MINERAL RESOURCES TASMANIA

Tasmania
DEPARTMENT of INFRASTRUCTURE, ENERGY and RESOURCES

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AUSTRALIA
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Helping Communities
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The effects of waste disposal on groundwater quality in Tasmania

Overview Report

Tasmanian Geological Survey Record 2002/17

Mineral Resources Tasmania
Tasmanian Geological Survey
Record 2002/17

The effects of waste disposal on groundwater quality in Tasmania An overview of NHT funded project NLP13188

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Executive Summary

In designing waste disposal sites the different types of waste to be accommodated must be considered, with different designs being required for different waste streams. Historically, the risks of polluting groundwater, soil or air have rarely been considered when selecting sites and drawing up the engineering designs for Tasmanian waste disposal activities (Gentizen, 1990*a*). Evidence of past sub-optimal practices was found during this study.

A project brief for this study is outlined in Appendix 1. An initial desktop study resulted in the identification of 176 waste disposal sites around Tasmania. A list of information used to assess each site is outlined in Appendix 2 (additional licensed and unlicensed sites may also exist). Of these sites, 126 were considered to be worth further investigation, with detailed investigations being made at ten of these sites. Detailed investigations were not undertaken at the majority of the sites identified by the initial study.

Ten site-specific reports, identifying hydrogeological settings and investigation results at the respective sites, were published. An additional site was investigated as a potential clay resource for compacted clay barriers and/or land restoration. Two supplementary reports outlined deeper groundwater systems in the vicinity of two initially investigated sites. All thirteen reports are listed in Appendix 3.

The storage and management infrastructure for waste appears to be the cause of groundwater pollution in the vicinity of two sewage lagoons (Bridport and Smithton) and five landfill sites (Scottsdale, Port Sorell, Port Latta, McRobies Gully and Chapel Street). Site specific issues affect the nature and extent of the contamination at each of these locations. Off-site discharges of polluted surface water were also identified at three of the landfill sites (Port Sorell, Scottsdale and McRobies Gully). Within the selective hydrological systems investigated, several dissolved metals (lead, manganese, nickel and zinc) and non-metallic inorganic compounds (ammonia and nitrate) notably exceeded the 95% protection level trigger values for toxicity in freshwater [*Australian and New Zealand Guidelines for fresh and marine water quality* (ANZECC AND ARMCANZ, 2000), Table 3.4.1]. An organophosphorus pesticide (Diazinon) significantly exceeded the guideline relevant 95% protection level trigger value in surface water at the Scottsdale waste depot.

As some investigations have identified large volumes of saturated fill (e.g. McRobies Gully and Port Sorell landfill sites), future research should include consideration of the shear parameters and density of geotechnical waste settings in historical landfills. Where a potential risk of slope failure in waste fill is identified, consideration should be given to long-term stabilising elements such as additional capping, anchors or sealing layers and drainage blankets. The provision of down-gradient buffer zones in council planning schemes should be investigated.

Recommendations to assist in the implementation of best practice environmental management at Tasmanian waste disposal sites, and the management of associated ecological risks, are outlined in Section 4 of this report. Key issues requiring attention include surface water controls and positioning fill material above the water table. Management options of existing plumes may vary significantly in approach and cost, from monitored natural attenuation (MNA) to permeable treatment beds, and pump and treatment. Future engineering designed barrier systems (liners and capping) will require quality control measures at the planning stage, during installation, and on-going monitoring to verify the integrity of the infrastructure.

Section 1: Project Findings

Introduction

Key characteristics of Australia's groundwater resources have been described by Young and Evans (1998):

- it is a hidden resource and therefore its processes are difficult to precisely identify;
- under most Australian conditions it is slow moving, with typical rates of movement of 0.1 to 1 metre per year;
- it is broad scale from local processes (metres to kilometres) to regional processes (tens of kilometres);
- natural contamination is common (e.g. nickel levels above guideline limits in basalts) and hence, the definition of what level of contamination is unacceptable is frequently difficult to define;
- diffuse pollutants do cumulate when multiple point sources exist in an area; and
- most pollution is irreversible and subsequently requires a conservation approach to management of the resource.

Pollution of groundwater by liquid or solid wastes from existing or proposed waste activities is considered to be an issue of great concern (Zezhong, 1993). Small amounts of landfill leachate can pollute large amounts of groundwater, rendering the resource unusable for domestic and many other purposes (Lee and Jones-Lee, 1996). A plume of pollutant is often present down-gradient from landfill sites. This plume can be recognised by elevated chemical components in the groundwater, which have been derived from the progressive breakdown and leaching of the waste. Allen (1998) states that a dilute and disperse strategy, although currently out of favour, is more likely to achieve sustainability. A 'bio-reactor' approach to landfills (increasing the rate of organic breakdown in the waste) still requires further research in Australia (Yuen, 2001).

Sewage effluent treatment ponds contain a hydraulic head and if unlined can allow diffuse contamination of groundwater in surrounding soil and bedrock. Organic concentrations and microbiological characteristics of the effluent can cause physico-chemical changes in soil, as a result of the nutrient and pathogen levels in the groundwater (Dawes and Goonetilleke, 2001).

The general risk assessment method for groundwater contamination is the application of the 'hazard— pathway—target' model. Risk analysis, evaluation, migration, ecotoxicity and bio-availability are all essential elements within the model (Correll, 2001). A risk assessment of groundwater contamination by waste disposal activities should include consideration of:

- Pollution point source(s) — waste composition, saturation level, hydraulic retention time and related water ecotoxicity.
- Transport pathways from the pollution point source(s) — preferred flow paths through unconsolidated sedimentary and consolidated fractured aquifers, existing surface water and man-made drainage systems, gas discharges to the atmosphere, and collection infrastructure to waste water treatment plants.
- Contamination enrichment systems (traps/ receptors) — bio-availability of down-gradient transport contamination pathways.

Investigations undertaken as part of this project have identified processes currently used in Tasmania for the ecological risk assessment of waste disposal activities (fig. 1). A scoping, screening and definitive ecological risk assessment provides risk estimates and other pertinent information to the risk manager and stakeholders. Each assessment has its own logic, determined by the types of information available and the decisions to be made (Suter, 2000).

Thom (2001*a*) has identified that the economics of landfilling in metropolitan Australia do not recover the expenditure costs and regulators should consider incineration facilities.

Summary abstracts from previous reports

Ten waste disposal sites, at various locations around Tasmania (fig. 2), were examined in detail and reports prepared. These reports detail the history of each site, management practices, hydrology, geology, investigation methods (including drilling), surface and groundwater chemistry, conceptual hydrogeological models, principal conclusions and recommendations for further work. The abstracts of these site-specific investigations are below.

Smithton (Blue Ribbon) abattoir

Poor weather conditions prevented access for the drilling of an appropriate number of boreholes to assess groundwater quality in the area of the Smithton Blue Ribbon abattoir disposal sites. Only limited data were collected at the site and extensive work is still required to assess surface and groundwater quality and related environmental implications.

Chapel and Jackson Street waste depots, Glenorchy

The Chapel and Jackson Street waste depots landfill footprints are located on Permian sedimentary

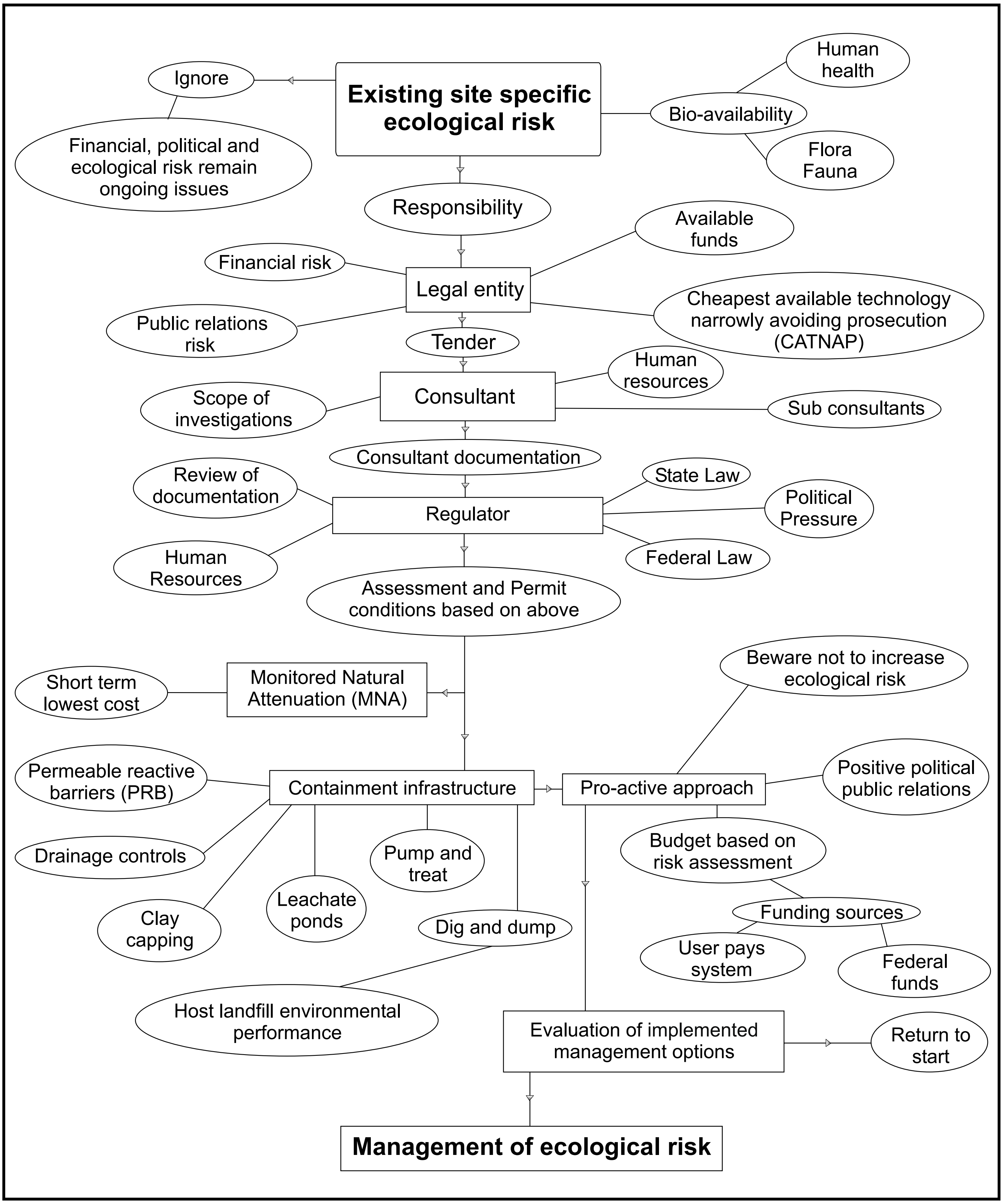

Figure 1

Flow chart illustrating the existing processes for ecological risk assessment of waste disposal activities in Tasmania.

consolidated rocks and Jurassic dolerite, which contain heterogenous fractured bedrock aquifers. Groundwater at the toe of the Chapel Street landfill footprint is elevated in chloride, ammonia, manganese and total petroleum hydrocarbon fraction C_{10}–C_{14}. Migration rate will be related to the fracture widths within the aquifers. No evidence of major groundwater contamination was identified around the Jackson Street landfill. Geophysical surveys have identified the extent of the Chapel Street waste depot and an area of partial clay capping. The saturation level of fill material within the Chapel Street landfill has on-going risk management implications, relating to stability and the local urban environment.

McRobies Gully waste depot, Hobart

The McRobies Gully waste depot is a landfill located in a valley close to the suburb of South Hobart. Data were collected for the site, including the testing of 14 groundwater bores within or adjacent to the landfill. It was found that water within the landfill contained some contaminants at levels significantly greater than bedrock water, but generally at the lower end of the range considered typical of operating landfills. Analysis of chemical signatures and water levels indicated limited hydraulic connection between fill and bedrock waters and generally only minor effects on groundwater quality.

A localised impact of high nitrate concentrations was observed in groundwater adjacent to the western gully of the landfill. Surface water inflows to the fill appear critical in the management of the site. Slope stability of the filled material and the associated level of risk were identified as issues requiring further investigation.

Port Latta waste depot

The Port Latta waste depot is a disposal site for general and hazardous waste materials. The local groundwater table slopes away from the site north towards Bass Strait. The regolith profile and related engineering grades of the clay material effects recharge to the fractured bedrock aquifer. Groundwater quality in the area of the leachate ponds is degraded. On-going monitoring and changes in the engineering design (i.e. filling sequence, surface water controls and leachate pond infrastructure) are seen as high priorities at the site.

Port Sorell waste depot

The Port Sorell waste depot was a disposal site for general and industrial waste. The waste depot was converted to a waste transfer station in 1995. The local groundwater table slopes towards the southeast. The waste fill has a hydraulic connection with the surface water drainage system. Clay-rich sediments appear to be perching and/or storing water. Groundwater and surface water quality are degraded around the site. Surface water management, capping of both landfills, appropriate disposal of sediments contaminated by hydrocarbons, leachate management infrastructure, and protection of the public from contaminated surface and groundwater are all seen as high priorities at the site.

Scottsdale waste depot

The Scottsdale waste depot is an 'open-gate' disposal site for general waste streams (including herbicide, pesticide and weedicide containers). The landfill footprint is located on the Jetsonville aquifer, a groundwater resource of State significance. Some groundwater and surface waters are degraded around the site. Surface water management, capping of the landfill, leachate management infrastructure, and protection of the public from contaminated surface and groundwater are all seen as high priorities at the site.

Bridport sewage lagoons

Groundwater was investigated in the area of the Bridport sewage lagoons to determine if the lagoons were affecting groundwater quality. The depth to the water table and groundwater quality data indicate that there is a hydraulic connection between the lagoons and the groundwater system. Groundwater quality down gradient is degraded compared to that up gradient of the lagoons. Further work is required to quantify the extent and nature of groundwater degradation.

Smithton sewage lagoons

Groundwater was investigated in the area of the Smithton sewage lagoons to determine if the lagoons were affecting groundwater quality. Significant nitrogen-based groundwater contamination was identified in excess of guideline limits. Natural attenuation processes appear to be occurring beneath adjacent farmland.

Stieglitz sewage lagoons

Groundwater was investigated in the area of the Stieglitz sewage lagoons to determine if the lagoons were affecting groundwater quality. The lagoons are situated close to perched shallow water tables. Further investigations are required to refine the hydrogeological model of the site and preferred pathways of flow from groundwater mounding beneath the lagoons.

Stanley sewage lagoons

Groundwater was investigated in the area of the Stanley sewage lagoons to determine if the lagoons were affecting groundwater quality. Nitrite and nitrate were detected at low concentrations in close proximity to the lagoons. The lagoons are located close to a landfill, which has the potential to affect groundwater quality in the area of the lagoons.

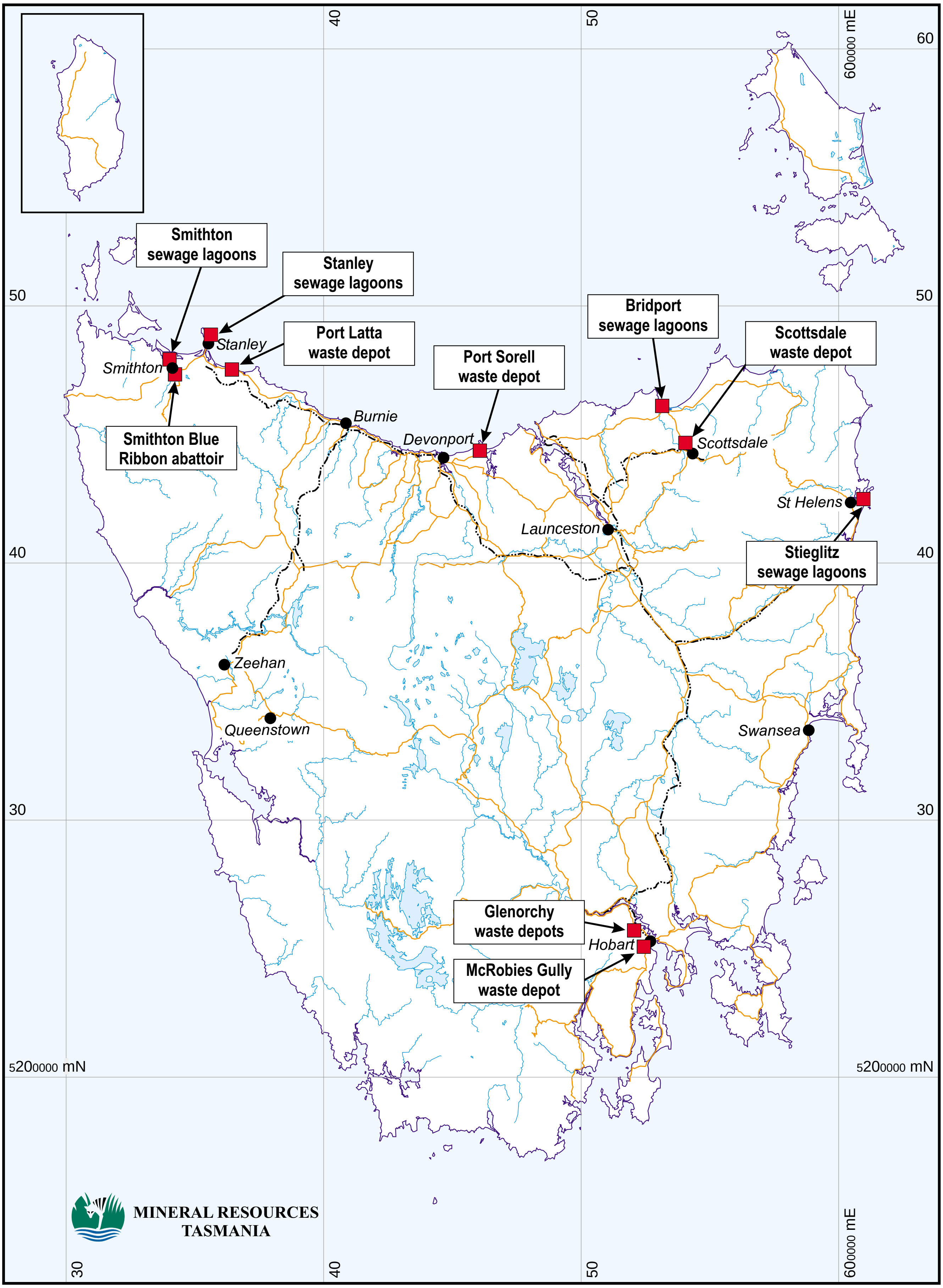

Figure 2

Location of ten waste disposal sites examined in detail

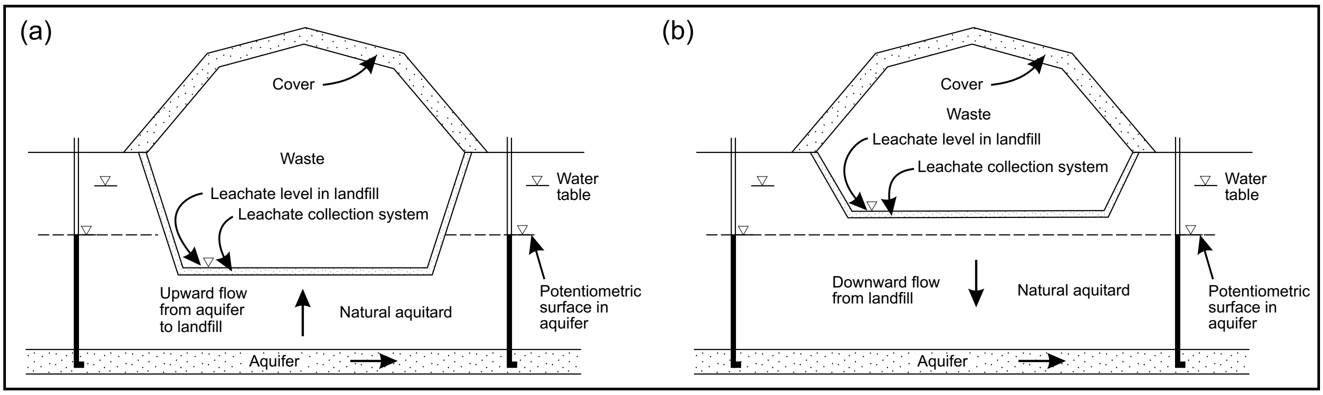

Figure 3

Two conceptual hydrogeological settings for waste disposal activities. (a) Barrier design involving a leachate collection system, a natural clayey deposit and downward advective-diffuse transport. (b) Barrier design involving a leachate collection system, a natural clayey deposit and upward advective and downward diffusion (a hydraulic trap) (from Rowe et al., 1997).

Future site-specific investigations will undoubtedly refine the understanding of issues identified in the above reports. Each site investigation report should be reviewed with respect to the identified local issues (including the spatial distribution of the factual data). When reviewing reports relating to fractured hard-rock aquifers readers should note that groundwater monitoring in fractured rock is often difficult and considered virtually impossible to carry out reliably. The main problem is that flow occurs through uneven rock fractures, and even closely-spaced boreholes may not intercept the fracture(s) that are principally responsible for the transport of leachate (Lee and Jones-Lee, 1996). Reports on sites with regolith/unconsolidated overburden (mainly clay-bound soils with relatively low conductivity values) illustrate that with suitable bore location (including a control bore) essential information can be provided on shallow unconfined aquifers.

Hydrogeological settings

Two ideal engineering design outcomes for local groundwater hydraulic conditions are illustrated in Figure 3. Actual hydrogeological settings for waste disposal activities around Tasmania vary considerably from site to site. Some problematic similarities exist between sites, which result in the degradation of water quality in the local area. These common themes include:

- Recharge of waste fill via groundwater above the basal height of the landfill (fig. 4*a*);
- Direct recharge of waste fills by up-gradient surface water;
- Rainfall infiltration due to inadequate capping of the waste site, which results in accelerated refuse degradation and leachate generation;
- Discharge of leachate from saturated waste fill into down-gradient surface waterways; and
- Discharge of leachate from waste fills into groundwater, via migration through sub-surface materials (fig. 4*b*).

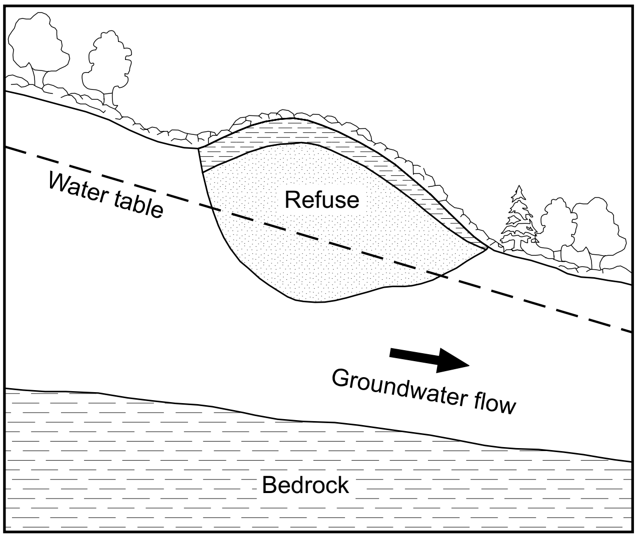

Figure 4a

Recharge of waste fill materials via groundwater above the basal height of the landfill (from Fetter, 1994).

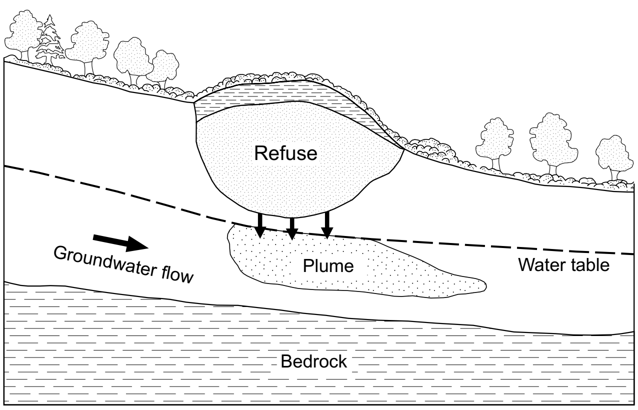

Figure 4b

Discharge of leachate from waste fills into groundwater, via migration through sub-surface materials (from Fetter, 1994).

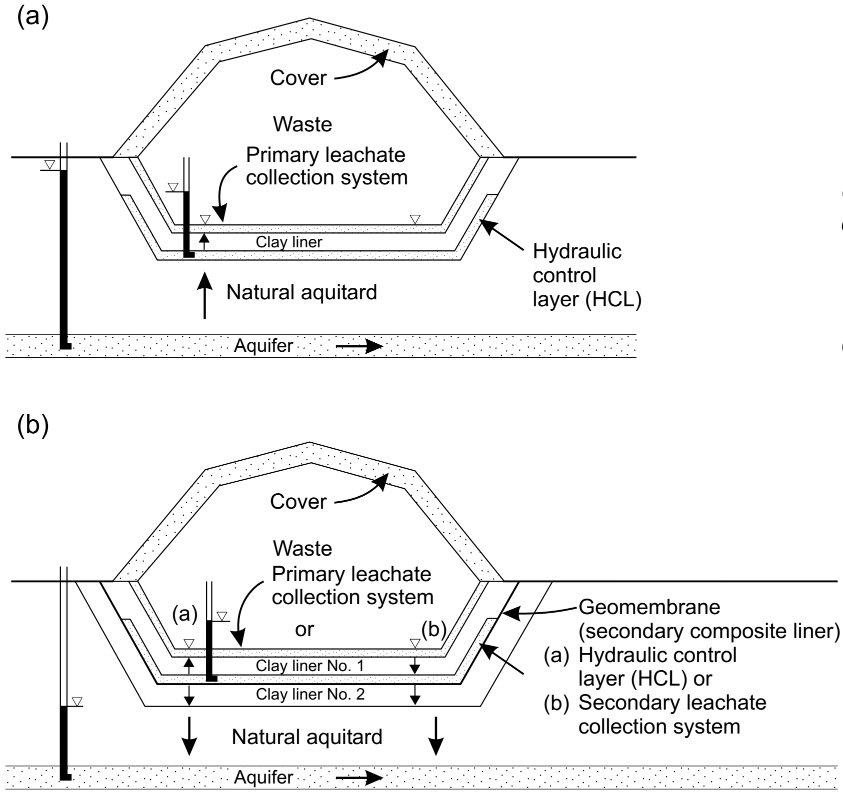

Figure 5

Two landfill barrier designs with respect to aquifer hydraulics within the local hydrogeological setting;

(a) A compacted clayey primary liner used in conjunction with a leachate collection system and hydraulic control layer to create a natural hydraulic trap.

(b) A compacted clayey primary liner used in conjunction with an engineered hydraulic control layer. A composite secondary liner (geomembrane and clayey liner) is used to maintain the hydraulic trap (from Rowe et al., 1997).

High rainfall areas appear to have very active hydrogeological systems during winter months. Although dilution levels may be significantly high during these times, it also most likely that the winter months represent the period of highest mass loading transport of contaminants within the local system. Figure 5 illustrates two landfill barrier designs with respect to aquifer hydraulics within the local hydrogeological setting.

Water quality degradation associated with waste disposal activities

The following statements are based on the findings of the Tasmanian site-specific reports undertaken as part of this project. The identified contaminants have similar chemical signatures to those stated in internationally published literature for sites in the United States of America (Fetter, 1994), Italy, Germany and Canada (Rowe *et al.*, 1997), and Australia (Hill *et al.*, 2000).

Sewage lagoons

Migration of degraded water from sewage lagoons has produced elevated levels of nitrogen-based contaminants in shallow groundwater at the Smithton, Stanley and Bridport sewage lagoons. Ammonia concentrations in the area of the Smithton lagoons ranged between 800 and 250 000 µg/L, exceeding the 95% protection level trigger values for toxicity in freshwater (900 µg/L) and marine water (910 µg/L) [*Australian and New Zealand Guidelines for fresh and marine water quality* (ANZECC AND ARMCANZ, 2000), Table 3.4.1]. Bicarbonate and chloride levels have also been identified as potentially elevated in groundwater around Tasmanian sewage lagoons. The microbiological characteristics of groundwater in close proximity to lagoons were not measured. These parameters can provide an indication of the level of microbiological contamination (pathogens), and should be measured wherever possible at sewage lagoons.

Landfills

Ammonia, nitrate, iron, manganese, chloride and total petroleum hydrocarbon fractions are all primary indications of water quality degradation associated with discharges of water from saturated waste fill. Other primary target parameters may be used to identify surface and groundwater pollution where large quantities of specific waste streams have been disposed of in particular landfills (e.g. hazardous and medical waste). Other contaminants may include phosphate, orthophosphate, calcium, magnesium, sodium, sulphate, copper, lead, nickel, zinc, organochlorine and organophosphorus pesticides.

The investigation reports compare the chemical compounds detected in the groundwater and surface waters to initial Tasmanian legislation limits and recently published guideline values. These include the *Environment Protection (Water Pollution) Regulations 1974*, emissions into inland water, *Australian Water Quality Guidelines for Fresh and Marine Water 1992*, and the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality, 2000*. Values in the Australian and New Zealand guidelines for fresh and marine water quality are dependent on the beneficial uses of the water (e.g. drinking water and crop production) and potential toxicity levels for elevated concentrations of high risk compounds causing water-based pollution.

The life cycle of a landfill (and related degradation phases of the organic waste over time) will control the physical and chemical behaviour of the landfill (Cairney and Hobson, 1998). Swarbrick (2001) discusses in detail the five phases associated with this process; these are:

(i) aerobic hydrolysis;

(ii) acidogenesis;

(iii) acetogenesis;

(iv) methanogenesis; and

(v) restoration.

Figure 6 shows the typical changes in landfill gas composition with respect to these five phases of the landfill life cycle. The decay process affects the rate of waste stabilisation, the potential for energy recovery, the quality of leachate and gases, and the destruction of many pathogens and some toxic organic compounds (Swarbrick, 2001).

Conservation of water resources in the area of waste disposal activities should consider groundwater and surface water as a single resource (Winter *et al.*, 1998). In England and Wales groundwater protection policy has been developed and confirmed in legislation to manage ecological risks associated with waste disposal activities (Marsland, 2000). The full extent and dimensions of water quality degradation may be difficult to identify in complex multi-element contamination patterns (Beck and Harwood, 2000).

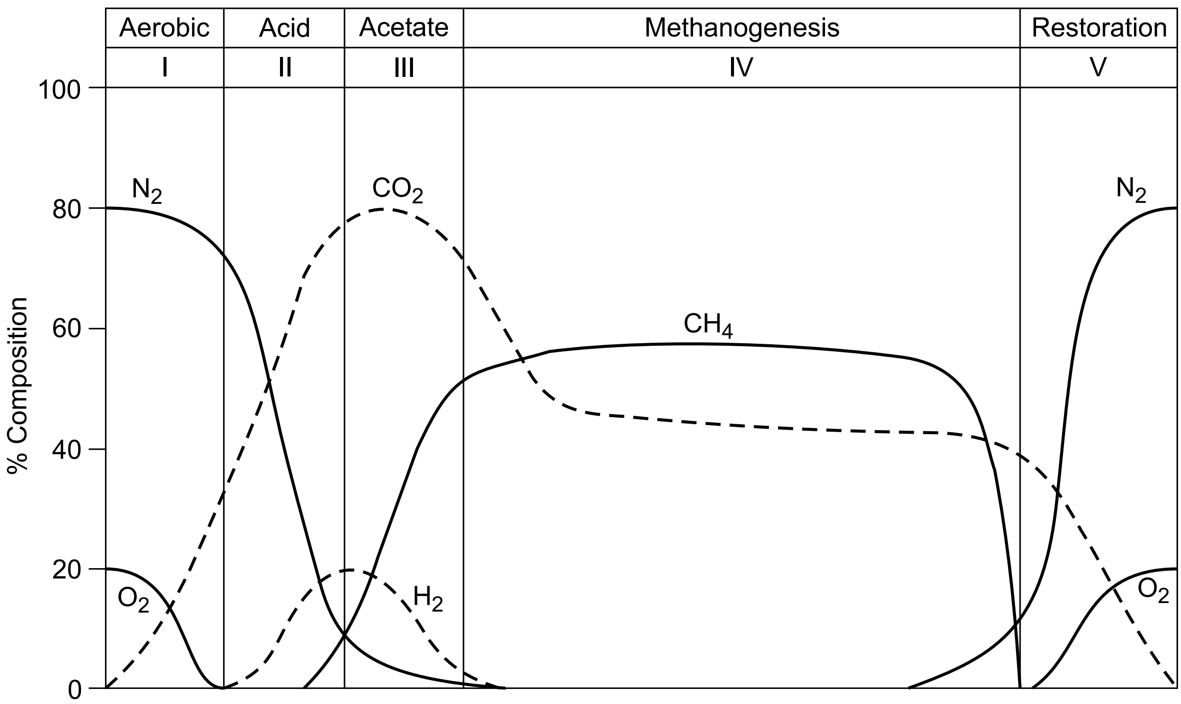

Figure 6

Typical changes in landfill gas composition with respect to the five phases of the landfill life-cycle (from Swarbrick, 2001).

Section 2: Tasmanian waste disposal sites that may potentially degrade groundwater quality

Identified landfill and sewage lagoons (potential point and diffuse sources of pollution) are shown on the map *Vulnerability of Tasmanian groundwater resources to pollution from waste disposal and sewage treatment activities*. Groundwater prospectivity, quality and the location of all known existing water bore sites are also shown on the map.

In this study groundwater contamination was identified at 60% of the sites investigated. If this percentage is extrapolated to the 176 sites identified by the initial desktop study, potentially up to 100 waste disposal sites may have contaminated groundwater in Tasmania.

As a general rule, contamination of groundwater near waste disposal sites is a result of the absence of appropriate infrastructure to address site-specific hydrogeological conditions. The selection of remediation technologies for the highest risk sites will depend on benchmark targets set by regulators. Deleterious effects to the ecosystem during remediation should also be considered (Adam and Blount, 2000).

Remediation actions for waste disposal sites are outlined in the **Rehabilitation/remediation** section of this report.

Section 3: Future management of Tasmanian waste disposal sites and groundwater conservation — the way forward

Scoping the Problem

In Antarctica (Babicka *et al.*, 2000) and Brazil (Diniz, 1998) geographic information system (GIS) databases have been developed and are used to monitor groundwater and surface water at potential pollution sites. A geo-environmental database should be developed for Tasmanian waste disposal sites, with the aim of identifying polluting sites within local hydrogeological conditions. The database must contain information on major regional hydrogeological aquifers and provide the essential scientific basis for the assessment of the magnitude and quality of these groundwater resources.

More intensive investigations and research are still required to gather data on the characteristics of local aquitards and aquifers and the extent of fluid flow and pollution within these systems. Marino *et al.* (1998) identified remote sensing within a GIS format as a useful tool in the management of areas exposed to temporal water pollution events.

A geo-environmental database would also aid in the hazard and risk ranking of the sites. Assessment of health and environmental risks of associated soil, groundwater, surface water and vapour contamination may be required at various sites (Bauer, 2000).

Section 4: Project Recommendations

In the following recommendations, certain documents and statutory instruments are regarded as representing minimum standards for the activities concerned.

Australian Standards

- AS1726–1993; Geotechnical site investigations
- AS2368–1990; Test pumping of water wells
- AS/NZS5667–1998; Water quality – sampling
- Agriculture and Resource Management Council of Australia and New Zealand. *Minimum construction requirements for water bores in Australia, 1997*.

Statutory Instruments

- *Environmental Management and Pollution Control Act 1994*
- *Water Management Act 1999*

Publications

- Environmental Protection Authority, Victoria
  Groundwater Sampling Guidelines, 2000
  Siting, Design and Rehabilitation of Landfills, 2001
- ROWE, R. K.; QUIGLEY, R. M.; BOOKER, J. R. 1997. *Clayey barrier systems for waste disposal facilities*. E & FN Spon : London.
- HARRIS, J. A.; BIRCH, P.; PALMER, J. P. 1996. *Land restoration and reclamation: Principles and practice*. Addison Wesley Longman : England.

Site investigations

Site selection

Key components for the siting of waste depots in Tasmania were initially identified by Gentizen (1990*b*). Current available technologies now allow for a more comprehensive assessment of waste disposal sites.

Initial consideration of the potential sites for a waste facility should take into account geological, hydrogeological, geophysical, hydrological and geomorphological information in a GIS format (Jewell *et al*., 1993), as well as community requirements (Whitehead, 2001; Proag and Kauppaymuthoo, 1998).

Sites should be selected based on good quality preliminary assessments carried out by suitably qualified and experienced personnel. The assessments should include:

- GIS desktop collation of all relevant data;
- geophysical information;
- preparation of topographic and geomorphological maps of the site and surrounding area;
- development of a geological model, with field mapping carried out where necessary;
- assessment of the surface hydrogeological setting at the site and in the surrounding area;
- assessment of the sub-surface hydrogeology;
- collation and interpretation of existing monitoring data relevant to the above;
- preliminary field investigation of surface and subsurface conditions and materials present at the site and within its potential radius of influence; and
- risk assessment of the affects of the proposed activities at the site on the surrounding environment and resources.

This preliminary assessment should be carried out at a scale appropriate to the size of the site and its presumed geological complexity (Dawes and Goonetilleke, 2001). Hatheway (1998) provides a *Site Conceptual Geologic Model* which includes:

- a design process for application of engineering geology to environmental mitigation projects;
- methods to meet the various design needs for environmental protection projects; and
- a design process for application of engineering geology to environmental compliance and restoration (remediation) projects.

A conceptual model of the local geological and hydrogeological settings is required in order to fully establish the components, elements, actions and goals within a site conceptual geological model. Design needs and engineering responses are important outcomes of the Hatheway (1998) model.

Assessment of materials at the site

Site-specific ground investigations are necessary to target and identify the properties of materials present on site and to assess the thickness of overburden in the site area. Such investigations should involve some subsurface investigation and be carried out by suitably qualified and experienced personnel in accordance with Australian Standard 1726–1993.

The minimum objectives of ground investigations should be to:

- confirm the thickness of overburden;
- obtain samples of overburden;
- determine relevant sub-surface hydrogeological parameters;
- carry out preliminary identification of aquifers and water table(s); and

- assess the thickness of the unsaturated zone at the site.

The engineering properties of materials encountered should be tested according to relevant Australian Standards, guidelines and other technical standards. Examples of properties to be determined include:

- moisture content;
- permeability (lateral and vertical);
- permeability (recompacted);
- shrink–swell characteristics; and
- shear strength.

Determination of the chemistry of the materials encountered should also be considered at this stage (e.g. Emerson tests).

In certain locations, an assessment of the likely slope stability of the site may be necessary and should incorporate data derived from the investigation work. The risk assessment process outlined in the *Landslide Risk Management Concepts and Guidelines* (Australian Geomechanics Society, 2000) should be followed when assessing slope stability issues.

Surface water

The influences of at least the following must be considered:

- the location of the nearest drainage line(s) to the site area;
- the water quality in the site area and nearby water courses;
- any information from any existing monitoring program; and
- any information with respect to historical records of flood events.

A monitoring regime to provide background data for subsequent consideration should be established if one does not already exist.

Consideration should also be given to the monitoring of local rainfall on a long-term basis.

Hydrogeology

The results of geophysical profiling can be extremely useful for choosing locations of (Hinze, 1990; Ezzy, 1999) and/or logging boreholes to investigate groundwater conditions and is recommended as an initial investigation tool (Howard, 1990; Daniels and Keys, 1990).

Sampling and in situ testing of each borehole should be carried out in accordance with relevant Australian Standards and guidelines, with regard to the conceptual model of the hydrogeology of the site developed from the desktop study information.

Installations for long-term groundwater monitoring should be constructed in this phase of work, to allow for the collection of sufficient baseline data (if a greenfields site).

In situ testing to establish key hydrogeological parameters for any aquifers present should also be carried out at this stage. The objectives of the testing should be the determination of hydraulic conductivity (K), transmissivity (T) and storage coefficient/specific yield (S) of each aquifer (Domenico and Schwartz, 1998; Kruseman *et al*., 1990). Care should be taken to ensure that the drilling techniques employed will enable identification and testing of multi-layered aquifer systems (Australian Drilling Industry Training Council, 1996). Consideration should be given to the use of multiport piezometer systems or nested bores in complex hydro-stratigraphical conditions (Driscoll, 1986; Ezzy, 2002*a*).

Development of hydrogeological model

Following completion of the subsurface investigation and testing, a hydrogeological model of each site should be constructed. If the *Site Conceptual Geologic Model* approach of Hatheway (1998) has been followed, the design and development of a numerical model should have greater reliability. Numerical models represent best practice, as they can be used predictively, and they allow the user to give consideration to the dispersion and chemistry of water and leachate. Such models require accurate calibration from high quality monitoring data, and design by experienced personnel. As such, a degree of caution should always be used in model interpretation. If both advective-dispersive and diffusive transport exists (i.e. a double porosity matrix), models should consider both domains (Leo, 2001). This mechanism of fluid flow most likely occurs in many Tasmanian fractured aquifers within sedimentary rocks.

Key factors necessary for the development of representative models may include:

- aquifer type;
- details of water table/potentiometric surface;
- determination of boundary conditions and identification of hydraulic connections;
- direction and rate of groundwater flow; and
- recharge/discharge parameters and understanding of surface–subsurface water interaction.

Correct identification and interpretation is essential to develop a representative model.

Valley sites are likely to be problematic, especially where high permeability colluvium overlies bedrock or underlies the proposed filling area. The presence of a valley compounds catchment and diversion factors, as will complex fracture zones in consolidated rocks (Ezzy, 2002*b*).

Construction of a facility

By their nature, the construction of waste disposal facilities is a progressive and repetitive process. Correct establishment of infrastructure should be carried out prior to further or additional construction.

General items to be considered include:

- the existing management of the site;
- catchment management of water resources;
- management of stormwater;
- liner design and construction;
- design and construction of leachate monitoring system;
- management of leachate;
- design and construction of groundwater monitoring system; and
- construction of leachate holding ponds.

Existing site management

The methods of disposal and handling of wastes should be examined in detail, and historical records checked. The waste streams present should also be examined and tested if needed.

Catchment management

Infrastructure should be established to separate the activities of the site from the natural water flows within the catchment. Primarily, this will involve the construction of infrastructure to deal with stormwater and separate infrastructure to transport and manage leachate. Hydrology calculations should be made for the up-gradient catchment and incorporated into the design of this infrastructure.

Stormwater management

The primary objective of appropriate management of stormwater is to direct it away from the activity being carried out at the site. The nature of the measures to be adopted will be site specific. This may involve the construction of lined cut-off drains around the perimeter of the site and, in certain situations, settlement ponds to remove solids and lower turbidity levels.

Consideration should be given to piping sections of the stormwater drains to prevent slope instability produced by infiltration.

Liner construction

The liner design and construction materials should reflect the types of waste involved at the facility. Liner designs will vary from site to site, but should be in accordance with relevant standards and best practice (*Siting, Design and Rehabilitation of Landfills*, EPA Victoria, 2001) plus international research (Chiasson *et al*., 1998; Han, 1998; Leite *et al*., 1998). If a single clay barrier is proposed, the design should consider the long-term effects of leachate on the liner (Jayasekera and Mohajerani, 2001) and migration of pollutants through the liner (Airey, 1993; Rowe *et al*., 1997). Erosion by rainfall prior to placement of the waste and localised subsidence of the substrata can cause liner defects and produce leakage (Haselgrove and Earl, 1993).

The suitability of lining and sub-base materials on and in the vicinity of the site should have been determined during the investigation phase. It is possible that additional quantities of suitable materials may be encountered during preparation of the site. Any such deposit should be mapped and the properties of the material determined during the construction phase.

Composite liner designs (Benson, 2001), including geo-synthetic clay liners (Phillips and Eberle, 2001), may be required for future Tasmanian waste disposal sites. A suitable construction quality assurance system should be used during construction of the designed liner system.

Leachate collection system

Design of the leachate collection system must be carried out according to the requirements of the site, using relevant Standards as a minimum. As noted above, it may be necessary to consider the use of multiple-layer collection systems and leak detection systems (Benson, 2001).

The clogging of leachate collection systems is dependent on the flow rate, leachate chemistry and the nature of the drainage material (Rowe and VanGulck, 2001). Maximum drainage potential into the piping should be provided by using a coarse gravel drainage blanket at the base of the fill. It is critical to ensure that the proposed collection system is suitable for all anticipated flows through the facility, and that it can be cleaned and inspected as required (Rowe *et al*., 1997).

Management of leachate

Leachate derived from the activity should be treated according to the stage of decay of the fill material and the probable chemistry present. Due regard should be given to the erection of protective safety barriers and signage around leachate lagoons.

Leachate holding lagoons represent a significant ecotoxicity risk and the design should be carried out with care (Benson, 2001), their location to some extent being controlled by the overall design of the site and the local thickness of the unsaturated zone. In selecting the site for such lagoons care must be taken to ensure that there will be no potential for connection between the leachate and groundwater. The catchment size, retention time and degree of recirculation required must be considered when determining the number, size and location of lagoons.

Due to the significant ecotoxicity risk of leachate lagoons, regulators should require that liners be designed to withstand the nature of the fluid within them. Leakage detection systems should be incorporated into the liner design (Cairney and Hobson, 1998).

Monitoring boreholes should be installed both up and down hydraulic gradient of the lagoon sites, and sufficiently early enough in the construction period to allow for the collection of representative baseline data before the lagoons are used (Bagchi, 1994).

Landfill gas collection system

A suitable system must be designed and constructed for the release of gas derived from decomposition of the fill material. This should be regularly maintained during the life of the facility and the gas either flared off or directed to other uses. On combustion methane converts into carbon dioxide, approximately twenty times less potent than methane in terms of global warming potential (Linich, 2001).

Monitoring of groundwater, surface water and gas vapour

An integral part of all monitoring is to ensure that baseline site characteristics can be compared to conditions in the waste disposal area (Rosin and Avalle, 1993).

Jewell *et al*. (1993) outlined field techniques which can be used for investigation and monitoring of soil, groundwater and vapour at former industrial or waste disposal sites. Leachate, surface water and groundwater monitoring procedures should follow a similar methodology to that given in Bagchi (1994). Cairney and Hobson (1998) provided a comprehensive description of monitoring equipment and observation networks required for monitoring landfill gas vapours. Isotope tracers can be used for quality control in pollution monitoring systems for landfill sites (Pellegrini *et al*., 1998).

Statistical analysis of monitoring data should be undertaken to confirm the percentage value of the Upper Confidence Level (UCL). A standard of 95% UCL_{mean} is considered appropriate for pollution monitoring (Hitchcock and Tuyl, 2001). The digital structural format for the storage of monitoring data should consider spatial and/or temporal auto-correlation, natural heterogeneity, measurement errors, small sample sizes and simultaneous existence of different types of data (Abbaspour *et al*., 1998; Adams *et al*., 2001).

Rehabilitation/remediation

The rehabilitation of waste disposal sites for high-value development is increasingly required, especially close to urban areas where demand is high (O'Neill *et al*., 2000). The three stages of the remediation process include site assessment, strategy development and implementation (Swane *et al*., 1993). Issues to consider during the process include landfill gas, leachate, pollution, geotechnical, groundwater, planning approval and community perception. The enhanced remediation strategy undertaken at the Homebush Bay Olympic site (Laginestra and Hughes, 2000) demonstrated the environmental and economic benefits of such a process.

Site assessment

Identification of the nature and extent of contamination

Non-intrusive geophysical techniques provide very useful information for the assessment of waste disposal sites. Measurements of small changes in gravity over a given area can be used to identify density variations within the fill, the horizontal and vertical extent of fill, and layering within the fill (Roberts *et al*., 1990*a*). By combining gravity and magnetic methods, an interpretation may be made on the extent of the landfill material and associated iron content (Hinze *et al*., 1990; Roberts *et al*., 1990*b*). Geophysical terrain conductivity mapping has been successfully used in Brazil to locate water tables and clay stratum in the proximity of landfills (Monier-Williams *et al*., 1990). Time-domain electromagnetic sounding is a proven tool in identifying environmental groundwater problems related to waste disposal sites (Hoekstra and Blohm, 1990). Various geophysical techniques for environmental investigations are outlined by Williams and Links (2001), who identified ground conductivity (EM), magnetics and gravity as the most appropriate techniques for identifying the extent of groundwater contamination associated with landfills.

The results of chemical monitoring over the life of the facility should be examined and any potential contaminants identified. Based on a review of all available data (geotechnical, historical and environmental), consideration should be given to the drilling of further boreholes to check for the spread of contaminant plumes in areas identified as high-risk zones. The likely quantity and quality of contaminants to manage should be estimated, with sampling according to Australian Standard 2368-1990 and AS/NZS 5667.11:1998. Calculation of the contaminants should be based on Darcy's law, calculation from mass outflow rates in the groundwater below the site, or by a solution of the water balance equation (Entenmann and Rappert, 1998).

Inorganic and easily biodegradable organic matter can build up significant concentrations and minerals in fine-grained soils that can selectively plug soils under waste disposal sites (Islam and Singhal, 2001). This may complicate the site assessment and leakage detection should focus on piezometric head, induced electric potential and temperature differentials (Haselgrove and Earl, 1993). This will require drilling waste fill at landfill sites.

Stability and subsidence of fill material

Practitioners undertaking slope stability analyses of landfills should take into account that waste, cover soils and engineered infrastructure (e.g. clay liners and capping) have completely different shear stress-strain properties. Spreading at the base of waste deposits and differential settlement may detrimentally affect liners, drainage systems and capping (Brandl, 2001). Shear strength parameters of waste fill appear to be dependent on deformation, and waste well into the fourth stage of degradation (methanogenesis) may be susceptible to secondary compression (Vilar *et al*., 1998).

Hausmann *et al*. (1993) have identified techniques and infrastructure available to improve bearing capacity, slope stability and volume stability. These techniques include:

- mechanical compaction;
- drainage;
- dewatering;
- consolidation;
- stabilisation with admixtures;
- construction of impermeable barriers with clay and synthetic liners;
- slurry walls;
- grouting; and
- deep mixing.

Strategy development and implementation

Management options for groundwater pollution

The application and limitations of isolation, covering and removal techniques should be considered when a remediation strategy is developed (Harris *et al*., 1996). Remediation can be either passive or active. Passive remediation is also known as Monitored Natural Attenuation (MNA) (fig. 7). MNA can attenuate common environmental contaminates and is a cost-effective way of improving barrier performance (Richards and Bouazza, 2001). Soil composition and surface properties (strongly influenced by the soil origin) contribute significantly to the attenuation capability of the soil (Yong *et al*., 1998). Depending on the time it takes for leachate to reach the aquifer, MNA may attenuate undesirable components of the leachate and reduce its impact (Depountis *et al*., 1998).

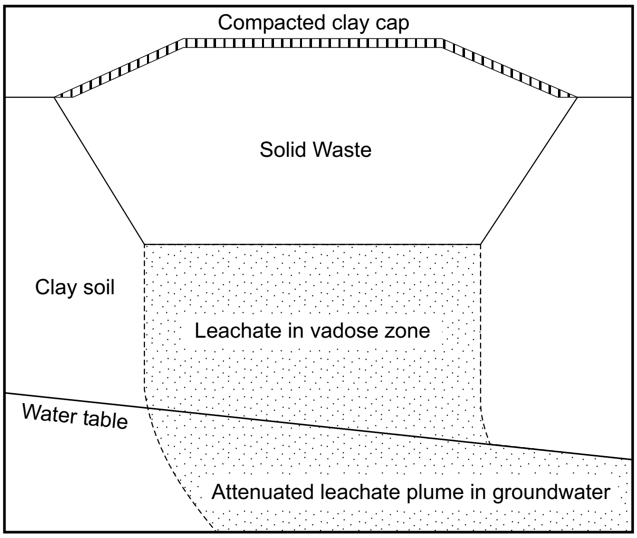

Figure 7

Natural attenuation of landfill leachate (from Fetter, 1994).

Active remediation involves additional infrastructure and high expenditure, with the application of numerical models normally used to verify results (Clement and Gautam, 2001). Solutions to sub-surface gaseous contaminants should also be included in a remediation strategy (Cairney and Hobson, 1998; Starke, 2001).

Grouting may be injected beneath the waste to repair leaks in liners (Osborne and Haselgrove, 1993) and/or prevent groundwater inflow (fig. 8). Slurry walls are low-permeability barriers emplaced in the subsurface. They confine contaminants by removing the potential for flow through the source (fig. 9). Up-gradient pumping may also prevent interaction with the waste materials (fig. 10). Up-gradient pumping may also be combined with the pump and treat approach (fig. 11).

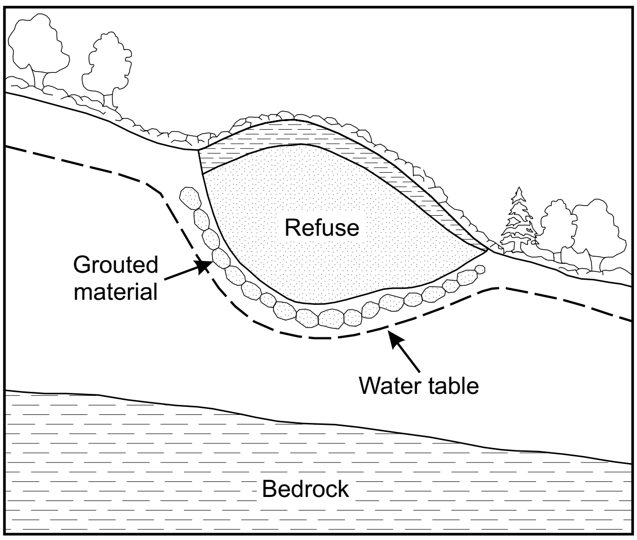

Figure 8

Application of grouting in the remediation of landfills (from Fetter, 1994).

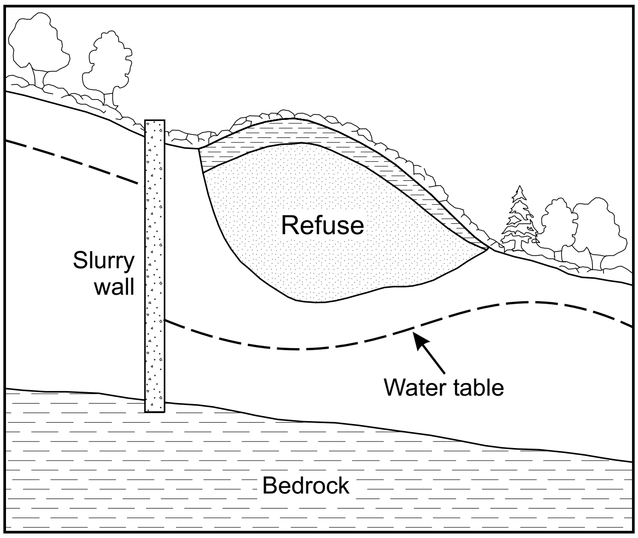

Figure 9

Application of slurry walls in the remediation of landfills (from Fetter, 1994).

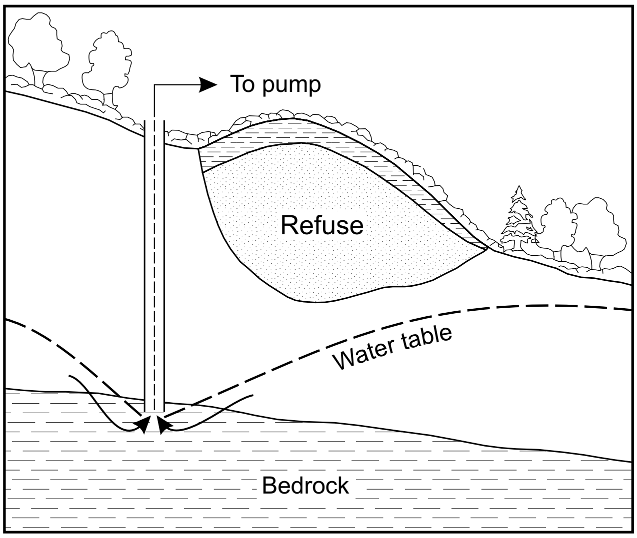

Figure 10

Application of up-gradient pumping in the remediation of landfills (from Fetter, 1994).

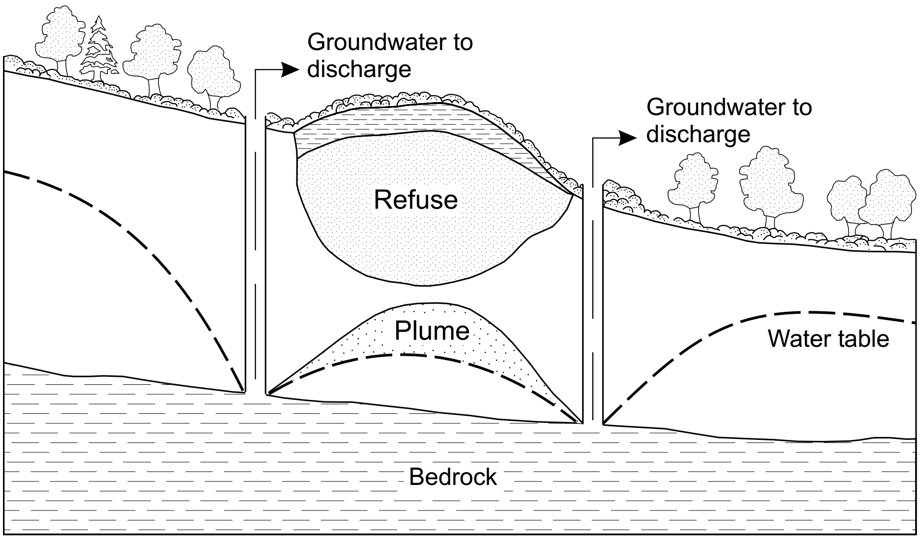

Figure 11

Combining up-gradient pumping and pump and treat applications in the remediation of landfills (from Fetter, 1994).

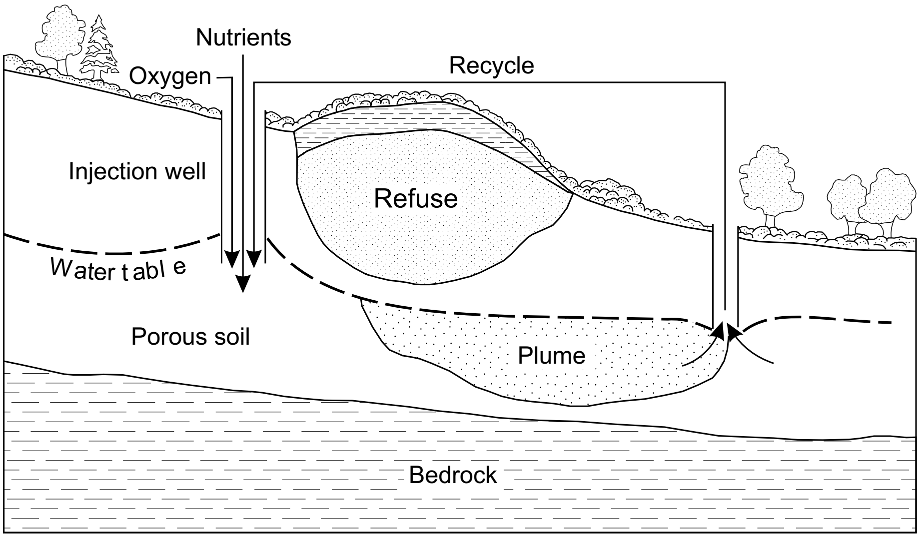

Figure 12

Application of the injection–recovery system for the remediation of landfills (from Fetter, 1994).

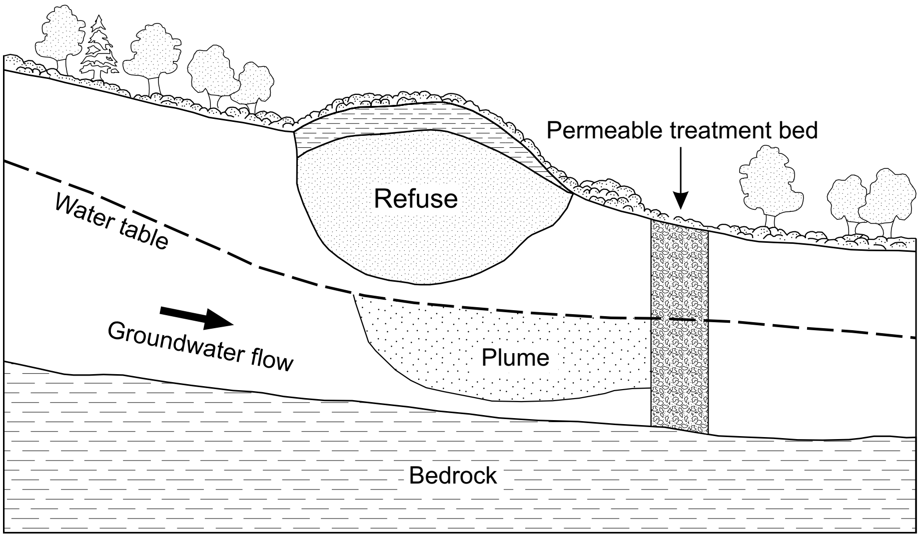

Figure 13

Application of permeable treatment beds in the remediation of landfills (from Fetter, 1994).

This combined method of applications can also be varied where the up-gradient bore becomes an injection well for recycled polluted water pumped from a down-gradient bore, i.e. injection–recovery system (fig. 12). The efficiency of permeable treatment beds (fig. 13) is highly dependent on the nature of the material used in the bed (Li and Li, 1998). Pump and treat applications should focus on mass removal and be aware of potential impacts causing hydraulic changes within the local groundwater system (Domenico and Schwartz, 1998).

Wetlands for the treatment of leachate offer a cost effective and environmentally sound technique to treat and dispose of landfill leachate. Construction and operation of a new wetland system requires an interdisciplinary effort including geologists, engineers and wildlife scientists (Mathewson and Mathewson, 1998).

It may not be possible to produce a conventional close-out solution for some facilities, in which case consideration should be given to removal of the material to an alternative facility, if remediation is not likely to be possible or cost effective (Cairney and Hobson, 1998).

Capping to prevent infiltration and consequent pollution

The selection of a capping design should take into account the nature of the fill material and the likely future risk to resources and the environment. Composite barriers and water balance covers (mono-layers) perform admirably in the field (Benson, 2001).

Compacted clay, high-density poly-ethane (HDPE), geosynthetic liners (GSL) (Kudrna *et al*., 1998) and fine sand capillary barriers (Vangpaisal and Bouazza, 2001) may be utilised for the capping of waste. The combination of any of the above in a composite liner is considered appropriate for sites identified as having a high ecological risk (Rowe *et al*., 1997; Benson, 2001).

The design of mono-layer covers should consider the soil material properties, sequencing and the use of vegetative cover (Weeks, 1993). Detailed recommendations for the design aspects of mono-layer covers are given in Jones *et al.* (2001).

Revegetation

Certain plants (i.e. shallow root species) are more suitable for preservation of the capping integrity than others and should be used as part of the rehabilitation scheme for any facility. Basic planting requirements need to be considered and include sun light for photosynthesis, anchorage in the ground, plus the availability of water, oxygen and nutrients (Cairney, 1998). The aim of the revegetation should be the establishment, management and maintenance of self-sustaining vegetation (Harris *et al*., 1996).

Construction on reclaimed landfill sites

Construction on landfill is generally avoided because of the difficulties with settlement, stability and environmental issues (Thom, 2001*b*). Particular attention must be given to settlement and bearing capacity, landfill gas migration (Bouazza and Kavazanjian, 2001), and corrosion protection for structures built on landfills (Phillips *et al*., 1993). Modelling of the future degradation of the waste may aid in the design of structures on waste fills (Chun and Jang, 2001).

Section 5: Discussion and Principal Conclusions

Discussion

A geo-environmental database is required for Tasmanian waste disposal sites. The integrity of the database will rely strongly on the detail and scale of the input data. Funding is required to gather data from existing sources and new data from the field, plus interpret the information within the database structure.

Further investigations are required at identified contaminated sites and strategies should be formulated for the remediation of these sites.

Emission-offset, tradeable emission-right and polluter-pays systems to control groundwater pollution were identified by Young and Evans (1998). The polluter-pays system identifies the surrogate indicator of pollution load to be levied and reduces the levy with decreasing levels of pollution over time. Funds from a pollution levy could be used to investigate and manage contaminated sites.

Principal conclusions

This project has identified that some problems exist with respect to waste disposal and water quality management in Tasmania. Contaminants may effect the ecosystem and other receptors. Source zones may be problematic. Further investigations are required to quantify the extent and nature of the problems on a statewide scale. Investigation and monitoring strategies are required to assess trends of contamination, related impacts and the effectiveness of remediation measures.

Progressive solutions to minimise ecological risks should be implemented for high-risk sites. Compared to other techniques, monitored natural attenuation may be the most appropriate method for managing low risk sites.

It is suggested that the Tasmanian Government use a conservation approach for the protection and management of Tasmanian groundwater resources (*Water Management Act 1999* and the *State Policy on Water Quality Management 1997*).

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[8 November 2002]

APPENDIX 1

Project Brief

The following project brief is provided to give an understanding of the management of the scope, objectives and final outputs of the project.

Project Description Investigation of groundwater resource degradation associated with waste disposal practices within Tasmania, Australia.

Purpose Examine the effects of waste disposal on groundwater quality within Tasmania and provide information to stakeholders that will assist to protect groundwater resources in the area of waste disposal activities. Using selective groundwater system parameters, identify sites where groundwater resources are most likely to be degraded.

Business Benefits

- Reduced environmental health risk to the general public.
- Better understanding of potential pollution pathways.
- Greater consideration of geotechnical criteria in regard to existing ongoing management and the location (plus construction) of future waste disposal sites.
- Assist State Government in the regulation of waste disposal activities.

Objectives

- Inspection of all relative activities.
- Discussion of sites with key stakeholders.
- Completion of study site classification list.
- Undertake northwest, northeast and southeast drilling programs.
- Sample all boreholes for groundwater quality.
- Pump test selective boreholes.
- Compile all site-specific factual data into geotechnical reports.
- Summarise all project work into a final report.

Scope

- Project is to be undertaken by a project officer, supervised by a project manager and overseen by a Steering Committee.
- Locate all known past and present waste disposal sites in Tasmania.
- Interaction with local government and private industry managers of waste disposal sites.
- Project consists of fieldwork, laboratory analyses and the completion of reports.
- The project is to be completed over a 2½ year period.

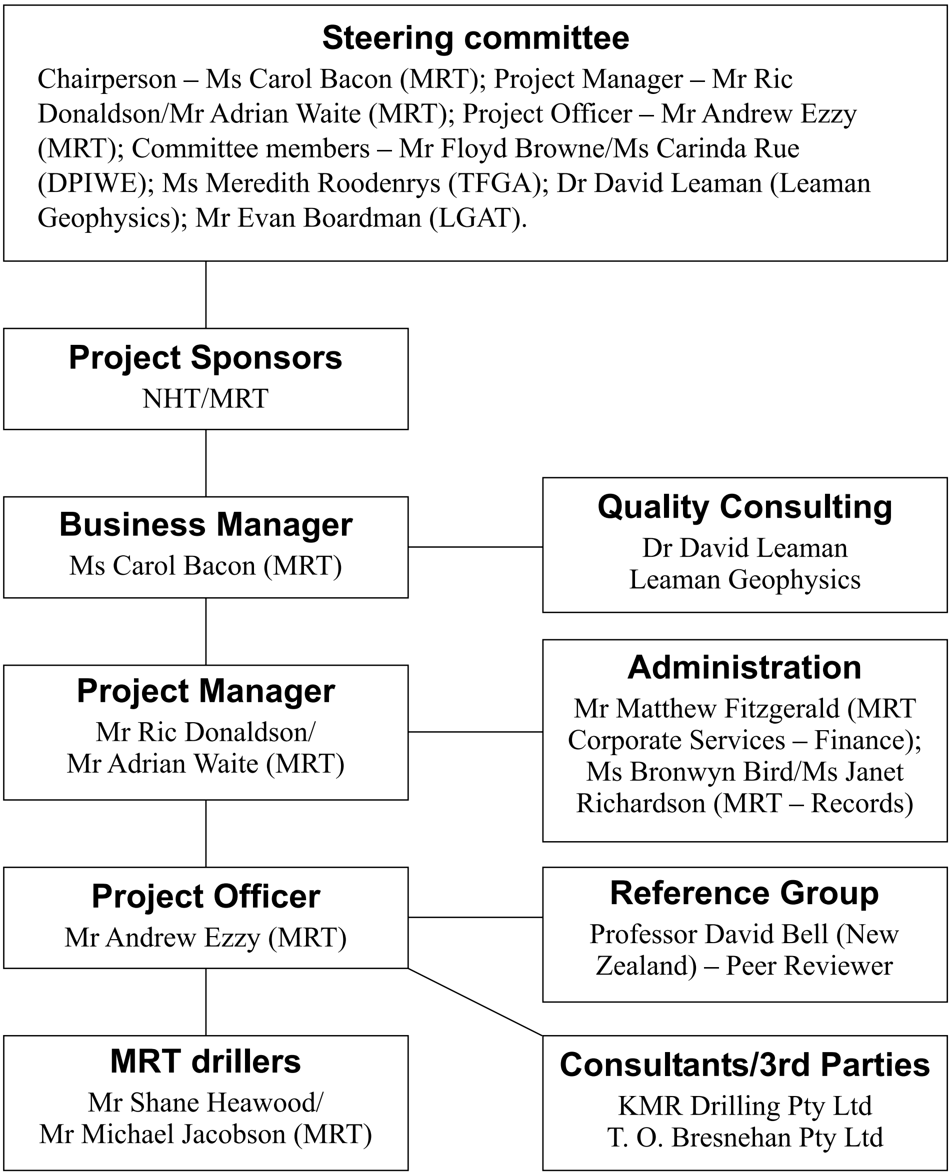
Major Deliverables

- Geotechnical reports relating to specific waste disposal sites.
- Final report including project recommendations to minimise environmental risks associated with waste disposal activities.
- Move towards Best Practice Environmental Management of waste disposal sites in Tasmania.

Risks

- Access to past historical information on selective sites.
- Limited access to sites for drilling.
- Human health issues exist during the drilling of boreholes through waste fill materials.
- Damage to infrastructure related to underground services within the study sites footprints.

Project Governance



APPENDIX 2

Initial desktop study sites

Category of activity	Council/ Municipality	Site location	AMG Easting	AMG Northing	Historical issues	Engineering designed infrastructure for BPEM	Lithologies	Structural geological setting	Hydrogeological setting	Approximate local annual rainfall (mm)	Known number of currently installed bores (November 1999)	Known groundwater and/or off site surface water pollutants	Potential groundwater and/or off site surface water pollutants
Waste water reuse scheme	Glamorgan-Spring Bay	Bicheno	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	Pathogens and nutrients
Waste water reuse scheme	Launceston	Lilydale	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	Pathogens and nutrients
Waste water reuse scheme	West Tamar	Legana	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	Pathogens and nutrients
Waste water reuse scheme	Southern Midlands	Bagdad	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	Pathogens and nutrients
Waste water reuse scheme	Brighton	Brighton	524500	5271500	Proposed project	TBD	Triassic and Permian sedimentary rocks, Jurassic dolerite	Jurassic emplacement structures over printed by post Jurassic tectonic activity	TBD	630	Some existing local bores, additional monitoring bores to be installed	TBD	Pathogens and nutrients
Waste water reuse scheme	Glamorgan-Spring Bay	Swansea WWTP Maria Street	587000	5336000	Irrigation has occurred for at least the last 8 years	TBD	Quaternary, Tertiary sedimentary terranes and Jurassic dolerite basement	Nature of dolerite intrusive form required	Fractured dolerite aquifer with unconsolidated overlying aquifer, and suspected interaction with Meredith River, plus current discharge into Saltwater Creek to the south, which both discharge into Great Oyster Bay to the east	600	Nil	TBD	Pathogens and nutrients
Sludge from sewage treatment plants used as fertiliser	Kingborough	Hazel Brothers Brookfield Estate, Margate	521800	5237700	Used for over 8 years. Failure of holding dams	Injection into soil	Jurassic dolerite, Permian sedimentary rocks, Tertiary basalt and related weathering products, plus North West Bay River Quaternary material	Permian Jurassic contact, and local internal faulting within the Permian sedimentary rocks (and possibly Jurassic dolerite)	Dolerite aquifer, Permian aquifer, Pm/Jd contact aquifer element, Tertiary basalt aquifer, Quaternary overburden aquifer, and related inter-reaction with North West Bay River. North West Bay River discharges into North West Bay approx. 2 km to the southeast	650	Local bores exist in dolerite to the south	TBD	Nutrients
Fish waste disposal, including that used as fertiliser	Kingborough	HBMI Leslie Vale	528000	5241000	Failure of holding dams	Nil	Permian sedimentary rocks overlying dolerite intrusive form	Suspected thermal remobilised contact	TBD	650	Nil	Fish oil	Nutrients
Fish waste disposal, including that used as fertiliser	Kingborough	Tasmanian Seafood Margate	517600	5226400	Historical ongoing disposal site	Small trench filling with two holding dams	Colluvium material over fractured Permian sedimentary rocks	Tectonic fracturing in the Permian sedimentary rocks	Fractured Permian aquifer which discharges to Oyster Cove Rivulet 0.5 km to the north. Oyster Cove Rivulet discharges into Oyster Cove 4 km to the east (Note Oyster Cove Historic site).	650	Nil	Nil	Nutrients
Fish waste disposal, including that used as fertiliser	Circular Head	Tasmanian Seafood Smithton	344500	5477800	Historical ongoing disposal site	Waste stream consists mainly of shells, which are crushed and spread over paddocks	Quaternary wind blown sands, most likely overlying Precambrian Cowrie Siltstone	Unconformity between Quaternary and Precambrian units	Unconfined unconsolidated aquifer overlying potential fractured bedrock aquifer	1200	Nil	Nil	Nil
Sewage treatment lagoons	Brighton	Bagdad	517900	5282550	Nil	Cement wave wall	Jurassic dolerite, upper Triassic sedimentary rocks and Quaternary alluvial	Triassic roof rocks	Fractured dolerite aquifer, Quaternary aquifer in catchment of Bagdad Rivulet	550	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	West Tamar	Beaconsfield	484900	5439900	Nil	Cement wave walls	Tertiary sediments	Tertiary sediments over bedrock	Outpour into Brandy Creek , 1 km southwest of Tamar estuary	800	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	West Tamar	Beauty Point (Ilfraville)	483400	5444550	Nil	Cement wave walls	Tertiary sediments and Triassic sandstone	Tertiary sediments, Triassic bedrock	Next to West Arm of Tamar Estuary, Triassic aquifer with possible Ghyben-Herzberg interface	800	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Dorset	Ben Lomond	555650	5401800	Nil	In situ lined lagoons	Quaternary dolerite block field with clay matrix	Dolerite scree over dolerite bedrock	Dolerite unconsolidated and fractured aquifer, next to (in the) Ford River	1400	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Glamorgan-Spring Bay	Bicheno	605000	5364700	Expansion for re-use scheme	Clay liner, design unknown	Quaternary sand and gravel	Quaternary sediments over bedrock	Quaternary aquifer	650	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Central Highlands	Bothwell	499600	5306700	Nil	Cement wave wall	Tertiary basalt and Quaternary alluvium	Tertiary basalt flow over Triassic roof rocks over dolerite	Tertiary fractured basalt aquifer and Quaternary aquifer next to Clyde River	550	Nil	Nil	Pathogens and nutrients

Category of activity	Council/ Municipality	Site location	AMG Easting	AMG Northing	Historical issues	Engineering designed infrastructure for BPEM	Lithologies	Structural geological setting	Hydrogeological setting	Approximate local annual rainfall (mm)	Known number of currently installed bores (November 1999)	Known groundwater and/or off site surface water pollutants	Potential groundwater and/or off site surface water pollutants
Sewage treatment lagoons	Dorset	Bridport	531850	5462400	Nil	Nil	Coastal plain Quaternary sediments overlying Mathinna Beds	Quaternary sediments over bedrock	Coastal plain Quaternary sand aquifer	760	Nil	Visual pollution in nearby test pit	Pathogens and nutrients
Sewage treatment lagoons	Brighton	Brighton	521750	5271300	Nil	Cement wave wall	Quaternary sand deposits overlying bedrock. Bedrock either Jurassic dolerite and/or Triassic sedimentary rocks	Possible Jurassic dolerite / Triassic sedimentary rocks contact	Next to Jordan River. Quaternary sand aquifer with interaction with the Jordan River. Possible deeper fractured dolerite and/or Triassic aquifers with a hydraulic differential.	680	2	Nitrate and faecal coliforms	Pathogens and nutrients
Sewage treatment lagoons	Clarence	Cambridge	536300	5257300	Nil	Nil	Quaternary alluvium over Tertiary sediments	On eastern rift zone of Meehan Range	Quaternary aquifer next to Barilla Rivulet	580	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Southern Midlands	Campania	535100	5276900	Nil	Cement wave wall	Quaternary and Triassic sedimentary rocks	Quaternary and Triassic sedimentary rocks over bedrock	Quaternary and Triassic aquifers next to Native Hut Rivulet	680	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Northern Midlands	Campbell Town	540000	5357500	Nil	Nil	Tertiary basalt and overlying weathering products	Tertiary basalt flow over bedrock	Tertiary basalt aquifer next to Elizabeth River	535	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Meander Valley	Carrick	501300	5402700	Nil	Cement wave wall	Quaternary river terranes, gravel and sand	Quaternary river terranes, gravel and sand most likely over Triassic sedimentary rocks	Quaternary aquifer 750 m from Meander River	780	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Northern Midlands	Cressy	505900	5385500	Nil	Cement wave wall	Tertiary sediments	Tertiary sediments over bedrock	Tertiary sediments aquifer, lagoon located on drainage line (implies shoestring hydraulic conductivity zone)	630	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Meander Valley	Deloraine	472000	5403500	Nil	Nil	Quaternary alluvium	Quaternary alluvium over Jurassic dolerite or Tertiary basalt	Quaternary aquifer with interface with Meander River	1050	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Huon Valley	Dover	501600	5204300	Nil	Cement wave wall	Quaternary alluvium over bedrock (Note bedrock may be Jurassic dolerite)	TBD	Next to Dover Rivulet	945	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	West Tamar	Exeter	496700	5427400	Nil	Cement wave wall	Quaternary material over clay and Jurassic dolerite	Jurassic dolerite/Triassic contact to the west	Fractured dolerite aquifer. 800 m from Tamar River	675	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Break O'Day	Fingal	580100	5389500	Nil	Cement wave wall	Quaternary alluvium	Quaternary over bedrock	Quaternary aquifer next to South Esk River	920	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Meander Valley	Hagley	492000	5402000	Nil	Cement wave wall	Quaternary alluvium over Tertiary sediments	Quaternary alluvium over Tertiary basalt and/or Tertiary sediments	Quaternary (Tertiary basalt/ sedimentary?) aquifer next to Murfetts Creek	955	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Central Highlands	Hamilton	485750	5287800	Nil	In situ clay from Quaternary alluvium sourced from dolerite	Quaternary alluvium over Triassic and/or dolerite	Triassic/dolerite contact to the north	Quaternary aquifer next to Clyde River. Commercial mineral water bore in close proximity.	550	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Southern Midlands	Kempton	515300	5291700	Nil	Cement wave wall	Quaternary alluvium over Triassic sedimentary rocks	Faulted Triassic bedrock	Quaternary unconsolidated aquifer [over upper Triassic fractured aquifer(?)]	550	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	West Tamar	Legana Industrial Park	504700	5421100	Nil	Cement wave walls	Quaternary marsh deposits over Tertiary sediments	Quaternary marsh deposits over Tertiary sediments over bedrock	Quaternary and Tertiary aquifer 1 km from Tamar River	850	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Southern Midlands	Lilydale	518000	5434000	Nil	Cement wave walls	Quaternary alluvium over Lower Permian sedimentary rocks	Quaternary alluvium over Lower Permian sedimentary rocks	Quaternary aquifer in catchment of Third River	725	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Northern Midlands	Longford	507500	5395500	Nil	2 lagoons with HDPE liners and five additional lagoons with cement wave walls	Quaternary River Terranes (gravel/sand) and Tertiary sediments	Quaternary over Tertiary sediments	Quaternary and Tertiary aquifers	700	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Kingborough	Margate	522300	5236200	Nil	Cement wave wall	Quaternary gravel and dolerite boulder beds over Tertiary basalt	Quaternary material over Tertiary basalt	Quaternary and Tertiary basalt aquifers with Ghyben-Herzberg interface next to North West Bay	680	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Derwent Valley	Mt Field	476250	5273600	Nil	Nil	Quaternary alluvium	Quaternary material possibly overlying Permian sedimentary rocks/Jurassic dolerite faulted contact	Quaternary aquifer next to Tyenna River	1230	Nil	Nil	Pathogens and nutrients

Category of activity	Council/ Municipality	Site location	AMG Easting	AMG Northing	Historical issues	Engineering designed infrastructure for BPEM	Lithologies	Structural geological setting	Hydrogeological setting	Approximate local annual rainfall (mm)	Known number of currently installed bores (November 1999)	Known groundwater and/or off site surface water pollutants	Potential groundwater and/or off site surface water pollutants
Sewage treatment lagoons	Southern Midlands	Oatlands	530200	5317300	Nil	Collapsing cement wave wall	Quaternary alluvium and Triassic sedimentary rocks	Quaternary alluvium over Triassic sedimentary rocks	Quaternary and Triassic aquifers. Next to Dulverton Rivulet	490	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Glamorgan-Spring Bay	Orford	572450	5286050	Nil	Cement wave wall	Triassic sedimentary rocks and Jurassic dolerite	Triassic sedimentary rocks and Jurassic dolerite faulted (?) contact	Triassic and dolerite aquifers. Next to drainage line which enters Prosser Bay 700 m to the north	660	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Central Highlands	Ouse	476400	5295900	Nil	NHT funded sand filter trial plant	Quaternary alluvium and Triassic sedimentary rocks	Quaternary alluvium over Triassic sedimentary rocks	Quaternary and Triassic aquifers. Next to Ouse River	560	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Northern Midlands	Perth	513900	5395200	Nil	Cement wave walls	Quaternary river terranes, gravel and sand	Quaternary most likely over Triassic sedimentary rocks	Quaternary/Triassic(?) aquifer next to South Esk River	700	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Latrobe	Port Sorell	460500	5446000	Nil	Cement wave wall, clay lined	Quaternary materials and Jurassic dolerite	Quaternary over Jurassic dolerite	Quaternary and Jurassic aquifers with possible Ghyben-Herzberg interface	850	Nil	Nil	Nutrients (depending on integrity of the liner)
Sewage treatment lagoons	Launceston	Prospect Vale	508000	5408500	Nil	Cement wave walls	Laterite Jurassic dolerite and Quaternary alluvium	Laterite Jurassic dolerite enclave around Quaternary alluvium	Quaternary aquifer next to Dalrymple Creek 1 km south west of the South Esk River	780	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	West Coast	Queenstown	378750	5337800	Nil	Cement lined, air pumped through lagoon	Quaternary alluvium over Silurian quartzite	Next to fault under Queen River	Quaternary aquifer next to Queen River	1700	Nil	Nil	Nil
Sewage treatment lagoons	Kentish	Railton	452000	5422500	Nil	Cement wave walls – failing	Quaternary alluvium	Quaternary alluvium over Quaternary marsh deposits	Quaternary aquifer	1230	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Huon Valley	Ranelagh	502700	5237800	Nil	Cement wave walls	Quaternary river terranes	Quaternary river terranes over bedrock	Quaternary aquifer next to Huon River	770	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Clarence	Richmond	535750	5267200	Nil	Nil	Quaternary alluvium	Quaternary alluvium over Triassic sedimentary rocks(?)	Quaternary aquifer ½ km from Coal River	620	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Break O'Day	Scamander	604275	5411050	Nil	In situ lined lagoons	Quaternary material over Devonian granodiorite	Devonian granodiorite intruded into Mathinna beds	Quaternary unconsolidated aquifer	810	One bore only to 3.6 m	Nil	Nutrients (depending on integrity of the liner)
Sewage treatment lagoons	Kentish	Sheffield	444500	5417100	Nil	Tertiary basalt wave walls	Tertiary basalt	Tertiary basalt flow	Tertiary basalt aquifer	1230	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Break O'Day	St Helens	605300	5424500	Nil	Cement wave wall	Quaternary alluvium	Quaternary alluvium over Tertiary sediments	Quaternary alluvium with Ghyben-Herzberg interface to Georges Bay	790	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Break O'Day	St Marys	598250	5395800	Nil	Cement wave wall	Quaternary alluvium	Quaternary alluvium over Triassic sedimentary rocks	Quaternary aquifer, next to St Marys Rivulet	960	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Circular Head	Smithton (Pelican Point)	340000	5479000	Nil	Synthetic liner on lagoon sides only	Quaternary wind blown sands	Quaternary material over bedrock	Quaternary aquifer with Ghyben-Herzberg interface to Duck Bay	1090	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Circular Head	Stanley	355700	5486750	Nil	Cement wave wall	Quaternary beach deposits	Quaternary over Tertiary basalt (?)	Quaternary aquifer, lagoons 150 m from beach to the east, with Ghyben-Herzberg interface to Bass Strait	790	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Break O'Day	Stieglitz	609000	5423500	Nil	Geo-fabric covered in tar used as liner for one lagoon.	Quaternary material over Tertiary sediments	Quaternary and Tertiary sediments over bedrock	Quaternary aquifer with interaction with Windmill and Chimney Pot Lagoons	790	3	Nitrate	Pathogens and nutrients
Sewage treatment lagoons	West Coast	Strahan	360400	5332000	Nil	Nil	Quaternary sand dune deposits	Quaternary sand over bedrock	Quaternary aquifer next to Manuka River and Macquarie Harbour	1700	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Glamorgan-Spring Bay	Swansea	586900	5335400	Proposed waste water reuse project	Nil	Tertiary sediments	Tertiary sediments over Jurassic dolerite	Tertiary aquifer and possible deeper fractured dolerite aquifer	600	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Glamorgan-Spring Bay	Triabunna	575700	5293500	Nil	Nil	Quaternary alluvium over Triassic sedimentary rocks	Jurassic dolerite/Triassic sediment contact to the north	Quaternary aquifer next to Spring Bay	620	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	West Coast	Tullah	384700	5378700	Nil	Nil	Quaternary gravel — fluvioglacial deposits	Quaternary gravel over Cambrian bedrock	Quaternary aquifer, next to Lake Rosebery	1400	Nil	Nil	Pathogens and nutrients

Category of activity	Council/ Municipality	Site location	AMG Easting	AMG Northing	Historical issues	Engineering designed infrastructure for BPEM	Lithologies	Structural geological setting	Hydrogeological setting	Approximate local annual rainfall (mm)	Known number of currently installed bores (November 1999)	Known groundwater and/or off site surface water pollutants	Potential groundwater and/or off site surface water pollutants
Sewage treatment lagoons	Central Coast	Turners Beach	436150	5442500	Nil	Cement wave wall	Quaternary alluvium	Quaternary material over bedrock	Quaternary aquifer. Forth River 500 m to the east	970	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	Meander Valley	Westbury	485500	5403500	Nil	Cement wave walls	Quaternary alluvium over Tertiary basalt	Tertiary basalt flow over deeper Jurassic dolerite	Quaternary unconsolidated and Tertiary basalt aquifers, Quamby Brook 20 m	955	Nil	Nil	Pathogens and nutrients
Sewage treatment lagoons	West Coast	Zeehan	363100	5360150	Nil	Some sides of lagoons have a plastic liner. Leakage observed in the area around the lagoons.	Quaternary alluvium	Quaternary alluvium over Silurian bedrock	Quaternary aquifer, next to Little Henty River	1500	Nil	Nil	Pathogens and nutrients
Abattoir waste disposal	Glenorchy	Cates abattoir, Collinsvale	512300	5255500	Over 100 000 tonnes of offal known to be buried in one area, other old trench sites exist. Blood water ploughed into paddocks	Settling ponds for blood water	Permian sedimentary rocks and Jurassic dolerite	Emplacement structures related to the Collins Bonnet regional dolerite feeder system, with isostatic tectonic overprinting.	Heterogenous complex fractured aquifer with colluvium overburden and respective regolith soil profiles. (Selective resistivity surveys required pre-drilling program)	1200	One bore	Nitrate	Nutrients
Abattoir waste disposal	Huon Valley	Griggs slaughter house, Huonville	506000	5227000	Waste irrigation for over three years and at least three known old and active offal pit areas	Safe and all, lagoon system, irrigation system. New offal pits are in clay	Permian sedimentary rocks – Fern Tree Formation	NW-SE striking fault and other local faulting	Two north-south drainage lines east and west of the irrigation area. Fractured aquifer, with spring discharges into adjacent drainage lines	830	Nil	Nil	Nutrients
Abattoir waste disposal	King Island	King Island abattoir	233250	5580500	Direct liquid waste disposal into Porky Creek for several decades.	Some primary solids traps.	Quaternary sand	Quaternary material over bedrock	Discharge into Porky Creek, 3.5 km east of coastline.	930	Nil	Nil	Nutrients
Abattoir waste disposal	Circular Head	Blue Ribbon Meats, Smithton	342500	5475000	Abattoir waste buried for over fifty years. Estimated volume of 500 000 tonnes of material	Nil	Quaternary material overlying Cambrian volcanic rocks at shallow depth	Unconformity between Quaternary and Precambrian	Quaternary sand unconfined aquifer overlying fractured bedrock aquifer. Springs beneath landfill footprint. Disposal site next to Coventry Creek, which discharges into the Duck River 1 km down stream. The Duck River enters Duck Bay 5 km to the north.	1200	Nil	Nil	Nutrients and metals
Solid waste disposal sites	Break O'Day	Stieglitz closed waste depot	608950	5423850	Closed approx. 1995	Nil	Quaternary marsh deposits	Quaternary material over bedrock	Quaternary aquifer next to Chimneys Lagoon	790	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Break O'Day	Ansons Bay closed waste depot	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Solid waste disposal sites	Break O'Day	St Helens waste depot	602300	5424900	Nil	Nil	Quaternary alluvium over Tertiary sediments	Quaternary and Tertiary material over bedrock	Quaternary unconfined aquifer next to Golden Fleece Rivulet	790	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Brighton	Boyer – Fletcher Challenge	508900	5265100	Pine trees planted in ash dump	TBD	Triassic and Permian sedimentary rocks	Tertiary faulting	Fractured Triassic and Permian aquifers near River Derwent	560	7	TBD	TBD
Solid waste disposal sites	Burnie	Mooreville Road waste depot Burnie	405750	5451350	Opened in 1984	Stormwater collection system beneath a clay liner. Clay liner has no record of permeability or quality control, limited leachate collection system	Heterogenous clays with variable permeabilities overlying Tertiary fractured basalt	Basalt fracture density/orientation mainly controlled by syn-genetic thermal jointing	Local/regional discharge point of unconfined fractured basaltic aquifer. High water table	1200	Several bores installed, some MRT monitoring data	TBD	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Burnie	View Street waste depot Burnie	406400	5453600	Closed 1984. Contains a large quantity of vegetables disposed of after fire in Burnie dock warehouses.	Stormwater piped throughout landfill internal structure, pipes of questionable integrity	Heterogenous clays with variable permeabilities overlying Tertiary fractured basalt	Basalt fracture density/orientation mainly controlled by syn-genetic thermal jointing	Local/regional discharge point of unconfined fractured basaltic aquifer. High water table	1200	Nil	Nil	Metals, hydrocarbons and nutrients

Category of activity	Council/ Municipality	Site location	AMG Easting	AMG Northing	Historical issues	Engineering designed infrastructure for BPEM	Lithologies	Structural geological setting	Hydrogeological setting	Approximate local annual rainfall (mm)	Known number of currently installed bores (November 1999)	Known groundwater and/or off site surface water pollutants	Potential groundwater and/or off site surface water pollutants
Solid waste disposal sites	Burnie	West Mooreville Road, Brambles industrial waste landfill, Burnie	401500	5449200	Unlined basalt quarry filled with waste stream from Burnie pulp mill. DPIWE historical photos indicated very poor management practices.	Stormwater/ leachate ponds, limited capping	Tertiary basalt flow on Burnie Precambrian quartzite and shale	Thermal contact between basalt and Precambrian units	Three fractured aquifers with a main north/south fracture orientation. Leachate spring discharge into a northwest tributary and main spring discharge into a northern tributary. Both tributaries join and discharge into the Cam River above a town water offtake point	1200	24 bores installed by CEE for Brambles.	TBD	TBD
Solid waste disposal sites	Burnie	Brickport Road closed industrial waste landfill, Burnie	405500	5455200	Closed in 1980's	Nil	Tertiary basalt flow on Burnie Precambrian quartzite and shale	Thermal contact between basalt and Precambrian units	Tertiary basalt and Precambrian aquifers next to Cooee Creek	1200	Nil	Nil	TBD
Solid waste disposal sites	Central Coast	Penguin waste depot	421350	5445375	Historical mine site	Sleeved stormwater pipe with no leachate pond	Ordovician conglomerate with Tertiary sediments and Quaternary alluvium	Tertiary and Quaternary material over Ordovician bedrock	Unconfined aquifer connected to filled drainage line.	1010	One - only for water supply, not designed for environmental monitoring	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Central Coast	Preston waste depot	424400	5431500	Nil	Nil	Cambrian mudstone and siltstone	TBD	Cambrian fractured aquifer	1100	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Central Coast	Castra closed waste depot	TBD	TBD	Nil	Nil	TBD	TBD	TBD	1620	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Central Coast	South Riana closed waste depot	414200	5429550	Closed in 1999	Leachate pond	Cambrian sedimentary rocks	Cambrian/Ordovician contact to the east	Cambrian fractured aquifer	1100	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Central Coast	Ulverstone closed waste depot	428600	5443050	Closed approx 1995	Rehabilitation plan nearing completion	Quaternary alluvium over Tertiary sediments	Tertiary and Quaternary material over Cambrian bedrock	Cambrian fractured aquifer	1010	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Central Highlands	Bradys Lake HEC closed waste depot	456040	532980	Nil	Rehabilitation plan completed	Jurassic dolerite	Nil	Fractured doleritic aquifer	TBD	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Central Highlands	Miena closed waste depot	474400	5350425	Nil	Nil	Jurassic dolerite	Nil	Fractured doleritic aquifer	TBD	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Central Highlands	Bothwell waste depot	503100	5307100	Nil	Nil	Lower Triassic sedimentary rocks	TBD	Triassic aquifer	550	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Central Highlands	Hamilton waste depot	486450	5287150	Old quarry site	Proposed clay liner, leachate collection system and ponds	Jurassic dolerite over Triassic sedimentary rocks	Dolerite/Triassic hornfels sub-horizontal contact	Dolerite and Triassic fractured aquifers	550	3 proposed bores	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Circular Head	Port Latta regional hazardous waste depot	362590	5475630	Started operation in 1994	Leachate clay liner, sub liner beneath landfill liner (contam-inated), leachate collection system and ponds, stormwater diversion system and settling ponds	Thick clay overburden on Precambrian Cowrie Siltstone	No known faults, folded metasedimentary rocks	All surface run off enters Stinking Creek that discharges into Bass Strait on the eastern side of the Port Latta pelletising plant	920	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Circular Head	Rocky Cape closed waste depot	372625	5474125	Rehabilitation complete	TBD	Precambrian Rocky Cape Group	Southwest-northeast faulting	Fractured aquifer with unconsolidated overburden (potential perched water table)	920	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Circular Head	Sundown closed waste - Parks and Wildlife	305900	5444950	Operated for over forty years, closed in 1995	Nil	Quaternary sand deposits	Quaternary material over bedrock	Quaternary aquifer. Leachate canal discharging into Sundown Creek	1090	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Circular Head	Marrawah closed waste depot	303400	5464900	Closed approx. 1995	Nil	Quaternary sand deposits	Quaternary material over bedrock	Quaternary aquifer	1100	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Circular Head	Mawbanna closed waste depot	TBD	TBD	Closed approx. 1995	Nil	Cambrian sedimentary rocks (Cowrie Siltstone)	TBD	Fractured Cambrian aquifer	1110	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Circular Head	Togari closed waste depot	321500	5462150	Closed approx. 1995	Nil	Quaternary sand deposits	Quaternary material over bedrock	Quaternary aquifer	1180	Nil	Nil	Metals, hydrocarbons and nutrients

Category of activity	Council/ Municipality	Site location	AMG Easting	AMG Northing	Historical issues	Engineering designed infrastructure for BPEM	Lithologies	Structural geological setting	Hydrogeological setting	Approximate local annual rainfall (mm)	Known number of currently installed bores (November 1999)	Known groundwater and/or off site surface water pollutants	Potential groundwater and/or off site surface water pollutants
Solid waste disposal sites	Circular Head	Smithton Duck River historical waste depot	341500	5476900	Nil	Clay capping	Quaternary alluvium	Quaternary material over bedrock	Quaternary aquifer next to the Duck River	1090	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Circular Head	Smithton closed waste depot, Montagu Rd	339300	5478650	Closed approx. 1995	Capping	Quaternary windblown sand deposits	Quaternary material over bedrock	Quaternary aquifer	1090	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Circular Head	Stanley closed waste depot	352800	5480950	Nil	Nil	Quaternary windblown sand deposits	Quaternary material over bedrock	Quaternary aquifer	950	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Clarence	Lauderdale waste depot	539900	5247950	Groundwater contamination confirmed by historical monitoring	Nil	Quaternary sand overlying Tertiary sediments	Several faults/contacts identified by regional geophysics study (Leaman, 1972)	Tidal wet land	645	Approximately 28	Ammonia	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Clarence	Wentworth Park waste depot	532000	5252250	Uncontrolled site	Nil	Quaternary deposits	TBD	Quaternary sand aquifer, tidal connection	645	Nil	Nil	TBD
Solid waste disposal sites	Derwent Valley	Peppermint Hill waste depot, New Norfolk	503800	5262600	Nil	Two leachate ponds, one with an unstable wall	Permian sedimentary rocks (Fern Tree Formation)	Several faults beneath landfill footprint	Permian fractured aquifer within close proximity to the River Derwent	570	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Derwent Valley	Strathgordon HEC closed waste depot	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Solid waste disposal sites	Derwent Valley	National Park closed waste depot	477400	5273750	Closed approx. 1995	Nil	Quaternary alluvium over Permian sedimentary rocks	TBD	Permian aquifer	1240	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Devonport	Gunn's unlicensed waste depot, Devonport	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	Nil	Iron, hydrocarbons and ammonia.	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Devonport	Spreyton closed waste depot	445400	5437400	Closed approx. 1995	Rehabilitation program in progress	Quaternary alluvium	Quaternary material over bedrock	Quaternary aquifer next to Mersey River	960	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Dorset	Scottsdale waste depot	538850	5448775	Operated for several decades. Trenches of herbicide and pesticide containers.	Nil	Thick Tertiary sandy sediments overlying Devonian-Carboniferous granodiorite	Tertiary sediments over bedrock	Highly permeable Tertiary sands in landfill footprint. Footprint located in the recharge area of a major State significant high quality and quantity aquifer	900	Two bores at medium depth and five shallow bores above the water table	Nitrate, metals and organophosphate pesticides	Metals, hydrocarbons, nutrients, organophosphate and organochlorides
Solid waste disposal sites	Dorset	Bridport waste depot	532300	5460000	Nil	Nil	Devonian Mathinna Beds	TBD	Fractured aquifer	760	One bore covered by fill	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Dorset	Tomahawk closed waste depot	564950	5474500	Nil	Nil	Quaternary sand	Quaternary material over bedrock	Quaternary sand aquifer	790	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Dorset	Pioneer waste depot	569700	5454480	Nil	Nil	Granite with quartz dominated regolith	TBD	TBD	TBD	Nil	Nil	Metals
Solid waste disposal sites	Dorset	Branxholm waste depot	561150	5441450	Nil	Nil	Tertiary basalt with regolith soils	TBD	Fractured aquifer with unconsolidated overburden (potential perched water table)	1035	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Dorset	Musselroe Bay waste depot	598880	5477770	Nil	Nil	Quaternary sand	Quaternary material over bedrock	Quaternary sand aquifer	890	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Dorset	Winnaleah waste depot	569200	5449275	Nil	Nil	Tertiary sediments	TBD	Unconfined aquifer close to drainage line	1030	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Dorset	Gladstone waste depot	584550	5465700	Nil	Nil	Granite with quartz dominated regolith	TBD	Unconfined aquifer close to drainage line	1050	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Flinders	Lackrana	599900	5561000	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Solid waste disposal sites	Flinders	Lady Barron	606100	5548500	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Solid waste disposal sites	Flinders	Cape Barron Island	587500	5530500	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Solid waste disposal sites	Flinders	Killiecrankie	571200	5589800	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Category of activity	Council/ Municipality	Site location	AMG Easting	AMG Northing	Historical issues	Engineering designed infrastructure for BPEM	Lithologies	Structural geological setting	Hydrogeological setting	Approximate local annual rainfall (mm)	Known number of currently installed bores (November 1999)	Known groundwater and/or off site surface water pollutants	Potential groundwater and/or off site surface water pollutants
Solid waste disposal sites	Flinders	Whitemark	588000	5557900	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Solid waste disposal sites	George Town	Beechford closed waste depot	496650	5457825	Closed 1999	Nil	Quaternary sand	Quaternary material over bedrock	Quaternary sand aquifer	670	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	George Town	Lefroy closed waste depot	TBD	TBD	Closed 1999	Nil	Quaternary material and Mathinna Beds	Quaternary material over Mathinna beds	Fractured sedimentary aquifer	760	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	George Town	Bellingham closed waste depot	514250	5459150	Closed 1999	Nil	Quaternary material and Mathinna Beds	Quaternary material over Mathinna Beds	Fractured sedimentary aquifer	870	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	George Town	Lulworth closed waste depot	506600	5460850	Closed 1999	Nil	Quaternary sand	Quaternary material over bedrock	Quaternary sand aquifer	760	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	George Town	Pipers River waste depot	505500	5451050	Nil	Nil	Tertiary material and Mathinna Beds	Quaternary material over Mathinna Beds	Fractured sedimentary aquifer	870	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	George Town	Mt George waste depot, George Town	487470	5449375	Large trench filling operation, discharges into old fill area	Stormwater cut off perimeter drains.	Jurassic dolerite overlain by clay deposits	Tertiary clays and in situ weathered dolerite	Fractured dolerite aquifer with high hydraulic head during storm events from catchment on Mount George.	845	Approximately four bores of unknown usefulness	TBD	Metals, hydrocarbons and nutrients
Solid waste disposal sites	George Town	Comalco closed waste depot, Bell Bay	490200	5446625	TBD	TBD	Quaternary and Tertiary sediments over Tertiary basalt and Jurassic dolerite	Faulted bedrock	Unconsolidated aquifer overlying fractured bedrock aquifer(s)	845	TBD	TBD	Metals and hydrocarbons
Solid waste disposal sites	George Town	Comalco historical waste depot, Bell Bay	TBD	TBD	TBD	TBD	Quaternary and Tertiary sediments over Tertiary basalt and Jurassic dolerite	Faulted bedrock	Unconsolidated aquifer overlying fractured bedrock aquifer(s).	845	TBD	TBD	Metals and hydrocarbons
Solid waste disposal sites	Glamorgan-Spring Bay	Orford waste depot	572800	5289975	Current extension of old site. Leachate contamination of stormwater perimeter drain from old filling areas	Old Site – nil: Extension – clay liner, leachate collection system, stormwater diversion	Thin soil profile over Triassic sedimentary rocks	Possible local scale faulting	Surface waters discharge into Sheas Creek to the west , approximately 100 metres before Sheas Creek enters Prosser Bay. Sheas Creek discharge area next to summer camping area.	610	1 bore	TBD	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Glamorgan-Spring Bay	Bicheno waste depot	606500	5361500	Past mining activity	Extension approved by DPEMP/ EMPCA process in 1999	Granite with regolith	TBD	TBD	650	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Glamorgan-Spring Bay	Triabunna closed waste depot	574300	5292400	TBD	Nil	Quaternary bay deposits	TBD	Filled tidal wet land	620	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Glamorgan-Spring Bay	Coles Bay closed waste depot	605250	5337200	Closed 1998	Nil	Quaternary sand over bedrock	TBD	Unconfined sand aquifer	600	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Glamorgan-Spring Bay	Swansea waste depot	586500	5335150	Nil	Nil	Jurassic dolerite	TBD	Jurassic dolerite fractured aquifer	600	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Glenorchy	Chapel Street waste depot	520100	5256000	No waste stream interception.	Stormwater cut off perimeter drain , some unknown depth of capping	Jurassic dolerite deposits and related colluvium deposits	Dolerite emplacement feature and internal post-Jurassic faults	Jurassic dolerite fractured aquifer discharging into landfill refuse. Humphrey Rivulet to the south 20 metres from landfill toe	610	2 shallow wells	Nitrate, iron	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Glenorchy	Jackson Street waste depots	520200	5256400	Extension of the Chapel Street site from the west. Surface seepages of leachate on landfill cover material	Glenorchy EMP review required, stormwater pipes beneath landfill	Permian sedimentary rocks (Bundella Formation) and Jurassic dolerite	Contact between the eastern sediments and western dolerite runs N-S through central part of site	Fractured rock dolerite and Permian sedimentary rocks aquifer systems with associated contact zone (hydraulic boundary condition)	610	Shallow wells	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Glenorchy	Creek Road closed waste depot	523750	5255050	Closed for several decades	Nil	Jurassic dolerite with regolith	Dolerite emplaced into Triassic sedimentary rocks	Jurassic dolerite fractured aquifer next to New Town Rivulet	610	Nil	Nil	Metals and hydrocarbons
Solid waste disposal sites	Hobart	New Town Bay closed waste depot	525700	5255800	Potential industrial waste streams	Nil	Tertiary and Quaternary alluvium plus Tertiary basalt	Sediment over bedrock	Unconfined aquifer next to New Town Bay	610	Nil	Nil	Metals, hydrocarbons and nutrients

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Solid waste disposal sites	Hobart	McRobies Gully waste depot	523475	5251250	Opened in 1974	Questionable integrity of stormwater pipes through landfill. Cement lined leachate ponds. Default engineered leachate collection system via contaminated stormwater collection system. Limited stormwater diversion system.	Permian (Malbina Formation) and Triassic (metamorphosed Knocklofty Formation) sedimentary rocks, plus Jurassic dolerite with related superficial surface deposits	Cascades Fault shearing zone — related to major basement structural feature known to be related to earthquake activity in the last 200 years	Fractured rock aquifers with dolerite on eastern side of Cascades Fault, Permian sedimentary rocks on the western side and Triassic sedimentary rocks to the south	610	Three medium depth bores, some historical monitoring data	TBD	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Huon Valley	Southbridge closed waste depot	502950	5233075	Nil	Nil	Quaternary alluvium over Jurassic dolerite	Sediment over bedrock	Unconfined aquifer next to Huon River	770	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Huon Valley	Southport closed waste depot	497225	5192575	Nil	Nil	Permian rock with regolith	TBD	fractured aquifer	985	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Huon Valley	Dover closed waste depot	499750	5202525	Nil	Leachate pond	Quaternary material over Triassic sedimentary rocks	Quaternary material over Triassic bedrock	Unconfined aquifer	945	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Huon Valley	Cygnet waste depot	507600	5221725	1999 EMP states that 'leachate has caused death in the environment'. Organophosphate pesticides have been detected in the Council monitoring regime.	Leaking leachate pond onto private land	Permian sedimentary rocks — Woody Island Siltstone	Tectonic fracturing	Several small catchments which all discharge into a tributary of Agnes Rivulet. Agnes Rivulet discharges into the Port Cygnet (Wildlife Sanctuary) 1.5 km to the southwest	865	Nil	Nutrients and organophosphate	Metals, hydrocarbons, nutrients, organophosphate and organochlorides
Solid waste disposal sites	Huon Valley	Geeveston waste depot	494925	5216625	1999 EMP recommends the installation of at least five monitoring bores. Leachate discharges onto adjoining property have been identified by DPIWE as a possible cause of cattle deaths on this property	1999 — decommissioning of old leachate pond and construction of larger leachate pond; construction of leachate clay liner of additional cell; stormwater perimeter cut-off drain improvements.	Triassic sandstone	TBD	Triassic sedimentary rock fractured aquifer with unconfined perched aquifer in regolith.	870	Nil	Metals and nutrients	Metals, hydrocarbons, nutrients, organophosphate and organochlorides
Solid waste disposal sites	Kentish	Sheffield closed waste depot	443480	5418450	Nil	Nil	Tertiary sediments	Tertiary sediments over bedrock	Unconfined aquifer	1230	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Kentish	Lake Barrington unlicensed waste depot, Parks and Wildlife	435250	5418150	TBD	TBD	TBD	TBD	TBD	1180	TBD	TBD	TBD
Solid waste disposal sites	Kingborough	Barretta waste depot, Margate	521400	5234100	Operated for several decades, continued discharge of leachate into North West Bay for over ten years	In situ clay, leachate pond, limited leachate collection system, stormwater diversion grand canal	Triassic and Permian sedimentary rocks	North–south tectonic basement fault between the Permian (west) and Triassic (east); detailed structural survey required to identify additional related secondary structural features	Permian aquifer; contact zone; Triassic aquifer; North West Bay Ghyben-Herzberg potential redox buffer.	680	5 bores	Metals and nutrients	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Kingborough	North Bruny closed waste depot	530100	5223400	Nil	Nil	Jurassic dolerite	Jurassic dolerite	Jurassic dolerite fractured aquifer	680	One bore	TBD	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Kingborough	Adventure Bay closed waste depot	526000	5203000	Closed 1998	Nil	Permian sedimentary rocks	TBD	Permian fractured aquifer	760	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Kingborough	Alonnah waste depot	520050	5204625	Nil	Nil	Jurassic dolerite	Jurassic dolerite	Jurassic dolerite fractured aquifer	760	Nil	Nil	Metals, hydrocarbons and nutrients

Category of activity	Council/ Municipality	Site location	AMG Easting	AMG Northing	Historical issues	Engineering designed infrastructure for BPEM	Lithologies	Structural geological setting	Hydrogeological setting	Approximate local annual rainfall (mm)	Known number of currently installed bores (November 1999)	Known groundwater and/or off site surface water pollutants	Potential groundwater and/or off site surface water pollutants
Solid waste disposal sites	Kingborough	Bruny Island neck historical waste depot	527700	5206100	Nil	Nil	Quaternary sand	Sediment over bedrock	Quaternary aquifer	760	Nil	Nil	Metals and hydrocarbons
Solid waste disposal sites	King Island	Currie active waste depot	230400	5576125	Nil	Nil	Quaternary sand	Sediment over bedrock	Quaternary aquifer	930	2 bores	TBD	Metals, hydrocarbons and nutrients
Solid waste disposal sites	King Island	Old Currie site	230500	5575300	Nil	Nil	Quaternary sand	Sediment over bedrock	Quaternary aquifer	930	Nil	Nil	Metals and hydrocarbons
Solid waste disposal sites	King Island	Very old Currie waste depot	230400	5574650	Nil	Stormwater infiltration trench in close proximity to the landfill footprint	Quaternary sand	Sediment over bedrock	Quaternary aquifer	930	Nil	Nil	Metals
Solid waste disposal sites	Latrobe	Port Sorell closed waste depot	460500	5443500	Over 80 000 tonnes of waste from pulp/paper plant and extensive amounts of liquid waste from various sources	Nil	Quaternary sand deposits with some clay strata lens overlying Jurassic dolerite	Dolerite fracture system unknown, overburden material is consolidated implying open fractures	Unconsolidated aquifer overlying fractured aquifer. Creek enters site from the northwest. Discharge from site passes residential area to the east. Extensive groundwater contamination plume expected to the northeast and east	850	Nil	Nil	Metals, hydrocarbons, nutrients and industrial chemicals
Solid waste disposal sites	Latrobe	Dulverton regional waste depot	448500	5427750	Opened in 1994 as northern regional site for four Councils	Stormwater perimeter drains and settling ponds, leachate collection system and HDPE lined leachate ponds, compacted clay liner	Siltstone, limestone and related surface deposits from catchments to the south (including dolerite talus), overlain by up to five metres of clay	Contact between limestone and siltstone/sandstone beneath site	Fractured aquifer believed to exist beneath the site at some unknown (most likely moderate) depth	1200	Extensive bore network installed and monitored	Nil	TBD
Solid waste disposal sites	Launceston	Remount Road waste depot, Launceston	512800	5417250	Operated for over ten years	Uncompacted in situ clays, leachate collection system and pond, which overflows to under engineered sewer line, perimeter stormwater cut off drains (often used for disposal of leachate due to lack of capacity of sewer line)	Mainly Jurassic dolerite with reports of sedimentary rocks in base of valley floor	Magnetic surveys and field mapping required to identify the three-dimensional structural setting of the dolerite and any additional lithologies	Fractured dolerite aquifer with various degrees of weathering. Possible contact and sedimentary aquifer. Resistivity surveys required pre drilling program	700	Approximately six, logs unknown	TBD	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Launceston	Lilydale closed waste depot	516125	5434200	Nil	Nil	Lower Permian sedimentary rocks	TBD	Fractured Permian aquifer	725	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Meander Valley	Deloraine waste depot	TBD	TBD	Nil	Over flowing leachate pond onto private land	TBD	TBD	TBD	1050	1 bore	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Meander Valley	Westbury waste depot	485775	5396000	Nil	Leachate pond	Jurassic dolerite	Jurassic dolerite	Jurassic dolerite fractured aquifer	920	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Northern Midlands	Longford closed waste depot	509250	5395025	Closed 1999	Clay capping	Tertiary sediments	Tertiary material over bedrock	Tertiary sedimentary aquifer	700	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Sorell	Carlton waste depot	553050	5253750	Refuse buried in trenches below the water table	New leachate and stormwater ponds and leachate collection system	Triassic sandstone	TBD	Triassic aquifer	530	Approximately three bores	TBD	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Sorell	Dunalley closed waste depot	TBD	TBD	Closed 1996	Nil	Triassic rock with regolith soils	TBD	Triassic aquifer	530	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Southern Midlands	Oatlands waste depot	532990	5313090	Operated for over ten years	No leachate collection system, unlined leachate ponds	Triassic sedimentary rocks, with various degrees of weathering	No major structures known to exist in the local area, expect Tertiary basalt feature (unknown if flow or plug) approximately 500 metres to the north	Triassic aquifer	490	Nil	Nil	Metals, hydrocarbons and nutrients

Category of activity	Council/ Municipality	Site location	AMG Easting	AMG Northing	Historical issues	Engineering designed infrastructure for BPEM	Lithologies	Structural geological setting	Hydrogeological setting	Approximate local annual rainfall (mm)	Known number of currently installed bores (November 1999)	Known groundwater and/or off site surface water pollutants	Potential groundwater and/or off site surface water pollutants
Solid waste disposal sites	Southern Midlands	Campania closed waste depot, Brown Mountain	537500	5280000	Closed 1999	Nil	Triassic sedimentary rocks, with various degrees of weathering	TBD	Triassic aquifer	630	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Southern Midlands	Ross closed waste depot	TBD	TBD	TBD	TBD	Triassic sedimentary rocks, with various degrees of weathering	TBD	Triassic aquifer	TBD	TBD	TBD	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Tasman	Port Arthur closed waste depot	TBD	TBD	TBD	TBD	Triassic sedimentary rocks, with various degrees of weathering	TBD	Triassic aquifer	TBD	TBD	TBD	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Tasman	Nubeena waste depot	561300	5227750	Nil	Overflowing silted up leachate pond.	Triassic sedimentary rocks, with various degrees of weathering	TBD	Triassic aquifer	890	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Waratah-Wynyard	Wynyard closed waste depot	392000	5462100	Closed in 1995. Cemetery next to landfill has high water table. School next to site	Stormwater pipes past through landfill	Quaternary material most likely overlying Permian sedimentary rocks	Unconformity between basement and Quaternary material	Landfill rests on the river gravels (flood plain) of the Inglis River, 1.8 km before the Inglis River discharges into Bass Strait. Unconfined unconsolidated aquifer with interaction with the Inglis River, overlying fractured aquifer - also in (hydraulic system) of Inglis River hydrosphere	1020	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	Waratah-Wynyard	Waratah closed waste depot	TBD	TBD	Closed 1998	Clay cover	TBD	TBD	TBD	2180	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	West Coast	Zeehan regional waste depot	362850	5359025	Old tailings dump site	Leachate collection system in new areas, no quality controls on leachate liner construction, stormwater diversion	Western Devonian Florence Quartzite faulted against eastern Silurian Crotty Quartzite, very little clay	Several faults beneath the landfill footprint, main N-S fault contact between the Florence and Crotty quartzites	Fractured aquifer(s) interaction with surface tributary to the Little Henty River. High water table with rapid fluctuations during rain events. Surface spring discharges	1500	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	West Coast	Trial Harbour (unlicensed) waste depot	349175	5356700	Nil	Nil	Precambrian sedimentary rocks	TBD	Fractured aquifer	2480	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	West Coast	Granville Harbour (unlicensed) waste depot	337350	5369300	Nil	Nil	Quaternary sand	Quaternary sand over bedrock	Quaternary sand aquifer	2360	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	West Coast	Tullah closed waste depot	TBD	TBD	Closed 1998	TBD	TBD	TBD	TBD	2180	TBD	TBD	Metals, hydrocarbons and nutrients
Solid waste disposal sites	West Coast	Rosebery closed waste depot	373475	5372500	Closed 1998	TBD	TBD	TBD	TBD	1960	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	West Coast	Strahan closed waste depot	359700	5332200	Closed 1998	In situ cover material	Quaternary alluvium	Quaternary material over bedrock	Quaternary aquifer	2140	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	West Coast	Queenstown old closed waste depot	377825	5334800	Nil	Nil	Quaternary alluvium over Cambrian mudstone	Quaternary alluvium over Cambrian mudstone	TBD	2140	Nil	Nil	Metals and hydrocarbons
Solid waste disposal sites	West Coast	Queenstown closed waste depot	378300	5387500	Closed 1998	Nil	Quaternary alluvium	TBD	Quaternary aquifer next to Queen River	2140	Nil	Nil	Metals, hydrocarbons and nutrients
Solid waste disposal sites	West Tamar	Beaconsfield waste depot	484900	5439900	Nil	Riverworks leachate treatment trial	Tertiary sediments	Tertiary material over bedrock	Tertiary aquifer next to Brandy Creek	800	One bore	TBD	Metals, hydrocarbons and nutrients
Solid waste disposal sites	West Tamar	Exeter closed waste depot	495200	5427200	Council sued by private land owner due to stock losses	Capping	Triassic sedimentary rocks, with various degrees of weathering	Triassic sedimentary rocks intruded by Jurassic dolerite	Triassic aquifer next to Stony Brook	865	Nil	Nil	Nutrients, hydrocarbons, metals, organophosphates and organochlorides

Category of activity	Council/ Municipality	Site location	AMG Easting	AMG Northing	Historical issues	Engineering designed infrastructure for BPEM	Lithologies	Structural geological setting	Hydrogeological setting	Approximate local annual rainfall (mm)	Known number of currently installed bores (November 1999)	Known groundwater and/or off site surface water pollutants	Potential groundwater and/or off site surface water pollutants
Dairy processing and effluent irrigation	Burnie	Lactos property	508000	5450000	Used extensively in the past as the only area for the disposal of milk by-products (whey) and wash-down water, presently only used for washdown water	Irrigation system from holding tanks	Tertiary basalt and related soils overlying Burnie shale	Tertiary basalt flow over Precambrian quartzite and shale	Rising springs in several locations on property. Cascades Creek discharges into Emu River	1200	Five bores installed in landslip area plus three bores installed below Betta milk irrigation area	TBD	Nutrients
Dairy processing and effluent irrigation	Burnie	Lactos – private property network	506000	5448000	Nil	Controlled application rates	Tertiary basalt and related soils overlying Burnie shale	Tertiary basalt flow over Precambrian quartzite and shale	Tertiary basalt fractured aquifer	1200	TBD	TBD	TBD
Dairy processing and effluent irrigation	Circular Head	Wayne Tennant property, Togari	322500	5468350	Irrigation scheme started in 1992. Some historical work done by David Crusher (DPIWE) & Loyd Matthews (MRT)	Two unlined ponds	Quaternary alluvial and colluvium deposits overlying Cambrian dolomite	Unconformity between Quaternary overburden and bedrock	Unconfined unconsolidated aquifer overlying karst-fractured? dolomite aquifer. In the Montagu River catchment (Montagu River 1 km to the west). Hump and hollow engineered drainage	1200	Two 18.3 metre bores, plus three old shallow piezometers	Nitrate	Nutrients
Dairy processing and effluent irrigation	Circular Head	James Finlayson property, Togari	322300	5464200	Some historical work done by David Crusher (DPIWE) & Loyd Matthews (MRT)	Irrigation scheme	Quaternary alluvial and colluvium deposits overlying Cambrian sedimentary rocks	Unconformity between Quaternary overburden and bedrock	Unconfined unconsolidated aquifer overlying karst-fractured? dolomite aquifer. In the Montagu River catchment (Montagu River 1.5 km to the west). Hump and hollow engineered drainage	1200	Two 18.3 metre bores, plus three old shallow piezometers	Nitrate	Nutrients
Dairy processing and effluent irrigation	Circular Head	Harcus Dairy, Van Diemen's Land Co., Woolnorth	318400	5482700	Nil	Unlined 2.25 megalitre holding primary and secondary ponds, irrigation scheme	Quaternary windblown sand	Quaternary sand over bedrock	Unconfined unconsolidated aquifer of unknown depth. Closest drainage line is Horsepiss Creek, 1 km to the west.	1200	One bore used as dairy supply	Nil	Nutrients and microbiological characteristics
Dairy processing and effluent irrigation	Waratah-Wynyard	UMT Burnie, Trevor Duniams property	378500	5466000	Used for whey and wash water irrigation for four years	Soil monitoring program, HDPE lined holding dam, filtered irrigation pipe system	Tertiary basalt and related soils overlying Burnie shales	Thermal contact between the Tertiary basalt and the Rocky Cape Group	Unconfined fractured aquifer, tributaries of Sisters Creek flow into Lake Llewellyn 2.25 km to the north	1200	Testiometers (?)	TBD	Nutrients and microbiological characteristics
Dairy processing and effluent irrigation	Waratah-Wynyard	UMT Burnie-Neville Atkinson property	386000	5462500	Used for whey and wash water irrigation for 4 years	Soil monitoring program, HDPE lined holding dam, filtered gravity feed irrigation pipe system	Tertiary basalt and related soils	Tertiary basalt interaction with unconsolidated materials	Unconfined fractured aquifer, tributaries enter the Inglis River 1.5 km to the east	1200	Testiometers (?)	TBD	Nutrients and microbiological characteristics
Dairy processing and effluent irrigation	Burnie	Betta Milk Burnie	408300	5450600	Small area used for irrigation for over ten years	Nil	Tertiary basalt and related soils	Tertiary basalt flow over Precambrian quartzite and shale	Sloping country with two interconnected small catchments	1200	Nil	Nil	Nutrients, microbiological characteristics phosphate, caustic soda.
Effluent irrigation from fruit processing	Huon Valley	Clements and Marshall, Cygnet	506000	5220500	High BOD	Holding dams and irrigation system	Permian sedimentary rocks - Bundella Formation and Quaternary sediments, with a small Cretaceous syenite plug?	No major faults known for one kilometre, field mapping implies high fracture density	Fractured aquifer with spring discharges, and related unconsolidated overburden material. Final discharge enters Port Cygnet bay to the east	865	Nil	Nil	Caustic soda

TBD = to be determined

APPENDIX 3

Site specific reports published as part of this project

EZZY, A. R. 2002. Groundwater quality investigations at the Bridport sewage lagoons. *Record Tasmanian Geological Survey* 2002/01.

EZZY, A. R. 2002. Groundwater quality investigations at the Port Sorell waste depot. *Record Tasmanian Geological Survey* 2002/03.

EZZY, A. R. 2002. Groundwater quality investigations at the Scottsdale waste depot. *Record Tasmanian Geological Survey* 2002/04.

EZZY, A. R. 2002. Groundwater quality investigations at the Smithton sewage lagoons. *Record Tasmanian Geological Survey* 2002/05.

EZZY, A. R. 2002. Groundwater quality investigations at the Blue Ribbon abattoir, Smithton. *Record Tasmanian Geological Survey* 2002/06.

EZZY, A. R. 2002. Groundwater quality investigations at the Port Latta waste depot. *Record Tasmanian Geological Survey* 2002/07.

EZZY, A. R. 2002. Groundwater quality investigations at the Stanley sewage lagoons. *Record Tasmanian Geological Survey* 2002/08.

EZZY, A. R. 2002. Groundwater quality investigations at the Stieglitz sewage lagoons. *Record Tasmanian Geological Survey* 2002/09.

EZZY, A. R. 2002. Groundwater quality investigations at the Chapel Street and Jackson Street waste depots, Glenorchy. *Record Tasmanian Geological Survey* 2002/11.

EZZY, A. R. 2002. Drilling investigations to identify groundwater flow directions in the area north of the Tolosa Street Reservoir, Glenorchy. *Record Tasmanian Geological Survey* 2002/12.

EZZY, A. R. 2002. Geotechnical investigations at the Dorset Council clay quarry, Jensens Road, North Scottsdale. *Record Tasmanian Geological Survey* 2002/13.

EZZY, A. R. 2002. Drilling and related geotechnical investigations of the Jetsonville aquifer at the Scottsdale waste depot. *Record Tasmanian Geological Survey* 2002/14.

EZZY, A. R. 2002. Hydrogeological investigations at the McRobies Gully waste depot, South Hobart. *Record Tasmanian Geological Survey* 2002/16.