Technical and Cost Comparisons of Candidate Final Cover Systems for Coal Combustion Residual (CCR) Unit Closures

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Environmental Show of the South
May 17, 2018, Chattanooga, Tennessee

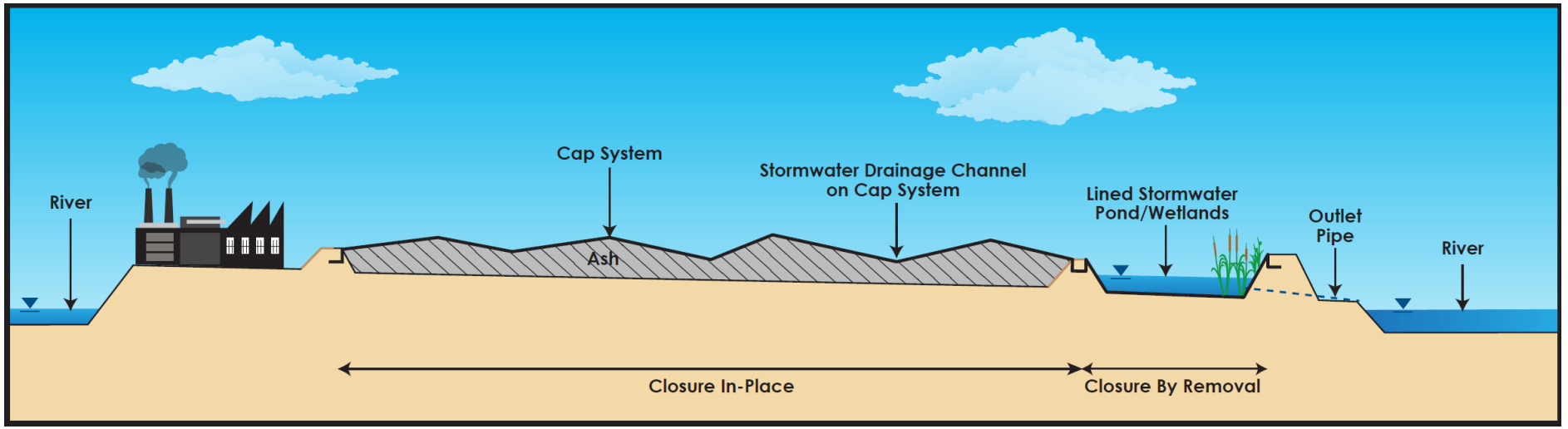
Acknowledgement:
- Sid Nadukuru, Ph.D., P.E., Cuneyt Gokmen, P.E., Rudy Bonaparte, Ph.D., P.E., Geosyntec Consultants
- Paul O'Malley, Watershed Geosynthetics

Agenda

- Introduction
- Regulatory Requirements
- Final Cover Systems
  - Soil-Only
  - Soil-Geosynthetic
  - Exposed Geomembrane
  - Engineered Synthetic Turf
- Cost Comparison

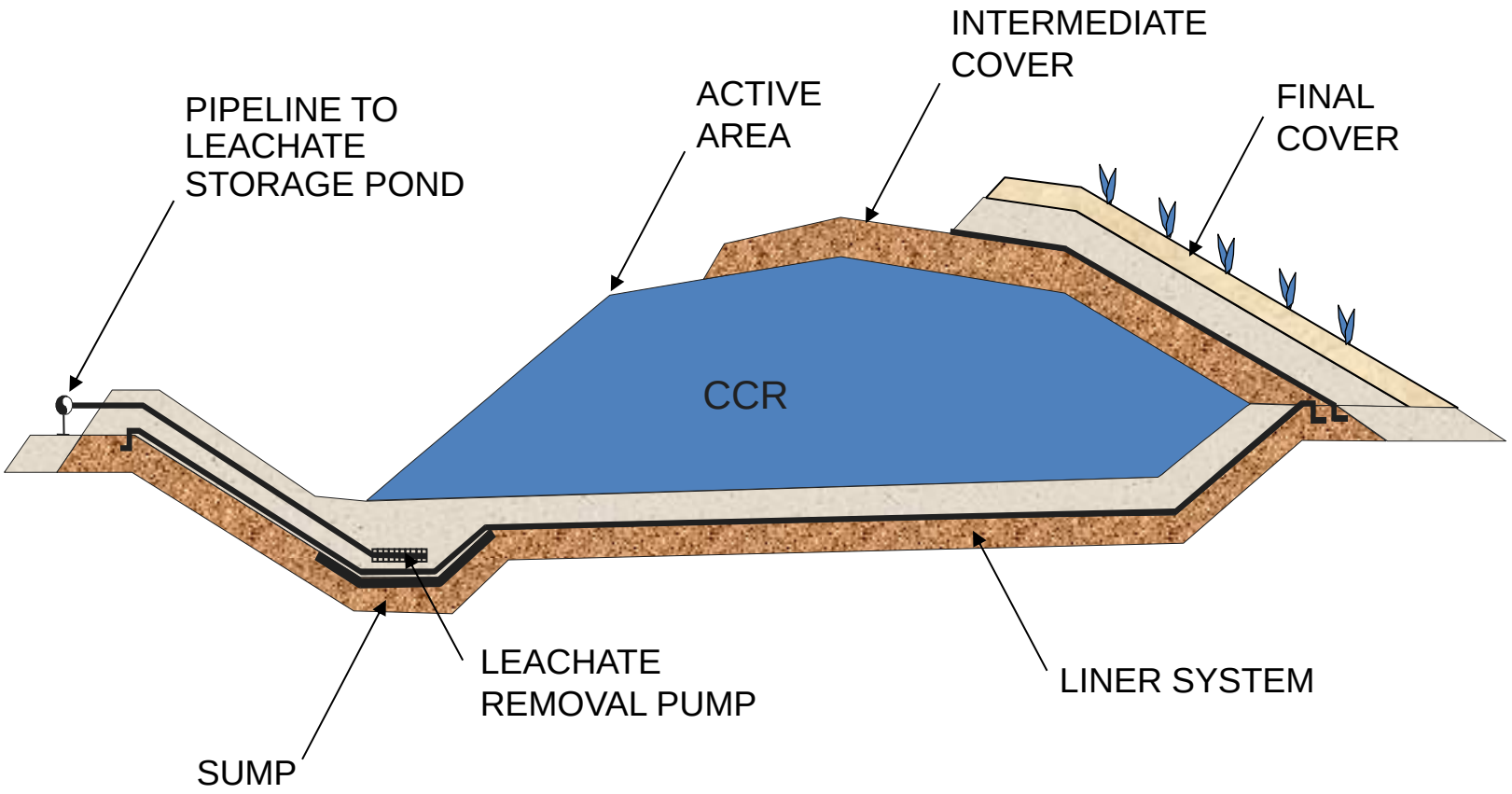
Introduction

- Coal Combustion Residuals (CCR) Surface Impoundment Closure Options:
  - Closure by removal: CCR excavated/dredged and transported to a new/existing, on-site/off-site landfill
  - Closure in-place: a final cover system installed on current or consolidated footprint



Schematic of a Conceptual CCR Surface Impoundment Closure
Not to Scale

Introduction



Schematic of a Typical CCR Landfill

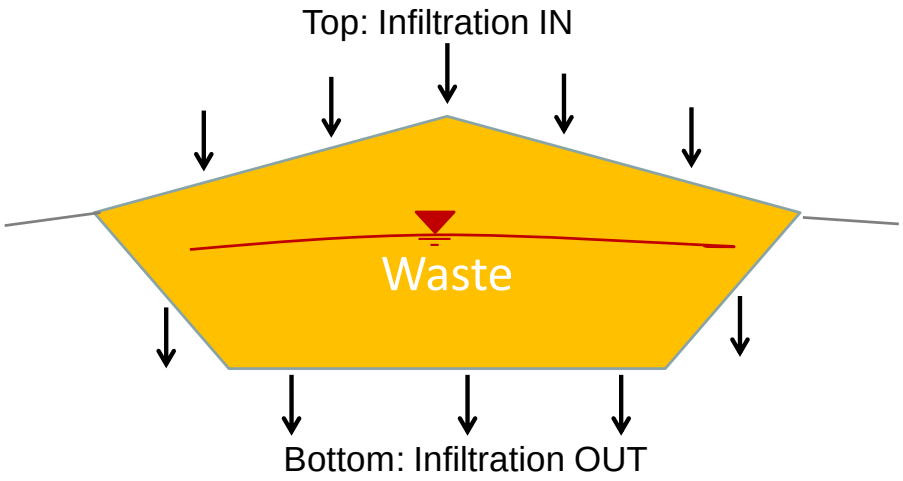
Not to Scale

Regulatory Requirements

- CCR unit closure requirements - §257.102 (d)(1):
  - *Control, minimize or eliminate, to the maximum extent feasible, post-closure **infiltration** of liquids into the waste and **releases** of CCR, leachate, or contaminated run-off to the ground or surface waters or to the atmosphere;*
  - *Preclude the probability of future **impoundment** of water, sediment, or slurry;*
  - *Include measures that provide for major slope **stability** to prevent the sloughing or movement of the final cover system during the closure and post-closure care period;*
  - *Minimize the need for further **maintenance** of the CCR unit; and*
  - *Be completed in the shortest amount of **time** consistent with recognized and generally accepted good engineering practices.*
- The final cover system is critical to achieve the above-specified performance requirements.

Regulatory Requirements

- Final cover system requirements - 257.102 (d)(3)(i)(A) through (D):
  - **Permeability**: must be less than or equal to the permeability of any bottom liner system or natural subsoils present, or no greater than 1×10^{-5} cm/s, whichever is less (in order to avoid the "bathtub" effect)
  - **Infiltration layer**: a minimum of 18 inches of earthen material
  - **Erosion layer**: a minimum of six inches of earthen material that is capable of sustaining native plant growth
  - **Integrity**: minimize disruption through a design that accommodates settling and subsidence

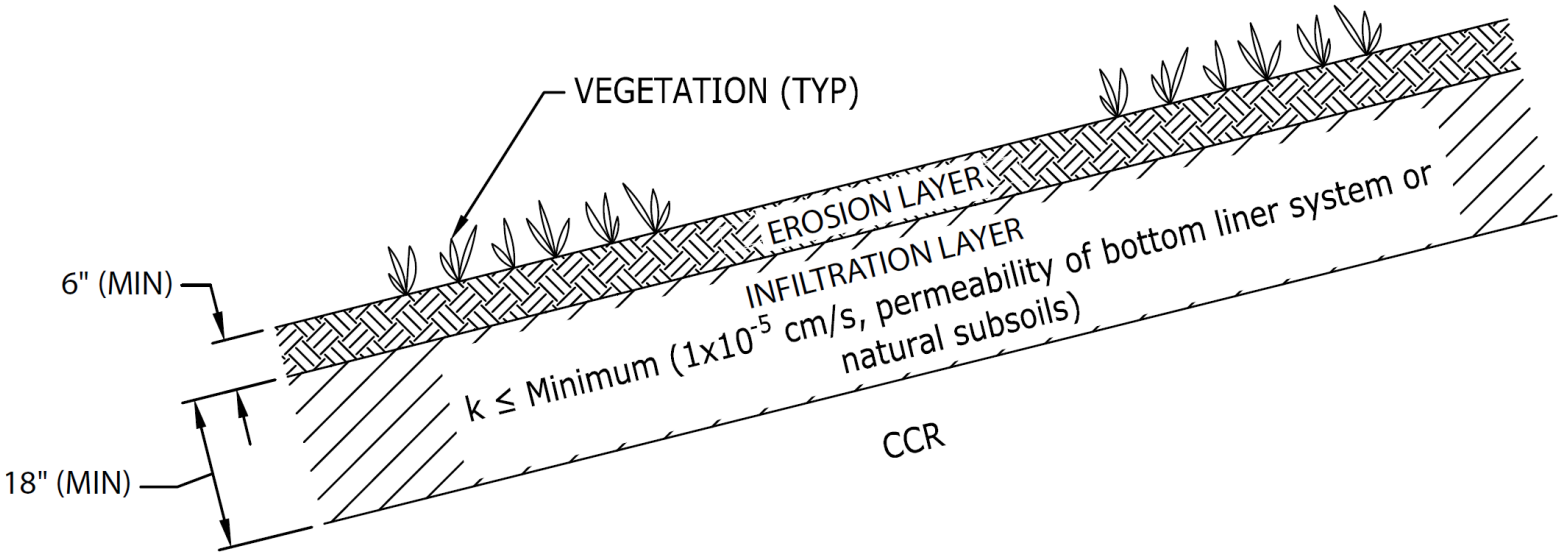


"Bathtub Effect": if Infiltration IN > Infiltration OUT

Regulatory Requirements

- Alternative final cover system design criteria - §257.102 (d)(3)(ii)(A) through (C):
  - **Infiltration layer**: equivalent reduction in infiltration
  - **Erosion layer**: equivalent protection from wind or water erosion
  - **Integrity**: minimize disruption through a design that accommodates settling and subsidence

Final Cover System (Soil-Only)

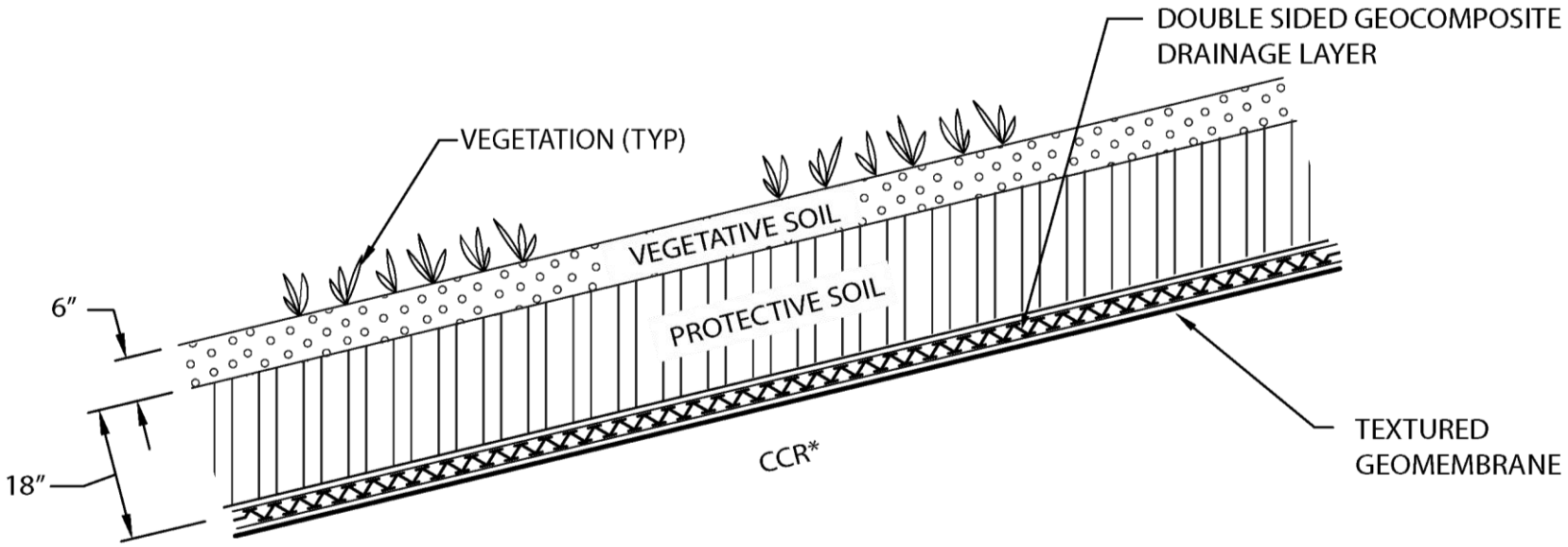


Soil-Only Final Cover System
(CCR Rule Prescriptive Final Cover System)

Final Cover System (Soil-Only)

- Soil-Only Final Cover System
  - Benefits
    - meets the prescriptive requirements and **complies** with the regulation
    - its **simple** configuration (straightforward to construct)
    - low construction **cost** when local source of cover soil is readily available
  - Challenges
    - high water **infiltration** through the cover system
    - susceptible to **cracking** from freeze-thaw and wet-dry cycles (i.e., weathering effects) and differential settlement, resulting in an increase in soil layer permeability over time
    - may require the construction of a very low permeability **clay** layer (as the infiltration layer), which can be challenging and expensive, if the permeability of the bottom liner system or natural subsoils is on the order of 1×10^{-7} cm/s, or less
    - excessive erosion or failure of the final cover slope may cause **release** of CCR (however, this issue can be mitigated through design)

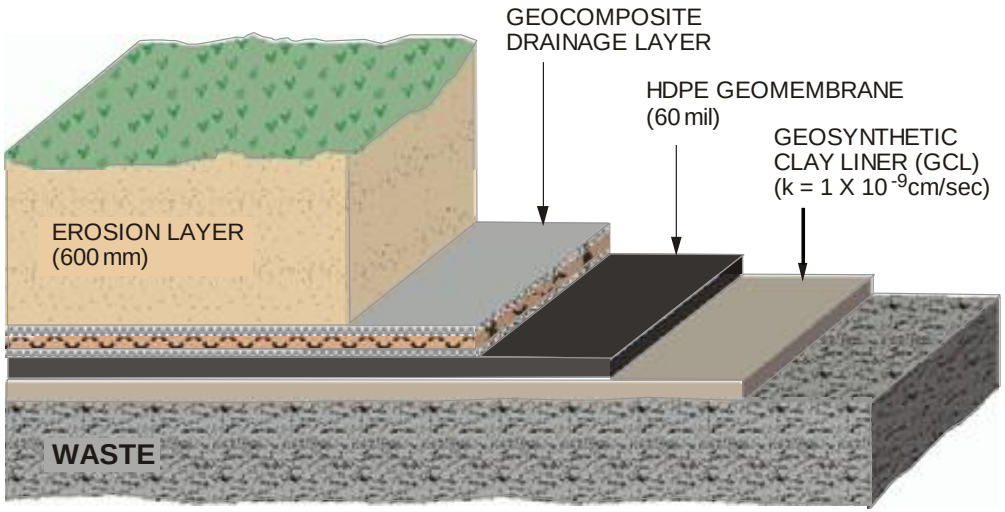
Final Cover System (Soil-Geosynthetic)



* An interim soil cover or a foundation layer for smooth grading may be needed above CCR

Soil-Geosynthetic Final Cover System – An Example
(Alternative Final Cover System)

Final Cover System (Soil-Geosynthetic)



Soil-Geosynthetic Final Cover System – Another Example

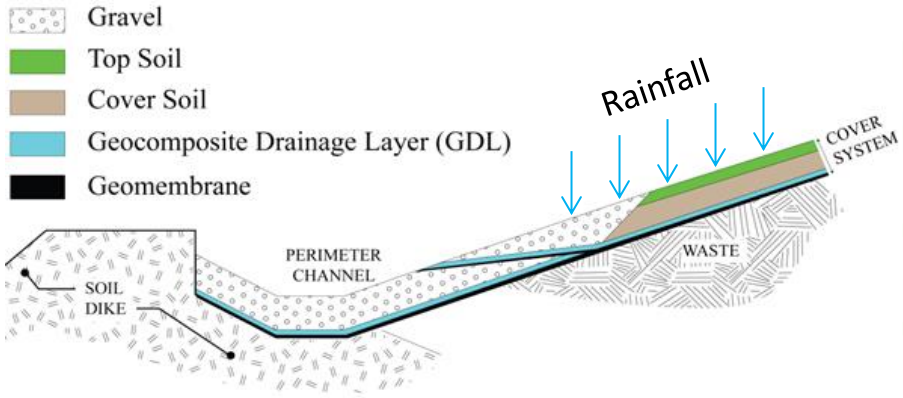
Geosynthetics installation

Final Cover System (Soil-Geosynthetic)

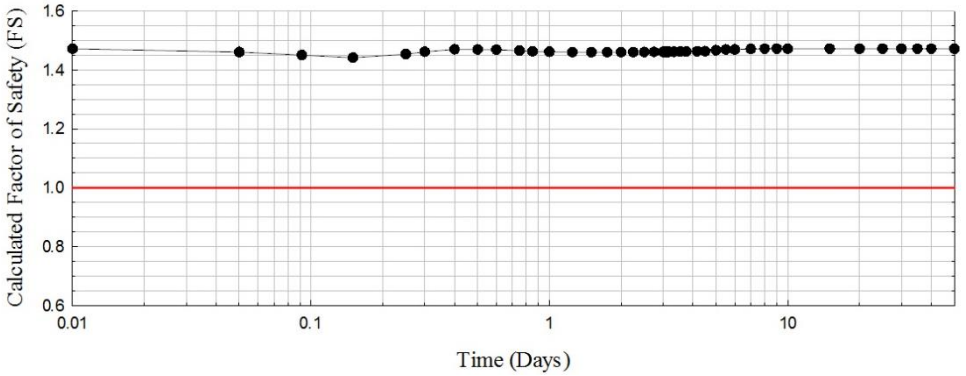
Final Cover System (Soil-Geosynthetic)

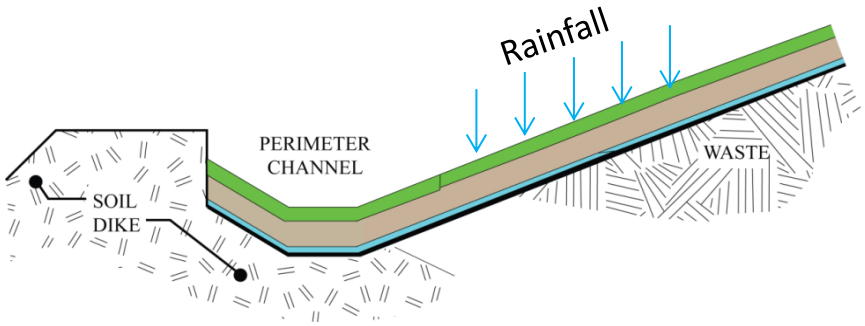
- Soil-Geosynthetic Final Cover System
  - Benefits
    - low **permeability** not required for the cover soils
    - CCR **contained** by the geomembrane (not exposed should the cover soils undergo excessive erosion or a slope failure)
    - very little water **infiltration** into the CCR (because of the extremely low permeability of the geomembrane)
    - geomembrane protected from ultraviolet (UV) light exposure and temperature fluctuations (a long geomembrane **service life**)
  - Challenges
    - relatively high construction and maintenance **costs**
    - potential for final cover instability due to **slippage** along geosynthetic interfaces when constructed on steep slopes
    - potential for final cover instability due to inadequate **drainage**

Final Cover System (Soil-Geosynthetic)



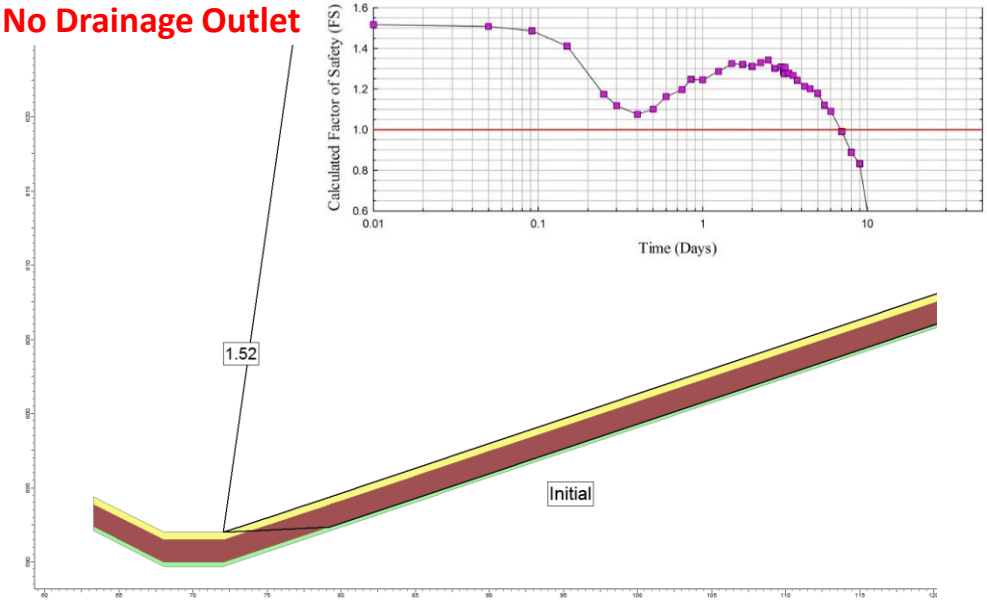
Final Cover System with Adequately Designed and Constructed GDL
(GDL daylights near the toe of the cover slope)





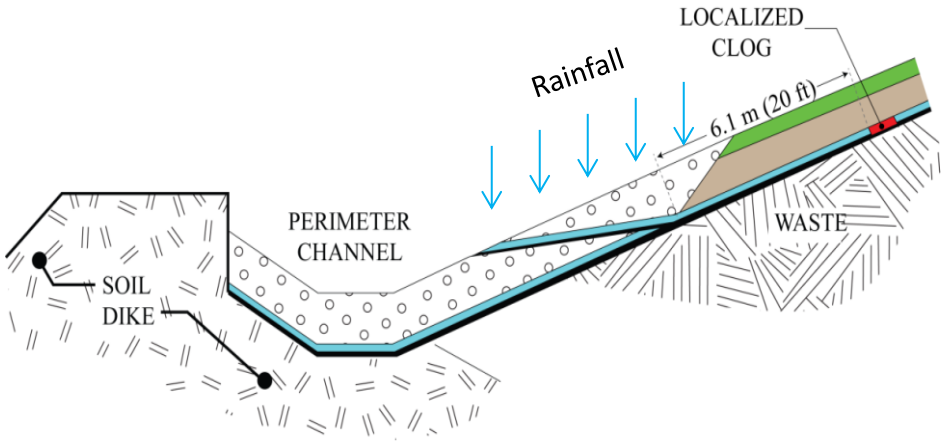
Final Cover System with No Daylighting of GDL
(no drainage outlet at the toe of the slope)

No Drainage Outlet

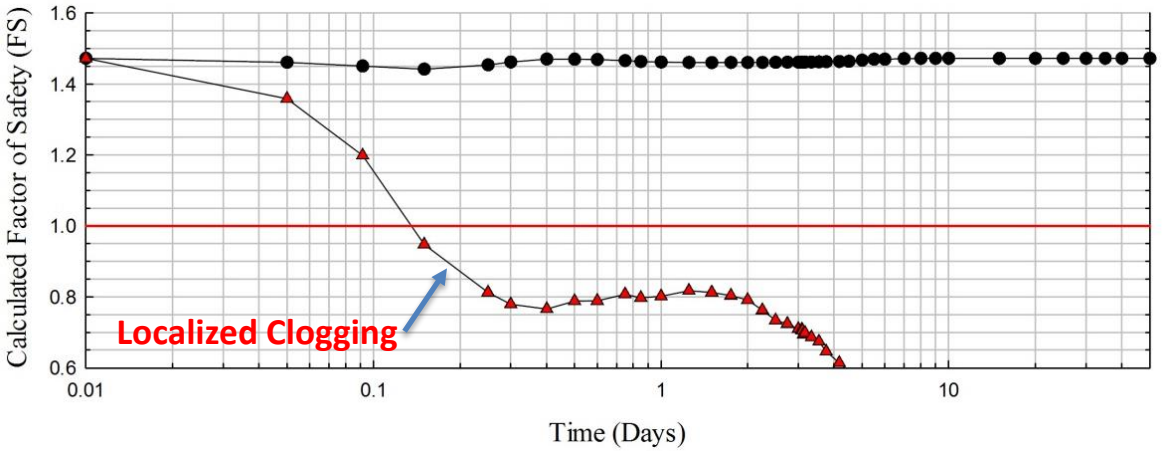


S. Nadukuru, M. Zhu, C. Gokmen, and R. Bonaparte, "A Combined Seepage and Slope Stability Analysis of a Landfill Cover System", Geotechnical Frontiers 2017, March 12-15, 2017, Orlando, FL, ASCE Geotechnical Special Publication No. 276, pp. 170-179.

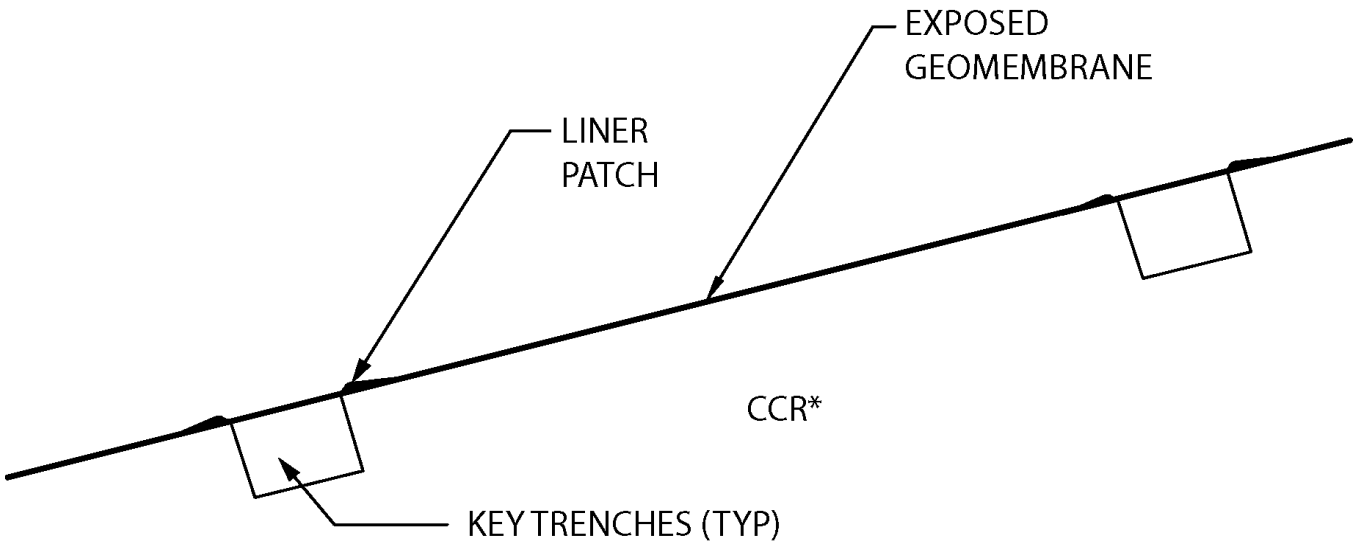
Final Cover System (Soil-Geosynthetic)



Final Cover System with Localized Clogging of GDL
(Clog modeled as a region of low permeability: 100 times less than that of GDL)



Final Cover System (Exposed Geomembrane)



* An interim soil cover or a foundation layer for smooth grading may be needed above CCR

Exposed Geomembrane Final Cover System
(Alternative Final Cover System)

Final Cover System (Exposed Geomembrane)

Final Cover System (Exposed Geomembrane)

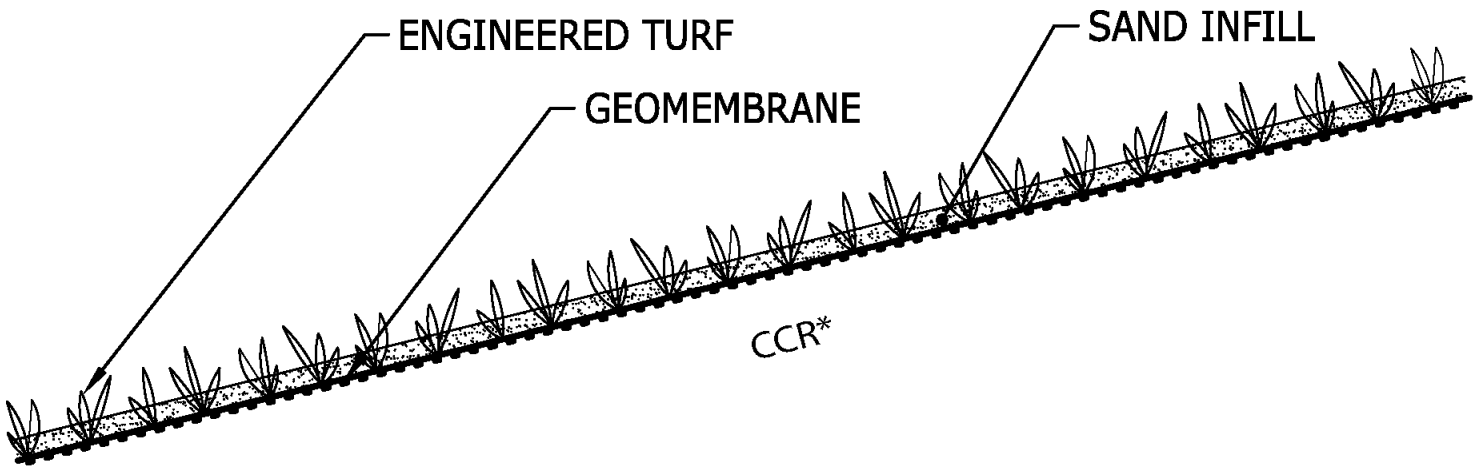
Final Cover System (Exposed Geomembrane)

- Exposed Geomembrane Final Cover System
  - Benefits
    - CCR **contained** by the geomembrane
    - very little water **infiltration** into the CCR
    - significantly reduced need for **soil** cover materials
    - faster **construction** and lower construction costs than soil-only and soil-geosynthetic covers
    - almost no concerns regarding final cover slope **stability**
    - significantly reduced post-closure **maintenance** requirements and costs
    - easier **access** to CCR after closure (if future beneficial reuse of the CCR ever becomes an option)
    - can be **converted** to a soil-geosynthetic final cover system at a later date (if desired by the owner or operator of the CCR unit)

Final Cover System (Exposed Geomembrane)

- Exposed-Geomembrane Final Cover System (continued)
  - Challenges
    - shorter **service life** of exposed geomembrane due to long-term UV degradation
    - potential geomembrane **wrinkling** (due to thermal expansion-contraction)
    - potential wind or gas **uplifting**
    - potential **puncture** by hail, vehicular traffic, animals, and other external loads and potential **burning** damage due to lighting strikes
    - may need **aesthetics** improvement (e.g., green, in stead of white or black geomembrane) to blend into the surrounding environment
    - limited regulatory **acceptance**

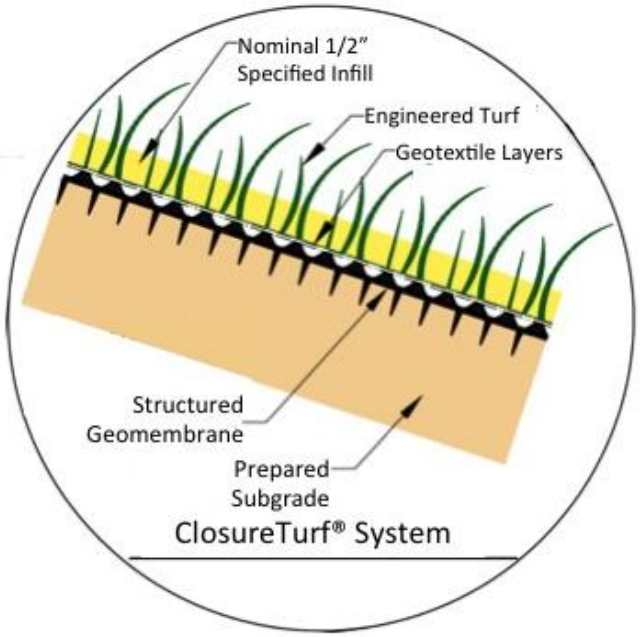
Final Cover System (Engineered Synthetic Turf)

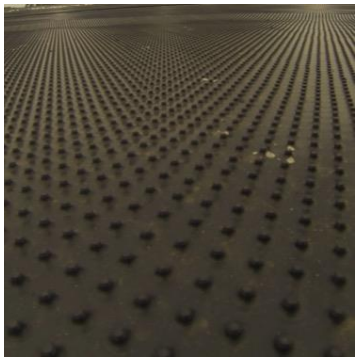


* An interim soil cover or a foundation layer for smooth grading may be needed above CCR

Synthetic-Turf Final Cover System
(Alternative Final Cover System)

Final Cover System (Engineered Synthetic Turf)





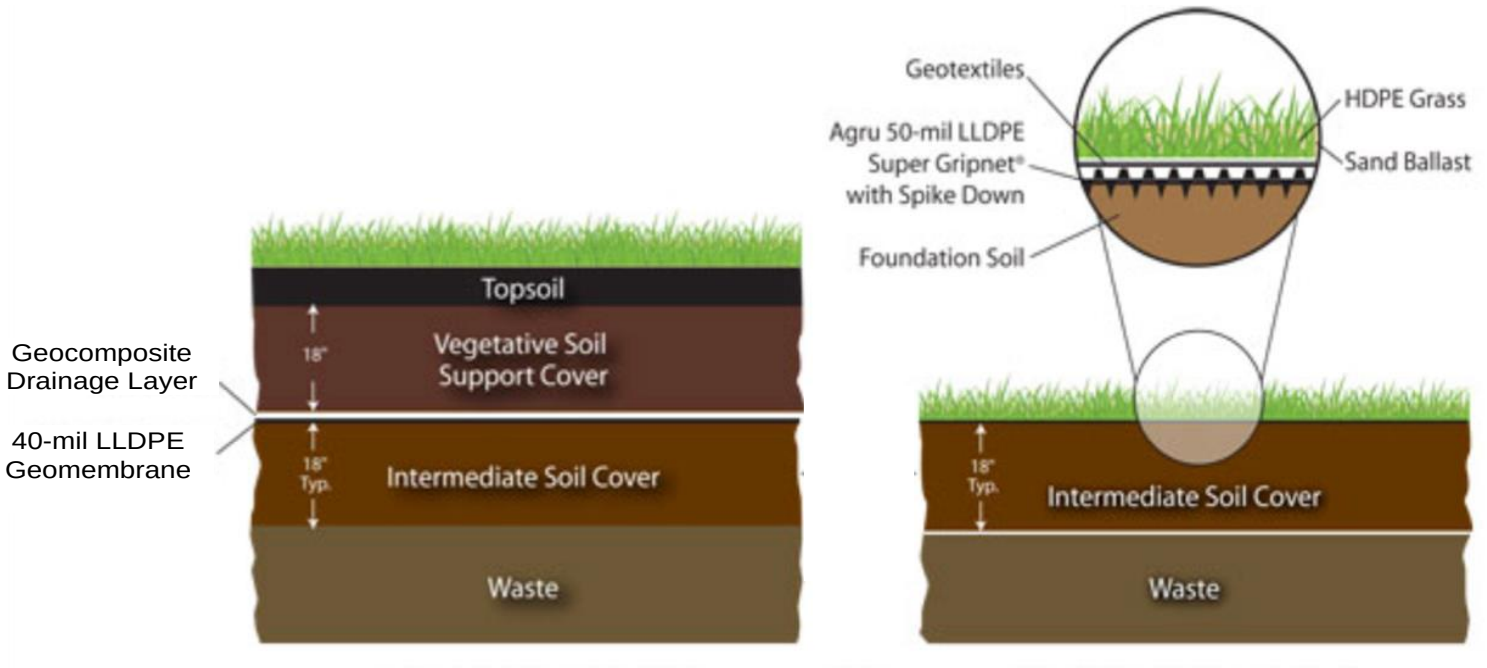
Structured Geomembrane

Engineered Synthetic Turf

Infill (ASTM C-33 Sand)

An Engineered Synthetic Turf Final Cover is NOT an Exposed Geomembrane Cover, because the geomembrane is covered and protected by the engineered turf and infill.

Final Cover System (Engineered Synthetic Turf)



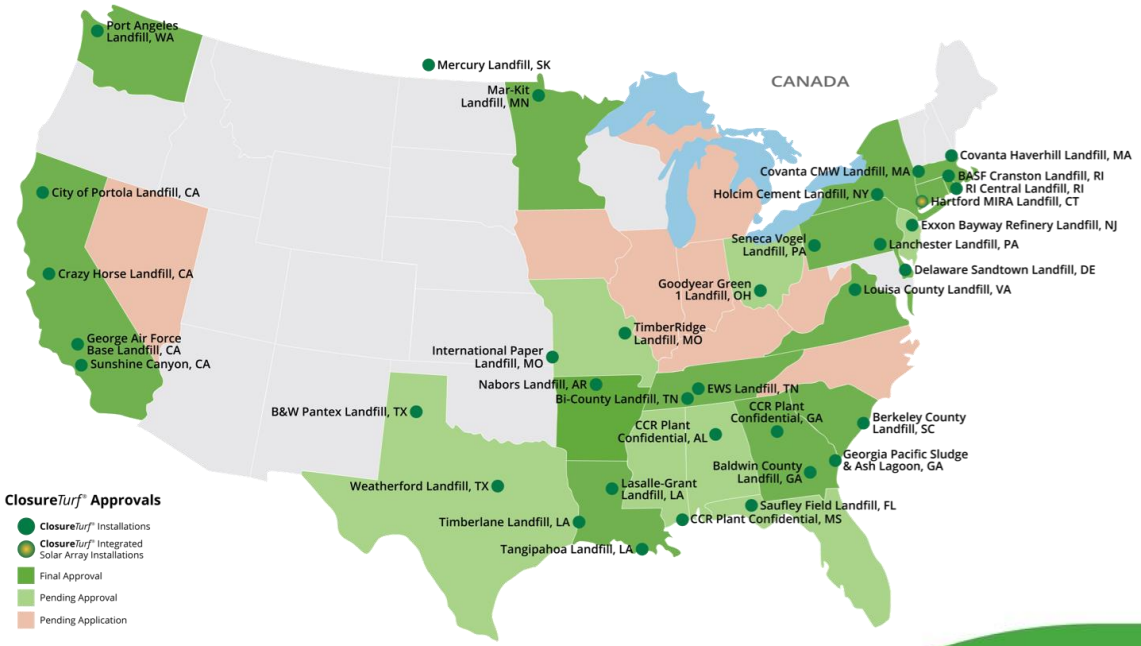
An Example Soil-Geosynthetic Cover vs. An Engineered Synthetic Turf Cover

Final Cover System (Engineered Synthetic Turf)

- Engineered Synthetic Turf Final Cover System
  - Benefits
    - no exposed geomembrane (improved **UV protection** and hence longer design life than the exposed geomembrane cover)
    - better **durability** to incidental damage (such as from animals and flying debris) than the exposed geomembrane
    - **wind resistance** provided by the synthetic turf and sand ballast
    - better **aesthetics** than the exposed geomembrane
    - significantly improved stormwater **runoff quality** (i.e., no soil erosion)
    - very little water **infiltration**
    - faster **installation** (no heavy construction equipment; less affected by weather conditions; not affected by availability or quality of soil)
    - almost no concerns regarding final cover slope **stability**
    - significantly reduced post-closure **maintenance** requirements and costs (80% - 90% less than a traditional soil cover)
    - easier **access** to CCR after closure for future beneficial reuse

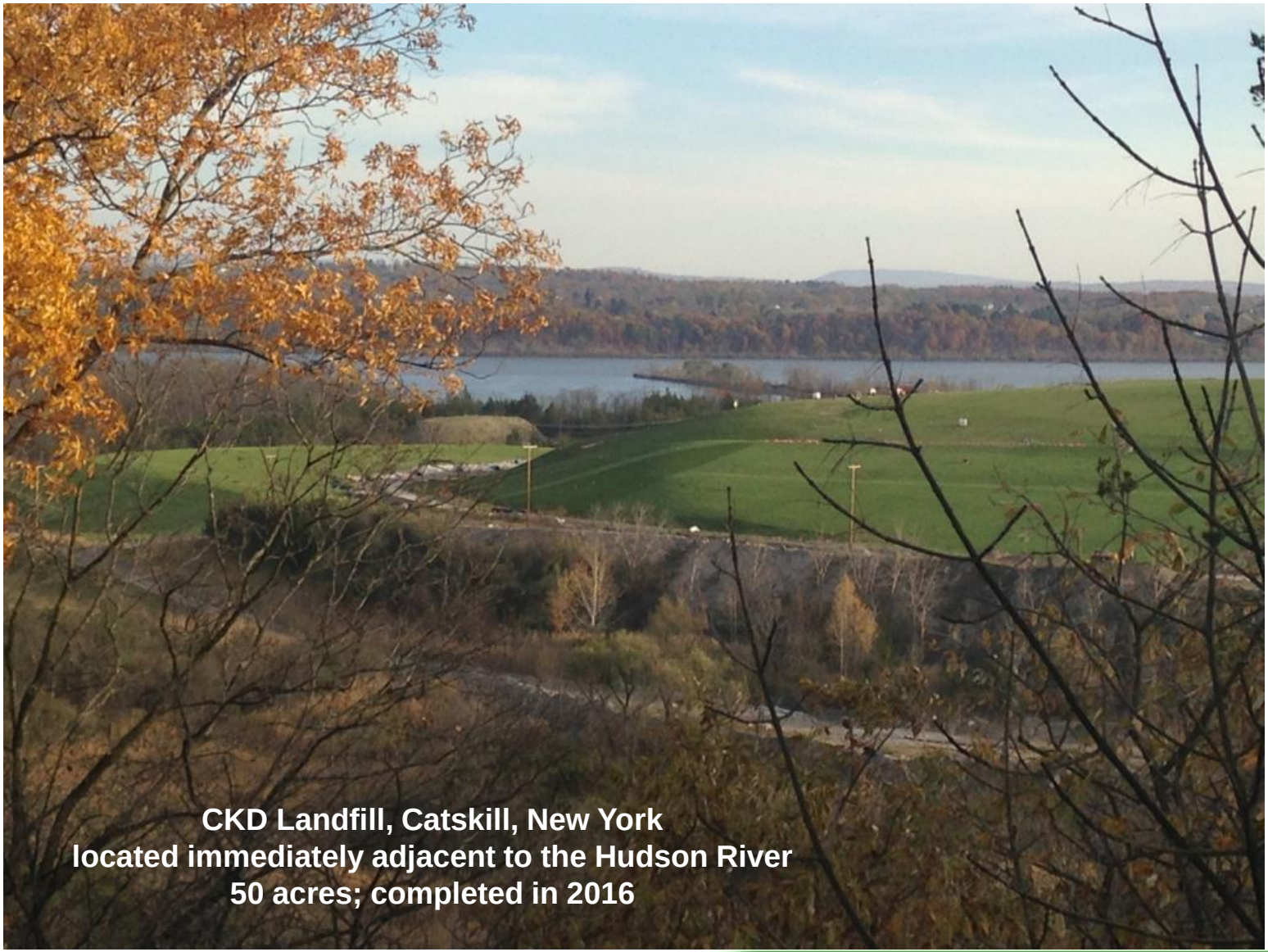
Final Cover System (Engineered Synthetic Turf)

- Engineered Synthetic Turf Final Cover System (continued)
  - Challenges
    - potential movement of sand infill
    - potential gas uplifting and wrinkling (less concern for CCR)
    - relatively short application history (i.e., less than 10 years) and regulatory acceptance in only a few states



- First ClosureTurf installation completed in 2009 at the LaSalle-Grant Landfill in Louisiana
- More than 1,200 acres installed at ~40 sites in 21 states and 1 in Canada
- Municipal, industrial landfills and coal ash impoundments
- Warm and cold climates and severe weather conditions (hurricanes, storms, and high winds)

Final Cover System (Engineered Synthetic Turf)



Final Cover System (Engineered Synthetic Turf)

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Final Cover System (Engineered Synthetic Turf)

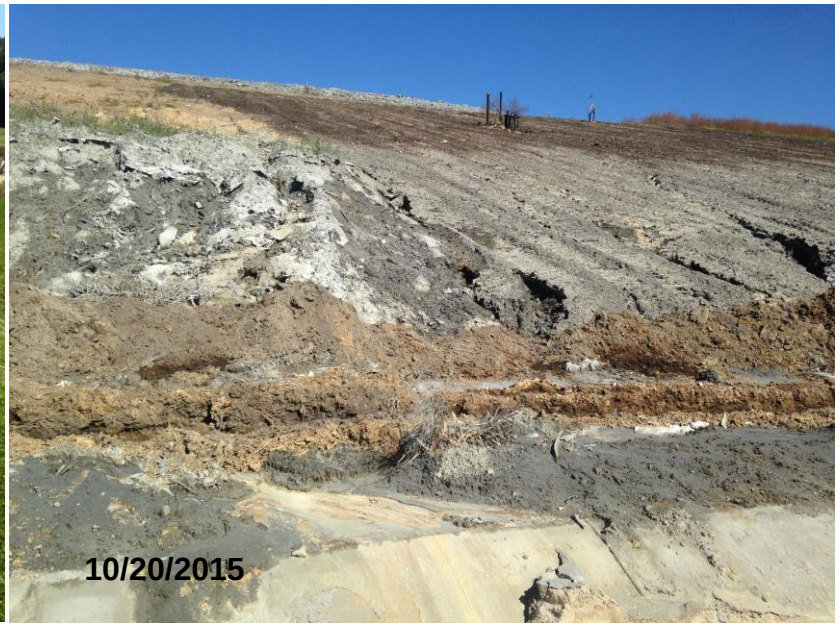
Final Cover System (Engineered Synthetic Turf)

Site: Berkeley County Landfill
Owner: Berkeley County
Location: Moncks Corner, SC
Completed: 2013
Closure Area: 12 acres

Final Cover System (Engineered Synthetic Turf)

- ClosureTurf survived more than 20 inches of rain over a four-day period in October 2015 (1-in-1000 event).
- No maintenance was required post event: small amount of sand migration to the bottom of the slope. Because there was enough coverage of sand, the sand did not have to be redistributed or replaced.

ClosureTurf



Soil Cover

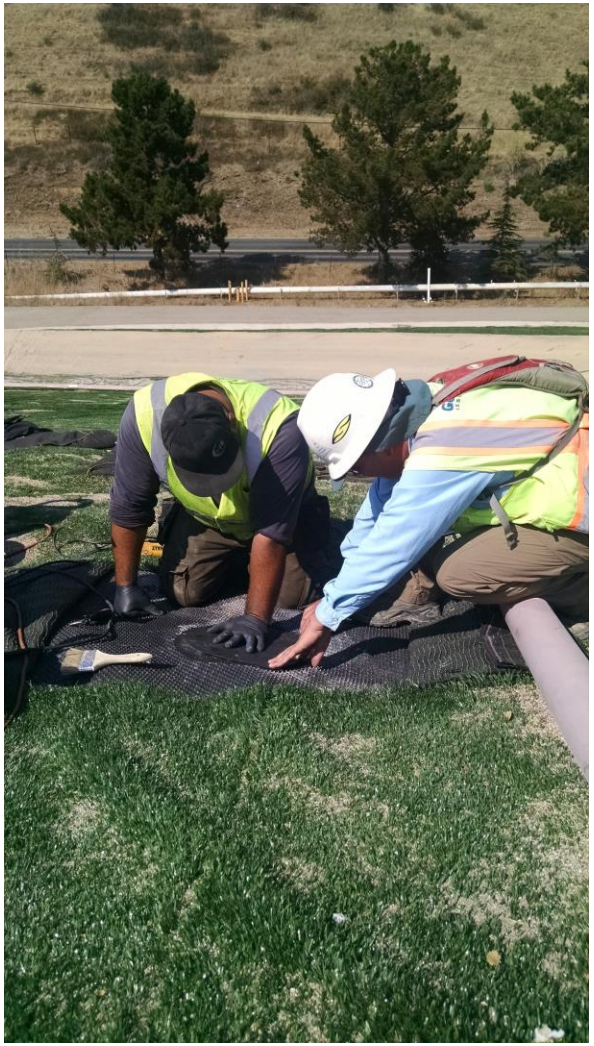
Final Cover System (Engineered Synthetic Turf)

Site: A MSW Landfill Located in the West Coast

Repair of depression area:

- Cut 4 small holes and “injected” a flowable fill and let it run down to the void.
- The mix was made of 3 sack fly ash and 1 sack concrete; it did not set up so hard as to damage the geomembrane.

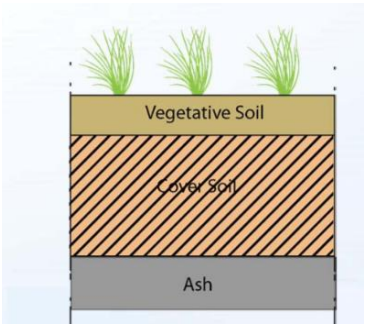
Final Cover System (Engineered Synthetic Turf)



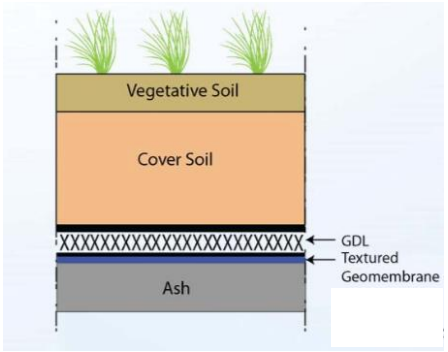
Repair of Depression Area on a Landfill Final Cover Side Slope

Cost Comparison

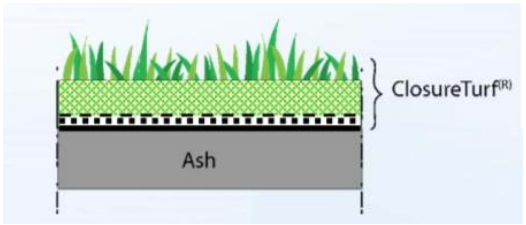
- Assumptions
  - Planning level cost estimates for a 40-acre CCR landfill closure
  - Final cover options:
    - **Soil-only cover**: consists of 6-in vegetative soil layer and 18-inch infiltration soil layer with permeability of 10^{-6} cm/s or less.
    - **Soil-geosynthetic cover** consists of 2-ft soil cover, 300-mil double-sided geocomposite drainage layer, and 60-mil HDPE geomembrane.
    - **ClosureTurf cover** consists of ½-in sand infill (HydroBinder for downchutes), engineered synthetic turf, and 50-mil HDPE structured geomembrane.



Soil-only Cover



Soil-geosynthetic Cover

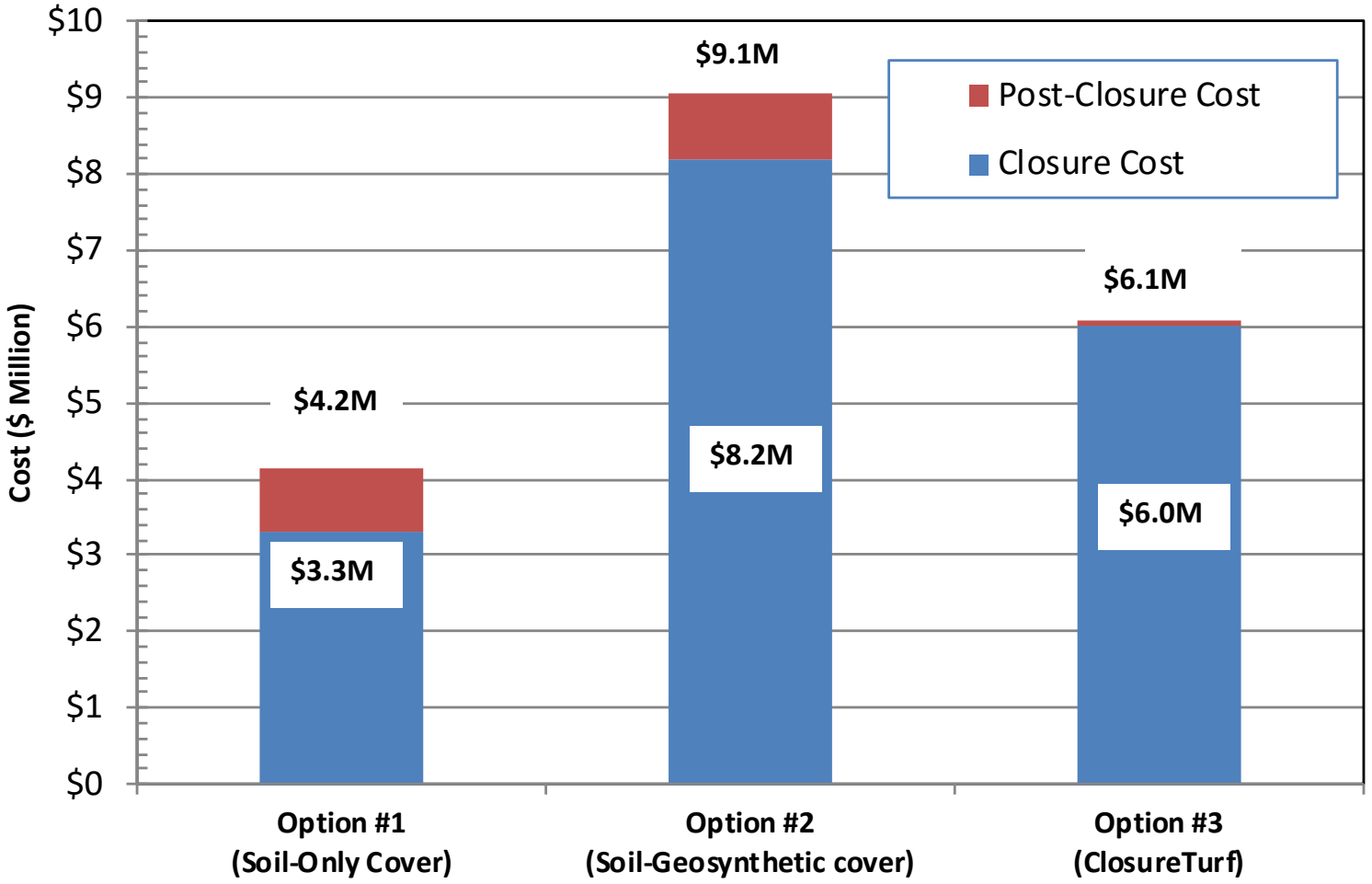


ClosureTurf Cover

Cost Comparison

- Cost Items
  - Planning, design, permitting and bidding (4% of Construction Costs)
  - Mobilization/demobilization (7% of Construction Costs) – for soil-only and soil-geosynthetic covers
  - Temporary erosion and stormwater runoff control
  - Geosynthetics (for soil-geosynthetic cover)
    - Installation of textured 60-mil HDPE geomembrane
    - Installation of 300-mil double-sided geocomposite drainage layer (GDL)
  - Installation of Gravel Drainage Features at GDL Daylight Locations (for soil-geosynthetic cover)
  - Installation of 18-in thick cover soil (for soil-only and soil-geosynthetic covers)
    - On-Site Source (80%)
    - Off-Site Source (20%)
  - Installation of 6-in thick vegetative cover soil (off-site source) (for soil-only and soil-geosynthetic covers)
  - Installation of ClosureTurf® cover system (assuming $2.75/ft^2, including materials, delivery, mobilization/demobilization, and installation)
  - Vegetation of cover soil
  - Final cover stormwater management features
  - Construction Quality Assurance (CQA) (6% of Construction Costs)
  - Contingency (12% of Construction Costs)
  - Post-Closure Care (30 years) in present value - $1,500/acre/year for soil-only and soil-geosynthetic covers; and $150/acre/year for ClosureTurf

Cost Comparison



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THANKS!