Chapter 1

Introduction to Store-and-Release Covers

Modern engineered landfills are expected to control fire and the spread of litter, limit contact with wildlife, minimize or eliminate the release of mobile contaminants to the surrounding environment, and provide acceptable end-of-service land use. From the perspective of environmental protection, release of contaminants to air and groundwater is often considered the most significant issue. Consequently, containment systems are used at modern landfills to control the movement of liquids and gases into and out of a landfill. A final cover is used to control the amount of precipitation that may enter the waste and create contaminated liquid (called leachate) that may contaminate groundwater. A liner is used beneath the waste to contain leachate and to preclude groundwater contamination. The combination of hydraulic barriers above and below the waste follows a design philosophy, often referred to as "dry tomb," intended to contain contaminants by minimizing flow through the containment system.

Covers and liners used in many modern landfills traditionally have employed low-conductivity materials and resistive barriers (e.g., clays and geomembranes) to impede the movement of water. However, over the last two decades, cover systems that rely on a combination of temporary storage of precipitation in soil near the surface followed by removal of the stored water by evaporation (E) and transpiration (T) have become popular, particularly in drier climates. Covers that function on this principle are described by a variety of names, including alternative covers, evapotranspirative covers, water balance covers, and store-and-release (S&R) covers. In this document, the descriptive S&R nomenclature is used throughout.

However, the contents of this document apply to covers described by any of the previously described names.

Use of store and release mechanisms to maintain a favorable water balance is a natural process that is not new to waste containment. Common experience informs us that plants make use of precipitation stored in near-surface soils and that those soils dry as a result. Indeed, even in conventional final covers that rely on hydraulic barrier layers, much of the water balance is managed by S&R mechanisms in the vegetated surface layer. However, in an S&R cover, these mechanisms become solely responsible for managing the water balance and for maintaining percolation below a desired threshold. The vegetated soil operates as a storage tank that is filled by precipitation events, and emptied during subsequent periods of evapotranspiration (ET). This mechanism for managing the water balance does not rely on the physical characteristics of a single design element (i.e. the low saturated hydraulic conductivity of a resistive barrier), but on an integrated system consisting of the soil, plants, and atmosphere in which the components must be carefully considered separately and in combination.

Selection of an appropriate landfill final cover requires careful consideration of the varied metrics for landfill performance, site-specific details, regulatory requirements, and cost. For example, there are some wastes that pose sufficient threat to human health and the environment that redundant containment systems are required. In such situations, covers that rely solely on the S&R mechanism to control the movement of water may not be appropriate, but a combination of S&R and resistive barriers may provide an adequate solution (e.g., see Waugh et al. 2006). There are also some climates characterized by either an excess of precipitation or a shortage of evaporative demand in which a combination of soil and plants may not provide sufficient control over the water balance to achieve adequately low percolation rates (Albright et al. 2004).

Additional factors specific to each landfill may also affect selection of a final cover, such as type of waste, depth to groundwater, proximity to existing or planned uses of groundwater resources, longevity requirements, and the capacity of underlying soils to limit the movement of contaminants that might escape the engineered containment system. For example, a less restrictive cover may be acceptable for a landfill containing relatively inert wastes that is sited in a favorable geological environment. Applications may also exist where the final cover is intended to transmit a higher percolation rate. For example, S&R covers may be particularly useful for bioreactor landfills in which the objective is controlled (rather than minimized) percolation into the waste to provide water for biological processes that degrade waste. Cases may also exist where regulations prohibit or strongly discourage the use of an S&R cover.

One of the attractive features of S&R covers is the significant cost savings that can be accrued when an S&R cover is used in lieu of a conventional cover. Much of the cost associated with conventional covers involves the purchase, hauling, and placement of the materials used for the hydraulic barrier. Both geomembrane and soil barriers require labor-intensive construction methods and transportation costs can be considerable if clay is not locally available. Water balance covers tend to be thicker than conventional covers, but soil placement methods are usually less costly. For example, costs for a conventional composite cover and two alternative S&R covers at a semi-arid site in eastern Oregon are shown in Figure 1.1. The conventional design consisted of 460 mm of compacted soil having a saturated hydraulic conductivity less than 10^{-5} cm/s, a geomembrane, a geosynthetic drainage layer, and 610 mm of vegetated cover soil. The S&R covers were monolithic designs (1.2 m and 1.5 m thick) constructed with on-site sandy silt and vegetated with local grasses. A field demonstration showed that either S&R cover was hydraulically equivalent to the conventional cover (Albright et al. 2004).

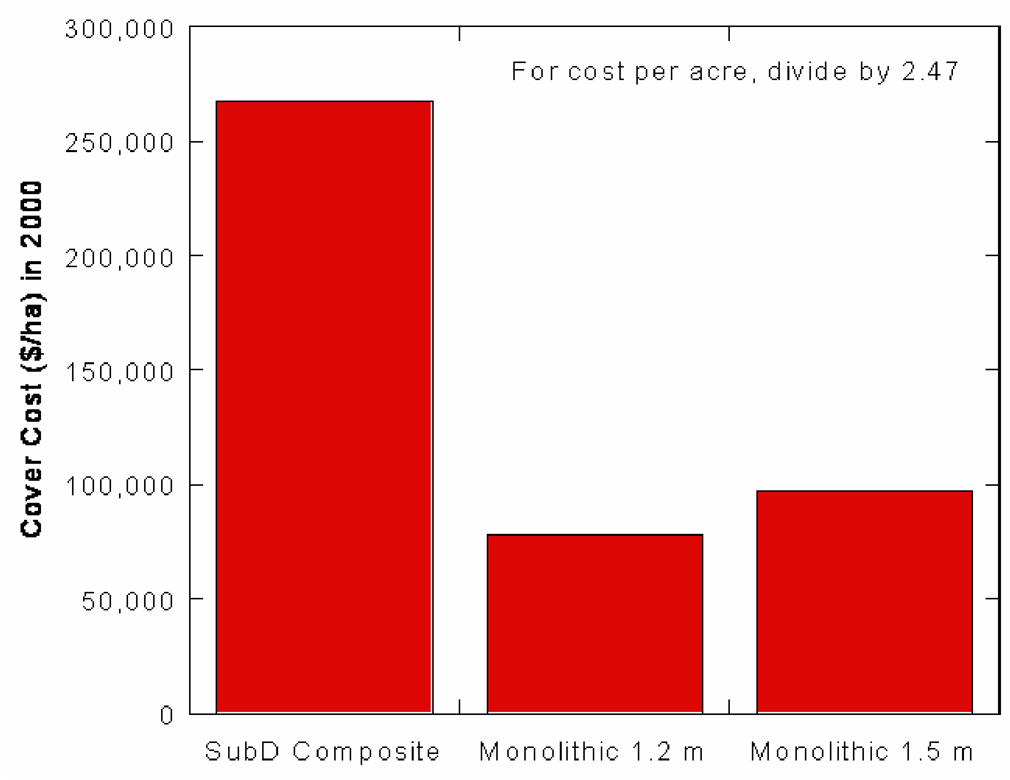

Figure 1.1. A comparison of projected construction costs of two S&R covers and a conventional (RCRA Subtitle D) design. The two S&R covers differ in the thickness of the soil profile (1.2 m and 1.5 m). The conventional consists of a 400-mm barrier layer of fine-grained soil (saturated hydraulic conductivity < 1×10^{-5} cm/s), a 1-mm geomembrane, a drainage layer, and a 300-mm surface layer. At this site a savings of 64% was realized with use of the thinner S&R cover.

Using the thinner cover at this Oregon landfill resulted in a cost savings of 64%, or $41,000 per acre (in 2000 US $). Costs are very site-specific, however, and a careful cost analysis should be conducted before deciding to proceed with an S&R cover. One particularly important factor is the cost associated with design and permitting, which typically is higher for S&R covers compared to conventional covers. Factors contributing to higher design and permitting costs include the site-specific nature of the design, fees associated with characterization of the soils and vegetation to support the design, labor associated with sophisticated predictive modeling that is not required for conventional covers, and costs associated with additional meetings between the designer, owner, and regulator to gain familiarly and confidence in the S&R cover.

This document describes the technical aspects of design and evaluation of S&R covers. Mechanisms controlling storage of precipitation in near-surface soils and subsequent removal of that stored water by ET are described. This includes soil properties related to water storage and plant ecology, the removal of stored water through transpiration by plants, and climatic factors that influence the water balance. Procedures used to compute required and available water storage capacities are presented, and modeling methods are described that can be used to evaluate S&R cover designs for various scenarios. Techniques used to validate designs and to monitor cover performance are presented.

In large part, the origins of this document rest on two decades of research in landfill final covers and information gleaned from approved closures. Several field research programs have directly measured the performance of a variety of final covers in a broad range of climates within the continental US. Those research results provide a good indication of the potential performance of different cover designs in different climatic regimes and insight into the mechanisms and variables affecting the hydrologic performance of final covers.