3	105	–	115	–	200	0.
5	MT22-E1			5.8	245	–	215	–	21	2.
6	MT22-E3a			35.6	70	–	75	–	150	0.
7	Shore 01			15.0	175	–	215	–	80	0.
8	Shore 02			7.6	40	–	35	–	20	0.
9	Shore 04			1.7	70	–	105	–	28	0.
10	Shore 05B			1.4	30	–	190	–	5	1.
11	Shore 09			20.4	530	–	1050	–	150	2.
12	Shore 10B			16.0	1100	–	270	–	200	6.
13	Shore 10C			17.6	3300	–	3100	–	850	5.
14	Shore 13			5.3	5850	–	7400	–	1400	28.
15	Shore 15			6.6	6650	–	1.10%	1.05%	540	35.
16	Shore 16C			6.0	2.65%	2.50%	4.00%	4.02%	780	95.
17	Shore 17			6.6	1050	–	1950	–	95	7.
18	Shore 18			4.3	780	–	950	–	25	3.
19	Shore 23			0.8	40	–	25	–	4	0.
20	Shore Hole 01			0.6	45	–	25	–	5	0.
21	Shore Hole 02			0.6	25	–	10	–	5	0.
22	Shore Hole 03-150			1.3	540	–	30	–	8	0.
23	Shore Hole 03-50			1.0	145	–	30	–	5	0.
24	Shore Hole 04			2.0	80	–	80	–	10	0.
25	Shore Hole 05			2.0	55	–	125	–	7	0.

Results in ppm unless otherwise specified

T = element present; but concentration too low to measure
X = element concentration is below detection limit
— = element not determined

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ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	1000.0.01.42013	24/12/85	118291	2 OF 4

TUBE No.	SAMPLE No.			Fe%	Cu	Cu	Zn	Zn	As	Cd
1	Shore Hole 05A			1.3	125	–	70	–	5	0.
2	Shore Hole 06			1.7	40	–	95	–	6	0.
3	Shore Hole 08A			1.7	35	–	80	–	6	0.
4	Shore Sample 06A			1.3	60	–	85	–	5	0.
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23	DETECTION			0.1	5	25	5	25	1	0.1
24	DIGESTION									
25	METHOD			101	101	104	101	104	114	10

Results in ppm unless otherwise specified
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X = element concentration is below detection limit
= element not determined

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ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	1000.0.01.42013	24/12/85	118291	3 of 4

TUBE No.	SAMPLE No.			Cd	Hg	Pb	Bi			
1	MT15-E1			–	0.040	x	x			
2	MT17-E4			–	0.120	375	x			
3	MT18-E4			–	0.740	1250	13			
4	MT21-E2			–	0.040	x	x			
5	MT22-E1			–	0.140	950	x			
6	MT22-E3a			–	0.010	x	x			
7	Shore 01			–	12.800	440	x			
8	Shore 02			–	0.060	x	x			
9	Shore 04			–	0.140	55	x			
10	Shore 05B			–	0.020	55	x			
11	Shore 09			–	0.430	2650	4			
12	Shore 10B			–	0.750	2300	13			
13	Shore 10C			–	0.800	3100	6			
14	Shore 13			28.5	0.080	25	x			
15	Shore 15			40.0	0.620	45	x			
16	Shore 16C			125.0	0.780	190	x			
17	Shore 17			–	1.800	1100	x			
18	Shore 18			–	0.030	95	x			
19	Shore 23			–	x	45	x			
20	Shore Hole 01			–	0.090	x	x			
21	Shore Hole 02			–	0.020	x	x			
22	Shore Hole 03-150			–	x	x	x			
23	Shore Hole 03-50			–	0.040	x	x			
24	Shore Hole 04			–	6.700	200	x			
25	Shore Hole 05			–	0.290	80	x			

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ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	1000.0.01.42013	24/12/85	118291	4 OF 4

TUBE No.	SAMPLE No.			Cd	Hg	Pb	Bi			
1	Shore Hole 05A			-	0.280	135	x			
2	Shore Hole 06			-	0.280	80	x			
3	Shore Hole 08A			-	0.060	65	x			
4	Shore Sample 06A			-	0.230	90	x			
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23	DETECTION			0.5	0.005	5	1			
24	DIGESTION									
25	METHOD			103	122	101	102			

Results in ppm unless otherwise specified

T = element present; but concentration too low to measure

X = element concentration is below detection limit

— = element not determined

AUTHORISED OFFICER

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Phone (09) 458 7999 52 Murray Road, Welshpool, W.A. 6106 Telex AA92560

ANALYTICAL REPORT No. 1[illegible].0.01.42214

THIS REPORT MUST BE READ IN CONJUNCTION WITH THE ACCOMPANYING ANALYTICAL DATA

Maunsell & Partners Pty Ltd
PO Box 7190
Cloisters Square
Perth
WA 6000

ORDER No.	PROJECT

DATE RECEIVED	RESULTS REQUIRED
13/01/86	ASAP

No. OF PAGES OF RESULTS	DATE REPORTED	No. OF COPIES	TOTAL No. OF SAMPLES
1	21/01/86	1	8

STATE OF SAMPLES		PRE-TREATMENT							ANALYSIS		
REFER BELOW	SAMPLE NUMBERS	DRY	CRUSH	SPLIT	PUL-VERISE	SIEVE	OTHER SEE REMARKS	NONE	REFER TO ANALYSIS SECTION	PREPARATION	METH
SO	various							1	FH		170

NWS 12/91
PCR
22 JAN 1986
FILE

RESULTS TO

as above

RESULTS TO

REMARKS

STATE OF SAMPLES	
whole core	WC
split core	SC
cutting	CU
rock	Ro
soil	SO
pulp	PU
water	WA
tissue	TI
stream sediment	SS
heavy mineral	HM

ANALYSIS — PREPARATION			
perchloric acid	A1	cold acid	CA
hydrochloric acid	A2	specific sulphide	SS
nitric acid	A3	other mixed acids	Ma
aqua regia	A4	alkaline attack	AA
nitric-perchloric	A5	volatilization	VO
HF mixture	A6	ignition	IG
HF under pressure	A7	pressed powder (XRF)	PP
fusion	A8	glass fusion (XRF)	GF

ANALYSIS — METHOD	
atomic absorbtion	AAS
x-ray fluorescence	XRF
spectrophotometry	SPEC
colorimetry	COL
chromatography	CHR
titration	TTN
other chemicals means	CHEM
miscellaneous	MISC
fluorescence	FLUO
inductively coupled plasma	ICP

AUTHORISED OFFICER R Ekam

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ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	1000.0.01.42314	21/01/86		1 of 1

TUBE No.	SAMPLE No.			PH						
1	MT17 17 4 1.0			3.9						
2	MT17 4 2.0			8.9						
3	PYRITES HOLE 2 1M			8.8						
4	PYRITES HOLE 2 2M			4.3						
5	PYRITES HOLE 2 3M			7.9						
6	SHORE 13			7.4						
7	SHORE 15			8.2						
8	SHORE 16C			8.0						
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23	DETECTION			0.1						
24	DIGESTION									
25	METHOD			1701						

Results in ppm unless otherwise specified

T = element present; but concentration too low to measure

X = element concentration is below detection limit

- = element not determined

AUTHORISED OFFICER

APPENDIX B

SITE INVESTIGATION NOTES

APPENDIX B

SITE INVESTIGATION NOTES

INTRODUCTION

The vacant Crown Land and the land owned by the University of Western Australia at McCabe Street in North Fremantle was subject to an analysis of the soil in the area. To complete this, a series of trenches, trial holes and random holes were excavated and samples of the soil were obtained to be analysed.

As well as trenches being excavated on the site itself, the area between the site and the Swan River was also sampled and analysed. The purpose of this sampling was to determine the extent of any leaching of the contaminants towards the river. At the Swan River foreshore, a series of holes were dug to determine the extent of any waste in the area. Samples were also taken at the drain outlets along the river front.

Excavation was carried out by a Massey Ferguson 50E backhoe fitted with a 600mm wide general purpose bucket.

The following description gives a general outline of the trenches excavated on the site as well as descriptions of the random holes. The measurements used in the descriptions are approximate and are only meant as an indication of the relative positions of the layers of materials.

SITE DESCRIPTION MT1

Trench MT1 comprised two excavations - the first being between MT1-50 and MT1-130 and the second between MT1-0 and MT1-40. Trench MT1 was referenced from the McCabe Street end (refer Figure 10).

- MT1-0-40

At MT1-0 the topsoil measured 200mm in depth and increased gradually to 600mm at MT1-40. Below the topsoil was a yellow-grey sand.

The remnants of a rubbish fire between MT1-18 and MT1-27 would, by inspection, possibly effect the soil to 300mm below the surface.

The soil was mostly fine-grained and was prone to collapse.

Note: No excavation between MT1-40 and MT1-50 as this section was through a disused borrow pit where access to the backhoe was restricted.

- MT1-50-130

The profile of trench MT1 over this length was generally consistent along its length. The topsoil was measured to 100mm thick. The topsoil consisted of surface vegetation and included a grey or brown sand. A grey coloured material with a limestone mix to 200mm was found below the topsoil. A layer of 100mm thickness limestone was the third layer; the final layer being a yellow-grey sand to the base of the trench. In some sections of the trench, isolated pockets of limestone were present in the cross-section. At the base of the trench, limestone pinnacles were reached. Spread in places between 1m and 2m apart, this limestone was very hard and was not excavated.

Between the peaks, the depth to the lowest point of limestone varied from less than 1m to approximately 2m.

A section of trench MT1 passed across a limestone track, i.e. between MT1-70 and MT1-90. The surface samples in this area will possibly not show the actual quality of the soil.

As the trench approached MT1-50, the amount of yellow sand present increased considerably. The limestone bed was also reached and was less than 0.5m deep. The area about MT1-50 had been used as a sand borrow pit.

As the trench approached the limestone bed, what appeared to be soft limestone cobbles became more frequent. At MT1-60, the cobbles measured 1cm to 1.5cm in diameter.

SITE DESCRIPTION MT2

Trench MT2 comprised two excavations. The first was between MT2-0 and MT2-97, the second between MT2-114 and MT2-138. No excavations were made between MT2-97 and MT2-114 due to thick vegetation and access problems. Trench MT2 was referenced from the McCabe Street end.

- MT2-0-97

Trench MT2 commenced at MT2-3.5 based on the arbitary datum peg. At this point the trench reached the limestone base at 0.5m depth. The profile consisted of yellow sand mixed with limestone pieces. Between MT2-3.5 and MT2-30 the trench consisted mostly of limestone to a depth of approximately 1.5m.

Between MT2-30 and MT2-97 the average profile of the trenches was topsoil 0-300mm; grey-yellow sand 300mm-1m; limestone pinnacles which varied from 1m to approximately 2m in depth. The amount of limestone in the cross-section decreased as the trench approached MT2-97.

. MT2-114-138

This section of trench MT2 was mostly limestone. The depth to the hard limestone bed varied between 1 and 1.5m below the surface but was generally less than 1m in depth. The hard limestone bedrock was overlain by softer, weakly cemented limestone.

SITE DESCRIPTION MT3

Trench MT3 extends 47m and was referenced from the McCabe Street end.

From MT3-0 to MT3-14, the trench profile consisted of a brown coloured material mixed with limestone to 0.5m depth. Below this layer was a very weakly cemented limestone to 1.7m. Between MT3-14 and MT3-36 the profile consisted of topsoil to 100mm of a grey material. Below this layer was a yellow-orange sand to the base of the trench at 1.5m.

Between the points MT3-20 at 300mm depth and MT3-47 between 0 and 200mm, pyrites waste material was present.

From MT3-36 to MT3-47, the profile consisted of layers of topsoil 0.50mm; limestone 50-600mm and yellow orange sand from 600mm to the base of the trench.

The depth to the base of the trench varied as limestone pinnacles similar to those in MT1 and MT2 were found. Between MT3-0 and MT3-14, the depth to the base of the trench was constant at 1.7m. Between MT3-14 and MT3-47 the depth varied between 0.5m and 1.5m.

SITE DESCRIPTION MT4

Trench MT4 was excavated to determine the extent of waste material encountered in Trench MT3. The profile showed that the difference between the pyrites cinders material and the virgin ground was quite distinct. From the front of the embankment (refer Figure 10), the pyrites cinders material extended 8m towards McCabe Street. The profile of the trench was as follows: grey earth and top soil; pyrites cinders, material; yellow-grey sand; light grey fibrous material (analysis shows to be asbestos); limestone bed. At 8m from the embankment the profile was: topsoil; yellow-grey sand to the base of the trench.

SITE DESCRIPTION MT6

Trench MT6 showed an amount of pyrites cinders material at the embankment below the topsoil. The average cross-section consisted of layers of topsoil, limestone, yellow-grey sand to the base of the trench.

SITE DESCRIPTION MT7

Trench MT7 had a similar cross-section to MT6. Pyrites cinders material was found in the embankment below the topsoil. The average trench profile consisted of topsoil with yellow-grey sand below to the base of the trench.

SITE DESCRIPTION MT8

Trench MT8 showed a profile of fine-grained grey sand. The trench being at an average depth of 0.5m-0.6m. The limestone bedrock was reached at this point.

SITE DESCRIPTION MT11

Trench MT11 is referenced from the fence dividing the Crown Land and the river reserve area and was excavated between the fence and the new cycleway. The trench profile comprises a sloping band of pyrites cinders material mixed with a grey soil. At the start of the trench the pyrites cinders was at a depth of 0.5m. Below this point limestone was present.

Note: Between 50 and 270mm pyrites cinders was more concentrated than between 270 and 500mm where the grey soil was more concentrated.

SITE DESCRIPTION MT12

Trench MT12 was excavated 50m east and parallel to trench MT11. The profile of this trench showed the following layers: topsoil, light coloured pyrites cinders, brown coloured soil and crushed limestone being the last layer. Throughout the cross-section of the trench the pyrites cinders was evident as a light coloured mixture in the soil.

SITE DESCRIPTION MT13

Trench MT13 comprised two excavations. The first being MT13-0 and MT13-6, between the Swan River and the boundary fence. The second excavation was between the fence and the new cycleway, i.e. between MT13-6 and MT13-11.7. Between MT13-0 and MT13-6 the trench profile showed mostly limestone below the topsoil. An orange material at 1m depth and 3.5m from the reference point showed the only variation through the length of the trench. Between MT13-6 and MT13-11.7 the layer below the topsoil was a mixture of limestone and pyrites cinders. However limestone and yellow sand featured below this layer to the full depth of the trench - on average approximately 1.3m. A grey material between the limestone and pyrites cinders and the limestone and yellow sand layers was evident through the length of the trench.

SITE DESCRIPTION MT14

Trench MT14 comprised two excavations. The first section being between the boundary fence and the Swan River (i.e. between MT14-14 and MT14-0); and the second being between the fence and the council pathway (between MT14-14 and MT14-25).

The profile of the section between MT14-0 and MT14-14 was consistent throughout and was as follows: grey coloured topsoil and crushed limestone to a depth of 1.5m.

At 12m from the peg a pocket of pyrites cinders was present to a depth of 1m - more likely to be an isolated load since no more evidence of pyrites cinders was found nearby.

The profile of the section between MT14-14 and MT14-25 was similar to the first section. However towards the end of the trench, a layer of pyrites 150mm thick was located 50mm below the surface.

SITE DESCRIPTION MT15

Trench MT15 extends 7.3m from the reference peg. The cross-section of the trench was consistent and was as follows: topsoil; pyrites cinders material; yellow sand. At the face of the trench the surface soil extended to 800mm below the surface but gradually decreased to a constant 100mm towards the end of the trench. The face of the trench MT15 commenced on an embankment. The surface soil appeared to be used as a filler on the pyrites cinders material since further samples on the embankment showed only a superficial cover over the cinders.

Approximately half way along the trench a layer of hard white material of 100mm thickness at depth 1.7m was observed. At the end of the trench this white material marked the transition from pyrites cinders to yellow sand.

SITE DESCRIPTION MT16

Trench MT16 had a complete cross-section of pyrites cinders material. The trench was excavated to a depth of 3m where the pyrites cinders became more solid and was difficult to excavate. The colour of the pyrites cinders became lighter as the trench became deeper (see Figure B-1).

SITE DESCRIPTION MT17

Trench MT17 consisted of crushed limestone and pyrites cinders materials. The trench had length 11.1m. Throughout the length of the trench a layer of 400mm thickness pyrites cinders was present 100mm below the surface. The band of sloping pyrites cinders descends to the base of the trench at the southern end. Crushed limestone was present above and below the sloping pyrites cinders band. An orange material of approximately 500mm thickness passes below the sloping pyrites cinders. Figure B-2 shows a cross-sectional view of the trench.

SITE DESCRIPTION MT18

Trench MT18 consisted of a number of layers as follows: soil; gravel; pyrites cinders material; crushed limestone; a grey material (possible limestone) and a yellow material (possibly yellow sand and limestone mixed). The pyrites cinders sloped to a depth of 1600mm at the face of the trench. At 6.2m from the peg, a thin layer of a blue material was present sloping to 400mm at the end of the trench. Figure B-3 shows the layers present and the layer of the blue deposit.

SITE DESCRIPTION MT19

Trench MT19 has a total length 7m from the reference peg and is of a similar description to MT17. The sloping pyrites cinders band was approximately 1m thick and descended to 1.8m at the face of the trench. Crushed limestone was present above and below the pyrites cinders band. See Figure B-4 for a sketch of the trench cross-section.

SITE DESCRIPTION MT20

Trench MT20 has a sloping pyrites cinders band of 600mm thickness which slopes to a depth of approximately 2m. Crushed limestone and lime sand was present above and below the pyrites. At the surface was a layer of road seal and gravel on top of the pyrites cinders. Figure B-5 shows a sketch of the trench cross-section.

SITE DESCRIPTION MT21

The trench profile of MT21 is similar to MT19 and MT20. However, the sloping pyrites cinders band which appears to be common in all trenches along the embankment is comprised of a number of different waste materials Figure B-6 shows the pyrites cinders to be surrounded by layers of gravel, limestone and furnace waste. The concrete pipe in the figure is approximately 1m below the surface and has a pyrites cinders fill above it. The pyrites cinders band had crushed limestone above and below as was observed from other trenches along and below as was observed from other trenches.

SITE DESCRIPTION MT22

Trench MT22 displays a similar cross-section to other trenches along the embankment. The pyrites cinders sloped to a depth of 2.4m at the face of the trench. Above and below the pyrites cinders was crushed limestone. See Figure B-7 for the profile of the trench.

SITE DESCRIPTION MT25

This trench was excavated between MT1 and MT2 as indicated on the contour map of the site. The cross-section of the trench showed layers of top soil; grey-yellow sand to 2.5m. This cross-section was consistent through the 15m length of the trench. Samples at 5m from the face of the trench were taken however waste material did not appear to be present in the area.

FORESHORE 1

An excavation at approximately 180m from the eastern site boundary at Minim Cove (Refer Figure 10 for position) was made to determine the extent of the seepage of the waste material vertically down the embankment. At this particular location, a certain amount of waste material had been either dumped or had seeped to the surface from the drain pipes uncovered during the excavation. The excavation showed that the pipes had split in places and the moist yellow slurry in the pipes had leaked. Samples of the material in the pipe and above and below the pipe were taken. These samples were taken to identify the material from the pipe.

A second excavation at Foreshore 1A was made to determine the extent of any lateral seepage of the waste material found at the excavation, Forehore 1.

The drainage system at Foreshore 1 may have connected to a seepage path at hole Foreshore 2. A considerable amount of staining on the rock face was observed at this point. At the shoreline below the staining the rocky beach has the distinct colouring of the pyrites cinders as well as slurry found in the area of foreshore 1.

SAMPLES TAKEN AT SHORE OF SWAN RIVER

Some samples were taken on the embankment between the Council Pathway and the Swan River extending from Minim Cove to the end of the site at the State Engineering Works. These samples were taken at evenly spaced points down the embankment mainly at drain outlets along the river. It was found that the areas appearing to have the highest concentrations of waste were at these outlets. Samples were taken consistently along the shoreline to determine the extent of any seepage into the river.

At Minim Cove, a series of trial holes to a maximum 400mm depth were made to determine any seepage which may be occurring in the area.

At each of the trenches along the embankment, MT15-22, samples were taken on the embankment in line with each trench. The samples were taken on average near the top of the embankment, half way down the embankment and near the bottom of the embankment. A fourth sample was taken between the new cycleway and the river at the top of the river embankment.

The samples taken below MT22 showed pyrites cinders at all sample points. The pyrites cinders was present under a 50mm or less top soil layer. Between MT22 and MT17, the samples showed limestone to be present even when the sample holes were taken to 200mm depth. At MT15 and MT16, pyrites cinders was present and was found in a similar manner to those samples at MT22.

A tree at MT16 showed the various effects of growing in a pyrites cinders. Some of the leaves at the top of the tree had the red staining of the pyrites cinders and the trunk of the tree showed staining in the wood.

It appears that at the trench MT22, the crushed limestone over the pyrites cinders had only a cosmetic effect. The samples show that the pyrites cinders in the embankment was not covered. The presence of pyrites cinders between MT21 and MT17 was not determined at the sample points. At the sample points in line with MT15 and MT16, the pyrites cinders had not been covered satisfactorily.

Generally, the pyrites cinders could be observed fairly regularly along the embankment. The material appeared as a light red colour due to mixing with the top soil.

WESTERN PYRITES CINDERS DUMP

Five trial holes to approximately 3m depth were dug in a grid pattern over the western pyrites cinders dump. A sixth hole was included in the grid however due to limited access, this hole was not excavated. The grid of trial holes for the dump is set out in Figure 10.

- Hole 1

The profile of this hole consists of the following layers: top soil 0-200mm; limestone 200-600mm; pyrites cinders 600-800mm; bricks mixed in limestone 850mm-1.6m; foundry waste material 1.6-3.65m. This trial hole appeared to lie outside the pyrites cinders dump area since only a small layer of pyrites cinders was present.

- Hole 2

Profile of hole consisted of: top-soil 0-150mm; fine grained limestone 150-800mm; light pyrites cinders materials 800mm-1.15m; pyrites cinders material 1.15-3.5m.

- Hole 3

Trial hole consisted of layers of: top soil 0-50mm; limestone 50-300mm; pyrites cinders 300mm-3.6m.

- Hole 4

Profile consisted of layers of: top soil 0-100mm; limestone 100-300mm; pyrites cinders 300mm-3.2m. At approximately 1.5m below surface a layer of limestone of 500mm thickness is present. The waste material is particularly dark in colour.

- Hole 5

Not excavated.

- Hole 6

Profile consisted of the following layers: top soil 0-300mm; pyrites cinders and limestone mix 300-450mm; orange material and limestone 450mm-1m. The limestone bedrock was reached at the 1m mark. Below 450mm, the soil appears to be virgin ground.

The trial holes in the western pyrites cinders dump showed cross sections expected for the area.

FOUNDRY WASTE DUMP

Four trial holes were excavated in the foundry waste area to a length of approximately 3m. The positions of each hole are set out in Figure 10.

- Hole 1

Cross-section of this trial hole had the following layers: top soil mixed with crushed limestone 0-500mm; foundry waste material 500-800mm; limestone 800mm to base of trench.

- Hole 2

The profile of this hole showed top soil to 100mm and foundry waste material between 100mm and the base of the trench at 3m.

- Hole 3

This trial hole showed a complete cross-section of foundry waste material to 3m depth.

- Hole 4

The top soil extends to 100mm below the surface below which is crushed limestone to 3m depth. This hole appears to indicate virgin ground in this area.

RANDOM TRIAL HOLES

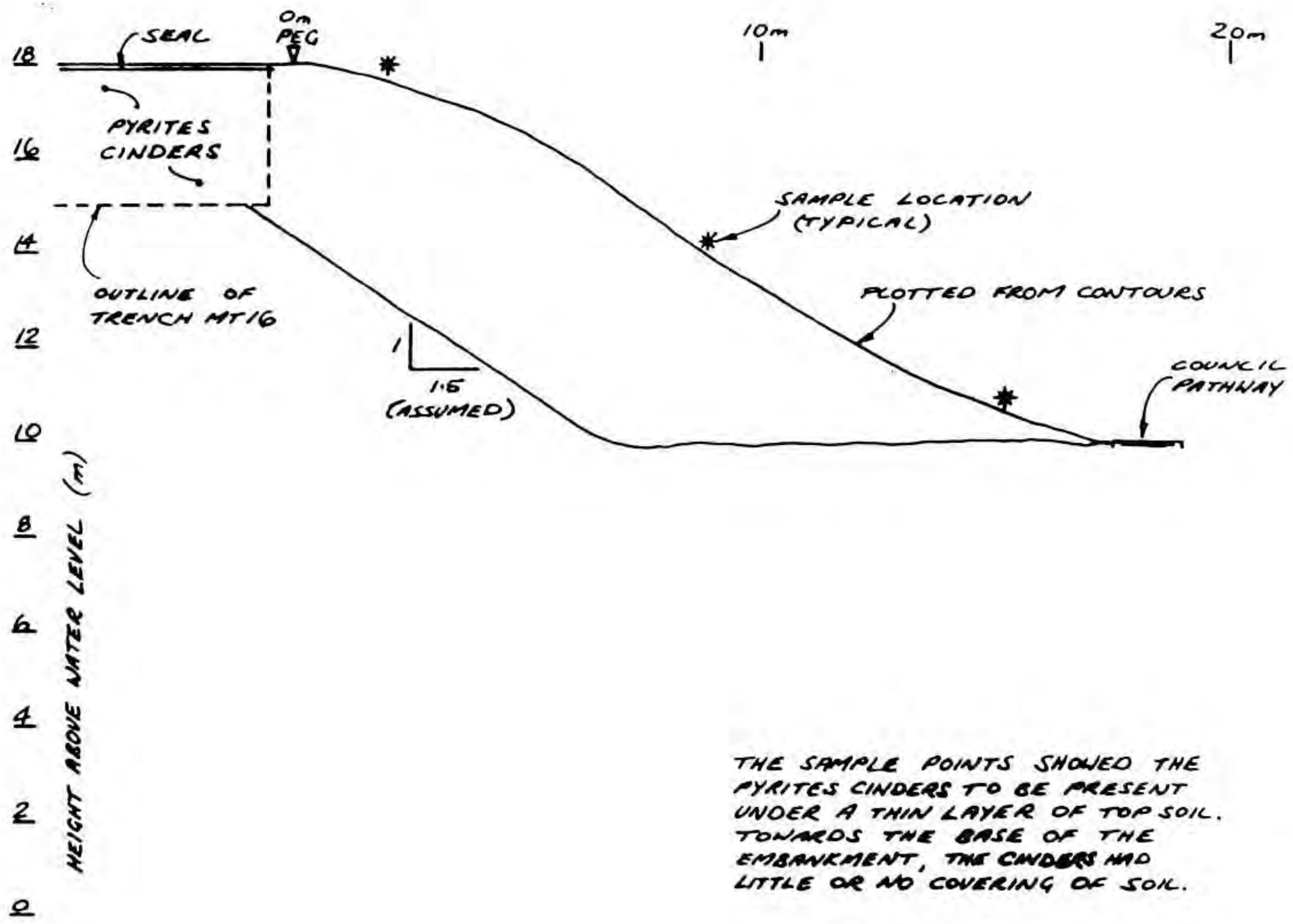
Apart from the excavations at defined points on the McCabe Street site, there were also a number of holes dug at random. These holes were excavated to identify any isolated waste disposal points.

Two holes were dug parallel to the trench MT2. These holes were situated on the high side of the trench approximately 50m apart and in a line approximately 30m parallel to trench MT2. These excavations found only limestone.

Three holes were excavated parallel to McCabe Street in the vicinity of trench MT2 as indicated on the contour map. These excavations showed limestone to be present.

Three holes were dug perpendicular to McCabe Street on an area where some type of material had been dumped. The positions of these holes is indicated on the contour map and samples were taken to determine the type of material in the area.

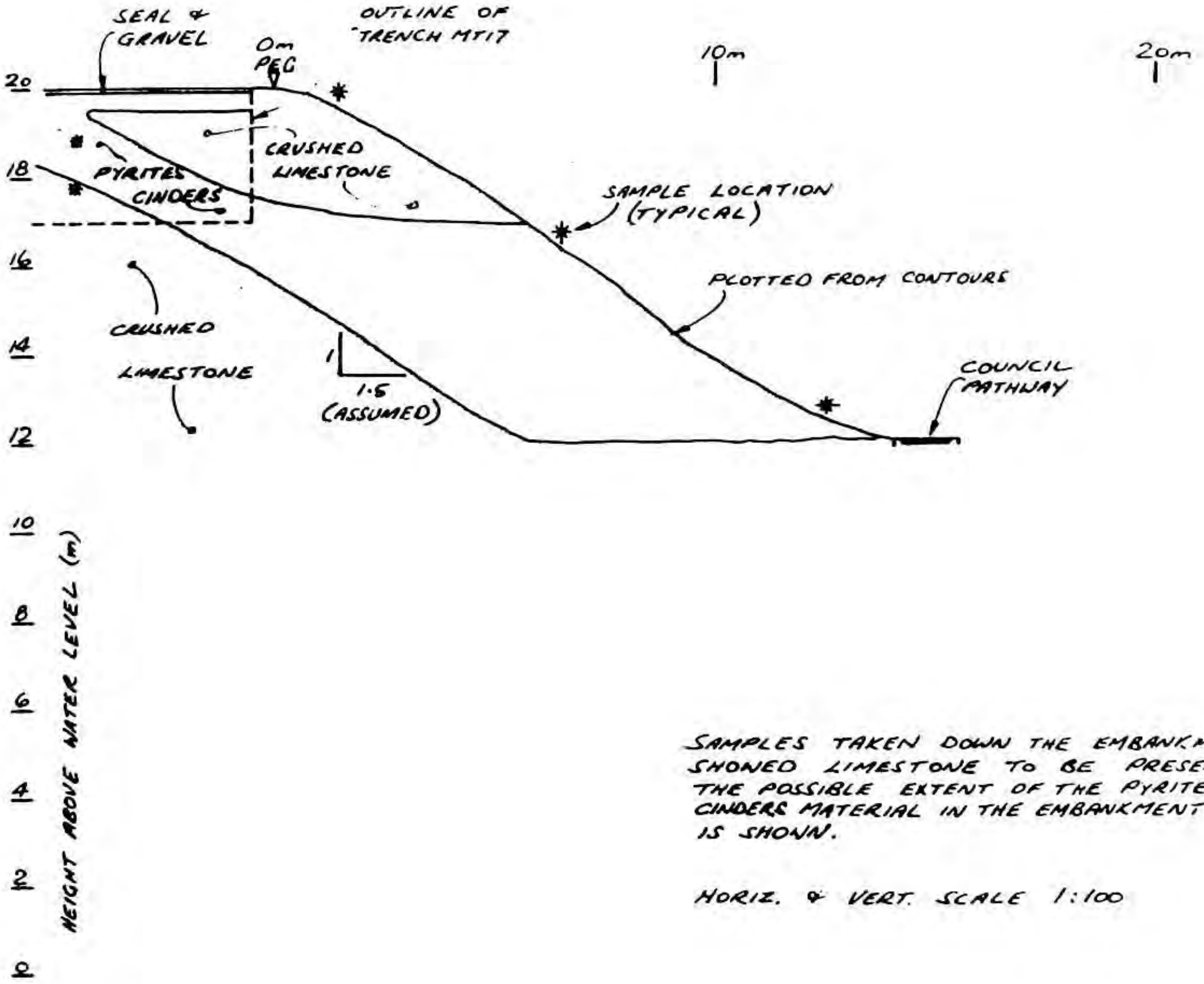
A hole to 1m depth was made in the vicinity of trench MT13 on the opposite side of the new cycleway. At this point, it appeared as if waste materials had been spilt or dumped and samples were taken to determine the components of this material.



THE SAMPLE POINTS SHOWED THE PYRITES CINDERS TO BE PRESENT UNDER A THIN LAYER OF TOP SOIL. TOWARDS THE BASE OF THE EMBANKMENT, THE CINDERS HAD LITTLE OR NO COVERING OF SOIL.

HORIZ. + VERT. SCALE 1:100

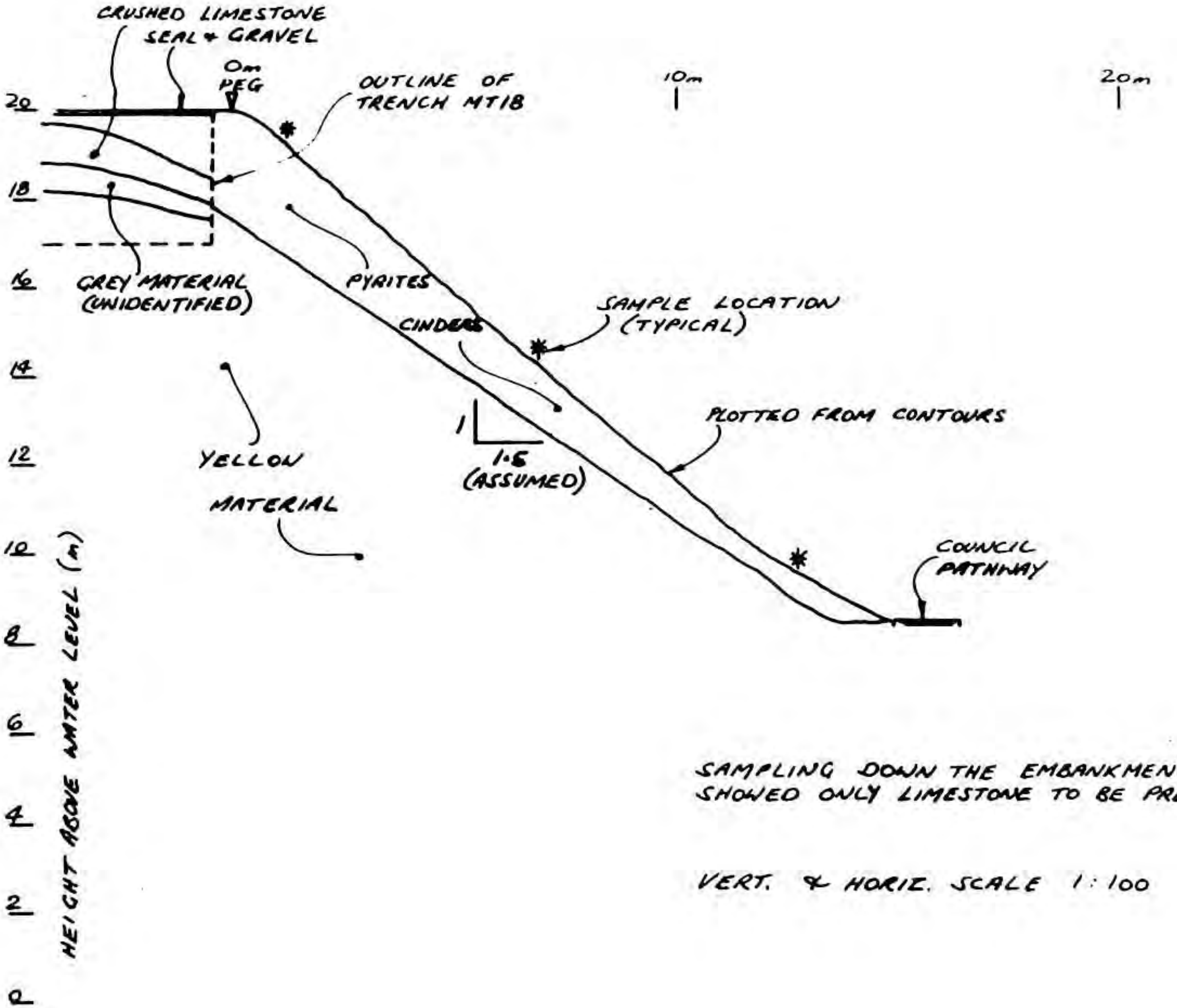
TRENCH MT 16
FIGURE B-1



SAMPLES TAKEN DOWN THE EMBANKMENT SHOWED LIMESTONE TO BE PRESENT THE POSSIBLE EXTENT OF THE PYRITES CINDERS MATERIAL IN THE EMBANKMENT IS SHOWN.

HORIZ. & VERT. SCALE 1:100

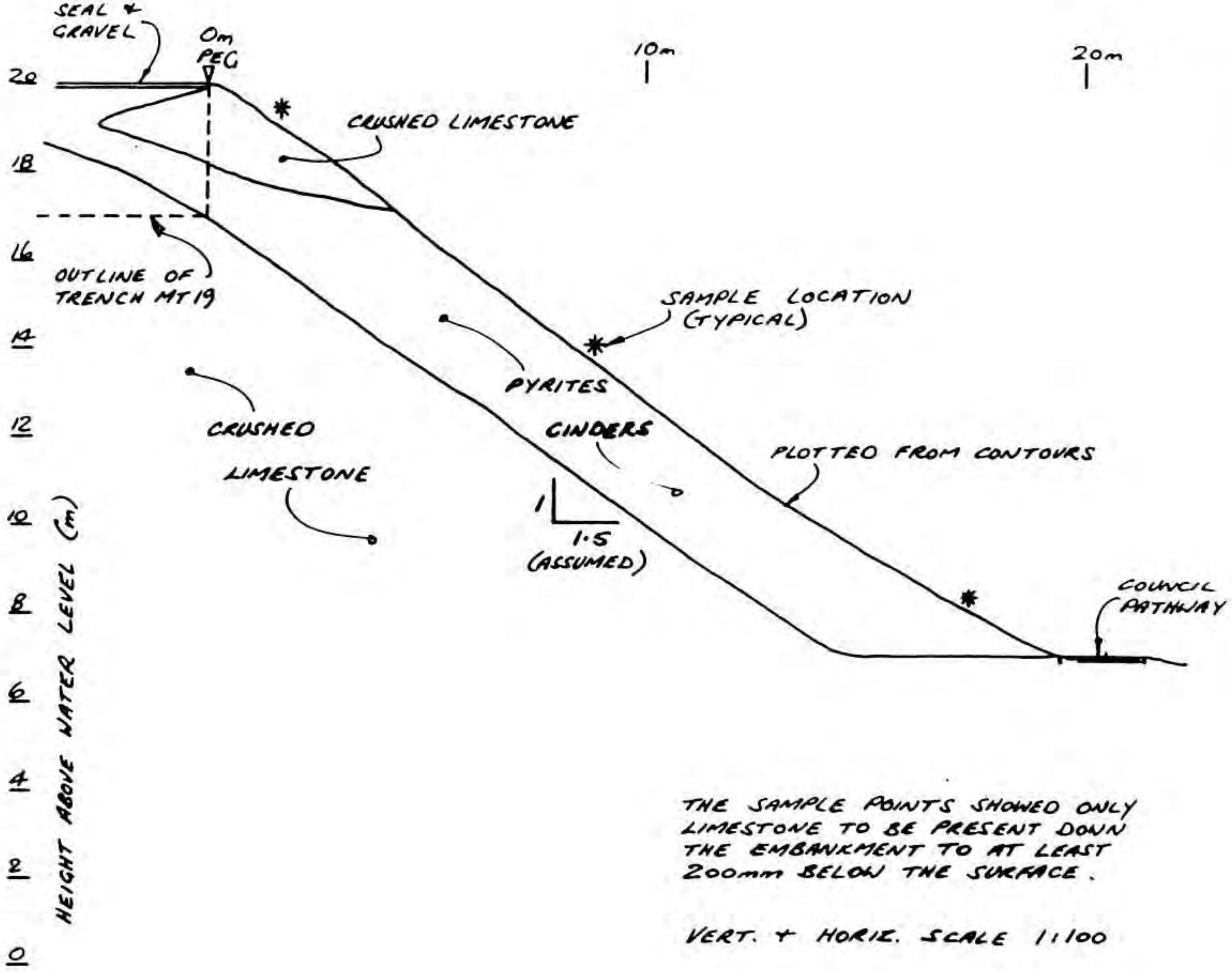
TRENCH MT 17
FIGURE B-2



SAMPLING DOWN THE EMBANKMENT
SHOWED ONLY LIMESTONE TO BE PRESENT.

VERT. + HORIZ. SCALE 1:100

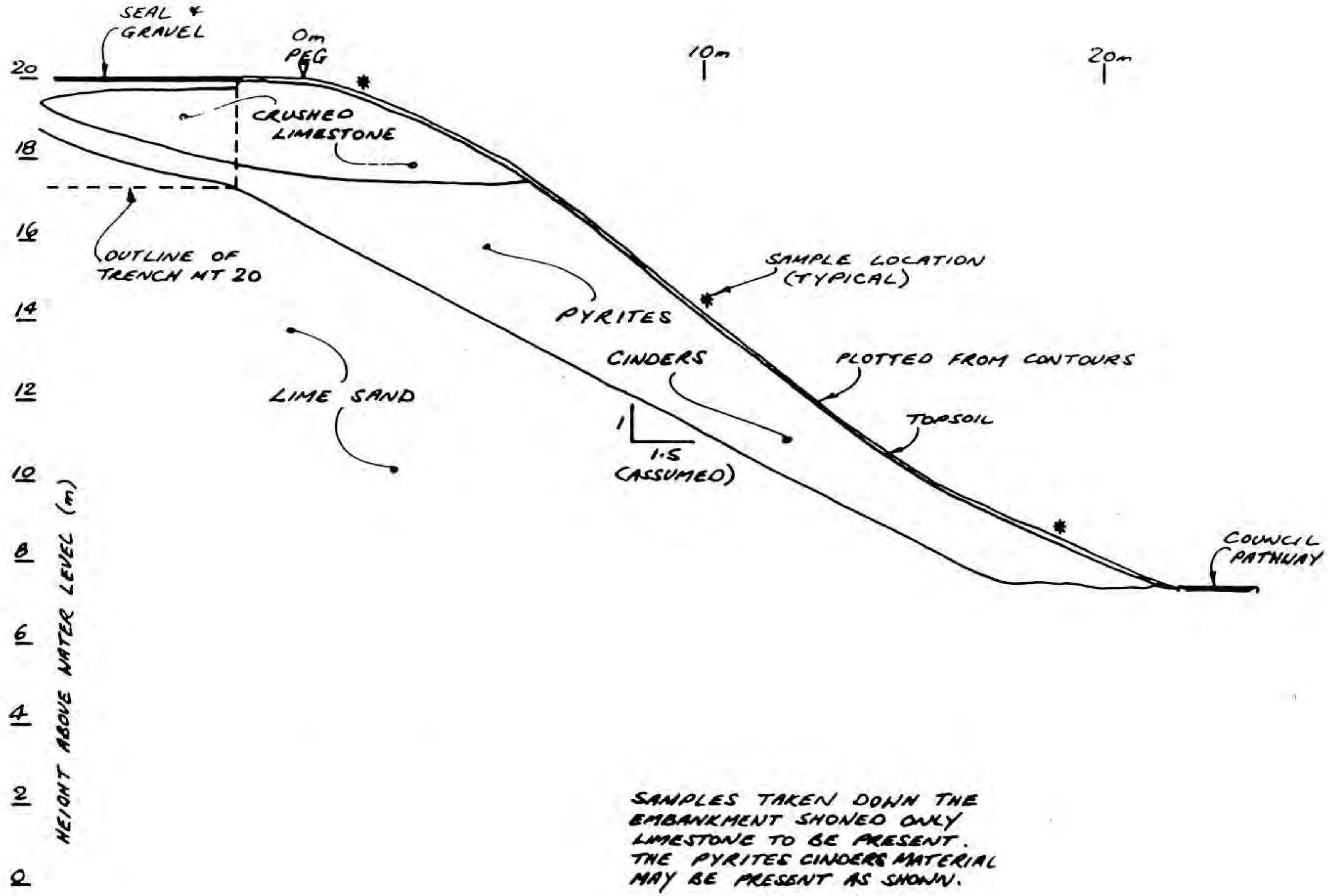
TRENCH MT 18
FIGURE B-3



THE SAMPLE POINTS SHOWED ONLY
LIMESTONE TO BE PRESENT DOWN
THE EMBANKMENT TO AT LEAST
200mm BELOW THE SURFACE.

VERT. + HORIZ. SCALE 1:100

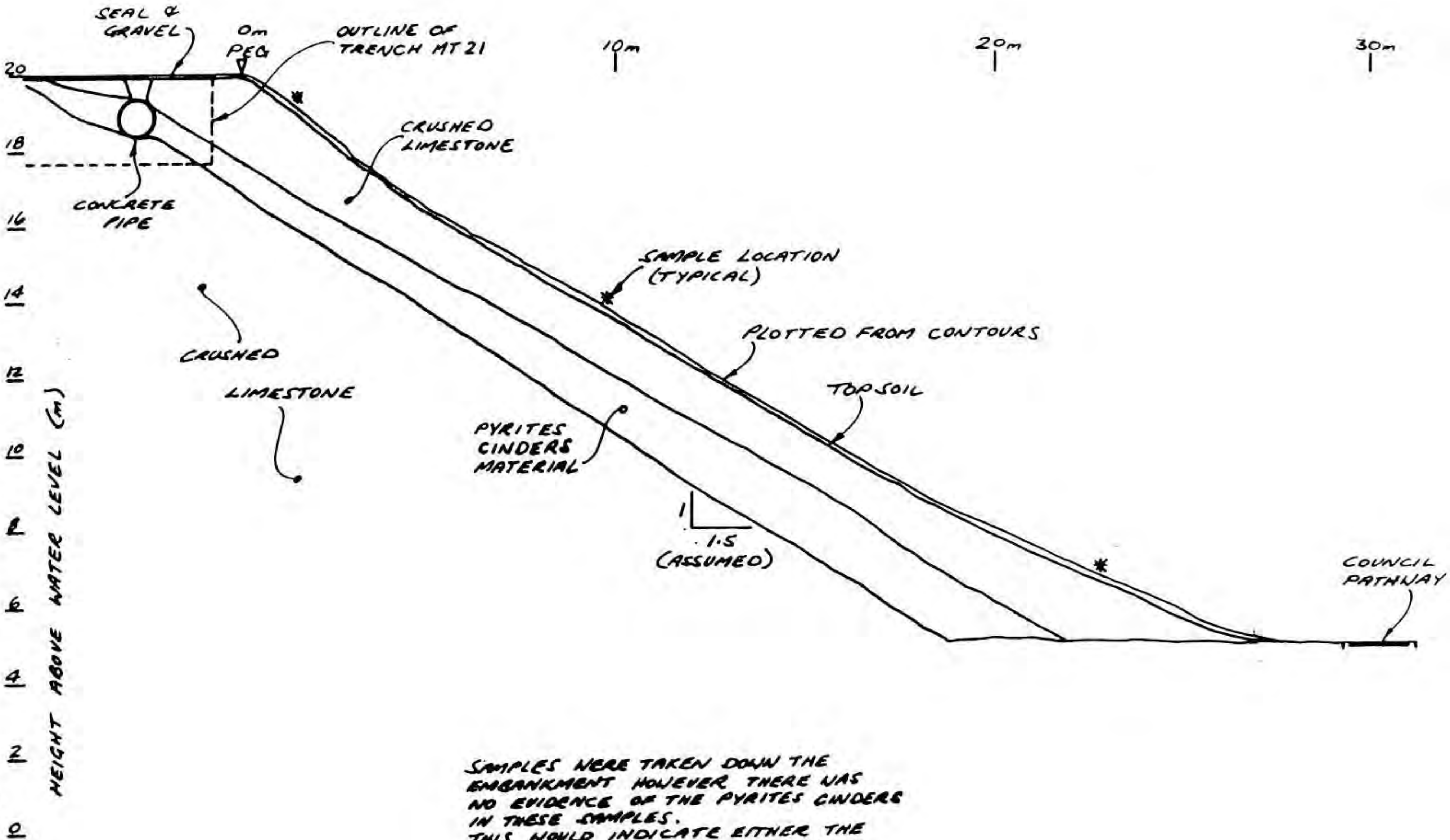
TRENCH MT19
FIGURE B-4



SAMPLES TAKEN DOWN THE EMBANKMENT SHOWED ONLY LIMESTONE TO BE PRESENT. THE PYRITES CINDERS MATERIAL MAY BE PRESENT AS SHOWN.

VERT. & HORIZ. SCALE 1:100

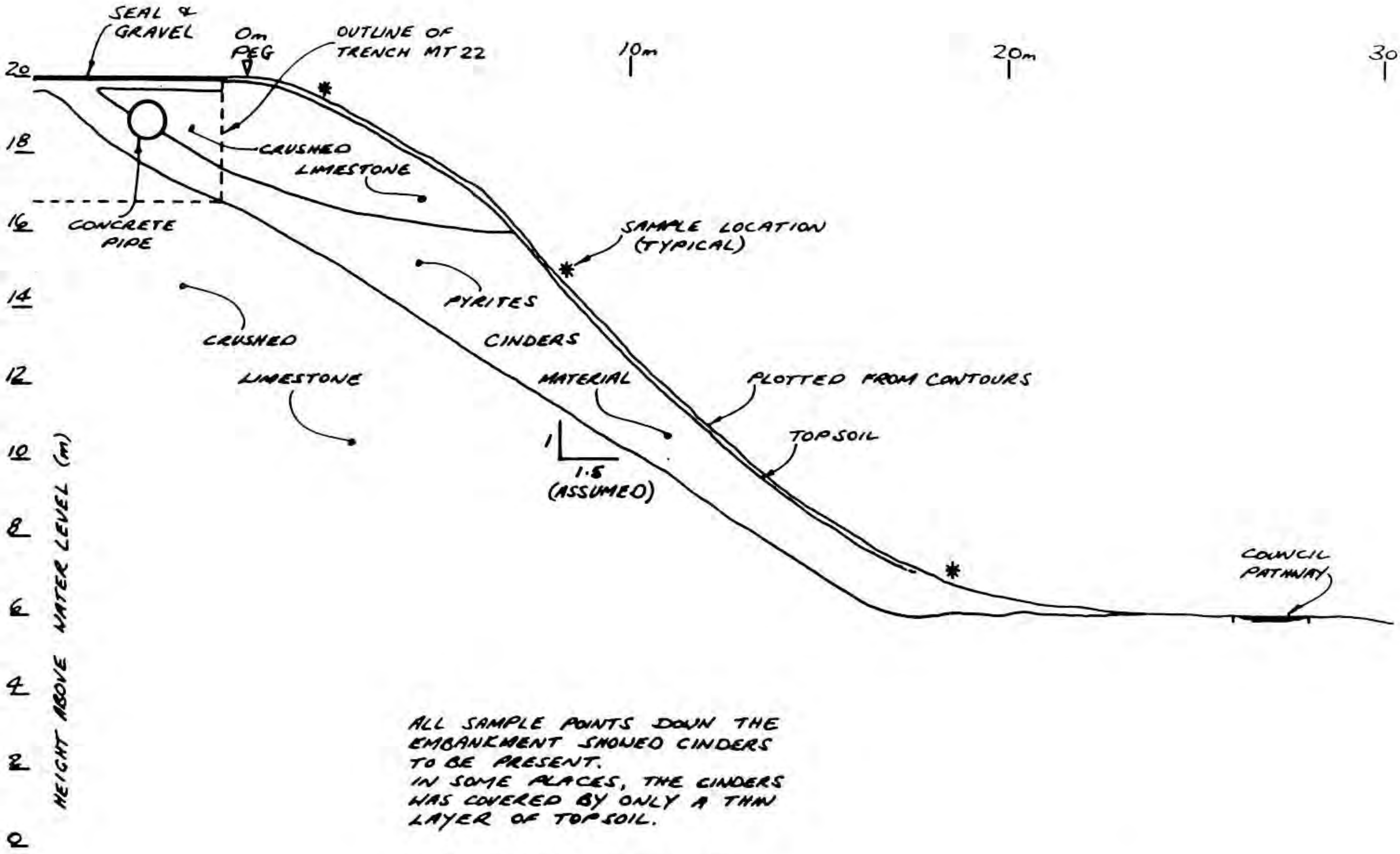
TRENCH MT 20
FIGURE B-5



SAMPLES WERE TAKEN DOWN THE EMBANKMENT HOWEVER THERE WAS NO EVIDENCE OF THE PYRITES CINDERS IN THESE SAMPLES.
THIS WOULD INDICATE EITHER THE CINDERS WAS BURIED AS SHOWN OR THERE WAS NO CINDERS PRESENT.

VERT. & HORIZ. SCALE 1:100

TRENCH MT 21
FIGURE B-6



ALL SAMPLE POINTS DOWN THE EMBANKMENT SHOWED CINDERS TO BE PRESENT.
IN SOME PLACES, THE CINDERS WAS COVERED BY ONLY A THIN LAYER OF TOPSOIL.

VERT. & HORIZ. SCALE 1:100

TRENCH MT22
FIGURE B-7

APPENDIX C

TOXICOLOGICAL ASSESSMENT

APPENDIX C

TOXICOLOGICAL ASSESSMENT

Selected data was supplied to Ms. B. Musgrove, Project Officer of the Toxic and Hazardous Chemicals Committee of the Total Environment Centre in New South Wales. Ms. Musgrove was requested to provide advice and to comment on the toxicological significance of the heavy metal contamination levels identified in these samples from the McCabe Street site. In particular, consideration was requested of the situation where the pyrites cinders, having been covered with 600-1000mm of clean fill, are exposed to contact by children due to erosion or some other disturbance of parts of this covering layer. A typical medium term contact period was envisaged as being over 8-10 weeks during the summer school vacation with visits to the site by particular individuals for 2-3 days per week.

During a later telephone conversation Ms. Musgrove was also provided verbally with selected analytical results from the beachline samples (refer Table VII).

The resultant report from Ms. Musgrove is also included with this Appendix.

The analyses attached to this Appendix were presented to Ms. Musgrove for evaluation.

RDG

RESOURCE DEVELOPMENT LABORATORIES

PERTH - Welshpool
52 Murray Road,
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Western Australia 6430
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(090) 21 7688
Telex: AA91784

MEEKATHARRA
Great Northern Highway
PO Box 120,
Meekatharra
Western Australia 6642
Telephone (099) 81 1086

ORIGINATOR: WELSHPOOL
TRS:al

DATE: 28 January 1986

RECEIVED MAUNSELL
1 RTM 29/1
2 PCR
29 JAN 1986
688
FILE

Maunsell & Partners
P.O. Box 7190
Cloisters Square
PERTH WA 6000

OUR REF : 1000.0.01.42326
YOUR REF : 118298
ATTENTION : Mr Paul Reed

Dear Sir

We received 10 mussel samples on the 14 January 1986 for analysis. The results are as follows :-

		Pb mgkg^{-1}	Hg mgkg^{-1}	Cd mgkg^{-1}	As mgkg^{-1}
M 12	Shore 12	<1	1.7	0.1	0.3
M 13	Shore 13	2	0.01	0.2	<0.1
M 15 14	Shore 15 14	<1	<0.01	<0.1	<0.1
M 16	Shore 16	1	0.07	0.5	0.3
M 17 18	Shore 17 18	2	0.04	0.4	<0.1
M 19	Shore 19	1	0.05	0.1	0.2
M 21	Shore 21	1	0.01	0.1	0.1
M 23	Shore 23	2	0.01	<0.1	0.1
M 5	Shore 5	1	0.07	0.1	0.3
M 8	Shore 8	<1	0.02	0.1	<0.1

Yours faithfully
RESOURCE DEVELOPMENT GROUP A Division of
Macdonald Hamilton & Co Pty Ltd

T R STAKER
Chartered Chemist

RESOURCE DEVELOPMENT GROUP

ANALABS

A division of MacDonald Hamilton & Co. Pty. Ltd.
52 Murray Road, Welshpool, W.A. 6106

Phone (09) 458 7999

Telex AA92560

ANALYTICAL REPORT No. 1000.0.01.42566

THIS REPORT MUST BE READ IN CONJUNCTION WITH THE ACCOMPANYING ANALYTICAL DATA

Maunsell & Partners
PO Box 7190
Cloisters Square
Perth
WA 6000

ORDER No.	PROJECT

DATE RECEIVED	RESULTS REQUIRED
04/02/86	ASAP

No. OF PAGES OF RESULTS	DATE REPORTED	No. OF COPIES	TOTAL No. OF SAMPLES
1	05/02/86	1	14

STATE OF SAMPLES		PRE-TREATMENT							ANALYSIS		
REFER BELOW	SAMPLE NUMBERS	DRY	CRUSH	SPLIT	PUL-VERISE	SIEVE	OTHER SEE REMARKS	NONE	REFER TO ANALYSIS SECTION	PREPARATION	METHOD
	various							1	S		60

RESULTS TO

as above

RECEIVED
MAUNSELL
1 Rm 7/2
3 JP
2 PCR
7 FEB 1986
FILE

RESULTS TO

REMARKS

This Laboratory is registered by the National Association of Testing Authorities, Australia. The test(s) reported herein have been performed in accordance with its terms of registration. [illegible]

STATE OF SAMPLES	
whole core	WC
split core	SC
cutting	CU
rock	RO
soil	SO
pulp	PU
water	WA
tissue	TI
stream sediment	SS
heavy mineral	HM

ANALYSIS — PREPARATION			
perchloric acid	A1	cold acid	CA
hydrochloric acid	A2	specific sulphide	SS
nitric acid	A3	other mixed acids	Ma
aqua regia	A4	alkaline attack	AA
nitric-perchloric	A5	volatilization	VO
HF mixture	A6	ignition	IG
HF under pressure	A7	pressed powder (XRF)	PP
fusion	A8	glass fusion (XRF)	GF

ANALYSIS — METHOD	
atomic absorbtion	AAS
x-ray fluorescence	XRF
spectrophotometry	SPEC
colorimetry	COL
chromatography	CHR
titration	TTN
other chemicals means	CHEM
miscellaneous	MISC
fluorescence	FLUOR
inductively coupled plasma	ICP

AUTHORISED OFFICER

ANALABS

A division of MacDonald Hamilton & Co. Pty. Ltd.

ANALYTICAL DATA

SAMPLE PREFIX	REPORT NUMBER	REPORT DATE	CLIENT ORDER No.	PAGE
	1000.0.01.42566	05/02/86		1 Of 1

TUBE No.	SAMPLE No.			S%						
1	MT03 47 0.05			0.48						
2	MT14 14 0.5			0.24						
3	MT15 Gen Sple			0.71						
4	MT16 Gen Sple			1.05						
5	MT17 6 0.45			1.55						
6	MT18-E4			0.66						
7	MT21-E2			1.30						
8	MT22-E3a			1.95						
9	Pyrites Hole 2 1m			0.48						
10	Pyrites Hole 2 2m			1.05						
11	Pyrites Hole 2 3m			0.85						
12	Pyrites Hole 3 1m			0.48						
13	Pyrites Hole 3 2m			0.76						
14	Pyrites Hole 3 3m			0.74						
15										
16										
17										
18										
19										
20										
21										
22										
23	DETECTION			0.01						
24	DIGESTION									
25	METHOD			603						

Results in ppm unless otherwise specified

T = element present; but concentration too low to measure

X = element concentration is below detection limit

— = element not determined

AUTHORISED OFFICER

PYRITES CINDERS STOCKPILE

Sample	Fe	Cu	Zn	As	Cd	Hg	Pb
PH1 0.7m	47600	400	405	420	2.3	0.96	1100
PH1 1.0m	1000	170	540	42	2.4	0.08	45
PH1 2.0m	2700	35	25	3	0.6	0.10	15
PH2 1.0m	46800	180	115	240	1.0	x	15
PH2 2.0m	42000	165	80	350	1.3	x	25
PH2 3.0m	42900	105	60	490	1.2	x	x
PH3 1.0m	48400	275	150	220	1.1	x	x
PH3 2.0m	46900	55	105	280	1.1	x	x
PH3 3.0m	45000	80	105	240	0.8	x	x
PH4 2.0m	47000	130	155	210	0.8	x	x
PH4 3.0m	50400	105	135	240	1.0	x	x
PH6 0.15m	900	20	20	5	0.5	0.04	x
PH6 0.4m	8600	120	1950	63	4.7	0.25	315
Arithmetic Mean	34962	142	296	216	1.4	0.11	115

Key to sample description:

PH1 - western pyrites cinders dump hole No. 1
0.7m - depth below ground level of sample location

EMBANKMENT TRENCHES

Sample	Fe	Cu	Zn	As	Cd	Hg	Pb
MT15 Gen Sample	35200	230	365	260	2.0	0.1	120
MT15 7/2.1	1000	500	1800	2	3.3	x	x
MT16 Gen Sample	48400	260	230	200	2.1	0.145	950
MT17 4/1.0	45900	850	950	1100	6.1	8.8	2250
MT17 4/20	300	5	20	2	0.2	0.03	x
MT17 6/0.45	15200	900	1100	110	4.5	0.54	775
MT17 6/1.0	300	5	20	2	0.2	0.020	x
MT17 6/1.5	200	5	20	2	x	0.010	x
MT18 7/0.4	1900	3400	6050	110	240	0.26	105
MT21 3.4/0.9	400	25	100	10	1.4	0.18	40
Arithmetic Mean	14880	618	1066	180	26	1.01	424

Key to sample description:

MT15 - Trench 15
7 - distance of sample location from reference point
2.1 - depth below ground level of sample location

TOXIC AND HAZARDOUS CHEMICALS COMMITTEE

TOTAL ENVIRONMENT CENTRE
18 ARGYLE STREET SYDNEY 2000 TELEPHONE 27 8476

REPORT TO MAUNSELL AND PARTNERS
ON
THE McCABE STREET DEVELOPMENT ON THE CSBP FERTILIZER WORKS SITE, MOSMAN PARK

By Betty Musgrove, Project Officer

of the

TOXIC & HAZARDOUS CHEMICALS COMMITTEE, of the TOTAL ENVIRONMENT CENTRE.

18 Argyle Street,
SYDNEY 2000

14th January, 1986.

1. This report endeavours to deal with the toxicological significance of the stockpiled pyrites cinders waste located on the river embankment at McCabe Street, Mosman Park.

   Toxicity levels for this type of situation are not easily obtained, as regulatory authorities in Australia rely mainly on information produced by the World Health Organization (WHO) and on other overseas standards. However, some toxicity data have been generated locally and these, together with overseas information, have been used as guidelines to assess the specific problem caused by the stockpiling of pyrites cinders at Mosman Park. Needless to say, in gathering this information with the help of some regulatory authorities, the confidential nature of the site and its specific problems, was meticulously adhered to.

2. In most tailings from mines, after weathering, the insoluble compounds remain close to the surface, the soluble compounds move downwards. This trend is also evident from the analytical data of the Mosman Park cinders waste dump; e.g. Cadmium or cadmium oxide in dilute sulphuric acid forms the very soluble, very toxic cadmium sulphate - a known carcinogen. In fact all soluble cadmium compounds are highly toxic.

3. <u>Threshold Limiting Values</u> (the level an average worker can endure without ill effects) of Dust or Fumes.

		mg/m^3 air
Iron (as ferric oxide)		5.0
Copper	cuprous	0.2
	cupric	1.0
Zinc	Zinc chloride	1.0
	Zinc chromate	0.05
	Zinc Oxide	5.0
Arsenic		0.2
Cadmium		0.05
Mercury	Metallic	0.05
	alkyl compounds	0.01
Lead		0.15

(From: Hazards in the Chemical Laboratory, Royal Society of Chemistry - Ed. L. Bretherick, 3rd edn, London, 1981)

4. Safe Ingestion Levels (personal communication - E. Stephanic, NSW Dept of Occupational Health)

		Ingestion/person (75 kg/day)
Arsenic	USA	0.1 - 0.2 mg
	Japan	0.07 - 0.37 mg
	UK	0.1 mg
Cadmium		10 - 60 μg
Cobalt		5 - 45 μg
Iron		9 - 35 mg
Lead		110 - 520 μg
Mercury		10 μg
Zinc		5 - 22 mg

5. Recommended Soil Levels.

(These values originate from the UK and have been provided by B. Dowling, NSW State Pollution Control Commission.)

Soil (mg/kg or p.p.m.)

	Uncontaminated, normal range	Public open space Formal playing fields	Amenities playing fields, Parks playgrounds, small children
Iron	-	-	-
Zinc	0.0 - 250	-	130
Cobalt	1 - 40	-	-
Arsenic	0 - 30	40	40
Cadmium	0 - 1	15	12
Mercury	0 - 1	20	4
Lead	0 - 500	2000	1500
Copper	0 - 100	1000	1000

The NSW State Pollution Control Commission (SPCC) has adopted the UK small children playing ground values as their yardstick for NSW.

After considering the pyrites cinders stockpile analyses at a depth of 0.7 m (the highest readings) it may be estimated that a child would have to ingest 2 kg of the soil per sitting, before suffering detrimental effects.

(The calculation was carried out by B. Dowling of the SPCC from a set of heavy metal values provided by the TEC.)

6. Concentration of heavy metals in water, permissable by Clean Waters Act (personal communication from B. Dowling, SPCC)

All values mg/l (or p.p.m.)

	Drinking Water	Aquatic Animals
Arsenic	0.5	0.01
Cadmium	0.01	0.0002
Copper	1.0	0.005
Iron (This figure used only for colour of water)	0.3	-
Mercury	0.001	0.0002
Zinc	5.0	0.03

7. In relation to the above values the leachate values which were obtained from Mr Reed by telephone must be regarded as very high.

Copper	26,500 p.p.m.
Zinc	40,000 p.p.m.
Arsenic	780 p.p.m.
Cadmium	95 p.p.m.
Lead	198 p.p.m.

People, and particularly children, using the area would be at risk if leachates at these concentrations were allowed to enter the river or accumulate on the beach.

8. Recommendations:

i. The leachate should be contained so that the river and beach are not polluted.

ii. The exposed pyrites dump should be covered with lime so as to prevent the formation of compounds, such as the very soluble cadmium sulphate. The lime should be covered with a layer of clay to lock in the heavy metals. Finally, the clay should be covered with 600-1000 mm of clean soil which should be planted with grass. If trees and shrubs are to be planted, plants with fibrous roots should be chosen so that they bind the soil and are not readily blown over, causing erosion (e.g. bottle brush, paperbarks, willows).

iii. The area should be regularly inspected to ensure that it is maintained properly.

iv. Records of analyses should be kept so that contaminated areas can be readily identified before they are exposed by soil removal.

v. The river should be regularly monitored for chemical pollution, in case unsighted leachate enters it.

Providing these recommendations are carried out, it is considered that the area would be environmentally safe.

APPENDIX D

COCKBURN SOUND STUDY

TABULATED VALUES OF BIOTA CONTAMINATION ANALYSES

APPENDIX D

COCKBURN SOUND STUDY
TABULATED VALUES OF BIOTA CONTAMINATION ANALYSES

The attached Tables 4.9 and 4.10 are reproduced from the following document;

Chegwidden A., "Technical Report on Distribution of Contaminants".
A report (No.5) to the Cockburn Sound Study 1976-1979.
Department of Conservation and Environment

The Tables have been included for the purposes of comparison of results from the Cockburn Sound and other studies with analysis results obtained in this investigation.

TABLE 4.9

MEAN CONCENTRATION OF HEAVY METALS IN WHOLE SOFT PARTS OF *MYTILUS EDULIS* FROM OTHER STUDIES

The results are given in $\mu g\ g^{-1}$ wet weight. The factor used for the conversion of dry weight results to wet weight results is 0.166.

Area		Cd	Cu	Pb	Zn	
North and South Island	Mean	0.6	8.3	0.7	12.6	
of New Zealand (1975) (14)	Range	0.3-1.6	1.7-18.0	0.2-2.0	3.8-26.0	
Derwent River Estuary,	Mean	3.1		33.1	85.6	
Tasmania (1976) (10)	Range	0.7-6.3		0.5-88.3	28.4-224	
Corio Bay	Mean	3.8	1.2	0.6	27.3	
Victoria (1976) (16)	Range	1.6-8.8	0.8-3.5	0.2-1.6	17.4-68.1	
						Cr
Western Port Bay	Mean	0.4	0.8	0.5	33.2	0.2
Victoria (1974-1976) (17)	Range	<0.1-4.0	<0.5-2.7	<0.1-1.9	16.9-54.9	<0.1-0.2
The United States						
(1976) (2)*						Ni
West Coast	Mean	0.8	1.1	0.6	24.7	0.3
	Range	0.4-1.7	0.6-1.4	0.3-1.5	14.9-43.2	0.2-0.4
East Coast	Mean	0.3	1.1	0.5	17.6	0.2
	Range	0.1-1.0	0.7-1.8	<0.1-1.6	11.1-31.3	0.1-0.6
						Cr
European Countries	Mean	0.22-	2.8	0.78	23	0.44
(1975) (15)	Range	0.09-0.44	0.8-9.4	0.30-2.1	13-44	0.28-0.60
European Countries	Mean	0.31	2.4	0.99	20	
(1977) (15)	Range	0.02-1.1	0.6-6.6	0.2-2.0	10-64	

* In this study areas of <u>very</u> high contamination were not included.

TABLE 4.10

TOTAL MERCURY CONTENT OF THE WHOLE SOFT PARTS OF *MYTILUS EDULIS*

The mean results of five individual mussels are given in µg g^{-1} wet weight. The factor used for the conversion of dry weight results to wet weight results is 0.166.

Area	No. of Samples	Mean	Standard deviation	Range
The Cockburn Sound Study 19.12.78				
Station No.				
12 (Woodman Point Beacon)		0.202	0.039	0.140-0.239
21 (A.I.S. Jetty)		0.201	0.034	0.153-0.244
26 (North B.P. Dolphin)		0.242	0.101	0.147-0.407
27 (C.S.B.P. Jetty)		0.212	0.081	0.127-0.336
30 (C.B.H. Jetty)		0.105	0.028	0.081-0.152
31 (Palm Beach Jetty)		0.101	0.023	0.063-0.124
33 (Colpoys Buoy)		0.239	0.058	0.143-0.300
13 (North Garden Island Dolphin)		0.113	0.032	0.079-0.150
Cockburn Sound	40	0.18	0.05	0.06-0.41
Derwent River Estuary, Tasmania (1976) (10)	22 sites	0.69	0.61	0.07-2.16
North and South Island, New Zealand (1975) (14)	70 samples	0.23	0.20	0.02-0.48
European Countries (1975) (15)	22 stations	0.05		0.02-0.13
European Countries (1977) (15)	21 stations	0.05		0.01-0.19

APPENDIX E

BUDGET COST ESTIMATES

APPENDIX E

BUDGET COST ESTIMATES

The various recommendations for Options I and II of th treatment are described in detail in Sections 8.2 an respectively. The calculations contained in this appendix hav carried out with a view to providing a budget estimate for out work associated with each recommendation given.

It is emphasised that the costs quoted are indicative only a require detailed confirmation and recalculation for design and purposes. However, with the information available from pa present studies of the site the estimates are considered sufficiently accurate for the scope of this report.

E1. OPTION I - MINIMAL SITE DEVELOPMENT

E1.1 Site Fencing

Assume existing fencing to State Engineering Works (Lot adequate. Remaining length required - 2,555m allowing for thr of 6m paired security gates.

1.2m chainlink fence, length required - 780m

1.8m fence cost at $11.57/m -		$ 29,561.35
Gates cost at $450/set -		1,350.00
1.2m fence cost at $7.10/m -		5,538.00
		$ 36,449.35
	say	$ 37,000.00

E1.2 Cycleway

The works involved are:

(a) Placement of 1.0m fill - assume 3m top width with 1:2 side slopes

Area - $\frac{3+7}{2}$ x 1 - $5m^2$

Volume - 5 x 830m length - $4150m^3$

Rate/m^3 - place and shape only - $2.50m^3$

Cost - 2.5 x 4150 - $ 10,375

(b) Remove and stack existing bricks and transport to new alignment.

Assume 1 labourer can lift and stack 3m - $6m^2$ of path/hour at a cost of $15/hr

Area to be lifted - 519x2 + 311x2 - $1660m^2$

Time reqd - $\frac{1660}{6}$ - 277hrs

Cost - 277x15 - $ 4,155.00

Assume 4 labourers + 1 fork lift for transport at $40/hr

No. of hours - $\frac{1660}{6x4}$ - 69hrs

Fork lift cost - 69x40 - $2760.00

Cost - 4155 + 2760 - $ 6,915.00

(Rate m^2 - $\frac{6915}{1660}$ - $4.16/$m^2$)

(c) Relay brickwork to path including bed preparation, compaction, laying, sanding, brick compaction but no cutting

Rate - $15/$m^2$

Cost - 1660x15 - $24,900.00

TOTAL COST - 10,375 + 6,915 + 24,900 - $ 42,190.00

say $ 43,000.00

E1.3 Stormwater Collection System Outfalls

The works involve excavation, removal and disposal of pipes and pits and backfill of excavations.

Detailed lengths of pipe are not available. However, from site inspections it is estimated that total pipe lengths are at least 200m.

Hand excavating would be required for approx. 3x30m = 90m of the embankment face to approx. 1m depth with a crane to remove pipes
- 1 week's work @ \$60/hr
  2 labourers @ \$15/hr

Remainder can be done by machine on a level surface.

Assume 1.5 x 1m trench section

Rates: Embankment face = 60x40 + 2x40x15
= 2400 + 1200
= \$3,600.00

110 x 1.5 x 1 = 165m^3

Rate = \$15/m^3

Cost = 165x15 = \$2475.00

Disposal of pipes - allow \$500.00

Backfill barriers - allow \$1000.00

TOTAL COST = 3600 + 2475 + 500 + 1000 = 7,575.00

say \$ 8,000.00

E1.4 Riverbank and Beaches

(a) Excavation of beach and riverbank material based on use of hydraulic excavator loading off-highway dump trucks hauling to on-site disposal area.

Volume to be moved - approx. 250m of beachline to 10m wide and 0.5m average depth and 10m of bank to 1.5m average depth

V - 250x7x0.5 + 250x10x1.5 - $4625m^3$

Rate for excavation and disposal in confined conditions approx. $\$15/m^3$

Cost - 15.0x4625		\$ 69,375.00
	say	\$ 70,000.00

(b) Replace excavated material with crushed limestone and bank protection of limestone boulders.

Fill required $5000m^3$ + 25% for tidal losses
- $6250m^3$

Rate - $\$10.10/m^3$ ($\$7.10/m^3$ to supply, $\$3.00/m^3$ to place)

Cost - 10.10x6250 - \$63,125

Limestone boulders to cover 250m of beach to 1.2m depth

V - 250x1.5x1.2 - $450m^3$

Rate - $\$50/m^3$

Cost - 50x450 \$ 22,500

(c) Removal and disposal of molluscs

Allow \$ 500

(d) Cover of disposed material with 0.5m crushed limestone

Volume of disposed material = 4625 + 25%
= 5781m^3

Approx. size = 50x40x3 = 6000m^3

Area of crushed limestone required
= 50x40 + 50x54 + 2x40x5.4
= 2702m^2

V = 2702x0.5 = 1351m^3

Rate = \$10.10/m^3

Cost = 10.10x1351 = \$ 13,645.10

(e) **Landscaping - allow for one plant/m^2 (intense planting) without reticulation - planting in May/June only.**

Area to be covered = 2500m^2

Rate/plant supply and plant = \$4.00

Cost - 2500x4 = \$10,000

TOTAL COST
= 70,000 + 63,125 + 22,500 + 500 + 13,700 + 10,000
= \$179,825

say \$ 180,000.00

E2. OPTION II - RESIDENTIAL DEVELOPMENT

E2.1 Area for Residential Development

The work comprises:

(a) Stripping of vegetation and disposal

Area affected = 332x70 + 225x98
= 45,290m^2

Allow stripping from 70% of area - buildings, limestone etc. need no treatment

A = 31,703m^2

Area for disposal also requires clearing

A = 160x58 + 240x72 = 26,560m^2 - 90% to be cleared

A = 23,904m^2

Total A = 23904 + 31703 = 55,607m^2

Rate = \$0.50/m^2

Cost = 0.50x55607 = $ 27,803.50

(b) Stripping of soil to nominal 0.3m depth

Allow for 70% of area to 0.3m depth

V = 0.3x0.7x45290 = 9,511m^3

Allow for 30% of area to 0.75m depth

V = 0.75x0.3x45290 = 10,190m^3

V = 9511 + 10190 = 19,701m^3

Allow for scraper operation with additional watering and care to minimise dust

Normal rate \$1.80/^{3} + 50% for added works

Rate = \$2.70/m^3

Cost = 19701 x2.7 = $ 53,192.70

say $ 55,000.00

(c) Cover of area with 1.2m for clean sand fill - place and compact

$V = 45290 \times 1.2 = 54{,}348m^3$

Rate = $\$1.50/m^3$ sand + $\$0.50/m^3$ compact
= $\$2.00/m^3$

Cost = 2x54348 =	$ 108,696.00

(d) Contingency for excavation and disposal of unidentified quantities of hazardous materials

Allow $20,000

TOTAL COST = 27,803 + 55,000 + 108,696 + 20,000
= 211,499.50

say	$ 212,000.00

E2.2 Pyrites Slurry Dump

This work comprises:

(a) Clearing of area

$$A = \frac{90 \times 140}{2} = 6{,}300m^2$$

Rate = $\$0.50/m^2$

Cost = 0.5x6300 =	$ 3,150.00

(b) Placement of PVC membrane including sand bedding layer

Area = $6{,}300m^2$

Rate = $\$5.00/m^2$

Cost = 5x6300 =	$ 31,500.00

(c) Sand cover to 1.0m depth - place only

V = 6300x1 = 6,300m^3

Rate = \$2.00/m^3

Cost = 2x6300 = \$ 12,600.00

(d) Limestone retaining wall to 1.8m total height

Length = 220m

Base width = 1.8x0.4 0.7m (approx.)

Top width = 0.5m

V $= \left(\frac{0.7+0.5}{2}\right) \times 1.8 \times 220 = 237.6m^3$

Rate = \$145.00/m^3

Cost = 145x237.6 = \$ 34,452.00

(e) Leach drain and sump - 100mm PVC slotted pipe in graded sand inside a filter cloth layer to restrict inflow of fines

Length = 220m

Rate = \$33.00/m

Cost = 33x220 = \$ 7,260.00

(f) Allow for 2 sumps to 2.5m depth

Rate = \$1,100.00/pit

Cost = 2x1100 = \$ 2,200.00

TOTAL COST = 3,150 + 31,500 + 12,600 + 34,452 + 7,260 + 2,200
= \$91,162

say \$ 92,000.00

E2.3 Embankment Pyrites Cinders Dump

(a) Excavation and disposal by hydraulic excavator to dump trucks.

Allow excavation rate as for trench excavation in sand to 3.0m depth + 30% for difficulty and watering for dust control etc.

Rate = \$9.00 + 30% = \$11.70/m^3

Volume to be removed = 14,400 + 20% (contingency)
= 17,280m^3

Cost = 17280x11.70 = \$ 202,176.00

say \$ 205,000.00

(b) Cover with sand fill

V = 360x30x10 = 10,800m^3

Rate = \$2.00/m^3

Cost = 10,800x2 = \$ 21,600.00

(c) Landscaping - area = 10,800m^2

Rate for planting = \$4.00/m^2

Cost = 4x10,800 = \$ 43,200.00

TOTAL COST = 205,000 + 21,600 + 43,200 = \$ 269,800.00

say \$ 270,000.00

E2.4 Lead Melters Site Treatment

Strip and dispose of contaminated soil to an approved toxic waste landfill site

A = $160x50 = 8,000m^3$

Allow 0.5m average depth

V = $8000x0.5 = 4,000m^3$

Rate = $\$8.00/m^3$

Cost = 8x4000 = $ 32,000.00

E2.5 Western Pyrites Cinder Dump and Foundry Waste Dump

Work comprises:

(a) Stripping of vegetation, rubbish etc. including batters

$A_P = 180x60 + 170x10 = 12,500m^2$

$A_F = 100x50 + 20x30 + 100x6 = 6,200m^2$

Area for embankment pyrites cinder
= 60x60 approx. = $3,600m^2$

Rate = $\$0.50/m^2$

Cost = 0.5x(12,500 + 6,200 + 3,600) = $ 11,150.00

(b) Place 300mm crushed limestone

Rate = $\$8.10/m^3$ ($\$7.10/m^3$ supply, $\$1.00/m^3$ place)

Cost = 22,300x8.10 = $ 180,630.00

(c) Place covering layer of 0.7m of fill

V = $22,300x0.7 = 15,610m^3$

Rate = $\$1.50/m^3$

Cost = 1.5x15,610 = $ 23,415.00

TOTAL COST = 11,150 + 180,630 + 23,415 = $ 215,195.00

say $ 216,000.00

E2.6 Passive Recreation Area Fill

Area = 160x130 + 90x110 + 60x100 + 100x90 + 120x200 + 60x60
= 73,300m^2

V = 73,300m^3

Rate = \$1.50/m^3

Cost = 73,300x1.5 = \$ 109,950.00

say \$ 110,000.00

E2.7 Landscaping

Passive Recreation Area - area = 73,300m^2

Allow 35% intensive planting

Cost = 0.35x73,300x4 = \$102,620.00

Allow 65% grass

Rate = \$0.5/m^2

Cost = 0.65x73,300x0.5 = \$ 23,822.50

Pyrites Slurry Dump - area = 6,140m^2

Rate = \$4.00/m^2 for intensive planting

Cost = 6140x4 = \$ 24,560.00

TOTAL COST = 102,620 + 23,822.5 + 24,560 = \$ 151,002.50

say \$ 150,000.000

APPENDIX F

MINERALOGICAL ASSESSMENT

APPENDIX F

MINERALOGICAL ASSESSMENT

Dr. J. Just, Consultant Mineralogist, was requested to advise on the mineralogical nature of the embankment pyrites cinders dump.

Dr. Just was requested to comment on the results of his work with particular reference to the possibility of leaching from this dump causing soil and biota contamination on the beachline and lower river embankment.

A copy of his brief report is attached.

Report on

MINERALOGICAL COMPOSITION OF PYRITE CALCINES FROM FREMANTLE

by Jiri Just, Mineralogist

This report has been prepared for Maunsell & Partners Pty. Ltd. at their request. The oppinions expressed in the report reflect the author's assesment of the situation.

SUMMARY

1. Location: Fremantle.
2. Problem: possible escape of heavy metals from pyrite calcines into wider environment.
3. Aim of the study: to determine if relict sulphides after possibly incomplete calcination of pyrite ores are still undergoing oxidation by atmospheric weathering.
4. Mineralogical composition of calcines as determined by x-ray diffraction and scanning electron microscope:
   - dominant: hematite
   - subordinate: quartz, gypsum
   - minor: barite, potassium feldspar
   - trace: magnetite, calcite?, plumbojarosite
5. Detected heavy metals minerals: zincian brochantite, azurite, plumbojarosite, cerussite ??, hydrated hydroxysulphates of iron and aluminium with small content of copper and zinc.
6. No sulphides were detected in the investigated samples, but the presence of ephemeral iron sulphates indicates that oxidation of sulphides to sulphuric acid is still taking place in the dump material.
7. Copper, zinc, and lead appear to be well contained within the dump material by neutralizing action of the limestone under low water flow conditions but copper and zinc could escape into the wider environment under conditions of increased water flow.

INTRODUCTION

The study of the mineralogy of pyrite calcines at the Fremantle site, Fremantle, has been undertaken on request of Maunsell & Partners, Pty. Ltd. in order to establish if any unreacted sulphides are present in the dump material and if there are curently taking place any chemical processes which could release heavy metals from the dump into the wider environment. I have visited the site on February 3rd, 1986, in the company of Mr. P. Reed of M & P and again on Feb. 6th to familiarise myself with the site, to collect samples for mineralogical study and to check my conclusions against the actual field situation. The samples for study of the bulk composition of the calcines were provided by M & P.

METHOD OF INVESTIGATION

The individual minerals were identified by x-ray diffraction (Debye-Scherrer powder method) and their composition qualitatively checked with a scanning electron microscope equipped with an x-ray energy dispersion spectrometer (SEM-EDS). The bulk composition of the calcines was determined by x-ray diffraction scan (XRD) for major and minor components and SEM-EDS for trace components.

RESULTS

Bulk composition of calcines.

The bulk mineralogical composition of the calcines has been determined on pulverised analytical rejects of sample MT 17-4-1.0. Hematite is the dominant phase, quartz and gypsum are subordinate, barite and potassium feldspar are minor components; magnetite, calcite ?, and a plumbojarosite and possibly cerussite are present in trace amounts. No copper or zinc minerals were found but EDS spectra collected during area scan of the sample indicated presence of trace amounts of copper and zinc.Hematite and magnetite are products of calcination of pyrite, quartz, barite, and potassium feldspar are residual minerals from the pyrite ores, calcite and some quartz are due to admixture of sandy limestone, gypsum and plumbojarosite are secondary minerals formed by weathering of incompletely burned calcine.

Secondary minerals (i.e. minerals formed formed in situ by weathering of the dump material).

Brochantite [$Cu_4(SO_4)(OH)_5$] is the most common copper mineral found on the dump. Small amount of zinc substitutes for copper in the lattice of the mineral. Brochantite occurs as minute bluish-green grains and coatings in the calcine matrix and in limestone fragments. It is formed in weakly acid to neutral environment by neutralisation of the acidic copper-bearing sulphate solutions by limestone.

Azurite [$Cu_3(CO_3)(OH)_2$] forms bright blue coatings on fracture surfaces of limestone fragments. It also is formed by neutralisation of the copper-bearing solutions by limestone but in conditions of elevated partial pressure of CO_2.

Plumbojarosite [$PbFe_6(SO_4)_4(OH)_{12}$] forms brownish-yellow friable nodules in the calcines. It is formed under more acid conditions than brochantite or azurite.

Gypsum [$CaSO_4$ x $2H_2O$] occurs as colourless or pale yellow aggregates of microscopic needles or as individual needles disseminated in the calcines. It has been formed by reaction of sulphuric acid released from decomposing pyrite with limestone. Much less often gypsum occurs as pulverulent efflorescences on the surface of soil, especially around shells of dead snails.

Iron sulphates. Several different hydrated sulphates or hydroxysulphates of iron were found in several places of the dump. They form bright yellow or white efflorescences on or immediately below the surface of the dump material as a result of evaporation of acid sulphate-rich solutions. The actual mode of occurence depends on local microclimatical conditions. Closer characterisation of these minerals would require a further, more detailed study which is not warranted at this stage.

Aluminium sulphate. An aluminium or aluminium-magnesium sulphate containing small amount of zinc has been found as white coatings and efflorescences on walls and debris in a sump at the foot of the dump.

DISTRIBUTION OF THE SECONDARY MINERALS

A visual estimate of abundance of secondary minerals has been attempted on the material around the trenches.

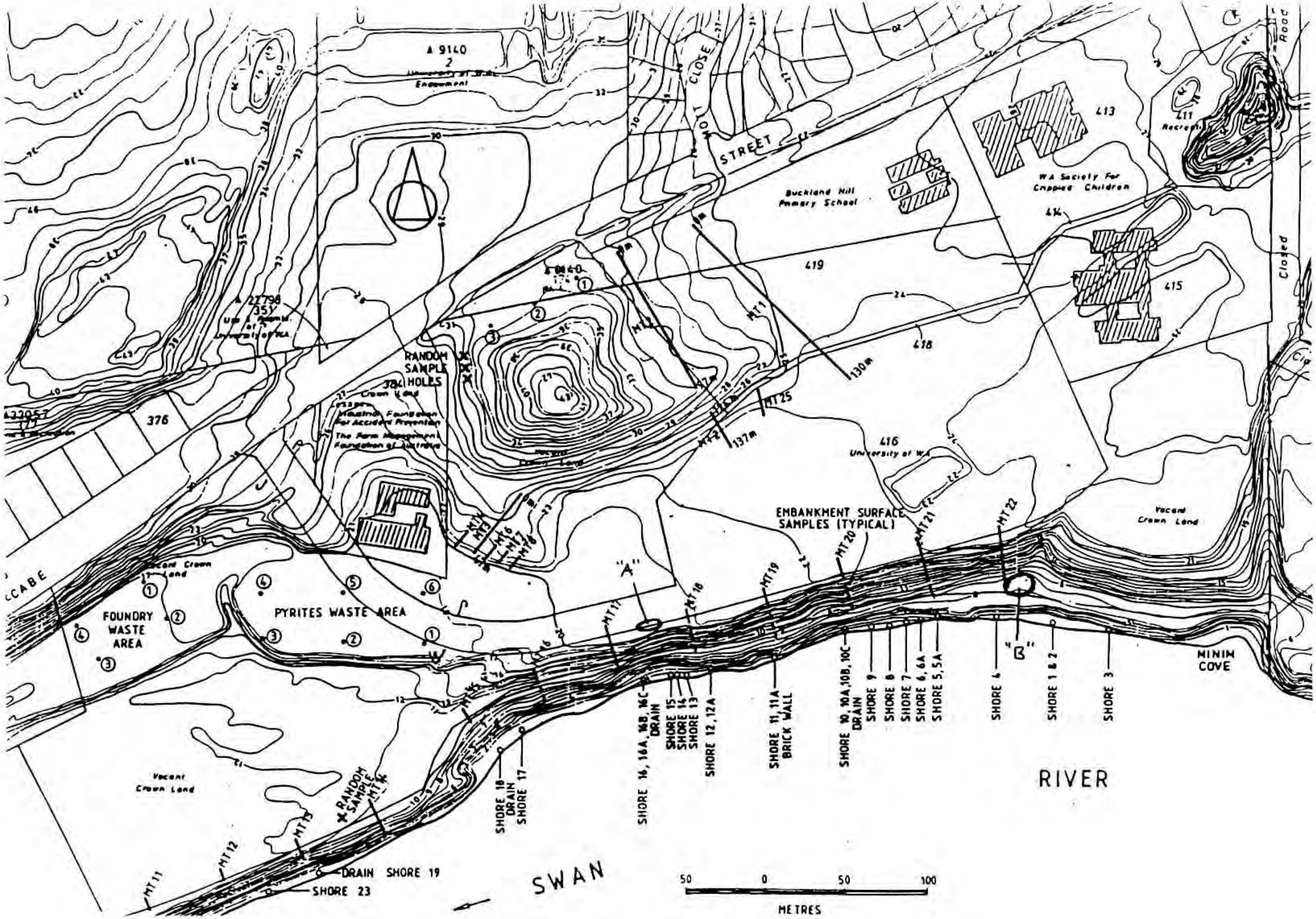
MT 16 no copper or lead minerals seen, but there are signs of active weathering.
MT 17 traces of brochantite, plumbojarosite common, signs of active weathering.
MT 18 brochantite common, azurite abundant, no plumbojarosite seen, area of very active weathering nearby.
MT 19 little brochantite.
MT 20 brochantite common.
MT 21 traces of brochantite.
MT 22 no copper or lead minerals seen.

Iron sulphates were found in larger quantities in two areas, marked "A" and "B" on the attached map. The "A" area is located at the top of the dump between MT 17 and MT 18. It is about 12 x 3 m in size and at the time of the visits it has been very dry. The surface of the dump is here covered with hard crust of calcines cemented by gypsum and other nondescript sulphates. Iron sulphates form bright yellow efflorescences just under the indurated crust. The crystallisation force of the sulphates causes the crust to lift and form characteristic "blisters" with cracked surface. In the "B" area the efflorescences of iron sulphates form at the foot of the dump on surface of moist soil between limestone boulders. In both cases the sulphate efflorescences seem to be ephemeral i.e. they are destroyed by rain and form again during drier period. Their occurence strongly suggest that there are still active sources of sulphuric acid in the dump, most likely residua of incompletely burned pyrite. The waters which deposit these sulphates would be chemically very aggresive.

CONCLUSIONS

Weathering of the pyrite calcines on the Fremantle site is producing an association of secondary minerals of copper, zinc, and lead which is similar to that formed in oxidation zones of some Cu-Pb-Zn deposits. The mode of occurence and ephemeral character of iron sulphate efflorescences are reminiscent of similar efflorescences formed on weathering dumps of pyrite-rich sulphide ores. Both these phenomena strongy suggest that for some reason the calcination of the pyrite ores has been incomplete and that the dump material still contains some unreacted sulphides, most likely pyrite (FeS_2) and/or pyrrhotite (FeS). These sulphides now oxidize, under the influence of atmospheric oxygen and moisture, to sulphuric acid and iron sulphates. The sulphuric acid mainly reacts with calcite in the sandy limestone in the dump forming gypsum, but a small part of it reacts with copper, zinc, and lead from the calcined pyrite ores to form plumbojarosite and soluble sulphates which further react with the limestone to form brochantite and azurite. In this way copper, zinc, and lead are fixed within the dump if the residence time of the groung waters within the dump is long enough to allow complete neutralisation of the acidic water by the limestone. If however the residence time is not sufficient for complete neutralisation, as could happen during rainy periods, copper, zinc, and possibly some lead could escape into the wider environment.

Perth, February 11th, 1986.


A 9140
2
University of W.A. Endowment
CLOSE
MOTT
STREET
Buckland Hill Primary School
W.A. Society For Crippled Children
413
411
Recreation
Road
Closed
419
415
418
416
University of W.A.
Vacant Crown Land
A 22798
35Y
Univ. of W.A.
RANDOM SAMPLE HOLES
384
Crown Land
Industrial Foundation For Accident Prevention
The Farm Management Foundation of Australia
Vacant Crown Land
130m
137m
MT1
MT2
MT25
376
A 22057
MCCABE
EMBANKMENT SURFACE SAMPLES (TYPICAL)
MT22
MT21
MT20
MT19
MT18
MT17
MT16
MT15
MT14
MT13
MT12
MT11
"A"
"B"
FOUNDRY WASTE AREA
PYRITES WASTE AREA
Vacant Crown Land
RANDOM SAMPLE MT14
SHORE 18 DRAIN
SHORE 17
SHORE 16, 16A, 16B, 16C DRAIN
SHORE 15
SHORE 14
SHORE 13
SHORE 12, 12A
SHORE 11, 11A BRICK WALL
SHORE 10, 10A, 10B, 10C DRAIN
SHORE 9
SHORE 8
SHORE 7
SHORE 6, 6A
SHORE 5, 5A
SHORE 4
SHORE 1 & 2
SHORE 3
MINIM COVE
DRAIN SHORE 19
SHORE 23
SWAN
RIVER
50
0
50
100
METRES

APPENDIX G

REFERENCES

APPENDIX G

REFERENCES

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