

**TOTAL ENVIRONMENTAL RESTORATION CONTRACT  
USACE CONTRACT NO. DACW33-03-D-0006  
TASK ORDER 3**

**SOURCE CONTROL REMEDIAL ACTION**

**REVIEW OF EXISTING CAP AND CONSIDERATIONS  
FOR FINAL CAP DESIGN**

**TECHNICAL MEMORANDUM**

**SILRESIM SUPERFUND SITE  
Lowell, Massachusetts**

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## **1.0 INTRODUCTION**

Tetra Tech FW, Inc. (TtFW), formerly known as Foster Wheeler Environmental (Foster Wheeler), has prepared this Technical Memorandum for the Silresim Superfund Site (the Site) under Task Order No. 03 of the U.S. Army Corps of Engineers (USACE) Total Environmental Restoration Contract (TERC) No. DACW33-03-D-0006.

### **1.1 Purpose**

The purpose of this memorandum is to review the current cap at the Silresim Site and to discuss potential final cap design options that satisfy applicable regulatory requirements and how these options affect the future use of the Site. This memorandum summarizes previous document findings and reviews new technologies that may be applicable to capping considerations at the Site.

### **1.2 Organization**

This Technical Memorandum is presented in eight sections.

Section 1.0, Introduction, presents the objectives of this memorandum and the organization.

Section 2.0, Background, discusses the site background and summarizes existing ROD requirement for site capping.

Section 3.0, Capping Overview, discusses capping objectives and basic cap construction including limitations and alternative cap designs.

Section 4.0, MatCon Capping Alternative, reviews the MatCon technology and its advantages.

Section 5.0, Existing Site Conditions, reviews the construction of the existing Silresim cap.

Section 6.0, Applicable Site Regulations, outlines regulatory requirements applicable to Silresim and briefly reviews the Massachusetts Department of Environmental Protection (MADEP) guidance document on engineered barriers.

Section 7.0, Site Capping Options, presents options to address the capping requirements at the Site and provides recommendations.

Section 8.0, References.

## **2.0 SITE BACKGROUND**

In 1984, a low permeability clay cap was installed over approximately 4.0 acres of the Silresim Property as part of an United States Environmental Protection Agency (USEPA) emergency response action. This cap included a vegetated 6-inch loam layer, a 14-inch barrier clay layer, a varying thickness supporting base fill layer and a 9-inch gravel layer over the contaminated soil. This cap was designed to reduce infiltration of water at the Site and to direct stormwater runoff to an interior swale that discharged into a closed drainage system into River Meadow Brook.

In 1994, Foster Wheeler mobilized to the Site to install the Groundwater Treatment Plant (GWTP). During mobilization, it was observed that the clay cap had desiccated in several areas, due in part, to the lack of a sustained vegetative layer. The subsequent construction of the treatment system and the associated groundwater extraction well system had also impacted the integrity of the cap and altered the existing cap drainage patterns. The construction of the GWTP and extraction well piping caused stormwater to pond on the cap in several locations. Due to surface water ponding and desiccation of the clay layer, significant infiltration of water into the subsurface was occurring. This reduced the effectiveness of the groundwater extraction and soil vapor extraction (SVE) remediation measures. Therefore, an improvement or replacement of the existing cap was required.

The purpose of the 1998 cap upgrade was to minimize stormwater infiltration into the subsurface and improve surface drainage. This was accomplished by improving existing drainage to remove surface water from the cap, and reduce the permeability of the barrier layer. In order to support selection of cap and drainage options, several conceptual cap upgrade alternatives were developed and evaluated. The evaluation included a discussion of the advantages, disadvantages, and cost of each option.

Based on the evaluation, Repairing the Existing Cap (Alternative - 1) was the recommended alternative. It was determined that improving drainage on the cap would have the most significant impact on the effectiveness of the cap upgrade. A secondary consideration was cap impermeability. The repaired clay cap was expected to provide an adequate low permeability barrier for the proposed short-term application. Repairing the existing clay cap was also the easiest to construct and the least expensive alternative.

The Phase I Source Control remedial activities include the design and implementation of the cap upgrade. The conceptual options for the cap upgrade and the selection of the preferred alternative were included in Section 4.0 of the Implementation Plan (Foster Wheeler, 1998a). The cap upgrade design was presented in a separate Implementation Plan (Foster Wheeler, 1998b) and subsequently implemented in the field by Foster Wheeler.

The objective of the cap upgrade was to minimize surface water infiltration to the groundwater, presumably lowering the groundwater table elevation which was expected to help reduce soil moisture in the vadose zone. It was proposed that the cap upgrade encompass the entire Site in the event that SVE implementation was expanded to other areas of the Site. The cap upgrade was meant to be a temporary solution with a minimum design life of 5 years. All options included a drainage plan for the Site. The options were evaluated based on a standard set of criteria that included cost, flexibility with future use of the Site, and ease of implementation. Installation of the most cost-effective option that satisfied the criterion was recommended. Existing site conditions following the cap upgrade are reviewed in Section 5.0.

## **2.1 ROD Requirements**

A Record of Decision (ROD) setting forth the selected remedy for the Site was signed on September 19, 1991 and includes both Source Control and Management of Migration components (USEPA, 1991). As part of the selected Source Control Action, a cap on the Silresim property is required and is defined in the following:

- ALL SOILS CONTAMINATED ABOVE THE CLEANUP LEVELS WOULD BE COVERED WITH A LOW-PERMEABILITY CAP CONFORMING TO RESOURCE CONSERVATION AND RECOVERY ACT (RCRA) SUBTITLE C STANDARDS (THE EXISTING CAP ON THE SILRESIM PROPERTY WOULD BE UPGRADED). CONTAMINATED SOIL WOULD REMAIN ON SITE, AND NO CONTAMINANTS WOULD BE REMOVED, TREATED, OR DESTROYED. THE CAP WOULD PREVENT DIRECT CONTACT WITH CONTAMINANTS IN SURFICIAL SOILS, MINIMIZE INHALATION EXPOSURE, AND LIMIT RAINWATER INFILTRATION AND THEREFORE CONTAMINANT MIGRATION IN THE GROUNDWATER. THE EXISTING CAP (INCLUDING THE CRUSHED STONE CAP IN THE NORTHEAST CORNER OF THE SITE) WOULD BE UPGRADED TO CONFORM TO RCRA STANDARDS. THE UPGRADED CAP WOULD, AT A MINIMUM, CONSIST OF AT LEAST 3 FEET OF LOW PERMEABILITY ( $LT (10^{-7})$  CM/SEC) SOIL LINER INCLUDING: 6 INCHES OF SAND BEDDING COVERED BY A SYNTHETIC LINER, 1 FOOT OF DRAINAGE LAYER SOIL, FILTER FABRIC, 2 FEET OF FINAL COVER, AND SEED AND MULCH. FINAL CAP GRADES IN ALL AREAS WOULD BE FROM 3 PERCENT TO 33 PERCENT. THESE AREAS WOULD HAVE TO BE PREPARED APPROPRIATELY SO THAT THE CAP COULD BE CONSTRUCTED. SITE PREPARATION ACTIVITIES MAY INCLUDE SITE GRADING AND REMOVAL OF DEBRIS, FENCES, SCRAP VEHICLES, ETC. CONSTRUCTION OF THE FENCE AND THE RCRA CAP WOULD BE ACCOMPLISHED USING COMMON, WELL-DEMONSTRATED CONSTRUCTION PRACTICES. NUMEROUS RCRA CAP INSTALLATIONS ARE ALREADY IN PLACE, AND STANDARD CONSTRUCTION PROCEDURES EXIST FOR THE INSTALLATION OF ALL COMPONENTS.

### **3.0 CAPPING OVERVIEW**

Landfill capping is a containment technology that forms a barrier between the contaminated media and the surface, thereby shielding humans and the environment from the harmful effects of its contents and also limiting the migration of the contents. A cap must restrict surface water infiltration into the contaminated subsurface to reduce the potential for contaminants to leach from the Site.

In 1976, Congress passed the Resource Conservation and Recovery Act (RCRA), tightening the regulatory oversight of existing landfills and establishing basic standards for covering landfills (i.e., landfill caps and leachate containment). Two types of caps were required:

- Caps for hazardous waste landfills are more stringent and consists of three layers:
  - 1) an upper vegetative (topsoil) layer;
  - 2) a drainage layer; and,
  - 3) a low permeability layer made of a synthetic material covering 2 feet of compacted clay.
- Caps for non-hazardous waste landfills are less stringent, designed in conjunction with the bottom liner system to keep wastes from migrating.

Landfill capping is the most common form of remediation because it is generally less expensive than other technologies and effectively manages the human and ecological risks associated with a remediation site. Rough industry cost are \$175K/acre for RCRA Subtitle D, and \$225K/acre for RCRA Subtitle C caps.

Capping is often used in combination with groundwater extraction (removal) or containment technologies to reduce and, if possible, prevent contaminant migration. Groundwater monitoring wells are often used in the area where a cap has been installed to detect any migration of the wastes that may unexpectedly occur. Capping is also associated with surface water controls such as ditches, dikes, and berms. These structures are used to receive rainwater drainage that flows from the cap.

### **3.1 Basic Cap Design**

The design of landfill caps is site-specific and depends on the intended functions of the system. Landfill caps can range from a one-layer system of vegetated soil to a complex multi-layer system of soils and geosynthetics. The material used in the construction of landfill caps includes low-permeability and high-permeability soils and low-permeability geosynthetic products. The low-permeability materials divert water and prevent its passage into the waste. The high permeability materials carry water away that percolates into the cap. Other materials may be used to increase slope stability.

All landfill caps have the same general objectives:

- They must prevent the vertical movement of water through the contaminated soil;
- They must provide efficient draining of surface water from the Site to prevent the occurrence of standing water;
- They must be easily maintained;
- They must be resistant to damage caused by the settling and consolidation of soils and other adverse conditions (heat, cold, UV radiation, etc.); and
- They must funnel away as much water as the underlying filter or soils are capable of handling.

The basic layout of a multilayer cap includes (from top to bottom): (1) a surface layer, (2) a protection layer, (3) a drainage layer, (4) a barrier layer, and (5) a gas collection layer. The surface layer usually promotes vegetative growth and evapotranspiration and consists of topsoil. The protection layer is designed to protect the underlying layers from intrusion, desiccation, and freeze-thaw damage and is usually made up of mixed soils. The drainage layer drains away infiltrating water and is made up of sands, gravels, or geotextiles. The barrier layer minimizes infiltration of water into the underlying waste and may direct gas to an emission control system. Barrier layers usually consist of compacted clay or geosynthetic liners, geomembranes, or composites. The gas collection layer transmits gas to collection points for removal or cogeneration and is usually made up of granular materials and piping.

The most common landfill covers currently being used are the RCRA C or D caps. However, these multi-layered cap systems are usually very complex and more costly when compared to alternative solutions.

#### Asphalt/Concrete Cap

The most effective single-layer caps are composed of concrete or bituminous asphalt. It is used to form a surface barrier between landfill and the environment. An asphalt concrete cap would reduce leaching.

### RCRA Subtitle C Cap

The RCRA C multilayered landfill cap is a baseline design that is suggested for use in RCRA hazardous waste applications. These caps generally consist of an upper vegetative (topsoil) layer, a drainage layer, and a low permeability layer which consists of a synthetic liner over 2 feet of compacted clay. The compacted clay liners are effective if they retain a certain moisture content but are susceptible to cracking if the clay material is desiccated. Also, alternate cap designs may be considered for specific situations.

### RCRA Subtitle D Cap

RCRA Subtitle D requirements are for non-hazardous waste landfills.

#### 3.1.1 Gas Collection System

Constructing an active landfill gas collection and treatment system should be considered where (1) existing or planned homes or buildings may be adversely affected through either explosion or inhalation hazards, (2) final use of the Site includes allowing public access, (3) the landfill produces excessive odors, or (4) it is necessary to comply with Applicable or Relevant and Appropriate Requirements (ARARs). Most landfills will require at least a passive gas collection system (venting) to prevent buildup of pressure below the cap and to prevent damage to the vegetative cover. If a passive venting system is required, the locations of lateral piping and vertical vents should be designed as dictated by the waste characteristics.

#### 3.1.2 Cap O&M

Operation and Maintenance (O&M) for caps require periodic inspections, correction of surface erosion problems and inspection of any leachate and gas management systems. An O&M plan must be prepared and must be approved by the pertinent regulators for the Site. O&M plans typically include:

- Visual inspection of the cap and mowing of any grassy areas during the growing season;
- Repairs of any erosion or surface slumping;
- Repairs of any damage to drainage control structures;
- Quarterly monitoring of any existing leachate levels and monitoring wells;
- Quarterly or semiannual monitoring of leachate quality;
- Monthly inspection of any existing components of the leachate collection system;
- Monitoring of any existing gas vents to clear any obstructions; and
- Quarterly or semiannual monitoring of the quality of vented gas.

#### 3.1.3 General Costs

The construction costs of a cap depends on the local availability of materials for the grading layer and cover soils. In general, compacted clay liners may cost more than geosynthetic clay liners, especially if the clay borrow source is distant from the Site. The cost of a cap also depends on the extent of leachate and gas management the Site requires, and therefore cannot easily be quantitatively determined.

The cost of a cap (per acre) can vary from \$500K for installation of a one-layer system to several million dollars for a multilayer cap. The cost is highly dependent on the local availability of materials suitable for construction and the requirements for monitoring, leachate collection, and gas collection. The O&M costs can vary from \$10K to \$50K per year, excluding administrative and reporting costs. The O&M costs are

highly depended on the amount of groundwater and surface-water sampling and any other specific O&M activities required by the applicable regulatory agency.

### **3.2 Capping Limitations**

Landfill caps do not lessen toxicity, mobility, or volume of hazardous wastes, but they do limit contact and migration. Landfill caps are most effective where most of the underlying waste is above the water table as a cap does not prevent the horizontal flow of groundwater through waste; it is only able to control the vertical entry of water into the waste.

Landfill cap integrity must not be compromised by present and future land use activities. Institutional controls are often required to protect the landfill. Compacted clay liners are effective if they retain a certain moisture content, but they are susceptible to cracking if the clay material is desiccated.

Caps have been shown to successfully contain a variety of contaminants, including volatiles, semivolatiles, metals, radioactive materials, corrosives, oxidizers, and reducers. As previously noted, storing materials containing these contaminants in landfills does not reduce their toxicity, mobility, or volume. However, when properly designed and maintained, landfills can isolate contaminated wastes from human and environmental exposure for long periods. Cap maintenance activities include vegetation control; construction-related repairs; and erosion, settlement, and subsidence adjustments. Long-term repairs and maintenance can be minimized if a rigorous QA/QC program is followed during cap construction.

Landfill caps have a limited life span as caps and their components are expected to eventually fail, although long-term inspection and maintenance can extend their effective lives (typical estimated life from 50 to 100 years). Changes in conditions, such as soil moisture and earth movement, should be monitored as indicators of potential problems and mitigated before hazardous releases occur. Fluctuations in ambient temperature and precipitation may also affect the cap's integrity by causing cracking or erosion. In addition, plant roots and burrowing animals can undermine the cap's integrity.

### **3.3 Alternative Cap Designs**

Alternative designs may be preferred and may be considered, as long as they are equivalent in performance to the standard caps. As an alternative to the expensive RCRA caps, a variety of less costly caps have been developed that may lower O&M costs compared to the conventional RCRA cap. Usually, these alternatives do not use clay layers that can provide a short circuit for percolation by drying, freezing, and cracking.

To meet the performance standards set forth under RCRA Subtitle C, the cap design should include the following layers:

- A base soil layer to support the other layers
- A low-permeability layer ( $1 \times 10^{-7}$  cm/sec or less)
- A drainage layer
- A soil cover, including a vegetative layer

Cap performance varies depending upon its function, where it is used, and future use of the capped area. Research has led to a variety of alternative landfill caps that are being field tested to gain regulatory approval. There are many designs and components for these caps, including capillary breaks, geosynthetic clay liners (GCL), geomembranes, vegetative caps, enhanced runoff, evapotranspiration (ET) caps, modified asphalt technologies or combinations of these. Cost-effective design alternatives now exist to match the need for hydrologic control at a particular site.

The USEPA allows an alternative landfill cap to be used for a RCRA Subtitle C cover if the regional administrator under 40 CFR 264.301 approves the design. Therefore, alternative landfill caps may be installed anywhere the design can meet regulatory approval.

The driving forces behind alternative covers are to meet environmental regulations and being equally protective of human health and the environment. Alternative covers also have the added benefits of maximizing the use of readily available construction materials, simplifying construction, streamlining quality assurance and control programs, increasing long-term cover integrity and stability, at a lower cost.

Most of the work with alternative covers is about 10 years old, and therefore, lacks significant track records to conclusively prove that alternative covers are equivalent to the originally prescribed cover. However, the operating and monitoring data available appears to justify the "equivalency" of alternative covers.

In one case study, cost savings of \$100K per acre were cited at the Rocky Mountain Arsenal site in Colorado, when the alternative cap costs were compared to the prescriptive RCRA Subtitle C cap.

Based on reviewing available data, the following factors must be carefully considered when exploring the use of an alternative cover material.

- The type of waste to be covered, and the degree of contamination;
- The post-closure use for the site;
- Site-specific factors such as rainfall;
- Size of site to be covered; and
- Location of site and proximity to construction materials, ranging from synthetic liner material such as geomembranes, to traditional clay cover layers, especially soils such as clays, and cover materials.

The key differences for alternative cap designs are fewer layers above the waste, and the absence of a clay barrier (typically 2 feet thick), which is offset by increasing the thickness of the soil cover above the barrier layer that sits on top of the waste. With fewer layers, construction times can be shortened. In addition, if no geomembranes are used such as a flexible membrane liner (FML) or GCL, there is no risk of membrane failure or slope stability problems, and maintenance requirements are reduced.

The advantages of an alternative cap are:

- Lowers capital costs and O&M costs compared to the conventional RCRA cap;
- Less layers of materials (typically, 3 layers are sufficient, compared to the 5 layers required with most RCRA C caps);
- Simpler and faster construction, using readily available materials;

- Does not use special geomembrane materials and the resulting special construction and QA/QC programs;
- Does not use clay layers which can provide a short circuit for percolation by drying, freezing, and cracking;
- Equal or better durability, longevity and environmental protection; and
- Maintains integrity if land settlement occurs.

#### 4.0 MATCON CAPPING ALTERNATIVE

The MatCon™ (**M**odified **A**sphalt **T**echnology for Waste **C**ontainment) system is an advanced modified asphalt technology that combines proprietary binder with tightly specified aggregates. MatCon Hot Mix Asphalt (HMA) offers unique advantages for environmental capping and containment. Unlike conventional asphalt concrete, MatCon permeability ( $<1 \times 10^{-7}$  cm/sec) is lower than that required under RCRA, while also offering resilience and longevity.

These qualities make MatCon a preferred containment alternative for environmental capping applications, particularly when site reuse is an objective. When MatCon is installed as a nominal 4-inch thick cap, a closed site may have a variety of potential alternative uses: parking lot, equipment storage, multi-use sports facilities, etc....

The first MatCon RCRA cap was installed in Ferndale, WA in 1989. Recent testing has shown that this cap continues to maintain its low permeability ( $<1 \times 10^{-8}$  cm/sec) despite the constant operation of heavy equipment and material staging operations directly on its surface. Throughout its dual use as a RCRA cap and active work surface, available data has indicated that the MatCon has experienced no cracking and has required no maintenance. In contrast, multi-layer geosynthetic or membrane type systems are subject to damage during construction and thereafter.

In 1999, as work began on the cover at Dover Air Force Base, the USEPA made MatCon a part of its Superfund Innovative Technology Evaluation (SITE) Program, devising a comprehensive test protocol comprising both standard environmental measurements of permeability and ASTM and specialized pavement tests to measure MatCon's durability and potential longevity. A year later, the USEPA added the MatCon cover at Elgin Tri-County Landfill Superfund Site, Illinois to the evaluation. The conclusion offered in the initial draft of the report was:

*"The evaluations at the Dover Air Force Base and Tri-County Landfill Superfund sites indicate that the MatCon cover is better than conventional RCRA Subtitle C or D covers as it relates to infiltration of water. The MatCon cover is significantly better than conventional asphalt covers in relation to permeability, flexure, load/deformation thermal crack resistance, tensile strength and aging/degradation properties. The MatCon cover is significantly faster to install than conventional RCRA C or D covers and is comparable in cost to installation of conventional covers."*

One reason why it has been accepted by regulators is that, unlike buried membranes or geosynthetics; a MatCon cap can be visually inspected anytime.

MatCon offers these additional advantages:

- MatCon does not crack like compacted clay or lose plasticity like high density polyethylene (HDPE) in arid climates or become brittle in arctic climates; nor is it subject to ultra-violet (UV) damage below the top millimeter, which is exposed;
- MatCon resists erosion, remains stable on slopes and conforms well to differential settlement of underlying materials;
- A thinner cross-section (4 to 12 inches vs. 2 to 9 feet) means less material import and more waste storage capacity;
- MatCon can be rapidly installed on a prepared subgrade (~1½ acres/day) and used the next day; and
- Manufacture of MatCon modified asphalt for environmental applications and installation is possible by local paving contractors, who are provided Quality Control protocols by the manufacturer.

According to the manufacturer, MatCon succeeds in the requirements of low permeability, strength and resilience and longevity, making it the only asphalt product that satisfies existing environmental regulations and requirements.

- Low Permeability. MatCon is designed to comply with RCRA permeability requirements with a coefficient of hydraulic conductivity of  $<1 \times 10^{-7}$  cm/sec. Field and laboratory data show MatCon typically surpasses this standard by at least a full order of magnitude ( $<1 \times 10^{-8}$  cm/sec) when properly installed. This is considerably less than the permeability of conventional highway pavements.
- Strength and Resilience. When conventional asphalt was first considered as an environmental containment material it was rejected, in part, because it was too sensitive to temperature changes. This drawback is overcome by modifiers in MatCon that both increase stiffness in hot weather and elasticity in cold weather. MatCon's superior resistance to low temperature thermal cracking was established by fixing specimens between rigid metal chucks within a temperature chamber; temperatures were lowered until the specimens cracked and failed. Data for conventional asphalt and MatCon show that MatCon develops stress more slowly and fails at a considerably lower temperature. Therefore, it has the ability to perform within a wide range of temperatures and loadings by resisting deformation under extremes of these parameters.
- Longevity. Longevity of the MatCon has been proven at Ferndale, with over 12 years of heavy use with no cracking and no maintenance costs. MatCon emerges from the environmental conditioning longevity tests virtually unchanged. Laboratory evaluation also included accelerated testing such as exposure to high oven temperatures, UV radiation, repeated air and water spray, and solvents such as kerosene and other petroleum hydrocarbons that confirmed MatCon's longevity.

MatCon has been well received by regulators and has been approved by State regulatory agencies for all projects where it has been proposed as an environmental cap including: Washington, Delaware, Illinois, California, Florida, Texas, New Mexico, Pennsylvania, and Kentucky (it has not yet been proposed in Massachusetts).

A rough cost estimate is approximately \$120K/acre for an installed 4-inch-thick cap, not including site and grade preparation. This makes MatCon a less expensive option than many RCRA caps, which may have the additional drawback of not permitting beneficial site reuse.

## 5.0 EXISTING SITE CONDITIONS

A detailed assessment of the existing cap at the Site was performed as part of the Final Phase I Implementation Plan, March 1998 (Foster Wheeler, 1998a). It was suggested in this document that four different subsurface cross sections exist at the Site. The areas are described in the document as follows:

Clay cap area – Originally consisted of a 14-inch barrier clay layer, a varying thickness supporting base fill layer, and a 9-inch gravel layer over the contaminated soil. This area covers approximately 2.5 acres.

Other impermeable areas – Includes the GWTF building and access road surfaces. Area is comprised of either concrete or asphalt at the ground surface supported by structural fill or dense grade crushed stone. The clay in these areas was removed during construction. Under the supporting fill or dense grade crushed stone is a GCL (asphalt area) or 40 mil HDPE (building area). The GCL product used was of the geotextile type, trade name Claymax, consisting of sodium bentonite as primary ingredient mixed with water-soluble adhesive and bonded to a woven upper and lower geotextile. This area covers approximately 0.4 acres.

“Corn row” areas – Provide frost protection for the groundwater extraction piping is comprised of a 6-inch loam layer, a 36-inch dense grade crushed stone layer, a 14-inch clay layer (replaced after installation of piping) and a 12-inch gravel layer over the contaminated soil. This area covers approximately 0.45 acres.

Dense grade area – Located immediately adjacent to the GWTP building. Area was backfilled to the height of the building floor and is approximately 4 feet higher than the original clay cap ground surface. This backfill was installed to provide frost protection for groundwater extraction piping and a level ground surface for construction and O&M activities. This area is comprised of a 6-inch loam layer, a 36 to 48-inch dense grade crushed stone layer, a 14-inch clay barrier layer, a varying thickness supporting base fill layer and a 9-inch gravel layer over the contaminated soil. This area covers approximately 0.4 acres.

GCL area – Located in the eastern portion of the property. Area was used to backfill contaminated soil that was generated during construction activities. This area is comprised of a 12-inch dense grade crushed stone layer and a GCL over the contaminated soil. This area covers approximately 0.5 acres.

In June of 1998, a subsequent report entitled Cap Drainage Improvements Final Design (Foster Wheeler, 1998b) detailed efforts to determine the thickness of the clay layer throughout the Site. Geoprobe were advanced in over 120 locations throughout the Site to determine the thickness and condition of the existing clay cap. Results indicated that there was no noticeable desiccation of the clay layer. The clay exhibited a high degree of plasticity, and appeared to have a high percentage of silt. The subsurface investigation also revealed that the existing clay cap is continuous over the Site and varies in thickness from 9 to more than 20 inches. Most of the sample locations indicate that the clay is at least 12 inches

thick. Geoprobe sampling locations and clay thicknesses are presented in Figure 1 for reference. In the fall of 1998, six inches of topsoil was added to the majority of the Site, and drainage improvements were installed to efficiently manage storm water runoff from the Site.

Differences in the five existing subsurface cap cross sections at the Site are in the amount and type of cover above the low permeability layer, and the type of low permeability layer. The amount and type of cover above the low permeability layer varies based on the existing land use at the Site. Future land use will determine the composition of this component of the final capping system, which is discussed in Section 7.0.

## **6.0 APPLICABLE SITE REGULATIONS**

The existing clay cap and drainage improvements, while effective in protecting human health and the environment in the short term, do not meet the requirements of the ROD to provide a cap conforming to RCRA, Subtitle C standards. A summary of the federal performance standards for RCRA caps as well as the equivalent state requirements can be found in Appendix A. Also included in Appendix A is a summary of specific cap component requirements as described in the various guidance documents authored to assist in the development of a final capping system that meets the performance requirements of RCRA.

### **6.1 MADEP Guidance**

The primary guidance document used in this Technical Memorandum to evaluate final capping options for the Silresim Site was the MADEP draft guidance document entitled "Guidance on the Use, Design, Construction, and Monitoring of Engineered Barriers," November 2002 (MADEP, 2002). This guidance document is the most current and provides guidance that is consistent with all other guidance publications with respect to final capping requirements for a hazardous waste site.

Regulatory requirements are based on relevant provisions of 310 CMR 40.0000, and an interpretation and application of the regulatory provisions and discretionary authority provided in RCRA Subpart N, 40 CFR 264.300 and 310 CMR 30.0600. MADEP's position on when and how an engineered barrier may be constructed is summarized in the following two statements:

- The use of an engineered barrier shall be limited to disposal sites where there are no other feasible alternative(s) to:
  1. reduce concentrations of oil and/or hazardous material in soil to levels below Upper Concentration Limits; and/or
  2. fixate contaminants present in soil in a manner that will reduce or eliminate environmental mobility and physiological availability.
- The design, construction, and post-construction monitoring of engineered barriers must be consistent with:
  1. the technical standards and industry practices for hazardous waste ("RCRA") landfills;
  2. the toxicity and/or mobility of contaminants of concern; and
  3. the sensitivity and use of the disposal site and adjacent properties.

Per MADEP, pursuant to the provisions of 40.0996(4)(c) of the Massachusetts Contingency Plan (MCP), an engineered barrier:

1. shall prevent direct contact with contaminated materials;
2. shall control any vapors or dust emanating from contaminated media;
3. shall prevent erosion and any infiltration of precipitation or run-off that could jeopardize the integrity of the barrier or result in the potential mobilization and migration of contaminants;
4. shall be comprised of materials that are resistant to degradation;
5. shall be consistent with the technical standards of RCRA Subpart N, 40 CFR 264.300, 310 CMR 30.600 or equivalent standards;
6. shall include a defining layer that visually identifies the beginning of the barrier;
7. shall be appropriately monitored and maintained to ensure the long-term integrity and performance of the barrier. Plans for the monitoring and maintenance of the barrier shall be submitted to the Department and shall document that one or more financial assurance mechanism(s) have been established and adequately provide for future monitoring, maintenance and any necessary replacement of the barrier; and
8. shall not include an existing building, structure or cover material unless it is designed and constructed to serve as an engineered barrier pursuant to the requirements of 310 CMR 40.0996(4).

## 7.0 SITE CAPPING OPTIONS

MADEP's guidance document suggests that a final capping system or "engineered barrier" has two design objectives: 1) to isolate contaminants from human activity, and 2) to contain volatile and/or soluble contaminants. To accomplish these two objectives, MADEP recommends an engineered barrier with the components outlined in Figure 2.

The components of the engineered barrier as presented in Figure 2 are defined in the guidance document as follows:

**Separation Layer** – The purpose of the Separation Layer is to isolate contaminants from potential human interaction, in order to minimize the future, long-term possibility of inappropriate disturbance/excavation of underlying soils, including unintended and/or unauthorized activities by (unprotected) construction crews. At most sites, the Separation Layer should be constructed out of clean soil, bituminous pavement, reinforced concrete, and/or some combination thereof. At sites where additional barrier elements are present (i.e., Containment Layers), the Separation Layer is one component in the overall isolation of underlying contaminants. At sites where additional barrier elements are not necessary, the Separation Layer must provide all needed isolation and/or encapsulation of underlying contaminants.

**Defining Layer** – The Defining Layer should be comprised of a geofabric, horizontal plastic snow fencing, horizontal chain-link fencing, grids of Warning Tape, or another inert material or unit that visually demarcates and identifies the area of concern. The defining layer should be situated below

the Separation Layer. If appropriate, a geosynthetic material used as a Drainage Layer may be considered a Defining Layer.

**Containment Layer** – Where required, the Containment Layer should be comprised of an integrated system of natural and/or synthetic materials acting in a coordinated manner to minimize the infiltration of surface water into underlying contaminated soils, and/or contain and control the migration of contaminant vapors and/or biogenic gases. The Containment Layer should contain the following elements, as dictated by site conditions and contaminant migration concerns:

- *Gas Vent Layer* – should be comprised of a layer of compacted soil at least 6-12 inches in thickness with a minimum hydraulic conductivity of  $1 \times 10^{-2}$  cm/sec. The Gas Vent Layer and supporting piping and venting network should be constructed below the Low Permeability Barrier. Alternatives for the Gas Vent Layer are discussed and detailed in Section 6.4.
- *Low Permeability Barrier* – should be comprised of a Low Hydraulic Conductivity Layer in intimate contact with a FML.
- *Drainage Layer* - should be comprised of a minimum 6-12 inch layer of soil with a minimum hydraulic conductivity of  $1 \times 10^{-2}$  cm/sec and minimum slope of 3%. In lieu of soil, the Drainage Layer may be comprised of a geocomposite product consisting of two non-woven geotextiles heatbonded to a drain core possessing an equivalent hydraulic transmissivity no less than  $3 \times 10^{-4}$  m<sup>2</sup>/sec (as detailed in Section 7.0, Reference 5). A predictive model should be used to provide site-specific estimates of percolation into the Drainage Layer and build up of hydraulic head over the Low Permeability Barrier, to aid in the design and evaluation of the selected installation.

Additionally, the guidance allows an alternative design of low permeability barrier in accordance with the following:

Based on information contained in *Design and Construction of RCRA/CERCLA Final Covers*, EPA/625/4-91/025, May 1991, the recommended USEPA landfill containment layer is a 0.5 mm (20-mil) Flexible Membrane Liner in intimate contact with a 24-inch layer of soil with a maximum hydraulic conductivity of  $1 \times 10^{-7}$  cm/sec. Using good construction practices, this design should ensure that infiltration of surface water through the containment layer will remain less than or equal to 1 gallon/acre/day. Accordingly, it is MADEP's position that parties who do not elect to use one of the recommended design options of this policy should provide justification on the long-term equivalency to this standard, and/or otherwise demonstrate why the proposed containment layer is consistent with the performance standards outlined in 40.0996(4)(c). While bituminous pavement and (Portland cement) concrete matrices are capable of achieving very low rates of hydraulic conductivity, overall performance and long term functionality are of significant concern, due to cracks that develop from differential settlement and/or thermal expansion and contraction. For this reason, the use of such materials as a Low Permeability Barrier would generally not be considered protective by MADEP unless complete and compelling documentation is provided which demonstrates a long-term level of infiltration control equivalent or superior to the recommended design options.

Despite differences in the five subsurface cap cross sections that exist at the Site, they all have a low permeability layer made up of either a clay layer or a GCL. This common low permeability layer could be

utilized to satisfy a portion of the low hydraulic conductivity layer requirements and provides a starting point for the overall final capping system design. The MADEP guidance suggests that the low hydraulic conductivity layer should consist of a 12-inch layer of compacted or amended soil with a maximum hydraulic conductivity of  $1 \times 10^{-4}$  cm/sec, in contact with a minimum 60 mil FML. Or, in lieu of the soil layer, a GCL may be used. Thus, the addition of a 60 mil FML across the Site, directly on top of the existing clay layer or GCL could satisfy the low hydraulic conductivity layer requirements. However, it should be noted that verification of the in-place permeability of the existing clay layer and possibly even the existing GCL may be required to demonstrate compliance.

Alternatively, the MatCon technology may be applied to the Site and would avoid the difficult situation of verifying existing materials integrity as noted above. With the MatCon alternative, the low hydraulic conductivity layer requirement would be addressed throughout the property and future O&M activities would potentially be significantly reduced.

The remaining components of the capping system will vary based on the future use of the Site. For the purposes of this Technical Memorandum, two future uses will be considered for the Site: 1) use of the Site or portions of the Site for a parking area, and 2) use of the Site as green space.

### **7.1 Future Uses as Parking Lot**

The MADEP guidance document recommends a separation layer consisting of 12 to 48 inches of suitable soil depending on the thickness of other engineered barrier compounds. MADEP specifically identifies bituminous pavement as an acceptable separation layer component and suggests a thickness of 8 inches, minus 1 inch for every 6 inches of containment and/or subbase layers. In areas where a clay layer constitutes a portion of the containment layer, a pavement thickness of 5 inches with a drainage/subbase layer of 6 inches could satisfy final capping system requirements. In areas where a GCL is present, 8 inches of pavement may be required. Refer to Option 1 of Figure 3 for a depiction of a conceptual final capping system design for future paved areas. Note that the final design of the capping system will require a geotechnical evaluation to confirm that the low permeability layers are sufficiently protected from frost damage and excessive loads given this particular capping component arrangement. Alternatively, with the MatCon technology, a paving thickness of only 4 inches has been accepted by regulators as outlined in Section 4.0.

### **7.2 Future use as Green Space**

As stated above, the MADEP guidance document recommends a separation layer consisting of 12 to 48 inches of suitable soil. If the future use of the Site is green space, a separation layer consisting of 48 inches of suitable soil should be incorporated into the final capping system design. This thickness can be reduced 1 inch for every inch of containment layer. In areas where at least 12 inches of clay layer constitute a portion of the containment layer, a 12-inch drainage layer overlain by an 18-inch protective layer of soil and 6 inches of top soil could satisfy the capping system requirements. Refer to Option 2 of Figure 3 for a depiction of a conceptual final capping system design for future green space areas. As noted previously, the final design of the capping system will require a geotechnical evaluation to confirm that the low permeability layers are sufficiently protected from frost damage and excessive loads given this particular capping component arrangement. Alternatively, suitable recreational facilities have been constructed directly on MatCon completed caps.

### **7.3 Drainage Improvements**

Existing stormwater management structures at the Site were designed based on a 10-year, 24-hour storm event. In order for the final capping system to meet RCRA requirements, the drainage system would need to be upgraded to handle a 25-year, 24-hour storm event for any capping design chosen. Also, the cap cross section in the drainage channels and other areas affected by the drainage system would need to be evaluated during the design stage to ensure that the RCRA capping standards are met. It should also be noted that the guidance documents suggest that major component layers be constructed at a minimum slope of 3% to promote drainage.

### **7.4 Recommendations**

Portions of the existing cap can be incorporated into a final capping system for the Site that meets the ROD requirement for a final cap meeting RCRA standards. As noted above, before any final decisions can be made, the ultimate end use of the Site must be first decided upon and finalized. The cap can be designed for a beneficial future use that includes a combination of parking and green space. As a next step, the detailed design must consider each of the existing five subsurface cross sections and the intended future use to come up with the most cost-effective capping system component combination that meets the regulatory requirements.

Based on available data, the MatCon capping alternative, as described in Section 4.0, should be considered for the Silresim property. This option would be implementable following a more detailed design investigation and would require general site regrading and existing wellhead modifications as appropriate. Additionally, use of this technology would result in the minimum amount of added materials height to the Site (several inches as opposed to several feet under existing RCRA C standards). The area to be paved with the MatCon technology is preliminarily estimated to be 3.5 acres.

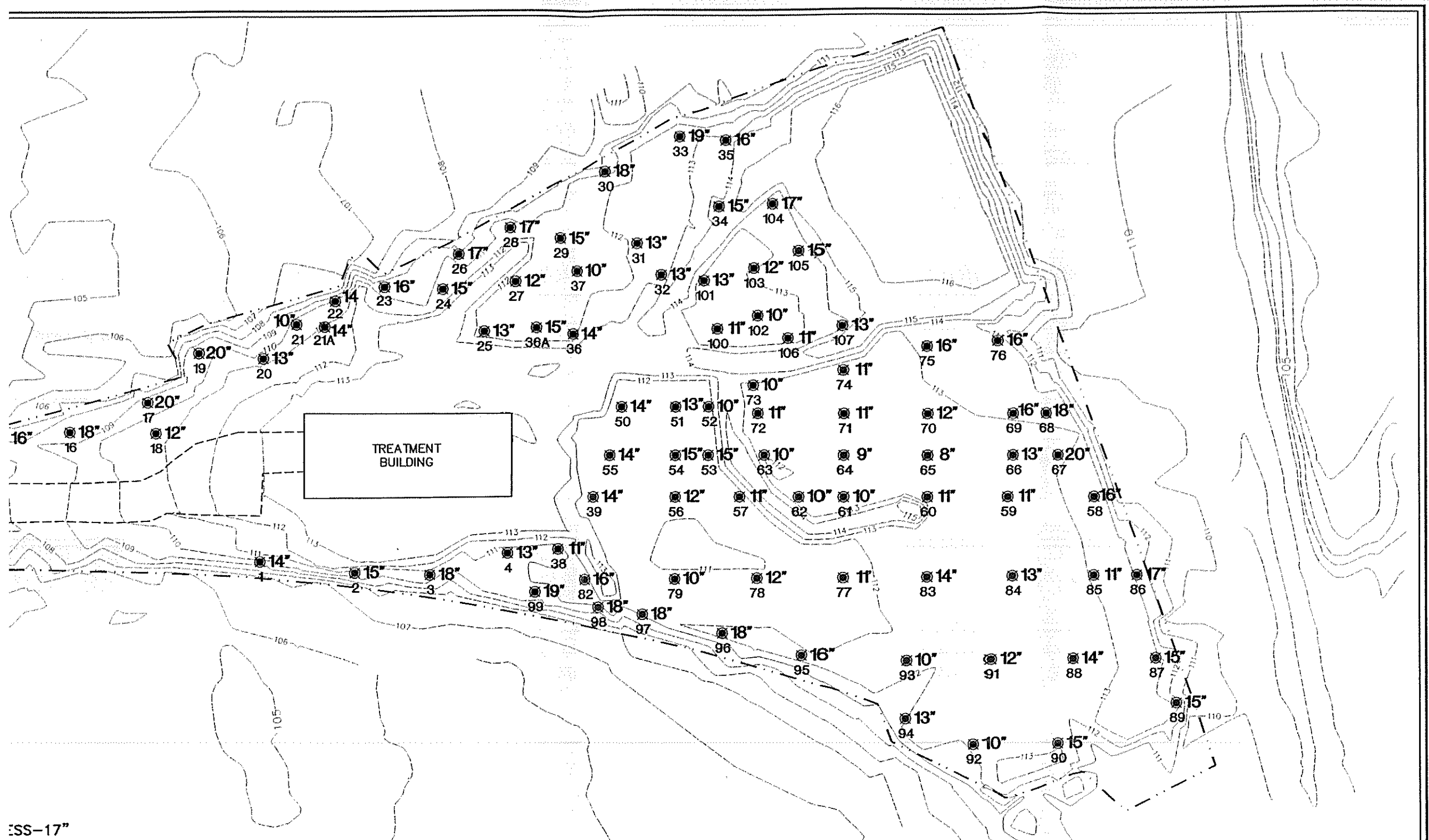
The use of the MatCon technology would appear to meet the regulatory requirement for both the separation layer and low hydraulic conductivity layer as defined in the guidance documents alternative design option. As an added benefit, use of this technology would avoid the issues of the integrity of the existing clay areas of the Site, as clay would not be required as the low hydraulic conductivity layer. Additionally, fewer institutional controls would be required to protect this type of cap as cap integrity is less likely to be compromised as compared to traditional cap construction techniques. As a preliminary selection, this alternative would allow for significant site reuse in a manner most beneficial to the surrounding area.

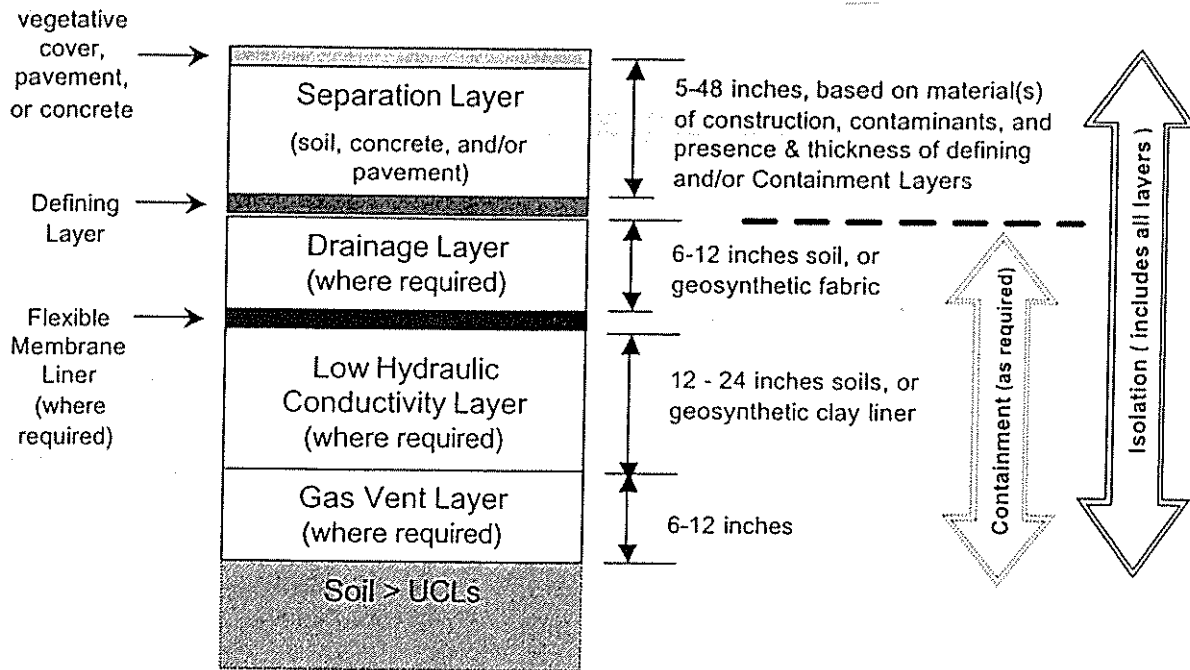
## **8.0 REFERENCES**

- Foster Wheeler, 1998a. *Final Phase I Implementation Plan*, Silresim Superfund Site, Lowell, Massachusetts, Foster Wheeler Environmental Corporation, March, 1998.
- Foster Wheeler, 1998b. *Phase I Implementation Plan, Cap Drainage Improvements Final Design Submittal*, Silresim Superfund Site, Lowell, Massachusetts, Foster Wheeler Environmental Corporation, June 1998.
- MADEP, 2002. *Guidance of the Use, Design, Construction, and Monitoring of Engineered Barriers*, Massachusetts Department of Environmental Protection, November 2002.

USEPA, 1991. Record of Decision Summary, Silresim Site, Lowell, Massachusetts, U.S. Environmental Protection Agency Region I, September 1991.

# Figures



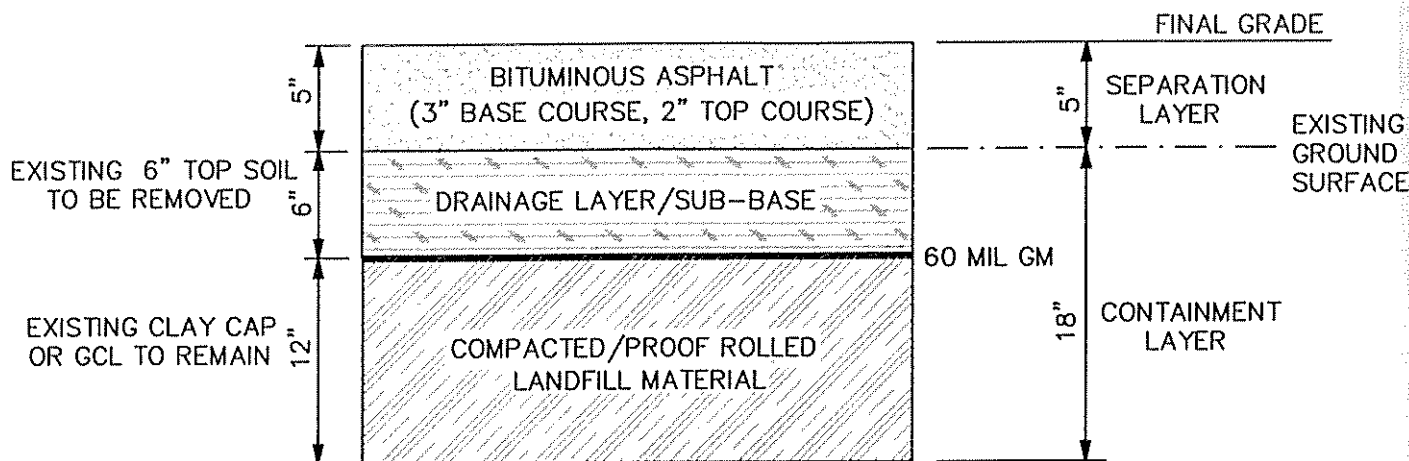


**FIGURE 2**

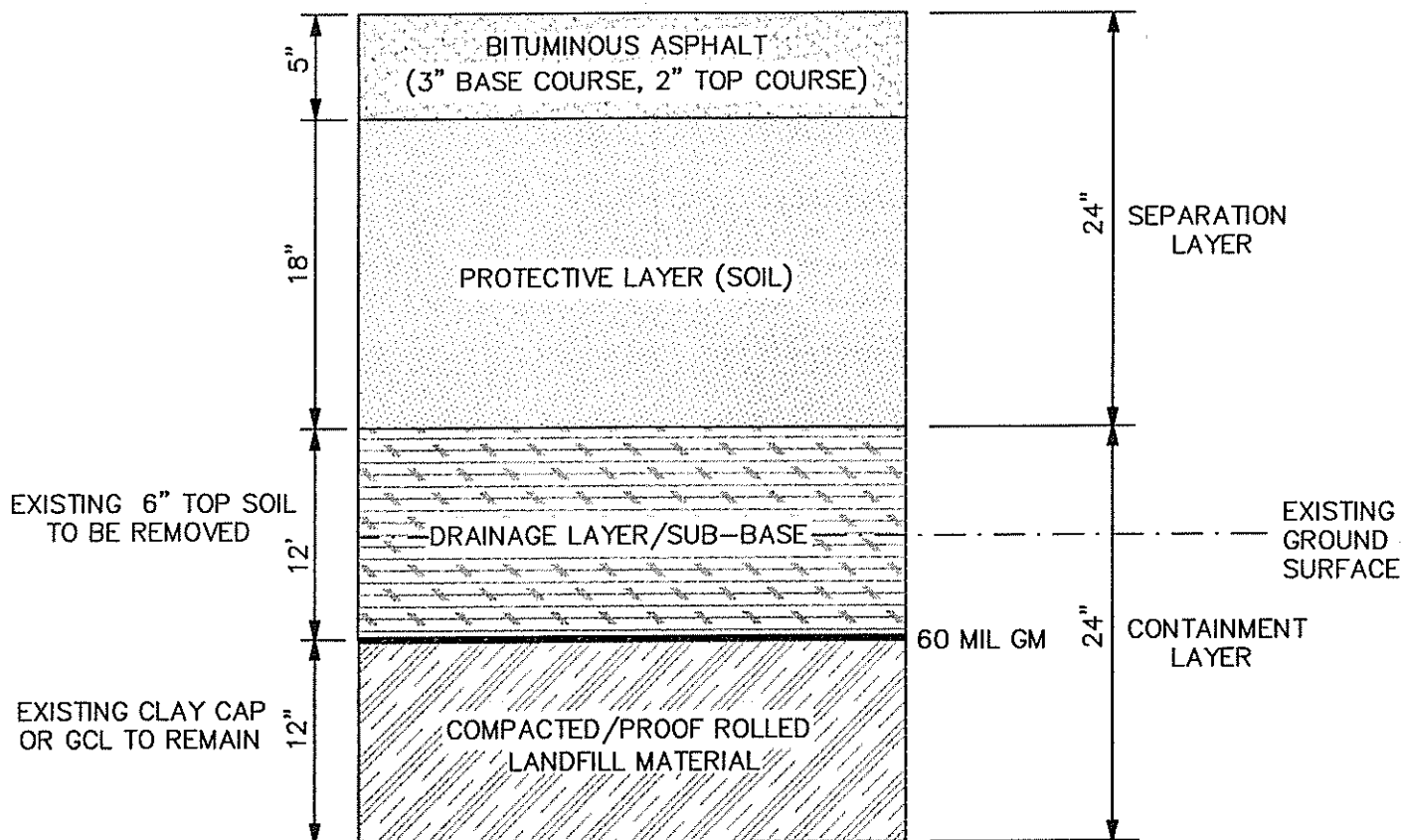
**SILRESM SUPERFUND SITE  
LOWELL, MASSACHUSETTS**

**ENGINEERED BARRIER  
DESIGN COMPONENTS**

NOT TO SCALE



**CAP OPTION 1**



**CAP OPTION 2**

**FIGURE 3**

SILRESIM SUPERFUND SITE  
LOWELL, MASSACHUSETTS

**SILRESIM RCRA CAP  
CAP OPTIONS 1 & 2**

NOT TO SCALE

**Appendix A**  
**Summary of Federal Performance Standards for RCRA Caps**

Regulation	Performance Criteria	Applicable Guidance Documents	Guidance Document Recommended Cap Composition
40 CFR 264 110-120	(a) Minimizes the need for further maintenance; (b) Controls, minimizes or eliminates, to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated run-off, or hazardous waste decomposition products to the ground or surface waters or to the atmosphere; and (c) Complies with the closure requirements of this subpart, including, but not limited to, the requirements of 40 CFR 264.		
40 CFR 264 300-317	At final closure of the landfill or upon closure of any cell, the owner or operator must cover the landfill or cell with a final cover designed and constructed to: (1) Provide long-term minimization of migration of liquids through the closed landfill; (2) Function with minimum maintenance; (3) Promote drainage and minimize erosion or abrasion of the cover; (4) Accommodate settling and subsidence so that the cover's integrity is maintained; and (5) Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.	EPA/625/4-91/025, May 1991 – Design and Construction of RCRA/CERCLA Final Covers  EPA/530-SW-89-047, July 1989 – Technical Guidance Document: Final covers on Hazardous Waste landfills and Surface Impoundments	<ul style="list-style-type: none"> <li>• 24” Vegetative/Protective Layer</li> <li>• 12” Drainage Layer</li> <li>• Synthetic Geomembrane 20 mil min</li> <li>• 24” Low Permeability Layer (10<sup>-7</sup> cm/s)</li> </ul> <p>Notes: Optional: 12” Gas Vent Layer if Needed</p>
		Revised Alternative Cap Design Guidance Proposed for Unlined, Hazardous Waste Landfills in EPA Region 1, USEPA, Region 1, February 2001	<ul style="list-style-type: none"> <li>• Topsoil Layer – min 3% slope</li> <li>• Protective Layer – sustain vegetation and protect low permeability layers from frost damage and excessive loads</li> <li>• 12” Drainage Layer at min 3% slope</li> <li>• Synthetic Geomembrane 60 mil min</li> <li>• 12” Low Permeability Layer (10-4 cm/s)</li> </ul> <p>Notes: Optional: 12” Gas Vent Layer if Needed Geosynthetic Clay Liner (GCL) can substitute for 12” low permeability layer</p>
310 CMR 30.580	The owner or operator shall close the facility in a manner that minimizes the need for further maintenance. Post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated runoff, or hazardous waste decomposition products to the ground water, surface water, soil, or the atmosphere shall be eliminated or minimized to the extent necessary to assure compliance with the previous sentence and to prevent any threat to public health, safety, or welfare, or the environment.		
310 CMR 30.600 - 633	At final closure of the landfill or upon closure of any cell, the owner or operator shall cover the landfill or cell with a final cover designed and constructed to: (a) Provide long-term minimization of migration of liquids through the closed landfill; (b) Function with minimum maintenance; (c) Promote drainage and minimize erosion or abrasion of the cover; (d) Accommodate settling and subsidence so that the cover's integrity is maintained; and (e) Have a permeability less than or equal to the permeability of the bottom liner system.		

Regulation	Performance Criteria	Applicable Guidance Documents	Guidance Document Recommended Cap Composition
310 CMR 40.996 (4) (c)	<p>An engineered barrier means a permanent cap with or without a liner that is designed, constructed and maintained in accordance with scientific and engineering standards to achieve a level of no significant risk for any foreseeable period of time. An engineered barrier:</p> <ol style="list-style-type: none"> <li>1. shall prevent direct contact with contaminated media;</li> <li>2. shall control any vapors or dust emanating from contaminated media;</li> <li>3. shall prevent erosion and any infiltration of precipitation or run-off that could jeopardize the integrity of the barrier or result in the potential mobilization and migration of contaminants;</li> <li>4. shall be comprised of materials that are resistant to degradation;</li> <li>5. shall be consistent with the technical standards of RCRA Subpart N, 40 CFR 264.300, 310 CMR 30.600 or equivalent standards;</li> <li>6. shall include a defining layer that visually identifies the beginning of the barrier;</li> <li>7. shall be appropriately monitored and maintained to ensure the long-term integrity and performance of the barrier. Plans for the monitoring and maintenance of the barrier shall be submitted to the Department and shall document that one or more financial assurance mechanism(s) have been established and adequately provide for future monitoring, maintenance and any necessary replacement of the barrier; and</li> <li>8. shall not include an existing building, structure or cover material unless it is designed and constructed to serve as an engineered barrier pursuant to the requirements of 310 CMR 40.0996(4).</li> </ol>	Guidance on the Use, Design, Construction, and Monitoring of Engineered Barriers - Draft, MADEP, November 2002.	<ul style="list-style-type: none"> <li>• Separation Layer: <ul style="list-style-type: none"> <li>Material of <u>Construction</u> Minimum <u>Thickness</u></li> <li>Suitable Soils 48", minus 1 inch for every inch of containment layer</li> <li>Bituminous Pavement 8", minus 1 inch for every 6 inches of containment layer</li> <li>Reinforced Concrete 5", minus 1 inch for every 10 inches of containment layer</li> </ul> </li> <li>• Containment Layer <ul style="list-style-type: none"> <li>▪ 6"-12" drainage layer or geocomposite product</li> <li>▪ 24" low permeability layer (<math>10^{-7}</math> cm/s) with 20 mil geomembrane <b>or</b> 12" low permeability layer (<math>10^{-4}</math> cm/s) with 60 mil geomembrane</li> </ul> </li> </ul> <p>Note: Optional: 12" Gas Vent Layer if Needed Geosynthetic Clay Liner (GCL) can substitute for 12" low permeability layer</p>

40 CFR  
264 - Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities  
110 Thru 120 – Subpart G – Closure and Post-Closure

40 CFR  
264 - Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities  
300 Thru 317 – Subpart N – Landfills

310 CMR 30 – Massachusetts Hazardous Waste Regulations  
500 - Management Standards for All Hazardous Waste Facilities  
580 - Closure

310 CMR 30 – Massachusetts Hazardous Waste Regulations  
600 - Technical Standards for All Hazardous Waste Facilities  
620 Thru 633 - Landfills

310 CMR 40 – Massachusetts Contingency Plan  
900 - Procedures and Standards for the Characterization of the Risk of Harm to Health, Safety, Public Welfare and the Environment  
996 (4) (C) – Engineered Barrier