DETAILED DESIGN FOR A NEW SANITARY LANDFILL FOR THE SUBIC BAY METROPOLITAN AUTHORITY, OLONGAPO, PHILIPPINES

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SUMMARY: The Subic Bay Metropolitan Authority (SBMA) was created in 1992, after the United States Navy closed down its operations. The former US Naval Base was converted to a freeport zone, utilizing the facilities left by the US Navy. In order to keep up with the demand of a growing enterprise zone, SBMA endeavored to ensure that adequate basic services were maintained, including solid waste management. To that end, SBMA contracted a landfill siting study to determine the most suitable location for a new landfill site. Following identification of a suitable location, the detailed design of a state of the art sanitary landfill was undertaken. While the design project included numerous components, three primary elements are addressed within this report. These elements consist of drainage and hydrology; leachate generation, handling, and treatment; and liner system design and stability.

1. INTRODUCTION

The SBMA was created in 1992, after the US Navy closed down its operations. The former US Naval Base was converted to a freeport zone, utilizing the facilities left by the US Navy. The Subic Bay Freeport Zone (SBFZ) has enjoyed tremendous success and economic growth, outweighing the financial and economic benefits that the former naval facility provided to Philippine citizens in terms of jobs and employment. In order to keep up with the demand of a growing enterprise zone, SBMA must ensure that adequate basic services are maintained, including solid waste management.

The existing landfills within the SBFZ will reach their design capacities in late 2003, according to SBMA personnel. This created the need to plan for new facilities. Along with this planning, SBMA proposed to utilize the current state of practice and industry standards in siting, designing, constructing, and operating its solid waste management facilities. The design of a modern sanitary landfill will ensure the safety and well being of the workers, residents, and locators at SBMA and the planned service area. It will also protect the valuable natural resources and the general environment of the SBFZ as a whole.

It was the intent of the project to site and plan for a facility that will be able to serve other surrounding cities and municipalities within the influence and boundaries of the Subic Special Economic Zone as defined by Republic Act 7227 of 1991. This included Olongapo City, Castillejos, San Marcelino and Subic in the province of Zambales, and Dinalupihan, Hermosa, and Morong in the province of Bataan. Initially however, the landfill will serve the SBFZ only until such time that an arrangement (political, financial, and legal) is developed and executed among SBMA and the other jurisdictions for the common use of the site, as a regional facility.

Utilizing the information and recommendations from the initial landfill siting study, a proposed landfill location was identified and a contract was let for the detailed design of a new solid waste facility within the SBFZ. The detailed design project included a determination of the necessary landfill capacity and site life, a detailed characterization of the subsurface, a drainage and hydrology analysis, preparation of a design report, specifications, CQA plan, and construction drawings, compilation of an environmental impact report, cost estimating, preparation of a site operation manual, and conducting training for site personnel regarding site operations. While there were numerous components to the overall design of the Subic Bay Sanitary Landfill, this case study focuses on three primary elements. These design elements consist of drainage and hydrology; leachate generation, handling, and treatment; and liner system design and stability.

2. DRAINAGE AND HYDROLOGY

The proposed drainage control system for the landfill was designed to accommodate the anticipated volume of precipitation and resulting run-off generated from the waste fill surfaces during the peak rainfall resulting from a 10 year, 2 hour storm event. The rainfall data used in the hydrology analysis of SBFZ sanitary landfill was provided by the Subic Bay Metropolitan Authority Engineering Department and represented precipitation recorded in Olongapo, Philippines. Upon review of the rainfall data, the peak 10 year, 2 hour storm event was identified to be 126 millimeters over the 2 hour storm period.

The surface hydrology of the SBFZ Sanitary Landfill was calculated using the rational method. This method calculates the peak run-off amounts of drainage areas that are generated during a specific rainfall event. The open channels and drainage structures were sized to accommodate the calculated peak run-off amount generated from the prescribed design storm. The run-off structures were sized using the software programs FlowMaster (Haestad 1997) and Culvert Master (Haestad 1995).

The SBFZ Sanitary Landfill was designed to maximize the amount of access roads and surface berms to control the run-off. Access roads were designed to slope inwards with the inside portion of the road as the drainage channel. The top surface of the capped landfill was designed to have multiple permanent berms constructed of compacted soil, which are positioned to allow diversion of surface flows to be directed into open channels or down-drain culverts.

A perimeter drainage channel will concurrently direct run-off from the waste fill grades to the sedimentation ponds. The sedimentation ponds will provide detention times that allow for the heavier fraction of suspended sediment to settle out. Water collected in the sedimentation ponds will slowly be released through de-watering stand pipes to off-site discharge points. To the extent feasible, all collected storm water diverted from the landfill will be used on-site for dust control, soil conditioning, or other operational tasks.

Prior to beginning the run-off calculation, several required parameters were determined. First, the hourly rainfall intensity (needed for the rational method) was determined for the design rainfall event. Next, the 21 hectares of waste fill grades and contributing graded areas were descretized into sub-areas delineating potential run-off flow paths and concentration points. The waste fill grades were subsequently divided up into 8 top sub-areas and 17 side-slope areas. The surrounding graded areas that also contribute to total run-off were divided into 4 sub-areas. Along the anticipated flow path, run-off concentration points were identified as channel grades and contributing sub-areas were encountered. A drainage division line was prescribed from the drainage center of the landfill cell, which separates the sub-areas into an east and west drainage route. Finally, a run-off coefficient was determined based on the character, condition, imperviousness, slope, and ponding characteristics of the soil of each sub-area.

The key design consideration involving the hydrology and drainage analysis involved diverting stormwater off of the initial waste management cell prior to refuse covering the entire module floor. The first waste management cell will be approximately 5 hectares in size in order to take advantage of economies of scale to obtain the most cost effective installation. A 5 hectare site will result in a large area of the cell being exposed to precipitation before a layer of refuse can be placed over the entire module. Any precipitation that enters the leachate collection and removal system (LCRS) will require treatment and disposal. In order to limit the amount of leachate, the surface area of the LCRS exposed to precipitation was reduced. This was accomplished by constructing a diversion berm through the LCRS within the first landfill development cell. Any stormwater entering the upgradient half of the cell will be diverted out of the LCRS and into a drainage channel outside of the cell. After refuse has been placed in the downgradient half of the module, the outlet to the drainage channel will be closed and the LCRS from the upgradient half of the cell will be connected to main collection system. This temporary diversion of stormwater will result in a substantial reduction in handling and treatment costs as the cell is developed. A detail of this system including the leachate collection system and liner system is shown on Figure 1.

3. LEACHATE GENERATION, HANDLING, AND TREATMENT

3.1 Leachate Generation Analysis

The following section provides a discussion of the simulations that were performed to estimate the leachate production for the landfill. The discussion includes descriptions of the computer model used to perform the analyses, the climatological and soil characteristic input parameters, the simulations performed, and the results of the analysis.

Leachate generation potential was estimated using the Hydrologic Evaluation of Landfill Performance Model (HELP), version 3.06. The HELP model was first generated in 1983 by the U.S. Army Corps of Engineers (USCOE) under contract with the USEPA. Documentation of the original version of the help computer program can be found in USEPA report 530 SW-84-010, dated June 1984 and the engineering documentation for version 3 was prepared by Schroeder (1994). The HELP computer program is a water balance model that uses climatological data and soil characteristics to predict the infiltration of precipitation that falls within the landfill boundaries. The HELP model, using a daily climatological data base to calculate run-off, infiltration, and evapotranspiration, models the effects of hydrologic processes, including precipitation, surface storage, run-off, infiltration, percolation, evapotranspiration, soil and waste moisture storage, and lateral drainage. The model simulates the effects of hydrologic processes on the water balance for a landfill by performing daily sequential analyses using a quasi-two-dimensional, deterministic approach. Water is apportioned to the different hydrologic pathways depending upon the precipitation occurrences and site conditions. Model output can provide daily, monthly, and annual water budgets.

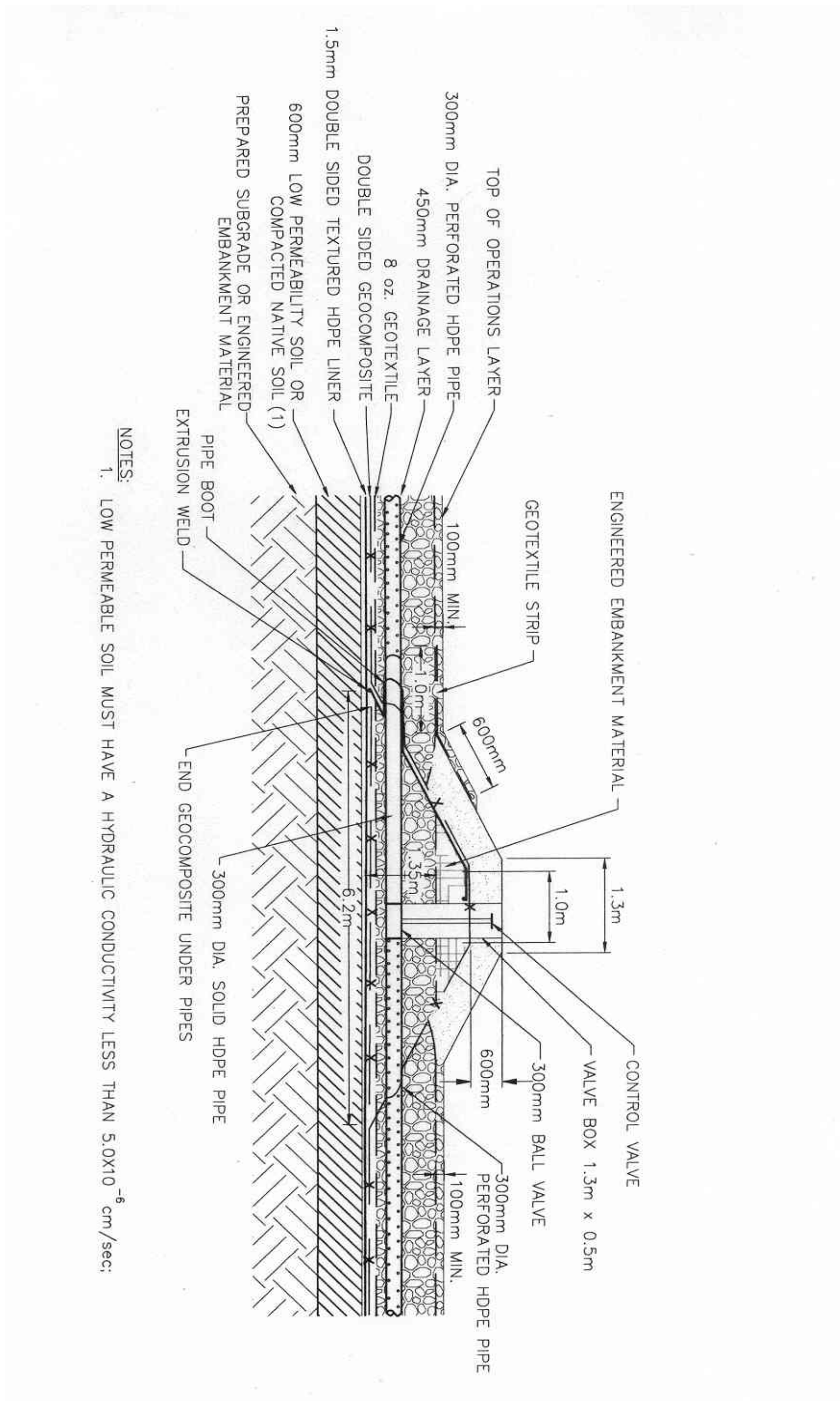

Figure 1. LCRS at Lateral Berm Section N.T.S.

In addition to optional default data containing values that describe climate, vegetation cover types, soil characteristics, municipal solid waste types, and run-off curve numbers, the program provides synthetically generated rainfall using monthly rainfall, temperature, and solar radiation information from 140 cities throughout the United States. The HELP model allows the user to modify these parameters to obtain a site-specific result.

To perform the HELP modeling for the landfill, the HELP model requires that the climate data be converted into daily values. Monthly rainfall was modified from the synthetic database for Miami, Florida, United States. Miami was selected for the rainfall synthesis because it was believed that the precipitation events and seasonal trends of that area best simulated the Philippines monsoon-type rainy season. To adjust this data to the SBFZ site, the average monthly rainfall generated over the last 44 years from a station in the Philippines was input to the model. It is believed that this resulted in a relatively accurate monthly rainfall model for the site that could be synthesized for daily simulations.

Data for evapotranspiration, temperature and solar radiation were not available for the region around the site; therefore, these parameters for the model were synthesized using default data files within the HELP program. In this instance, it was determined that the remaining climate data would be represented by the nearest station within the data base, Honolulu, Hawaii.

The landfill was modeled in the HELP analyses based on the total depth of waste anticipated in the first development phase. This simulation was performed for an open landfill condition (without final cover) assuming five, 3-meter thick lifts of waste; each covered with a 150-mm thick layer of uncompacted daily cover soil. The liner was modeled with a 1.5-mm HDPE geomembrane overlain by a geosynthetic drainage net as the leachate collection layer.

The simulation used an affected area of 0.4 hectares with approximately 50% of the area allowed for run-off based on the proposed filling and construction plan. The value from the 0.4 hectare acre area was then used to determine the flow from the various phases of the landfill. The initial moisture content of the municipal waste layer was adjusted to a level of approximately 95% of the maximum field capacity of the waste, ensuring that leachate generation would occur early in the simulation period. The simulation was performed using a conservative five year operational period.

The results of the simulation indicated that the peak daily flow from a 0.4 hectare unit would be approximately 138 cubic meters. The average annual flow would be approximately 7,500 cubic meters. Since the landfill liner area is about 20 hectares, the total average annual outflow could be as high as 367,500 cubic meters.

The results of the HELP model also indicated that the average head over the liner would be less than 5 mm given the use of a high flow geocomposite. Gecomposites similar to those used in the analysis can provide the required flow capacity under an overburden pressure in excess of about 780 kPa. The landfill will have a maximum depth of about 20 meters. Given a unit weight of 10 kilo Newtons per cubic meter, the pressure exerted on the geocomposite would only be about 200 kPa.

3.2 Leachate Handling and Treatment

Based on the large volume of leachate that was predicted to be generated by the HELP model, it was deemed infeasible to build a storage pond that would contain the entire annual generated leachate at build-out of the landfill. It was decided that a treatment system would be the most effective method of handling the leachate. A passive system consisting of a primary leachate storage pond in series with several bioreactive wetlands was selected for the design.

The storage pond was designed based on the available space within the landfill property and on the assumption that it be able to store at least the first six months of leachate generation from the first phase of development, plus the rainfall that will directly fall within the lined pond limits. Based on the calculations, a pond with a volume of at least 41,000 cubic meters is required. The designed pond has an actual capacity of approximately 59,500 cubic meters. The leachate storage pond will be double lined with a secondary liner of soil and HDPE geomembrane overlain by a geonet leak detection layer and a primary HDPE geomembrane. The calculations indicate that this larger pond would contain about 7 months of generated leachate plus the total average annual rainfall.

Leachate will be pumped into the storage pond using a low head, high volume submersible pump with components that are compatible with the chemistry of the water. This pump will be situated in the main collection sump, which will be the primary collection point throughout the life of the operation of the landfill. Given this information, the pump was sized to handle the average flow at build-out of the facility, approximately 719 liters per minute.

Once leachate is pumped into the storage pond, it will fill the pond until it gravity flows out through two discharge pipes positioned approximately 1 meter below the pond crest. As the pond fills, the leachate will be aerated using mechanical aerators to reduce the water's biological oxygen demand (BOD) prior to entering the wetlands treatment ponds. The aerated water will gravity feed into a series of four wetland treatment ponds, the first two of which will be lined with a HDPE geomembrane. The final two will be unlined. The water will migrate through each of the ponds being treated by native aquatic plant species to reduce contaminants to acceptable levels prior to discharge. The system has been designed such that all waters can be recirculated back to the leachate pond, if necessary, and any one pond can be taken off line for cleaning or repair.

4. LINER SYSTEM DESIGN AND STABILITY

An earthquake hazard analysis for the landfill site was performed during the design using three separate methods. The methods included performing a historical search of the earthquake record for all recorded earthquakes that have occurred in the area around the site, a deterministic analysis of all known earthquake sources in close proximity to the site, and a probabilistic seismic risk analysis.

The stability of the proposed landfill site was evaluated under both static and pseudo-static (earthquake) conditions using limit equilibrium analyses. Failure surfaces along the liner interfaces and circular surfaces through the refuse and subgrade were evaluated using the modified Janbu method (Janbu 1968). These analyses were performed for both the final fill and interim fill configurations.

For the stability analyses, the computer program PCSTABL5 was used (Siegel 1975). The proposed landfill geometries were modeled based on the proposed base grades, berm heights, and fill heights as shown on the design drawings. Groundwater was also modeled (in the circular analyses) based on an average depth of approximately 1.5 meters below the base liner. A leachate depth over the liner of between 300 mm and 450 mm was also utilized in all of the analyses.

The proposed liner design for the facility will consist of 600 mm of prepared low permeability soil overlain by a double textured 1.5-mm high density polyethylene (HDPE). The membrane will be overlain by a drainage material consisting of geocomposite drainage media or free-draining gravel. Figure 2 provides details of each of the two liner system options. The drainage layer will be covered by one meter of operations soil to protect the drainage material from the waste. The waste will be placed over the operations soil in sequential lifts at an external slope of 1 vertical to 3.5 horizontal to a maximum depth of 21 meters over the liner or approximately elevation 156 meters above mean sea level.

The shear strengths and other input parameters for the materials used in the analyses were based on laboratory testing of the proposed liner materials and based on industry standard values for the waste fill. Pseudo-static analyses were performed using an earthquake coefficient equal to 0.15 g.

Given the results of the analyses that were performed, it was concluded that the stability of the proposed landfill configuration was satisfactory, with a minimum static factor of safety of 1.8 for interim conditions and a minimum factor of safety of 1.9 for ultimate build-out. All pseudo-static analyses indicated that the site is stable under the estimated earthquake loading conditions with all factors of safety exceeding 1.0.

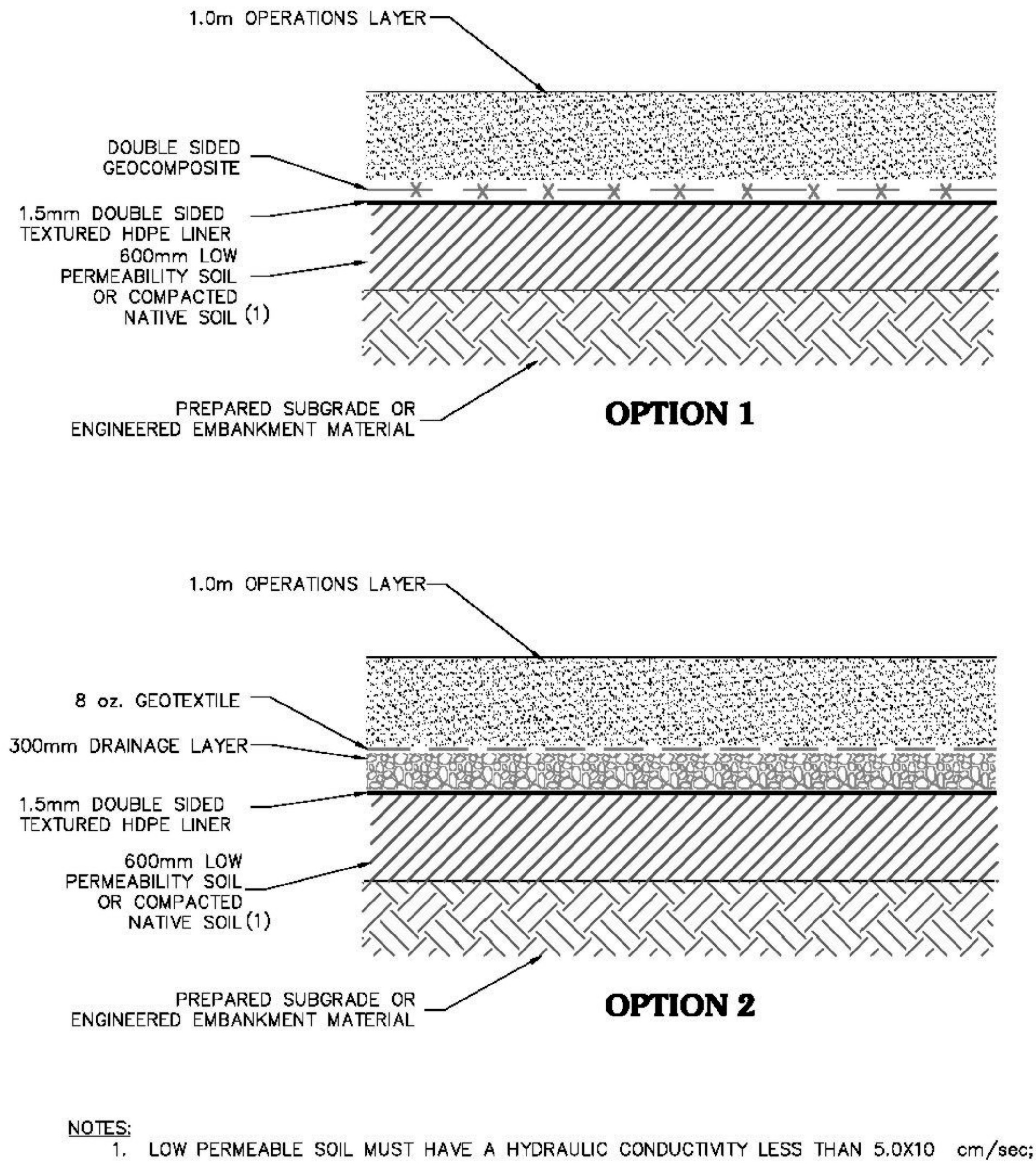

Figure 2. Bottom Liner System Detail N.T.S.

5. CONCLUSION

The design of the New Subic Bay Sanitary Landfill involved many engineering aspects and components. Within this paper, the more critical design issues were discussed including the drainage and hydrology, leachate generation, handling, and treatment, and liner system design and stability.

During the latter portion of 2003, the Subic Bay Metropolitan Authority solicited bids from contractors to begin construction of the Phase 1 area of the New Subic Bay Sanitary Landfill. Along with the construction of a new landfill, the solicitation will also include the closure construction of the existing open dump. By conducting both projects simultaneously, the Authority will ensure that a suitable location is available to take the waste generated within the Freeport Zone, while the old open dumpsite is closed and secured.

REFERENCES

Haested Methods, Inc. (1995), "Culvert Master, Version 1.0", Waterbury, Connecticut. Haested Methods, Inc. (1997), "Flow Master Open Channel Flow Module, Version 5.15", Waterbury, Connecticut.

Janbu, N., (1968), "Slope Stability Computations", Soil Mechanics and Foundation Engineering Report, The technical University of Norway, Trondheim.

Schroeder, P. R., Dozier, T.S., Zappi, P. A., McEnroe, B.M., Sjostrom, J. W., and Peyton, R.L., (1994), *The Hydrologic Evaluation of Landfill Performance (HELP) Model: Engineering Documentation for Version 3*, EPA/600/R-94/168b, U.S. Environmental Protection Agency Office of Research and Development, Washington, D.C.

Siegel, R.A., (1975), "Computer Analysis of General Slope Stability Problems", Purdue University, Report JHRP - 75 - 8, School of Engineering.