VII. Remedial Action 3 — Soil Reuse

A. Introduction

Soil reuse is defined as using soil that has contamination at levels above site-specific cleanup criteria for purposes such as landfill cover or recycling. The first step in determining whether soil can be reused is to characterize the nature of contamination. Please note: Soil reuse/characterization is discussed in section V.C.2. All sampling procedures and analytical methods used to characterize contamination must conform to the Technical Requirements N.J.A.C. 7:26E and the NJDEP's *Field Sampling Procedures Manual*. All efforts should be made to accurately delineate the contamination in soils prior to excavation. Once soil is adequately characterized, no further sampling should be necessary to make a remedial or reuse decision. However, it should be noted that additional testing may be required by a disposal or recycling facility to meet its permit requirements or site-specific acceptance requirements. If a recycling or disposal facility has been selected, contact the facility to determine its acceptance criteria.

B. Soil Categories

Soils are categorized according to the type and amount of contaminants present as follows:

- Soils that contain hazardous waste;
- Non-hazardous (ID 27 waste); or
- Soils that contain contaminants below regulatory concern, i.e., below cleanup criteria.

1. Hazardous

Soils that contain hazardous waste must be managed as such when contamination is above the non-hazardous waste limits (Appendix C) or is otherwise classified a hazardous waste. These soils must be managed as a hazardous waste in accordance with N.J.A.C. 7:26-G et seq. The only options for soils that contain a hazardous waste are on-site remediation or off-site management as a hazardous waste.

2. Non-hazardous

Contaminated soil is non-hazardous when both of the following criteria are met:

a. The contaminant levels are above the most stringent soil cleanup criteria established by NJDEP. Appendix A is a listing of the NJDEP Soil Cleanup Criteria dated July 11, 1996 which can be used as guidance; however, site specific cleanup levels must be discussed with the case manager assigned to your site. Refer to section "III. Soil Cleanup Criteria and Other Contaminated Media," pg. 6 at the beginning of this document for a discussion of the Soil Cleanup Criteria.

b. The waste is not classified as a hazardous waste (see Appendix C - Hazardous Waste Levels).

3. Soils That Contain Contaminants Below Regulatory Concern

Soils that contain contaminants at levels that are below the most stringent site cleanup levels established by NJDEP for a specific site are not of regulatory concern with the exception of sites in the Pinelands Area (see section C.2.a. below). Please refer to section C below for additional reuse considerations.

C. Options For Reuse of Soils

1. Non-hazardous Soils

The most common reuse applications for minimally contaminated soils are roadway sub-base material, landfill cover, and recycling facilities. Soils with levels of contamination exceeding the most stringent site-specific cleanup levels established by NJDEP cannot be reused without prior NJDEP approval. In all cases, the reuse of soils also must be protective of ground water and surface water bodies and subsurface structures, such as basements and indoor areas, as well as all other potential human and ecological receptors.

2. Site-specific Soil Reuse Proposals

If NJDEP guidance is required for reuse on a site-specific basis (i.e., reuse at a location without a recycling permit to reuse soil), submit a Soil Reuse Proposal to the Site Remediation Program. Prior to NJDEP approval of a Soil Reuse Proposal, the generator of the soil must submit its determination of waste classification along with the rationale used for characterization of the soil. For cases that are under review by the Site Remediation Program, contact the assigned case manager to get approval of a Soil Reuse Proposal. The Bureau of Field Operations, Case Assignment Section, should be contacted for cases that do not have an assigned case manager in the Site Remediation Program. Any party that elects to perform work with NJDEP oversight, including the review of sampling results and plans related to soil use/reuse, will be required to enter into a Memorandum of Agreement with NJDEP for that task unless already under a control document such as a Memorandum of Agreement or Administrative Consent Order or the regulatory requirements of the Industrial Site Recovery Act Program, the Underground Storage Tank Program, or other NJDEP programs.

All soil use/reuse applications must meet the following criteria:

a. Pinelands Area

Soils generated outside or within the Pinelands Area that contain contaminants at or below the most stringent cleanup levels established by NJDEP shall not be moved from the site of generation into or within the Pinelands Area unless the soils are at or below the receiving site's background levels. Soils generated in the Pinelands Area that exceed background levels may not remain in the Pinelands Area but may be used elsewhere with written permission from NJDEP. Written approval from the New Jersey Pinelands Commission must be obtained before any land disturbance or moving of soil at any level of contamination within the Pinelands Area.

b. Objectionable Odors or Appearance

Soils having objectionable odors, including petroleum or synthetic chemical odors, shall not be used in residential areas or other locations where the public would be exposed or where such odors or appearance would render a site or its improvements unusable for their reasonably intended purpose. Specifically, the soils to be used must not violate the air pollution rules, N.J.A.C. 7:28-1 et seq., or local nuisance codes.

c. Regulatory Compliance

The soils must be used in accordance with all applicable federal, state, and local requirements.

d. Allowable Storage Time

Non-hazardous soils must not be stockpiled at the site of generation or elsewhere for more than six months from the date of excavation pursuant to the Solid Waste Regulations, N.J.A.C. 7:26-1.1;1.4. Therefore, soil reuse considerations and subsequent actions should be acted upon as soon as possible. Refer to section V.B.2 (Excavation — Regulatory Concerns) for staging/storage considerations.

3. Approved Contaminated Soil Recycling Centers in New Jersey

Soil that is accepted at an NJDEP permitted recycling center, which is authorized to accept contaminated soils by its permit, does not require a Solid Waste Regulation exemption or a prior site-specific reuse approval. Contact the Bureau of Landfill and Recycling Management, Division of Solid and Hazardous Waste, for further information (609/984-6650).

4. Out-of-state Recycling

For recycling soils out-of-state, a written determination from NJDEP is required as to the non-applicability of the solid waste management regulations set forth in N.J.A.C. 7:26-1 et seq. For sites without a Site Remediation Program lead (i.e., Industrial Site Recovery Act, Bureau of Underground Storage Tanks, Bureau of Field Operations) and for the recycling of soil as a solid process waste, contact the Bureau of Resource Recovery and Technical Programs (609/984-6985). Sites with a Site Remediation Program lead must send this information in lieu of a Soil Reuse Proposal to the assigned case manager for an approval. The following are the standard requirements pursuant to N.J.A.C. 7:26-1.1(a)1, and 1.7(g) for approval to send soils out-of-state:

a. A letter, sent to the Bureau of Resource Recovery and Technical Programs from the generator of soil, certifying that the soil in question has been analyzed or is known in accordance with N.J.A.C. 7:26G-5.1 not to contain a hazardous waste. This also must include any necessary test results documenting that the soil contains constituents and hazardous waste characteristics below their regulatory levels. (See Appendix C – Hazardous Waste Levels.)

b. A letter sent to the Division of Solid and Hazardous Waste from the receiving facility stating they agree to accept the specified amount of soil, indicating intention and method to beneficially use or reuse the soil and the time frame for such activity from the date of receipt at the facility. In addition, a copy of this information must be sent directly to the solid waste coordinator of the county of the soil's origin.

c. A letter sent to the Division of Solid and Hazardous Waste from the appropriate regulatory agency of the receiving state or a copy of a current facility permit verifying that facility is operating in accordance with applicable rules and regulations and can accept the soils for the declared use/reuse.

d. Once the soil is delivered to the identified use/reuse facility, a letter from the facility or a bill of lading stating the date and amount of soil received must be sent to the Division of Solid and Hazardous Waste and the solid waste coordinator of the county of the soil's origin.

5. Operational Landfill Cover

Operating landfills that are permitted to accept ID 27 waste may use non-hazardous soil for daily landfill cover with approval from the Bureau of Landfill and Recycling Management. Fine grained soils which may create erosion problems or are easily windblown are prohibited for use as daily cover. The following information should be submitted for approval:

a. A letter from the landfill owner/operator indicating acceptance of the soil. The landfill owner/operator shall state that he/she has reviewed all technical data pertaining to the contaminated soil.

b. A copy of the soil test results.

c. A letter from the Bureau of Resource Recovery and Technical Programs denoting the waste classification of the soil.

The completed application should be mailed to:

NJDEP
Division of Solid and Hazardous Waste
Bureau of Landfill and Recycling Management
P.O. Box 414
Trenton, NJ 08625-0414

The case manager must be copied on all related correspondence if the case is a Site Remediation lead site.

6. Soils That Contain Contaminants Below Regulatory Concern

Soils that contain contaminants at levels below the most stringent site cleanup levels established by NJDEP for a specific site are not of regulatory concern with the exception of sites in the Pinelands Area. Soils with contaminant levels below site-specific standards set by NJDEP are suitable for on-site reuse without treatment or prior approval. Off-site reuse of suspected or known contaminated soils is permissible only if written NJDEP approval is obtained or if the soil is recycled at an approved recycling center. In addition, the minimum criteria for all use/reuse applications, as noted in Section VII.C.2, "Site-specific Soil Reuse Proposals," also apply to soils below regulatory concern.

Soils that contain contaminants below regulatory concern and are not petroleum contaminated may be mixed with source separated concrete, brick and block generated on-site and may be recycled on-site as clean fill. Such operations are exempted from the requirement to obtain approval from the department in accordance with the Recycling Regulations at N.J.A.C. 7:26A-1.4(a)2. To qualify for this exemption, any necessary county and municipal approvals for the activity must be obtained. General requirements applicable to the recycling activity are located at N.J.A.C. 7:26A-1.4(b)1-5. The department, the host county and the host municipality must be provided with written notification of the recycling activity pursuant to N.J.A.C. 7:26A-1.4(b)5. The department's notification should be mailed to:

NJDEP, Office of Permitting and Technical Programs
Bureau of Resource Recovery and Technical Programs
Division of Solid and Hazardous Waste
P.O. Box 414
Trenton, NJ 08625-0414

The case manager must be copied on all related correspondence if the case is a Site Remediation lead site. For further information, contact the Bureau of Landfill and Recycling Management (609/984-6650).

VIII. Remedial Action 4 — Containment and Exposure Controls

A. Introduction

Containment and exposure control remedies include a variety of engineered systems that are implemented for the purpose of encapsulation or covering of contaminated soils that will be left untreated within an "area of concern" (AOC) or site. Such engineered systems include cap systems, liner systems, barrier walls and containment vaults. The primary purposes of such systems are to eliminate direct contact exposure with contaminated soils and/or to eliminate migration of contaminants from the soil to ground water, air or other clean soil areas. Contingent upon the types, quantities and characteristics of the contaminants present in the soils, there may be a need to include leachate collection systems, groundwater remediation systems and/or monitoring systems or gas collection and/or treatment systems in conjunction with the engineered containment system selected for the site or AOC. In all cases, containment and exposure control remedies will require establishment of Institutional Controls as part of implementation of the remedy, since future use of the site/AOC will be restricted due to contaminants left untreated. Any future use of the site must be compatible with the selected containment system. Use of containment and exposure controls is the "presumptive remedy" for any "historic fill" AOC's/sites.

Pursuant to the provisions of the N.J.A.C. 7:26E-5.1(d)3, the use of engineering and/or institutional controls must be commensurate with the degree of risk associated with the contaminants left on-site and must be reviewed and approved by the Department. For example, stricter engineering controls may be required based upon the future use of the site, residential versus non-residential. In evaluating the appropriateness and the long-term and short-term effectiveness of engineering and/or institutional controls, the Department will consider contaminant characteristics (i.e., toxicity, mobility, volume, etc.), future site use and surrounding site uses, and the presence of free/residual products, off-spec or discarded product or by-product from a manufacturing or industrial process. Whenever practicable, the Department will require the treatment or removal of free/residual product or non-soil hazardous material such as off-spec or discarded product or by-product materials, prior to implementation of remedial actions that rely on engineering and/or institutional controls. The person responsible for conducting the remediation must demonstrate to the Department that any contaminated soils left on-site can be reliably contained by the proposed controls and that the remedy is protective of human health and the environment. In addition, any contaminated ground water below or adjacent to an area of contaminated soil must be addressed by the person responsible for conducting the remediation as a separate remedial action or in conjunction with the selected containment and exposure control remedy.

Long-term operation, maintenance and monitoring of any engineered containment system is critical for any site or AOC where contaminated soils will be left on-site. The provisions at N.J.A.C. 7:26E-6.1(b)5 require the person responsible for conducting the remediation to report back to the Department on a regular basis regarding the continued adequacy of any engineering and/or institutional controls. Accordingly, preparation of a site-specific maintenance and monitoring plan and provision of adequate resources to support implementation of the plan are key elements of a containment and exposure control remedy.

Design and construction of containment and exposure control remedies will vary greatly from site to site, contingent upon the nature and extent of contamination being left on-site and the intended future use of the site and surrounding properties. The key factors to consider in selecting and implementing such remedies include: (1) Cap/Wall/Liner construction (i.e., permeable, impermeable, thickness, materials, slope stability, settlement, etc.); (2) Surface water controls and erosion controls; (3) Generated gas controls (i.e., migration, collection, treatment); (4) Leachate controls (i.e., migration, collection, treatment); and, (5) Long-term Operation, Maintenance and Monitoring Programs. These key factors also need to be addressed in the Remedial Action Work Plan. Each of these key factors is discussed below in greater detail.

Finally, the selection of a remedial action for soil contamination that utilizes containment and exposure controls must comply with other applicable federal, state and/or local laws or regulations. In addition to the provisions of N.J.A.C. 7:26E-1 et.seq., other primary laws/regulations one must consider and evaluate include:

RCRA/HSWA
CERCLA/SARA
NCP
Local municipal solid waste plans/codes
Floodplain/wetland regulations/controls
Stream encroachment regulations
Toxic Substance Control Act

B. Gas Control Systems

1. Gas Generation

The contaminated material present at the site may generate large volumes of methane gas or other toxic gases. If this generated gas is allowed to accumulate, there may be potential for gas explosion and/or cap "blow-out." It also provides stress to vegetation by lowering the oxygen content available at the roots, severely affecting the ability of the cover to support vegetation. In the absence of adequate paths or channels for the gas to escape, gas pressures can increase sufficiently to physically disrupt the cover system. Other problems include odor, toxic vapors, and uncontrolled gas migration, which may impact nearby properties.

2. Gas Migration

Final cover design and incorporation of gas migration control measures affect gas migration. Low hydraulic conductivity soil layers and geomembranes are very effective barriers to gas migration. Properly designed granular fill soil or geosynthetic drainage materials can provide effective corridors for channeling gas migration. Other channels affecting migration are cracks that may develop due to differential settlement and subsidence.

3. Gas Control Systems

Two gas control systems, passive and active, are available and should be evaluated at every site suspected of gas generation. Passive systems provide corridors to intercept lateral gas migration and channel the gas to a collection point or vent. These systems use a composite liner and vent in the cover system. The liner prevents uncontrolled vertical migration while the gas collection layer under the liner intercepts all vertical migration and directs it to the vent. Active systems generate a zone of negative pressure to increase the pressure gradient and make the gas flow toward the vents. This can be accomplished by installing gas extraction wells and using exhaust blowers. The extraction well system must be designed properly to prevent the well from drawing air from the surface which may result in destroying suction capacity needed to draw gas to the well. Collection and treatment of gas condensate must also be addressed in design and implementation of such systems.

C. Leachate Control System

The function of a leachate collection system is to minimize or eliminate the migration of leachate away from the contaminated soil area. Leachate collection systems commonly used are trench drains and vertical wells. Trench drains consist of underground trenches filled with coarse aggregate soil and generally equipped with perforated pipe for greater hydraulic efficiency. They are used to intercept and channel leachate to a sump, wet well, or appropriate surface discharge. Vertical extraction wells are wells drilled in the plume and screened in a highly permeable water bearing zone. The intent is to collect highly contaminated leachate or leachate/ground water mix.

Some implementation and operation and maintenance considerations concerning leachate collection include the following:

- A properly designed leachate collection system should provide a reduction in the potential for migration of leachate to surface water and ground water;
- Extraction systems will require ongoing maintenance to maintain effectiveness;
- Drilling conditions must be considered;
- Leachate collection is typically cost effective compared to recovering dispersed contaminants;
- A leachate collection system may result in an increase in soil settlement as a result of leachate extraction; and
- An effective collection system generally will require a thorough characterization of hydrogeology of the site before design or installation of the system.

The primary data needed for designing a leachate collection system include the following:

- Topographic characteristics of the site that may impact the leachate collection system;
- Site soil characteristics (e.g., permeability, grain size distribution);
- Hydrogeologic characteristics (e.g., depth to ground water, flow direction and velocity); and
- Waste characteristics (e.g., composition, moisture content, age).

Either on-site or off-site treatment of leachate may be a feasible option. Leachate quality varies from site-to-site and also will vary over time. Once the constituents and associated concentrations of the leachate are known, an appropriate remedial action can be selected. Generally, leachate is treated by conventional means such as chemical, biological, and physical treatment.

Off-Site Treatment:

Discharge to a publicly owned treatment works either by pipeline or by truck may be appropriate for leachate streams containing concentrations of contaminants that are amenable to treatment provided by the publicly owned treatment works. More often, pretreatment may be required before discharge to the publicly owned treatment works. Major considerations include the constituents of the leachate and their concentrations, the type of treatment used by the publicly owned treatment works, the remaining treatment capacity of the publicly owned treatment works, the volume of leachate to be disposed of, and the expected duration of the discharge. NJDEP considers discharge to a publicly owned treatment works as the least preferred option.

D. Containment System Design and Construction

A cap provides a physical separation between the contaminants and humans, animals, and plant roots. Cover systems placed over regulated hazardous waste landfill units must comply with the New Jersey Hazardous Waste Landfill Closure Requirements found in N.J.A.C. 7:26-10.8(i). Another objective of using a cap is to promote more effective surface drainage and to maximize runoff, thus reducing infiltration of water into the underlying media and minimizing impacts to the ground water. A cap's impermeable layer (usually clay or a synthetic liner) must be covered by an adequately thick layer of soil to avoid damage from freeze/thaw action. Also, the material under the impermeable cap must be well compacted to minimize damage from differential settlement. The different types of capping technologies typically used include native soil cover, single barrier (e.g., geomembrane, asphalt/concrete, clay), and composite barrier (e.g., clay plus geomembranes). When implementation of the engineering controls are determined appropriate, then the recommended engineering control may include a single barrier cap for the insoluble contaminant(s) and composite caps for the more soluble contaminants (e.g., hexavelent chromium).

1. Native Soil Cover

The use of native soil as cover for containment of hazardous materials may be appropriate where surface water infiltration and subsequent leachate generation are not controlling factors. Soil caps are used to control erosion and direct contact. Soil covers also may be used as an interim remedy (interim cap) to reduce contact hazards prior to design and construction of an impermeable cap. Soil covers are generally low in initial cost and the construction materials are readily available from local sources. Soil covers must be vegetated to minimize erosion. Soil covers can be used only if reduced infiltration is not a design goal. Native soil may not be stable on steep slopes; therefore, the slope may be limited to 33 percent. A typical soil cover that provides the above limited functions is 18 to 24 inches thick with six inches of topsoil for vegetation purposes. With adequate vegetation and proper maintenance soil cover thicknesses may be reduced if engineering evaluation and justification can be provided by a New Jersey Licensed Professional Engineer.

2. Single Barrier (Synthetic, Asphalt/Concrete, and Clay Cap)

The main functions of a single barrier cap are to reduce surface infiltration, prevent direct contact, limit gas emissions, and control erosion. The most commonly used barrier layers are synthetic liners (geomembranes), asphalt or concrete, and clay soils. These layers serve as low permeability layers that reduce surface water infiltration into the underlying waste material. The low permeability layer, except asphalt or concrete, is usually overlain by a drainage layer and a vegetative protective layer.

Any synthetic liner should be located below the maximum depth of frost penetration, and the type of liner material is recommended to be a minimum of 40 mils in thickness. The liner should be protected by an overlying drainage layer that is free of rock, fractured stone, debris, cobbles, rubbish and roots. Sudden changes in grade that may impair the liner should be avoided. The liner should be installed on a granular protective layer of soil overlying the waste material. It should be installed on a smooth soil surface. It should be noted that extreme care must be taken to prevent the liner from being punctured by sharp objects.

In commercial areas, an asphalt or concrete barrier layer is generally preferred so that the areas may still be used as roads or parking areas. The asphalt or concrete layer must be adequately designed, complying with the local/county requirements (approximately 4" to 8" thick), to withstand the expected vehicular traffic on the surface. The soil layer under the cap must be well compacted to avoid cracks in the cap which will allow infiltration of surface water. The cap surface should be properly graded and have a good drainage system to avoid ponding on the finished surface.

Clay layers must also be located below the maximum depth of frost penetration. The clay materials can achieve very low permeabilities (e.g., 1x10-7 cm/sec) if they are well compacted and if their moisture content is controlled. A drainage layer with soil material above the clay layer, as specified above for synthetic liners, should be provided. The clay layer should have a thickness of 12 inches.

A typical cross section of a single barrier cap consists of the following layers (from visible top to top of contaminated materials):

- Vegetative and protective layer, 18” to 24” soil including 6” top soil;
- Geotextile filter fabric (to prevent migration of fines to the drainage layer below);
- Drainage layer with 6” of granular soil or geosynthetic drainage material;
- Barrier layer, either 12” of clay or 40 mil thick synthetic liner or geosynthetic liner or geosynthetic clay liners; and,
- Protective layer, 12” of compacted soil subgrade (placed on top of waste). Site specific factors can prompt variances to this typical design.

3. Composite Caps

A composite cap provides an additional impermeable layer which acts as a backup in case of leakage through the first impermeable layer. A composite cap consists of a compacted clay layer overlain by a synthetic liner. The composite cap is also overlain by the drainage layer and vegetative/ protective layer. A composite cap reduces infiltration to a minimum. The protective layer (subgrade) under the lower barrier, if required, can act as a gas collection layer. A composite cap can be used when the waste material is characterized as similar to a hazardous waste. A slurry wall may be constructed along the perimeter of the cap to contain the ground water plume, if required.

A typical cross section of a composite barrier cap consists of the following (from visible to top of contaminated materials):

- Vegetative and protective layer, 18” to 24” soil including 6” top soil;
- Geosynthetic drainage layer;
- Geotextile fabric (to prevent migration of fines to the drainage layer below);
- 6” of soil/sand (drainage layer);
- Geomembrane liner (40 mil minimum);
- 24” of clay or geosynthetic clay liner;
- Geosynthetic drainage layer; and,
- Protective layer, 12” of compacted soil subgrade (placed on top of contaminated materials). Site specific factors can prompt variances to this typical design.

4. Containment

Vertical walls or barriers may be a viable technology for soil and/or ground water containment at the contaminated sites where the soil is leaching contaminants to underlying groundwater. Their use warrants some consideration since they may improve the overall effectiveness of a containment system. Extraction wells are often used to increase the effectiveness of the vertical barrier by creating an inward groundwater gradient. The impermeable vertical barriers may be constructed out of bentonite slurry, a grout curtain with cement or chemical grouts, or sheet piling cutoff walls using wood, precast concrete or steel.

An ideal barrier will completely encircle the contaminated site, will be keyed into a lower aquitard (impervious layer), and will include a low permeability cap and a groundwater collection system to maintain an inward hydraulic gradient across the barrier. Such a barrier is generally more effective in controlling movement of ground water and pollutants than an up gradient or down gradient barrier or a partially-penetrating barrier (that is, one that is not keyed in to an impervious layer).

a. Slurry Walls:

In general, slurry trenching involves excavating a trench through or under a slurry of bentonite clay and water, and then backfilling this trench with the original soil with or without slurry mixed in. Most commonly, the trench is excavated down to, often into, an impervious layer in order to shut off the ground water flow. The width of the trench can vary, but it is typically from 2 to 5 feet. The slurry used in this practice is essentially a 4 to 7 percent by weight suspension of bentonite in water. Bentonite is a clay of the montmorillonite group 2:1 expanding lattice clays, mined in the western United States, principally in Wyoming, and is often called Wyoming bentonite. The use of slurry walls is generally limited to relatively flat and unconfined sites. A distance of 50 to 75 feet of open area adjacent to the trench is required for mixing bentonite with backfill materials.

b. Grout Curtains:

Grout curtain installation is another method of ground water control. Grouting is, in general, the pressure injection of one of a variety of special fluids into a rock or soil body to seal and strengthen it. Once in place, these fluids set or gel into the rock or soil voids, greatly reducing the permeability of and imparting mechanical strength to the grouted mass. When carried out in the proper pattern and sequence, this process can result in a curtain or wall that can be a very effective ground water barrier. The cost of installing a grout curtain can be three times as costly as a slurry wall. It is rarely used when ground water has to be controlled in soil or loose overburden. The major use of curtain grouting is to seal voids in porous or fractured rock where other methods of ground water control are impractical.

The pressure injection of grout involves drilling holes to the desired depth and injecting grout by the use of special equipment. In curtain grouting, a line of holes is drilled in single, double or triple staggered rows (depending on site characteristics) and grouting is accomplished in descending stages with increasing pressure. The spacing of the injection holes is also site specific and is determined by the penetration radius of the grout out from the holes. Ideally, the grout injected in adjacent holes should touch between them. If this process is done properly, a continuous, impervious barrier (curtain) will be formed.

The equipment used in pressure grouting is, for the most part, sophisticated special machinery. This machinery includes pumps and specialty drills for the boring of injection holes. Often the pumps are connected to a manifold to allow grouting of several holes at once. In nearly all cases, the pumps are equipped with gages and meters to monitor grout pressures and volumes.

c. Sheet Piling Cut-off Walls:

Sheet piling can be used to form a continuous containment wall or barrier. Sheet piles can be made of wood, precast concrete, or steel. Wood is an ineffective barrier. Concrete is used primarily where great strength is required. Steel is the most effective in terms of ground water cut-off and cost. Steel sheet piling cut-off walls involve driving interlocking piles into the ground with a pneumatic or steam-driven pile driver. Lengths of the piles are commonly available from 4 to 40 feet, although longer lengths are available by special order.

For construction of a sheet piling cut-off, the pilings are assembled at their edge interlocks before they are driven into the ground. The piles are then driven a few feet at a time over the entire length of the wall. This process is repeated until the piles are all driven to the desired depth.

The performance life of a sheet piling can be between 7 and 40 years, depending on the condition of the soil in which the wall is installed. Sheet piling walls can be installed in various types of soils ranging from well-drained sand to impervious clay, with soil resistivities ranging from 300-ohm cm to 50,000 ohm cm, and with soil pH ranging from 2.3 to 8.6. Additional protection of the sheet piling wall against corrosion can be achieved by using hot-dip galvanized or polymer-coated sheet. Steel sheet piles should not be considered for use in very rocky soil.

5. Construction Quality Assurance

Construction quality assurance is critical for producing engineered cover systems that will perform satisfactorily. The critical construction quality assurance issues for cover systems are (1) control of subgrade preparation; (2) soil placement/compaction; (3) drainage layers, and (4) deployment of the geomembrane and geomembrane field seams. The drawings and specifications prepared for construction of a cap system must be signed and sealed by a New Jersey Licensed Professional Engineer. The specifications should include the most important and useful quality control tests for soil materials used in cover systems, which are: grain size, moisture content, proctor moisture density, Atterberg's limits, permeability, and shear strength. The construction quality assurance plan must also include the longevity for the expected life of the cap. The construction contractor and inspector are responsible for the construction of the cap system in accordance with the drawings and specifications.

a. Control of Subgrade Preparation

Prior to the placement of random fill material (protective layer directly on top of the contaminated material), the surface of the contaminated soil area should be cleared of vegetative cover and compacted to stabilize the contaminated material. Unstable areas can be undercut and back-filled with random fill. In certain circumstances, limited excavation and reshaping of the contaminated area can minimize the volume of random fill material required, which could result in substantial cost savings. Materials which are unsuitable for use as random fill include debris, roots, brush, sod, and organic and frozen materials. The random fill is placed in lift thicknesses of 8 to 12 inches. The random fill layer should have a minimum thickness of 12 inches to provide a firm foundation for the overlying layers of the cap.

b. Soil Placement/Compaction

Construction issues are critical when placing the select fill (granular soil) on synthetic liners. The select fill material should be placed starting at the toe of the cover working up the slope and parallel to the toe. The first layer of select fill should be placed in a thick loose lift of 15 to 18 inches in depth. Equipment should not be driven or pulled directly on any underlying synthetic liner. Equipment is allowed on areas underlain by the liner only after the first layer of select fill has been placed. The select fill should not be dropped or dumped onto liners from a height greater than 12 inches. The select fill should be placed onto the synthetic liner by dropping (not pushing) the fill from a small front end loader.

The thickness of a lift should not exceed the specified value, especially for materials having low hydraulic conductivity. Otherwise, the lower portion of the lift may be inadequately compacted, the bonding of lifts is likely to be poor, and the hydraulic conductivity could be larger than desired. Control of lift thickness is critical for low hydraulic conductivity compacted soil liners.

Fill elevations are usually controlled with grade stakes. Care must be taken to remove grade stakes and repair the resulting holes. The Construction Quality Assurance inspector should make sure that grade stakes are not buried in the cover system. To accomplish this, an inventory system is recommended in which all grade stakes are numbered and accounted for each day. One advantage of ferrous metal grade stakes is that, if inadvertently buried in the cover system, they can be found with a metal detector. The holes left by grade stakes should be packed with soil liner material or bentonite tamped into the hold in layers with a rod.

To protect the synthetic liners, achieve a stable structure, and to enhance the soil’s ability to support the vegetative cover, the fill material at the top (vegetative and protective layer) should be minimally compacted. Generally, traffic compaction using placement equipment is sufficient.

c. Drainage Layer

The primary functions of the drainage layer are to intercept water that infiltrates the selected fill and then to convey the water out from beneath the cover. The drainage layer should be designed to minimize the amount and residence time of water being in contact with the low permeability layer. The drainage layer must slope to an exit drain and discharge away from the toe of the cover. The drainage layer generally consists of either a geonet or 6 to 12 inches of granular material. Geonet drainage materials should identify the following characteristics:

- hydraulic transmissivity (the rate at which liquid can be removed);

- compressibility (the ability to maintain open pore space, and thus transmissivity, under expected overburden);
- deformation characteristics (the ability to conform to changes in shape of the surrounding materials);
- mechanical compatibility with the synthetic liner (the tendency for the drainage material and the liner to deform each other);
- useful life of the system; and,
- ability to resist physical, chemical and biological clogging.

As for drainage layers with granular material, normal compaction is usually adequate. One potential problem to avoid is bulking of wet or damp sands; compaction in lifts will overcome such problems. Of greater importance than the degree of compaction is protecting drainage materials from contamination by fines. Over-compaction of the drainage materials can grind up soil and increase the amount of fines. The specifications should not permit use of nondurable materials that are easily broken down.

d. Deployment of the Geomembrane and Geomembrane Field Seams

The subgrade (the material beneath the liner) must be prepared to be free of sharp objects of any kind that can damage the geomembranes. Ruts caused by the compaction equipment or by the geomembrane placement equipment must be leveled by hand. Ruts are particularly troublesome if they freeze in their uneven profile. They must be leveled before the geomembrane is placed by waiting until the ground thaws or by breaking the uneven surfaces. Geomembranes should never be placed in ponded water. Seaming can never be accomplished under such conditions. In addition, the synthetic liner must be properly anchored to prevent it from slipping.

The geomembranes should be placed in accordance with a predetermined roll or panel layout. Layout is a site-specific consideration, but plans are generally supplied by the geomembrane manufacturer, fabricator, or installation firm. Usually, the rolls or panels are ordered in a particular direction. After a roll or panel is initially positioned, it usually must be shifted for exact positioning. The entire roll or panel must then be inspected for blemishes, scratches, and imperfections. Finally, the roll or panel is weighted down with sandbags to prevent movement by wind or any other disturbance. If complete rolls or panels have been captured by gusts of wind, they can be damaged and may need replacement.

Quality control of the geomembrane field seams is very important. The individual panels of liner material must be sufficiently overlapped for field seaming. There are many types of geomembrane seams that can be used in the field. The method of field seaming used should be appropriate to the type of geomembrane and in accordance with the procedures recommended by the manufacturer of the material. The common types of seams are solvent seams, thermal seams and extrusion seams. A quality control technician should inspect each seam. Any area showing defects should be marked and repaired. Non-destructive tests should be employed to check all seams. In addition, some samples should be sent to a laboratory for destructive seam tests for failure in sheer or peel modes to evaluate the quality of the field performance.

E. Long-Term Operation, Maintenance and Monitoring

The time required for post-closure monitoring of hazardous waste units or solid waste landfills is generally 30 years after closure activities have been completed. However, under current state law, monitoring is required until unrestricted use criteria or standards are achieved. Key monitoring parameters include ground water, air quality, gas migration, subsidence (settlement), and surface erosion. It is necessary to incorporate the proper instrumentation into the cover design and construction in order to monitor these parameters of concern. Baseline conditions must be measured either prior to or immediately after construction, depending upon the parameter of concern. Consistent and accurate record keeping during the post capping period is essential. In addition, properties where caps are constructed as a long-term remedy must be subject to certain use restrictions or other institutional controls. Capped sites not in use are normally fenced to prevent trespassing. Institutional controls and deed notices are used to prevent any activities that could harm the constructed remedy. Throughout the period of operation, maintenance and monitoring, a site access/easement must be available to the site.

1. Ground Water

If ground water has been impacted, continued monitoring may be necessary. Ground water monitor wells are normally placed both up and down gradient from the final cover. Baseline ground water analyses for index parameters are taken prior to construction of the final cover. The ground water is sampled and monitored during the post-capping period. It may be necessary to abandon or raise existing monitor wells where fill material will cover the wells during cap construction.

2. Air Quality

In cases where the contaminated material may generate gases, gas concentrations released from the contaminated material should be monitored for both the underground lateral movement of gas and for air quality at the vent outlet locations. Gas monitoring stations should be located around the perimeter of the cap between any developments or areas of concern. The lower explosive limit of gas is the primary parameter of concern. The monitoring stations should be in place prior to placement of the low permeability layers. Air quality should be monitored on the final cover surface for toxic gases emitted from the vent system. For passive systems, internal gas pressures may be a concern and can be measured using pressure cells.

3. Subsidence

Subsidence is a critical parameter to monitor because of the damage that can be caused by differential settlements to the clay barrier, synthetic liner, penetration connections, drainage provisions and gas collection systems. The level of differential settlements during post-closure monitoring may be quite large. Evidence of settlement can commonly be found by walking the cover after a rain storm and looking for ponding. Subsidence depressions also can be found through an annual survey of the cover using either conventional or aerial survey methods. Subsidence depressions must be remediated below the level of the barrier system. Remediation requires removing the cover system in the region of subsidence and backfilling the depression with lightweight fills. This fill may either be more contaminated material, waste, or commercial lightweight aggregates. The full cover profile must then be rebuilt over the new fill.

4. Surface Erosion

All cover systems will erode and require long term maintenance. Cover systems with moderate slopes and a vegetative cover will typically require annual maintenance of 0.5 percent of their surface area. This percentage increases with slope. Thus, all covers that use vegetative covers require an annual inspection and repair program. Such repair may include cleaning out surface water swales, replacing cover soil, and re-establishing vegetation. The annual inspection should verify that the vegetative cover is being mowed at least annually to prevent the growth of trees. Also, maintenance logs need to be maintained which document the inspection condition(s), repair(s), etc. of the cap.

F. References

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4. NJDEP. *Discussion Paper on Landfill Closure and Remediation Issues.* April 1993.

5. Environmental Protection Agency. *Handbook for Remedial Action at Waste Disposal Sites.*