HOROTIU LANDFILL STAGE 6B: DESIGN, CONSTRUCTION & CONSTRUCTION QUALITY ASSURANCE

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ABSTRACT
The design, construction and CQA of the 2.9ha extension to the Horotiu landfill, near Hamilton, are described. The landfill has a composite liner comprising a 1.5mm HDPE FML, over a GCL, over a 350mm Compacted Clay Liner. Leachate drains into the sand blanket and gravel strip drains on the base of the landfill, into a longitudinal central leachate drain, then to a 1.5m diameter HDPE leachate pump station at the low point of the landfill.

An additional 500mm thick compacted clay layer was incorporated into the design over the western part of the site, where the geotechnical investigation identified a layer of gravel near the ground surface. A plan to prevent uplift of the liner in the event of a flood on the Waikato River was developed.

The variable clay used for the clay liner required special procedures for compaction control. The value of professional independent CQA testing and observation was demonstrated by the high quality of the final construction and the straightforward final regulatory approval of the landfill.

1 INTRODUCTION

1.1 Location & Site History

The Horotiu Landfill is located approximately 15km north of Hamilton, between River Road and the Waikato River. The site was originally a sand mine which opened in the 1970's. Hamilton City Council (HCC) developed the landfill as the main municipal landfill for Hamilton's refuse. Filling starting in 1985 and since then approximately 1.7 million tonnes of municipal waste has been placed at the landfill, over an area of about 21 hectares.

The landfill has been designed and constructed in stages as the site developed, and the engineering design was altered to suit the site layout and changing landfill performance standards. The landfill is operated by Perry Environmental Services Ltd, and now accepts about 10,000 tonnes of refuse per month.

1.2 Stage 6 Resource Consents & Planning

Stage 6 of the landfill was consented in 1999, after an Environment Court appeal. The consents allowed for discharge of up to 933,500 tonnes of municipal solid waste until 31 December 2006, and imposed various conditions including:

- minimum specifications for liner and final cover,
- requirements for independent Peer Review of design, construction operation and monitoring of the landfill,
- contingency plans in the event of flooding and uplift of the landfill liner due to high river levels.

During the consent process it was recognised that a suitable level of environmental protection was required due to the landfill's close proximity to the Waikato River and the lack of natural containment. HCC planned to construct Stage 6 in up to 3 cells, and the first cell (Stage 6a, approximately 3ha) was opened in 2002. The new cell filled much quicker than expected, and in late 2004 HCC engaged Opus International Consultants Ltd (Opus) to investigate and design a new cell (Stage 6B) to provide Quality Assurance services for the construction.

2 GEOTECHNICAL ASSESSMENT

2.1 Site Geology

The geology of the site was described by the University of Waikato (1997) as Taupo Pumice Alluvium overlying Hinuera Formation. Most of the Taupo Pumice Alluvium has been removed as part of the previous sand mining. The Hinuera formation comprises mainly sands and gravels, interbedded with silt and some peat. Since deposition ceased about 15,000 years ago, downcutting by the Waikato River created a low level terrace, before continuing to its present entrenched position.

2.2 Sub-surface conditions

Geotechnical investigations were undertaken as part of the consent process and specifically for Stage 6B (Opus 1997, 1998, & 2005b) and included boreholes, test trenches and cone penetrometer tests. The sub-surface conditions within Stage 6B comprise interbedded sands and silts of the Hinuera Formation and Taupo Pumice Alluvium, typical of the conditions encountered elsewhere at the site. A highly permeable sandy gravel layer, typically 1m thick, was encountered within about 0.5m to 1.5m of the surface over much of the western part of the site. The groundwater level is controlled by the nearby Waikato River and is typically within 1m to 2m of the mined ground surface.

3 DESIGN

3.1 Stage Capacity

HCC survey the operational landfill at least quarterly to determine the volume of airspace used within the period. This information, along with the weighbridge records, showed a total density of about 0.75 tonnes of refuse per m^3 of airspace was typically being achieved. From this information and their predictions of future refuse tonnages, HCC decided that Stage 6B should be designed to contain a volume of $315,000m^3$.

3.2 General Arrangement

To provide an efficient fast-track design, cost-effective construction, and to ensure compatibility with the adjacent stages and compliance with the consents, a general arrangement of the landfill similar to the previous stage was adopted. The general layout of the stage is shown in Figure 1 and shows:

- A relatively long narrow cell (approximately 275m long by 105m wide, about 2.9ha) perpendicular to the Waikato River
- The cell floor grading (2% transversely and 1% longitudinally) to a low point as far from the river as practical
- A single leachate chamber within the cell at the low point
- The liner no lower than RL11.5m, and containment bunds with a minimum crest elevation of RL15.6 to minimise the risk of flooding into the cell (Opus 2001).
- Internal bund slopes of 4H:1V, sufficiently flat to make installation of the clay and synthetic liners easier
- Refuse slopes of 9H:1V, expected to flatten to 10H:1V after refuse settlement.

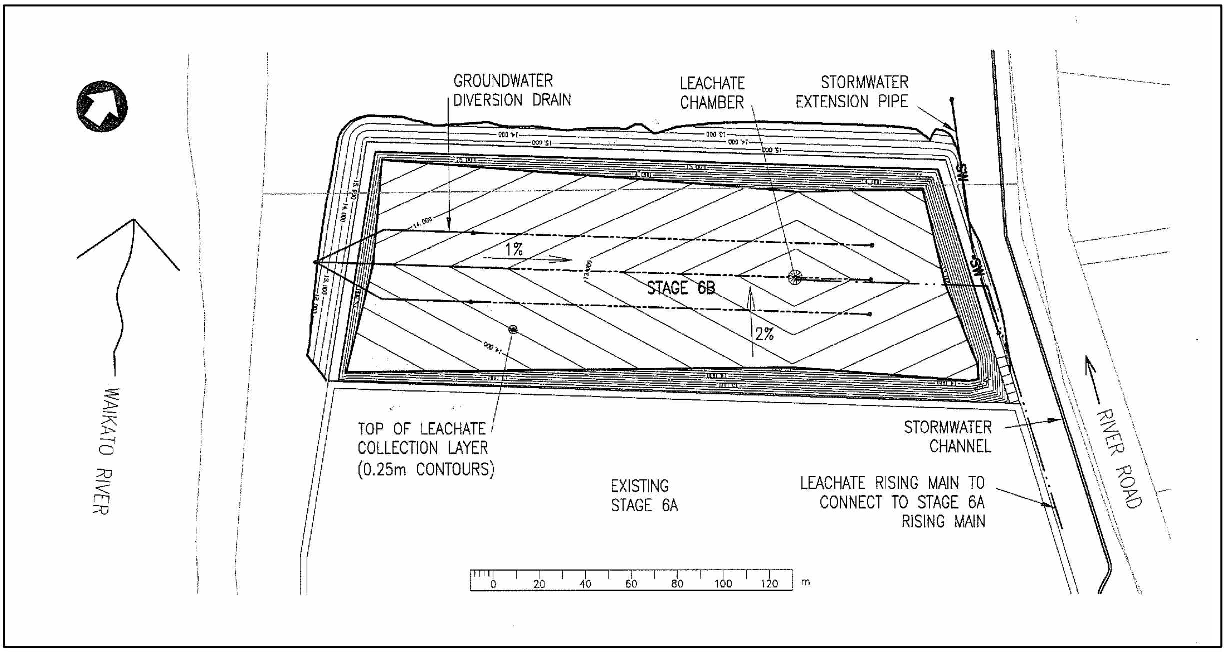

Figure 1: General Layout of Stage 6B

3.3 Seismic performance

The stability of the landfill under static and earthquake loading was examined in detail as part of the consent process (Opus, July 1998) and peer reviewed by Engineering Geology Ltd (1998). It was concluded that under the worst earthquake scenario (PGA=0.26g) some liquefaction of the soils underlying the landfill was likely and permanent displacements of the liner could be expected in that event. Although some damage to the liner system was likely, there was a low risk of leakage from the landfill due to earthquakes. This analysis was based on the adjacent Stage 4 of the landfill and was considered representative for Stage 6.

To mitigate the risk of liner damage, groundwater diversion drains (Beca 2000) were incorporated into the design of Stage 6B. These drains provide a means of sampling water from directly under the landfill to provide early indication of any liner rupture after an earthquake, and should also enable extraction of any contaminated groundwater by pumping from the drains to minimise the downstream effects. The groundwater diversion drains comprise three parallel 110mm diameter perforated HDPE pipes within trenches backfilled with drainage gravel. The drains were constructed under the landfill and are connected to a manhole within the western bund.

3.4 Staging

To ensure that construction of at least part of Stage 6B was completed prior to Stage 6A being full, Stage 6B was split into two roughly equal cells, separated by a temporary bund. The first cell has available airspace of 67,000m^3. The temporary bund was almost 2m high at its highest point, and was intended to contain leachate within the operating cell and prevent stormwater runoff from the adjacent area in to the operational cell. The bund was constructed out of sand later used for the leachate drainage layer, and was covered with FML. Once the remainder of the construction was complete the bund was removed.

3.5 Landfill Liner

The liner for the landfill comprises a:

- 1.5mm thick HDPE Flexible Membrane Liner (FML) textured on the bottom side only – manufactured by SL Chile, over

- Bentomat DN3 Geosynthetic Clay Liner (GCL) with a maximum permeability of 5×10^{-11} m/s , - manufactured by CETCO Technologies Ltd in China, over
- 350mm thick compacted clay liner (CCL) with a maximum permeability of 10^{-8} m/s.

3.6 Additional protection over western part of the landfill

The gravel layer encountered in the western part of the landfill, because of its relatively continuous nature and its higher permeability than most of the surrounding ground, could reduce leachate travel times to groundwater and the Waikato River if a liner breach and subsequent leachate leak were to occur. This increased risk was mitigated by incorporating an additional low permeability soil liner in this area to offset the higher permeability of the gravel layer. This additional liner comprises a 0.5m thick layer of clayey soils, compacted to a similar standard to the CCL and with a maximum permeability of 1×10^{-7}m/s.

3.7 Leachate Drainage & Management

The leachate drainage system must keep leachate depths below the 500mm permitted under the leachate discharge consent (Waikato Regional Council, 1999). The Stage 6A system (Beca, 2000) has performed well over the last four years so a similar system was adopted for Stage 6B. The leachate drainage system incorporates:

- Lateral floor slopes of 2% and longitudinal floor slopes of 1%
- A 300mm thick leachate collection layer of well graded sand/gravel
- Gravel strip drains in a herringbone pattern at 20m intervals across the base (normal to the contours). Bidim A44 geotextile under the gravel protects the liner from damage.
- A central 160mm diameter HDPE leachate collection drain
- a 1.5m diameter HDPE pump chamber at the low point.

Most of the concrete manholes in previous stages have suffered severe degradation due to chemical attack from the leachate. In other places the manholes (both concrete and HDPE) have tilted and separated at joints, probably due to a combination of differential downdrag as the refuse settles and lateral movement of the refuse. The chamber design for 6B is more resistant to these types of failure as it incorporates an HDPE shroud and is a thicker profile “Black Brute” pipe (SN10000, Profile 190). The design also incorporates an improved jointing detail using a spigot and socket joint with an internal weld acting as a butt surface, a full circumference external weld, and screws to act as locators and resist shear forces.

The 75mm diameter rising main connects to the existing rising main running between the landfill and River Road. The leachate is collected in two on-site retention ponds and then pumped to the HCC wastewater treatment plant for treatment and final disposal.

3.8 Liner Uplift Contingency Plan

The underside of the landfill liner is close to the normal groundwater level at the site. Until there is sufficient refuse on the liner, there is a risk that uplift and possible damage to the liner could occur if the groundwater level rose during a Waikato River flood. Uplift occurred during construction of a previous stage, with subsequent damage and repair costs.

The consents for the landfill recognised this potential and required the consent holder to prepare a contingency plan to manage this risk. The contingency plan (Opus, 2005a) outlines a procedure for automatic warning of high Waikato River level using the Environment Waikato Monitoring system, and a system of mobilising pumps to site with sufficient warning to be ready to pump water in the landfill if uplift is threatened. Flooding of the cell to prevent uplift was not required, although the lower trigger level to mobilise the pumps to site was exceeded a few times during the construction period. Once the refuse in the landfill reached sufficient height to counteract the potential uplift pressures, the contingency plan was retired.

3.9 Cover System

The following minimum interim cover for Stage 6 is specified in the resource consent (Waikato Regional Council 1999) and was adopted for Stage 6B. Within four years of completing filling, HCC are required to confirm the final cover system.

- 150mm of topsoil, over
- 600mm of compacted clay with a maximum permeability of 10^{-7} m/s, over
- 200mm of intermediate cover.

3.10 Gas Extraction

To manage odour and reduce greenhouse gas emissions, the consents required that gas be extracted from the landfill once it was capped. Waste Management Ltd (2006) designed the Stage 6B system, which uses vacuum to extract gas from bores and the leachate chamber. There is enough high quality gas being generated from the existing stages to enable electricity production using a 1MW co-generation engine, and Stage 6B will also supply to the engine.

4 CONSTRUCTION & CONSTRUCTION QUALITY ASSURANCE (CQA)

4.1 General

Perry Environmental Ltd were the main Contractor for the construction of the landfill and undertook the bulk earthworks for construction of the base, constructed the CCL and stormwater drainage works. Skellerup Ltd installed the GCL and FML, Brian Perry Civil Ltd installed the leachate drainage pipework and chamber, and Schicks Earthworks Ltd installed the leachate drainage blanket, all as sub-contractors to Perry. Perry Environmental Ltd engaged MWH to carry out day to day management of the construction project for them. Opus were engaged by HCC to provide independent Quality Assurance services, including on-site testing, construction observation and laboratory testing, to ensure the landfill was built according to the approved design.

Work began on site in March 2005, with the bulk earthworks for the base (45,000m3) completed in September, the CCL (10,000m^3) completed in February 2006, the GCL and FML (29,000m^2) installed by March 2006, followed shortly after by the leachate drainage blanket (9,000m^3). The first part of Stage 6B was approved to accept refuse in January 2006 and the second part was completed and approved in April.

4.2 Compacted Clay Liner

There was no suitable soil on site to construct the CCL, so overburden from a nearby quarry was used. The soil, mainly completely weathered Greywacke with some Ash, was tested prior to construction. Most of the tested soil was found to give adequate permeability, although some was too wet to use without significant drying.

The Contractor generally spread the delivered soil using a bulldozer then compacted it with an 18t sheepsfoot roller. Water carts were used to wet the soil when required, especially during summer when the exposed surface dried very quickly. Frequent re-work was needed to repair desiccation cracking. During winter, it was virtually impossible to dry the clay once it got too wet to compact, as the rate of drying was very slow and frequent rainfall re-wetted the soil. Drying was successful in summer. Thin plastic (silage wrapping) was used successfully to prevent drying of the CCL, and with somewhat less success to prevent wetting during rain.

The philosophy for the CQA of the CCL to verify the low permeability liner was well constructed was to:

- Ensure suitable soil was used, by source testing prior to construction and observation of soil delivered to site
- Ensure the soil was compacted well and at an appropriate moisture content by frequent Nuclear Densometer (NDM) testing
- Verify the permeability of the CCL by regular tri-axial permeability tests.

For most of the earthworks operations (eg: CCL construction), the Contractor determined by visual inspection and their compaction methodology when the work was ready for testing, and then requested QA testing and approval. This effectively meant the CQA testing was also used as Construction Quality Control (CQC) for the Contractor, which provided some overall efficiency.

Adequate compaction of the CCL was verified by max air voids of 5%, min of 100% of Standard compaction at the tested water content, and minimum corrected vane strength of 80kPa. The thickness (minimum 350mm) was verified by differences in survey from the underside to the finished level, and straight-edge testing to avoid ponding. Figure 2 summarises the compaction testing of the CCL and also illustrates the variability of the soils used. Oven water content tests were used to verify the sometimes unreliable on-site NDM measurements of water content. To avoid delaying construction while the lab testing was carried out, provisional approval of tests was given on the basis of the CQA staff's visual observations and NDM water readings. This worked reasonably well, with only occasional incorrect provisional approval then requiring re-work.

Only two of the 38 lab permeability tests on samples from the CCL exceeded the maximum permeability of $1x10^{-8}$m/s, both also failed the compaction testing. The areas were re-worked and then tested again and found to satisfy the compaction and permeability requirements. These results suggest the specification worked well.

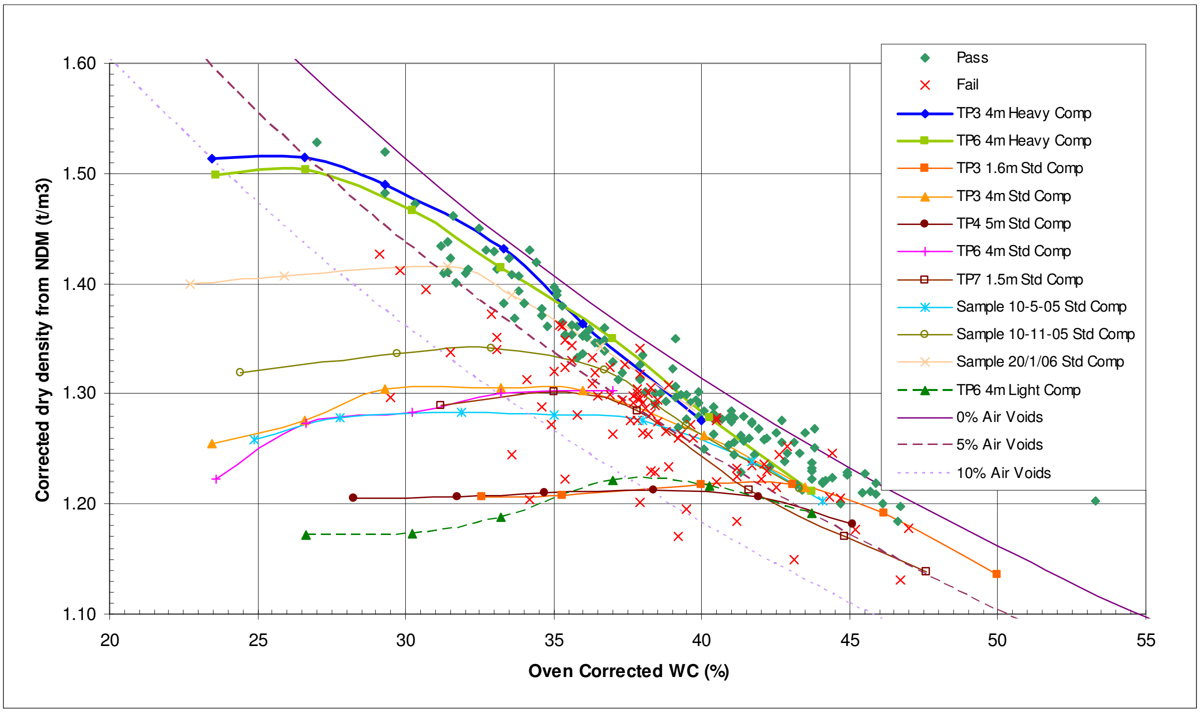

FIGURE 2: CCL Compaction Test Results

Figure 3: CCL during construction

Figure 4: Leachate drainage blanket, central drain, chamber, rising main and cable duct

4.3 Synthetic Liners

Some of the GCL had to be replaced soon after installation after it was found to have hydrated when stormwater from an adjacent unlined area ran under the liner. While hydration itself is not a defect, it softens the bentonite which displaces within the GCL when walked over and leaves thin spots.

Seaming the new FML to the existing FML from adjacent Stage 6A proved difficult as the old liner was very dirty and out of shape where it had been in the anchor trench. Isolated holes at the top of the adjacent liner were found where the drainage blanket was thin or non-existent, which appeared to be caused by damage from the refuse compactor.

The HDPE liner expands and contracts significantly as the temperature changes. Most of the leachate drainage blanket was placed at night when the cooler temperature reduces the development of wrinkles, avoiding the possibility of folds developing. As the leachate blanket was placed progressively, small wrinkles gathered. These were cut out and re-seamed.

Skellerup carries out their own extensive CQC for the FML installation, which involves regular trial welds with destructive testing before starting production welds, non-destructive testing for completeness of weld on every production seam using either air pressure testing of double wedge welds or spark testing of extrusion welds, and destructive strength testing of a proportion of the welds. Keeping good CQC records of the installation is a demanding role and needs a full time person on a busy site.

The CQA for the FML installation included thorough checking of the Skellerup's CQC records, detailed inspections of all seams, observation of welds to ensure good practice is being followed, and duplicate off-site destructive testing of some welds by the Opus Central Laboratory in Wellington.

Assuming the Contractor has the right equipment, then the skills and experience of the welder is the most important variable in obtaining a good seam. This is even more important for extrusion welds, which should be avoided unless necessary. Other countries (TWI, 2005) require HDPE welders to be formally trained and licensed. Although this system could be difficult/expensive to impose in a small market like New Zealand, this requirement should be considered further, probably by the NZ geosynthetics industry, to provide a higher level of confidence in welder skill.

4.4 Leachate Drainage

Placing the leachate drainage blanket was fairly straightforward and went well. Figure 4 shows a photo of the drainage blanket, the central leachate drain and chamber, the rising main and electrical duct and the herringbone gravel drains.

4.5 CQA Summary

Any defective work that could not be repaired on the day it was observed was covered by a Corrective Action Request (CAR) issued to the Contractor. Sixty-six CARs were issued during construction mainly associated with inadequate compaction of the CCL and defects in the FML installation. Regular progress reporting during construction kept all parties, particularly EW and the Peer Reviewers, informed of issues as they developed. This resulted in a successful no-suprises environment and straightforward final approval of the landfill to accept refuse.

5 DISCUSSION

5.1 CQA engaged by the Contractor or Client

EW required independent CQA for the landfill, to provide a higher level of confidence that the landfill had been constructed correctly. For previous stages of Horotiu construction Opus was engaged by the Contractor to provide the CQA observation and testing services. This enabled some efficiency to be gained in using the resources already on site for CQA to carry out CQC work for the Contractor. For Stage 6B HCC engaged Opus directly, with the aim of removing from the contractors pricing a significant cost that is external to their main business, hopefully resulting in contract cost savings to HCC. However, HCC then became subject to the cost of re-tests for failed construction, that may have eventually offset any saving.

A more equitable arrangement has been established for the ongoing final capping work at the landfill, which involves the CQA Consultant being engaged and paid by HCC, but re-tests of failed construction are recorded separately and the costs are claimed back from the Contractor.

5.2 Specification for CCL using a variable source of clay

Conventional specifications for compaction control of clay require a minimum percentage of maximum dry density at Standard compaction to be achieved, and the compacted water content to be within some range of the optimum water content. The compaction properties and natural water content of the source soil for the Horotiu CCL are highly variable (eg: optimum water contents vary from 30% to 45%, natural water contents from 27% to 53%) which effectively make the conventional type of specification unworkable for this material. We successfully adopted a specification which manages this inherent variability in the source soil by controlling the compaction by air voids (maximum 5%), minimum percentage (100%) of

Standard dry density at the compacted water content, and a minimum Pilcon vane strength (80kPa).

5.3 On-site CQA observation during Construction

The role of the CQA consultant is to independently certify that the landfill has been constructed in accordance with the design (drawings, specifications etc). While the independent on-site and laboratory testing (eg: compaction and permeability testing of CCL) are a vital part of that role, it is equally important that the CQA consultant have frequent visits to site to observe the construction practice. This enables reasonable testing frequencies to be adopted while still providing confidence that the construction is satisfactory.

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