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Engineering Design File

Project No. **22522**

Alternatives for Protection of Staging Area Liner Systems

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Five alternative liner systems that would achieve the 15-year design life are presented and discussed in this Engineering Design File. In these alternatives, high-density polyethylene geomembrane and hot mix asphalt concrete were considered for the barrier liner material. Paving asphalt concrete and compacted soil were considered for the protective layer or surface above the liner, owing to their potential in preserving the overall durability characteristics of the liner system. The advantages and disadvantages of each alternative are presented and examined in this study and an optimum alternative is recommended.

In addition, several short-term alternatives were also developed and evaluated to address staging a small amount of waste for a period of less than 2 years.

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Five alternative liner systems that would each achieve the 15-year design life are presented and discussed in this Engineering Design File. In these alternatives, high-density polyethylene geomembrane and hot mix asphalt concrete were considered for the barrier liner material. Paving asphalt concrete and compacted soil were considered for the protective layer or surface above the liner, owing to their potential in preserving the overall durability characteristics of the liner system. The advantages and disadvantages of each alternative are presented and examined in this study, and an optimum alternative is recommended.

In addition, several short-term alternatives were also developed and evaluated to address staging a small amount of waste for a period of less than 2 years.

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ABSTRACT

This Engineering Design File presents the results of the liner system alternative analysis conducted for the INEEL CERCLA Disposal Facility staging piles. Liner system alternatives were developed based on literature review of currently available materials for a liner system. The primary requirements imposed on the alternative analysis were durability and permeability. Durability of the liner system addresses the issues associated with integrity, effectiveness, and longevity of the liner system. Cost was factored into the evaluation study subsequently, to further narrow the alternatives.

Five alternative liner systems that would each achieve the 15-year design life are presented and discussed. In these alternatives, highdensity polyethylene geomembrane and hot mix asphalt concrete were considered for the barrier liner material. Paving asphalt concrete and compacted soil were considered for the protective layer or surface above the primary liner to preserve the overall durability characteristics of the liner system.

Each of the alternatives selected satisfies the essential requirements of durability and permeability of a liner system. With regards to durability, the hot mix asphalt concrete/fluid applied asphalt membrane liner composite appears to be superior over the high-density polyethylene geomembrane liner, especially where a compacted soil layer is used as protective soil. Both of the liner materials could perform very well as a barrier layer between the staged waste and the natural soil.

In addition, several short-term alternatives were developed and evaluated to address staging a small amount of waste for a period of less than **2** years.

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FIGURES

ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
DOE	Department of Energy
DOE-ID	Department of Energy Idaho Operations Office
EDF	Engineering Design File
EPA	Environmental Protection Agency
ESCR	environmental stress cracking
FAAM	fluid applied asphalt membrane
HDPE	high-density polyethylene
HMAC	hot mix asphalt concrete
ICDF	INEEL CERCLA Disposal Facility
INEEL	Idaho National Engineering and Environmental Laboratory
PAC	paving asphalt concrete
RCRA	Resource Conservation and Recovery Act
ROD	Record **of** Decision
SSSTF	Staging, Storage, Sizing, and Treatment Facility
TSCA	Toxic Substances Control Act

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Alternatives for Protection of Staging Area Liner Systems

1. INTRODUCTION

1.1 Background

The October 1999 ***Final Record of Decision, for the Idaho Nuclear Technology and Engineering Center, Operable Unit 3-13*** (DOE-ID 1999) states that contaminated surface soils will be removed and disposed in the INEEL CERCLA Disposal Facility (ICDF). The ICDF Complex will be an on-Site facility for the treatment and disposal of low-level hazardous, mixed, and some Toxic Substances Control Act (TSCA) wastes. The ICDF Complex included necessary subsystems and support facilities to provide a complete waste disposal system. The major components of the ICDF Complex are the disposal cells (which include the evaporation pond and leachate collection system) and the Staging, Storage, Sizing, and Treatment Facility (SSSTF).

The ICDF Complex is a low-level, hazardous, TSCA, and mixed waste disposal facility (landfill cells and evaporation pond) with an authorized capacity of approximately 510,000 yd^3. The Record of Decision (ROD) states that Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)-generated wastes within the Idaho National Engineering and Environmental Laboratory (INEEL) facility will be removed and disposed of in the ICDF Complex. The ICDF evaporation pond will provide treatment/disposal capability for CERCLA-generated aqueous wastes. The ICDF landfill can accommodate multiple cells, and each disposal cell will be engineered to meet the substantive requirements of DOE Order 435.1, “Radioactive Waste Management;” the Resource Conservation and Recovery Act (RCRA) Subtitle C; the Idaho Hazardous Waste Management Act; and TSCA polychlorinated biphenyl landfill design and construction requirements. The cells will be closed with an engineered cap to meet the ROD requirements.

1.2 Purpose and Scope

The ICDF Complex is scheduled to be operational in July 2003. A minimal amount of waste is contaminated soils that must subsequently be treated at the SSSTF. An area (bounded by four comers) has been identified at the ICDF Complex, wherein incoming waste that is not sent directly to the landfill will be unloaded and will comprise the bulk soil staging pile. The agencies have required that a liner be designed and constructed under the staging piles.

The purpose of this Engineering Design File (EDF) is to prepare a detailed alternative analysis and recommended proposal for the design and construction of a liner system for the staging piles. The factors examined in the alternatives analysis include liner integrity, effectiveness, longevity, and cost. These factors are summed into three broad categories of durability, permeability, and cost. The advantages and disadvantages of alternatives are discussed and an alternative is recommended.

2. MAJOR ASSUMPTIONS

The alternative analysis was based on the following major assumptions:

1. The maximum defined physical size of the storage area (as defined in the ***INEEL CERCLA Disposal Facility Complex Remedial Action Work Plan*** [DOE 20031) is 150 ft x 270 ft.

2. The staging pile liner system would be constructed by building the system up above the existing grade (i.e., no excavation would be required to construct the liner system).

3. The length of time the waste remains stockpiled in the storage pile is short enough that the volume of the leachate expected while the waste is in the storage pile is small.

4. Because of the waste's relatively short duration of time in the storage pile, the liner system would not require provision for any specialized leachate collection system.

5. The waste that would be stored in the staging pile would be covered and no operations would be allowed during inclement weather (e.g., periods of precipitation and high winds).

6. The materials stored in the staging pile would primarily include material from remediation sites that are similar to the silty soils and alluvium from the site.

7. The design life of the staging pile liner system is 15 years, which is consistent with the design life of the ICDF Complex. A shorter term (less than two years) design life, for small amounts of waste, was also considered.

8. The liner system will be disposed of in the landfill, before closure.

3. CRITERIA FOR ALTERNATIVE EVALUATION

3.1 Regulations Pertaining to Staging Piles

The bulk soil staging area will be managed according to 40 CFR 264.554, "Staging Piles." The ICDF Complex Remedial Action Work Plan outlines the design and operational requirements (DOE-ID 2003).

The bulk soil staging pile area is not intended for conversion into a permanent disposal facility. Therefore, the liner system alternatives evaluated in this EDF are single-liner systems only.

3.2 Liner Design Criteria

According to the Environmental Protection Agency (EPA), the most important environmental condition to which a liner system is exposed in a waste pile is the overburden pressure (U.S. EPA 1988). The maximum height of waste to be stored at a particular time is expected to be approximately 10 ft. Given that this anticipated waste height may be lower than a typical waste pile, other environmental factors may be more critical in the design of the bulk soil staging pile liner system. The primary concern for the ICDF Complex bulk soils staging area is to eliminate the possibility of secondary contamination from the stockpiled soils. The following section examines the possible environmental stresses that could act on the liner system for the staging piles. An attempt is then made to identify possible criteria to use as a basis for sizing the alternative liner systems considered in this evaluation study.

3.2.1 Environmental Stresses

The principal environmental stresses encountered in a typical liner system are divided into two types; namely, chemical stresses and physical stresses.

Chemical stresses are caused by dissolved organic and inorganic chemicals in the wastes and waste liquids that are contained in the waste impoundment facilities. Because it is difficult to characterize the mechanics of chemicals inducing stresses in the liner systems, the effects on the properties of a liner system are emphasized instead. Examples of these effects are manifested by the following:

1. Degradation of the base polymer of a liner system through chemical processes such as oxidation and hydrolysis, which results in embrittlement and loss of physical properties of the liner that may be important to its performance

2. Depolymerization which results in softening and loss of physical properties

3. Absorption of waste constituents, which can result in increased permeability and loss in strength and other physical properties, if the amounts become sufficiently large.

The effects of chemical stress may take extended periods of time to become apparent, particularly when the concentration of aggressive constituents in a waste liquid is low.

Physical stresses are independent of any chemical stresses and can take place primarily during construction and during the early service life of a waste facility when the waste liquid is not in contact with the liner or other construction materials. Many factors can induce physical stresses to the liner system, as reported in the literature **(U.S.** EPA **1988, 1983).** However, the most applicable to the bulk soil staging pile are as follows:

1. Stresses during installation (laying out) of the liner on the ground

2. Stresses due to dropped objects, such as tools, which could result in puncture of the liner

3. Stresses due to traffic

4. Stresses over irregularly shaped surfaces due to large aggregates next to the surface of the flexible membrane liner, or due to differential settlement in the case of a less flexible asphalt concrete liner.

A combination of physical and chemical stresses could also occur, which could affect the liner system in several different ways. For example, absorption of organics and subsequent swelling of flexible membrane liners can cause the liners to increase permeability. In addition, semicrystalline liners under mechanical stresses when in contact with some chemicals can crack by environmental stress cracking (ESCR).

The choice of the materials for use in the liner system is dependent on the anticipated physical and chemical stresses. Because there are various types of liner materials available, highdensity polyethylene (HDPE) and hot mix asphalt concrete (HMAC) were used as the basis for this alternatives evaluation, as the design requirements could vary depending on each different liner material involved.

3.2.2 Equipment Loading

Construction equipment considered in this liner system alternative evaluation study, as anticipated during the operation of the waste pile facility, consist of the following:

- Cat **966-G** Front-End Loader
- Cat **775E** Dump Truck

- Cat **420** Rubber-Tired Backhoe
- Cat ***246*** Bobcat Loader.

3.2.3 Stormwater Drainage

The surface of the **bulk** soil staging area would be elevated slightly above the surrounding grades based on the thickness of the liner systems and the need to promote stormwater runoff. The surface of the staging ***area*** would be sloped a minimum of **2%** to promote runoff and minimize the potential for standing water. The drainage from the bulk soil staging area would enter the sitewide stormwater system after exiting the storage area.

4. LINER SYSTEM ALTERNATIVES

Various liner systems are currently available, but the ones considered in the alternative analysis were limited to the criteria discussed in the previous section. The major requirements imposed in the alternative analysis were durability and permeability, in order for the liner system to perform its fundamental functions. These general criteria are believed to cover the factors stated previously in the scope of work, namely: integrity, effectiveness, **and** longevity of the liner system. Cost was factored into the equation subsequently, to narrow the options.

Based on the criteria discussed above, the primary liner systems considered were limited to the following materials:

- High-density polyethylene (HDFE)
- Hot mix asphalt concrete (HMAC).

The following reasons led to the decision to consider these two materials for the primary liner:

1. The need to simplify the evaluation process, considering the relatively non-critical nature of the liner system design for waste piles
2. The lack of specific regulatory criteria for liner system design of waste piles
3. The difficulty of establishing **a** distinct quantitative comparison between alternatives consisting of various types of liner materials and components in the liner system, since these materials have differing physical and chemical properties, field behavior, and responses to environmental stresses.

4.1 High-Density Polyethylene

Although HDPE is the only type of geomembrane discussed in this evaluation, other types may be considered during implementation if anticipated waste types can be established that are compatible with the geomembrane material. These other liners (such as ***XR-5,*** and PVC) could offer even better advantages than HDPE, including lower coefficient of thermal expansion/contraction, higher flexibility (elongation at yield), greater puncture resistance, factory welding so that larger panels can be deployed, and easier field seaming.

Over the past few years, HDPE has been an enormously popular product for use as a liner in waste containment applications due to its ultraviolet resistance, low cost, and very good overall chemical resistance. The standard minimum HDPE thickness required to provide adequate puncture resistance is **60** mil (Koerner **1998).**

Despite its popularity, HDPE has some disadvantages, as reported in the literature. Some of the disadvantages that are applicable to the bulk soil staging pile liner system design include the following:

1. Being sensitive to ESCR due to its crystal lattice structure

2. Being a very stiff "flexible" liner and having a high coefficient of thermal expansion, which often require special design considerations

3. Being almost impossible to repair without the use of an expensive extrusion gun

4. Requiring field welding (on most environmental grade HDPE liners), which greatly increase installation and third party field quality control costs

5. Being fabricated in widths of **22** ft, thus requiring field seaming at joints during installation.

4.1.1 Thickness Consideration

The thickness of **an** HDPE liner is related to the pressures exerted on it. The current design mechanics are based on deformations that the liner might experience during its service life (Koerner **1998).** These deformations might be caused by the following:

1. Areal differential settlement of subgrade soils

2. Settlement of backfilled zones beneath the liner (e.g., in pipe trenches)

3. Localized settlements around pieces of aggregate or localized "soft" areas beneath the liner

4. Any kind of anomalous conditions that place the liner in tension.

The minimum liner thickness recommended for an HDPE geomembrane in a typical liner design is **1.5** mm (60 mil) (Koerner **1998).** Thus, in a typical design, the first step is to assume the minimum recommended thickness of 60 mil and then verify this thickness for adequacy, according to whichever of the deformations discussed above is critical to the project.

For the bulk soil staging pile, the liner system is envisioned to be constructed on a properly prepared, leveled, and compacted subgrade. **As** stated in the ***Geotechnical Report for the Conceptual Design of the ZCDF ut Waste Area Group 3, Operable Unit 3-13*** (DOE-ID **2000),** the site subgrade soils appear to consist of primarily medium dense to very dense silty sand and gravel materials. The Standard Penetration Test blowcounts associated with these materials in the upper 5 ft ranged between **23** and **50** blows per foot and generally increase with depth. With proper methods of subgrade preparation, it is expected that differential settlements associated with the subgrade soils would be very small.

It is expected that a soil cover will be used above the HDPE liner and that the subgrade may consist of sand and gravelly materials. Therefore, localized settlements, formed as a result of loading on top of the liner around pieces of aggregate in the subgrade (see Item **3** above), may need to be checked for the staging pile liner design, as discussed in the next section.

4.1.2 Geomembrane Protective Soil

In this project, protective soil is recommended above the HDPE geomembrane mainly as a protective layer against mechanical, weather, and other environmental damage. Perhaps the most important factor is the protection of the HDPE liner from damage against the repetitive exposure of the liner system to heavy equipment loading during the operation of the staging pile facility. As discussed previously, the most critical loading that would be induced to the liner is due to the loading from a fully loaded dump truck (Cat 775E) that is anticipated during the operation of the facility. This load was estimated to induce a ground contact pressure of as much as 65 psi at the surface of the liner system.

The actual loading that would be transmitted to the underlying HDPE liner will depend on the thickness of the protective soil above the geomembrane. In typical landfill design, a minimum of 12 in. of protective soil is recommended above the low-permeability liner. Because the bulk soil staging pile liner system would be exposed frequently to cycles of loading/unloading of wastes and heavy equipment loading during its design life, a minimum 24-in. of protective soil is recommended. This soil thickness also reduces the amount of load that is transmitted to the underlying HDPE liner to about 9 psi (from about 19.1 psi for a 12-in. soil cover), which is similar to the stress level transmitted to the underlying liner due to the weight of the 10-ft waste pile.

4.1.3 Cushion Geotextile

In situations where geomembranes are placed on or beneath soils containing relatively large-sized stones (e.g., poorly prepared soils subgrades with stones protruding from the surface or resting on the surface), and/or soils subgrades over which geomembranes (particularly textured) have been dragged (dislodging near-surface stones), a protective geotextile is typically used to avoid puncturing of the geomembrane. Koemer provides a method of designing the required mass per unit area of the geotextile to achieve a specified factor of safety against puncture (Koerner 1998).

For the staging area liner system, it is recommended that a cushion geotextile be required only above the HDPE geomembrane for puncture protection from overlying soil cover material. The subgrade for the liner system is expected to consist of subrounded to rounded sand and gravel material. As during ICDF construction, the subgrade can be compacted to a smooth and firm condition that poses a negligible puncture threat to the HDPE geomembrane. Thus, assuming proper control of the subgrade is maintained during staging liner system construction, a cushion geotextile below the geomembrane is not warranted.

4.1.4 Chemical Compatibility

A liner/leachate compatibility study for HDPE geomembrane and the expected chemicals from ICDF landfill waste has been conducted (EDF-ER-278). This study indicated that HDPE geomembranes can be exposed to high doses of radiation without being damaged, and are compatible with leachate from hazardous waste landfills such as those generated at the ICDF landfill and evaporation pond.

4.2 Hot Mix Asphalt Concrete

Hot mix asphalt concrete is a controlled hot mixture of asphalt cement and high quality mineral aggregate compacted into a uniform dense mass. It is similar to highway paving asphalt concrete (PAC) but has a higher percentage of mineral fillers and a higher percentage (usually 6.5 to 9.5%) of asphalt cement. A hard grade asphalt, such as 40-50 or 60-70 penetration grade asphalt is usually used in HMAC, which makes it better suited in lining applications than the softer paving asphalt (Asphalt Institute 1976).

Hot *mix* asphalt concrete can be compacted into a permeability of less than 10^{-9} cm/sec (Hinkle **1976).** For waste containment applications, the major factor to consider is the selection of an aggregate that is compatible with the waste. For example, the mix design should avoid using aggregates containing carbonates if highly acidic wastes are anticipated.

Hot mix asphalt concrete offers the following advantages:

1. HMAC is resistant to light vehicular traffic and effects of weather extremes (such as temperature).

2. It retains enough flexibility to conform to slight deformations of the subgrade and avoid rupture from low-level seismic activity.

3. It can be placed with conventional paving equipment and compacted to the required thickness (Asphalt Institute **1966).**

4. It is a durable material, as evidenced by its use dating back centuries as a water-resistant material **(U.S.** EPA **1983).**

5. It has shown resistance to acids, bases, inorganic salts (to a **30%** concentration) and to some organic compounds found in industrial wastes (Asphalt Institute **1976).**

6. It has good resistance to inorganic chemicals and low permeability to corrosive gases such as hydrogen sulfide and sulfur dioxide.

7. It exhibits self-healing properties because of its viscoelastic nature. This property suggests that cracks resulting from seismic or subsidence events would heal without involving outside forces, such as heating or compaction (Mancini et al. **1995).**

8. It can be constructed with a conventional paving machine in desired lifts to achieve a low permeability.

The disadvantages of **HMAC** include the following:

1. Hot mix asphalt concrete is generally not resistant to organic solvents and chemicals, particularly hydrocarbons in which they are partially or wholly soluble.

2. It is not an effective liner for disposal sites containing petroleumderived wastes or petroleum solvating compounds such as oils, fats, aromatic solvents, or hydrogen halide vapors.

4.2.1 Thickness Consideration, Mix Design, and Compaction

In applications where **HMAC** is used as an impermeable lining, the required thickness depends on the desired permeability, the percentage of asphalt used, and the gradation of the aggregate being used. Frequently, however, the thickness is decided based on previous experience. The most common thickness reported in the literature for hydraulic applications is **2** to **4** in. to achieve the minimum permeability of the liner (Styron and Fry **1979,** Haxo **1976,** Hinkle **1976).** Permeability of less than **1 x** 10^{-9} **cm/sec** has been reported for this range of thickness (Hinkle **1976).** The most common mix uses roughly 7 to **11%** of asphalt concrete and aggregates, having less than **10%** passing the **U.S.** Standard Sieve No. **200.**

Compaction of asphalt during placement dictates the quality of the finished liner (Bureau of Reclamation **1963).** The Asphalt Institute recommends that the liner should be compacted to at least **97%**

of the density obtained by the Marshall Method or less than **4%** voids (Asphalt Institute 1976,1981). The subgrade should be properly prepared and compacted before placement.

4.2.2 Fluid Applied Asphalt Membrane Coating

Fluid applied asphalt membrane (FAAM) coating contains mostly asphalt with less than 15% polymer, and is applied by spraying the coating into the surface of the HMAC to create a more impermeable and flexible liner. The FAAM coating has been used with favorable feedback at the Hanford Site Permanent Isolation Surface Barrier (Mancini et al. 1995). The FAAM application is seamless and forms a strong bond to the surface of the underlying **HMAC,** which prevents lateral water movement between the two materials and provides a stable construction surface. The composite asphalt barrier (HMAC/FAAM) is reported to be functionally equivalent to an RCRA bentonite clay and HDPE barrier. It has exceeded the RCRA performance criteria, demonstrating permeability of less than 2×10^{-8} cdsec for **HMAC,** and less than 1×10^{-11} cm/sec for FAAM coating.

A lower viscosity asphalt, such as AR-4000 graded asphalt cement, is more appropriate than AR-6000 for the HMAC mix for a warm, arid climate (Mancini et al. 1995). About 7 to 8% by weight of AR-4000 compacted to at least **96% of** maximum density was used.

4.2.3 Chemical Compatibility

Hot mix asphalt concrete liners are generally not resistant to organic solvents and chemicals, particularly hydrocarbons in which they are partially or wholly soluble. These characteristics limit the effectiveness of these types of liners for disposal sites containing petroleumderived wastes or petroleum solvating compounds, such as oils, fats, aromatic solvents, or hydrogen halide vapors.

5. LINER SYSTEM ALTERNATIVES

This section outlines and describes the five alternatives considered for the staging area liner systems that would be expected to last for the 15-year design life. The advantages, disadvantages, and estimates of costs of each alternative are discussed and presented. The basis of the cost estimates is presented in Section 5.5. Details of the cost estimates for each alternative are attached in Appendix **A.** A copy of the relevant calculations is given in Appendix B.

In addition, several short-term alternatives were developed and evaluated to address staging a small amount of waste for a period of less than **2** years. This analysis is presented in Section **5.7.**

5.1 Alternative 1: High-Density Polyethylene with Protective Soil

Alternative 1 consists of a 60-mil HDPE liner, a 12-oz cushion geotextile, and 24-in. thick protective soil. **As** discussed in the previous section, the 12-oz geotextile is provided for protection of the HDPE geomembrane liner against puncture, and as a cushion to prevent potential damage to the HDPE during construction and operation of the waste pile. Figure 1 shows the schematic section of the Alternative 1 liner system. As discussed previously, the 24-in. protective soil **is** provided as a protective layer against mechanical, weather, and other environmental damage to the HDPE. Using a **24-in.** thick soil cover (as opposed to the typical 12-in. minimum) would minimize the effects of surficial equipment loading to the underlying liner, specifically reducing the live load stresses to a level similar to the anticipated overburden pressure from the waste pile. The 24-in. thickness is also necessary to minimize the risk that equipment operating above the liner could accidentally dig into the soil cover, thereby damaging the HDPE liner and compromising its primary function as an impermeable barrier layer.

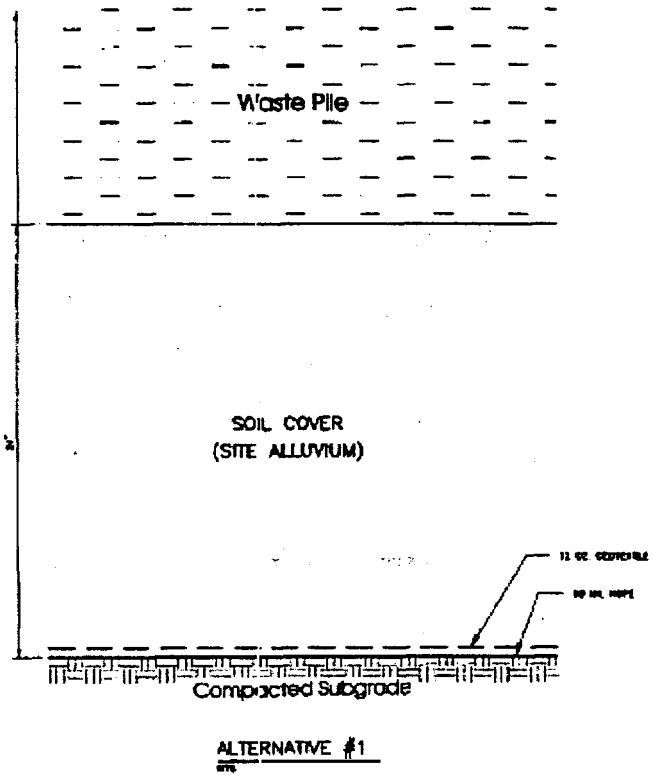

Figure 1. Alternative 1 schematic.

Prior to placement of the HDPE liner, the existing surficial subgrade soil should be properly prepared, leveled, and compacted to a density of at least 95% of the maximum dry density in accordance with ASTM D1557. The soil cover should be compacted in lifts **of** ***6*** to 8 in., and to a density of at least 95% of the maximum dry density.

The cost of this alternative is estimated to be $155,000.00. Potential annual costs associated with maintenance and replenishment to maintain the minimum required thickness **of** the protective soil cover are estimated at $10,500. (Note: these costs are presented in **2003** dollars.)

The major advantages of this liner system alternative are as follows:

- The arrangement is simple and straightforward and, thus, easy to construct.
- As long as damage to the HDPE geomembrane would not occur, the liner system configuration could work effectively.
- Large potential savings in cost could be realized if the protective soil could be obtained from on-Site excavations such as the site alluvium.

The major disadvantages for this alternative are as follows:

- There is no hard and flat surface on which the equipment could operate.

- Uncertainty exists in the durability of the 24-in. protective soil above the HDPE for the 15-year design life of the facility. There is a high risk of potential damage to the geomembrane liner, resulting from the equipment (particularly a backhoe) accidentally digging into the soil cover during operation of the facility. The soil cover could look like the same material as the waste being stockpiled, making it difficult for equipment operators to determine if they are digging into the soil cover.

- Soil cover will likely require periodic maintenance and replenishment to maintain minimum required thickness. It is assumed that 6 in. of soil cover would require replacement once every year during the design life of the staging area.

- When the facility is no longer needed, the liner and soil cover would require higher disposal cost, due to larger material volumes.

5.2 Alternative 2: High-Density Polyethylene with Asphalt Surface

This alternative consists of (from bottom to top) a 60 mil HDPE, a 12 oz cushion geotextile, a 12-in. soil cover, and a 5.5-in. thick PAC, Figure 2 shows the schematic section of this alternative. This alternative is very similar to Alternative 1 except that the upper 12 in. of soil cover have been replaced by the 5.5-in. thick PAC. The purpose of the PAC is to act as a structural support against the heavy equipment loading expected during operation of the facility. It can also act as a rigid material to distribute the loading more uniformly to the underlying liner. The thickness of 5.5 in. was the minimum required thickness of paving asphalt for the anticipated equipment loading, assuming a 15-year design life and a California Bearing Ratio of 10 for the subgrade material below the asphalt. A 50% design reliability was used in the design calculations, owing to the limited exposure to loading of this PAC layer, as compared to a normal, heavy-duty highway pavement. As required in Alternative 1, the soil cover should be properly compacted.

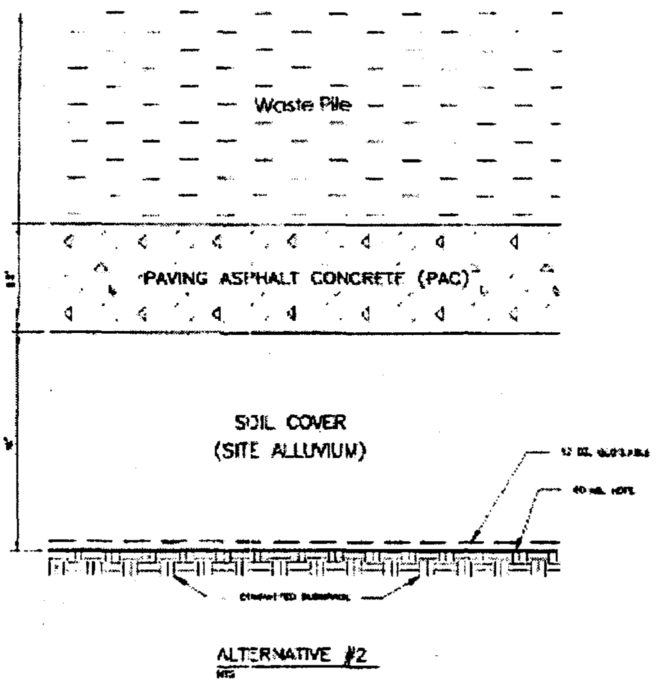

Figure 2. Alternative 2 schematic.

The cost of this alternative is estimated to be $219,000.00. Potential annual costs associated with maintenance and repair to maintain the PAC layer are estimated at **$3,800.** (Note: these costs are presented in 2003 dollars.) These maintenance costs assume that a seal coat is applied to the PAC once every **3** years.

The advantages of Alternative 2 are as follows:

- The hard, flat surface layer **of** the PAC provides a good working surface for the loading/unloading **of** the wastes.
- The PAC surface provides a rigid layer that would offer better load distribution to the underlying liner.
- The PAC layer is a semi-impervious layer that could minimize leachate infiltration and migration into the underlying liner.
- The presence of the PAC layer could reduce the impact and dynamic loadings caused by heavy equipment operating at the surface **of** the liner system.
- The PAC serves as a rigid barrier that ensures protection of the underlying liner from accidental damage by operating equipment. The rigid layer would not allow any equipment to dig into the soil layer.

The disadvantages of Alternative **2** are as follows:

- The PAC layer is placed directly in contact with the waste pile and could undergo chemical reactions. Potential reactions would be dependent on the chemical constituents of the waste pile.
- The PAC layer would require occasional repair/maintenance. It is assumed that application of a seal coat would be required once every **3** years during the design life of the staging area.

5.3 Alternative 3: Hot Mix Asphalt Concrete with Soil Cover

This alternative is similar to Alternative 1, with the exception that the HDPE geomembrane liner and the 12-oz geotextile is replaced with 4-in. thick HMAC coated with FAAM. The HMAC would need to be compacted in 2 lifts, at 2 in. per lift, to achieve the permeability requirements. The FAAM coating will provide additional impermeability and flexibility at the surface of the HMAC. Figure 3 shows the schematic section of this alternative.

The cost of this alternative is estimated to be $185,000.00. Potential annual costs associated with maintenance and replenishment to maintain the minimum required thickness of the protective soil cover are estimated at $10,500. (Note: these costs are in 2003 dollars.) Alternative **3** has advantages similar to the first three items for Alternative 1. However, because of its thicker section and rigidity, the HMAC liner's durability is superior to that of the HDPE, from the standpoint of vulnerability to physical damage due to heavy equipment loading. Construction of the HMAC is a seamless process that can be performed with conventional paving equipment and compacted to the required thickness and permeability.

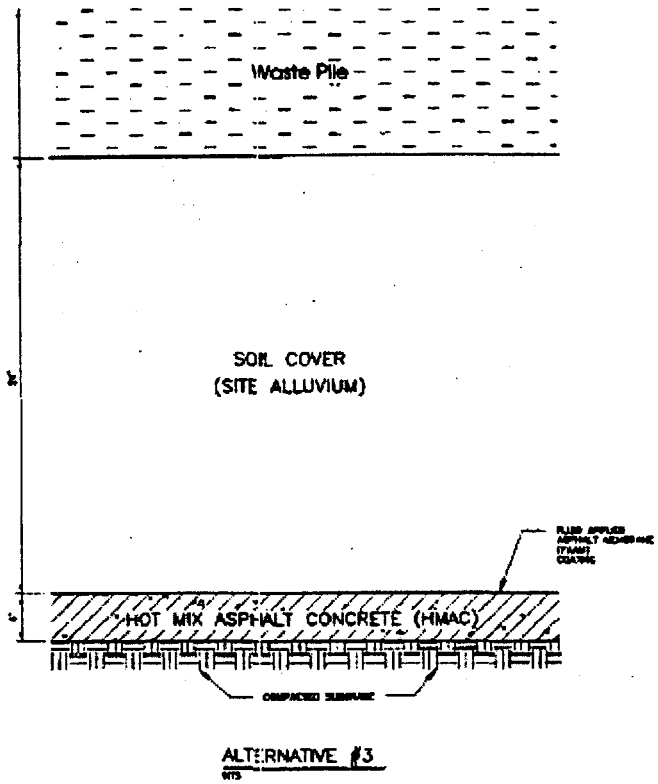

Figure 3. Alternative 3 schematic.

- The major disadvantage of Alternative 3 is that a liner/leachate compatibility study may be required to demonstrate that no adverse effects to the liner's permeability characteristics could occur in the event of a leachate infiltration/migration into the liner. Because of the relative rigidity of the asphalt (compared to HDPE), it has greater potential for cracking. This problem, however, was dealt with by providing the FAAM coating, which improves the flexibility, impermeability, and self-healing properties of the HMAC. As in Alternative 1, this alternative will likely require periodic maintenance and replenishment to maintain minimum required thickness of the protective soil cover.

5.4 Alternative 4: Hot Mix Asphalt Concrete with Asphalt Surface

This alternative consists of 5.5-in. thick PAC over a 4-in. HMAC liner with FAAM coating. No soil cover is required between the PAC and HMAC/FAAM layers, as the PAC could be constructed directly on top of the HMAC/FAAM. Figure 4 shows the schematic section of this alternative.

The cost of this alternative is estimated to be $199,000.00. Potential annual costs associated with maintenance and repair to maintain the PAC layer are estimated at $3,800. (Note: these costs are presented in 2003 dollars.) These maintenance costs assume that a seal coat is applied to the PAC once every 3 years.

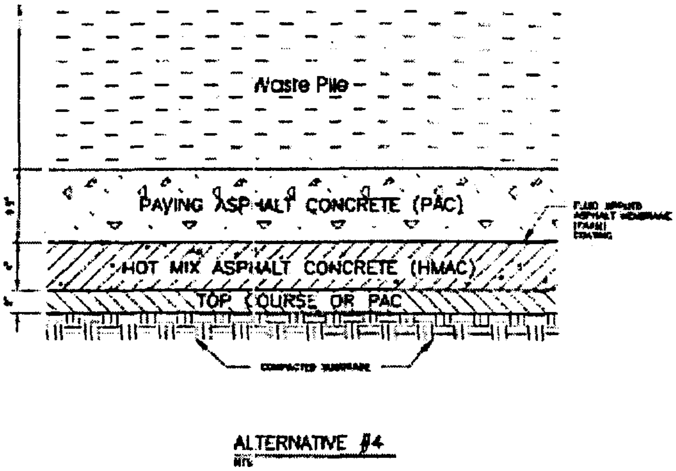

Figure **4.** Alternative **4** schematic.

This alternative retains the advantages associated with the presence of the rigid PAC layer at the surface, as discussed for Alternative **2.** An additional advantage is that the 12-in. layer of soil cover is not required above the HMAC/FAAM, which could reduce the cost, and at the same time could demonstrate performance equivalent to Alternative 2. The resulting liner thickness for this alternative is only about **12** in., which is less than half of the thickness of the other three alternatives. This reduced thickness could translate to savings in the cost of having to build ramps for trucks to access the facility.

The major disadvantages discussed for Alternative **2** also apply to this alternative. In addition, because of the relatively thinner section, the heavy wheel loads are now closer to the HMAC/FAAM liner system, making it vulnerable to physical damage that could result from repetitive action of heavy equipment loading.

5.5 Alternative 5: Hot Mix Asphalt Concrete Surface with Base Course Subgrade

This alternative consists of (from bottom to top) a 12-in. thick granular base course, and a 5.5-in. thick HMAC. Figure 5 shows the schematic section of this alternative. The purpose of the HMAC is to act as a structural support against the heavy equipment loading expected during operation of the facility.

The thickness of 5.5 in. was the minimum required thickness of **HMAC** for the anticipated equipment loading, assuming a 15-year design life and a California Bearing Ratio of 10 for the subgrade material below the asphalt. A 50% design reliability was used in the design calculations, owing to the limited exposure to loading of this HMAC layer, as compared to a normal, heavyduty highway pavement. ***As*** required for the soil cover in Alternative **2,** the granular base course must be properly compacted.

The cost **of** this alternative is estimated to be $200,000. Potential annual costs associated with maintenance and repair to maintain the HMAC layer are estimated at $3,800. (Note: these costs are presented in 2003 dollars.) These maintenance costs assume that a seal coat would be applied to the HMAC once every 3 years.

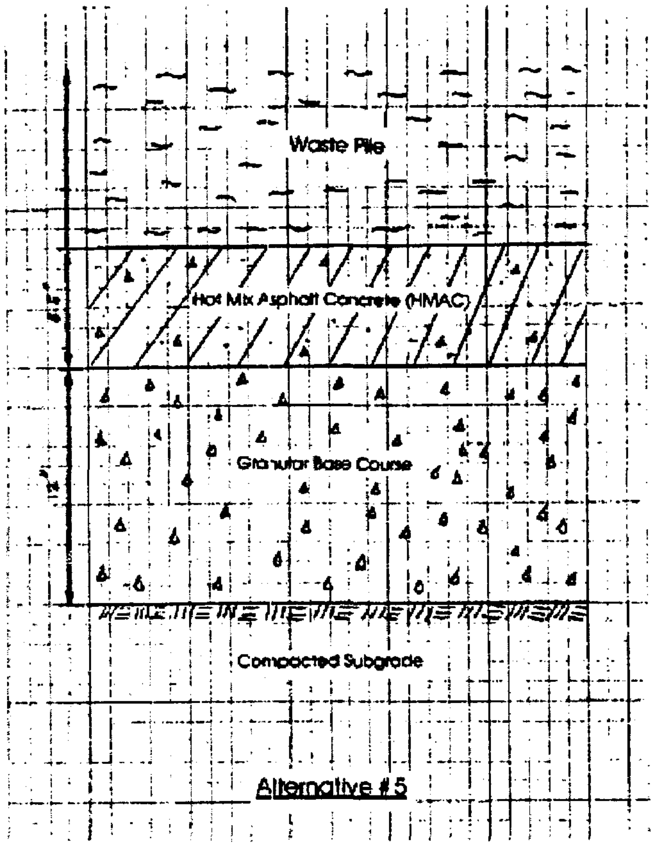

Figure 5. Alternative 5 schematic.

The advantages of Alternative 5 are as follows:

- The hard, flat surface layer of the **HMAC** provides a good working surface for the loading/unloading of the wastes.
- The **HMAC** layer is a semi-impervious layer that would minimize leachate infiltration and migration.
- The HMAC serves as a rigid barrier that ensures protection of the underlying soil. The rigid layer would not allow digging of any equipment into the underlying **soil.**
- The **HMAC** layer can be visually inspected for damage.
- The disadvantages of Alternative 5 are as follows:
- The HMAC layer is placed directly in contact with the waste pile and could undergo chemical reactions, depending on the chemical constituents of the waste pile.

Potential cracking of the HMAC surface due to repetitive equipment loading would require periodic maintenance. **It** is assumed that application of a repair seal coat to the HMAC would be required once every **3** years during the design life of the staging area.

5.6 Basis of Cost Estimates

The assumptions used in the cost estimates presented in this EDF are listed below. The printout of spreadsheets that were used to develop the cost estimates are attached in Appendix A. The unit costs used in this estimate were based mostly on historical information from CH2M HILL, and may not necessarily reflect the most current, local unit costs. The cost estimates only include construction costs and applicable maintenance costs. Maintenance costs are based on estimated annual costs and are presented in 2003 dollars.

- Plan Area = 150 ft x 270 ft
- *60* mil HDPE (textured) – \$7.00 per yd^2
- 12 oz geotextile – \$1.50 per yd^2
- Soil cover above liner – \$5.00 per yd^3 (unit cost of onsite native materials)
- Granular base course – \$15.00 per yd^3 (material cost only)
- Paving asphalt concrete (PAC) – \$40.00 per ton
- HMAC with FAAM Coating – \$55.00 per ton
- HMAC – \$50.00 per ton
- HMAC or PAC Repair seal coat – \$2.50 per yd^2
- Unit weight of asphalt = 145 pounds per ft^3
- Miscellaneous (allowance for clearing/grabbing/etc.) — 10% of project cost
- Mobilization costs — 10% of project cost (includes bonds, insurance, temporary facilities, health and safety, and demobilization)
- Contingency — **30%** of project cost
- Site Factor — 20% of project cost (includes **40-hr** Health and Safety training, monitoring, security constraints).

5.7 Short-Term Alternatives

Several short-term alternatives also were developed and evaluated to address staging a small amount of waste for a period less than 2 years. The criteria used for this alternative included the following:

- Maximum staged volume of 840 yd^3, which is an area approximately 70 ft^2
- Maximum storage period of 2 years
- Permissible to rip or tear a flexible liner during waste removal.

The following alternatives were developed as part of the short-term evaluation:

- Asphalt concrete pavement surface placed directly on existing subgrade
- Geomembrane placed on sand or geotextile cushion
- Nonreinforced lean concrete mud mat.

The asphalt concrete pavement surface would consist of one lift (2 in.) of asphalt placed on the existing subgrade at the SSSTF. The area would be sloped to drain at a minimum of 2%. The waste would then be placed, graded to eliminate depressions on top of the waste, and covered with tarps. During removal of waste, the asphalt surface would provide a surface that allows easy removal. Following removal and disposal of all waste, the asphalt would be removed and placed in the ICDF landfill. The cost of this alternative would be approximately $10,000, based on a total area of 4,900 ft^2 to be paved, and a cost of $2.00 per yd^2 of asphalt.

The geomembrane alternative would consist of placing a cushion layer on the axisting subgrade. The area would be sloped to drain a minimum 2%. The cushion could be sand material obtained from the sand stockpile at the permanent stockpile location, or a cushion geotextile. The geomembrane could be HDPE, PVC, polypropylene, or similar material. Several materials other than HDPE provide one piece of material that can be placed with no seaming. A HDPE geomembrane would require seaming and therefore some quality control would be required to ensure a watertight seam. An access ramp of 3 ft of clean soil would be required at the edge of the geomembrane to allow trucks to dump from a protected liner area. The waste would continue to be placed and spread in a 3-ft-thick lift, and then additional waste could be placed on top of the initial 3 ft layer of waste. The waste would then be graded to eliminate any depressions and covered with tarps. During removal of the waste from the geomembrane lined area, caution used by the loader operator would reduce punctures. However, in the removal of all the waste, punctures are likely to occur. Following removal of all waste, the geomembrane and portions of the underlying soil should be removed and disposed of in the ICDF landfill. The estimated cost for this alternative would be approximately $6,000.

The concrete mud mat would consist of excavating a 6-in.-thick staging area and pouring a lean concrete mix. This mud mat would provide a surface similar to the asphalt alternative except that cracking would be much more likely for the nonreinforced concrete. The estimated cost for this alternative would be approximately $8,200, based on a total volume of 91 yd^3 at a cost of $90.00 per yd^3 of concrete.

6. CONCLUSIONS AND RECOMMENDATIONS

This EDF presents the results of the liner system alternative analysis conducted for the ICDF Complex bulk soil staging pile. The bulk soil staging area will be managed in accordance with 40 CFR 264.554. The ICDF Remedial Action Work Plan outlines the design and operational requirements (DOE-ID 2003).

Alternatives were developed based on literature review of currently available materials. The advantages and disadvantages associated with using each of these materials were examined. The primary requirement imposed on the alternative analysis was durability of the liner system in order for the liner system to perform its fundamental function as a barrier between the staged waste and the natural soils. Durability of the liner system addresses the issues associated with integrity and longevity of the liner system. In this liner system alternative evaluation, liner effectiveness is defined as the ability of the liner system to perform as follows:

Properly function as a barrier between the staged waste and the natural soil.

Demonstrate adequate strength and/or flexibility characteristics to withstand physical and chemical stresses.

Five alternative liner systems that achieve the desired 15-year design life are presented and discussed in this EDF. In these alternatives, the materials considered for the **primary** liner material include the HDPE geomembrane, the HMAC with or without FAAM. Liner system components above the liner were selected according to their effectiveness as a protective layer or surface to preserve the overall durability characteristics of the liner system. The materials that were assessed to satisfy these requirements (with due consideration to cost) are PAC and compacted soil cover. Specifically, the five liner system alternatives presented in this EDF include the following:

1. Alternative 1: HDPE with Soil Cover

2. Alternative 2: HDPE with PAC Surface

3. Alternative 3: HMAC/FAAM with Soil Cover

4. Alternative **4:** HMAC/FAAM with PAC Surface

5. Alternative 5: HMAC Surface with Base Course Subgrade.

Because these alternatives were chosen according to the established criteria mentioned previously, each of the alternatives satisfies the essential requirements of durability and permeability of a liner system, amidst some potential disadvantages identified for each of the alternatives.

With regards to durability, the HMAC appears to be superior to the HDPE geomembrane liner, especially where a compacted soil layer is used as a protective soil cover. Both the HDPE and **HMAC** liners could perform very well as an impermeable barrier layer against leachate migration.

With regards to the component above the primary liner, the PAC protective surfacing appears to be superior to the compacted soil cover for this application, because of the potential exposure of the liner system to repeated live loads during its 15-year design life. However, the potential of cost savings associated with using soil cover instead of the PAC surface may be so great (especially if onsite soils are available) that modifications could be made to Alternatives 1 and 3 to improve the durability rating **of** the liner system. Such modifications could involve increasing the cover thickness to further reduce the risk of damaging the underlying liner.

With respect to cost, the five alternatives are similar (approximately 30% difference in construction cost between the lowest and the highest). The construction cost breakdown is as follows:

- Alternative 1 (HDPE plus Protective Soil Cover) – $155,000.00
- Alternative **2** (HDPE plus Protective Soil Cover plus PAC) – $219,000.00
- Alternative 3 (HMAC plus Protective Soil Cover) – $185,000.00
- Alternative **4** (HMAC plus PAC Overlay) – $199,000.00
- Alternative 5 (HMAC Surface with Base Course Subgrade) – $200,000.00.

Maintenance and repair costs were also estimated for each of the long-term alternatives. Costs were normalized to an annual basis in 2003 dollars. Alternatives 1 and 3 require replacement of *6* in. of soil cover every year at an annual cost of $10,500. Alternatives **2,4** and **5** require application of a repair seal coat to the **PAC** or **HMAC** working surface once every **3** years, at an annualized cost of $3,800.

For a long-term alternative that could last for 15 years, either Alternative 4 or Alternative **5** is recommended. The anticipated costs of these two alternatives from the standpoint of material disposal after the life **of** the staging area facility are lower. The **HMAC** is also anticipated to perform the required function of a barrier between the natural soils and the staged wastes better than Alternative 1.

For a short-term alternative that would provide segregation of the wastes *from* the natural ground, the pavement alternative is recommended. The concrete alternative was not recommended because it would be susceptible to cracking, while the liner alternative is operation sensitive, in order to maintain the integrity of the liner during waste placement. The pavement alternative would provide easier operation and has adequate flexibility to perform for the 2 year expected life.

7. REFERENCES

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Appendix A

Cost Estimates

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INEEL ICDF STAGING PILE

ORDER OF MAGNITUDE COST OPINION

DATE: 5/30/03
PROJECT NO:
ESTIMATE BY: D Hedlgin/K. Sampaco

DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL	LABOR/EQUIPMENT UNIT HOURS	LABOR/EQUIPMENT CREW RATE	LABOR/EQUIPMENT UNIT COST	LABOR/EQUIPMENT TOTAL	TOTAL UNIT COST	TOTAL COST	COMMENTS
Cell Dimensions: (feet by feet)	150	270									
Alternative 1: HDPE plus 2' Soil Cover											
60-mil HDPE Geomembrane, Textured	4,500	SY	$7.00	$31,500.00	0	$0.00	$0.00	$0.00	$7.00	$31,500	
Geotextile, 12oz	4,500	SY	$1.50	$6,750.00	0	$0.00	$0.00	$0.00	$1.50	$6,750	
Soil Cover above Liner	3,000	CY	$5.00	$15,000.00	0.02	$447.46	$8.95	$26,847.36	$13.95	$41,847	
Misc. Detail	1	LS	$0.00	$0.00	0	$0.00	$0.00	$0.00	$8,009.74	$8,010	% allowance clear, grub, anchor trenches, etc
SUBTOTAL										$88,107	
MOBILIZATION	10.0%									$8,811	Includes bonds, insurance, temp facilities, health, safety, demob, etc
SUBTOTAL										$96,91a	
CONTINGENCY	30.0%									$29,075	
SUBTOTAL										$125,993	
SITE FACTOR	20.0%									$29,075	40hr training, monitoring, security constraints, etc
CONSTRUCTION TOTAL (ROUNDED)										$155,000	
O&M Replacment Costs - Annual	750	CY	$5.00	$3,750.00	0.02	$447.46	$8.95	$6,711.84	$13.95	$10,500	Replace 6" soil cover during waste pile movement every year

NOTE: The above cost opinion is in March 2003 dollars and does not include escalation, engineering, construction management, sales tax, or financial.
The cost opinion shown has been prepared for guidance in project evaluation from the information available at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

INEEL ICDF STAGING PILE

ORDER OF MAGNITUDE COST OPINION

DATE 5/30/03
PROJECT NO:
ESTIMATE BY: D Hedlgin/K. Sampaco

DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL	UNIT HOURS	LABOR/EQUIPMENT CREW RATE	LABOR/EQUIPMENT UNIT COST	LABOR/EQUIPMENT TOTAL	TOTAL UNIT COST	TOTAL COST	COMMENTS
Ceil Dimensions: (feet by feet)	150	270									
Alternative 2: HDPE plus 1' Soil Cover plus 5.5" PAC											
60-mil HDPE Geomembrane, Textured	4,500	SY	$7.00	$31,500.00	0	$0.00	$0.00	$0.00	$7.00	$31,500	
Geotextile, 12oz	4,500	SY	$1.50	$6,750.00	0	$0.00	$0.00	$0.00	$1.50	$6,750	
Soil Cover above Liner	1,500	CY	$5.00	$7,500.00	0.02	$447.46	$8.95	$13,423.68	$13.95	$20,924	
Paving Asphalt Concrete (PAC)	1,346	TN	$40.00	$53,831.25	0	$0.00	$0.00	$0.00	$40.00	$53,831	5.5" average thickness
Misc. Detail	1	LS	$0.00	$0.00	0	$0.00	$0.00	$0.00	$11,300.49	$11,300	% allowance-clear, grub, anchor trenches, etc
SUBTOTAL										$124,305	
MOBILIZATION	10.0%									$12,431	Includes bonds, insurance, temp facilities, health, safety, demob, etc
SUBTOTAL										$136,736	
CONTINGENCY	30.0%									$41,021	
SUBTOTAL										$177,757	
SITE FACTOR	20.0%									$41,021	40hr training, monitoring, security constraints. etc
CONSTRUCTION TOTAL (ROUNDED)										$219,000	
O&M Replacment Costs -Annual	4,500	SY	$2.50	$11,250.00	0	$0.00	$0.00	$0.00	$2.50	$3,800	Apply PAC repair seal coat once every 3 years

NOTE: The above cost opinion is in March 2003 dollars and does not include escalation, engineering, construction management, sales tax, or financial.
The cost opinion shown has been prepared for guidance in project evaluation from the information available at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

INEEL ICDF STAGING PILE

ORDER OF MAGNITUDE COST OPINION

DATE: 5/30/03
PROJECT NO:
ESTIMATE BY: D Hedgin/K. Sampaco

DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL	LABOR/EQUIPMENT UNIT HOURS	LABOR/EQUIPMENT CREW RATE	LABOR/EQUIPMENT UNIT COST	LABOR/EQUIPMENT TOTAL	TOTAL UNIT COST	TOTAL COST	COMMENTS
Alternative 3: 4" HMAC plus 2' Soil Cover											
Soil Cover above Liner	3,000	CY	$5.00	$15,000.00	0.02	$447.46	$8.95	$26,847.36	$13.95	$41,847	
Hot Mix Asphalt Concrete (HMAC) w/ FAAM	979	TN	$55.00	$53,831.25	0	$0.00	$0.00	$0.00	$55.00	$53,831	4' average thickness
Misc. Detail	1	LS	$0.00	$0.00	0	$0.00	$0.00	$0.00	$9,567.86	$9,568	% allowance-clear, grub, anchor trenches, etc
SUBTOTAL										$105,246	
MOBILIZATION	10.0%									$10,525	Includes bonds, insurance, temp facilities, health, safety, demob, etc
SUBTOTAL										$115,771	
CONTINGENCY	30.0%									$34,731	
SUBTOTAL										$150,502	
SITE FACTOR	20.0%									$34,731	40hr training, monitoring, security constraints. etc
CONSTRUCTION TOTAL (ROUNDED)										$185,000	
O&M Replacment Costs -Annual	750	CY	$5.00	$3,750.00	0.02	$447.46	$8.95	$6,711.84	$13.95	$10,500	Replace 6" soil cover during waste pile movement every year

NOTE: The above cost opinion is in March 2003 dollars and does not include escalation, engineering, construction management, sales tax, or financial.
The cost opinion shown has been prepared for guidance in project evaluation from the information available at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL	LABOR UNIT HOURS	LABOR CREW RATE	EQUIPMENT UNIT COST	EQUIPMENT TOTAL	TOTAL UNIT COST	TOTAL COST	COMMENTS
Cell Dimensions: (feet by feet)	150	270									
Alternative 4: 4" HMAC plus 5.5" PAC Overlay											
Hot Mix Asphalt Concrete (HMAC) w/FAAM	979	TN	$55.00	$53,831.25	0	$0.00	$0.00	$0.00	$55.00	$53,831	4 average thickness
Paving Asphalt Concrete (PAC)	1,346	TN	$40.00	$53,831.25	0	$0.00	$0.00	$0.00	$40.00	$53,831	5.5' average thickness
Misc. Detail	1	LS	$0.00	$0.00	0	$0.00	$0.00	$0.00	$5,383.13	$5,383	% allowance-clear, grub, anchor trenches, etc
SUBTOTAL										$113,046	
MOBILIZATION	10.0%									$11,305	Includes bonds, insurance, temp facilities, health, safety, demob, etc
SUBTOTAL										$124.350	
CONTINGENCY	30.0%									$37,305	
SUBTOTAL										$161,655	
SITE FACTOR	20.0%									$37,305	40hr training, monitoring, security constraints, etc
CONSTRUCTION TOTAL (ROUNDED)										$199,000	
O&M Replacment Costs -Annual	4,500	SY	$2.50	$11,250.00	0	$0.00	$0.00	$0.00	$2.50	$3,800	Apply PAC repair seal coat once every 3 years

NOTE: The above cost opinion is in March 2003 dollars and does not include escalation, engineering, construction management, sales tax, or financial.
The cost opinion shown has been prepared for guidance in project evaluation from the information available at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

INEEL ICDF STAGING PILE

ORDER OF MAGNITUDE COST OPINION

DATE: 5/30/03
PROJECT NO:
ESTIMATE BY: D. Hedglin/K. Sampaco

DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL	LABOR/EQUIPMENT UNIT HOURS	LABOR/EQUIPMENT CREW RATE	LABOR/EQUIPMENT UNIT COST	LABOR/EQUIPMENT TOTAL	TOTAL UNIT COST	TOTAL COST	COMMENTS
Alternative 5: 5.5" HMAC plus 12" Base Course											
Granular Base Course	1,500	CY	$15.00	$22,500.00	0.02	$447.46	$8.95	$13,423.68	$23.95	$35,924	
Hot Mix Asphalt Concrete (HMAC)	1,346	TN	$50.00	$67,289.06	0	$0.00	$0.00	$0.00	$50.00	$67,289	5.5" average thickness
Misc. Detail	1	LS	$0.00	$0.00	0	$0.00	$0.00	$0.00	$10,321.27	$10,321	% allowance-clear, grub, anchor trenches, etc
SUBTOTAL										$113.534	
MOBILIZATION	10.0%									$11,353	Includes bonds, insurance, temp facilities, health, safety, demob, etc
SUBTOTAL										$124,887	
CONTINGENCY	30.0%									$37.466	
SUBTOTAL										$162.354	
SITE FACTOR	20.0%									$37,466	40hr training, monitoring, security constraints, etc
CONSTRUCTION TOTAL (ROUNDED)										$200.000	
O&M Replacment Costs - Annual	4,500	SY	$2.50	$11,250.00	0	$0.00	$0.00	$0.00	$2.50	$3,800	Apply HMAC repair seal coat once every 3 years

NOTE: The above cost opinion is in March 2003 dollars and does not include escalation, engineering, construction management, sales tax, or financial.
The cost opinion shown has been prepared for guidance in project evaluation from the information available at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Updated
8/31/02

TRADES'					
Carpenter	1	36.00	1.40	1.2	$60.48
Cement Mason	1	37.02	1.40	1.2	$62.19
Electrician	1	43.83	1.40	1.2	$73.63
Fence Laborer	1	12.77	1.40	1.2	$21.45
Flagger	1	26.18	1.40	1.2	$43.98
Ironworker	1	37.17	1.40	1.2	$62.45
Laborer	1	30.86	1.40	1.2	$51.84
Pipe Layer	1	31.34	1.40	1.2	$52.65
Painter, .	1	28.63	1.40	1.2	$48.10
Plumber	1	46.06	1.40	1.2	$77.38
Oper-Heavy	1	38.54	1.40	1.2	$64.75
Oiler/Mechanic	1	37.60	1.40	1.2	$63.17
Teamster	1	35.47	1.40	1.2	$59.59
Welder	1	30.86	1.40	1.2	$51.84

CREWS

Excavation							
Foreman	1	39.54	39.54	Pickup	10.00		
Oper-Heavy	1	38.54	38.54	Trench Box	0.00		
Oiler	1	37.60	37.60	Excavator	80.00		
Laborer	1	30.86	30.86		90.00		
			146.54		1		
	T&I		1.40		$90.00		
	OH&P		1.2		1.2		
			$246.19		$108.00	f	354.19

Backfill							
Foreman	1	39.54	39.54	Pickup	10.00		
Oper-Heavy	2	38.54	77.08	Roller	20.00		
Oiler	0	37.60	0.00		0.00		
Laborer	3	30.86	92.58	Dozer/Loader	50.00		
			209.20		80.00		
	T&I		1.40,				
	OH&P		1.2		1.2		
			$351.46		$96.00	$	447.46

Pipe & Manhole							
Foreman	1	37.00	37.00	Pickup	10.00		
Operator	1	36.00	36.00	h e	$100.00		
Oiler	1	37.60	37.60				
Laborer	3	30.86	92.58		0.00		
			203.18		110.00		
	T&I		1.40		1.2		
	OH&P		1.2				
			$341.34		f132.00	$	473.34

Load						
Foreman	1	37.00	37.00		$0.00	
Operator	1	36.00	36.00	Loader	$80.00	
Laborer	0	30.86	0.00	Pickup	10.00	
			73.00		$90.00	
	T&I		1.40			
	OHBP		1.2	OH&P	1.2	
			$122.64		$108.00	$230.64

Place & Compact							
Foreman	1	37.00	37.00	Pickup	10.00		
Operator	2	36.00	72.00	Dozer (2)	$80.00		
Laborer	1	30.86	30.86				
			139.86		90.00		
	T&I		1.40		1.2		
	OHBP		1.2				
			$234.96		$108.00	$	342.96

CREWS (continued)

Hauling							
Teamster	1	35.47	35.47	Truck 8 Trailer	45.00		
			35.47		45.00		
	T&I		1.40				
	OH&P		1.2	OH&P	1.2		
			$59.59		$54.00	$	11359
Misc							
Foreman	1	37.00	37.00				
Carpenter/Laborer	1	36.00	36.00	Misc	5.00		
			73.00		5.00		
	T8I		1.40				
	OH&P		1.2	OH&P	1.2		
			$122.64		$6.00	$	128.64

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Appendix B

Calculations

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Subject: Geomembrane Puncture Protection (Cushion Geotextile) Calculations
Calcs by: KSampaco/CH2M HILL

Date: 03/04/2003

Geomembrane Puncture Proctection Calculations
Prepared by: K. Sampaco
Date: 03/04/2003

Reference: R.M. Koerner, "Designing with Geosynthetics" 4th Edition, p. 535-537, 1998

Koerner presents design method for protection of 60 mil (1.5mm) thick HDPE Geomembrane.
Note: Greater thickness geomembrane will have greater FS

$FS = p_{allow}/p_{act}$

p act = values from ground pressure calcs (σ_c) or static pressure from landfill contents
p allow = allowable pressure (kPa) where:

p allow = $(50 + 0.00045M/H^2) x [1/(MF_S \times MF_{PD} \times MF_A)] x [1/(RF_{CR} \times RF_{CBD}]$ where:

M =	geotextile mass per unit area (g/m^2)
H =	protrusion height (m) = 1/2 max stone size height or d_{50}
MF_S =	modification factor for protrusion shape; (1.0 angular, 0.5 subrounded, 0.25 rounded)
MF_{PD} =	modification factor for packing density; (1.0 isolated, 0.5 - 0.83 dense varies with stone size
MF_A =	modification factor for arching; (1.0 hydrostatic, 0.25 - 0.75 geostatic deep to shallow
RF_{CR} =	reduction factor for long-term creep; (1.3 average value for 12 mm protrusion height)
RF_{CBD} =	reduction factor for long-term chemical/biological degradation; (1.3 average value for moderate leachate)

Calculations:

p act =	65	psi - maximum landfill contents pressure
p act =	448.1	kPa
M =	12	oz/yd^2
M =	405.6	g/m^2 (1 oz/yd^2 = 33.8 g/m^2)
H =	0.0254	m equals 1/2 max particle size (1")
MF_S =	1.0	angular crushed gravel
MF_S =	0.5	subrounded crushed gravel
MF_{PD} =	0.5	12.5 mm dense packed gravel
MF_A =	0.5	moderate arching
RF_{CR} =	1.3	average for 12.5 mm protrusion
RF_{CBD} =	1.3	moderate leachate

for H = 12.5 mm (1" particle size) and angular gravel (MF_s = 1.0)
p allow = 787.9 kPa
FS = 1.8
for H = 125 mm (1' particle size) and subrounded gravel (MF_s = 0.5)
p allow = 1575.9
FS = 3.5
Koerner (1998) recommends minimum global FS > 3.0 for packed stones/rock thus OK for 12oz/yd^2 geotextile over geomembrane, even for angular gravel at max particle size of 1.5 inches.

Summary Table--12 oz/yd^2 geotextile			Summary Table--12 oz/yd^2 geotextile		
Angular rock (MF_s = 1.0)			Subrounded rock (MF_s = 0.5)		
Max Size (In)	H (mm)	FS	Max Size (In)	H (mm)	FS
0.5	6.4	23.8	0.5	6.35	47.6
0.75	9.5	10.9	0.75	9.525	21.9
1	12.7	6.2	1	12.7	12.5
1.5	19.1	2.9	1.5	19.05	5.8
2	25.4	1.6	2	25.4	3.5

Subject: Geomembrane Puncture Protection (Cushion Geotextile) Calculations
Calcs by: K. Sampaco/CH2M HILL

Date: 03/04/2003

Geomembrane Puncture Proctection Calculations
Prepared by: K. Sampaco
Date: 03/04/2003

Reference: R.M. Koerner, "Designing with Geosynthetics" 4th Edition, p. 535-537, 1998

Koerner presents design method for protection of 60 mil (1.5mm) thick HDPE Geomembrane.
Note: Greater thickness geomembrane will have greater FS

$FS = p_{allow}/p_{act}$

p act =	values from ground pressure calcs (σ_c) or static pressure from landfill contents
p allow =	allowable pressure (kPa) where:

p allow = $(50 + 0.00045M/H^2)x[1/(MF_S \times MF_{PD} \times MF_A)]x[1/(RF_{CR} \times RF_{CBD}]$ where:

M =	geotextile mass per unit area (g/m^2)
H =	protrusion height (m) = 1/2 max stone size height or d_{10}
MF_S =	modification factor for protrusion shape; (1.0 angular, 0.5 subrounded, 0.25 rounded)
MF_{PD} =	modification factor for packing density; (1.0 isolated, 0.5 - 0.83 dense varies with stone size
MF_A =	modification factor for arching; (1.0 hydrostatic, 0.25 - 0.75 geostatic deep to shallow
RF_{CR} =	reduction factor for long-term creep; (1.3 average value for 12 mm protrusion height)
RF_{CBD} =	reduction factor for long-term chemical/biological degradation; (1.3 average value for moderate leachate)

Calculations:

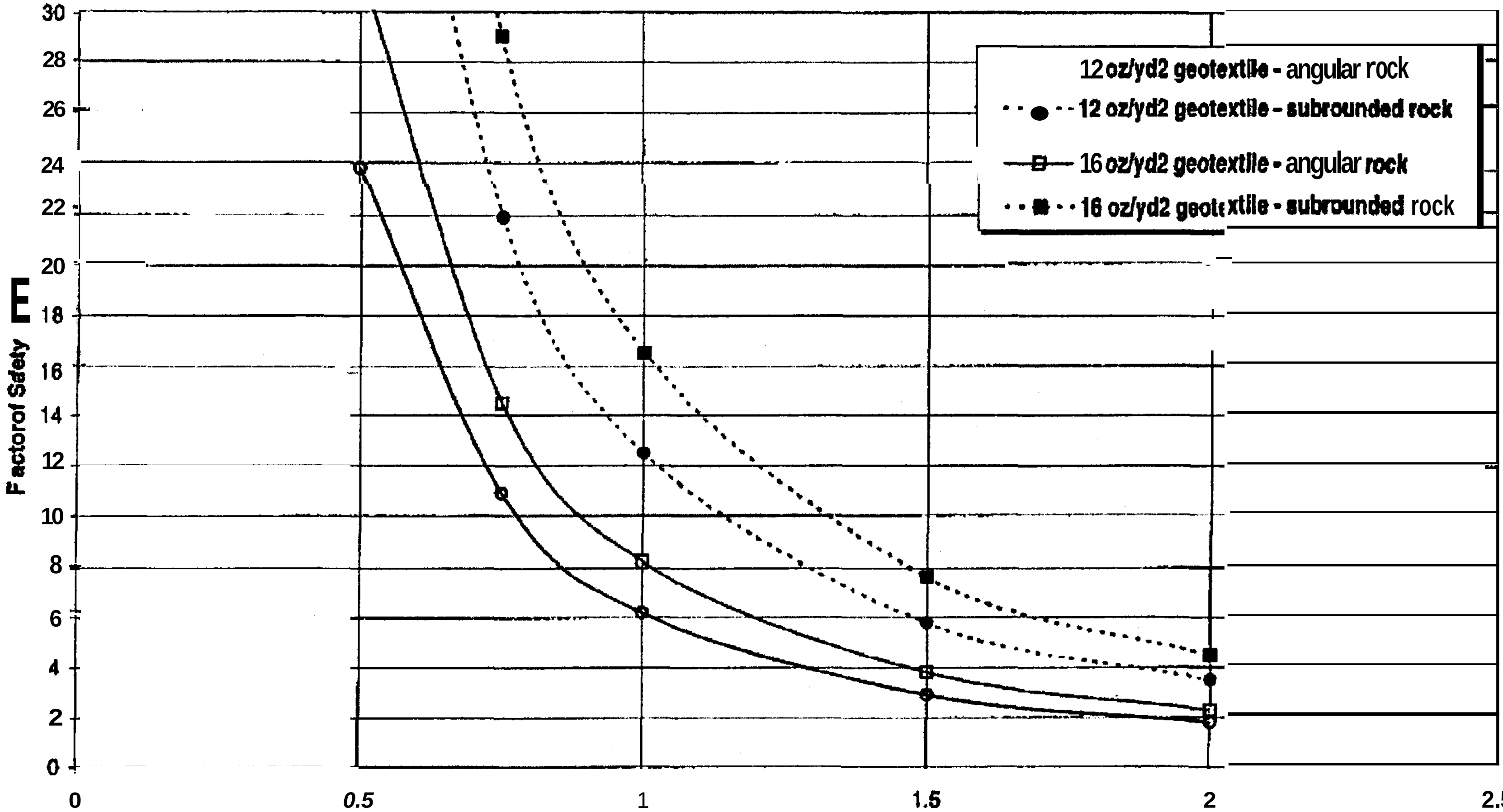
p act =	65	psi - maximum landfill contents pressure
p act =	448.1	kPa
M =	16	oz/yd^2
M =	540.8	g/m^2 (1 oz/yd^2 = 33.8 g/m^2)
H =	0.0254	m equals 1/2 max particle size (1")
MF_S =	1.0	angular crushed gravel
MF_S =	0.5	subrounded crushed gravel
MF_{PD} =	0.5	12.5 mm dense packed gravel
MF_A =	0.5	moderate arching
RF_{CR} =	1.3	average for 12.5 mm protrusion
RF_{CBD} =	1.3	moderate leachate

for H = 12.5 mm (1" particle size) and angular gravel (MF_s = 1.0)
p allow = 1011.1 kPa
FS [illegible]
for H = 12.5 mm (1" particle size) and subrounded gravel (MF_s = 0.5)
p allow = 2022.3
FS [illegible]
Koerner (1998) recommends minimum global FS > 3.0 for packed stones/rock thus OK for 16 oz/yd^2 geotextile over geomembrane, even for angular gravel at max particle size 1.5 inches.

Summary Table--16 oz/yd^2 geotextile			Summary Table--16 oz/yd^2 geotextile		
Angular rock (MF_s = 1.0)			Subrounded rock (MF_s = 0.5)		
Max Size (In)	H (mm)	FS	Max Size (In)	H (mm)	FS
0.5	6.4	31.6	0.5	6.35	63.3
0.75	9.5	14.5	0.75	9.525	29
1	12.7	8.2	1	12.7	16.5
1.5	19.1	3.8	1.5	19.05	7.6
2	25.4	2.3	2	25.4	4.5

Subject: Geomembrane Puncture Protection (Geotextile Cushion) Calcs
Calcs by: K,L Sampaco/CH2M HILL

Date: 03/04/2003



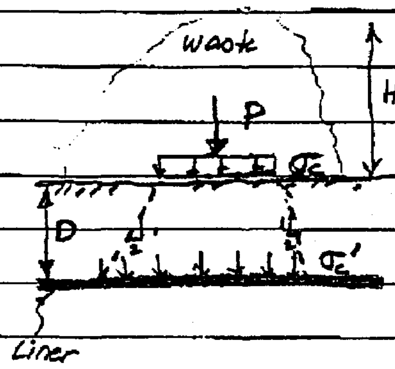
Liner Alternative Evaluation

BY: KLS DATE: 03/07/2003

PROJECT NUMBER: SHEET 1 OF 1

◉ Estimate required thickness of cover to reduce stresses due to equipment loads to an equivalent weight of the 10' waste (maximum height of waste in the storage pile – assumed based on Mark Nickson's email):

CASE 1: CAT 775E DUMP TRUCK (maximum Load)



Ground Pressure, $\sigma_c = 65$ psi

Wheel Load = 41,300 lbs = P

$$\sigma_c' = \sigma_c \left[\frac{R^2}{(R+D)^2} \right]$$

$$R = \left[\frac{P}{\pi \sigma_c} \right]^{1/2};$$ R is the equivalent circular radius of contact

$$R = \left[\frac{41{,}300 \text{ lbs}}{\pi (65 \text{psi})} \right]^{1/2} = 14.2 \text{ inches}$$

For 10' waste with $\gamma_{wt} \approx 120$ pcf :

$$\sigma_c' = 120 * 10' * \frac{1 \text{ ft}^2}{144 \text{ in}^2} \approx 8.3 \text{ psi}$$

∴ Due to Equipment loading :

D (ft)	D (in.)	σ_c' (psi)	σ_c' (psf)
1'	12"	19.10	2749
2'	24"	8.98	1293
2.5'	30"	6.71	966

∴ Need a minimum of 2' of cover to reduce effect of equipment loading to the effect of the 10' waste.

Loads Per Tire for Construction Equipment

BY: KLS DATE: 03/06/2003

PROJECT NUMBER: SHEET 1 OF 3

Estimate Loading Per Tire :

(1) CAT 966 G-WHA (Front-end Loader)

Waste Handling Arrangement

Total Operating Weight, $W = 54,215$ lb

Tire Model = 26.5 R 25 (Michelin), Tread ⇒ XHA

Inflation Pressures: Front ≈ 45 psi
Rear ≈ 25 psi

∴ Front load could be as high as 80% of the Rear.

Model Has 4 tires.

- If equal load per tire ; W'

$$W' = \frac{54,215 \text{ lb}}{4} = 13,554 \text{ lbs.} \Rightarrow W_F' = W_R'$$

Front Rear

- If Front = 80% more than the rear ⇒ $W_F' = 1.8\, W_R'$

$$2W_F' + 2W_R' = 54,215 \text{ lbs.}$$

$$\therefore 2\left[1.8\, W_R'\right] + 2W_R' = 54,215 \text{ lb.}$$

$$5.6\, W_R' = 54,215 \text{ lb.}$$

$$W_R' \cong 9682 \text{ lb.}$$

$$\therefore \quad W_F' = 1.8(9682) = 17,426 \text{ lb.}$$

∴ Minimum Tire Load = 13,554 lbs
Maximum Tire Load = 17,426 lbs

For the Front Tires.

Inflation Pressure = 45 psi

BY: KLS DATE: 03/06/2003
PROJECT NUMBER: SHEET 2 OF 3

For the Rear Tires:

Inflation pressure ≅ 25 psi

Min. Load ≅ 9,700 lbs.

Max. Load ≅ 13,600 lbs.

Front Rear

(2) Tandem Dump Truck (CAT 775E)

Total operating weight = 239,000 lbs.

Tire : 24 R35

Tread: XDT A4

Inflation Pressure : 80 psi (Front & Rear)

Rear Axle = 69%

Front Axle = 31%

$\therefore$ Rear Axle Load $= W_R =$ 239,000 * 0.69 = 164,910 lb.

Tire Load $= W_R' = \frac{W_R}{4} = \frac{164,910}{4} = 41,230$ lbs

Front Axle Load $= W_F = 0.31\,(239,000) = 74,090$ lbs

Tire Load $= W_F' = \frac{W_F}{2} = 37,045$ lbs

Ground Pressures/ Contact Pressures

BY: KLS DATE: 03/07/2003

PROJECT NUMBER: SHEET 3 OF 3

(3) CAT 420 Backhoe (Rubber-Tired) $\rightarrow W_T = 21{,}605$ lbs.

If equal load for all tires:

$$W_F' = W_R' = \frac{21{,}605 \text{ lbs}}{4} \approx 5{,}400 \text{ lbs per tire}$$

If one axle is 70% more than the other axle:

$$2W_F' + 2W_R' = 21{,}605 \text{ lbs.}$$

$$2W_F' + 2(1.7W_F') = 21{,}605 \text{ lbs.}$$

$$2W_F' + 3.4W_F' = 21{,}605 \text{ lbs}$$

$$W_F' \cong 4{,}000 \text{ lbs.}$$

$$W_R' = 1.7(4{,}000 \text{ lbs}) \approx 6{,}800 \text{ lbs.}$$

$\therefore$ Use Range of 4,000 to 6,800 lbs for tire load.

(4) Bobcat Loader (CAT 246)

Operating Weight = 7,087 lbs

Tire Model: Goodyear 12-16.5

Inflation Pressure = 35 psi

$$\text{Maximum Weight per Tire} = \frac{7{,}087 \text{ lbs}}{4} \simeq 1772 \text{ lbs.}$$

Liner Alternatives

BY: KLS DATE: 03/05/03

PROJECT NUMBER: SHEET 1 OF

● Information on Michelin Tires for Use in Heavy Construction:

① Tandum Dump Truck – CAT 775E [W = 239,000 lbs]

Tire: 24 R 35

Tread: XDT A4

Inflation Pressure: 80 psi (Front and Rear)

② CAT 966 G – Front End Loader [W ≅ 54,215 lb] —

Tire: 26.5 R 25

Tread Arrangement: XHA

Inflation Pressure: 45 psi (Front)
25 psi (Rear)

③ CAT 420 Rubber-Tired Backhoe [W ≅ 21,605 lbs] ←

Front Tire: 12.5/80 R 18

Tread Arrangement: XM 37

Inflation Pressure: 40 psi

Rear Tire: 16.9 R 28

Tread Arrangement: XM 27

Inflation Pressure: 24 psi

● INFO provided by: Cody firm
~~Western States Equipment Co.~~
Idaho Falls, Idaho
(208) 552-2287

March 7, 2003

To: King Sampaco – CH2MHILL
Fr: Dave Strang – Michelin EM Technical Support
Subject: Contact Area and Ground pressure

Here are calculations of the requested information.

Tire Size	Tire pressure	Load	Total contact area	Ground Pressure	
26.5R25	45 psi	13600 lbs	305 in2	45 psi ✓	CAT 966G Front-end Loader
	45 psi	17500 lbs	372 in2	47 psi ✓	
	25 psi	9700 lbs	382 in2	25 psi ← 26 psi	CAT 966G Front-end loader
	25 psi	13600 lbs	460 in2	29 psi ← 30 psi	
24.00R35	80 psi	37000 lbs	605 in2	61 psi ✓	CAT 775E Dump Truck
	80 psi	41300 lbs	639 in2	65 psi ✓	
12R16.5	35 psi	1800 lbs	58 in2	31 pd ✓	Loader (CAT 246)

16.9R28 XM27 and 12.5/80R18 XM37 - These product8 belong to the Agricultural product line. I have requested the information. Hope to have the information by next week.

NOTE: All figures above are calculations and are not verified by actual measurements. The calculations will vary with change in any of the following – (load, tire pressure, road surface, temperature, machine type and use, load configuration). When using these calculations and safety is an issue, always error on the side of safety.

UNITS
Inches

Thickness Estimate for the PAC Surface Layer

Assumptions:

Design #2 CBR=10

(1) Traffic — 10,000 vehicles/year @ 3.5 ESAL/vehicle, multiplied by 15 years = 525,000 ESAL's

(2) CBR = 10, M_r ~ 9,389 (Using NCHRP 128 conversion)

Flexible Pavement Analysis

Structural Number	2.26
Design E 18's	525.000
Reliability	50.00
Overall Deviation (*)	0.45
Soil Resilient Mod.(*)	9,389
Initial Serviceability	4.20
Terminal Serviceability	2.00

UNITS
No Units

Solve FOX

Structural Number 2.26

PgDn FOR LAYER DETERMINATION

FLEXIBLE PAVEMENT THICKNESS DETERMINATION

Layer Number	Layer(*) Coefficient a (i)	Drainage Coefficient m (i)	Layer Thickness t	a(i)*Cd*t	Additional Thickness Needed
Upper	0.42	1.00	5.50	2.31	-0.12
2					
3					
4					
5					
6					

Required Thickness of Paving Asphalt Concrete (PAC)

Σ 2.31
SN Required = 2.26 (Ok)

UNITS
Inches