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Environmental investigations and rehabilitation considerations at the Ottery Mine, Emmaville, N.S.W.

GEOLOGICAL SURVEY OF NEW SOUTH WALES
DEPARTMENT OF MINERAL RESOURCES

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Clive 9239-III

Accompanying Plans: *10934 Ottery Mine Survey (1:1000)*
11132 The Ottery Mine – Water and Stream Sediment Sampling Results

Plan 10934 also available at 1:500 scale

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ABSTRACT

The derelict Ottery tin/arsenic mine is responsible for pollution of a small creek which joins the Beardy River. Water and sediments in this creek are contaminated with arsenic, cadmium, copper, iron, lead and zinc. The main source of the pollutants is continuous outflow from underground workings via an adit. During rainfall additional contamination is caused by leaching from waste dumps and toxic residues on the remains of an arsenic refinery. The quality of water in the Beardy River does not appear to have been significantly affected. Encrustations on the refinery contain high concentrations of arsenic and are hazardous to public safety. Open shafts, collapsed workings and contaminated waste dumps pose additional dangers. The mine has historical and scientific importance. The remains of the arsenic refinery are a unique historical example of metallurgical processing. The mine has potential for the discovery of reserves of tin ore and a slimes dump and tailings dam have potential for retreatment for tin recovery.

Three options are presented for the future of the site:

Option 1	Site preserved as is.
Option 2	Partial rehabilitation - structures retained.
Option 3	Complete rehabilitation - structures demolished.

Essential safety measures are immediately required and are common to all options. It is recommended that Option 2 be implemented and that the site not be excluded from any applications for prospecting or mining authorities provided special conditions are applied for protection of the structures and rehabilitation works.

CONTENTS

LIST OF PLATES

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

This report forms part of a continuing programme of investigations of the environmental effects of abandoned, existing and proposed mining operations throughout the State, particularly with regard to water quality, which is being carried out by the Geological Survey and Chemical Laboratory Branches of the Department of Mineral Resources. The Department has also maintained a programme of rehabilitation of derelict mine sites since 1976, for which reports such as this are required as part of the process of selecting and ranking mine sites for rehabilitation, and also to determine the site problems to be dealt with during rehabilitation.

The Ottery mine is a derelict underground tin/arsenic mine located near Emmaville in northern New South Wales. Environmental investigations at the mine developed as a result of enquiries by the Water Resources Commission and the Health Commission of N.S.W. in early 1974. Advice was sought from the Department concerning the pollution of waterways by effluent from the old mining site. A preliminary investigation indicated very high concentrations of arsenic and other toxic metals in the creek draining the mine and a subsequent routine water sampling programme conducted between 1974 and 1977 confirmed the early results. Analysis of compounds coating the brickwork ruins of the processing plant were also found to contain very high arsenic levels.

In 1975 the State Pollution Control Commission engaged a firm of consultants to undertake a study of derelict mined land in the Emmaville area (Gutteridge, Haskins & Davey, 1975) and the Ottery mine was regarded as a significant problem site and received a high priority for rehabilitation. This was recommended mainly on the grounds of public safety and water pollution. However it was also considered that the mine had historical and educational value which should be preserved in any rehabilitation programme.

In 1977 the Department sought the advice of the Historical Buildings and Sites Advisory Committee of the N.S.W. Planning and Environment Commission as it was thought that the derelict structures may warrant preservation for their historical, scientific or tourist value. A technical report is currently being prepared by officers of the Commission to enable a decision to be made by the Heritage Council of New South Wales.

Rehabilitation plans for the mine depend to a considerable extent on whether the site, or any part thereof, is to be preserved under the provisions of the Heritage Act (1977). The community is showing a growing awareness of its heritage and it is foreseeable that the Department will give greater consideration to preserving and possibly restoring some of the State's old mines in its rehabilitation programme.

This report examines all the environmental and related issues involved at the Ottery mine, and describes the problem of water pollution and the extent of toxic waste material on the site. A review of the mine's potential for renewed production and/or historical preservation has also been made.

BACKGROUND DATA

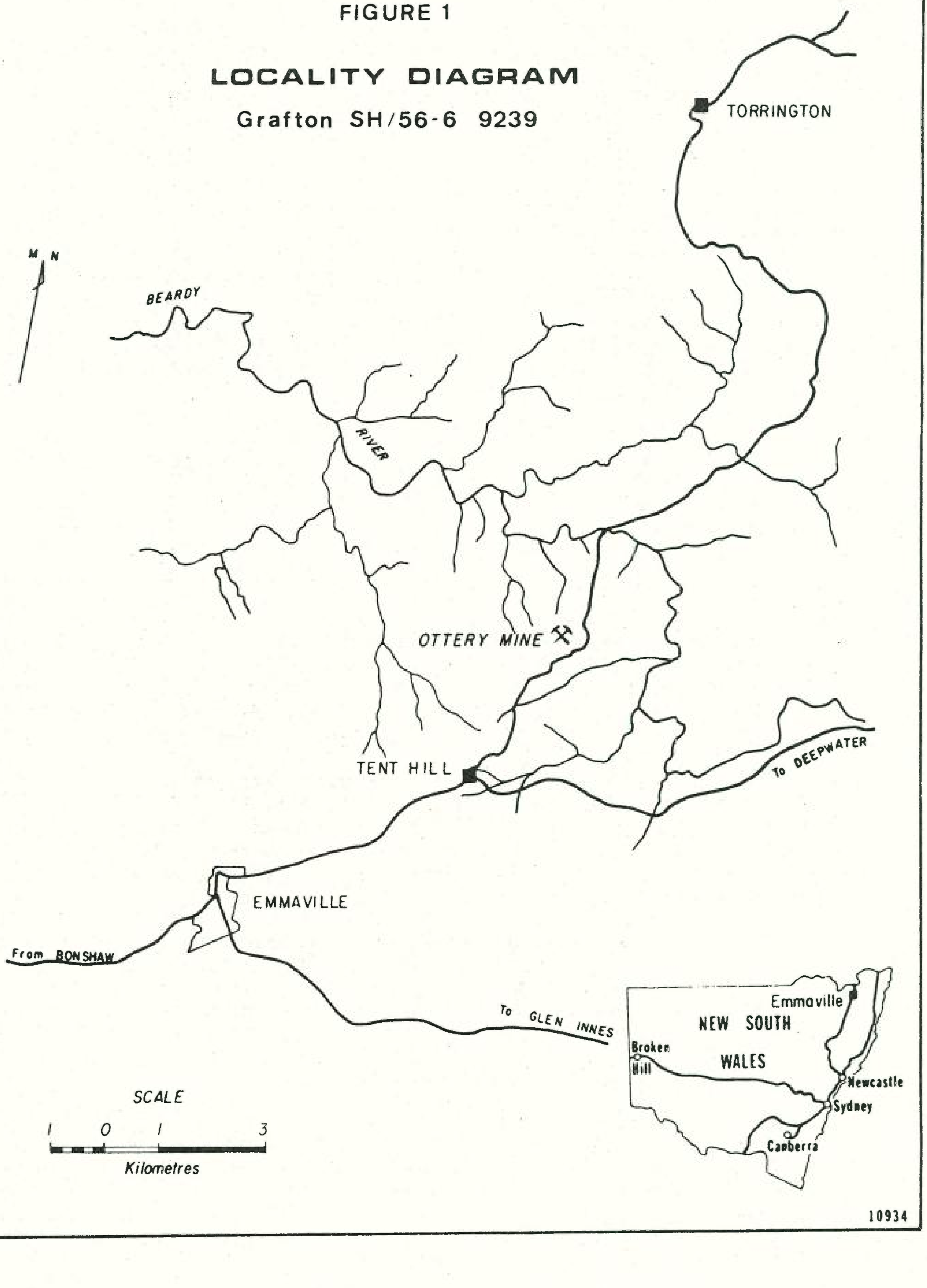
Location

The Ottery mine is located 8 km northeast of Emmaville in the New England region of New South Wales. The mine is situated to the west of the Tent Hill - Torrington Road about 2.5 km north of the old mining village of Tent Hill (Figure 1). A topographic map on a scale of 1:100,000 covers the mine area (CLIVE 9239 G.R.700460).

FIGURE 1

LOCALITY DIAGRAM

Grafton SH/56-6 9239



History of Mining

The town of Emmaville owes its existence to the discovery of alluvial tin in Vegetable Creek in the year 1872. The district proved to be very rich in both alluvial and lode tin. The speculation associated with the discovery caused a great influx of population and a new mining boom (Lobsey, 1972).

The Ottery tin mine was one of the first underground base metal deposits exploited in the Emmaville district. It was discovered by, and named after, Alexander Ottery about 1881. The mine was worked continuously for tin from 1882 to 1905 by the Glen Smelting Company who set up a smelter and 15 head stamp battery at nearby Tent Hill. On average fourteen men were employed, and the mine produced about 2,500 tonnes of tin concentrates during this period. Details of these early operations are contained in Carne (1911). There is no official record of any production or activity during the period 1905 to 1920 and it would appear that the mine remained closed. Plate 1 shows the Ottery tin workings in 1906.

In 1920 the mine was acquired by the Sydney based firm of William Cooper and Nephews (Aust.) Pty. Ltd., for the sole purpose of producing arsenic for the manufacture of sheep and cattle dips and other pesticides. Mr. A. C. Julius was appointed mine manager.

The exploitation of the rich arsenic lode was an extensive and costly process. The production of a high grade white arsenic required refining to a minimum purity of 99.7% arsenic trioxide (As_2O_3). A complex treatment plant was constructed between 1920 and 1922, consisting of over 450,000 bricks, mostly made by the company locally at Tent Hill. Plate 2 shows a panoramic view of the mine in 1922 while Plate 3 shows the corresponding view of the ruins as they are today.

The first stage in the treatment process involved feeding the coarse ore to a bench of 8 roasting kilns and the fine ore to a mechanical furnace for calcining. The kilns required no fuel other than the sulphur content of the ore itself, whereas the fine screened ore required the assistance of wood fuel. The resulting arsenic fumes passed to a set of 66 condensation chambers, arranged in two blocks of 33 chambers each. The arsenic gases were cooled and sublimed on the interior brickwork as solid crystals of crude arsenic trioxide. The two blocks of chambers were necessary for a continuous operation, as one set was used for the condensing operation, the other was cooled for extraction of the precipitated arsenic. After cooling, the powdery crystals were removed and transported to the refining section.

The second stage in the process was necessary to remove the remaining impurities. This required the crude arsenic to be resublimed in a coke-fired reverberatory furnace. The gases passed to a second set of 66 condensation chambers and the process repeated as in the first stage. The refined arsenic trioxide was then barrelled and transported to Sydney.

The four groups of cooling chambers were connected by a common flue to a central stack at the top of a steep hill. This gave a good natural updraft and complete cooling, before allowing the escape of residual gases to the atmosphere.

As the handling of arsenic was a potentially hazardous occupation, entry of men into the chambers was avoided wherever possible. When handling

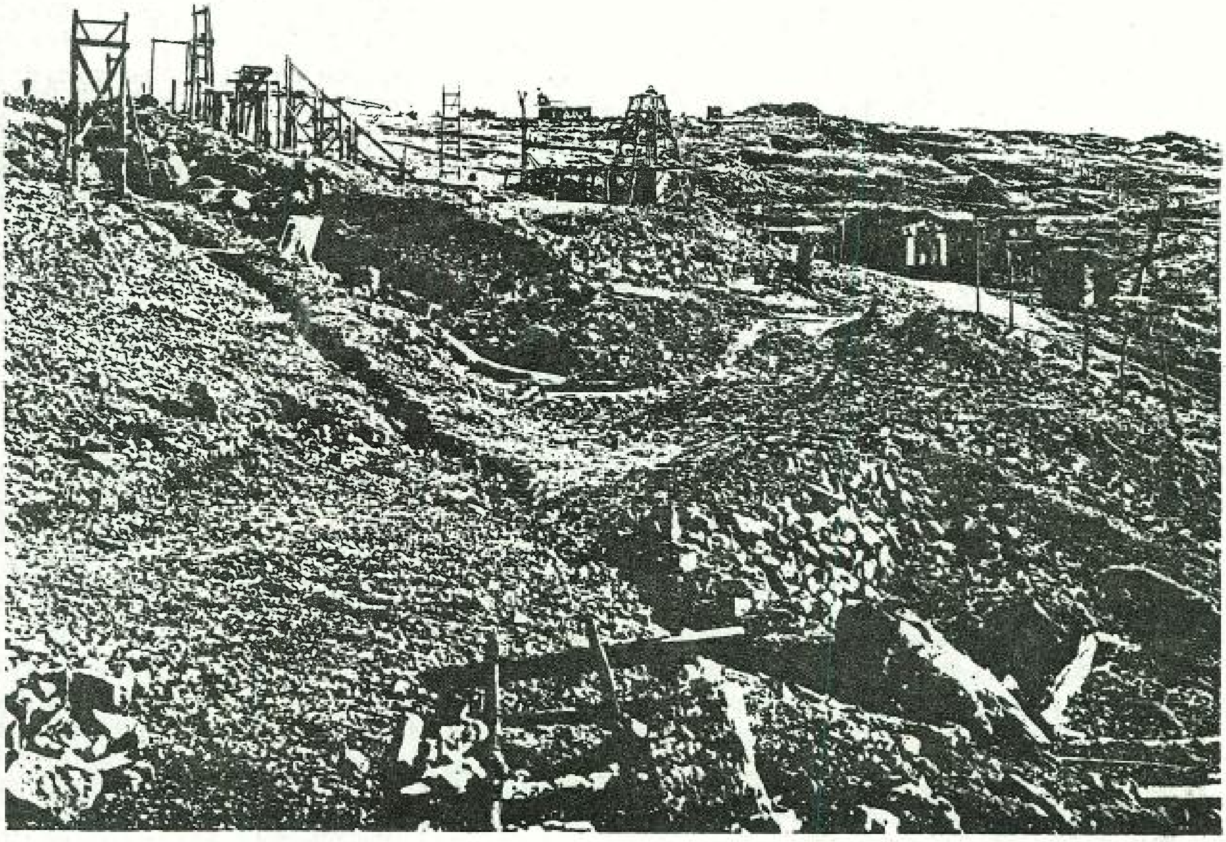


Plate 1. The Ottery tin workings 1906. Photograph reproduced from Carne (1911).

(Grafton 0010)

the arsenic, the men took all sorts of precautions such as the rubbing of soft soap into susceptible areas, the wearing of silk bloomers under their work clothes, and painting their bodies with a red paint substance (composition unknown) made up by the mine manager (Julius, 1972). The mine management was very safety conscious and no reports of deaths or major accidents from arsenic poisoning from the mine have been found in Departmental records.

In 1927 satisfactory recoveries of arsenic were being effected and it was decided that a tin treatment plant should be added to recover the tin oxide in the ore (Kenny, 1939). A ten-head battery was installed together with grinding pans and concentrating tables. Twenty eight men were employed during this period. A lack of water for the tin plant became a problem and so a concrete weir was put across the Beardy River two kilometres to the east of the mine. During the next two years much of the calcined ore previously used for arsenic extraction and then dumped was put through the tin plant.

In the latter half of 1929 mining operations ceased because of the economic depression and low mineral prices. Around 1932, A.C. Julius entered into a tribute with William Cooper and Nephews, who were still the owners, but were not prepared to re-open the mine themselves under such depressed prices. Rather than let the mine and plant fall into ruins, Mr. Julius and up to ten men, managed to work the mine for about four years by austere methods (Julius, 1972).

The mine closed in 1936 due to cheaper imported arsenic and was ultimately bought from Coopers by Burma Malay Tin Ltd. Repairing and reconditioning commenced in 1939. A freshwater dam for storage of boiler feed and dressing water was constructed at the mine. All ore was treated directly through the tin plant and no arsenic was produced during this period. Prolonged dry weather forced the operations to close in 1940. The company pulled down the plant buildings and equipment and transferred them to other areas held by them.

In 1956 the Guardian Trading and Investment Company Pty Ltd reconditioned the mill and set up equipment to treat the remains of the old calcine dump. Three men were employed, the operations being reasonably successful with a low grade concentrate being obtained. Operations ceased in 1957. Further minor attempts were made to mine and treat the dumps by prospectors in the sixties. No further work has been attempted to the present day.

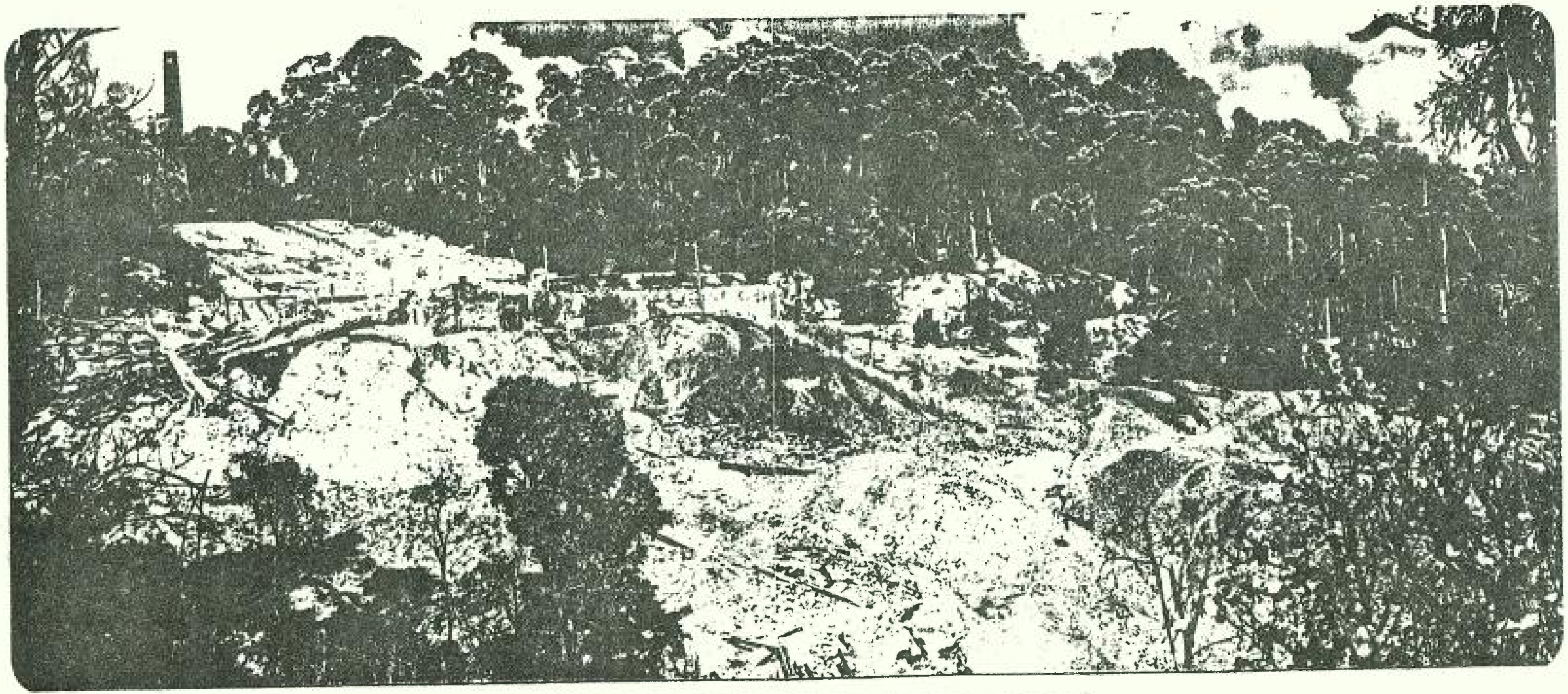
The decline and eventual closure of the Ottery mine as an arsenic producer was principally due to competition from imported arsenic. This is discussed more fully in Appendix 5 where Figure 5 graphically depicts the demise of Australian produced arsenic.

Geology and Mineralization

The Ottery mine is one of the largest metalliferous lode deposits (in terms of tonnes of ore mined) so far found in the New England region of N.S.W. Five fissure veins containing both tin and arsenic are present within a narrow belt of granite, between sediments to the west and the Tent Hill Porphyrite to the east (Weber 1975). Figures 2 and 3 after Kenny (1939) show the surface geology and extent of underground workings respectively.

In the lodes, arsenopyrite, cassiterite and pyrite occur with a little pyrrhotite also being present. Minor minerals include marcasite, chalcopyrite, sphalerite, and rare stannite, bismuth and bismuthinite. The principal gangue is quartz.

Plates 2 and 3. The Ottery mine and arsenic refining plant in 1922. (Photos courtesy of H. Julius). Below, the remains of the site as they are today.



(Grafton 0020, 0025, 0569 B, 0569C)

The main workings cover an area about 250 x 100 m and extend down to a depth of 79 m. Only the No. 1 and No. 4 lodes have been developed to any great extent. Over 110,000 t of ore were milled, with grades averaging around 2.2% tin and 9% As_2O_3. Total recorded production from the mine is 2004 t of white arsenic and 2737 t of tin concentrate.

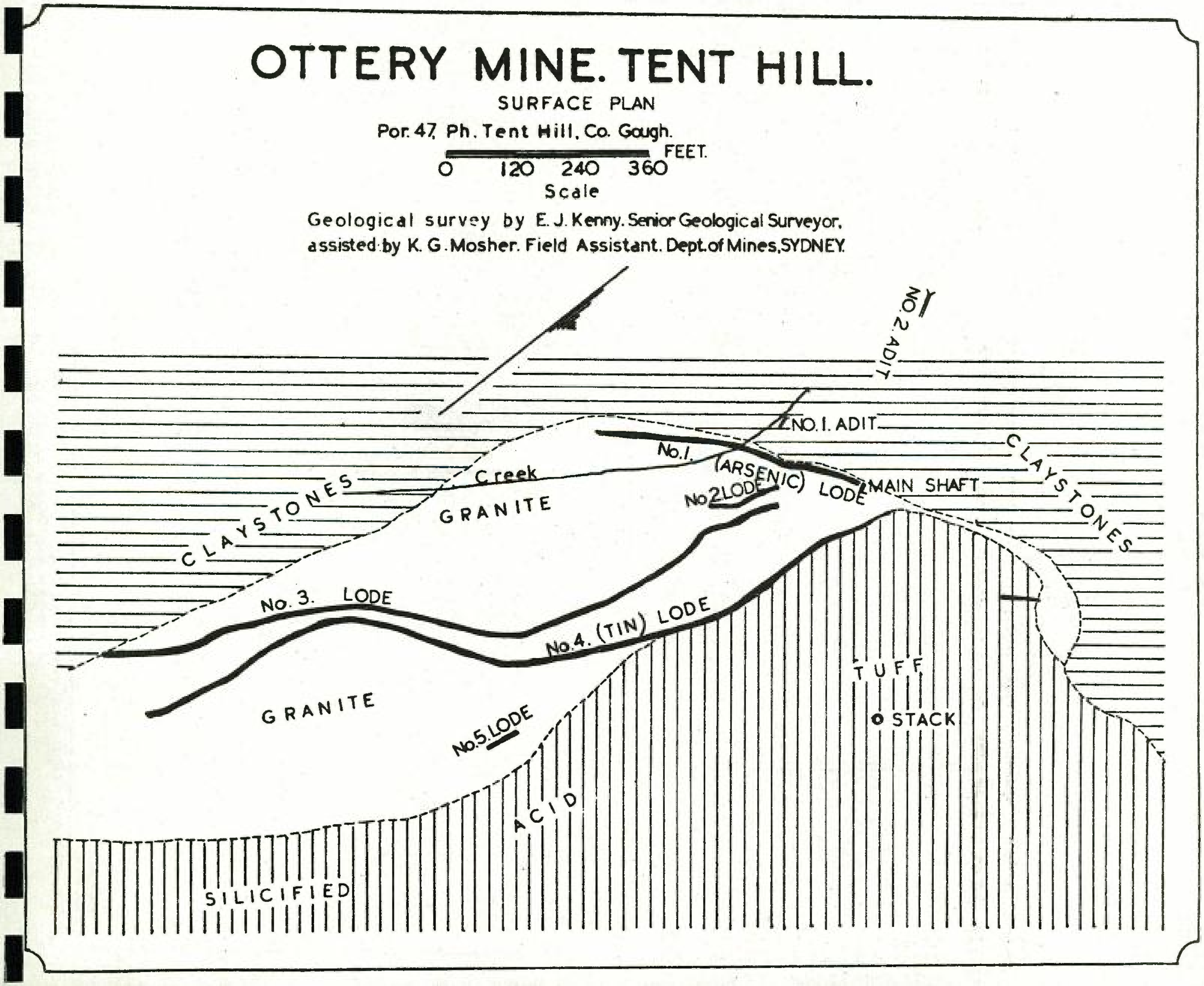
Further reference to mineralization is made in a later chapter on "Economic Potential". The recorded production figures of arsenic for the Ottery mine are given in Figure 5 (Appendix 5).

Land Ownership and Mining Titles

Most of the land on which the Ottery mine workings are situated is encompassed within portion 47, Parish Tent Hill, County Gough. Part of the workings to the north of the tin concentration plant lie outside portion 47. The registered owner of portion 47 and of the minerals (excluding gold) is John Hughes Gibson (deceased) - Executor of Estate: G. W. Gibson. The Severn Shire Council, however, have indicated an intention to auction portion 47 due to non-payment of rates.

FIGURE 2

(After Kenny, 1939)



Two Mining Lease Applications (P.L.L.A.'s 1007 and 1009) and one Mining Purposes Lease Application (M.P.L.A. 938) were made by the above owner in 1976. All three applications were refused by the then Minister for Mines as the subject areas contained arsenic contaminated tailings and residues which were considered to be potentially dangerous.

Subsequently another Mining Lease Application (M.L.A. 139) was made in 1977 by Loloma Ltd and Base Minerals (in liquidation). The subject area in this case takes in a much larger area than the Ottery mine. The above applicants are active in alluvial tin mining in the Emmaville area and the extent to which they are interested in the Ottery mine itself is not known. A number of other tin mining titles are in existence between the Ottery mine and Emmaville. Figure 4 outlines the current situation with regard to mining titles in the Tent Hill area, and Plan 10934 shows the portion boundaries in relation to the mine workings.

FIGURE 3

(After Kenny, 1939)

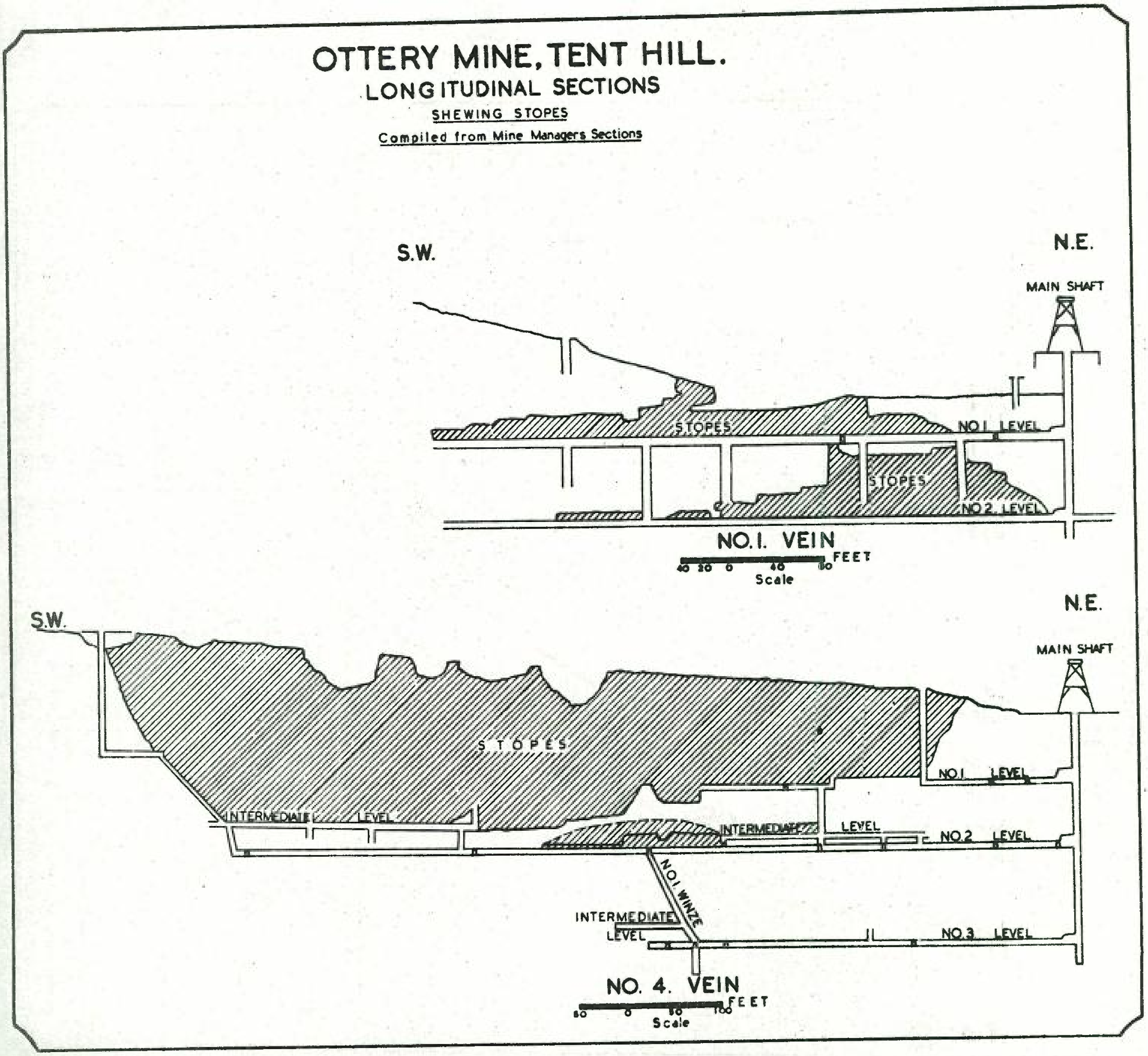
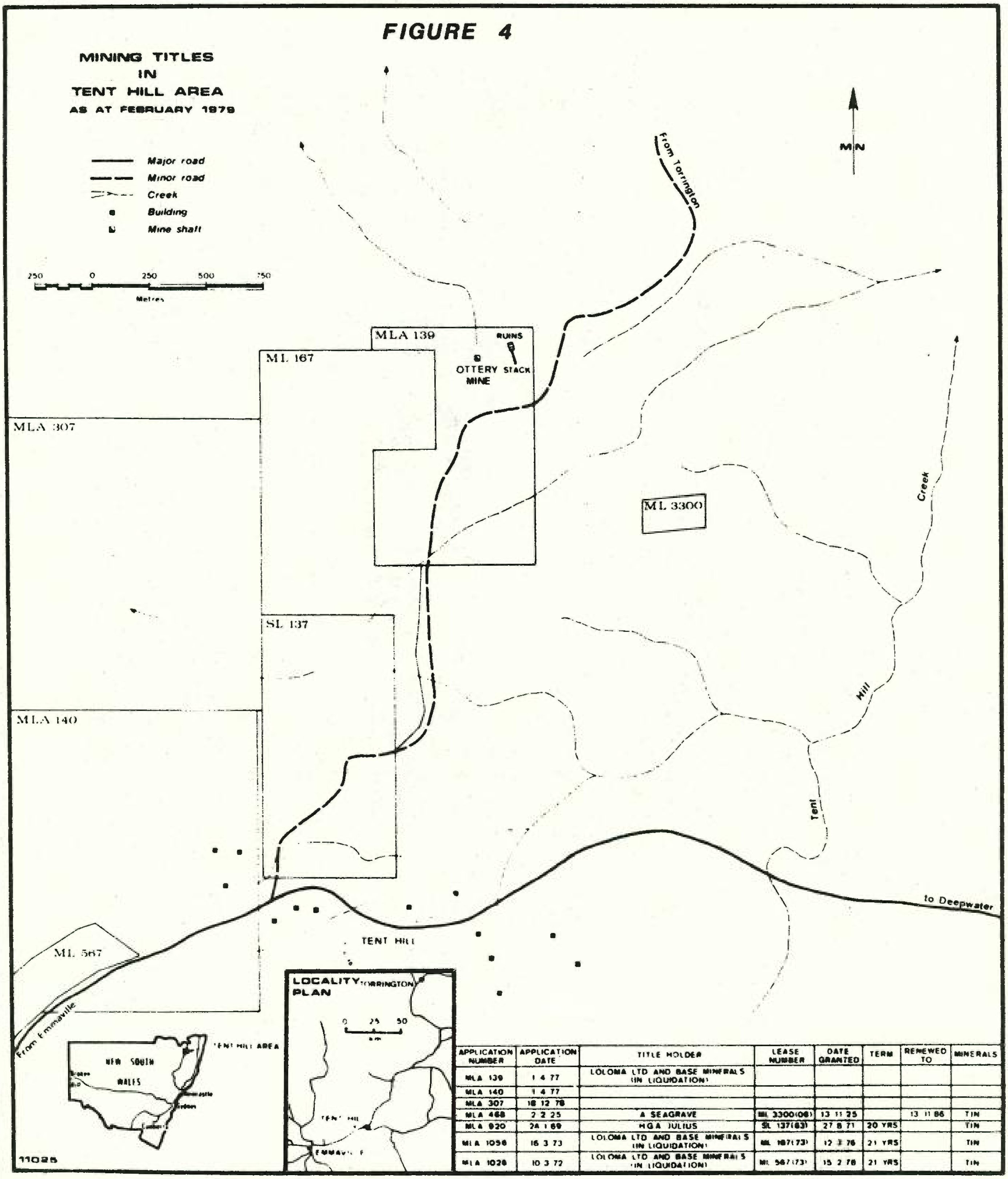


FIGURE 4



MINING TITLES
IN
TENT HILL AREA
AS AT FEBRUARY 1979

APPLICATION NUMBER	APPLICATION DATE	TITLE HOLDER	LEASE NUMBER	DATE GRANTED	TERM	RENEWED TO	MINERALS
MLA 139	1 4 77	LOLOMA LTD AND BASE MINERALS (IN LIQUIDATION)					
MLA 140	1 4 77						
MLA 307	18 12 78						
MLA 468	2 2 25	A SEAGRAVE	ML 3300(06)	13 11 25		13 11 86	TIN
MLA 920	24 1 69	HGA JULIUS	SL 137(63)	27 8 71	20 YRS		TIN
MLA 1056	16 3 73	LOLOMA LTD AND BASE MINERALS (IN LIQUIDATION)	ML 167(73)	12 3 76	21 YRS		TIN
MLA 1028	10 3 72	LOLOMA LTD AND BASE MINERALS (IN LIQUIDATION)	ML 567(73)	15 2 78	21 YRS		TIN

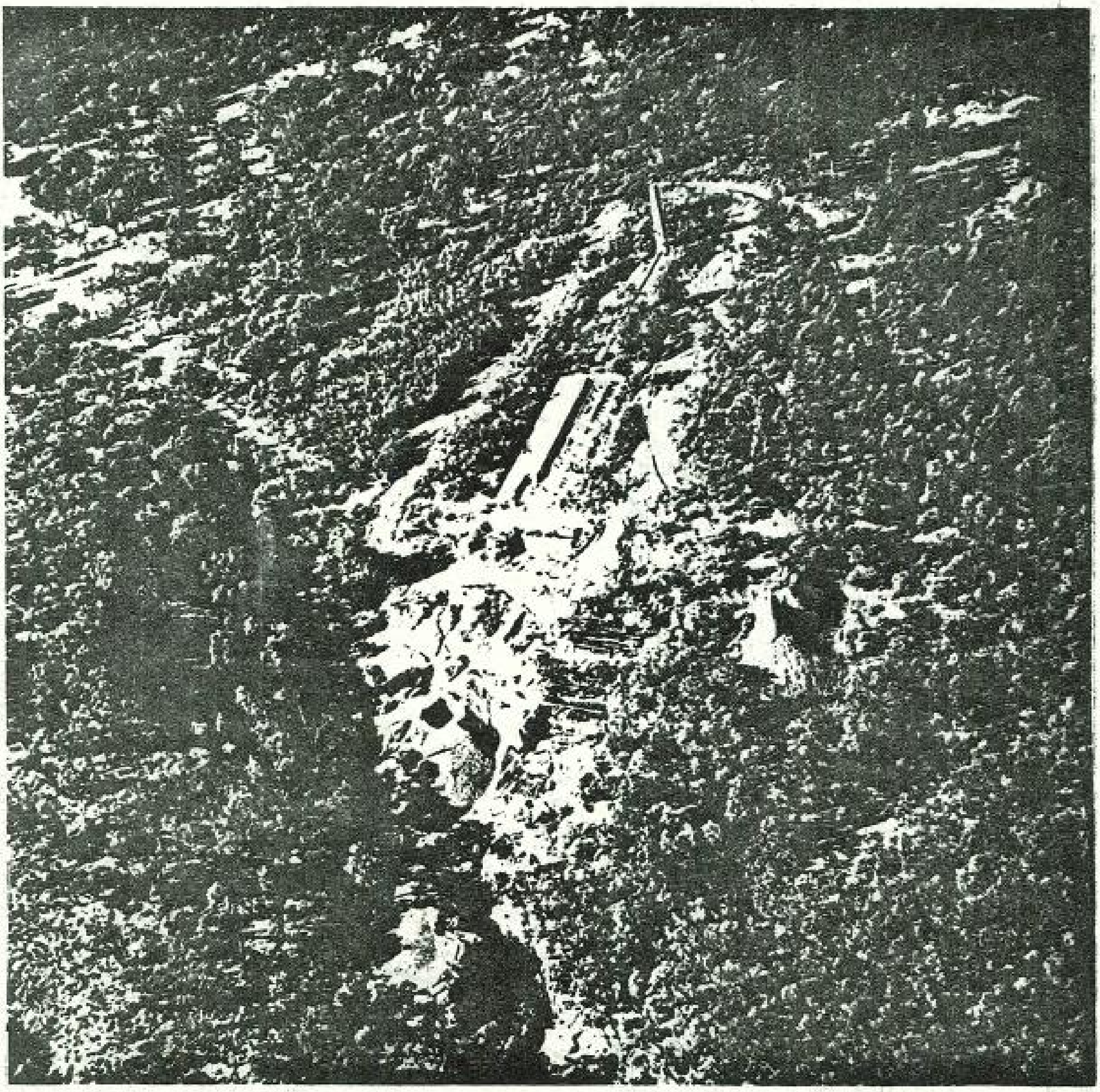


Plate 4. Aerial view of the mine site.1976.

(Grafton 0345)

Description of the Environment

Physiography

The Emmaville area is typical of the dissected plateau country of the northern part of the New England Tableland. The topography surrounding the Ottery mine is undulating to hilly, moderately timbered and characterised by poor quality soils. Land use mainly comprises grazing in the more open country, and alluvial tin mining. The Ottery mine workings lie on the side of a steep hill at the head of a narrow gully. All drainage from the mine flows into a small unnamed ephemeral creek which enters the Beardy River approx. 3 km downstream. The general course of the Beardy River (also known locally as Glen Creek) is northwesterly until it joins the Dumaresq River near the Queensland border.

The area receives moderate rainfall with an annual mean of 849 mm (33 inches). It is fairly evenly distributed throughout the year, but with a maximum in the summer months when thunderstorms are active. Rainfall is lowest in the months of April and May. Appendix 1 summarizes the rainfall characteristics of the area based on Commonwealth Bureau of Meteorology records for Emmaville, the nearest weather station for which full records are available.

The Mine Site

The mine site was surveyed by cartographers from the Geological Survey of N.S.W. in September 1978. The resulting plan (10934) is a combination of this survey work and that of an old mine plan (dated 1925) which depicted underground workings and surface structures. Aerial photographs of the mine site have also been taken by this Department and Plate 4 shows a general view of the main workings.

The Ottery mine is typical of many abandoned metalliferous mines throughout the State. Numerous derelict structures, open mine workings, eroding slimes dams and spoil dumps, and with miscellaneous junk spread over about 8 hectares, are a relict of almost a century of sporadic mining.

Since 1958 most of the plant, machinery and buildings have been disposed of, with only the extensive brick structures of the arsenic works remaining (Plate 5). Much of the refinery, once the pride of the district, is in ruins and has been deteriorating at a rapid rate. A tall chimney stack, still in excellent condition, dominates the crest of the hill. The burnt-out timber framework and concrete foundations of the tin concentrating plant are still evident below the main shaft.

The main shaft, which is open, has been built up with an extensive timber retaining wall and a large mullock dump on the down hill side. The mine workings extend up the gully to the southwest of the main shaft. There are numerous adits, small shafts, holes and collapsed stopes scattered through the bush. Several large circular open cuts, thought to be relics from the earliest tin producing days, occur towards the top of the hill. Two old functioning freshwater storage dams occur to the northeast and southwest of the mine workings.

Two large waste dumps partially block the drainage line below the arsenic chambers. A mullock stockpile (Plate 6) consists of crushed rock up to about 5 mm size (coarse calcines from the kilns). Below this a flat-topped slimes dump consists of very fine calcined residues

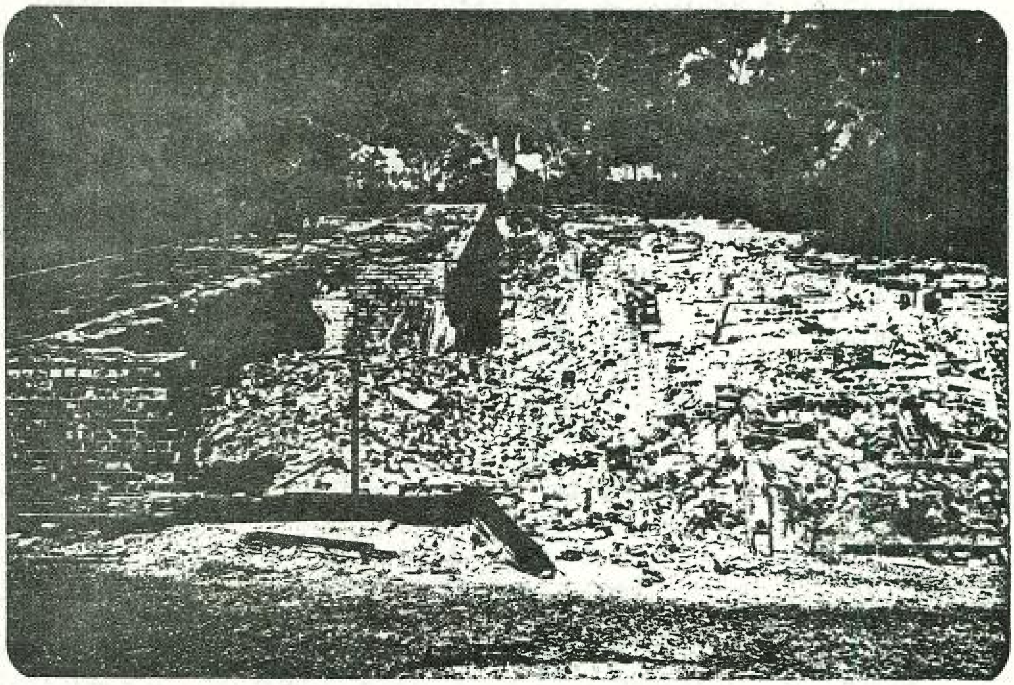


Plate 5. Ruins of the arsenic refinery - crude arsenic chambers (first stage) on right hand side and refined arsenic chambers (second stage) on left hand side.

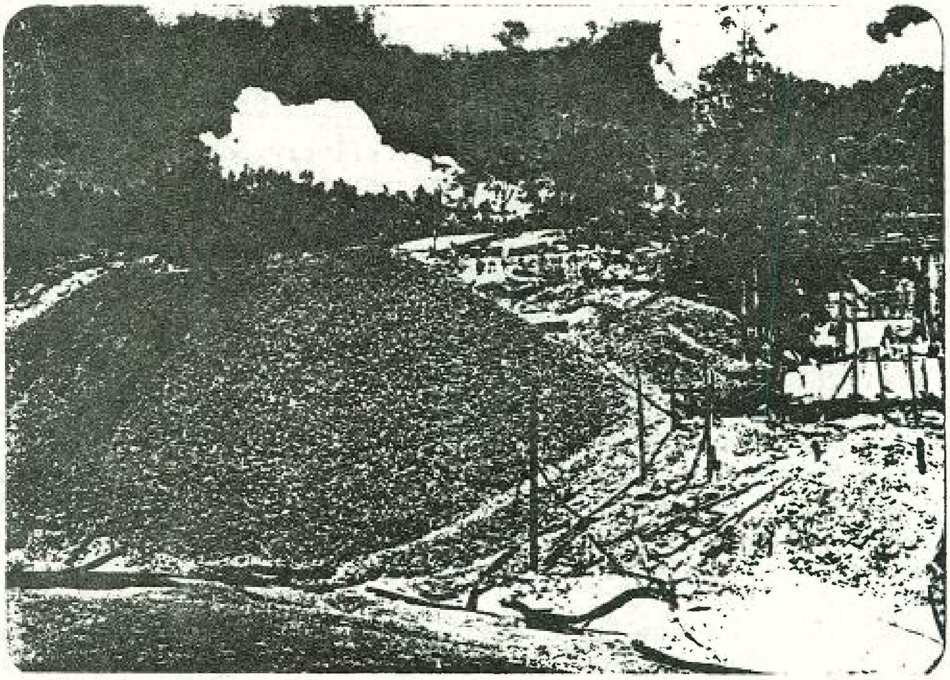


Plate 6. Mullock stockpile next to tin plant.

(Grafton 0193)

from the arsenic furnaces, most of which has been retreated for tin at various times. A five head stamper and engine used in the retreatment still stands next to the dump. A large spoil dump has been built up below the main shaft and there are other waste dumps at the entrances to both of the adits (see Plan 10934).

No. 1 adit, on the 20 m level (below the shaft collar) has been driven into the side of the gully to the west of the main shaft. Access to the underground workings can be obtained through this entrance which is open (Plate 7). Some ground seepage occurs, but no water flows out of this adit. No. 2 adit, on the 43 m level, is located in the middle of the lower watercourse (Plate 8). The entrance is inaccessible and polluted water flows directly from the adit down the creek to the Beardy River. Down the creek below the workings a large tailings dam is present in a tributary gully on the eastern side. This is almost full of sediment but the dam wall is breached and minor erosion is taking place.

The mine site was completely devoid of vegetation in the tin mining days at the turn of the century (see Plate 1) and any vegetation that existed in the 1920s was probably destroyed by a combination of arsenic fumes and the getting of wood for fuel and mine timber. With the exception of contaminated waste areas and sites of former buildings, much of the area is now covered with regrowth of scrub and small trees. Wattle trees, in particular, seem to thrive in the area and cover much of the hillside above the chambers. Because of the vegetation, most of the site, with the exception of the chimney stack, is not visible from the nearby road.

ENVIRONMENTAL IMPACTS

Aesthetics

Visual impact is small in magnitude and minor in importance. The mine is secluded, not easily accessible, and some distance from the nearest town. Most of the site cannot be seen from the Tent Hill - Torrington Road; only the chimney stack is visible above the trees from one vantage point on the road. The site itself is unattractive with its derelict workings, waste dumps, etc., however it has appeal to those interested in historical mining practices.

Safety

Mine Workings

Open mine workings, particularly shafts and steep-sided open cuts are a potential danger to both humans and animals. The main shaft nearly 80 m deep, consists of three compartments, is close-timbered and in very good condition down to water level between No.2 and No.3 level. A few rotting timbers partially cover an otherwise completely open collar which is also collapsing around the sides (Plate 9). This situation is considered to be hazardous to public safety. The many small shafts and areas of collapsed workings in the gully to the southwest are likewise dangerous, particularly as they are often obscured by dense undergrowth. The open cuts are small, circular, and vary between 7 m and 10 m deep and have quite steep and unstable sides (Plate 15). Old plans suggest that stoping took place beneath the open cuts.

The entrance to the No.1 adit tunnel is completely open and invites public access to the underground workings. The entrance to the

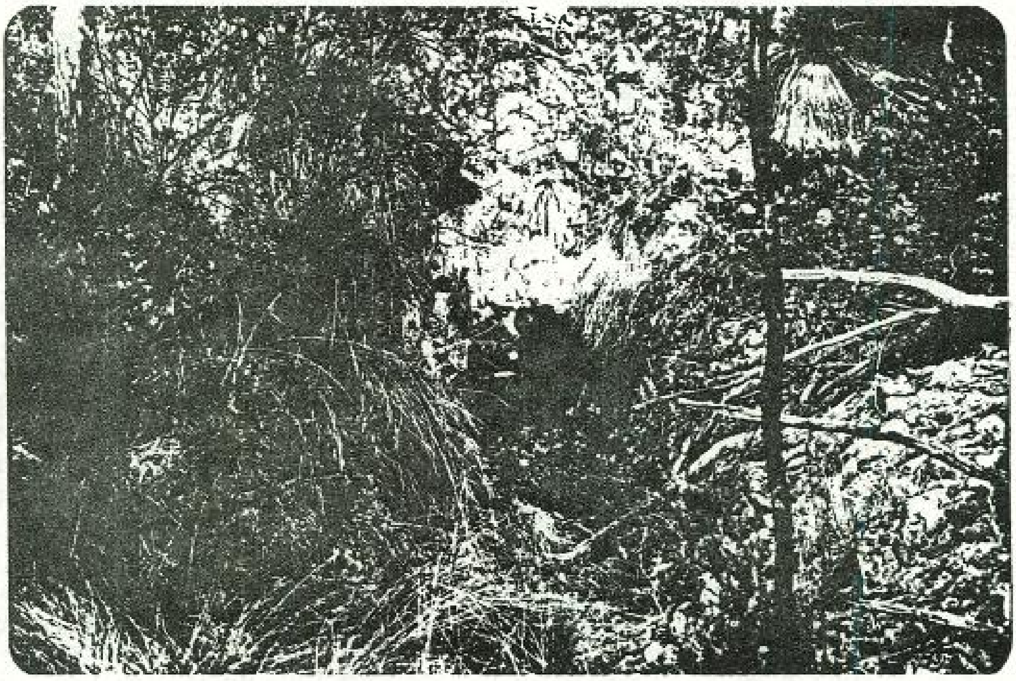


Plate 7. Open portal to No.1 adit.

Plate 8. Polluted water flowing from No.2 adit.

(Grafton 0572)

No.2 adit (in the creek bed) is open, but because of the partially collapsed portal and extensive water flow, is inaccessible. Plate 10 shows the condition of the underground workings on the No.1 level.

Buildings and Structures

It has been 44 years since the arsenic refining plant has been operational and much of the brickwork has fallen to ruin. The first stage chambers are in a much greater state of disrepair than the relatively intact chambers used for refinement of the crude arsenic trioxide. The sulphurous fumes from the roasted ore would have been very corrosive and would have weakened the brickwork and cement ceiling of the first-stage chambers, which subsequently collapsed.

While parts of the arsenic refinery brickwork and the timber framework of the tin plant are potentially unstable, the public hazard here is not considered to be of major significance. The chimney stack is in remarkably good condition, considering its age, and does not appear to be in danger of falling. The stability of buildings and structures on the site is therefore not regarded as a safety problem at present.

Arsenic Encrustations on Brickwork

Much of the brickwork of the condensation chambers is coated with compounds which have very high arsenic contents (Plates 11 and 12). Handling of the bricks could be extremely dangerous.

In 1974 the Department became concerned at allegations that members of the public had been removing bricks for use in the construction of barbecue pits. Warning signs were erected by the Severn Shire Council, but appeared to have no effect as evidence of removal of bricks was apparent into 1976. At this time, suggestions were being made that the structures should be preserved as an historic relic of old-time mining and metallurgical procedures. Therefore to protect the chambers against further "robbery" of bricks and to protect the public against arsenic poisoning, a barbed-wire fence was erected around the structure by the Department in 1976. This appears to have been effective, in that it has stopped people removing bricks, however the design of the fence is such that it will not prevent inquisitive people climbing through it to inspect the chambers at close-hand. All of the warning signs erected by the Council have disappeared with the exception of one at the entrance to the site.

Samples of the material coating the brick condensation chambers were collected in February 1974 and September 1978. The results of analysis and testing are given in Table 1. See Appendix 4 for details of analytical techniques employed.

The encrustations on brickwork exposed to weather are predominantly pink in colour, and are most profuse on the roofless sections of the first-stage series of chambers. The encrustation has the appearance of having formed out of reaction with water and the cement mortar between the bricks (Plate 11).

X-ray fluorescence analysis of this pink material showed that it contains minor amounts of iron. The arsenic content of the samples collected varied between 31.5 and 34.8%. X-ray diffraction tests of this material proved inconclusive, however chemical evidence indicates that it is arsenic pentoxide (As_2O_5) with minor amounts of iron compounds. The pink coloration is probably due to the presence of these iron compounds.

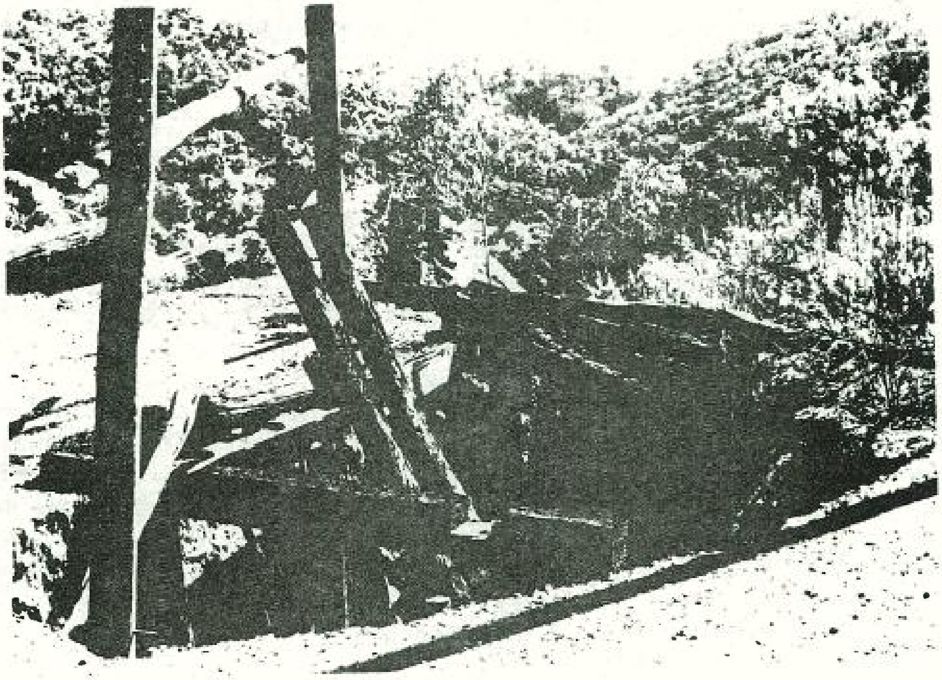


Plate 9. Open collar of main shaft.
(Grafton 0570B)

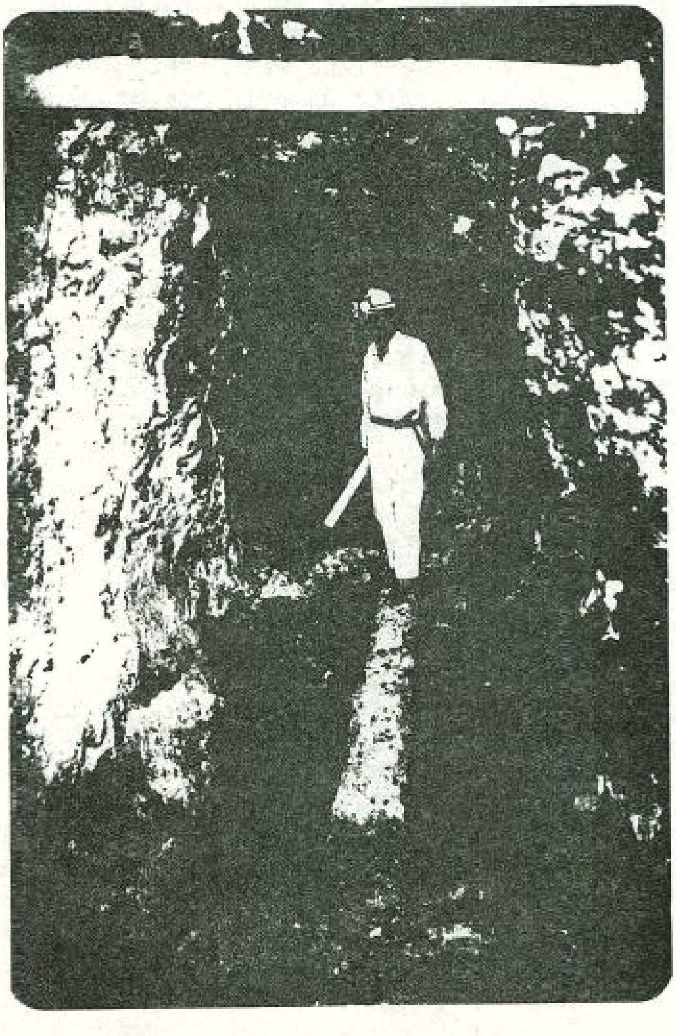


Plate 10. Plank covering a winze on No.1 level.

TABLE 1

RESULTS OF ANALYSIS OF ENCRUSTATIONS

Description	Sample No.	pH	Arsenic %				Solubility
			Total	Present as As III	Present as As V	As III expressed as As_2O_3	
Pink encrustations from first-stage chambers used to produce crude arsenic trioxide (As_2O_3)	G74/304	1.5	34.8				Extraction of the crushed sample with water in a 1 to 50 ratio (i.e. 1 g in 50 ml) solubilises 80% of the arsenic. (This extract contains 5000 mg arsenic/litre).
	G78/1803	2.3	31.5	0.2	31.3	0.26	
White encrustations from inside brick chambers used to refine arsenic trioxide	G74/303		35.7				Extraction of the crushed sample with water in a 1 to 50 ratio solubilises 25% of arsenic. (This extract contains 2000 mg arsenic/litre).
	G78/1841		72.5	72.4	0.1	95.6	
	G78/1802	3.3	40.4	36.3	4.1	47.9	

The material lining the interior of the second-stage chambers is different in both appearance and chemical composition to the pink encrustation. The material is white and much more crystalline (Plate 12). X-ray diffraction analysis showed that it consists of arsenic trioxide (As_2O_3) gypsum and quartz. The arsenic content in this white material was variable (35.7% to 72.5% arsenic) and depended on the particular chamber sampled.

Potential Hazard of Arsenic Compounds

The toxicology and hazardous properties of arsenic compounds are discussed in Appendix 5. Practically all arsenic compounds are poisonous and ingestion, inhalation or absorption through the skin can cause death or permanent injury. Acute arsenic poisoning has been caused by ingestion of as little as 100 mg, while 130 mg has been reported (Browning, 1961) as a fatal dose (about 1/50th of a level teaspoon by weight of powdered arsenic trioxide). Therefore the encrustations on the brick chambers are extremely dangerous even to touch. The pink, fluffy nature of some of the encrustations makes them look very inviting, particularly to children. The general public should be kept well away from the chambers and any other material on site that contains a significant amount of arsenic.

Waste Dumps

There are five major waste dumps on the mine site and a tailings dam in an adjoining creek. Three of the dumps contain waste rock produced in the development of the underground workings and occur at the three main exits of the mine - viz. the two adits and the main shaft. A fourth dump below the arsenic chambers contains crushed and roasted ore of a generally uniform size, with very little fine material. The fifth waste dump, and the most important as far as water pollution is concerned, is the slimes or calcines dump. This consists of very fine residues from the arsenic furnaces. It has been placed across the main drainage line and, as a result, a significant portion of this dump has been eroded and washed down the creek (See Plate 13).

A few samples from both the slimes dump and the tailings dam were taken in 1962 by King (1964) to identify possible exploitable sources of heavy metals and some of the less common metals (e.g., rare earths). Table 2 (from King 1964) shows that both the slimes dump and tailings dam contained of the order of 1 to 2% tin and the slimes dump up to 6% arsenic. Both were also minor sources of rubidium and lead.

The C.S.I.R.O. - Melbourne University Ore Dressing Laboratory has twice undertaken research work on the extraction of tin from tailings at the Ottery mine. Hart (1945) refers to treatment of 60,000 tons of sand containing 0.9% tin while Blaskett (1950) refers to the recovery of tin from residues from roasting arsenical ore.

TABLE 2

ANALYSIS OF TAILINGS DAM AND SLIMES DUMP (from King, 1964)

	Sample No.	Tin %	Arsenic %	Lead %	Sulphur %	Rubidium %	Major Mineral
Tailings Dam	1	2	1		0.15	0.08	Cassiterite
	2	0.3	2	0.5	1.81	0.12	Hematite
	3	0.6	1		0.83	0.07	Hematite
Slimes Dump	4	1.2	6		7.73	0.05	Arsenopyrite
	5	1	0.8	0.3	0.64	0.1	Hematite

Sampling of Waste Material

Samples of waste material were collected during this investigation from three of the dumps at the Ottery mine. In addition one auger hole was drilled in the tailings dam. The locations, descriptions and results of analysis of the samples are given in Table 3.

Samples of the dumps were taken to determine their heavy metal content as an aid in assessing their likely contribution to water pollution and to establish whether any toxicity exists either as a barrier to revegetation, or as a potential safety hazard. Volume and density measurements were also made as a means of estimating the total metal content and the quantity of material that would need to be disposed of, if necessary. The total metal content was also considered to be of importance in terms of the possible economic retreatment of any of the waste materials on site.

The auger hole was drilled to a depth of 1.87 m in the centre of the tailings dam and six samples collected at various depths. The dam was sampled to determine if it was in fact, a tailings dam and not just a sediment dam.

The dump materials were tested for pH and both total and soluble metal concentrations. The term "soluble" refers to metals which were easily extracted by deionised water, and is an indication of the amounts of the various metals which are readily available for leaching by rainwater. Details of the analytical methods employed are given in Appendix 4. The tailings dam was sampled only for total arsenic and tin content.

Waste dump D (sample MD-1) has a significant arsenic content of 0.6% and high lead content (1300 μg/g), however, due to their relatively low solubility there appears to be no potential pollution problems with respect to arsenic or any other toxic metals leaching from this dump. Similarly waste dump A (SS-1) is not a source of soluble toxic metals. It is unlikely, however, that either of these dumps would support vegetation without a covering layer of earth and topsoil.

The slimes dump consists of the calcined residues from the arsenic furnaces. It is composed of five distinct horizontal layers based on colour. Some of these layers can be seen in Plate 14, and a brief description is given in Table 3. Each of these layers was sampled individually and one composite sample was also analysed.

The arsenic concentration in the slimes dump ranges between 0.55% and 19.30% with an average concentration, based on the relative thickness of the various layers, of about 6 to 7%. Scorodite (hydrated iron arsenate - $FeAsO_4.H_2O$) was the only arsenic mineral that could be identified in the dump samples. This mineral is virtually insoluble in water. The middle layers (samples SD-3 and SD-4) have extremely high concentrations of arsenic and sample SD-4 was found to contain relatively high levels of readily soluble arsenic. (However the soluble arsenic represented only 1% of the total arsenic in this sample.) Extracting 1 g of this sample with 100 ml of water would produce a solution with an arsenic concentration of 20 mg/l. The average concentrations, based on the relative thickness of the different layers, of some metals in the slimes dump are: lead 1300 μg/g; zinc 250 μg/g; copper 180 μg/g; and cadmium 5 μg/g. The level of lead is high, however the "soluble" lead content is relatively low (30 μg/g). The concentrations of zinc and copper are not unduly high, however 80% of the zinc and 30% of the

TABLE 3

RESULTS OF ANALYSIS OF WASTE MATERIAL

LOCATION	DESCRIPTION OF SAMPLE	SAMPLE NUMBER	ASSAY NUMBER	pH	ARSENIC		CADMIUM		ZINC		COPPER		LEAD		IRON	TIN	APPARENT DENSITY	TRUE DENSITY	BULK DENSITY	MOISTURE CONTENT	DUMP VOLUME	DUMP MASS
					TOTAL	"SOLUBLE"	TOTAL	"SOLUBLE"	TOTAL	"SOLUBLE"	TOTAL	"SOLUBLE"	TOTAL	"SOLUBLE"	TOTAL	TOTAL						
				(extract)	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	%	%	gm/cc	gm/cc	gm/cc	%	m^3	t
Waste Dump D	Screened crushed rock	MD–1	G78/1140	4.65	6.000 (0.60%)	<5	2	<1	290	<5	60	<5	1.300	<5	6.4	0.59					1.000	
Waste Dump A	Mullock	SS–1	G78/1147	4.35	2.500 (0.25%)	5	6	<1	290	<5	110	<5	650	<5	5.7	0.86					1.100	
SLIMES DUMP	Composite sample of all distinguishable layers.	SD–1*	G78/1141	2.05	37.000 (3.7%)	200	5	2	260	160	290	130	1.200	10–20	8.1	0.82	1.2	2.9			2.200	3.300
	Top layer (brown) 0.1 m thick	SD–2	G78/1142	3.65	13.500 (1.35%)	<5	2	<1	120	<5	70	<5	2.350	<5	12.8	0.75	1.5	3. .	1.44	2.2		
	Second layer (white) 8.9 m thick	SD–3*	G78/1143	2.55	168.000 (16.8%)	250	7	<1	70	5	250	5	300	10–20	13.8	0.60	1.2	3.2	1.38	3.6		
	Third layer (grey–green) 2.4 m thick	SD–4*	G78/1144	1.65	193.000 (19.3%)	2.000	3	<1	60	40	240	25	350	10–15	14.2	0.58	1.2	3.0				
	Fouth layer (brewn) 3.4 m thick	SD–5*	G78/1145	1.85	12.000 (1.2%)	200	3	<1	130	40	160	40	3.500	80	12.8	0.65	–	–	1.58	6.6		
	Bottom layer (yellow) 4.0 m thick	SD–6	G78/1146	3.15	5.500 (0.55%)	10	8	5	515	505	150	120	200	<5	8.2	0.32	1.3	2.8				
TAILINGS DAM	Auger depth 8.20 m	TD–1	G79/298		6.400 (0.64%)											0.32			1.44	9.5	7.600	
	Auger depth 0.47 m	TD–2	G79/299		4.400 (0.44%)											0.34						
	Auger depth 0.62 m	TD–3	G79/300		4.700 (8.47%)											0.32						
	Auger depth 1.14 m	TD–4	G79/301		4.400 (0.44%)											0.21						
	Auger depth 1.49 m	TD–5	G79/302		14.000 (1.4%)											0.59						
	Auger depth 1.87 m	TD–6	G79/303		34.000 (3.4%)											0.83						
Waste Dump E	Mullock																				600	
Waste Dump C	Mullock																				70	
Waste Dump B	Mullock																				1.500	

* Scorodite ($FeAsO_4.2H_2O$) detected by X–ray Diffraction.

– insufficient sample

copper are in readily soluble forms.

The slimes dump is a potentially significant source of arsenic pollution for the adjacent stream, and a possible minor source of lead, cadmium, zinc and copper. However, except in periods of rain, the mine water draining from the adit would be the major source of toxic metal pollution in the creek. The acidity and toxic metal content of the slimes dump make it unsuitable for direct revegetation.

The levels of metals found in the samples from the tailings dam indicate that it was, in fact, used as a tailings dam and not just as a sediment dam. The arsenic and tin concentrations generally showed an increase with depth in the auger hole.

The sample analyses of both the slimes dump and tailings dam generally were comparable with those of King (1964).

Density and Volume Calculations

Density measurements were made of the slimes dump in order to determine the amount of material present and to calculate the tin content of the dump. Density values are listed in Table 3. A description of the techniques used in their determination, and the significance of the various values, is given in Appendix 4.

The volume of the tailings dam, slimes dump and five other waste dumps were computed from survey data. The approximate volumes are given in Table 3. Excluding the tailings dam, the total volume of the waste dumps is approximately 6,500 cubic metres. The total volume of the various open cuts has been calculated as 13,000 cubic metres. It is therefore possible to dispose of all the waste dumps in the open cuts with additional space available for disposal of any brick structures, if necessary.

Using an average bulk (in situ) density value of 1.5 gm/cc (tonnes/m^3) and a volume of 2200 cubic metres, the mass of the slimes dump is estimated to be 3,300 tonnes. The slimes dump has an average moisture content of 4%, so the dry mass of the dump is 3,170 tonnes. The overall tin concentration of this dump, based on a weighted average for each of the layers analysed, is estimated at 0.6% metallic tin, calculated on a dry weight basis. The total tin content is therefore 19 tonnes.

The tailings dam is estimated to contain an average of 0.4% tin. This value is based on the results of one auger hole which penetrated to less than one-third of the anticipated depth of tailings material. Using a bulk density value of 1.4 tonnes/m^3, a dump volume of 7,600 cubic metres and a moisture content of 9.5%, the total tin content of the tailings dam can be estimated as approximately 40 tonnes.

The implications of these calculated tin contents, in terms of retreatment of the slimes dump and tailings dam, are discussed in a later section of this report (see ECONOMIC POTENTIAL).

Water and Sediment Pollution

Three main sources of water pollution have been identified at the Ottery mine site.

TABLE 4

WATER SAMPLING RESULTS

Average Concentrations Feb. '74 to Jan. '77. (Range of concentrations is given in brackets).

All concentrations in mg/l except pH, and Ec (µmho/cm)

PARAMETER	STATION									
	1	2	3	4	5	6	7	8	9	10
Number of samples collected	9	7	5	6	6	5	8	8	8	2
pH	2.5 (1.5 – 3.1)	2.6 (1.6 – 3.6)	5.3 (3.9 – 6. 0)	2.6 (1.7 – 3.3)	2.6 (1.7 – 2.9)	2.6 (1.8 – 3.0)	2.9 (1.9 – 3.7)	6.4 (5.2 – 8.0)	6.6 (6.1 – 8.0)	6.9 (6.7 – 7.1)
Ec	3160 (2100 – 3900)	1980 (1100 – 2700)	110 (60 – 220)	2080 (1160 – 2850)	1530 (950 – 2000)	1210 (760 – 1700)	1050 (700 – 1550)	325 (185 – 520)	340 (185 – 520)	210 (42 – 375)
Sulphate	2030 (1220 – 3150)	980 (660 – 1440)	9 (2 – 22)	1080 (400 – 2040)	610 (120 – 1190)	460 (240 – 1010)	310 (120 – 770)	9 (<2 – 19)	44 (11 – 140)	8 (3 – 12)
Antimony	<0.03 (<0.01 – 0.12)	<0.02 (<0.01 –<0.02)	<0.03 (<0.01 – 0.04)	n.c. (<0.01 –<0.02)	n.c. (<0.01 –<0.02)	n.c. (<0.01)	<0.02 (<0.01 – 0.03)	<0.02 (<0.01 – 0.03)	<0.02 (<0.01 – 0.03)	n.c. (<0.02 –<0.08)
Arsenic	7.3 (<0.01 – 21.8)	2.6 (<0.01 – 16.1)	0.03 (<0.01 – 0.10)	0.5 (0.02 – 1.9)	0.9 (<0.01 – 4.87)	0.07 (<0.01 – 0.15)	0.12 (<0.01 – 0.69)	0.03 (<0.01 – .06)	0.08 (<0.01 – 0.31)	0.006 (0.006)
Cadmium	0.40 (0.24 – 0.58)	0.20 (0.11 – 0.34)	n.c. (<0.001 –<0.03)	0.18 (0.04 – 0.3)	0.13 (.04 – 0.24)	0.10 (0.047 – 0.14)	0.07 (0.04 – 0.11)	<0.002 (<0.001 – 0.009)	<0.002 (<0.001 – 0.005)	<0.002 (<0.001 – 0.002)
Copper	3.3 (1.35 – 6.5)	1.6 (0.15 – 2.6)	n.c. (<0.005 –<0.1)	1.5 (0.36 – 2.5)	1.2 (0.37 – 2.1)	0.78 (0.41 – 1.0)	0.59 (0.27 – 0.9)	0.02 (<0.005 – 0.1)	<0.01 (<0.005 – 0.018)	n.c. (<0.004 –<0.005)
Lead	<0.1 (<0.05 – 0.2)	n.c. (<0.005 –<0.2)	n.c. (<0.005 –<0.2)	n.c. (<0.005 –<0.2)	<0.1 (0.01 –<0.2)	n.c. (<0.005 –<0.2)	n.c. (<0.005 –<0.2)	<0.006 (<0.005 – 0.013)	<0.01 (<0.005 – 0.033)	<0.009 (<0.004 – 0.014)
Zinc	56 (29 – 76)	29 (12 – 56)	<0.11 (0.024 – 0.34)	27 (9 – 46)	21 (7 – 28)	15 (5 – 24)	12 (5 – 17.5)	1.14 (<0.005 –5.9)	0.69 (<0.005 – 4.3)	5.6 (3.5 – 7.7)

n.c. not calculated

Note: where lower limit of range < limit of detection, average calculated using lower limit of detection.

1. Water discharging continuously from underground workings has been observed flowing at the rate of approximately 3 litres per minute during normal dry weather conditions, and up to 75 litres per minute during heavy rainfall. The No.2 adit is the exit for the water which flows directly into the creek (Plate 8). During dry weather the discharge is due to groundwater seepage, while during wet weather the flow is augmented by surface water entering the workings through the many small shafts, open cuts and collapsed stopes on the hillside.

2. Runoff and throughflow from the waste dumps add to the pollutant load of the creek. Analyses of waste dump materials are given in Table 3. The principal source of pollutants is the slimes dump (Plates 13 and 14).

3. Surface runoff from the refinery area is contaminated with arsenic. The brick condensation chambers are coated with arsenic compounds which are partly soluble. Sections of the first-stage chambers have no roof and the compounds on the brickwork are exposed to rain.

Water Sampling

All drainage from the site passes into a small tributary of the Beardy River. For much of its length this creek is visibly polluted with orange coloured slimes covering the creek bed. A water sampling programme was established in order to determine the source, the level, and the extent of pollution caused by the abandoned mine workings.

Monitoring of water quality at the Ottery mine was carried out between February 1974 and January 1977. Samples were collected on an approximate three-monthly basis from October 1974. Water and stream sediments were collected from ten permanent stations on waterways in the catchment area. Plan 11132 gives the location of these sites.

Six of the sampling points were established on the stream draining the mine site (stations 1, 2, 4, 5, 6, 7) and two stations were situated on the Beardy River, downstream from the inflow of mine drainage (stations 9 and 10). The background water quality in the catchment was monitored at two sites, one on the Beardy River, upstream from the mine drainage inflow (station 8), and the other on a small tributary of the stream draining the mine site (station 3).

Station 1 is within 20 metres of the No. 2 adit. Water at this site consists almost entirely of mine drainage from the adit. However, it does include some surface runoff following periods of rain, as well as seepage from the slimes dump.

Water samples were analysed for a number of metals, pH, electrical conductivity and sulphate levels. Metal concentrations were determined in the stream sediments. Full details of analytical results are contained in Appendices 2 and 3. Table 4 provides a summary of the results of water analyses, in the form of averages and ranges of the values found at each site during the monitoring period.

Direct comparison of the average value at each site is not strictly possible as not all sites were sampled on every occasion. During the period January 1975 to November 1975, all the mining - affected sites,

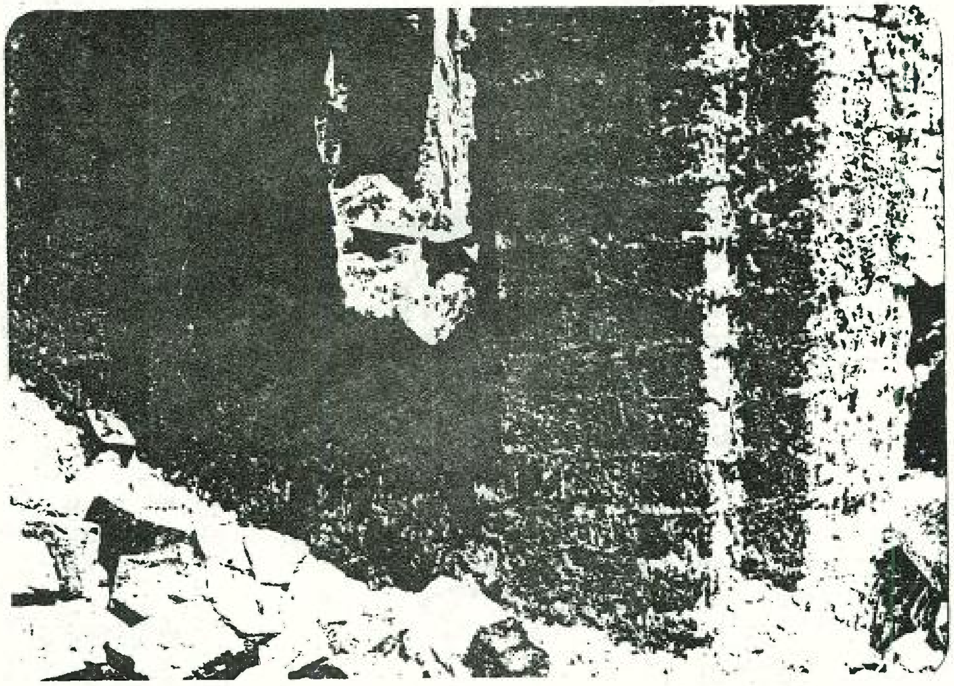


Plate 11. Arsenic concentrations on external brickwork of crude arsenic chambers.

(Grafton 0178J)

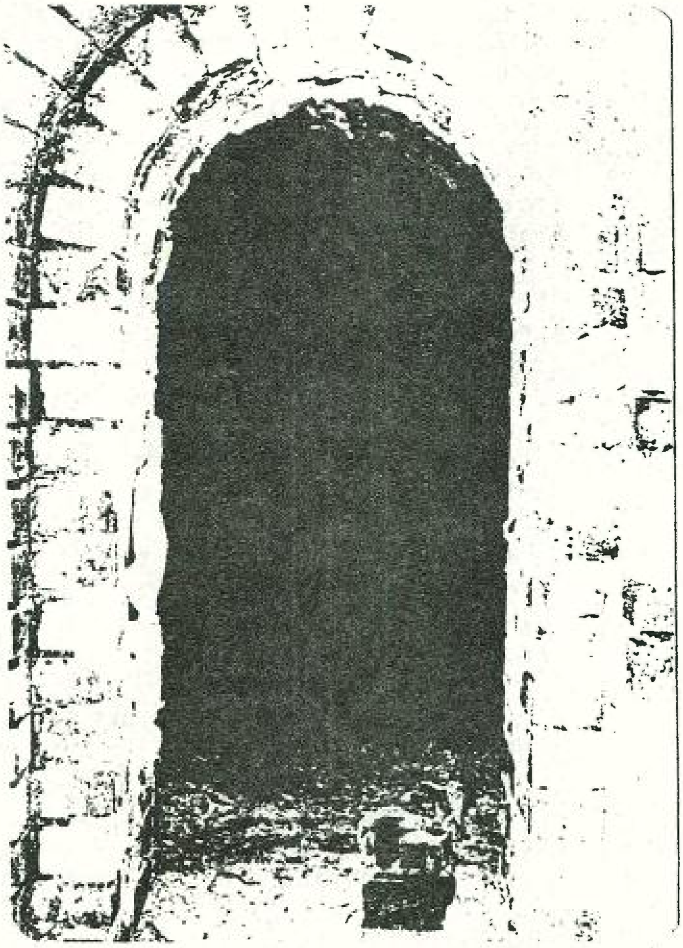


Plate 12. Remains of arsenic trioxide on the internal brickwork of the refined arsenic chambers.

(Grafton 0198)

apart from station 10, were sampled on four occasions. The average values of pH, sulphate, arsenic, cadmium, copper and zinc for the year 1975, together with their distribution in the waterways, are illustrated on Plan 11132.

The mine drainage is very acidic; very high in arsenic, zinc and sulphate; and relatively high in cadmium and copper. The pH values are very low (acidic) for the entire length of the creek draining the mine site.

Comparison of electrical conductivity values near the adit (station 1) with background values (station 3) shows that the mine site is the major source of salinity in the catchment area of the creek. Sulphate, a product of sulphide oxidation, is the main anion in the mine drainage.

There is a general trend towards decreasing levels of most parameters downstream. The drop in both electrical conductivity (i.e. salinity) and sulphate levels is due to the diluting effect of runoff and groundwater seepage from the catchment area below the mine site. The rates of decrease in zinc, cadmium and copper concentrations are similar to that found for sulphate. This indicates that the decrease in these metals can also be attributed to dilution effects. Arsenic concentrations, however, decrease much more rapidly than sulphate. The downstream decrease in arsenic is considered to be mainly the result of the precipitation of insoluble arsenic complexes, rather than merely a dilution effect.

Stream Sediment Sampling

The results of stream sediment analysis are given in Appendix 3. Plan 11132 shows the variation in the levels of metals, proceeding downstream from the mine site. Sediments collected from the stream draining the mine site are typically high in arsenic (0.4 to 4.8%) and iron (4.0 to 24.8%). The arsenic content decreases to some extent before the junction with the Beardy River. Relatively high levels of lead, compared to background values, were found at most sites in this waterway. A high tin concentration was found at station 1, similar to the concentration of tin in the slimes dump.

Waste material washed from the mine site, and particularly the slimes dump, is a major source of the metals found in the creek sediments. A further source of both iron and arsenic would be insoluble complexes precipitated from the mine drainage water.

Arsenic, iron and lead values in sediments in the Beardy River do not appear to be affected by drainage from the Ottery mine site. This may be due to the contaminated sediments being diluted by the much higher load of sediment in the Beardy River.

A sediment sample, collected from the vicinity of station 1 in September 1978, was tested to determine the metal concentrations in the various sediment phases. The sample was extracted in sequence with deionised water, ammonium acetate and hydrazine chloride solutions, using the method proposed by Gatehouse (1977). The deionised water removes water-soluble components, the ammonium acetate extracts easily exchangeable ions, while the hydrazine chloride extraction determines the metals associated with the iron and manganese oxide phase. The first two leachings are generally considered to remove the more readily available cations and anions. In the natural system, the iron and manganese oxide

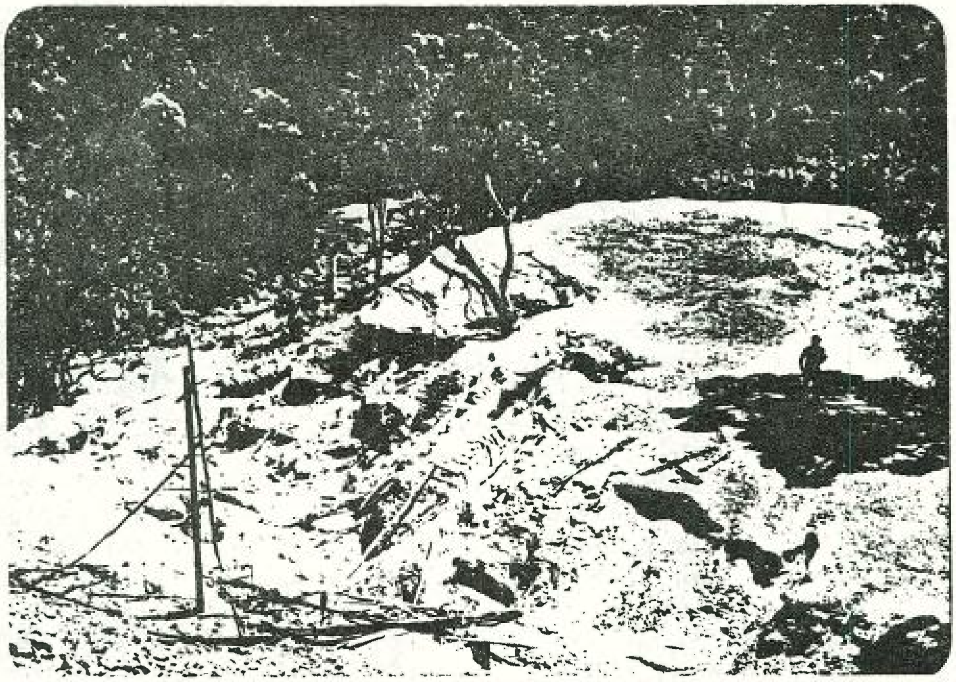


Plate 13. Erosion of slimes dump.
(Grafton 0191)

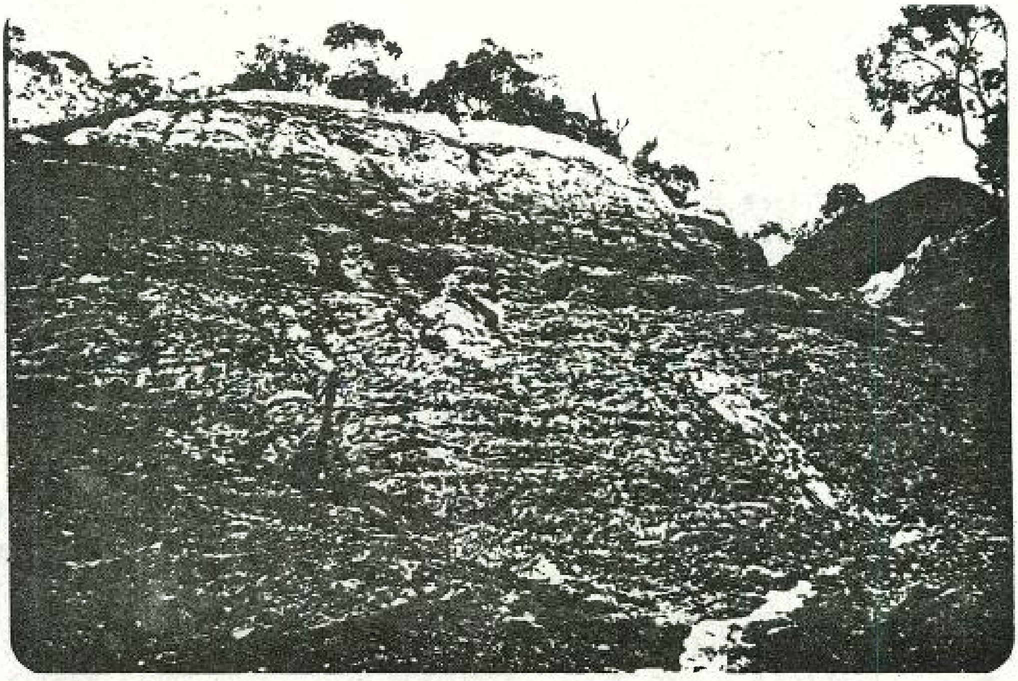


Plate 14. Water seepage through one of the bottom layers of the slimes dump.

phase will be stable under suitable conditions of pH and oxidising potential.

Details of extraction procedures and analytical methods are given in Appendix 4. The results of extraction are listed in Table 5, in terms of the amount of metal extracted per gram of sediment. The total concentration of each metal in the sediment is given for comparison.

TABLE 5

SEQUENTIAL EXTRACTION OF STREAM SEDIMENT FROM STATION 1

	Arsenic (µg/g)	Copper (µg/g)	Lead (µg/g)	Zinc (µg/g)	Cadmium (µg/g)	Iron (%)
Deionised water (pH 3)	<10	10	<10	20	<1	0.02
Ammonium Acetate (pH 3)	125	15	<10	25	<1	0.25
Hydrazine Chloride (pH 3)	2600	6	<10	80	<2	8.7
Total Concentration	31,000	150	1,000	190	<1	21.0

The metals in the sediment at Station 1 are predominantly in stable forms under the prevailing oxidising conditions in the stream. At least 80% of the arsenic, lead and copper are bound up in minerals and complexes which would be stable under all likely conditions.

The iron oxide phase could be a potential source of arsenic pollution if ever conditions in the stream were altered to a reducing state. Such a change would require an influx of decomposing organic material into the system, together with negligible flow. Rehabilitation of the site by revegetation of dumps and sealing of mine shafts is unlikely to drastically alter the present oxidising conditions and therefore affect the stability of metals in the sediments.

Water Quality Evaluation

The maximum acceptable levels of the major pollutants for a designated water usage are given in Table 6.

TABLE 6

WATER QUALITY CRITERIA
(Compiled from Hart, 1974)

Water Use	Maximum Acceptable Concentration (mg/1)						pH
	As	Cd	Cu	Pb	Zn	SO_4	
Domestic	0.05	0.01	1.0	0.05	5.0	250	6.5-9.0
Irrigation	0.1	0.01	0.2	5.0	2.0	960	4.5-9.0
Stock Watering	1.0	0.01	2.0	0.5	20.0	1000	5.5-9.0
Aquatic Life	0.05	0.03	0.01	0.02	0.1	-	6.0-9.0

The entire length of the creek draining the mine site is heavily polluted and unsuitable for any use. There are no apparent farming activities being undertaken in the vicinity of the creek and no licensed water users, so the contaminated water is not required for stock watering or irrigation purposes. The creek is not used for domestic water supply. It is not known what effect the creek has on local wildlife, however it has been reported (Gutteridge, Haskins and Davey, 1975) that kangaroos have been observed drinking from it. The acid mine drainage has almost certainly eliminated any biological life in the creek.

The high levels of toxic metals and acidity persist in the creek until confluence with the Beardy River, where considerable dilution takes place. The inflow of mine drainage does not appear to markedly affect the quality of water in the river, apart from occasional high concentrations of arsenic (levels of 0.31 and 0.18 mg/l arsenic were found in two out of eight samples collected at station 9). These higher concentrations do not persist further down the river at station 10. There is no domestic off-take from the river for 60 km downstream from the confluence.

It is a matter of concern that the general public visiting the mine can have access to potentially poisonous water. Available literature suggests that arsenic concentrations of more than 0.25 mg/l in water taken over a long period of time can cause poisoning (see Appendix 5 for information on arsenic toxicity). By comparison, arsenic levels in excess of 20 mg/l have been found in creek water close to the mine. Consumption of several litres of this water would be required to reach a fatal dose, and this is unlikely to occur unintentionally because of the unpalatable taste of the acidic water. Small quantities, however, could cause illness.

ECONOMIC POTENTIAL

Further mining might occur at the Ottery mine site in one or more of three ways: firstly, the existing mine could be reopened to work extensions of the known deposits; secondly, the site might be within a larger ore zone; or thirdly, retreatment of waste material might be carried out on a small scale.

Known Deposits

There are five veins known to be present (see Figure 2). The general strike of the lodes is N.E. and S.W., they dip north westerly at angles between 45° and 80° and have the character of contact deposits. The No.1, or arsenic lode is 260 m long, 1 m wide and has been worked on two levels. The tin lodes, of which there are four, are from 0.15 m to 1 m wide and up to 500 m in length (Weber, 1975).

Only the No.1 and No.4 lodes have been worked to any appreciable extent, and if there were to be any further underground tin mining it is most likely to involve these two veins. Both have been stoped from the surface to the 43 m level (No.2 level). The No.1 vein contained about 0.8% tin and 12% arsenic over widths of 1 to 1.5 m. A little ore remains between the No.1 (22 m) and No.2 (43 m) levels in this vein (Mine Record 2661).

No.4 vein contained around 2.5% tin, and less arsenic than No.1 vein. Stoping up to 10 m in width has been carried out. The length of the ore shoot decreased with depth from 240 m at the surface to 60 m at the No.2 (43 m) level.

No.1 vein is virtually untested below the 43 m level. No.4 vein is untested below the disappointing 74 m level, where the vein had flattened and thinned. If the vein steepens again at depth, then the ore shoot could well thicken. The veins need to be tested below the 74 m level, by drilling or by underground development.

Former mine manager, Mr A.C. Julius, estimated (in 1938) that approximately 18,000 t of ore containing 4% tin exist within an 83 m long section of the shoot on the No.4 vein between the Nos 2 and 3 levels (Mine Record 2661). Based on this estimate, this shoot would contain tin worth about $10 million (March, 1980 values). This figure does not permit an estimate of the profitability and therefore the feasibility of mining this mineralization. It is nevertheless highly likely that the shoot can be mined for considerably less, provided a suitable treatment plant is available.

The arsenic content of the ore however, is a hindrance to possible renewed mining development since it would be an impurity which would have to be removed during metallurgical processing to recover the tin.

The workings below No.1 level are now inaccessible. Future prospecting (and/or mining) could be done in such a way as to re-open these levels. Consequently, when any such renewed mining or prospecting finished, the mine could be left with accessible workings. This might enhance its future value as a heritage/tourist attraction, but would involve administrative and public safety problems.

It is considered that the mine has good potential for the discovery of extensions to the known deposits.

Inferred Geological Potential

The Ottery mine appears to be situated at the northern end of a tin stockwork zone which is several kilometres long and up to 500 m wide. Loloma Ltd is presently mining the southern end of this zone (at Emmaville) by open-cut methods. It is not known at this stage whether the northern parts of this zone are sufficiently rich to warrant mining.

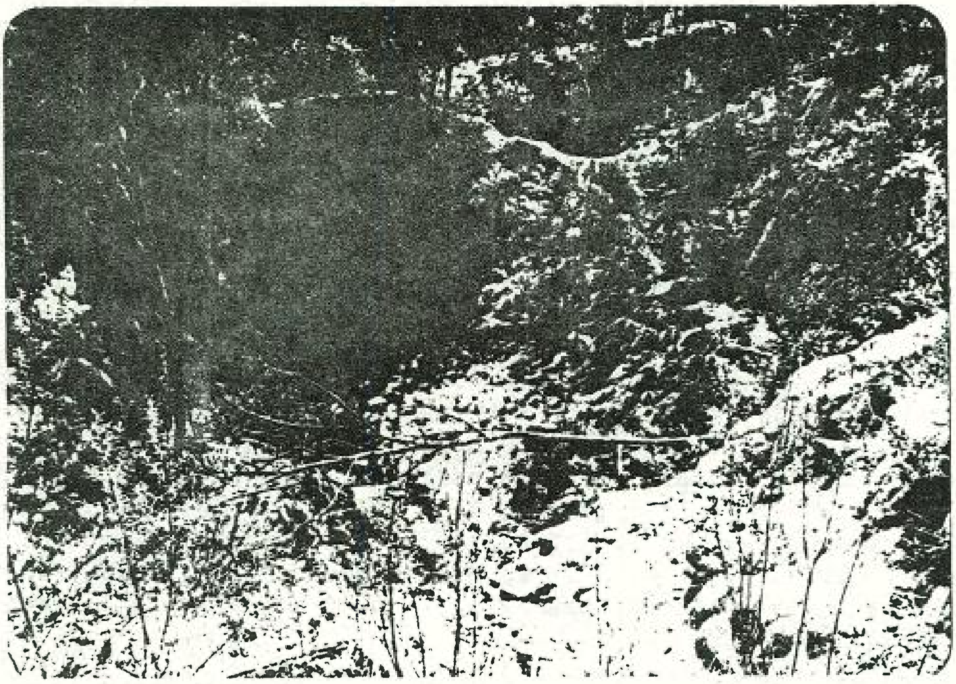


Plate 15. Open cuts scattered through the bush.

(Grafton 0571)

It is considered that the mine area has moderate potential for incorporation in an inferred large, low-grade, near-surface, tin stockwork deposit.

Retreatment of Waste Dumps

It has been determined, in a previous chapter, that waste material at the Ottery mine contains a little tin and could perhaps be re-treated if a suitable plant were available. It was estimated that the slimes dump contained 19 tonnes of metallic tin worth about $300,000 (March 1980 values). The tailings dam may also contain significant quantities of tin. Further research, however, would be necessary to determine if the tin was economically and technically recoverable.

HISTORICAL PRESERVATION

The Heritage Council of New South Wales, under the authority of the Minister for Planning and Environment, is responsible for the preservation of the State's environmental heritage. This embraces those places, buildings or works that are of historic, scientific, cultural, social, archaeological, architectural, natural or aesthetic significance to the State. Old mine workings can be included in such classifications. The Minister for Planning and Environment may, upon the recommendation of the Heritage Council, place an interim or permanent conservation order over all or part of any of these sites that warrant protection.

The Heritage Council has been looking at a number of old mining sites throughout N.S.W. with a view to preservation - the Ottery mine is one of these sites. Naturally, any rehabilitation measures that might be proposed for the Ottery mine would be significantly affected if any conservation order was issued under the Heritage Act (1977).

Notwithstanding the fact that the Council has investigated the historical significance of the Ottery mine for preservation, this report also discusses the historical and other aspects related to preservation of the mine. The views of the Department of Mineral Resources on these aspects may differ from those of the Heritage Council. It is considered that the following factors are of importance in discussing the merits of preservation of the Ottery mine:

Historical Importance
Architectural and Industrial Archaeology Value
Tourism Potential
Scientific and Educational Importance

Historical Importance

Dating from 1882, the Ottery mine is one of the oldest underground mines in the Emmaville District - established only 10 years after the alluvial tin boom that created the town itself. Emmaville's heritage has evolved entirely around the mining industry and the Ottery mine is thus an important part of this heritage.

An excellent historical and photographic coverage of the mine exists, something which many of the other old mines in the district, and indeed in the whole State, do not always have. A first hand account of the history of the mine is also available from Mr Harry Julius (son of the former mine manager), who himself worked at the mine during its latter stages.

Much of the intrinsic appeal of the old mine is largely due to it being an arsenic mine. The majority of the general public would probably not realise that arsenic occurs in a natural mineral ore and can be simply mined and milled for recovery. There are, however, only four localities in Australia where arsenic minerals have been mined as the principal ore. These are the Ottery and Mole River mines in N.S.W. and two mines in Queensland. Only the Ottery and Mole River mines were equipped with on-site refining plants capable of producing the final product.

The arsenic mining industry ceased in Australia in 1952 and it is unlikely that it will ever recommence. A more detailed account of the history and production of arsenic in Australia is given in Appendix 5.

Architectural and Industrial Archaeology Value

The major attraction at the Ottery mine is the intricately constructed brick checkerwork condensation chambers. Parts of these are still in relatively good condition despite being robbed of bricks over the last few years. Various proposals have been put forward on a number of occasions involving a) restoring the refining plant to its original state, which would involve rebuilding and cleaning the arsenic encrusted brickwork; b) preservation as is; or c) preservation after cleaning the brickwork. Consideration was given to this latter proposal, but rejected by the Department in 1977 on the grounds of cost and practicability. "It appeared impractical to clean the building structures or satisfactorily remove all contaminated ground, as solid residues collected by such work would have to be disposed of safely and the handling of toxic liquors would be particularly difficult in the existing natural watercourse". (File T76/3068).

The Ottery arsenic treatment plant can be considered to be unique in Australia. The design of the refinery is thought to be Portuguese (Godden pers. comm.) and has some architectural and archaeological merit. The University of New South Wales School of Industrial Arts has expressed considerable interest in the treatment works as an excellent example of an historical method of industrial processing. The University has organised excursions to the mine by industrial archaeology students and has indicated a strong desire for the treatment plant to be not only preserved but if possible restored (Godden pers. comm.). There is no doubt that the extraction of arsenic by the process of sublimation is an unusual method of metallurgical processing and that the Ottery refining plant has a certain degree of technical and scientific importance.

The Mole River mine is not unlike the Ottery mine, in that the ruins of the refining plant are still present, however, the design of the condensation chambers and flue system are completely different and not in such a good state of preservation. A photograph of the remains of the Mole River plant is included in Appendix 5.

Tourism Potential

Tourism in the Emmaville district is mainly confined to fossicking for gemstones. However discussions with the Glen Innes Historical Society and the Glen Innes Lapidary and Gem Club revealed that many tourists visiting Emmaville are directed by these organisations to the Ottery mine. They also informally expressed an interest in having the mine preserved. A small rock and mineral museum in Emmaville features some photographs of the Ottery mine and is also likely to direct tourists to it. It is considered, however, that the general isolation of the site, the small number of people that visit the area, and the possible hazard to public safety would preclude development of the site as a tourist attraction.

Scientific and Educational Importance

Access to surface and underground rock exposures at the mine may be valuable in terms of scientific and educational interest. Being one of the major metalliferous mines in the New England region its geological importance cannot be questioned (see previous chapter). Completely sealing off the underground workings could therefore meet with opposition from government, academic and company geologists.

Geology, mining and industrial archaeology students have visited the mine and although there may be some teaching benefit from student excursions to the mine, its educational value alone is not considered to be a major factor in favour of complete preservation.

Partial preservation of particular features could satisfy both scientific and educational needs.

Heritage Value and Preservation

The arsenic refining plant is worthy of preservation on historical, scientific and architectural grounds. The fact that the brickwork of the refinery is coated in extremely poisonous arsenic compounds means however, that any plans for complete preservation or restoration could be impractical when public safety and cost are taken into account.

The arsenic refinery should not be considered in isolation. It is an integral part of the whole mine site and in fact the rest of the Ottery mine may also be worthy of preservation for its historical value. Total preservation of the whole site however, would involve the inheritance of toxic waste dumps and a significant water pollution problem.

REHABILITATION

The rehabilitation of abandoned mines is carried out under the supervision of the Department of Mineral Resources using funds provided by the N.S.W. Government. Rehabilitation programmes are designed to ensure public safety, to minimise erosion and pollution and to provide permanent environmental improvements that will result in a site compatible with its surroundings, and requiring a minimum of maintenance. A set of guidelines for derelict mined land rehabilitation programmes has been published jointly by the Department and the State Pollution Control Commission (S.P.C.C. 1978).

The rehabilitation eventually carried out at the Ottery mine will depend on factors outside the scope of this report, including the attitude of the Heritage Council of N.S.W. regarding preservation at the site, and on the availability of funds. Accordingly, three courses of action or "options" are presented. Each option possesses advantages and disadvantages.

Option 1 assumes that the mine site, as a whole, is to be preserved and maintained as far as possible in its present state as an historic site for its scientific, educational or tourist potential. It is also assumed that some form of conservation order would be issued under the Heritage Act (1977), and that the Heritage Council or some local authority would be responsible for supervision and maintenance of the site. Some measures for public safety are nevertheless required (see below).

Option 2 assumes that the brickwork structures on the site are of sufficient historical importance to warrant preservation in their present state, but that the remainder of the site is to be rehabilitated.

Option 3 assumes that the importance of public safety and environmental protection outweight the merits of historical preservation, and therefore full rehabilitation is required.

Carrying out Option 1 and the essential works recommended, does not prevent either partial (Option 2) or complete (Option 3) rehabilitation from being carried out in the future.

Restoration of the arsenic chambers and kilns is not considered in any option as it is not regarded as being economically or technically feasible. None of the options precludes prospecting or reopening the underground mine, subject to certain conditions in each option.

Essential Safety Measures

Regardless of which course of action is undertaken, public safety should be of prime consideration in implementing any of the recommendations, and irrespective of options decided upon the following measures are considered essential:

1. As the main shaft, below the collar, is still in excellent condition, and the mine is considered to have future exploration potential, the main shaft should be rendered safe by engineer-designed capping, and leaving provision for natural up-draught ventilation.

2. All other dangerous shafts and collapsed stopes should be filled in. A borrow area would be required for this fill if mullock was not to be used.

3. The entrance to Adit No. 1 should be fitted with a gate of steel mesh to prevent public access but to allow for official entry to the underground workings and ensure natural in-draught ventilation.

Option 1 - Site to be left essentially in its present state, with minimum erosion control measures

1.1 Carry out essential safety measures.

1.2. Preserve all existing features and contours on site including waste dumps.

1.3 Drainage channels should be constructed to divert run-off from above the condensation chambers, the main waste dump areas, any collapsed stopes, and from above the open cuts. This is common to all options.

1.4 The breach in the tailings dam should be repaired and a pipe or other suitable bypass outlet installed. This is common to all options.

1.5 The existing wire fence surrounding the brick chambers should be upgraded so as to prevent unauthorised access. This should be accomplished by replacing the entire fence with one more impenetrable (e.g., high cyclone wire mesh). For official access for scientific investigation or maintenance, some form of locked gateway should be installed.

1.6 A number of prominent, clearly worded vandal resistant signs, warning of the hazards on the site, should be erected some distance inside the fence (to prevent theft and damage). A similar sign should be erected at the main entrance to the site. These signs should be made of material that will withstand adverse weather conditions and discourage vandalism.

1.7 The protective fence and all warning signs must be inspected and maintained regularly. All surface structures should be examined periodically to ensure their stability and safety.

1.8 Information pamphlets giving historical and technical details of the mining and processing, of the rehabilitation work carried out, and outlining the dangers associated with handling materials on the site, could be prepared and readily available to the public from the nearest district office of the Department of Mineral Resources and any local historical societies or tourist offices.

1.9 An information board could be erected in an appropriate place on the site (e.g., inside fence) to inform the public of the historical and technical details of the mining and processing and of any rehabilitation work carried out. This should include a site plan (e.g., Plan 10934) and a large panoramic photograph (e.g., Plate 1) of the original operations. The board would need to be made as permanently weatherproof and vandal resistant as possible.

1.10 For this option to be feasible a managing authority would have to be formalised so that provision of ongoing maintenance funds etc. can be guaranteed.

1.11 The Department of Mineral Resources should monitor the quality of water in the creek draining the mine for a period after any rehabilitation, to assess its effectiveness. This is common to all options.

1.12 Mining and prospecting titles to be granted only with the inclusion of special conditions for prevention of damage to any structure, and precluding retreatment of waste dumps.

Advantages

1a) The character of the mine site as a whole would be preserved (not withstanding unavoidable natural deterioration and vandalism). Waste and slimes dumps, the tailings dam, open cuts and the present site contours are characteristic of the mining scene and would complement the preservation of the brick chambers. The whole site would be of much greater value for scientific and historical research and tourism than if only the chambers were to be preserved. A complete historical and pictorial record of the mining operations exists. This could be used to increase the historic, scientific and tourist potential of the mine.

1b) This option would provide an opportunity for preservation of part of Emmaville's heritage which has evolved entirely around the mining industry. It would also provide a further tourist attraction for a region that currently has a strong tourist industry based around mining and fossicking. The mine is one of the oldest in the district.

1c) If the site was to be well maintained and supervised as an historical preserve, then the present rate of vandalism and scavenging of materials on site may decrease.

Disadvantages

1a) The public would continue to be exposed to the potentially harmful materials in the refinery structures and the waste dumps.

1b) The refinery area and the waste dumps would continue to be sources of contamination of surface runoff, although the diversion drainage channels recommended (1.3) should reduce the level of contribution of these sources to water pollution.

1c) There may be legal and moral responsibility involved in encouraging public access to a mine site that is not completely safe.

1d) Inspection and maintenance of the site would be required at regular intervals, requiring allocation of responsibility.

1e) Erosion would gradually become worse.

1f) The site would not revert back to its natural state after what should essentially be a temporary landuse, i.e., there is conflict with the Department's philosophy of rehabilitation after mining.

1g) If the site becomes well known as a tourist attraction, significantly more people would visit the site than do at present. Deterioration of the site and surrounds may be accelerated and the more people that visit the mine the more likely that an accident might occur.

1h) The site will deteriorate naturally and it may be difficult to preserve the structures indefinitely without some form of restoration of the brickwork.

1i) The possibility of retreating the slimes dump would be removed.

Option 2 - Part rehabilitation of the site, with structures retained

2.1 As for recommendations 1.1, 1.3 to 1.11.

2.2 Most of the structures on the site to be retained depending on their value for historical preservation. Demolish and dispose of only those structures considered at the time to be structurally unsafe.

2.3 All waste dumps and any other toxic surface material should be disposed of by burial in the open cuts. Waste buried in this manner should be underlain by a layer of clay at least 0.1 m thick to prevent seepage into underlying stopes. Toxic residues can then be covered by crushed rock from the mullock dump and a further layer of clay. A suitable clay borrow area is required. Retreatment of the slimes dump could be carried out before, or as part of, rehabilitation.

2.4 All bare areas and buried waste dumps should be covered with topsoil and revegetated. The tailings dam does not require revegetating(see 1.4).

2.5 The entry of surface water to the underground workings should be prevented as far as possible. This could be accomplished by the filling of all surface openings combined with drainage control (see 1.3).

An assessment should then be made of the reduction in mine water flow, if any, from adit No. 2 (and therefore of the groundwater contribution) and consideration then given to the need for complete sealing of this adit. The effectiveness of this action must be balanced against the possible progressive flooding of the underground workings and the emergence of diffuse springs at the ground surface.

2.6 Prospecting titles should be granted only with the inclusion of special conditions for prevention of damage to any structure. Mining titles should contain the same conditions, but to be granted only after a three year period from the date of rehabilitation. This should be subject to review, however, by the Department's Environmental Management and Policy Committee.

Advantages

2a) The most important historic features of the site (the arsenic refining works) would be preserved.

2b) Burial of the toxic slimes dump would eliminate one of the potential hazards on the site and remove a source of water and sediment pollution.

2c) The volume of mine water drainage into the creek would be reduced by preventing surface water from entering the underground workings. This would decrease the load of pollutants in the creek. Mine drainage may be reduced even further if sealing of the No. 2 adit proved feasible.

2d) Problems of erosion and aesthetics would be significantly reduced.

2e) Provision would be made for retreatment of the slimes dump before, or as part of, rehabilitation.

Disadvantages

2a) The character of the mine site would be partly destroyed.

2b) Toxic material on the brickwork of the condensation chambers would still remain as a public safety hazard.

2c) The structures would still be a source of water pollution from rainfall runoff.

2d) There may be a legal and moral responsibility involved in encouraging public access to a mine site that is not completely safe.

2e) Some long term maintenance on the fence and warning signs and general site supervision would still be necessary.

2f) The possibility of retreating the slimes dump would be removed after rehabilitation.

2g) The cost would be greater than Option 1.

Option 3 - Complete rehabilitation of the whole site, with structures removed

3.1 As for recommendations 1.1, 1.3, 1.4, 1.11, 2.3, 2.4, 2.5.

3.2 The mine should be totally rehabilitated using methods normally employed by the Department of Mineral Resources and the Soil Conservation Service. These methods should include demolishing and disposing of all surface structures such as the chimney, condensation chambers, kilns and tin plant. These materials should be buried in the open cuts (see 2.3).

3.3 Parties interested in the preservation of the structures should be given adequate notice of the Department's intentions to enable them to carry out such investigations of the site as they may desire prior to rehabilitation work being commenced.

3.4 The stamp battery and engine should be removed to the Department's historical mining equipment exhibit at Londonderry.

3.5 The site should be exempted from mining titles (but not prospecting titles) for a period of 3 years to allow an adequate period for revegetation. This should be subject to review, however, by the Department's Environmental Management and Policy Committee.

Advantages

3a) The major hazards to public safety, such as the toxic materials in the refinery area and the slimes dump, would be removed.

3b) Disposal of waste dumps and surface structures would remove the major sources of contamination of surface runoff on the site. As in Option 2 reducing the volume of mine drainage water would reduce the pollutant load in the creek.

3c) Other environmental problems such as erosion and aesthetics would be minimised.

3d) This option would provide a further example of the Department's responsibility in rehabilitating derelict mine areas.

3e) Minimum short-term maintenance would be required, although on going maintenance commitments might arise if subsequent problems were encountered.

Disadvantages

3a) Irretrievable loss of an historic and scientific asset.

3b) This option may be in conflict with the views of other organisations interested in preserving the mine.

3c) The cost would be higher than Option 2 and much higher than Option 1.

3d) Mining in the short term would be prohibited and the possibility of retreatment of the slimes dump would be removed, unless this was to be carried out before, or as part of, the rehabilitation work.

Effects of Rehabilitation on Water Quality

Implementation of drainage control measures, common to all options, will reduce the total volume of mine water draining from adit No. 2, as well as reducing contamination of surface run-off. Filling of all surface openings (Options 2 and 3) would further reduce the volume of surface water entering the mine. It is unlikely, however, with all these measures that the quality of the mine water will be greatly affected. Therefore, although the load of pollutants in the creek will decrease, the levels of toxic metals and acidity close to the mine site will still be far in excess of the maximum levels acceptable for most water usage (Table 6).

Burial of the slimes dump and refinery structures would also reduce the pollutant load in the creek. The contribution from these sources is perhaps not as significant as the input from mine water drainage, and is mainly confined to periods of wet weather. Completely sealing adit No. 2, and preventing surface water from entering the workings, would initially eliminate mine water drainage. The long-term effectiveness of such an action would depend on whether springs at the surface eventually formed as a result of a build-up of water in the underground workings.

In order for the lower reaches of the creek (downstream from Station 5) to satisfy water quality criteria for agricultural use, at least with respect to toxic metals content, the pollutant load would need to be reduced to less than 10% of the present level (i.e., a 10-fold decrease). Even then the average pH value would only be raised one and a half units, to about 4.5. A 10-fold decrease in pollutant load could not be achieved without a similar decrease in the volume of water draining from adit No. 2 and would probably also require the virtual elimination of all sources of surface run-off contamination.

Regardless of the rehabilitation measures undertaken, it is unlikely that the quality of the creek water at the mine site will ever comply with accepted water quality standards for most uses. Complete, or perhaps even partial, rehabilitation of the site may reduce the pollutant load sufficiently for the lower reaches of the creek to contain levels of metal pollutants acceptable for agricultural purposes.

CONCLUSIONS

Pollution

The abandoned Ottery tin/arsenic mine is a source of significant contamination of the creek draining the mine. The whole length of this waterway is heavily polluted by arsenic, cadmium, copper and zinc. Most of the pollution during dry weather is derived by flow from the underground workings via the No. 2 adit. In times of rainfall, additional sources of water pollution arise from runoff from waste dumps and toxic residues on the remains of the arsenic refinery. There has been no appreciable change in the water quality over the last five years.

The mine drainage flows into the Beardy River, the quality of which, as a result of dilution, has not been significantly impaired. The acid mine drainage has eliminated any biological life in the mine creek and the water is generally unsuitable for any use for the entire length of the stream. The creek water is not used for stock watering or irrigation and there is no domestic off-take in the mine creek or in the Beardy River for 60 km downstream. The effect of the mine drainage on the natural environment is very localised.

The sediments in the mine creek are also heavily contaminated with iron, arsenic and other toxic metals. Most of this contamination arises from erosion of waste dumps containing high concentrations of these metals and is also due to precipitation of iron and arsenic from the creek water. The metals in the stream sediments are stable under existing conditions and are unlikely to be released into the water unless stream conditions are drastically altered.

Safety Hazards

The brick ruins of the arsenic refining plant are covered by encrustations which contain very high arsenic levels. These are hazardous to public safety. Numerous open shafts, open cuts and collapsed workings are also dangerous to the public. A slimes dump, consisting of residues from the arsenic furnaces, contains high arsenic levels. It is a potential safety hazard in addition to being a major pollution source. Creek water at the mine is toxic.

Heritage and Scientific Value

The mine is one of the oldest underground mines in the Emmaville district and has potential for historical preservation. The arsenic refining plant is an excellent example of an historical method of metallurgical processing and is worth retaining on its industrial archaeology merits. However due to the poisonous arsenic compounds contaminating the structures, the desirability of preserving or restoring the plant is open to question. The Heritage Council of N.S.W. is undertaking a study on the historical aspects of the mine.

Underground access provides a unique opportunity to scientifically examine a major vein tin deposit in New England.

Rehabilitation

In accordance with its general policy, the Department of Mineral Resources would normally undertake rehabilitation of the mine. However, due to the considerations being given to preservation, certain options and recommendations have been provided in this report.

A mining title application is current over the mine. The potential for reworking must also be considered. A slimes dump and tailings dam contain tin concentrations that may be amenable to retreatment.

The options presented for the future of the site are:

Option 1	Preservation as is.
Option 2	Partial rehabilitation - structures retained.
Option 3	Complete rehabilitation - structures demolished.

Essential safety measures are required irrespective of the option chosen. Some drainage and erosion control measures are common to all options. Each option, if implemented in order, does not preclude the succeeding option. None of the options precludes future prospecting or mining, subject to certain conditions in each option.

RECOMMENDATIONS

1. It is recommended that the essential safety measures be implemented.
2. The authors consider that Option 2, together with the essential safety measures, balances the interests of historical preservation against the requirements for public safety and environmental protection. Option 2 is therefore recommended.
3. The authors consider that prospecting and mining authorities can be granted over any area which includes the site, provided they are subject to special conditions for the protection of the rehabilitation works and the structures, as outlined in Option 2.

   It is therefore recommended that the site not be excluded from any application for prospecting or mining authorities, provided that such special conditions are applied.

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APPENDICES

APPENDIX 1

RAINFALL DATA - EMMAVILLE

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Average Monthly Rainfall													
1884-1964													
(inches)	4.07	3.47	2.80	1.59	1.84	2.55	2.39	2.02	2.21	3.31	3.34	3.82	33.41
(millimetres)	103	88	71	40	47	65	61	51	56	84	85	97	849
Number of Rain Days													
1931-1960	8	8	6	5	5	7	7	6	6	8	8	8	82

Source: Commonwealth Bureau of Meteorology

APPENDIX 2

THE OTTERY MINE - WATER SAMPLING RESULTS

STATION NUMBER	OTT-1										OTT-2			
DATE COLLECTED	14/2/74	2/10/74	2/10/74	31/1/75	16/4/75	8/7/75	18/11/75	18/2/76	7/8/76	13/1/77	2/10/74	31/1/75	16/4/75	8/7/75
ASSAY NUMBER	74/288	74/1871	74/1874	75/142	75/488	75/1217	75/1977	76/382	76/1597	77/73	74/1876	75/143	75/489	75/1218
pH		2.65		2.4	2.6	1.5	2.5	2.4	2.7	3.1		2.6	2.6	1.55
ELECTRICAL CONDUCTIVITY		3800		3500	2800	2100	3000	2750	3900	3450		2700	2150	1550
ALKALINITY														
SULPHATE		2950		2300	1220	1500	1540	1440	3150	2150		1440	1100	660
NITRATE		13												
CHLORIDE		67												
CALCIUM		200												
MAGNESIUM		87												
POTASSIUM		9												
SODIUM		45												
BICARBONATE														
TOTAL IONS (TDS)														
HARDNESS		870												
			Filtered											
ANTIMONY	< 0.01	< 0.01	< 0.01					< 0.02	< 0.02	0.12	< 0.01			
ARSENIC	5.70	7.40	6.10	6.30	0.79	< 0.01	< 0.01	19.4	21.8	5.78	0.58	0.75	0.39	< 0.01
CADMIUM		0.40	0.42	0.34	0.31	0.24	0.48	0.40	0.58	0.41	0.34	0.20	0.175	0.11
COPPER		1.40	1.35	2.40	4.70	1.93	4.70	6.5	3.7	2.65	1.95	1.40	2.6	0.82
LEAD		< 0.20	< 0.20	0.20	0.05	0.059	0.20	< 0.05	< 0.05	< 0.05	< 0.20	< 0.20	0.01	< 0.004
ZINC		69	64	62	46	28.6	53	40	76	61.5	56	35	27	14.3

STATION NUMBER	OTT-2(cont.)			OTT-3					OTT-4					
DATE COLLECTED	18/11/75	7/8/76	13/1/77	2/10/74	16/4/75	8/7/75	18/11/75	18/2/76	2/10/74	31/1/75	16/4/75	8/7/75	18/11/75	13/1/77
ASSAY NUMBER	75/1978	76/1598	77/74	74/1872	75/490	75/1219	75/1979	76/383	74/1873	75/144	75/491	75/1220	75/1980	77/75
pH	2.7	2.7	3.6	4.9	5.9	3.85	6.0	5.6	2.7	2.6	2.7	1.7	2.6	3.3
ELECTRICAL CONDUCTIVITY	2000	2350	1100	140	80	60	220	63	2850	2500	2100	1160	1880	1980
ALKALINITY				18										
SULPHATE	770	1440	440	2	2	7	10	22	2040	1390	1050	400	620	960
NITRATE				< 3					11					
CHLORIDE				9					53					
CALCIUM				2					140					
MAGNESIUM				2					66					
POTASSIUM				2					2					
SODIUM				10					33					
BICARBONATE				21										
TOTAL IONS (TDS)				51					2340					
HARDNESS				13					620					
ANTIMONY		< 0.02	< 0.02	< 0.01				0.04	< 0.01					< 0.02
ARSENIC	< 0.01	16.1	0.48	0.01	0.03	< 0.01	< 0.01	0.10	1.90	0.75	0.28	0.02	0.13	0.19
CADMIUM	0.20	0.27	0.13	< 0.03	< 0.001	< 0.001	< 0.001	0.002	0.30	0.16	0.195	0.04	0.16	0.21
COPPER	2.0	2.2	0.15	< 0.10	0.02	0.003	0.008	< 0.004	1.80	1.2	2.5	0.36	1.5	1.9
LEAD	< 0.2	< 0.2	< 0.2	< 0.20	< 0.005	0.024	0.024	0.027	< 0.20	< 0.2	< 0.02	0.008	< 0.005	< 0.1
ZINC	24	32	12	< 0.05	0.07	0.06	0.34	0.024	46	33	27	8.7	19	28

STATION NUMBER	OTT-5						OTT-6					OTT-7		
DATA COLLECTED	2/10/74	31/1/75	16/4/75	8/7/75	18/11/75	7/8/76	2/10/74	31/1/75	16/4/75	8/7/75	18/11/75	2/10/74	2/10/74	31/1/75
ASSAY NUMBER	74/1879	75/153	75/492	75/1221	75/1981	76/1599	74/1880	75/154	75/493	75/1222	75/1982	74/1882	74/1881	75/147
pH		2.9	2.65	1.7	2.7	2.8		3.0	2.7	1.8	2.9			3.0
ELECTRICAL CONDUCTIVITY		1850	1500	950	1350	2000		1700	1300	760	1070			1550
ALKALINITY														
SULPHATE		1010	120	320	430	1190		1010	190	240	410			770
NITRATE														
CHLORIDE														
CALCIUM														
MAGNESIUM														
POTASSIUM														
SODIUM														
BICARBONATE														
TOTAL IONS (TDS)														
HARDNESS														
													Filtered	
ANTIMONY	< 0.01					< 0.02	< 0.01					< 0.01	< 0.01	
ARSENIC	0.04	0.15	0.22	0.03	< 0.01	4.8	0.08	0.06	0.15	0.04	< 0.01	0.07	0.07	0.02
CADMIUM	0.15	0.08	0.14	0.04	0.12	0.24	0.12	0.08	0.14	0.047	0.10	0.11	0.11	< 0.05
COPPER	0.90	1.0	1.5	0.37	1.1	2.1	0.90	0.70	1.0	0.41	0.88	0.75	0.75	0.4
LEAD	< 0.20	< 0.20	0.01	0.011	< 0.1	< 0.1	< 0.20	< 0.2	0.005	< 0.005	< 0.005	< 0.20	< 0.20	< 0.2
ZINC	23	25	20	6.5	118	28	19	24	17	5.1	11	16	15	17.5

STATION NUMBER	OTT-7(cont.)						OTT-8							
DATE COLLECTED	16/4/75	8/7/75	18/11/75	18/2/76	7/8/76	13/1/77	2/10/74	31/1/75	16/4/75	8/7/75	18/11/75	18/2/76	7/8/76	13/1/77
ASSAY NUMBER	75/494	75/1223	75/1983	76/384	76/1600	77/77	74/1883	75/156	75/495	75/1225	75/1984	76/385	76/1601	77/78
pH	2.9	1.9	2.9	2.8	3.1	3.7		7.1	5.95	5.15	6.1	6.0	8.0	6.4
ELECTRICAL CONDUCTIVITY	1060	700	1030	1130	990	880		520	260	190	285	185	515	330
ALKALINITY														
SULPHATE	120	230	360	384	400	215		3	< 2	9	12	19	7	10
NITRATE														
CHLORIDE														
CALCIUM														
MAGNESIUM														
POTASSIUM														
SODIUM														
BICARBONATE														
TOTAL IONS (TDS)														
HARDNESS														
ANTIMONY				< 0.02	0.03	< 0.02	< 0.01					0.03		< 0.02
ARSENIC	0.05	0.03	< 0.01	0.69	0.04	0.08	0.02	0.06	0.03	0.02	< 0.01	0.04		0.05
CADMIUM	0.095	0.045	0.08	0.043	0.08	0.04	< 0.001	< 0.001	< 0.001	0.009	< 0.001	< 0.001	< 0.001	0.003
COPPER	0.5	0.27	0.64	0.42	0.9	0.65	< 0.004	< 0.004	0.1	0.038	< 0.004	< 0.004	< 0.005	0.006
LEAD	0.005	< 0.004	0.006	0.005	< 0.1	0.015	< 0.004	< 0.004	0.005	0.008	< 0.004	< 0.004	< 0.004	0.013
ZINC	13	4.97	8.3	10.1	11.0	9.3	0.01	< 0.01	0.03	0.84	0.02	0.024	2	5.9

STATION NUMBER	OTT-9								OTT-10					
DATE COLLECTED	2/10/74	31/1/75	16/4/75	8/7/75	18/11/75	18/2/76	7/8/76	13/1/77	7/8/76	13/1/77				
ASSAY NUMBER	74/1884	75/157	75/496	75/1224	75/1985	76/386	76/1602	77/79	76/1603	77/80				
pH		7.2	7.85	4.5	6.3	6.3	8.0	6.1	7.1	6.7				
ELECTRICAL CONDUCTIVITY		460	270	220	290	185	520	420	42	375				
ALKALINITY														
SULPHATE		48	24	43	22	19	11	140	3	12				
NITRATE														
CHLORIDE														
CALCIUM														
MAGNESIUM														
POTASSIUM														
SODIUM														
BICARBONATE														
TOTAL IONS (TDS)														
HARDNESS														
ANTIMONY	< 0.01					0.03	< 0.02	< 0.02	< 0.08	< 0.02				
ARSENIC	0.02	0.31	0.04	< 0.01	< 0.01	0.03	< 0.005	0.18	0.006	0.006				
CADMIUM	< 0.001	< 0.001	0.005	< 0.001	< 0.001	0.003	0.003	< 0.001	< 0.001	0.002				
COPPER	0.008	0.01	0.02	0.007	< 0.004	< 0.004	0.018	0.006	< 0.004	< 0.005				
LEAD	< 0.004	< 0.004	< 0.004	0.023	< 0.004	< 0.004	< 0.004	0.033	< 0.004	0.014				
ZINC	0.2	0.07	0.07	< 0.005	0.220	0.019	0.4	4.3	7.7	3.5				

APPENDIX 3

THE OTTERY MINE - STREAM SEDIMENT SAMPLING RESULTS

STATION NUMBER	DATE	ASSAY NUMBER	SIEVE ANALYSIS		TRACE METAL CONTENT IN MICROGRAMS PER GRAM												
			Fraction	%	Cu	Pb	Zn	Ni	Co	Fe %	Mn	As %	Sb	Ag	Cd	Bi	Mo
OTT-1	18/2/76	76/392	+25	85													
			-25 + 80	10	205	3800	200	10	10	15.8	50	1.8	100	26	1	140	1
			-80 + 150	3	300	1450	240	10	10	19.0	50	3.2	< 30	21	1	170	1
			-150	2	320	1250	255	10	10	21.2	50	4.8	< 30	27	1	200	1
	7/8/76	76/1644	+25	53													
			-25 + 80	26	135	700	460	5	< 5	18.3	50	2.9	< 20	7	2	80	< 1
			-80 + 150	10	165	750	580	10	< 5	21.5	50	3.4	< 25	7	3	80	< 1
			-150	10	170	700	620	5	< 5	24.8	100	3.7	< 25	8	3	80	< 1
	13/1/77	77/184	+25	22													
			-25 + 80	58	65	410	85	10	10	5.4	50	1.2	< 20	5	2	60	2
			-80 + 150	13	120	900	165	10	15	10.0	<50	1.4	< 20	9	20	100	< 1
			-150	7	180	1150	280	10	20	18.0	50	3.2	< 20	15	2	160	< 2
OTT-2	7/8/76	76/1645	+25	58													
			-25 + 80	36	100	950	170	< 5	< 5	9.7	50	1.6	< 20	8	< 1	90	< 1
			-80 + 150	3.1	270	1400	330	5	< 5	16.5	50	2.6	< 20	14	1	150	< 1
			-150	2.4	225	1050	295	5	< 5	17.7	100	4.8	< 25	16	1	150	< 1
OTT-4	13/1/77	77/186	+25	79													
			-25 + 80	19	115	1200	160	20	20	14.0	100	1.6	< 20	11	3	90	2
			-80 + 150	1	175	1150	225	10	20	16.0	100	1.8	< 20	11	2	100	< 1
			-150	1	170	900	245	20	15	18.0	100	2.4	< 20	11	1	100	< 1
OTT-5	7/8/76	76/1646	+25	77													
			-25 + 80	21	115	1200	180	< 5	< 5	12.2	50	1.5	< 20	9	< 1	90	< 1
			-80 + 150	0.9	240	1150	300	5	< 5	18.4	50	2.7	< 25	10	1	130	< 1
			-150	0.9	220	900	380	10	< 5	15.0	100	3.8	< 25	12	2	120	< 1
OTT-6	7/8/76	76/1650	+25	62													
			-25 + 80	34	80	750	140	5	< 5	8.8	100	1.1	< 15	7	< 1	70	< 1
			-80 + 150	2.2	140	1050	220	5	< 5	13.3	100	1.6	< 20	9	< 1	110	< 1
			-150	1.4	135	650	210	10	< 5	11.4	100	1.8	< 20	7	< 1	90	< 1
	13/1/77	77/187	+25	62													
			-25 + 80	36	90	1100	150	20	15	13.0	100	1.4	< 20	10	2	70	2
			-80 + 150	1	155	950	195	15	15	12.0	150	1.2	< 20	10	1	80	< 1
			-150	1	105	410	200	15	15	8.0	200	1.4	< 20	6	1	50	< 1

STATION NUMBER	DATE	ASSAY NUMBER	SIEVE ANALYSIS		TRACE METAL CONTENT IN MICROGRAMS PER GRAM												
			Fraction	%	Cu	Pb	Zn	Ni	Co	Fe %	Mn	As %	Sb	Ag	Cd	Bi	Mo
OTT-7	18/2/76	76/394	+25	99													
			-25 + 80	1.1	55	510	125	5	10	7.6	100	1.1	<15	6	< 1	50	1
			-80 + 150	<0.1	135	2150	180	5	10	13.0	50	-	-	20	1	110	1
			-150	0.1	95	540	180	15	10	10.4	100	-	-	7	1	70	1
	7/8/76	76/1647	+25	71													
			-25 + 80	24	100	950	335	5	< 5	10.4	100	1.1	105	7	2	70	<1
			-80 + 150	2.2	145	750	555	< 5	< 5	-	-	1.3	<15	-	-	-	<1
			-150	2.2	-	-	-	-	-	-	-	1.6	<15	-	-	-	-
	13/1/77	77/188	+25	92													
			-25 + 80	7	70	750	115	15	15	10.0	150	1.0	<20	7	1	50	2.
			-80 + 150	0.2	55	245	110	10	10	4.6	150	0.3	-	7	8	20	<1
			-150	0.6	45	150	130	15	10	4.0	200	0.4	-	2	1	10	<1
OTT-8	18/2/76	76/395	+25	86													
			-25 + 80	14	10	140	35	5	5	2.4	150	.0017	<15	2	<1	< 20	< 1
			-80 + 150	0.1	40	190	75	5	10	3.4	300	-	-	2	<1	20	< 1
			-150	0.1	25	110	95	5	15	3.2	500	-	-	< 2	<1	<20	1
	7/8/76	76/1648	+25	91													
			-25 + 80	9	< 5	10	20	< 5	< 5	0.8	200	.0009	< 15	<2	<1	<10	< 1
			-80 + 150	<0.1	5	30	50	< 5	10	1.8	700	.0038	65	2	<1	<10	< 1
			-150	<0.1	10	30	45	< 5	15	1.7	750	.0016	200	< 2	<1	< 10	<1
	13/1/77	77/189	+25	86													
			-25 + 80	14	10	90	65	10	10	1.8	250	.0011	<20	<2	1	<10	<1
			-80 + 150	0.3	85	600	295	10	20	6.4	550	-	-	4	2	50	<1
			-150	0.1	155	165	330	10	20	3.2	850	-	-	2	3	20	<1
OTT-9	18/2/76	76/396	+25	83													
			-25 + 80	16	5	20	40	15	10	1.2	350	.001	<15	< 2	<1	<20	<1
			-80 + 150	0.3	<5	15	15	5	5	0.8	200	-	-	< 2	<1	<20	<1
			-150	0.1	10	105	75	5	10	1.8	500	-	-	< 2	<1	< 20	1
	7/8/76	76/1649	+25	81													
			-25 + 80	18	5	20	65	20	15	1.2	200	.0068	<15	< 2	<1	< 10	<1
			-80 + 150	0.3	45	200	90	20	20	4.4	400	.0037	<15	2	<1	30	<1
			-150	0.3	20	100	100	25	15	2.5	600	.0015	<15	< 2	<1	10	<1

STATION NUMBER	DATE	ASSAY NUMBER	SIEVE ANALYSIS		TRACE METAL CONTENT IN MICROGRAMS PER GRAM												
			Fraction	%	Cu	Pb	Zn	Ni	Co	Fe %	Mn	As %	Sb	Ag	Cd	Bi	Mo
OTT-9	13/1/77	77/190	+25	72													
			-25 + 80	27	15	20	65	20	15	2.2	550	.0030	<20	<2	1	<10	1
			-80 + 150	0.4	20	200	90	20	20	2.6	750	.0165	<20	<2	<1	<10	<1
			-150	0.6	25	100	100	25	15	2.6	800	.0068	<20	<2	<1	<10	1
OTT-10	13/1/77	77/191	+25	85													
			-25 + 80	15	15	50	60	15	10	1.6	250	.0090	< 20	< 2	6	<10	<1
			-80 + 150	0.2	45	215	125	10	15	3.4	450	-	-	2	12	20	<1
			-150	0.2	25	125	495	15	10	2.2	450	-	-	< 2	< 1	<10	< 1

APPENDIX 4

SAMPLE COLLECTION AND ANALYSIS — METHODS AND PROCEDURES

The following collection techniques and methods of analysis were employed by the Chemical Laboratory, Department of Mineral Resources, in the water quality monitoring programme and other research undertaken at the Ottery mine.

Water Samples

Preparation of Sample Containers

Sample bottles are made of translucent, low density polythene. Bottles for both general water quality testing and trace metal analysis were prepared according to the recommended procedures in Australian Standard 2031, Part 1-1977. Samples for trace metal analysis were preserved with nitric acid. Samples for general water quality assessment were preserved by storing in a refrigerator prior to analysis.

Analysis of Water Samples

All analyses were carried out in the laboratory. The parameters measured and the method of analysis are listed below.

Parameter	Method
pH	Measured on a pH meter.
Electrical Conductivity	Measured on a conductivity meter.
Sulphate	Colorimetric method.
Zinc	Zinc, cadmium and copper were measured on an Atomic Absorption Spectrophotometer (AAS), using background correction where applicable.
Cadmium	
Copper	
Lead	Lead was analysed by either AAS or Anodic Stripping voltammetry.
Arsenic	Arsenic was measured by either a colorimetric technique (molybdenum blue) or by X-ray Fluorescence (XRF) after precipitation onto membrane filters.
Antimony	Measured by XRF as for arsenic.

Stream Sediment Samples

Preparation of Sample Containers

High density 2 litre plastic, wide mouth, screw top jars are used to collect stream sediment samples. The jars were soaked in hot detergent solution, rinsed twice with deionized water, drained and carefully dried in a forced air oven at about 60°C.

Collection and Preparation of Stream Sediment Samples

Sediment samples were collected in stream beds and care was taken to make sure these are active sediments and not stream bank material which had collapsed into the water course. Samples were transferred to 2 litre plastic jars and transported back to the laboratory.

After settling overnight, excess water was carefully siphoned off the samples, and each sample was transferred to an aluminium cake tin (230 mm diameter, 70 mm depth) for drying. The samples were dried at 80°C in a forced air oven, with occasional mixing using a wide blade spatula. The dried samples were then returned to the original jars and these were mechanically shaken for about 30 minutes to break up any aggregates of sediments.

Obtaining a representative sediment sample is difficult because of the variation in stream flows (and hence the bed load) between any two sampling times. Thus, the proportion of any particular size fraction in a sediment will be dependent on the flow conditions experienced at that point.

In an attempt to overcome this problem, all dried samples were first sieved to minus 7.5 mm (3/8 in.) to eliminate all large pebbles. Four size fractions were then taken from the sample, (+25#, -25 +80#, -80 +150# and -150#) but only the three finest fractions were analysed. This is because the greater proportion of heavy metals in sediments normally travels in the finest fractions (as fine tailing material and surface coatings on particles) and so much greater contrast will be obtained by comparison of these fractions. Also by analysing each of these fractions, more meaningful comparisons can be made of samples taken at three monthly intervals because the diluting effect of large particles, low in heavy metal concentration, is minimized.

The sieving was done with a nest of plastic sieves fitted with nylon sieving cloths. The -25 +80# fraction was ground prior to analysis. A sieve analysis was carried out on each sample for the four size fractions.

Analysis of Sediments

Parameter	Method
Copper Lead Zinc Nickel Cobalt	Hot perchloric/nitric acid digestion. Determined by AAS
Iron Manganese Silver Cadmium Bismuth Molybdenum	Hot perchloric/nitric acid digestion. All except molybdenum determined directly by AAS molybdenum determined by solvent extraction then AAS
Antimony	Sublimation with ammonium iodide. Determined by solvent extraction then AAS
Arsenic	X-Ray fluorescence

Extraction

A stream sediment, collected at Station 1 in 1978, was tested with various extracting solutions to determine the availability of metals in the sediment. The pH of the sediment was determined on a 1 to 5 ratio extraction with deionised water, using a pH meter. The sediment was extracted sequentially with several aliquots of deionised water, ammonium acetate and hydrazine hydrochloride. The pH of the last two extractants was adjusted to the pH of the sediment, using sulphuric acid and sodium hydroxide.

The amounts of iron, copper, lead, zinc and cadmium extracted by each of the solutions was determined by atomic absorption spectroscopy. Arsenic was determined using a Gutzeit procedure.

Waste Material

Samples of waste material from the Ottery mine were ground prior to analysis. The methods of analysis used are given below.

Parameter	Method
pH	5 g in 25 ml deionised water, pH determined by a meter.
Total metals	X-Ray Fluorescence Spectroscopy. Arsenic determined by wet chemical procedures.
"Soluble" metals	Extraction with deionised water. Various ratios of sample to extractant were used to measure the absolute amounts of soluble metals. Arsenic determined by Gutzeit procedure. Other metals determined by AAS.

Density Measurement

Three different methods of density measurement were attempted in order to calculate the mass of waste material present.

The true density was calculated with an air comparison pycnometer which measures the volume enclosed by the outer surface of the particles excluding open pore spaces. This method assumes total compaction of the material.

The apparent density was determined by a very approximate method whereby a sample is packed firmly into a known volume and the weight recorded. This method includes open spaces between the particles, but to estimate the correct degree of compaction is difficult.

The bulk (or in-situ) density was determined using a "sand replacement method". The waste material from a carefully excavated small hole is weighed to give mass (M). The volume of the hole is measured by refilling it with a calibrated sand (of known density D). The mass of sand (S) needed to fill the hole is weighed. The bulk density is given by M.D/S. This is the most accurate method of calculating the density of material in-situ.

Encrustations on Brickwork

Samples of encrustations were generally ground prior to analysis. Methods of analysis for pH and "soluble" arsenic were the same as for dump samples. Total arsenic was determined by wet chemical procedures.

APPENDIX 5

ARSENIC

Arsenic, though not an abundant element, is a metalloid that occurs widely in nature. Arsenic occurs in minor quantities as the native metal, but more commonly as a constituent of 30 or more minerals, chiefly as arsenides of lead, copper, nickel, cobalt and bismuth. The most abundant arsenic mineral is arsenopyrite (mispickel), FeAsS, which contains 46% arsenic.

Most arsenic is produced in the form of arsenic trioxide (As_2O_3), generally known as "white arsenic" or simply "arsenic", and is usually recovered as a by-product in the smelting of metallic ores.

The most important uses of arsenic result from its toxic properties. Arsenic has been used principally in insecticides, fungicides and sheep and cattle dips, which require arsenic of the highest grade. The use of arsenical compounds has been greatly reduced over the years in favour of less persistent and less toxic synthetic organic compounds (Flack, 1967).

Toxicology

Arsenic is an element that is not essential for human nutrition but is normally found in trace amounts in human tissues. It is acutely and chronically toxic to man, but the biological effects vary with differences in chemical form, solubility, dose, rate of exposure and route of intake. Arsenic compounds are cumulative, potent, protoplasmic poisons that block cell and tissue respiration, can paralyze smooth muscle and cause many small haemorrhages (Lapedes, 1977).

The commonest cases of persons being poisoned by arsenic are those in which the arsenic is taken in a mixture or powder, but poisoning can also result from inhaling arsenical fumes or dust, and also by continual contact with the skin, especially when accompanied by perspiration. Most arsenic salts are soluble to some extent and are rapidly absorbed through the gastrointestinal tract or skin. Vapors are absorbed through the lungs (Hart, 1974).

Acute arsenic poisoning has been caused by ingestion of as little as 100 mg of arsenic trioxide, while 130 mg has been reported as a fatal dose. Arsenic is more poisonous in the form of a fine powder, being more soluble, than coarser particles. Furthermore, arsenic accumulates in the body, so that small doses may become fatal in time. A single dose may require ten days for complete disappearance (McKee and Wolf, 1963) and this slow excretion is the basis for a cumulative toxic effect.

McKee and Wolf (1963) summarised available data concerning arsenic in water which suggested that arsenic concentrations in the range 0.2 to 10.0 mg/l taken over a long period of time by human beings was poisonous. They also suggested that drinking water containing concentrations between 0.05 and 0.25 mg/l was safe. There was evidence of increased accumulation of arsenic in the body of populations using well water with concentrations between 0.1 to 1.4 mg/l, however no specific illness was observed. Several instances were reported where cancers of the skin and liver were attributed to arsenic in domestic water supply.

Australian Production

Arsenic produced in Australia has been almost entirely a by-product of metallurgical operations for the recovery of other metals - principally gold. The few isolated mines in N.S.W. and Queensland, which were operated for the recovery of arsenic alone were worked by the firm processing the arsenic, and operations were only carried on when oxide could be produced and landed at their works at less than ruling market rates (Pearson, 1949). Either white arsenic or arsenical concentrate has been produced in each of the Australian States with the exception of Tasmania and the Northern Territory. Table 7 and Figure 5 summarize the total production of arsenic in Australia.

In the latter half of the 19th century arsenic associated with metalliferous ores was considered a nuisance, and regulations were made to compel the product being destroyed or else buried in old abandoned mine workings. Only when its value as a pesticide was realised did production of arsenic become significant. Small tonnages of ore were produced in South Australia and in N.S.W. prior to 1912, however prices were low and no further production ensued until an improvement in the market price and a strong demand in Queensland for arsenic for prickly pear poison resulted in major production in several States within the period 1916 to 1936 (Gardner, 1945). The most important mining areas were the New England region of N.S.W. and the Stanthorpe area of Queensland.

During the course of the first world war the demand for arsenic was so great for munitions, poison gas, germicides and medical purposes, that all supplies available in Australia were shipped to England. In 1931 new developments in the Wiluna goldfields of Western Australia stimulated arsenic production, such that by 1932 the State was the leading producer of arsenic in the Commonwealth. During 1935-36 arsenic could be imported at a very low price, causing a cessation of mining at all centres except Wiluna, where large scale production of arsenic as a by-product at a low price continued until 1949 when the ore bodies were exhausted. Dump material was retreated in the following two years.

Arsenic has not been produced from Australian mines since 1952. All of Australia's requirements of arsenic are imported, at a lower price than could be obtained locally. Most of the imported arsenic comes from Sweden, the Bolidan copper smelter producing enough arsenic as by-product to supply the world's entire demand. Figure 5 graphically illustrates the demise of Australian production in favour of imported arsenic, and the declining levels of imported arsenic due to the manufacture of organic compounds.

Sources of Supply

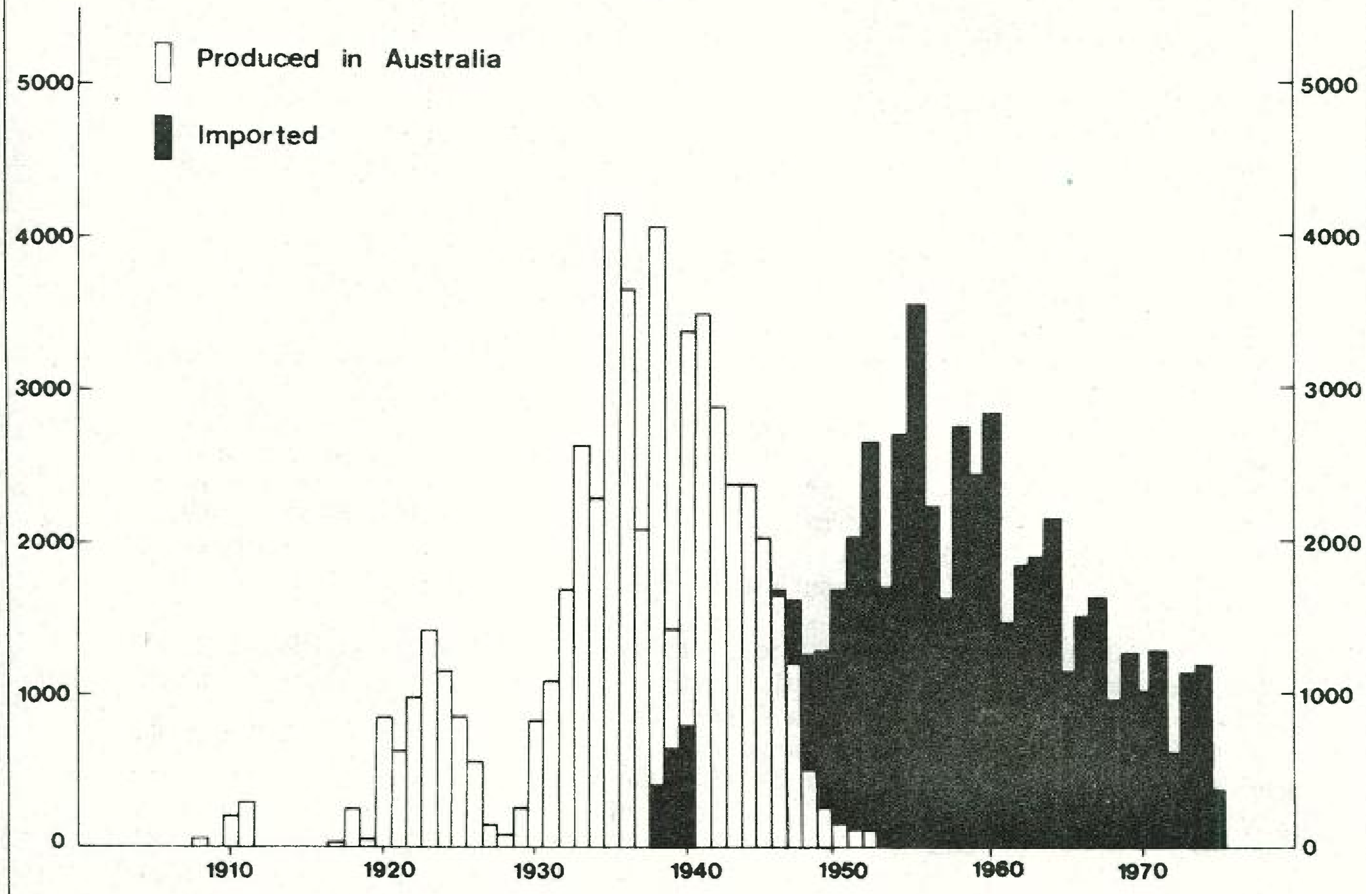
Western Australia

Arsenopyrite is of widespread occurrence in the auriferous deposits of Western Australia but only three centres have produced commercial quantities of arsenic - the Wiluna Gold Mines, the Ingliston Consols Gold Mine, and the Transvaal Gold Mine.

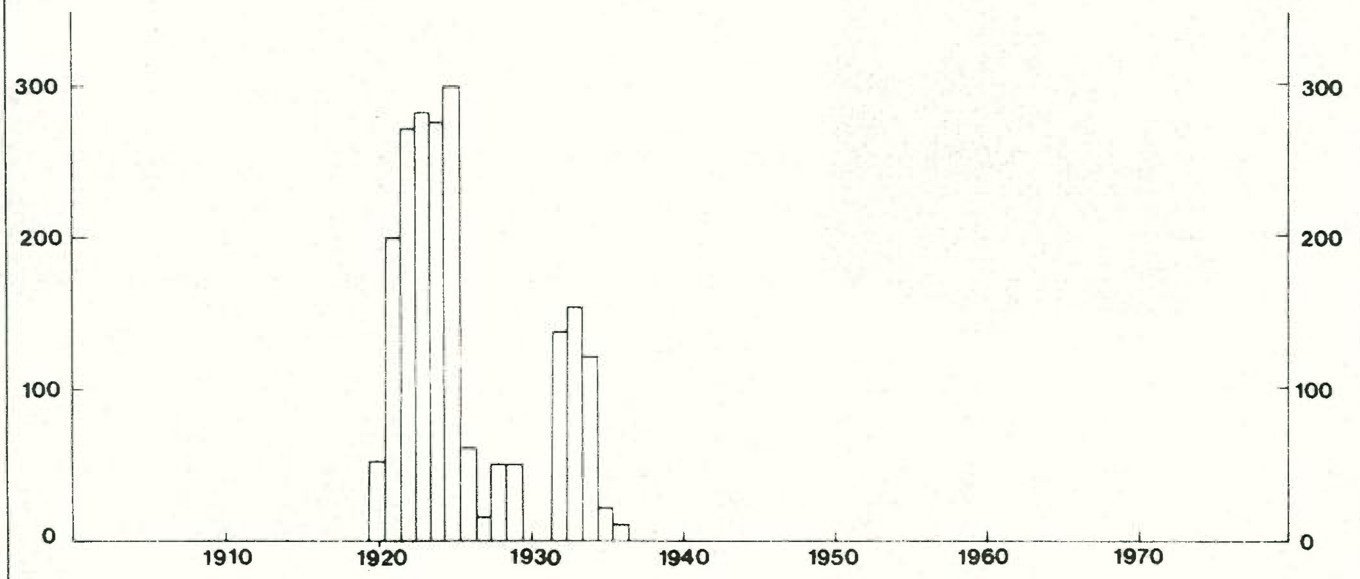
Almost two-thirds of the Australian arsenic production has come from the Wiluna Gold Mine. The flotation concentrate from the gold ores contained a high proportion of arsenopyrite. An arsenic plant was constructed on the property of the Wiluna Gold Corporation Ltd in 1931.

FIGURE 5

AUSTRALIAN PRODUCTION AND IMPORT OF ARSENIC
(As_2O_3 in tonnes)



PRODUCTION OF ARSENIC — OTTERY MINE
(As_2O_3 in tonnes)



11133

The concentrate was roasted and most of the arsenic content collected in steel and concrete condensing chambers and, finally, in an electrostatic precipitator (Gardner, 1945). The crude arsenic was refined in a mechanical furnace owned and operated by the Victor Leggo Mining Co. Pty Ltd. From 1936 to 1943, this plant provided practically the whole of Australia's requirements of refined arsenic, and in some years a considerable surplus was exported.

The Transvaal (Jupiter) Mine was the second most important producer in Western Australia. The concentrates containing gold and arsenic were shipped to Leggo's Bendigo works, where the gold was extracted and the arsenic produced as refined white arsenic. Similarly, at the Ingliston Consols Extended Gold Mine, auriferous concentrates were despatched from the mine - no refining of arsenic taking place on site (McLeod, 1965).

South Australia

Arsenic deposits in South Australia are small, and have contributed only a minor proportion of the total Australian production. The three sources of recorded production come from the Callington District and the Talisker Mine. All of the ore was treated outside the State as the output was not sufficient to warrant installation of treatment plants (Winton, 1925).

Victoria

Arsenopyrite occurs in many gold mining localities in Victoria. Refractory arsenical ores were treated at two metallurgical works, Leggo's and Liddell's, in Bendigo, and also at a metallurgical works at Ballarat. These plants recovered arsenic from concentrates purchased from Victorian gold-mines and also from interstate mines. None of the Victorian mines had a large output of arsenical ore (Gardner, 1945).

Queensland

The entire Queensland arsenic output has come from the Stanthorpe district. The largest mine was the Jibbinbar Mine which was operated by the Queensland State Government for the sole purpose of producing cheap arsenic for the manufacture of prickly pear poisons. In 1917 there were estimated to be 30 million acres of land in Queensland infected with this pear, and that it was spreading at the rate of 1 million acres per annum. The State Government set aside an area of 150 acres for prospecting for arsenic, production commencing at Jibbinbar in 1919. Arsenic acid was claimed to be superior to all other chemicals for pear destruction and there was a great demand for it at this time.

At the Jibbinbar State Works an Edwards reverberatory furnace was in operation, the ore treated as it came direct from the mine. The flue product without refining contained an average of over 90% of arsenious oxide, and in this impure form it was marketed (Dunstan, 1920).

The Sundown and Beecroft mines, also in the Stanthorpe district, were active, but concentrates were shipped to the Victorian arsenic works, no recovery being made locally.

New South Wales

Arsenic ores have been recovered at eight main centres in N.S.W. and small quantities have been recovered at numerous other localities. The New England region was the most important area of the State accounting for

85% of total production. The Ottery and Mole River mines were the State's premier producers of arsenic. As far as can be ascertained from Departmental records these were the only two mines in the State equipped with a plant capable of the production of refined arsenious oxide.

At Mole River (near Tenterfield) Roberts Chemicals Ltd, operated furnaces and flues for the production of white arsenic and arsenic pentoxide. The greater portion of the chemical plant was used for the manufacture of pentoxide for prickly pear eradication. The treatment plant is of considerably different design to that at the Ottery mine, having no series of condensation chambers, simply one long flue leading to the stack. The ruins of this plant are still present at the mine (Plate 16).

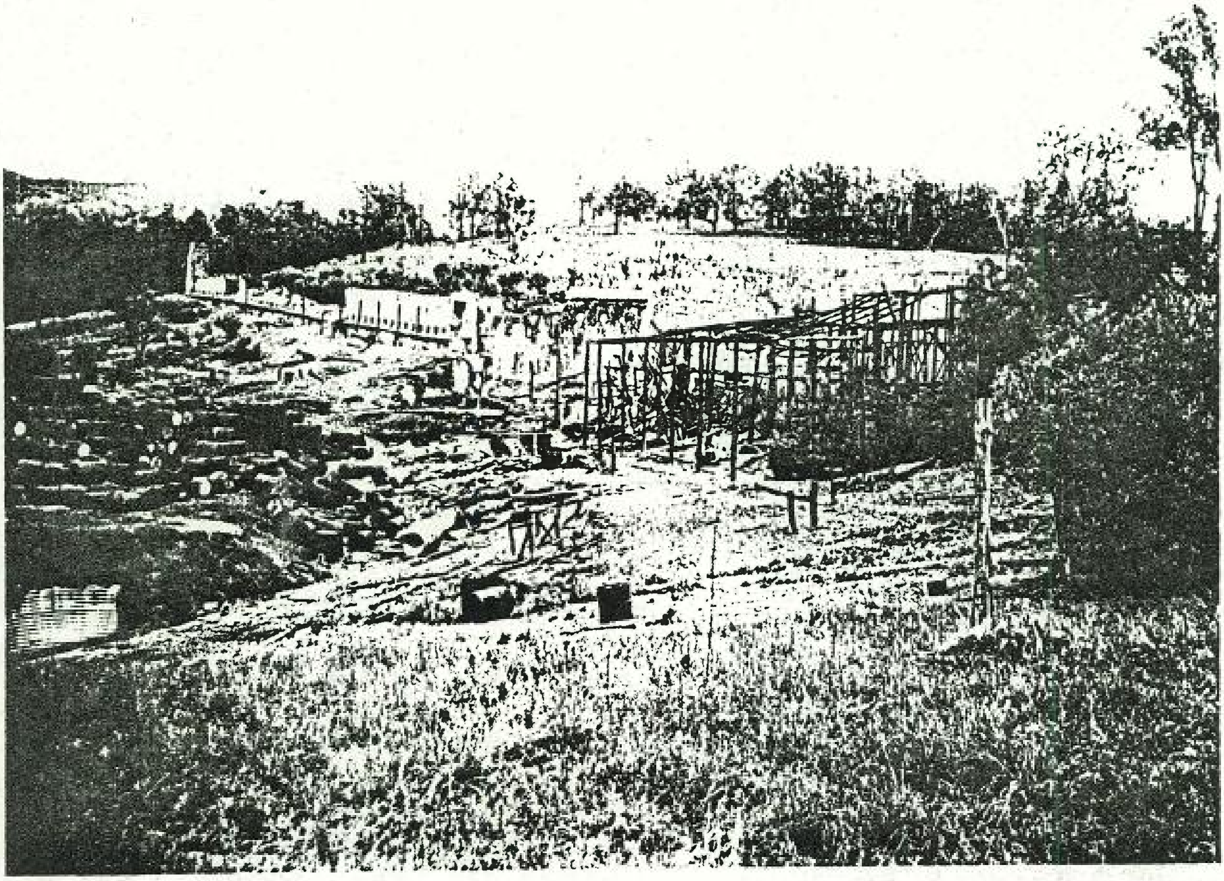


Plate 16. Remains of treatment plant at Mole River arsenic mine 1974. (Grafton 0178J)

Worked originally for gold, the Valla arsenic mine (Nambucca area) was operated by Victor Leggo and Company, the ore being roasted on site and the concentrate dispatched to the company's work at Bendigo. Similar procedures were adopted with the other producing mines in N.S.W., the roasted concentrate being sent to the various metallurgical works in Victoria.

TABLE 7

ARSENIC PRODUCTION IN AUSTRALIA
(expressed as As_2O_3 in tonnes)

Major Producing Mines+

Mine	State	Production	Period
Wiluna	WA	39664	1931-1949
Mole River	NSW	2905	1923-1936
Ottery	NSW	2004	1920-1936
Jibbinbar	QLD	1653	1919-1924
Beecroft	QLD	1185	1917-1927
Transvaal and Ingliston Consols	WA	1102	1916-1947
Valla	NSW	909	1921-1932
Rockvale	NSW	601	1923-1928
Conrad	NSW	566	1908-1911
Sundown	QLD	254	1920-1923
Preamimma	SA	165	1900-1907
Brungle and Wyangle	NSW	91	1920-1923
Callington	SA	63	1924-1925
Moruya	NSW	41	1909-1911
Webbs Consols	NSW	22	1924-1925
Cape Jervis	SA	3	1924
		51228	

Total Production by State+

WA	40813
VIC	11046*
NSW	7169
QLD	3094
SA	231
	62353

* Individual production figures for Victorian mines not recorded. Total Victorian production estimated by Victor Leggo Mining Co. Pty Ltd, but may include shipments from other States.

\+ Source of Data - Kalix et al. (1966).

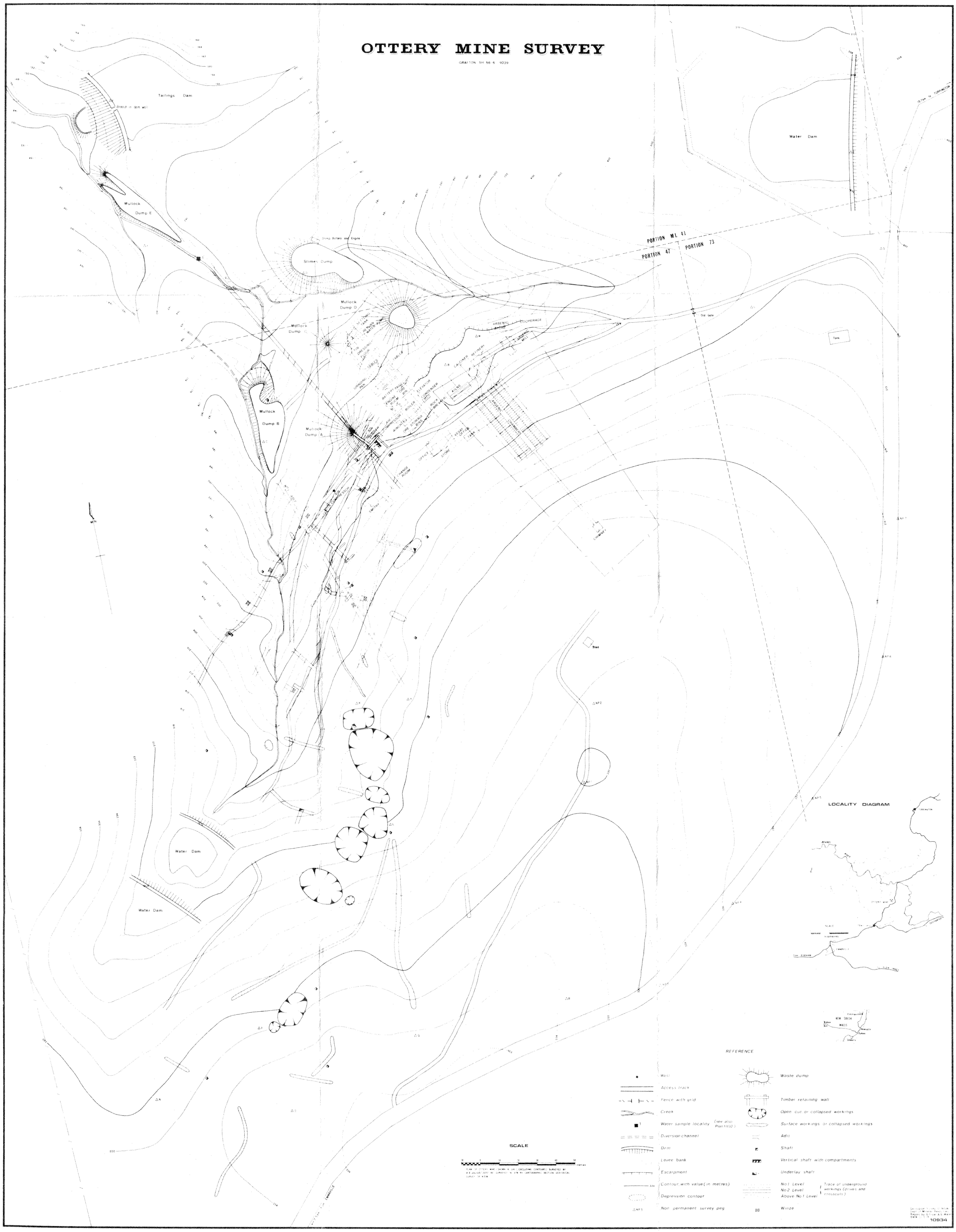
NEW SOUTH WALES - DEPARTMENT OF

Environmental investigations and
rehabilitation considerations at the
Ottery Mine, Emmaville, NSW

Borrower's name	Date	Ext

OTTERY MINE SURVEY

GRAFTON SH 56-6 9239



THE OTTERY MINE

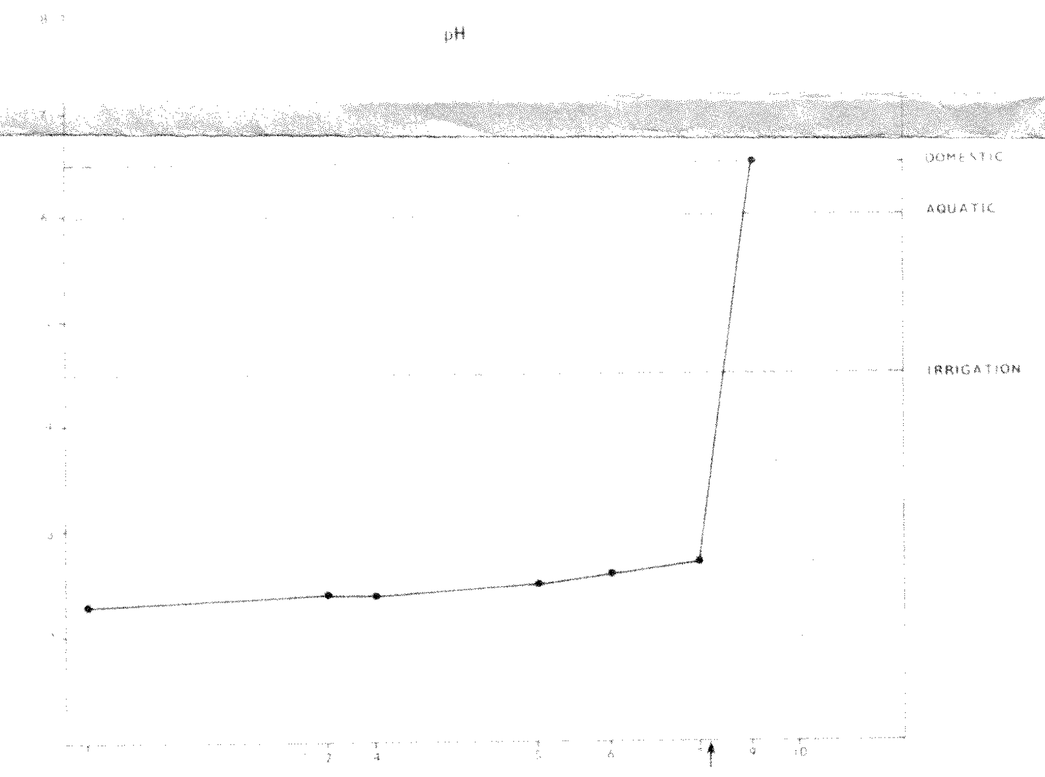
WATER AND STREAM SEDIMENT SAMPLING RESULTS

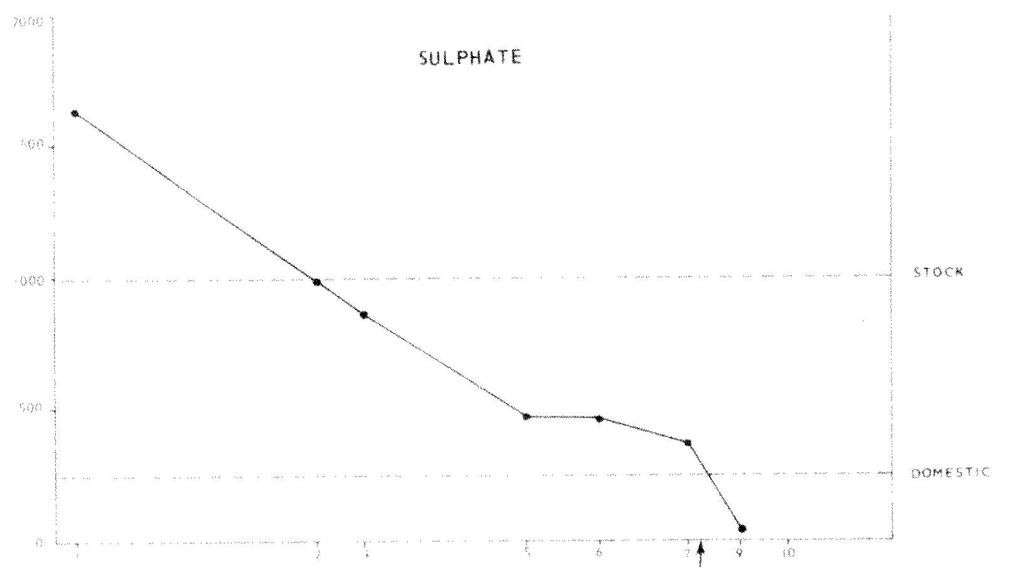
DOWNSTREAM TRENDS

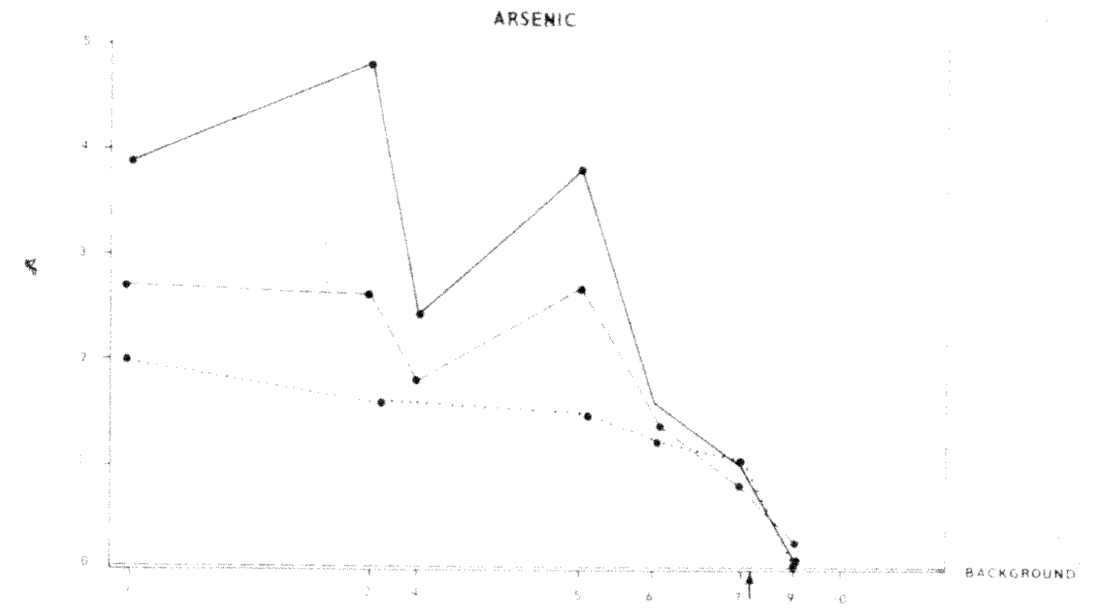
AVERAGE WATER QUALITY
(Four samples collected at each
station during 1975)

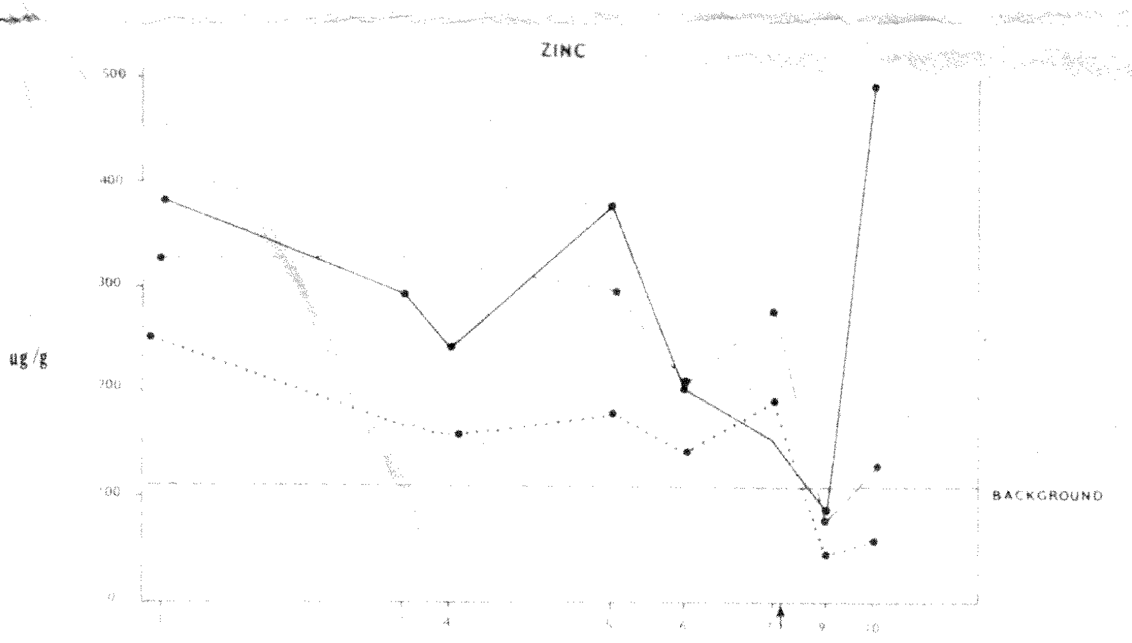
AVERAGE TRACE METAL CONTENT IN STREAM SEDIMENTS
(One to three samples collected at each station during 1976 – 77)

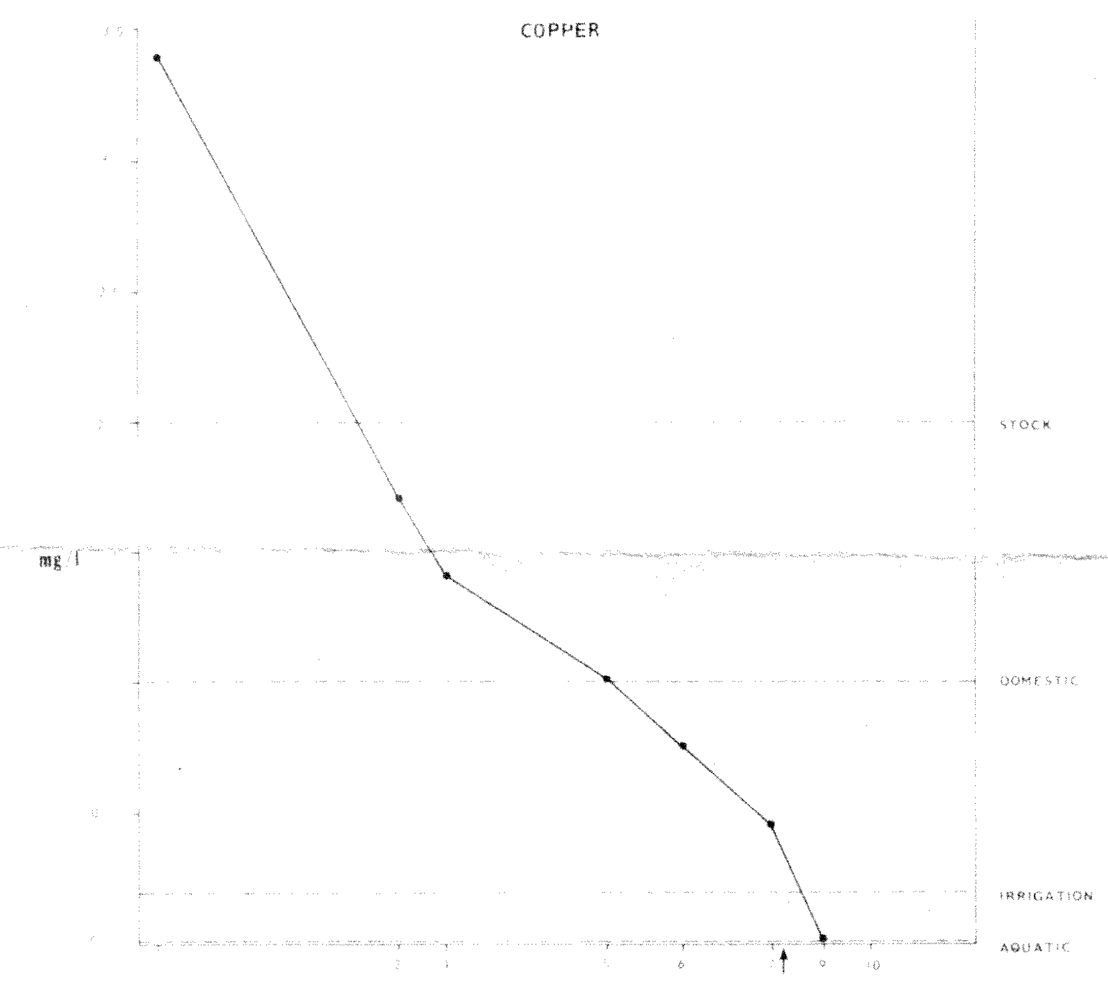
NOTE: VERTICAL SCALES ARE DIFFERENT FOR ALL GRAPHS

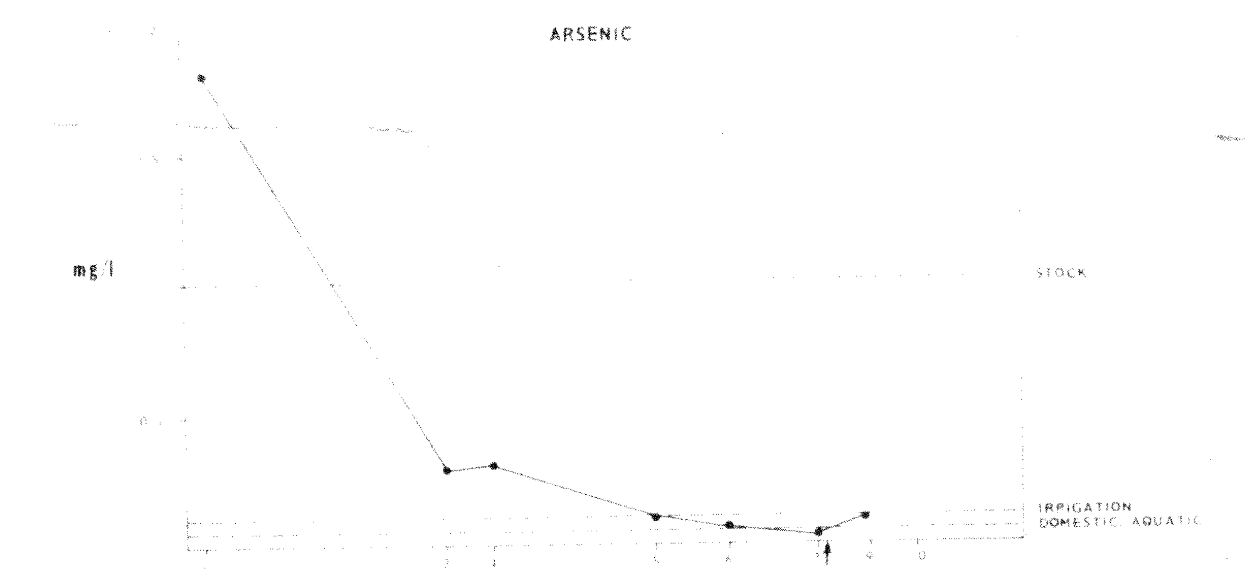


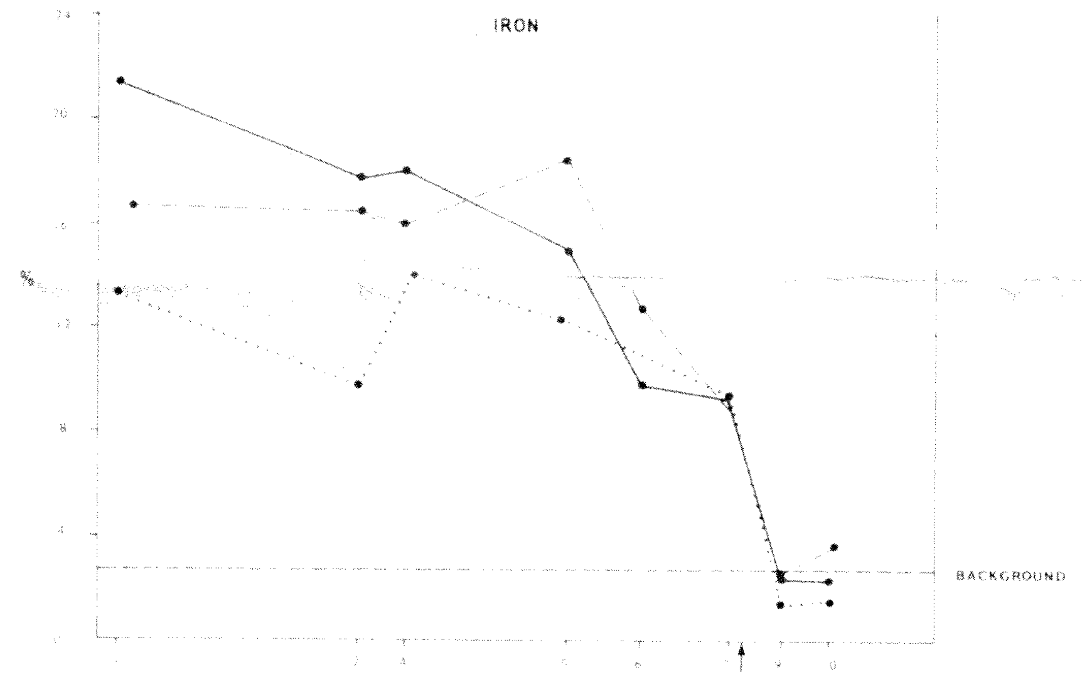


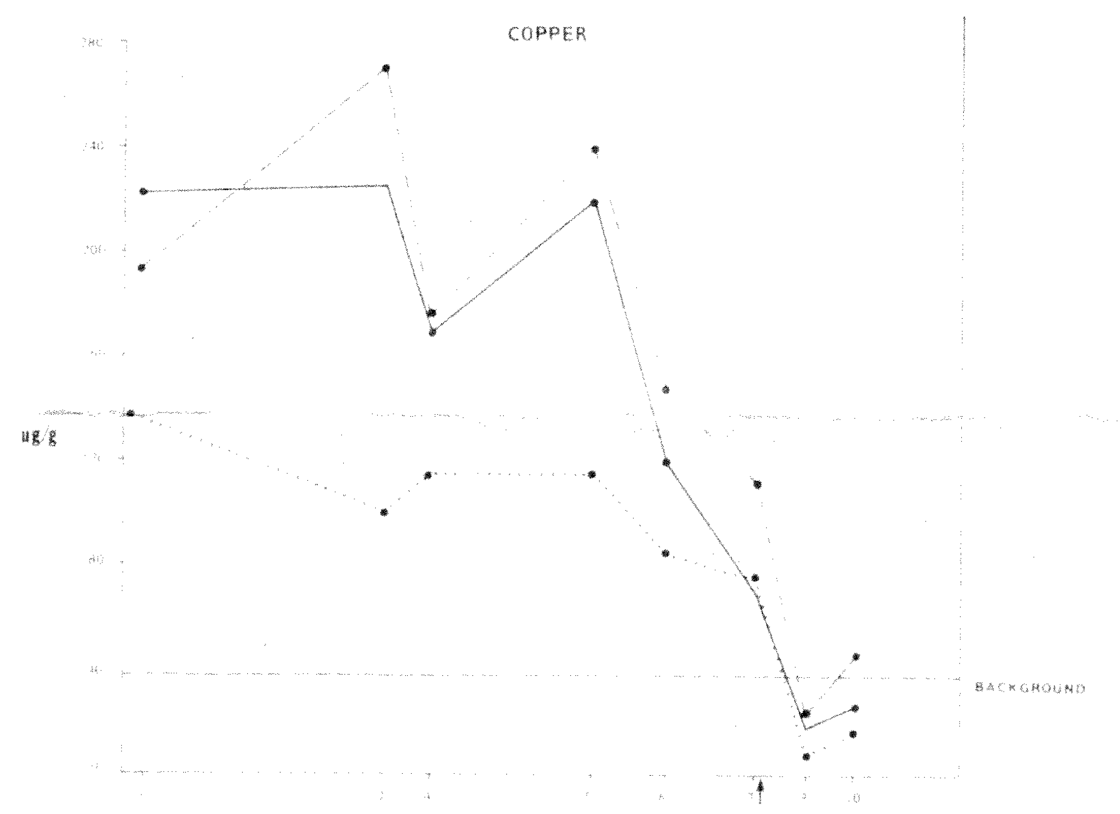


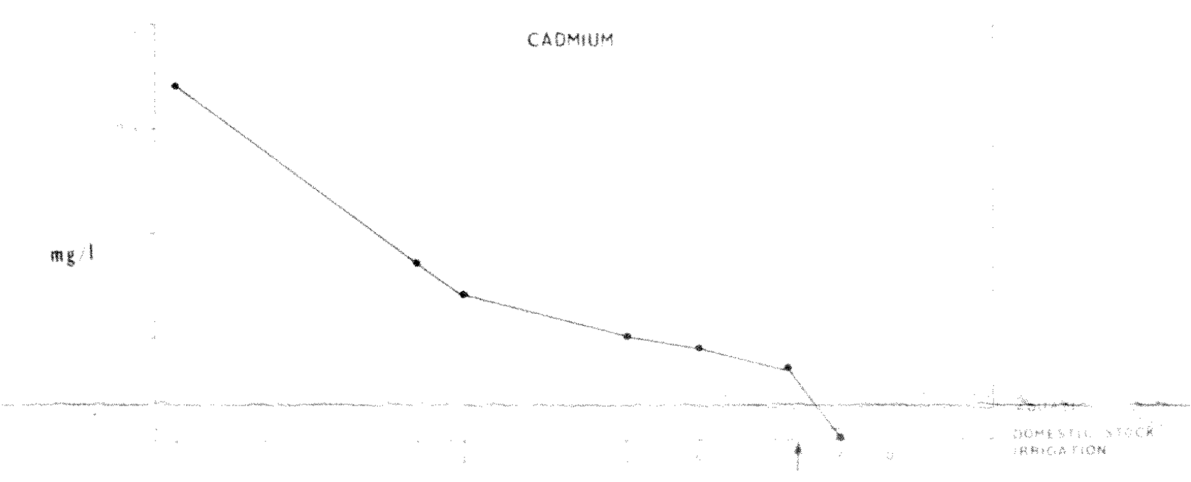


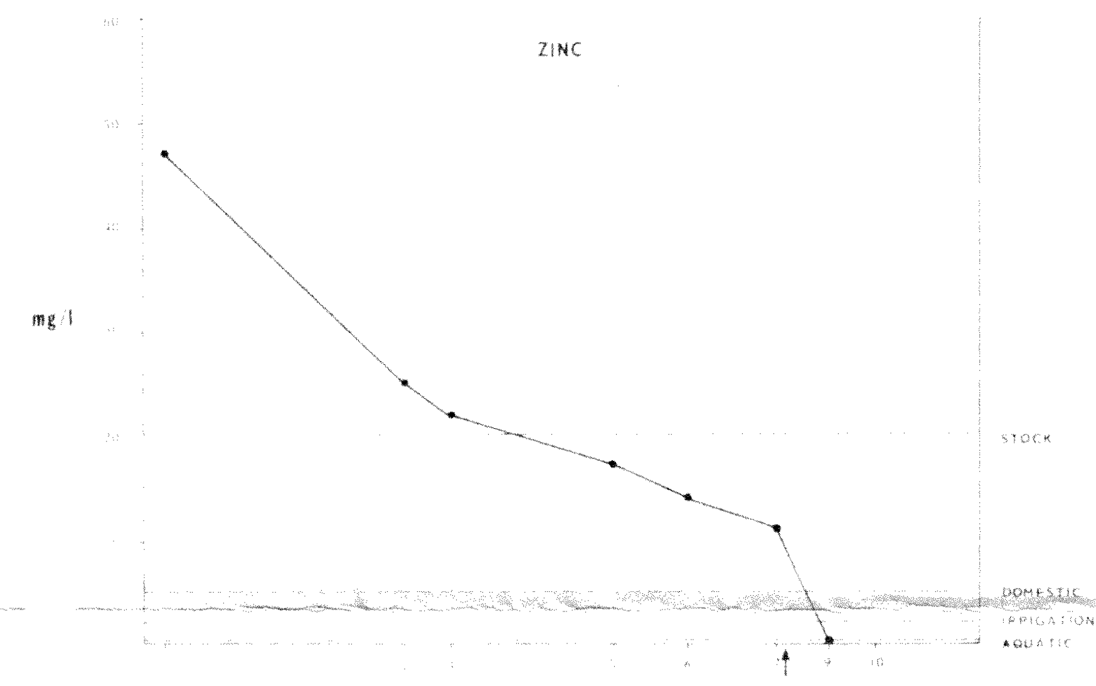


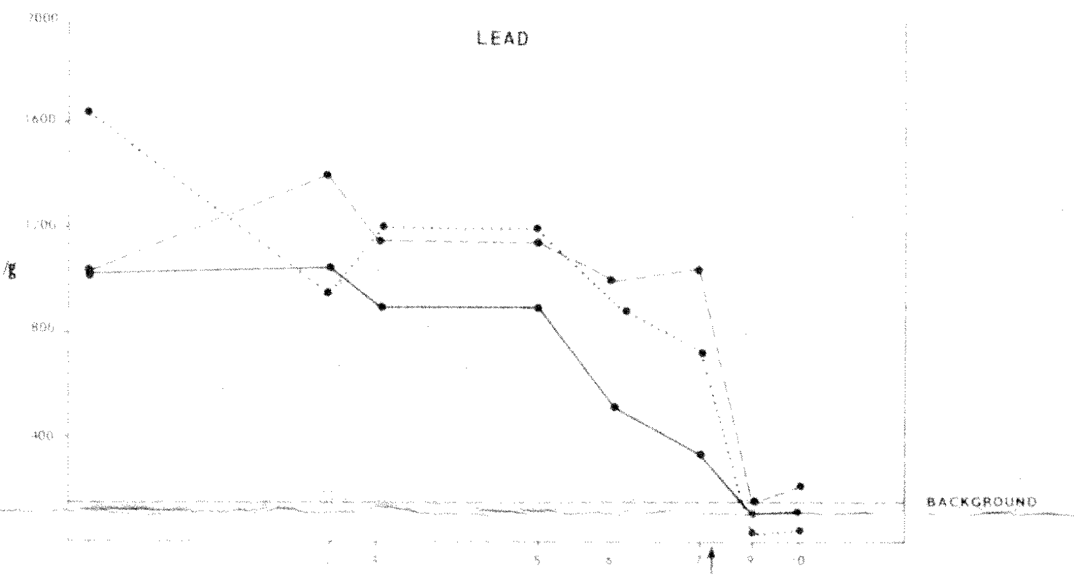




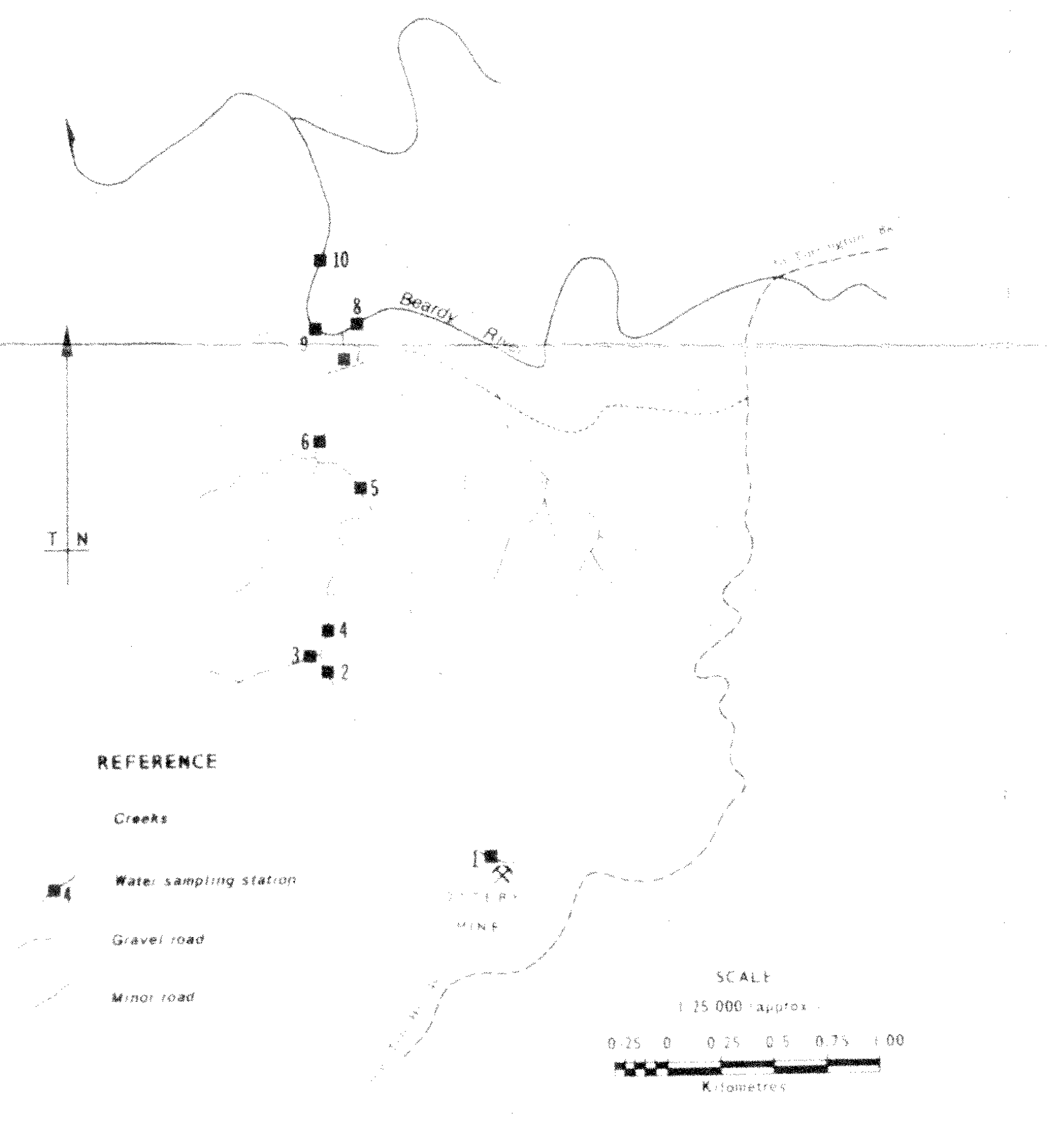








TENT HILL
WATER SAMPLING STATIONS
BELOW THE OTTERY MINE
Grafton SH 56 6 9239 111



— — Acceptable concentration levels dependent upon waters designated use

SIEVE ANALYSIS

- *25 + 80 # fraction*
- *80 + 150 # fraction*
- *−150 # fraction*

The background level was estimated by averaging all size fractions from station 8

REFERENCE

Sampling Station

Confluence with Beardy River

HORIZONTAL SCALE
0 0·5 1·0
Kilometres

7290

11132

Geological Survey of N.S.W.
Dept of Mineral Resources

Report by G Toyer & S Wain
Date 11 5 79