

## DESIGN AND CONSTRUCTION OF CASTLEMAINE LANDFILL

**DON RICHARDSON**  
Golder Associates Pty Ltd  
Melbourne, Australia

### SUMMARY

In 1994 a new landfill was designed and constructed in accordance with strict environmental and regulatory requirements on a former alluvial gold mining site in Castlemaine, central Victoria. The landfill includes staged filling in specially constructed cells, leachate management and progressive rehabilitation. A major geotechnical aspect of the project was lining the base of the landfill cells with a low permeability liner constructed by ripping, breaking down, moisture conditioning and compacting the on site weathered sedimentary rock. The liner construction works were generally performed in accordance with specified relative compaction, moisture and particle size requirements to achieve a median permeability of between  $4.0 \times 10^{-9}$  and  $9.4 \times 10^{-9}$  m/s.

### INTRODUCTION

Castlemaine is a rural Victorian centre with a regional population of about 15000. This paper outlines the design and construction of a new landfill for the centre. Included is a description of the regulatory framework at the time as well as the site conditions such as hydrogeology and geology which were main factors in design. A prime objective of the landfill design was to protect the local environment.

Of particular interest was the utilisation of the on-site weathered sedimentary rock to construct a low permeability liner in the base of the landfill cells. It is understood that this has limited precedent in Australia. The paper describes the construction of the liner including construction methods, compliance testing during construction, permeability testing using single-ring infiltrometers as well as some observations of the broader 'nuts and bolts' issues involved with building a major earthworks project.

### SITE DESCRIPTION AND HYDROGEOLOGY

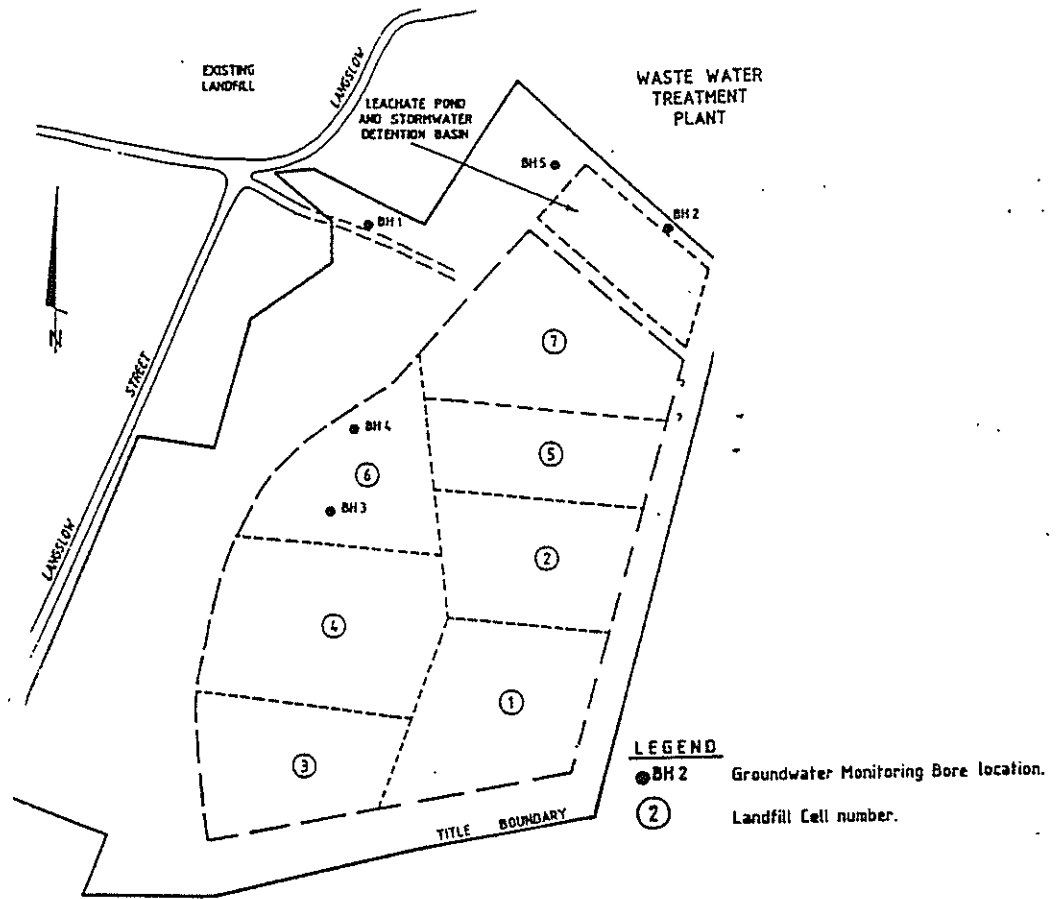
The general layout of the landfill is shown in Figure 1. The site has an area of about 9 hectares. It slopes from south to north with a change in elevation of about 25 metres.

The site is underlain by weathered Paleozoic age sandstone and siltstone with well developed near vertical bedding. Soil cover is thin to absent on parts of the hillside due to gold mining activities using sluicing and alluvial mining techniques. However the remaining soils are of two origins:

- Tertiary age sand and gravels which cover the rock on the upper part of the site.
- Quaternary age alluvial and colluvial soils which occur in drainage lines on the lower part of the site.

Permeability tests indicated permeabilities in the rock ranging from  $2 \times 10^{-4}$  to  $4 \times 10^{-6}$  m/s. The depth to the groundwater table under the lower parts of the site was a minimum of about 2 m and increased southwards under the hillside. The groundwater flow direction was to the north east and the groundwater underflow was calculated to be about 22 m<sup>3</sup>/day. [6] The groundwater quality at the down gradient site boundary was characterised by a mean total dissolved solids (TDS) concentration of 3740 mg/L. This indicates that the groundwater has a beneficial use as stockwater but is unsuitable for potable or irrigation water [4].

Figure 1. Site Plan (Scale 1:5000)



## REGULATORY FRAMEWORK

The Environment Protection Authority (EPA) in Victoria stipulate that new landfill be permitted through a Works Approval system. This requires a technical evaluation of the impact on the environment by the landfill. Of particular relevance in the regulatory guidelines for municipal waste landfills is the development of necessary control measures to protect the beneficial uses of the local groundwater and surface water. [5,1].

## LANDFILL DESIGN

Taking into account the site specific conditions such as hydrogeology, geology, climate and topography the landfill was designed to minimise environmental impact in accordance with the regulatory framework.

Leachate is produced within a landfill when moisture enters refuse, extracts contaminants into a liquid phase and produces sufficient moisture to initiate liquid flow. [3] The estimation of leachate volumes and quality during the design is beyond the scope of this paper.

Water quality at the landfill has been protected by implementing the following control measures to minimise leachate generation and minimise the transfer of leachate into surface water and groundwater.

- i) Diversion of all stormwater around the site.
- ii) Staged operation of the landfill in a series of cells which are capped and rehabilitated as they are completed.
- iii) Minimising seepage of leachate through the base of the landfill cells by construction of a low permeability liner using the on-site weathered sedimentary rock. The liner can also attenuate contaminants such as metals in the leachate which could pollute the groundwater.
- iv) A leachate collection system to remove leachate from the cells to maintain low hydraulic head on the liner

- v) Progressive capping of the landfill cells to promote runoff and minimise leachate generation. The capping consists of about 500 mm of low permeability soil overlain by topsoil and with a minimum surface gradient of 5%. The cap will be revegetated as part of the site rehabilitation.

The following sections of this paper focus on the above item iii) as one of the major geotechnical aspects in the overall landfill design.

### **Requirement for a Low Permeability Liner for the Landfill Cells**

The siltstone/sandstone at the site has well developed bedding that dips near vertically. It was considered that this could potentially allow locally rapid infiltration of leachate and allow concentrations of leachate along the preferred flow paths. Therefore it was considered necessary to disrupt any preferred flow paths, to limit permeability and to provide an attenuating layer. Based on the quality of groundwater leaving the site and the potential beneficial uses of the water it was considered that an appropriate level of protection would be provided by the construction of a 600 mm thick liner in the base of the landfill cells with a minimum median surface permeability of  $1 \times 10^{-8}$  m/sec. This was a requirement of the EPA Works Approval for the landfill.[2]

### **Material Selection**

It was considered that in the absence of sufficient quantities of suitable on-site clays that the on-site weathered siltstones and sandstones were the most cost effective materials to construct the liner. Preliminary laboratory testing indicated that the target hydraulic conductivity requirements could be met provided that the rock is ripped and compacted to achieve a Dry Density Ratio (AS 1289.5.4.1) of at least 95% Standard (AS 1289.5.1.1) and at a moisture content of not less than optimum (OMC).

### **Liner Construction Trials**

A construction trial was performed to assess construction methods that could satisfy the permeability requirement for the liner using the on site weathered rock and produce a specification for the liner construction. A 600 mm thick trial pad measuring about 21 m x 12 m overall was constructed in three layers. The following construction procedure was found to be satisfactory to meet the permeability requirement.

- rip the weathered siltstone and sandstone to a depth of about 600 mm. Track roll with a bulldozer to assist in breaking down the rock.
- stockpile the ripped material.
- moisture condition to just wet of OMC by spraying water from water truck and continually mixing with the dozer until evenly mixed.
- spread out moisture conditioned material and compact with eight passes of Dynapac 10 tonne vibrating padfoot roller.

Field density, laboratory classification and grading tests were performed on the compacted materials. The compacted material can be characterised as a Sandy Gravelly Clay of low plasticity. The fines had a Plasticity Index of about 6 %, Liquid Limit of about 22 %, linear shrinkage of about 2 to 3 % and moisture content of between about 11 % and 15 %.

The median vertical permeability of the trial pad was found to be  $4.0 \times 10^{-9}$  m/s. This is less than the minimum of  $1 \times 10^{-8}$  m/s required by the EPA Works Approval. The method of permeability testing is described in the following section.

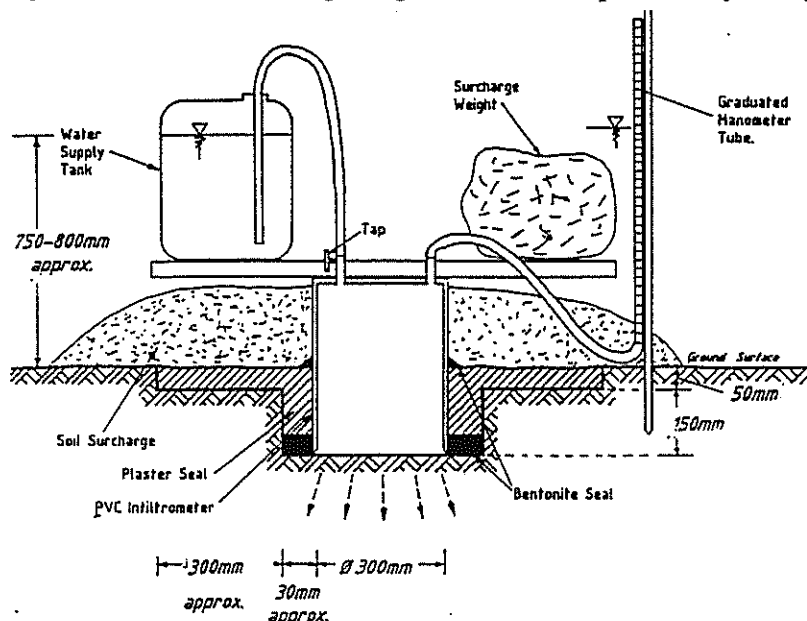
It was concluded from the Liner Construction Trial that the requirements of the EPA Works Approval could be met using the on site siltstone and sandstone materials as a base liner for the proposed landfill cells subject to the liner being constructed to meet specified requirements for relative density, moisture variation and particle size distribution as outlined below.

### **Permeability Testing**

The single ring infiltrometer permeability test was considered to be the most appropriate to measure permeability to meet the Works Approval requirement. Laboratory permeability testing of undisturbed samples was initially considered but because of the nature of the material and the range of particle sizes it would not have been practical to recover and test representative samples.

The infiltrometer set up is shown in Figure 2. It consists of a 300 mm diameter, 400 mm long P.V.C. tube sealed at one end and with a bevelled cutting edge at the other. The tube is seated into the bottom of a shallow flat based hole excavated to a depth of about 200 mm below the surface. The annulus around the PVC tube is then backfilled with bentonite and plaster to provide a seal. Soil is then mounded over the seal and surrounding ground to provide a surcharge.

Figure 2. Cross section of single ring infiltrometer for permeability testing



The infiltrometer is filled with water and connected to a water container to maintain a constant head. Also connected to the top of the infiltrometer is a graduated manometer tube. The test area inside the infiltrometer is saturated for about 24 hours and then a flow measurement is taken by turning off the water supply and measuring the fall in water level in the manometer tube over time (generally 30 minutes). The test procedure is repeated several times at intervals greater than 1.5 hours to monitor any change in the rate of infiltration.

#### Specification for Construction of the Landfill Cell Base Liner

Construction of the landfill cell base liners was specified to be as follows

- i) Maximum layer thickness of 200 mm after compaction.
- ii) The liner material shall be compacted to a Hilf Density Ratio (Rapid Method) AS1289.5.7.1-1993 of not less than 95% STANDARD.
- iii) The moisture content of the compacted material shall be between 0% to 3% Wet of the Optimum Moisture Content. Testing was in accordance with the Hilf Moisture Variation (Rapid Method) AS1289.5.7.1-1993
- iv) The particle size distribution of the compacted material shall have greater than 70% of material passing the 2.36 mm sieve and greater than 35% of material passing the 0.075 mm sieve. Testing is to be in accordance with AS1289.C6.1.

Compliance testing to be undertaken at the completion of each 200 mm layer at a rate of about 10 tests per hectare to assess compliance with items i), ii) and iii) above. Five field permeability tests were carried out per cell on the completed cell base liner to confirm that the required permeability had been achieved.

#### Construction Method

The 600 mm thick base liner for the landfill cells No. 1, 2 and 3 was constructed by Leech Earthmoving Pty. Ltd., Castlemaine. Each cell had a base area of between about 0.6 and 0.9 hectares and was constructed in two stages (Stage A and B). The cell locations are shown on the Site Plan, Figure 1. The other four landfill cells are proposed to be constructed at a later date. Site equipment generally included a bulldozer, scraper,

water truck and vibrating padfoot roller. A grader was used at times to trim embankment slopes and areas subject to overfilling. The preparation of a 200 mm layer over an area of about 0.7 hectares generally took about 1 to 1.5 days.

After initial surface preparation the following construction procedure was considered to be the most effective and efficient by the contractor.

- Rip the weathered siltstone with a bulldozer and break up the ripped rock by track rolling with the bulldozer and with passes with the vibrating pad foot roller.
- Transfer to base of landfill cell using a scraper. Spread out the material in thin layers of about 50 mm thickness.
- Add moisture by spraying with one pass of water truck at the top and bottom of each 50 mm layer. Tying was sometimes required to assist in achieving an even mix.
- Compact with about four passes of vibrating padfoot roller.
- At the end of each day or 200 mm layer seal the surface with the wheels of a fully laden scraper. Before placing further material the surface was pricked with the pad foot roller to prevent laminations and assist the bonding between layers.

### Results of Compliance and Permeability Testing

The results of permeability and the compliance testing are summarised in Table 2 below.

Table 2 . Summary of compliance and permeability testing for the landfill cell base liner, Castlemaine landfill

CELL	SPECIFICATION	1A and 2A	1B and 2B	3A	3B	overall
Number of tests		21	21	15	12	69
HILF DENSITY RATIO (% Standard) - range of results - mean	>95%	95 to 98.5 96.9	93 to 98 96.3	95.5 to 101.5 99.3	97 to 101.5 98.5	93 to 101.5 97.8
VARIATION FROM OPTIMUM MOISTURE CONTENT (OMC) - range of results (% Wet) - mean (% Wet)	0 to 3% Wet	0.5 to 3.0 1.7	0 to 3.5 1.0	0 to 3.5 2.1	0 to 2.5 1.58	0 to 3.5 1.6
PARTICLE SIZE DISTRIBUTION						
% passing 19.0 mm - range of results - mean	not specified	90.0 to 98.4 95.2	87.4 to 99.1 96.1	97.9 to 98.8 93.8	81.9 to 96.3 90.4	81.9 to 99.1 93.9
% passing 2.36 mm - range of results - mean	>70%	73 to 90 80.5	72.4 to 91.3 83.9	60.5 to 84.5 70.6	56.3 to 74.1 65.3	56.3 to 91.3 75.1
% passing 0.075 mm - range of results - mean	>35%	54.6 to 71.6 61.2	38.8 to 71.1 58.7	38.6 to 64.3 53.6	41.4 to 58.3 48.9	38.6 to 71.6 55.6
MEDIAN PERMEABILITY (m/s)	< 1.0 x 10 <sup>-8</sup>	8.8 x 10 <sup>-9</sup>	4.0 x 10 <sup>-9</sup>	4.4 x 10 <sup>-9</sup>	7.3 x 10 <sup>-9</sup>	4.2 x 10 <sup>-9</sup>

### DISCUSSION

Construction to meet the specified requirements for relative density, moisture conditioning and particle size distribution resulted in a liner with median permeability of not more than  $1 \times 10^{-8}$  m/sec. As a point of comparison the permeability of the leachate pond liner constructed from the on-site clays was measured to be between  $1.4 \times 10^{-11}$  m/sec and  $4.8 \times 10^{-11}$  m/sec. The decision to construct a trial pad prior to bulk earthworks at the site had proven to be very effective and useful. Based on the permeability results being close to the required minimum, it was evident that it was critical to enforce the specification requirements noted above. A general trend was noted that the greater the breakdown of the weathered rock to material passing the 0.075 mm sieve, the lesser was the permeability.

Difficulties were experienced with variations in the degree of strength and weathering in the rock across the site. Rock from several areas proved to be more difficult to break down than from other areas. It was suggested by the contractor that the materials used in construction of the test pad may not have been representative of some others at the site. Could it be argued that the variability was not adequately accounted for at the planning and design phase of the project? Or was it more an issue of how the contractor planned and managed sourcing of the rock? Ultimately this issue was resolved by allowing some flexibility with the location of sourcing the more suitable lower strength rock across the site. Similarly, there was also some flexibility with the design subgrade levels for the cell bases to allow sourcing a greater quantity of suitable rock from these areas if appropriate. This prevented effective burial of suitable source rock beneath the cells.

The project enhanced my understanding of the nuts and bolts of construction. This includes the practicalities of what can and cannot be achieved in the field. The two issues raised above are examples of situations when it is paramount to enforce specified requirements and others when they can be interpreted in a more flexible manner. A key to the whole process is to have a superintendent who can make clear, impartial and resolute decisions. This requires a sound understanding of the engineering and contractual issues as well as excellent communication and people skills. Mr. Malcolm Styles of the City of Castlemaine fulfilled this role admirably.

### CONCLUSION

The new Castlemaine landfill was designed in accordance with strict environmental and regulatory requirements. The site hydrogeology indicated that the design needed to incorporate various control measures to protect the beneficial use of the regional groundwater as stockwater. One of the main geotechnical control measures involved lining the base of the landfill cells with a low permeability liner by ripping, breaking down, moisture conditioning and compacting the on site weathered sedimentary rock. Construction was performed in accordance with specified requirements for relative compaction, moisture conditioning and particle size. The target permeability requirement stipulated in the Works Approval of not more than  $1 \times 10^{-8}$  m/sec was achieved. In general, construction proceeded smoothly and was completed within the estimated timeframe and budget. The landfill is now operating successfully. On a personal level the project was an excellent opportunity for the author to be involved with current practice in landfill design. It also provided valuable hands on experience with laboratory and field geotechnical testing techniques. My site role gave me exposure to what I like to refer to as the 'nuts and bolts' or the day to day practical issues related to construction. These are not necessarily technically based but of no less importance in the construction of a large earthworks project.

### ACKNOWLEDGEMENTS

The author would like to thank Mr Malcolm Styles from the Wangaratta Rural City Council (formerly City of Castlemaine) and Mr Peter Thornton of Golder Associates for their assistance during the project and for permission to base this paper on the project.

### REFERENCES

1. Protection Authority Victoria 1991. *State Environmental Protection Policy (Siting and Management of Landfills Receiving Municipal Wastes)*, Victorian Government Gazette No.S40
2. Environment Protection Authority Victoria 1992. *EPA Works Approval WA 1584*, Environment Protection Authority Victoria, Melbourne
3. Farquar G.J.1987, Leachate: Production and Generation, *Proceedings of the Canadian Society for Civil Engineering Centennial Conference, Montreal*
4. National Health and Medical Research Council 1990, *National Water Quality Guidelines Draft*
5. Parker, R J and Thornton, P N 1994. *Landfill Design - Controlling Leachate*, Papers for ACADS/AGS Geotechnical Landfill Design Seminar, Melbourne
6. Thornton, P N, Kerby, N E and Styles, M D G 1994. Evolution of a Landfill, Castlemaine Victoria, *Proceedings of the Second National Hazardous and Solid Wastes Convention, Melbourne*