

## Appendix II-A: The Use of Caps as Engineering Controls

Caps are one of the most common pathway elimination remedies used by remediators at sites with subsurface contamination. Capping prevents exposure via direct contact by acting as a barrier between a human receptor and the contaminated subsurface media. Impermeable caps can also help to prevent vertical movement of contaminants via stormwater infiltration. Different caps work more effectively in different situations, so site-specific information should be used to determine which cap system to select.

The conceptual site model (see Section II of this manual) should be used to identify potential receptors and related contaminant migration and exposure pathways. The receptors and pathways to be addressed should be evaluated before cap construction takes place to ensure that installation of the cap will achieve the desired result. Remediators should clearly understand the nature and extent of contaminants at their site and the current and projected future conditions.

The guidance provided in this addendum applies solely to the use of caps in attaining an Act 2 standard. Caps used at landfills, RCRA sites, or other non-Act 2 sites may have requirements that differ from the guidance provided in this addendum. Additionally, this guidance is intended to supplement existing guidance; it is not regulation and should not be interpreted as such. This guidance is provided to inform remediators of pertinent information to consider when selecting cap systems and some of the options that are available. Remediators may choose to consider alternative technologies other than those discussed herein when addressing their specific situation. Remediators may need to develop a different approach than what is described in this guidance to provide the best fit for their specific situation.

A cap is a barrier over contaminated media that eliminates an exposure pathway or controls contaminant migration. A cap can be used as an institutional or engineering control used to attain an Act 2 standard. Therefore, remedies that use a cap require a cleanup plan which describes the selected remedy. If a cap already exists at the site (e.g., a parking lot) and needs to be preserved as part of the remedy, then the cleanup plan should describe the manner in which the cover will be maintained. Where used as an activity and use limitation, a remediator must properly record an environmental covenant pursuant to the Uniform Environmental Covenants Act to ensure the cap is properly maintained in the future. The final report should include as-built plans and details of the cap construction and photographs documenting installation of the cap if available. The post-remedial care plan and environmental covenant should include a map depicting the extent of the cap as well as monitoring and maintenance requirements.

General Goals for Caps – Caps are generally used for the following purposes:

- Protection from direct contact with soil containing contamination at concentrations resulting in an unacceptable risk;
- Prevention of the migration of contamination throughout the subsurface (upward, downward, and laterally);
- Prevention of the migration of contamination to surface water via stormwater runoff.

Cap Construction Considerations – The following factors should be considered during the design, construction and maintenance of most caps, where appropriate:

- Erosion from precipitation, surface water flow or wind;
- Cracking and deterioration from natural influences including water saturation and freeze/thaw cycles;
- Expected human activities on the land covered by the cap;
- Settlement and shifting of the cap and subsurface;

- Potential damage from migration of groundwater into the cap;
- Contaminant migration, including migration to the surface of the cap and potential vapor migration. Refer to Section IV of this manual when evaluating the vapor intrusion pathway.

### **Protection from Direct Contact with Contaminants**

Design Goals – In addition to the cap construction considerations presented above, the design should prevent direct contact exposure to contaminated soil for as long as the contaminant concentrations remain at unacceptable levels. Cap designs should consider site-specific factors, including, but not limited to:

- Current and potential future land use (anticipated future activities that could result in creating an exposure pathway to the soil should be addressed with land use restrictions);
- The nature of the contaminants (concentrations, mobility, toxicity, etc.);
- The types of potential exposure pathways (e.g., ingestion or inhalation);
- Contaminant degradation and daughter products resulting from such degradation, if any;
- The specifications of the capping material, the quality control of the cap construction, and the operation and maintenance (O&M) and inspection requirements; and
- The reliability of the assurances that access restrictions, O&M, and inspections will be performed for as long as the soil contaminant concentrations beneath the cap would result in an unacceptable risk.

Soil Caps – Soil caps can be used to prevent direct contact exposure to contaminated soils. Cap thickness depends on various factors including the type and intensity of the land use above the cap and the contours/slope of the area being capped. In general, caps used to prevent direct contact with contaminated soil are constructed with two feet of uncontaminated soil including a vegetated cover to prevent erosion and deterioration. The vegetated cover usually consists of six inches of topsoil, with appropriate seeding or sod to establish a good growth of grass. When a vegetated cover is used, consideration can be given to reducing the thickness of the uncontaminated soil layer by the same amount as the vegetated cover thickness (i.e., 1.5 feet of uncontaminated soil with an additional six inches of topsoil for a total cap thickness of two feet). Cap designs of less than two feet thickness may be appropriate when additional design features, such as the use of warning fabrics, are considered or if the likelihood of deterioration is low (e.g. flat surfaces, low foot/vehicle traffic, etc.). Other materials, such as gravel, may substitute for vegetated topsoil, as discussed below. Capping materials should be durable and meet the performance specifications required for the site. DEP recommends placement of a demarcation boundary (warning fabric) on top of the contaminated soil and beneath the soil cap. The slope for uncontaminated soil with vegetated topsoil direct contact cover should normally not be steeper than a 3:1 horizontal-to-vertical ratio. Steeper slopes may be considered on a case-by-case basis if it can be shown that erosion will be adequately controlled through additional design features and/or O&M. Steeper slopes will generally call for an evaluation of the need for slope reinforcement to provide long-term stability. However, cap design should use lower slopes when possible and good cover vegetation to slow down stormwater runoff velocities to prevent erosion. The remediator should provide documentation of clean fill (or regulated fill at non-residential sites) used in the cap consistent with DEP's Management of Fill policy.

Pavement covers – Pavement systems may be used to prevent direct contact exposure to contaminated soils. Contaminated soil particles can work their way up through pavement surfaces where pavement settlement, shifting, cracking, freeze/thaw cycles, weathering, and deterioration are not adequately

addressed in the design, construction, and maintenance of the cap. Pavement material should have appropriate bottom base soil preparation (grading, recompaction, dewatering, etc.) and sufficient base course to minimize freeze/thaw, settling, and shifting problems, which can cause pavement deterioration. Pavement thickness and overall design can be determined based on normal paving procedures to ensure structural integrity. Generally accepted pavement construction guidance sources should be used such as the American Association of State Highway Transportation Officials.

Buildings or Structures – An existing or new building or structure may be used to prevent direct contact exposure to contaminated soils, provided the building slab or basement walls/floor are evaluated for the general cap construction considerations discussed above. Buildings with badly cracked slabs or basement floors or walls in contact with contaminated soil should be repaired. Dirt floors in buildings should be treated like any other portion of the site with bare soils.

Other Materials – The following materials, by themselves, may not be acceptable for a direct contact cover system because contaminated soil could migrate through them. However, they may be substituted for the top six inches of vegetated topsoil portion of the soil direct contact cover system using the thickness indicated:

- Gravel or stone – Thick enough to prevent erosion; six inches recommended.  
Note: A permeable cap constructed entirely of gravel/stone may be used to prevent direct contact if it is used in combination with a geotextile layer to prevent soil particle migration and if adequate maintenance is provided to retain the intended thickness of the cap.
- Geomembranes – A synthetic membrane liner made from thin continuous polymeric sheets is acceptable if the material is not considered an untreated geotextile. Geomembranes constructed from low density polyethylene (LDPE), high density polyethylene (HDPE), or polyvinyl chloride (PVC), are generally acceptable. If the geomembrane is not buried beneath a soil cover, resistance of the material to degradation from exposure to ultra-violet light must be considered in the design and postremediation care plan.
- Geotextiles – A woven or nonwoven geotextile is not acceptable for a direct contact cover by itself except as a very short-term temporary cover to prevent erosion. A geotextile layer may be used to:
  - Prevent contaminated soil particles from migrating to uncontaminated layers;
  - Provide a demarcation layer between the uncontaminated cap material and contaminated soil; or
  - Provide physical reinforcement and enhanced stability.

Note: Use of a geotextile warning fabric is encouraged for sites where future construction or utility work is anticipated.

Horizontal Extent of Cap – The cap should be designed and constructed to provide adequate protection from exposure to all areas that have contaminant concentrations that do not meet the selected Act 2 standard. The cap design thickness should extend horizontally to a perimeter line beyond where unacceptable contamination has been delineated to ensure adequate protection from direct contact.

### **Prevention of Migration of Contaminants**

Design Goals – If the control of contaminant movement is necessary to meet the chosen Act 2 standard, the cap design should minimize the migration of contaminants from contaminated soil to groundwater or to the surface via soil moisture or vapor migration. The cap construction considerations presented above

should also be considered for caps designed to prevent contaminant migration. The transport of chemicals to receptors of concern could occur via upward or downward movement of dissolved contamination in soil moisture and from volatile contaminant movement upward and downward in soil gas by vapor diffusion or bulk soil-gas flow. The cap may require features to control these modes of transport. If the infiltration of surface water, precipitation, or snow melt through contaminated soil needs to be significantly minimized, then the cover system should include a layer or layers that reduce such infiltration to the greatest extent practicable. The design of these types of cap systems should consider site-specific factors, including, but not limited to:

- The nature of the contaminants (concentrations, degradation, solubility, mobility, toxicity, etc.);
- Depth of the contamination (Note: The deeper the contamination is, the less effective an infiltration barrier may be, or the barrier's horizontal extent may need to be extended).
- The quality of construction and the operation, maintenance and inspection program for the site; and
- The reliability of O&M and inspections to maintain the remedy for as long as the unacceptable soil contaminant concentrations persist.

Low-permeability Cap Designs – Typical materials used in the construction of low-permeability caps for reducing water infiltration include, but are not limited to, geomembranes, engineered mixtures of properly compacted fine sand, silt and clay, clay barriers, geosynthetic clay liners, concrete, and pavement. Typical materials used in the construction of vapor barriers include plastic membranes made of polyethylene or propylene, and semisolid barriers that are applied by spraying or pumping.

Buildings or Structures – An existing or new building or structure may be used to prevent infiltration into contaminated soils provided the building has a sound roof and roof runoff is managed to minimize runoff infiltration into contaminated soils. Dirt floors in buildings should be treated like any other portion of the site with bare soils. The potential for vapor intrusion into buildings should be evaluated in accordance with the guidance provided in Section IV of this manual.

Multiple Pathway Designs – A cap that meets the requirements for prevention of infiltration will likely be acceptable for prevention of direct contact. All cap systems should be designed and evaluated for the pathways being addressed.

Horizontal Extent – The guidance provided above on the horizontal extent of cap designs for protection against direct contact exposure also applies to the prevention of contaminant migration to groundwater using the applicable groundwater protection standards. However, the horizontal extent of the cap may need to extend beyond the direct contact footprint to address contamination in deeper soil horizons.

VOC Contaminant Migration – VOC concentrations in soil and shallow groundwater may be a source of contaminant vapors that can migrate, transporting the VOCs to locations that may not be currently contaminated. Certain types of caps, such as pavement, may limit the upward vertical migration of vapors to the surface but may force them to migrate horizontally to create new contamination in soil and groundwater. The cap may also direct vapors into buildings, increasing indoor air contaminant concentrations. Vapors could migrate into the cap itself contaminating the previously uncontaminated material and potentially damaging it (for example, certain VOCs can degrade asphalt or kill vegetation). It may be necessary to treat or remove the sources of vapors or provide active or passive venting below and/or adjacent to a cover to remove soil vapors and prevent vapor migration.

## **Inspections and Maintenance**

The post-remediation care plans (PRCP) and environmental covenants must contain appropriate conditions to ensure that the integrity of the cap is maintained. Please refer to Section III.E of this manual for information on long-term stewardship obligations for post-remediation care plans and environmental covenants. Factors to consider and DEP's recommended best practices include the following:

- The extent of the cap should be well defined such that the owner, contractors, DEP, and other parties can readily identify the restricted area. The cap boundaries should be clearly marked on a map or site figure.
- A professional survey of the cap boundaries is beneficial, for instance when the cap is not readily visible, landmarks used to define the boundaries change, the cap area is large, or the cap boundaries are irregular.
- Caps should be inspected periodically depending on how likely they are expected to require routine maintenance and the potential risks from cap disturbance. In cases where caps are more likely to experience disturbance (e.g., on sloped surfaces or in high-use areas), inspections should be more frequent.
- Inspections should take place during and after any activities that disrupt or penetrate the cap, such as landscaping work, utility trenching, and construction.
- All inspections should be recorded in writing. Photographs are useful documentation of the cap condition. Inspection records should be maintained for a period of three years and must be made available for DEP review upon request.
- The remediator should consider the need to develop a health and safety plan to address potential future exposures to contaminated soil beneath the cap by construction and utility workers.
- Qualitative or quantitative criteria may be developed in the PRCP to determine when disruptions to cap integrity that could impair its effectiveness must be repaired.
- Disruptions of soil caps, including excavation, removal, penetration, erosion, loss of vegetated topsoil, or any other cumulative thinning of the original cap thickness, should be repaired within 30 days of the date of discovery.
- Disruptions of pavement, buildings, and other structural caps, including removal, penetration, significant cracking, erosion, or other opening(s), should be repaired within 30 days of the date of discovery.

Both the discovery and repair of cap disruptions should be reported to DEP as required by the PRCP and environmental covenant within one month of occurrence. The reporting should describe the nature and cause of the disruption, explain the corrective actions taken, and document that repairs were made (e.g., photographs).