Innovative design for landfill caps: a case study of the City of Ottawa's Trail Road Landfill

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ABSTRACT
As part of the interim closure of Stages 3 and 4 for the Trail Road Landfill site, the City of Ottawa decided to install a low-permeability geosynthetic cap in order to minimize infiltration and leachate generation. The design service life for the interim cap was required to be a minimum of 15 years. This is the estimated time before operations in these stages would resume, in accordance with the plans for vertical expansion of the landfill as granted by the Ontario Ministry of the Environment. Various interim cap options were considered at the conceptual design stage, ultimately leading to the selection of an exposed geomembrane cover. This paper discusses the interim cap system selection process as well as associated design challenges such as the design of the wind uplift countermeasures to prevent excessive vertical and lateral movement of this 320,000 m^2 (32 hectare) cap as well as the challenges associated with stormwater management. An interim progress report of the site works that began in late 2007 is also presented.

RÉSUMÉ
Par suite de l'interruption provisoire des étapes 3 et 4 du projet du site d'enfouissement Trail Road, la Ville d'Ottawa a décidé d'installer sur le site un dispositif de recouvrement à faible perméabilité afin de réduire au minimum les infiltrations d'eau et la production de lixiviats. La durée de vie du recouvrement choisi devait être d'au moins 15 ans. C'est en effet la durée prévue de l'arrêt des travaux, selon les plans d'expansion verticale du site élaborés par le ministère de l'Environnement de l'Ontario. Après l'examen de plusieurs options, le choix s'est arrêté sur une géomembrane de recouvrement. Ce document décrit le processus de sélection du système de recouvrement ainsi que les défis que présentait le projet, notamment sur le plan de la conception de mesures visant à contrer le soulèvement sous l'action du vent et atténuer le mouvement vertical et latéral de la membrane de 320 000 m^2 (32 hectares), ainsi que les problèmes associés à la gestion des eaux pluviales. Nous présenterons aussi un rapport d'étape provisoire des travaux, qui ont débuté à la fin de 2007.

1 INTRODUCTION

The Trail Road Landfill is the City of Ottawa's primary landfill site and has been operated by the local municipal government since it was opened in May of 1980. The landfill footprint covers a total area of approximately 65 hectares and was developed in four stages. Stages 1 and 2 are unlined landfill cells and Stages 3 and 4 are engineered landfill cells underlain by a low-permeability liner and leachate collection system. Early in 2000, the City of Ottawa undertook an Environmental Assessment (EA) for an expansion of the site given that the last stage was fast approaching its approved limit. Site expansion plans were approved by the Ministry of the Environment in 2005 for the vertical increase of Stages 1 through 4. Although Stage 4 was the active landfilling area at the time, City staff decided to complete the vertical expansion of Stages 1 and 2 in anticipation of potential future urban growth immediately to the east of the landfill site. Providing a temporary cap on top of Stages 3 and 4 would significantly reduce leachate generation at the site and the need for off-site haulage while Stages 1 and 2 were being vertically expanded. The minimum service life of the temporary cap is estimated to be 15 years.

2 DESIGN OBJECTIVES

Overall objectives for choosing the interim cap included selecting a cost effective low-permeable interim cap for Stages 3 and 4 that would result in the reduction of leachate generation at the site for a period of at least 15 years. The interim cap was also required to be compatible with the newly installed gas extraction well network that supplies gas to an on-site power generation facility. The cap was designed to provide access routes for all terrain vehicles to service the gas extraction wells that are located on top of Stages 3 and 4. Other design considerations included upgrading the existing site drainage network and the ability to easily remove the cap upon re-opening Stages 3 and 4 to continue with the vertical expansion plan in these Stages.

3 CONCEPTUAL DESIGN

During the site expansion EA process, it was determined that limited quantities of clay were available in the area for the construction of a low-permeability soil cap. As such, the conceptual design considered either a buried geosynthetic barrier layer or an exposed geosynthetic cap. An exposed geosynthetic cap offered several advantages over a buried barrier layer including: no concern for slope stability of materials overlying the barrier layer; minimized maintenance requirements (i.e., no concern for erosion of surficial cap materials and no care of vegetated cap); and, lower costs for removal of the interim cap (i.e., no cover soils to be excavated).

As with any low-permeability cap design, the conceptual design needed to consider the potential for significant and differential waste settlement due to decomposition of heterogeneous waste materials, variable compaction rates, etc. As such, a relatively flexible cap material was desirable.

With an exposed geomembrane interim cap, wind uplift was identified as a critical design element. Given the design objective to provide access routes to the landfill gas extraction wells, the conceptual design included the use of pathways for both travel routes and for ballast against wind uplift.

4 SELECTION PROCESS

A unique two-stage selection process was employed to achieve the desired end product for the landfill owner. The first part of the process was a Request for Proposal that allowed companies to propose various capping technologies. The cap and installer were then pre-selected for inclusion into a General Contract. The second phase was a General Contract that included the supply and installation of the pre-selected cap along with all of the necessary drainage and earthworks.

4.1 Request for Proposal

The preliminary design had identified that the preferred concept for the interim landfill cap was an exposed geomembrane. A Request For Proposal (RFP) was used to select the geomembrane and the supplier/installer of that product. The RFP provided the terms of reference for capping including the purpose of interim cap, approximate areas and interim grades for cap, proportion of top slopes versus side slopes, typical cap cross section, and performance requirements of the geomembrane.

4.2 Evaluation Criteria

The evaluation criteria were divided into two basic sections, a technical proposal and a price proposal. As part of the technical proposal, proponents were evaluated on the following criteria:

i. Products and construction method including any protective materials such as geotextile, modifications to typical cross sections, quantities of geomembrane with allowance for seaming, seaming methods, equipment and training, Quality Assurance / Quality Control (QA/QC) requirements, accommodation of heavy equipment access, construction schedule, and seasonal considerations.
ii. preliminary details for anchoring, resistance to wind uplift, penetrations by leachate and gas structures, and protection for foot / All Terrain Vehicle (ATV) access paths to landfill gas wells
iii. removal and options for reuse/recycling/disposal
iv. warranty and demonstrated service life
v. corporate profile, key staff, experience, and project references.

The price proposal was evaluated on the following items:

i. 2007 supply and installation unit price
ii. 2008 supply and installation unit price
iii. Provisional price to extend the weathering warranty to 15 years
iv. Provisional price to insure the 15 year warranty.

The proposals received were scored on the five technical proposal items and the four price proposal items. 60 out of 100 points were available for the technical items, and 40 points for price items.

4.3 Selection of Optimal Solution and Award

Proposals were received from four proponents. Each proponent identified alternative geomembrane products and/or alternative thicknesses of geomembrane for the cap. A selection committee then performed a thorough review of the proposals and evaluated them based on the criteria noted above, awarding points for each category. Proposals were deemed to be worthy of further evaluation provided they received at least 45 points (out of possible 60 points) in the technical items.

Layfield proposed two alternative geomemrbane products: High Density Polyethylene (HDPE 30) and 30-mil Enviro Liner 6030 (EL6030).

Layfield recommended HDPE 30 as the lowest cost geomembrane that met the Owner's minimum specified performance requirements in the RFP. HDPE 30 has an approximate service life of 15 years in exposed conditions as was specified, however, an extended 15-year warranty was not available in the 30 mil thickness.

EL6030 was found to be a superior choice for this landfill cap as it exceeded the provisional requirement for an extended 15 year exposed weathering warranty. For this project, the material warranty was extended to 20 years. For exposed use, EL6030 was found to be the most durable flexible liner of equal thickness due to a special additive package of UV stabilizers and antioxidants

Enviro Liner's other important qualities for this project are its flexibility and ability to remain intact through excessive elongation. EL6030 is a flexible membrane liner (FML), giving it a number of advantages over stiffer products like HDPE. Firstly, EL6030 can be factory prefabricated into large panels and folded without damaging the membrane. HDPE cannot be folded and must be entirely field fabricated, increasing risk to quality, safety, and productivity. Also Enviro Liner's flexibility makes it immune to environmental stress cracking, a failure pattern associated with highly crystalline materials like HDPE. With elongation at break of more than 800%, and actual measured values often exceeding 1000%, EL6030 has significant ability to accommodate subgrade settlement. Finally, studies of realistic puncture mechanisms (such as truncated cone testing) repeatedly show that Enviro Liner's high elongation properties make it tougher to puncture than higher tensile, but stiffer materials. Table 1 illustrates a comparison of the physical properties for different geomembrane materials.

Table 1 Comparison of Geomembrane Properties

Property	ASTM STD	ENVIRO LINER EL6030	HDPE 30	HDPE 40	HDPE 50
Thickness (Nominal)	D5199	30 mil	30 mil	40 mil	50 mil
Tensile Strength at Break [1]	D638 for EL D6693 for HDPE	115 ppi	114 ppi	152 ppi	190 ppi
Elongation at Break[1]		800%	700%	700%	700%
Tear Resistance	D1004	16 lbs	21 lbs	22 lbs	35 lbs
UV Resistance 20,000 hours (Black Styles Only)	G154 % Retained	90.5%			
Exposed Warranty		20 yr	5 yr	10 yr	15 yr

1. Strain rate: EL6030 per ASTM D638 is 20" per minute. HDPE 30 per ASTM D6693 is 2" per minute. Slower strain rates for HDPE result in breakage at higher percent elongation.

5 FINAL DESIGN CHALLENGES

There were several unique challenges faced by the design team on this project. Key challenges included wind uplift countermeasures, gas well access paths, connection details for vertical pipe penetrations and design of a perimeter collection ditch.

5.1 Ballast System Design

The design of the ballast system, which consisted of a series of granular-filled ballast trenches, anchor trenches and landfill gas well access paths, was based on uplift predictions using equations in Giroud et al. (1995). The design wind speed was in excess of 90 km/h. The elastic properties of the EL6030 were viewed as favourable from a durability perspective (e.g., in accommodating differential settlement, etc.), however they also contributed to relatively large potential uplift values. At the design wind speed it was predicted that the geomembrane could lift by between about 5.5 to 7.5 metres at a spacing between anchor/ballast trenches of between 25 metres and 35 metres. With this relatively close spacing for ballast requirements, the ballast network was simplified on the side slope portions of the waste mound by designing only a few across-slope ballast trenches instead of multiple trenches running up and down the side slopes. On the top portion of the waste mound, the number of required ballast trenches was decreased by designing the landfill gas well access paths to also provide adequate ballast. The ballast network is illustrated in Figure 1.

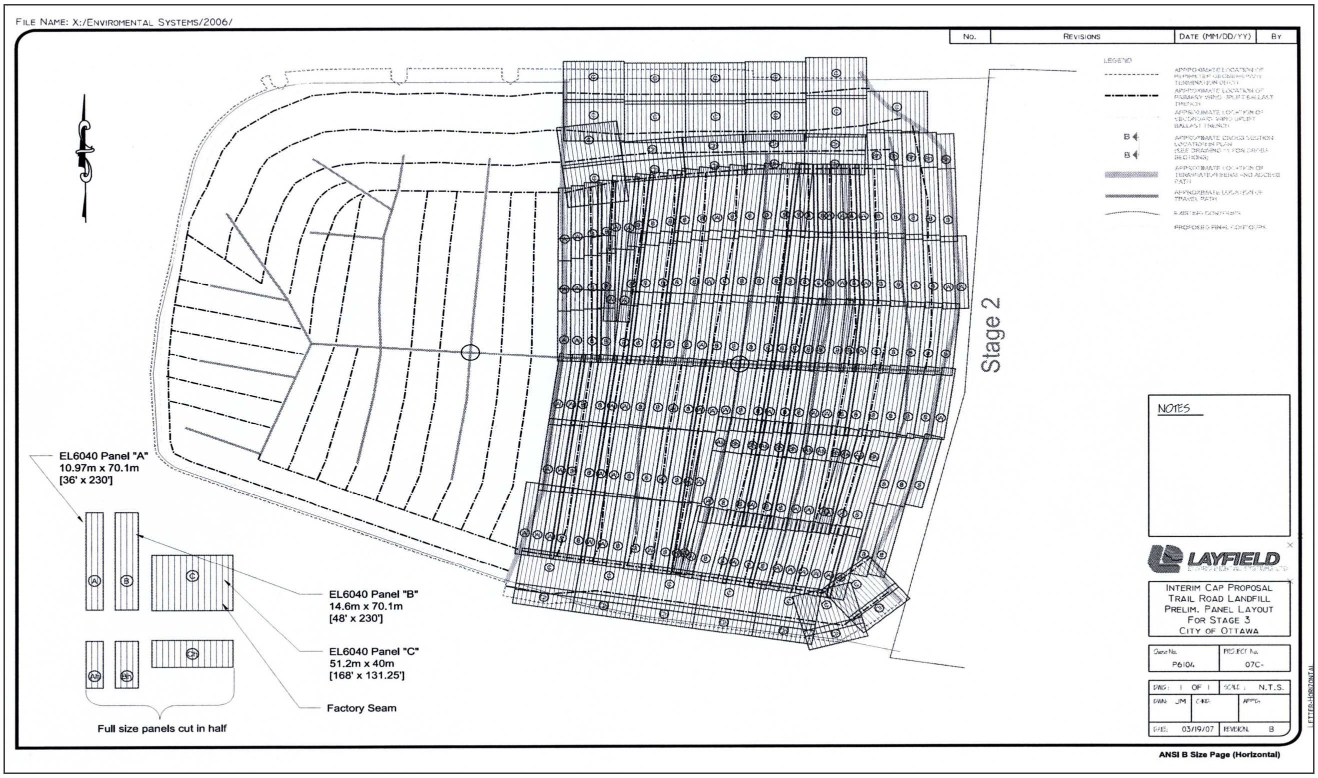

Figure 1 Geomembrane Panel Layout and Ballast Network

The flexibility of the EL6030 product facilitated a unique ballast trench design where encapsulation was achieved by placing the geomembrane down one side of the ballast trench and across the bottom, then folding the geomembrane back across itself and over the granular ballast material after the trench had been filled. A typical wind uplift ballast trench is illustrated in Figure 2.

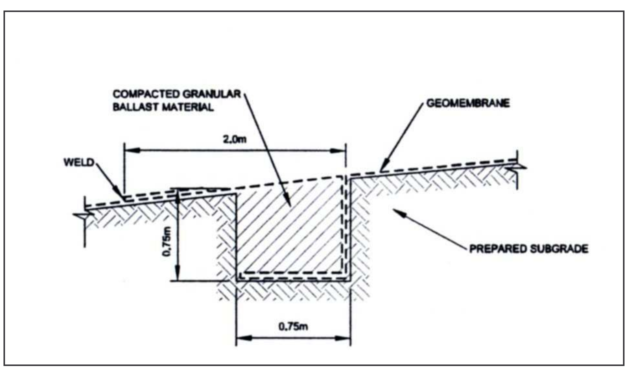

Figure 2 Primary Wind Uplift Ballast Trench

5.2 Access Path Design

The landfill gas well access paths were recessed into the cap to provide a degree of lateral containment for the exposed granular path base material. A geocomposite was incorporated into the design to facilitate drainage from the ends of the paths (see Figure 3).

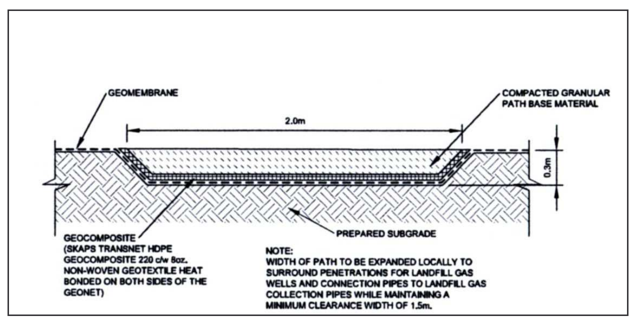

Figure 3 Access Paths to Gas Wells

5.3 Geomembrane Panel Layout and Installation

The geomembrane panel layout (Figure 1) was a complex undertaking that went through numerous iterations due to the highly irregular shape, grade changes and numerous trenches. The use of roll stock material was considered, however, it was determined that this would defeat one of the primary advantages of using Enviro Liner, factory pre-fabrication. A final panel layout was determined using three standard panel sizes. This would minimize time spent in the field sorting individual panels, as well as eliminate the need to carefully coordinate fabrication and shipping of particular panels to meet the field placement plan. One drawback of this plan was higher waste factors due to the complexities of the area and the "standard" panel size type layout.

The design required close cooperation between the General Contractor and the Liner Installer since any disturbance to the prepared bedding material by heavy equipment would need to be repaired prior to liner installation. Few past projects have required both contractors to work so closely together. As indicated above, the process involved the General Contractor excavating an anchor trench (see Figure 2), the Liner Installer placing a liner panel then folding it back. While the General Contractor backfills the trench, the Liner Installer moves to the next area to install more material. This process meant that the Liner Installer had to work in two or more areas at the same time to maintain a continuous work flow. This further substantiated the need for standard panel sizes in the original layout.

Due to the exposed nature, 15 year warranty requirement, and liner size, increased manufacturing and fabrication testing was requested. This included increased frequency of Enviro Liner physical property testing and testing of all shop seams. Project specific low temperature brittleness and UV test results were required. The Consultants have full time QC personnel on site, as well as Layfield's designated QC technician.

5.4 Site Drainage

The site drainage network was originally sized for a final cap placement over Stages 3 and 4 that would incorporate a vegetated cover. Therefore, the site drainage network needed to be re-sized to accommodate the significant additional storm runoff generated by the exposed low-permeable interim cap. Culvert crossings in the existing outside perimeter ditch were replaced with larger concrete box culverts. The existing perimeter ditch grades at the north end of the landfill site were virtually flat and there was no opportunity to increase the grade due to existing infrastructure already in place. Therefore, this portion of the ditch was lined with the EL6030 material due to the low roughness coefficient thereby minimizing the size of ditch required to convey the additional flows from the capped portion of the site. Lining the ditches with the EL6030 material also helped to protect the drainage ditches from erosion during severe storm events and the spring thaw. The site stormwater management pond was also fitted with an outlet control structure to limit the amount of runoff leaving the site during the interim cap condition.

Other unique design features included the use of granular-filled ballast tubes in the portions of the drainage ditches that were lined with EL6030 and to minimize stress to the liner around pipe penetrations in the event that wind uplift were to occur at these locations (see Figure 4). In addition, careful consideration was needed in extending the geomembrane cap around and past existing leachate collection system access pads (see Figure 5).

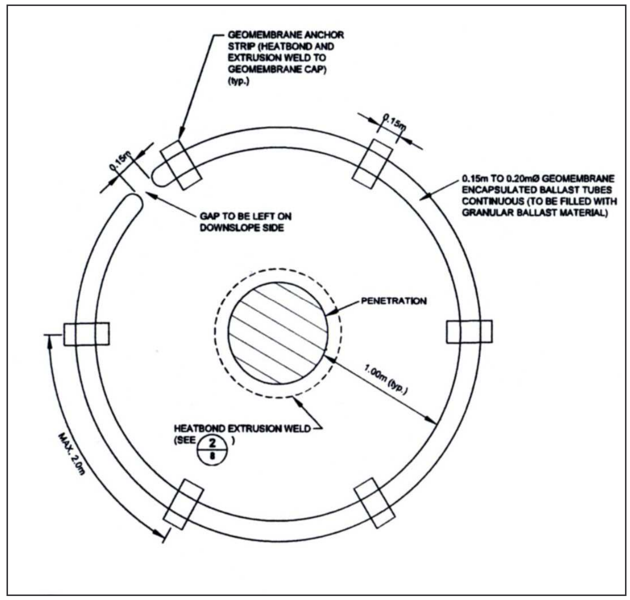

Figure 4 Ballast Detail at Pipe Penetrations

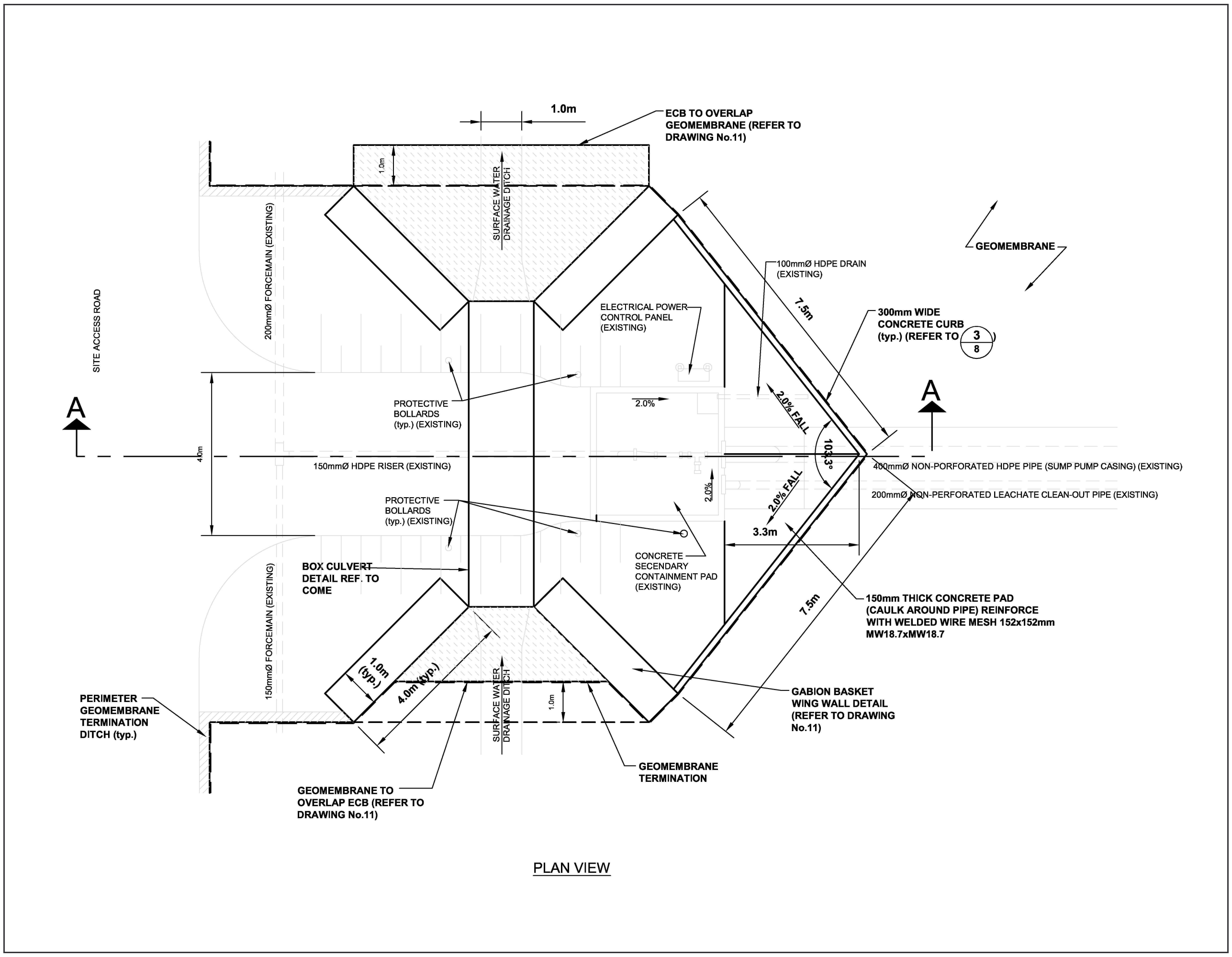

Figure 5 Leachate Collection System Access Pad Detail

6 INTERIM PROGRESS REPORT

The Request for Proposals was issued in March 2007, the geomembrane contract award was in May, and production of the geomembrane began in June. The General Contract was awarded in August and installation of the geomembrane cap began in October, 2007.

Approximately 15% of the total project was completed in the fall of 2007, which is equivalent to half of the top area of Stage 3 (ref. Figure 1). The start was later than expected and the late fall weather hampered the installation. The complexity of the installation required some time to determine the best deployment and seaming methods. Wind gusts up to 70 km/hr were experienced with effects on the installed cap material that were well within the predicted degree of uplift, lending assurance that the wind uplift designs should be sufficient to withstand heavy winds over the long term.

The majority of the work will be completed in 2008, which includes the remaining half of the Stage 3 top, the Stage 3 slopes, and all of Stage 4. It is expected that the slopes will be more of a challenge given the multiple trenches going across the slope(s) and the larger liner panels.

The majority of the area that had been completed with geomembrane cap by the end of 2007 has not been observed lifting from the subgrade – even during high wind events.

One relatively localized area has been observed lifting up. It was discovered that the landfill gas wells in this area, however, had been shut off due to mounding leachate conditions. Even with little or no wind, some degree of geomembrane uplift in this area was observed, presumably due to positive landfill gas pressures under the cap, resulting in a convex shape between adjacent ballast trenches. The photo in Figure 6 was taken on January 9, 2008 during a wind storm with gusts of up to 70 km/h. As visible in the photo, notable uplift occurred during this windstorm in the localized areas with positive underlying landfill gas pressures. The magnitude of the wind uplift was within the predicted design range considering the winds speeds at the time. There has been no visible evidence of damage to the geomembrane or pull-out from the adjacent ballast trenches to date.

Figure 6 Photo of Wind Uplift on January 9, 2008

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