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Hydrologic Evaluation of Landfill Performance: HELP 4.0 User Manual

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Hydrologic Evaluation of Landfill Performance
HELP 4.0 User Manual

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Notice/Disclaimer

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Foreword

The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The Center for Environmental Solutions and Emergency Management (CESER) within the Office of Research and Development (ORD) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. CESER collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. CESER's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

Center for Environmental Solutions and Emergency Management
Greg Sayles, *Director*

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1. Basic Landfill Design Concepts

1.1 Leachate Production

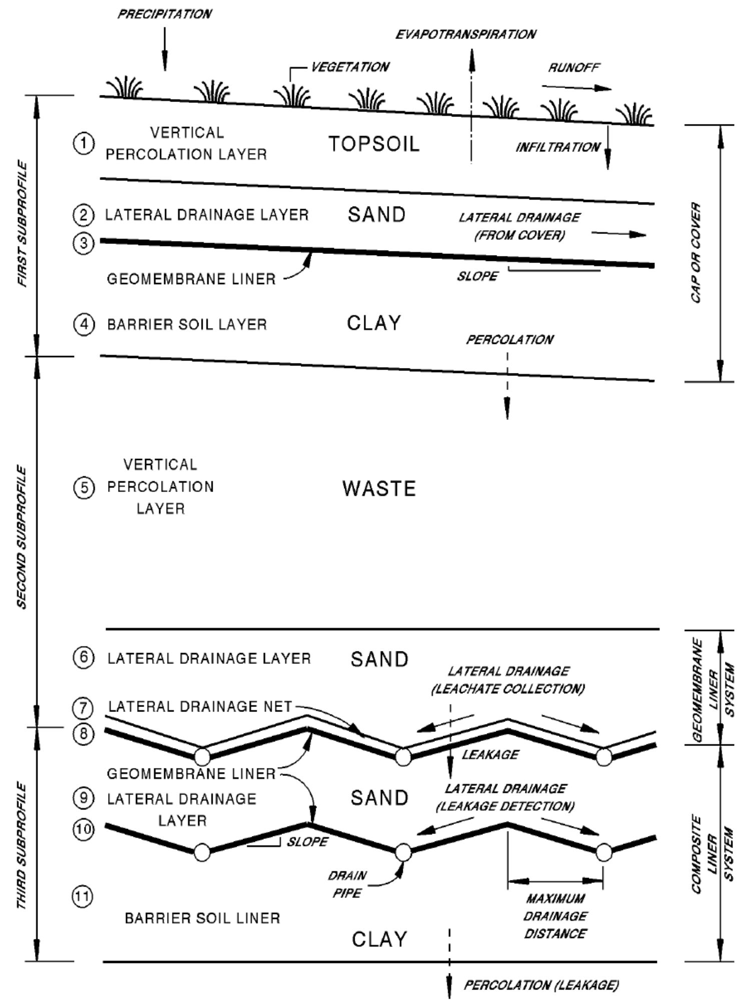
Storage of any waste material in a landfill poses several potential problems. One problem is the possible contamination of soil, groundwater, and surface water that may occur as leachate produced by water or liquid wastes moving into, through and out of the landfill migrates into adjacent areas. This problem is especially important when hazardous wastes are involved because many of these substances are resistant to biological or chemical degradation, and thus are expected to persist in their original form for many years, perhaps even for centuries. Given this possibility, hazardous waste landfills should be designed to prevent any waste or leachate from moving into adjacent areas. This objective is beyond the capability of current technology but does represent a goal in the design and operation of today's landfills.

In the context of a landfill, leachate is described as liquid that has percolated through layers of waste material. Leachate may be composed of liquids that originate from a number of sources, including precipitation, groundwater, waste consolidation, initial moisture storage, and reactions associated with decomposition of waste materials. The chemical quality of leachate varies as a function of a number of factors, including the quantity produced, the original nature of the buried waste materials, and the various chemical and biochemical reactions that may occur as the waste materials decompose. In the absence of evidence to the contrary, most regulatory agencies prefer to assume that any leachate produced will contaminate either ground or surface waters; in the light of the potential water quality impact of leachate contamination, this assumption appears reasonable.

The quantity of leachate produced is affected to some extent by decomposition reactions and initial moisture content; however, it is largely governed by the amount of external water entering the landfill. Thus, a key first step in controlling leachate migration is to limit production by preventing, to the extent feasible, the entry of external water into waste layers. A second step is to collect any leachate that is produced for subsequent treatment and disposal. Techniques are currently available to limit the amount of leachate that migrates into adjoining areas to a virtually immeasurable volume, as long as the integrity of the landfill structure and leachate control system are maintained.

1.2 Design For Leachate Control

Key landfill design features used for leachate control include liner systems, lateral drainage layers, and a final cap or landfill cover. The following schematic diagram illustrates these key design features, which are outlined below.



Schematic of Landfill Profile Illustrating Typical Landfill Features

The bottom layer of soil may be naturally existing material or it may be hauled in, placed and compacted to specifications following excavation to a suitable subgrade. In either case, the base of the landfill should act as a liner with some minimum thickness and a very low hydraulic conductivity (or permeability). Treatments may be used on the barrier soil to reduce its permeability to an acceptable level. As an added factor of safety, an impermeable synthetic membrane may be placed on the top of the barrier soil layer to form a composite liner.

Immediately above the bottom composite liner is a leakage detection drainage layer to collect leakage from the primary liner, in this case, a geomembrane. Above the primary liner are a geosynthetic drainage net and a sand layer that serve as drainage layers for leachate collection. The drainage layers composed of sand are typically at least 1-ft thick and have suitably spaced perforated or open joint drain pipe embedded below the surface of the liner. The leachate collection drainage layer serves to collect any leachate that may percolate through the waste layers. In this case where the liner is solely a geomembrane, a drainage net may be used to rapidly drain leachate from the liner, avoiding a significant buildup of head and limiting leakage. The liners are sloped to prevent ponding by encouraging leachate to flow toward the drains. The net effect is that very little leachate is expected to percolate through the primary liner and virtually no migration of leachate through the bottom composite liner to the natural formations below. Taken as a whole, the drainage layers, geomembrane liners, and barrier soil liners may be referred to as the leachate collection and removal system (drain/liner system) or, more specifically, a double liner system.

After the landfill is closed, the leachate collection and removal system serves basically in a back-up capacity. However, while the landfill is open and waste is being added, these components constitute the principal defense against contamination of adjacent areas. Thus, care must be given to their design and construction. Day-to-day operation of a modern sanitary landfill calls for wastes to be placed in relatively thin lifts, compacted, and covered with soil each day. Thus, wastes should not remain exposed for more than a few hours. Although the daily soil cover serves effectively to hide the wastes and limit the access of nuisance insects and potential disease vectors, it is of limited value for preventing the formation of leachate. Thus, even though a similar procedure can be used for hazardous wastes, the drainage/liner system must function well throughout and after the active life of the landfill.

When the capacity of the landfill is reached, the waste cells are covered with a cap or final cover, typically composed of four distinct layers. At the base of the cap is a drainage layer and a liner system layer similar to that used at the base of the landfill. Again, geomembrane liners would normally be used in conjunction with the barrier soil liner for hazardous waste landfills but have been used less frequently in municipal waste landfills. The top of the barrier soil layer is graded so that water percolating into the drainage layer will tend to move horizontally toward some removal system (drain) located at the edge of the landfill or subunit thereof. A layer of soil suitable for vegetative growth is placed at the top of final cover system to complete the landfill. A 2-ft-thick layer of soil having a loamy, silty nature serves this purpose well. The upper surface is graded so that run-on is restricted and infiltration is controlled to provide moisture for vegetation while limiting percolation through the topsoil. Runoff is promoted but controlled to prevent excessive erosion of the cap. The vegetation used should be selected for ease of establishment in a given area, promotion of evapotranspiration, and year-round protection from erosion. The root system should not penetrate, disrupt, or desiccate the upper liner system (Layers # 3 and # 4). Grasses are usually best for this purpose; however, local experts should be consulted to aid in selection of appropriate species.

The combination of site selection, surface grading, transpiration from vegetation, soil evaporation, drainage through the sand, and the low hydraulic conductivity of the barrier soil liner serves effectively to minimize leachate production from external water. Added effectiveness is gained by the use of geomembrane liners in the cap in conjunction with the barrier soil liner. The cap should be no more permeable than the leachate collection and removal system so that the landfill will not gradually fill and overflow into adjacent areas following abandonment of the landfill (a phenomenon sometimes referred to as the "bathtub" effect).

The HELP model has been developed as a tool to be used by designers and regulatory reviewers to evaluate and select practical landfill designs that minimize leakage of leachate to adjacent areas and, thus, minimize potential contamination problems.

2. About the Model

2.1 Overview

The **Hydrologic Evaluation of Landfill Performance (HELP)** model is a quasi-two-dimensional hydrologic model of water movement across, into, through and out of landfills. The model accepts weather, soil, and design data. It uses solution techniques that account for key factors affecting water movement in a landfill, including: surface storage; snowmelt; runoff; infiltration; evapotranspiration; vegetative growth; soil moisture storage; lateral subsurface drainage; leachate recirculation; unsaturated vertical drainage; and leakage through soil, geomembrane, and composite liners. Landfill systems including various combinations of vegetation, cover soils, waste cells, lateral drain layers, low permeability barrier soils, and synthetic geomembrane liners may be modeled. The model was developed to conduct water balance analysis of landfills, cover systems, and solid waste disposal and containment facilities. As such, the model facilitates rapid estimation of the amounts of runoff, evapotranspiration, drainage, leachate collection, and liner leakage that may be expected to result from the operation of a wide variety of landfill designs. The model, applicable to open, partially closed, and fully closed sites, is a tool for both designers and permit writers.

HELP model **Version 4** was developed by EPA ORD/CESER. HELP model **Versions 1, 2, and 3** were developed by the U.S. Army Engineer Waterways Experiment Station (WES) for EPA. The model was developed in response to needs in the Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, better known as Superfund), as identified by the EPA Office of Land Management and Emergency Response.

As in the earlier versions of the model, the hydrologic processes modeled can be divided into two categories: **surface processes** and **subsurface processes**. The surface processes modeled are snowmelt, interception of rainfall by vegetation, surface runoff, and surface evaporation. The subsurface processes modeled are evaporation from the soil profile, plant transpiration, unsaturated vertical drainage, barrier soil liner percolation, geomembrane leakage, and saturated lateral drainage.

Daily infiltration into the landfill is determined indirectly from a surface water balance. Infiltration is assumed to equal the sum of rainfall, surface storage, and snowmelt minus the sum of runoff, additional storage in snowpack, and evaporation of surface water. No liquid water is assumed to be held in surface storage from one day to the next except in the snowpack or when the top soil is saturated and runoff is not permitted. Each day, the available water for infiltration, runoff or evaporation from water on the surface is determined from the surface storage, discharge from the snowpack and/or rainfall. Snowfall is added to the surface snow storage which is depleted by either evaporation or melting. Snowmelt is added to the available water and is treated as rainfall except that it is not intercepted by vegetation. This available water is used to compute the runoff by the Soil Conservation Society (SCS) rainfall-runoff relationship. The interception is the measure of water available to evaporate from the surface. Interception in excess of the potential evaporation is added to infiltration. Surface evaporation is then computed. Potential evaporation from the surface is first applied to the interception; any excess is applied to the snowmelt, then to the snowpack and finally to the groundmelt. Potential evaporation in excess of the evaporation from the surface is applied to the soil column and plant transpiration. The snowmelt and rainfall that does not run off or evaporate is assumed to infiltrate into the landfill along with any ground melt that does not evaporate.

The first subsurface processes considered are soil evaporation and plant transpiration from the evaporative zone of the upper sub-profile. A vegetative growth model accounts for the daily growth and decay of the surface vegetation. The other subsurface processes are modeled one subprofile at a time, from top to bottom, using a design dependent time step ranging from 30 minutes to 6 hours. A storage-routing procedure is used to redistribute the soil water among the modeling segments that comprise the sub-profile. This procedure accounts for infiltration or percolation into the subprofile and evapotranspiration from the evaporative zone. Then, if the subprofile contains a liner, the model computes the head on the liner. The head on the liner is then used to compute the leakage/percolation through the liner and, if lateral drainage is permitted above the top of the liner, the lateral drainage to the collection and removal system.

2.2 Model Assumptions

The modeling procedures are based on many simplifying assumptions. Generally, these assumptions are reasonable and consistent with the objectives of the model when applied to standard landfill designs. However, some of these assumptions may not account for unusual designs.

2.2.1 Runoff

Runoff is computed using the SCS method based on daily amounts of rainfall and snowmelt. The model assumes that areas adjacent to the landfill do not drain onto the landfill. The time distribution of rainfall intensity is not considered. As such, the model cannot be expected to give accurate estimates of runoff volumes for individual storm events on the basis of daily rainfall data. However, because the SCS rainfall-runoff relationship is based on considerable daily field data, long-term estimates of runoff should be reasonable.

The SCS method does not explicitly consider the length and slope of the surface over which overland flow occurs. HELP v4.0 provides two methods (labelled Methods 2 and 3) that address this limitation by including procedures for computing curve numbers that take into consideration the effect of slope and slope length (the SCS limitation is not addressed in Method 1). This limitation is not a concern if the slope and slope length of the landfill do not differ dramatically from those of the test plots upon which the SCS method is based. The SCS method would probably underestimate runoff somewhat where the overland flow distance is very short, or the slope is very steep, or when the rainfall duration is very short and the intensity is very high.

2.2.2 Water Flow

The HELP model assumes Darcian flow by gravity influences through homogeneous soil and waste layers. It does not consider explicitly preferential flow through channels such as cracks, root holes, or animal burrows but allows for vertical drainage through the evaporative zone at moisture contents below field capacity. Similarly, the model allows vertical drainage from a layer at moisture contents below field capacity when the inflow would occupy a significant fraction of the available storage capacity below capacity. The drainage rate out of a segment is assumed to equal the unsaturated hydraulic conductivity of the segment corresponding to its moisture content, provided that the underlying segment is not a liner and is not saturated. In addition to these special cases, the drainage rate out of a segment can be limited by the saturated hydraulic conductivity of the segment below it. When limited, the model computes an effective gradient for saturated flow through the lower segment. This permits vertical percolation or lateral drainage layers to be arranged without restrictions on their properties so long as they perform as their layer description implies and not as liners.

The model assumes that a) the soil moisture retention properties and unsaturated hydraulic conductivity can be calculated from the saturated hydraulic conductivity and limited soil moisture retention parameters (porosity, field capacity, and wilting point) and b) that the soil moisture retention properties fit a Brooks-Corey relation (Brooks et al., 1964) defined by the three soil moisture retention parameters. Upon obtaining the Brooks-Corey parameters, the model assumes that the unsaturated hydraulic conductivity relationship with soil moisture is well described by the Campbell equation.

The model does not explicitly compute flow by differences in soil suction (soil suction gradient) and as such does not model the draw of water upward by capillary drying. This draw of water upward is modeled as an extraction rather than transport of water upward. Therefore, it is important that the evaporative zone depth be specified as the depth of capillary drying. Drainage downward by soil suction exerted by dry soils lower in the landfill profile is modeled as Darcian flow for any soil having a relative moisture content greater than the lower soils. The drainage rate is equal to the unsaturated hydraulic conductivity computed as a function of the soil moisture content. As such, the rate is assumed to be independent of the pressure gradient.

2.2.3 Leakage

Leakage through barrier soil liners is modeled as saturated Darcian flow. Leakage is assumed to occur only as long as there is head on the surface of the liner. It is assumed that the head driving the percolation can be represented by the average head across the entire liner and can be estimated from the soil moisture storage. It is also assumed that the liner underlies the entire area of the landfill and, conservatively, that when leakage occurs, the entire area of the landfill leaks. The model does not consider aging or drying of the liner and therefore the saturated hydraulic conductivity of the liner does not vary as a function of time.

Geomembranes are assumed to leak primarily through holes. The leakage passes through the holes and spreads between the geomembrane and soil until the head is dissipated. The leakage then percolates through the soil at the rate dependent on the saturated hydraulic conductivity and the pressure gradient. Therefore, the net effect of a geomembrane is to reduce the area of percolation through the liner system. The model assumes the holes to be uniformly distributed and the head is distributed across the entire liner. The model does not consider aging of the liner and therefore the number and size of the holes do not vary as a function of time. In addition, it is conservatively assumed that the head on the holes can be represented by the average head across the entire liner and can be estimated from the soil moisture storage. It is also assumed that the liner underlies the entire area of the landfill.

The lateral drainage model is based on the assumption that the saturated depth profile is characteristic of the steady-state profile for the given average depth of saturation. As such, it is assumed that the lateral drainage rate for steady-state drainage at a given average depth of saturation is representative of unsteady lateral drainage rate for the same average saturated depth. In actuality the rate would be somewhat larger for periods when the depth is building and somewhat smaller for periods when the depth is falling. Steady drainage implies that saturated conditions exist above the entire surface of the liner, agreeing with the assumptions for leakage through liner systems.

2.2.4 Vegetative Growth

The model assumes the vegetative growth and decay can be characterized by a vegetative growth model developed for crops and perennial grasses. In addition, it is assumed that the vegetation transpires water, shades the surface, intercepts rainfall, and reduces runoff in similar quantities as grasses or as an adjusted equivalence of leaf area index.

2.3 Additional Technical Documentation

For additional technical documentation, please refer to the Engineering Documentation for HELP Model version 3 available on the EPA's Hydrologic Evaluation of Landfill Performance (HELP) Model web page.

https://www.epa.gov/land-research/hydrologic-evaluation-landfill-performance-help-model

3. Getting Started

3.1 Downloading the Software

HELP v4.0 is written for Microsoft Excel and has been tested for use in Excel 2007 (Windows operating system) and higher. The version of the model can be downloaded from EPA's website at the following address: https://www.epa.gov/land-research/hydrologic-evaluation-landfill-performance-help-model.

The model uses macros, which require that you enable macros when you first open the file (see text box). After enabling macros, read the initial disclaimer and click the **OK** button to proceed to using HELP v4.0.[1]

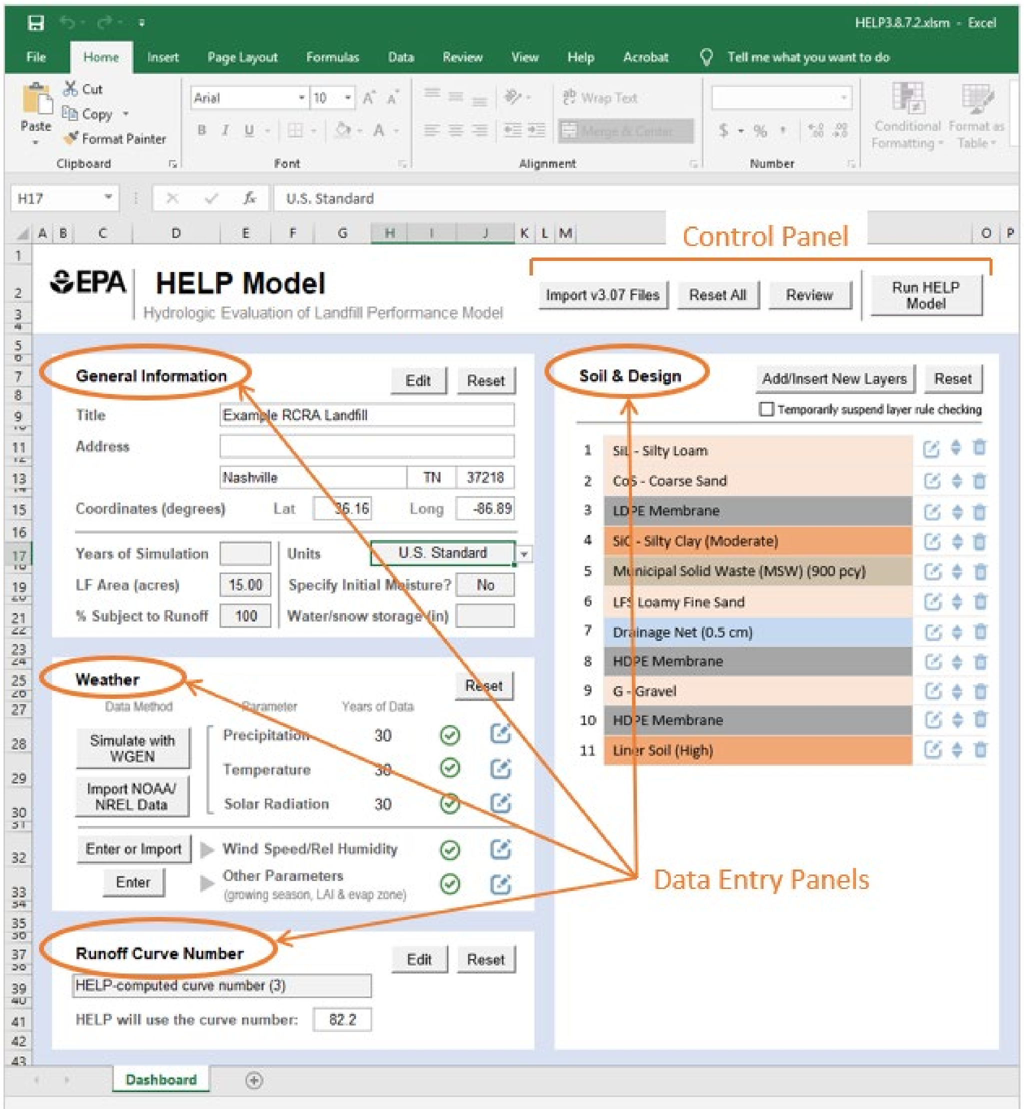
Enabling Macros in Excel

HELP v4.0 uses an Excel workbook with embedded macros to support the user interface. The use of spreadsheets with macros received from an unknown source can represent an IT systems security risk. Therefore, MS Excel requires that you confirm the source by clicking the "Options" button or "Enable Content" button at the top of the screen (depending on the version of Excel that you are using) before you begin.

3.3 Overview of User Interface

The interface of the model is a worksheet titled **Dashboard**. The Dashboard consists of five main panels, including an overarching **Control Panel** and four panels for providing model input: **General Information**, **Weather**, **Runoff Curve Number**, and **Soil & Design**.

[1] Note that zooming in or out with Excel could change relative font sizes and visible text. It is recommended that zoom not exceed +/- 10%.



The **Control Panel** allows you to initiate actions that apply to the whole model, including importing data files from HELP v3.07, resetting all fields, reviewing model input, and running the HELP model. These actions are described in more detail in the following sections. With a few exceptions, the four data input panels work independently, allowing you to input data and model values in any sequence. You are encouraged to decide on the units of measure for the model (see **General Information** panel) before you enter information that references a specific system of measurement (e.g., landfill area). In addition, the model will not compute a runoff curve number using Method 3 until you have entered information about the topmost layer of the landfill in the **Soil & Design** panel. The model will prompt you to alert you to these types of information dependencies.

The general recommended workflow for entering information and running the model is as follows:

- Download any external files that you plan to use, including weather data from external sources or parameter value files for weather simulation (see **Section 4.3**)

- Import and/or enter information describing the landfill location and weather context and landfill design parameters
- Review information using the **Review** function in the **Control Panel**
- When you have met all input requirements and are satisfied with the model inputs, run the HELP model and review the output

Additional information regarding each of these steps is described in Sections 4-6.

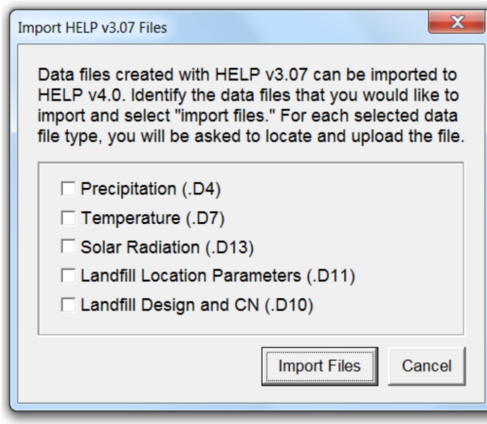
4. Inputting Data

The following section provides stepwise guidance for importing and/or entering information in each of the input panels. The model includes aids to help you find information from external sources (e.g., weather data) and to check for missing information and values that are outside of the expected range. In some cases the model will allow you to continue entering information even when missing or invalid values are encountered. This is intended to allow you to build the model with minimal disruptions to your work flow. The model will check for missing and invalid values and remind you to enter or correct this information before it will run (see **Section 6**).

Appendix A includes a list of model input requirements and valid ranges for each data element or model parameter value. Input requirements for each panel are described below.

4.1 Importing HELP v3.07 Data Files

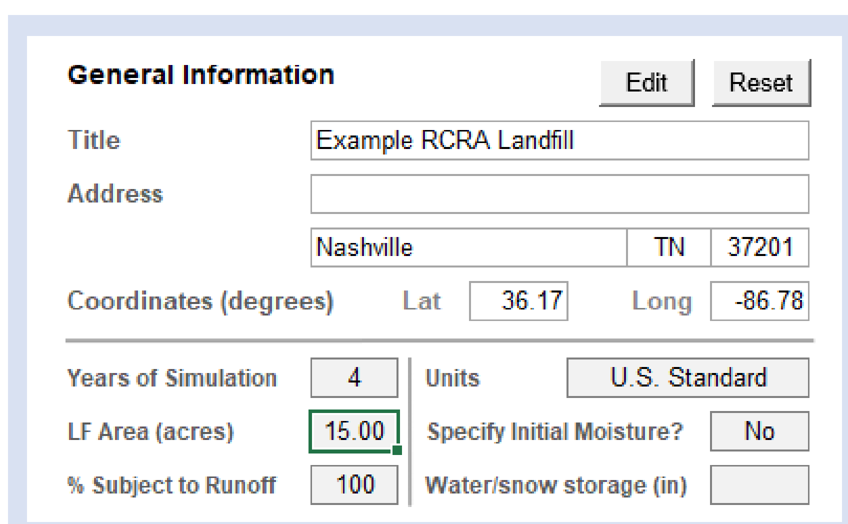
HELP v4.0 allows you to import precipitation, temperature, solar radiation, other landfill location parameters (e.g., wind speed, relative humidity), curve number values, and landfill design information generated using HELP v3.07. To do so, click the **Import v3.07 Files** from the **Control Panel** at the top of the dashboard. A pop-up window with several import options will be displayed.



Check the box next to the data file(s) that you wish to import and click **Import Files**. A file browser window will open for you to navigate to and select the data files. See **Appendix A** for a list of data elements and model parameter values that will be imported from each HELP v3.07 data file type.

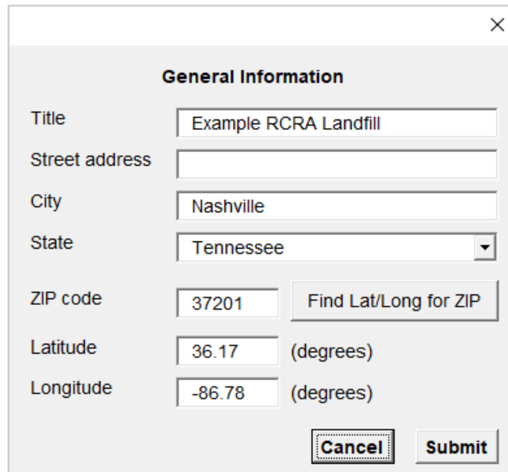
4.2 General Information

General information used in the HELP model includes landfill location information and model simulation parameters. You can import elements of general landfill information from existing HELP v3.07 data files (.D10 and .D11) or enter the information directly through the interface. **Section 4.1** describes how to import general information.



Depending on the type of information, the model will ask you to input information through a pop-up user form (when you click **Edit**) or directly via the interface, as outlined below. If you click **Reset** in the **General Information** panel, all information in the panel will be deleted. If you import HELP v3.07 data files containing general information, existing information in the **General Information** panel will be overwritten by imported information.

4.2.1 Landfill Title and Location



To enter or edit landfill title, address, and latitude and longitude coordinates, click **Edit** in the top right corner of the **General Information** panel, and a separate data entry form will pop-up. Enter the project title, street address, city and state. The HELP model requires valid latitude coordinates. If you plan to simulate weather using the built-in weather generator (see **Section 4.3.1**), the model will also require valid longitude coordinates. If you know the latitude and longitude of your landfill site, you can enter them directly in the **Latitude** and **Longitude** fields (in decimal degrees). If you do not know the latitude and longitude, you can enter the 5-digit **ZIP code** for the landfill, and click on the **Find Lat/Long for ZIP**. The model will look up the latitude and longitude associated with the ZIP code and populate both the **Latitude** and **Longitude** fields.[2]

User Tip

4.2.2 Modeling Parameters

Modeling parameters are located in the lower portion of the General Information panel. Enter values for the following parameters directly through the user interface

[2] Note that HELP v4.0 is designed for use with latitudes and longitudes in the U.S.

- **Units:** Select either U.S. Standard or Metric.
- **Years of Simulation:** Enter number of years (1 – 100) you would like the simulation to run. Note that the number of years must be less than or equal to the shortest number of years of daily data available for precipitation, temperature or solar radiation (e.g., if you have 30 years of precipitation data and 10 years of solar radiation data, years of simulation can be no more than 10).

> **User Tip**
>
> Enter units of measure at the start of data entry. This information is required prior to entering other information that references a specific system of measurement (e.g., landfill area). A warning message will display to alert you of this dependency.

- **Landfill Area:** The size of the landfill approached horizontally at birds-eye view, in acres or hectares depending on the selected measurement system.

- **% Subject to Runoff:** The portion of the area that is sloped in a manner that would permit drainage off the surface. Runoff estimates predicted by the model are equal to the computed runoff by the curve number method times this percentage. The difference between the computed runoff and the actual runoff is added to the infiltration.

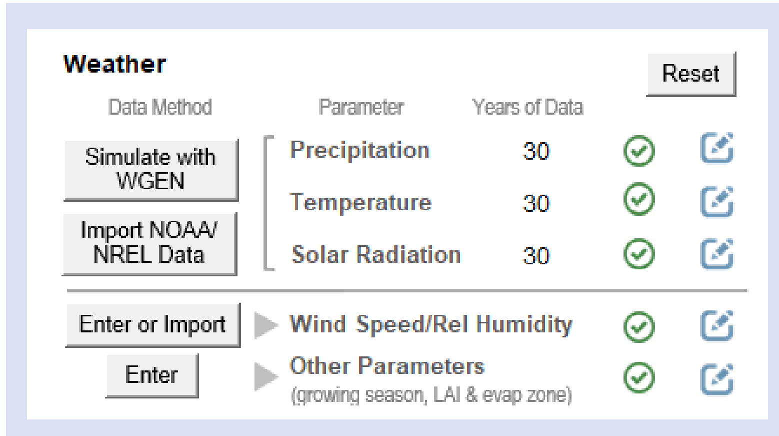
- **Specify Initial Moisture?** Initial moisture content for the landfill layers can be specified if data are available. If you know the initial moisture content, select **Yes**. If you select **No**, the model assumes near steady-state values and runs the first year of the simulation to improve the initialization to steady-state. Soil water content at the end of this year of initialization are used as the initial values for the simulation period.

- **Initial water/snow water storage on landfill:** If you decide to specify initial moisture, enter the amount of water or snow water on the landfill surface. You can enter 0 for no initial water or snow water on the surface. If you do not specify initial moisture, this value will be treated as zero in the model.

> **User Tip**
>
> If you answered **Yes** to the **Specify Initial Moisture?** question, you will be asked to specify initial moisture for certain landfill layers in the **Soil & Design** input panel.

4.3 Weather Data

The HELP model requires several inputs to model the weather context of a landfill, including daily precipitation, temperature and solar radiation; average annual wind speed; quarterly relative humidity; growing season start and end dates; maximum leaf area index (LAI); and evaporative zone depth. Depending on the parameter, you can import weather data from existing HELP v3.07 data files (.D4, .D7, .D11 and .D13), simulate weather data using the WGEN weather generator, import data downloaded from National Oceanic and Atmospheric Administration (NOAA) or National Renewable Energy Laboratory (NREL) websites, or enter the information directly through the interface.



Section 4.1 describes how to import general information from existing HELP v3.07 files from the **Control Panel**. The **Simulate Weather** button in the **Weather** panel allows you to run a weather simulation for precipitation, temperature and solar radiation using the built-in WGEN weather generator. The **Import NOAA/NREL Data** button in the **Weather** panel allows you to import data downloaded from NOAA and NREL websites. The **Enter or Import** button for wind speed and relative humidity generates a form that can be used to import data from NREL or enter data directly. The **Enter** button for other parameters generates a form for entering growing season, leaf area index, and evaporative zone depth information. The **Enter/Edit** icons  allow you to see and edit weather data inputs. If you click **Reset** in the **Weather** panel, all information in the panel will be deleted.

4.3.1 Synthetic Weather Generation (WGEN)

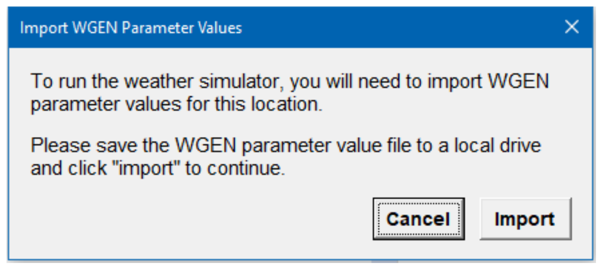
HELP v4.0 will generate up to 100 years of daily precipitation, temperature, and solar radiation data stochastically for a location. The synthetic weather generator is based on a routine developed by the USDA Agricultural Research Service (Richardson and Wright, 1984). Weather parameter values used in the synthetic weather generator are imported from a database of calculated weather parameters for over 13,000 points located on a 0.25 x 0.25 degree grid across the continental U.S. The program retrieves parameter values from the closest grid point in the dataset based on the latitude and longitude specified for the landfill location. For more information on WGEN and the gridded dataset used to develop location-specific parameter values for use in WGEN, please refer to **Appendix B**.

User Tip

The weather simulation option in HELP v4.0 requires a set of 60 weather parameter inputs to synthetically generate weather for a specified location. These inputs are stored in a WGEN parameter values file. Before running the **Simulate Weather** option, it is necessary to download the “WGEN Par Values for OPP Grid.xlsx” file from https://www.epa.gov/land-research/hydrologic-evaluation-landfill-performance-help-model, store the file on your local PC, and note the folder location as you will navigate to it when running the simulation. The model will alert you if the file is not available.

To generate synthetic weather data (precipitation, temperature, and solar radiation), verify that the latitude and longitude coordinates have been entered in **General Information**, then click the **Simulate Weather** button in the **Weather** panel.

A prompt for the WGEN parameter value file is displayed the first time the weather simulation is run for a given location or any time that the location information is reset. See the **User Tip** text box above for information on downloading the parameter value file). If you are prompted to import WGEN parameter values, click **Import** on the Import WGEN Parameter Values dialog to continue. A file browser window will open for you to navigate to and select the parameter value file. Select the file and click **Open**.



Once the parameter values are imported (or if you imported the values for a previous weather simulation for the same location), the program will prompt you to input the number of years of weather data to be synthetically generated, from 1 to 100. Enter the number of years and click **Submit** to run the weather simulation. The weather simulation will generate daily values of precipitation, temperature, and solar radiation for the number of years specified. When finished, the data status column in the **Weather** panel will show a check mark (✓).

The resulting output may be viewed or edited by clicking the **Enter/Edit** icon.

4.3.2 Importing Precipitation and Temperature Data

You can import daily precipitation and temperature data from existing Help v3.07 .D4 and .D7 files, respectively, as described in **Section 4.1**, or synthetically generate precipitation and temperature values using the **Simulate Weather** option, as described in **Section 4.3.1**. Alternatively, you can import daily precipitation and temperature data that you have downloaded from NOAA’s National Centers for Environmental Information (NCEI) Climate Data Online (CDO) website. To import NOAA data, first download data files from three weather stations near the landfill using the procedure described in **Appendix C**.

User Tip

The HELP model requires that you import daily weather data in full year increments (January 1 - December 31). If you attempt to import a partial year of data, the model will interpret the data for the part of the year for which you did not import data as “missing” and the import will fail (you will receive an error message indicating too many missing values).

Once you have downloaded the files, click the **Import NOAA/NREL Data** button in the **Weather** panel. A dialog will prompt you to choose the type of data to import. To import precipitation and temperature data from NOAA, select this option and click the **Import Data** button. A pop-up window reminding you to download data will appear. Click **Import** from this window, and a file browser window will open for you to navigate to and select the three data files (precipitation, minimum temperature, and maximum temperature), one at a time. Once the import is complete, the data status column will show a check mark (✓), and the years of precipitation and temperature data available for simulation will be displayed in the **Weather** panel.

To view or edit daily precipitation or temperature data, click the **Enter/Edit** icon next to **Precipitation** or **Temperature** in the **Weather** panel, and the model will open (unhide) the **Precipitation D4** or **Temperature D7** worksheet, respectively. These worksheets contain daily data in a 10 column by 3,700 row matrix. Each year of data is contained in 37 rows, resulting in totaling 370 cells, where cells 366-370 are ignored for a typical year and cells 367-370 are ignored for leap years. Average monthly rainfall or temperature are shown near the top of the worksheet to the right of the 10 columns of daily data. This allows you a quick check to ensure the data qualitatively seem appropriate for the site location.

Modifying Daily Precipitation, Temperature and Solar Radiation Data

The model allows you to edit daily precipitation, temperature and solar radiation data in the respective worksheets (e.g., to simulate a storm or drought event). However, any changes should be carefully documented and daily values should fall within valid ranges (see Appendix A) to avoid errors and erroneous results. Note that if you imported weather data from v3.07 files, the monthly average values will not automatically recalculate when you change daily values. To reset changes to imported daily precipitation, temperature and solar radiation data, you can re-import the original data files.

After viewing precipitation or temperature data, click **Return to Main Dashboard**. This will close the precipitation or temperature worksheet and return you to the main user interface.

4.3.3 Importing Solar Radiation Data

You can import daily solar radiation data from an existing Help v3.07 .D13 file, as described in **Section 4.1** or synthetically generate solar radiation values using the **Simulate Weather** option, as described in **Section 4.3.1**. Alternatively, you can import solar radiation data that you have downloaded from NREL's National Solar Radiation Database (NSRDB). To import NSRDB data, first download data files using the procedure described in **Appendix D**.

Once you have downloaded the files, click **Import NOAA/NREL Data** next to **Solar Radiation** in the **Weather** panel. A dialog will prompt you to choose the type of data to import. To import solar radiation data from NREL (NSRDB), select this option and click the **Import Data** button. A pop-up window reminding you to download data will appear along with a prompt to enter the site name. After entering the Site Name, click **Import** from this window, and a file browser window will open for you to navigate to and select the directory containing the data files. Once complete, the data status column will show a check mark (✓) and the years of solar radiation data available for simulation will be displayed in the **Weather** panel.

To view or edit daily solar radiation data, click the **Enter/Edit** icon next to **Solar Radiation** in the **Weather** panel, and the model will open (unhide) the **Solar Radiation D13** worksheet. The solar radiation worksheet is structured using the same approach as the precipitation and temperature worksheets, as described in **Section 4.3.1**. After viewing solar radiation data, click **Return to Main Dashboard**, and the program will close the worksheet and return you to the main user interface.

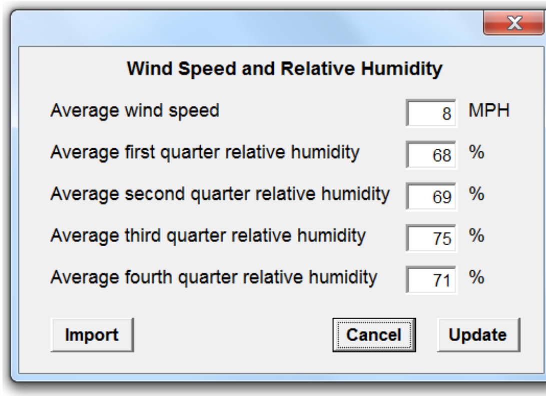
4.3.4 Wind Speed and Relative Humidity

HELP v4.0 uses average annual wind speed and average quarterly relative humidity to model monthly evapotranspiration (see text box). You can import wind speed and relative humidity data from an existing Help v3.07 .D11 file (along with other information; see **Appendix A**), as described in **Section 4.1**. Alternatively, you can import wind speed and relative humidity data that you have downloaded from NREL's NSRDB or enter the information directly.

HELP v4.0 Approach to Modeling Evapotranspiration

Unlike previous versions of the model, the HELP 4.0 model does not permit the use of a default evapotranspiration option with location specific guidance. HELP v4.0 requires location-specific average annual wind speed and average quarterly relative humidity to model monthly evapotranspiration at the site.

To import NSRDB data, first download data files using the procedure described in **Appendix E**. Once you have downloaded the files, click **Enter or Import** next to **Wind Speed/Rel Humidity** in the **Weather** panel. Then, click the **Import** button on the resulting pop-up user form. A pop-up window reminding you to download data will appear. Click **Import** from this window, and a file browser window will open for you to navigate to and select the data file.



To enter the data directly or to edit imported or previously entered data, click the **Enter or Import** button or click the **Enter/Edit** icon next to **Wind Speed/Rel Humidity** in the **Weather** panel, and a pop-up user form will be displayed. Enter or edit the average annual wind speed and/or average quarterly relatively humidity values for the landfill location and click **Update**.

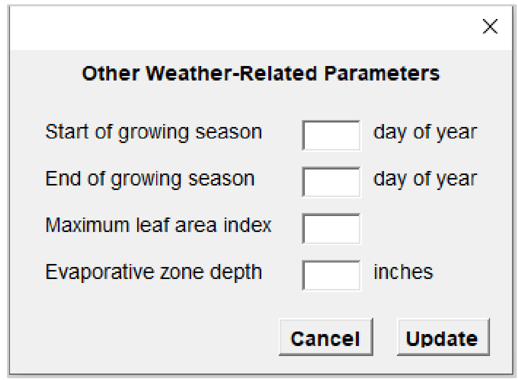
Once the wind speed and relative humidity data are complete (imported and/or entered directly), the data status column in the **Weather** panel will show a check mark (✓).

User Tip

The HELP model v3.07 .D11 file contains wind speed, relative humidity, growing season, leaf area index, and evaporative zone depth data. When you import from a .D11 file (i.e., using the **Import v3.07 Files** button from the **Control Panel**), any previously imported or entered data for these fields will be replaced. If you plan to use HELP v3.07 data for one or more of these parameters, it is recommended that you import the .D11 files first (e.g., before importing an NSRDB file containing wind speed and relative humidity data).

4.3.5 Other Weather-Related Parameters

Other weather-related parameters used by the HELP model are growing season start and end dates, maximum leaf area index, and evaporative zone depth. Definitions of these parameters and data sources are described in **Appendix F**.



You can import data for these parameters from an existing Help v3.07 .D11 file (along with other information; see **Appendix A**), as described in **Section 4.1**. Alternatively, you can enter the data directly by clicking the **Enter** button or the **Enter/Edit** icon next to **Other Parameters** in the **Weather** panel, after which a pop-up user form will display. This user form will also allow you to edit imported data. See the **User Tip** text box above for considerations regarding the order of data import, entry and editing. Enter or edit the values for growing season start and end dates, maximum leaf area index, and evaporative zone depth for the landfill location and click **Update**.

Once the other weather-related parameters are complete (imported and/or entered directly), the data status column in the **Weather** panel will show a check mark (✓).

4.4 Runoff Curve Number

As with previous versions of the model, HELP v4.0 models the rainfall-runoff process using the Soil Conservation Service (SCS) curve-number method. The model uses an SCS runoff curve number (CN) for Antecedent Moisture Condition II (AMC-II) determined using one of the following methods:

Method 1, User-specified CN: The user enters an SCS AMC-II CN directly

Method 2, Modified User's CN: The user enters an SCS AMC-II CN, landfill surface slope, and slope length, and the model computes a modified SCS AMC-II CN, accounting for slope and slope length

Method 3, HELP-computed CN: The user enters the landfill surface slope, slope length, and vegetative cover, and the model computes an SCS AMC-II CN based on these inputs and the soil texture of the topmost layer (entered in the **Soil & Design** panel, as described in **Section 4.5**)

Vegetative Cover (CN Method 3)

If you use Method 3 to determine an ACS AMC-II CN, the model will provide a dropdown list with the following options for specifying the quality of vegetative cover on the landfill:

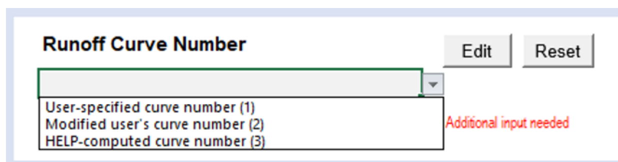
- Bare ground
- Poor stand of grass
- Fair stand of grass
- Good stand of grass
- Excellent stand of grass

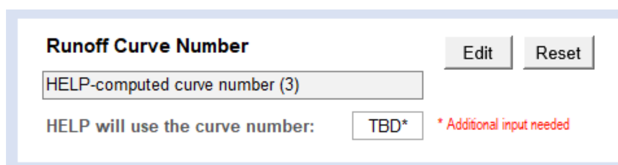
Most landfills will tend to have a poor or fair stand of grass, as landfills are typically not ideal support systems for vegetative growth.

You can import runoff curve number information from existing HELP v3.07 data files (.D10) or enter the information directly through the interface. **Section 4.1** describes how to import existing .D10 files from the **Control Panel**.

To enter information, directly, click in the text box in the **Runoff Curve Number** panel, and then click the drop down arrow to display the list of methods for computing the SCS AMC-II CN. Select the desired method from the options listed.

Next, click **Edit**, and the model will display a pop-up user form for entering information required for the selected method. When you are done entering the required information, click **Submit**. The user form will close, and the SCS AMC-II CN entered by you (Method 1) or computed by the model (Method 2 or 3) will be displayed in the Runoff Curve Number panel. If insufficient information is entered, the SCS AMC-II CN field will display "TBD" along with a note explaining that additional input is required.





User Tips

If you click **Reset** in the **Runoff Curve Number** panel, all information in the panel will be deleted. If you import existing .D10 files, existing information in the Runoff Curve Number panel will be overwritten by imported information.

The HELP model v3.07 .D10 file contains model simulation, runoff curve number and landfill design inputs (See **Appendix A**). When you import from a .D10 file, any previously imported or entered data for these fields will be replaced. If you plan to use HELP v3.07 data for one or more of these parameters, it is recommended that you import the .D10 files first.

Method 3 computes an SCS AMC-II CN based on inputs from both the **Runoff Curve Number** and **Soil & Design** panels. If you enter CN inputs for Method 3 before specifying the topmost layer of the landfill, the CN in the Runoff Curve Number panel will display "TBD." When you specify the topmost layer, the CN will be computed and displayed.

4.5 Soil & Design

The landfill profile, including information about layer functions and the characteristics of soils, geomembranes and other materials, is specified in the **Soil & Design** panel. The panel allows you to set up the profile by importing data or defining and initial number of layers, specify and edit layer types and properties, and adjust the design by adding, moving and deleting layers. For information on the default layer textures and their associated characteristics, refer to the table in **Appendix G**.

You can import elements of general landfill information from existing HELP v3.07 .D10 data files or start from scratch with a new landfill profile. **Section 4.1** describes how to import existing .D10 files. **Section 4.5.1**, below, describes how to start a new profile from scratch. **Sections 4.5.2 and 4.5.3** describe how to specify new layers and edit existing layers (newly defined or imported). **Section 4.5.4** describes how to rearrange the landfill profile by adding, moving and deleting layers. If you click **Reset** in the **Soil & Design** panel, all information in the panel will be deleted.

Layer Rules, Data Validation and Data Validation Control in the Soil & Design Panel

Information Requirements and Layer Rules

The HELP model includes requirements for the information that must be provided when specifying layers, as outlined in **Table 1** (below) and **Appendix A**. The model also requires that the arrangement of layers in the landfill profile conform to the following basic rules:

- A vertical percolation layer cannot be underlying a lateral drainage layer
- A barrier soil liner cannot be underlying another barrier soil liner
- A geomembrane liner cannot be placed between two barrier soil liners
- A geomembrane liner cannot be underlying another geomembrane liner
- A barrier soil liner cannot be placed directly between two geomembrane liners
- The top layer cannot be a barrier soil liner
- The top layer cannot be a geomembrane liner
- The profile can contain no more than five barrier soil liners and geomembrane liners

Data Validation Approach and Control – Layer Information

The program will check for missing information, values outside the valid range, and consistency of layer arrangement with the above rules when you click **Submit** after entering values or editing information for a layer. If you try to submit a layer with incomplete or invalid information, the program will notify you and give you the option of returning to the form to fill in the information or saving the layer with incomplete information. You can **Edit** the layer later or use the **Review** function from the **Control Panel** to identify missing data before you run the model.

Data Validation Approach and Control – Layer Arrangement

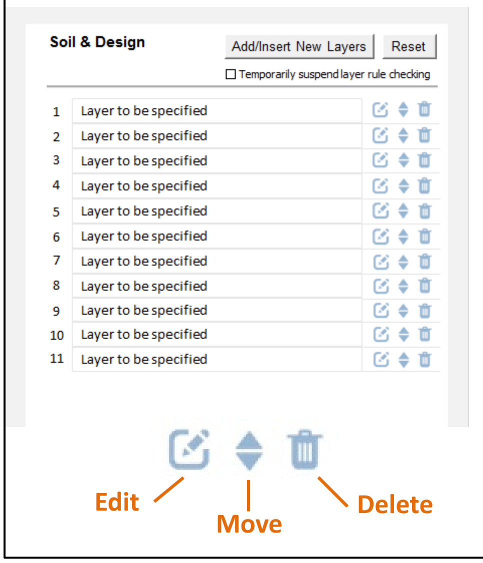
In addition, the program will check for consistency of layer arrangement when you **Move** or **Delete** layers. You can turn off layer rule checking (e.g., if you are in the midst of moving several layers) by clicking **Temporarily suspend layer rule checking** in the **Soil & Design** panel. You can use the **Review** function from the **Control Panel** to check for conformance with layer rules before you run the model.

4.5.1 Setting Up a New Landfill Profile

To define a landfill profile from scratch, start by clicking **Add/Insert New Layers**. A pop-up user form will asking to specify the number of layers (up to 20) to include in the initial profile. Note that the number of layers can be changed after this initial specification, as explained in **Section 4.5.4**. After entering the initial number of layers, click **Submit**.

The program will produce a "blank" profile. Each layer will initially be labelled "Layer to be specified." To the right of each layer will be three icons that are used for editing, moving, and deleting layers (see figure to the right). From this blank profile, you can add information for each layer by clicking the **Enter/Edit** icon next to each layer, as described in **Section 4.5.2**.

Blank Profile



4.5.2 Specifying a New Landfill Layer

To specify information for a new layer, click the **Enter/Edit** icon next to the layer. For a new layer, the program will produce a pop-up user form asking you to select a layer category from a drop-down menu and to specify whether the layer will be a standard HELP layer, a previously saved custom layer, or a new custom layer. After making these selections, the user form will display the fields appropriate for the selected layer category and will prepopulate information for standard layers and previously defined which they are editable, and whether the layer characteristic is required, conditional, or optional for a particular layer category. **Appendix G** provides a list of standard layers included in the HELP Model, including texture numbers, descriptions, and layer characteristics (e.g., porosity, hydraulic conductivity).

Texture Numbers

The HELP model uses texture numbers to refer to standard soil, waste, geosynthetic drainage nets, and geomembranes included in the model. See Appendix G for standard layers and associated texture numbers. These are the same standard layers and texture numbers used in HELP v3, and the texture numbers can be used to cross-referencing the model versions. When the user defines a custom layer, HELP v4.0 automatically defines a new texture number for the custom layer (HELP v3.07 defaults to a texture number of 0). The new texture number is displayed in the pop-up user form for the layer (when you click the **Edit** icon) and is listed in the output (**Model Data**). These texture numbers are included as a reference so you can reuse the custom layers in modified or new designs.

After entering the required information for a layer, click **Submit**. If you click **Reset** while entering or editing information for a layer, the user form and characteristics of the layer will be deleted. If you try to submit a layer with incomplete or invalid information, the program will notify you of missing fields or invalid values. You will have the option of correcting the information or saving the incomplete/invalid information. Incomplete or invalid values will need to be corrected before you run the HELP model. See **Sections 4.5 and 5** for a description of the layer validation approach and control.

After submitting information for a layer, you can continue to edit information for blank ("to be specified") layers as described above until the landfill profile is completely specified. After entering the required information for a layer, click **Submit**. If you click **Reset** while entering or editing information for a layer, the user form and characteristics of the layer will be deleted. If you try to submit a layer with incomplete or invalid information, the program will notify you of missing fields or invalid values. You will have the option of correcting the information or saving the incomplete/invalid information. Incomplete or invalid values will need to be corrected before you run the HELP model. See **Sections 4.5 and 5** for a description of the layer validation approach and control.

Table 1. Landfill Layer Data Elements

Layer characteristic	Layer Category							Editable?		Notes
	Final cover soil (topmost layer)	Vertical percolation layer (soil)	Lateral drainage layer (soil)	Barrier soil liner	Waste	Geomembrane liner	Geosynthetic drainage net	Standard Layer	Custom Layer	
Layer thickness	R	R	R	R	R	R	R	Yes	Yes	
Total porosity	R	R	R	R	R		R	No	Yes	
Field capacity	R	R	R	R	R		R	No	Yes	
Wilting point	R	R	R	R	R		R	No	Yes	
Saturated hydraulic conductivity	R	R	R	R	R	R	R	No	Yes	
Initial moisture	C	C	C		C		C	Yes	Yes	Required for categories labelled "C" when user chooses to specify initial moisture
Drainage length			C				R	Yes	Yes	Required for lateral drainage layer when it is the lowest drainage layer in a subprofile
Drainage slope			C				R	Yes	Yes	Required for lateral drainage layer when it is the lowest drainage layer in a subprofile
Leachate recirculation			O					Yes	Yes	
Recirculation to layer			C					Yes	Yes	Required for lateral drainage layer when leachate recirculation is non-zero

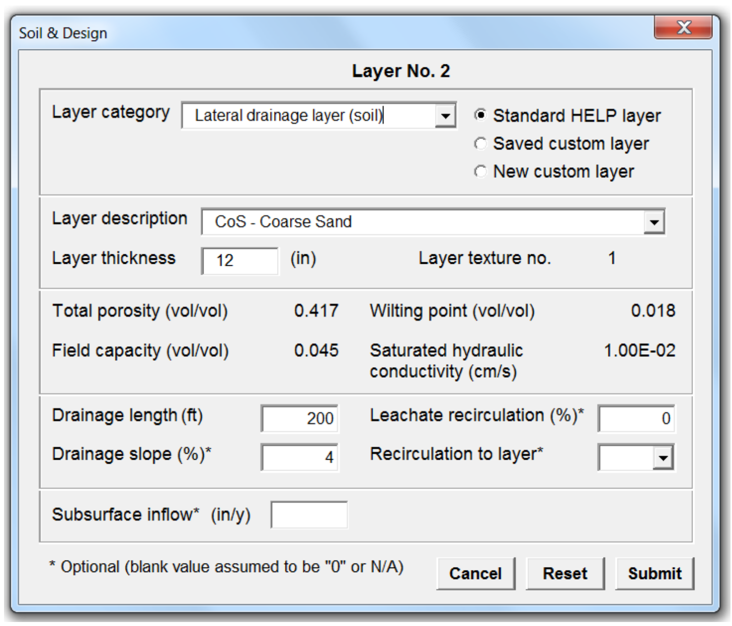
Layer characteristic	Layer Category							Editable?		Notes
	Final cover soil (topmost layer)	Vertical percolation layer (soil)	Lateral drainage layer (soil)	Barrier soil liner	Waste	Geomembrane liner	Geosynthetic drainage net	Standard Layer	Custom Layer	
Subsurface inflow	O	O	O	O	O	O	O	Yes	Yes	
Membrane pinhole density						R		Yes	Yes	
Membrane installation defects						R		Yes	Yes	
Membrane placement quality						R		Yes	Yes	
Geotextile transmissivity						C		Yes	Yes	Required for membrane when placement quality = 6

Legend: R - Required, C - Conditional, O – Optional

After submitting information for a layer, you can continue to edit information for blank ("to be specified") layers as described above until the landfill profile is completely specified.

4.5.3 Editing Landfill Layers

To edit the information for a landfill layer, including a layer imported from a HELP v3.07 .D10 file, click the **Enter/Edit** icon next to the layer. The program will produce a pop-up user form with the previously defined information for the layer. **Table 1** describes the fields that will be displayed depending on the layer category. If you change the layer category on click **Reset** while editing a layer, this will reset the user form, and you will be asked to enter a layer description and additional information, as described in **Section 4.5.1** for a new layer. If you change the layer description while editing a layer, the form will update information corresponding to the new layer description (e.g., predefined porosity values for a standard soil layer).



After editing information for a layer, click **Submit**. The program will run a layer validation check. If missing or invalid values are found, you will have the option of correcting the information or saving the incomplete/invalid information. Incomplete or invalid values will need to be corrected before you run the HELP model. See **Sections 4.5 and 5** for a description of the layer validation approach and control.

4.5.4 Adding, Moving and Deleting Layers

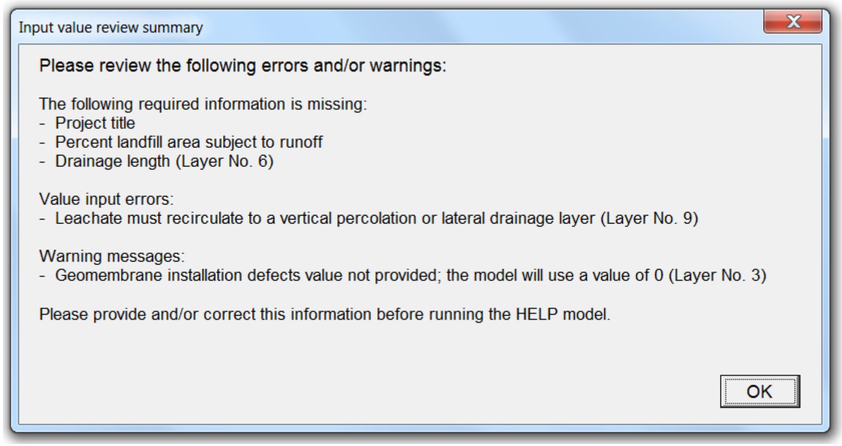
The program gives you the option of adding and rearranging layers in the Soil & Design panel using the **Add**, **Move** and **Delete** icons (see **Section 4.5**). To add a layer click **Add/Insert New Layers**, and the program will display a user form asking you to specify the number of layers to add and the position of the new layer(s). To move a layer to a new position in the profile, click the **Move** icon next to the layer to be moved. The program will display a user form that asks you to specify the new location of the selected layer. To delete a layer, click the **Delete** icon next to the layer.

The program will check layer rules when you add, move or delete layers and will notify you if the resulting layer arrangement is inconsistent with layer rules (see text box in **Section 4.5**). You can turn off layer rule checking (e.g., if you are in the midst of moving several layers) by clicking **Temporarily suspend layer rule checking** in the **Soil & Design** panel. Inconsistencies with the layer rules will need to be corrected before you run the HELP model. See **Sections 4.5 and 5** for a description of the layer validation approach and control.

5. Reviewing Data Quality

HELP v4.0 uses three layers of data validation to help assure the quality of model inputs and results. First, the model reviews user input when you enter information in a pop-up user form and click **Submit** or when you perform other functions like moving or deleting layers or changing the runoff curve number method. Second, the model allows you to review model inputs at any time by clicking the **Review** button from the **Control Panel**. Finally, when you click **Run HELP Model** from the **Control Panel**, the program reviews input before running the modeling routines.

The different data validation routines review data and other modeling input for completeness (i.e., review for missing values) and check whether data and values are within the valid range and are expressed in valid formats (e.g., numeric vs. non-numeric). **Appendix A** lists input requirements and valid ranges used by the validation routines. The model also reviews the landfill profile to ensure that layers arrangement is consistent with model requirements, as described in **Section 4.5**.



If missing values, values outside of the valid range, or values using invalid formats are detected during data entry and editing, the program will notify you of the missing/invalid input. In most cases, the model will give you the option of filling in or correcting the input before continuing or saving the input with the expectation that you will return and complete or correct the input before running the model. This is intended to allow for efficient data entry and editing. If you do not return and complete or correct the input, missing or invalid input will be identified when you click **Review** or **Run HELP Model**. The model will not run until all missing and invalid input is addressed.

The review functions also check for inputs that could represent incorrect interpretation of the input requirements. For example, if the model requires an input expressed as a percentage (e.g., 10%) and detects an input value of less than 1 (e.g., 0.1), it will generate a warning message to alert the user to check and confirm the input. Warning messages do not need to be addressed for the model to run.

6. Running the Model and Saving Results

It is recommended that the model be saved with the current inputs, prior to running the model. After reviewing your input and saving a copy of the model, click **Run HELP Model** from the **Control Panel**. The program will run a data validation check. If detected, the program will notify you of missing or invalid values and will stop running. If the inputs pass the validation check, the program will run the model. As the program cycles through simulation years, it will generate a temporary worksheet for each year, indicating that the model is running. These worksheets will later be moved to an output file where you can review the information in detail.

User Tips

If a run-time error is encountered while working with the model, the program should be reloaded by closing and reopening the HELP Model v4.0 in Excel. This will reset any protections in worksheet and avoid potential issues with running the model following an error condition. If a run-time error is encountered after the model has started generating output, you may find a residual "Tempout" file in the directory from which you launched the model. You must delete this file before your next run or your output may not be saved properly.

To avoid any potential data loss, it is recommended that a clean version of the model, including your current inputs, be saved prior to running the model.

Longer simulation run times have been noted with HELP Model v4.0 compared to the previous version. This is in part a function of Excel limitations and, in some cases, individual operating environments. EPA has taken steps to optimize run times and, if further opportunities to optimize run-times are identified, may implement further improvements in the future.

When the HELP model is finished running, a dialog box will appear and asking you to identify the format(s), Excel or PDF, for saving output file(s). When you select the desired format and click **Submit**, a file browser window will open for you to navigate to and save the output file(s).

The output files will contain the following tabs (Excel) or pages (PDF):

Model Input: Summary of model input, including landfill layer information, general design data, evapotranspiration data, and mean monthly rainfall and temperature data.

Annual Simulation Output: Simulation results by year including daily estimates for rainfall, runoff, evapotranspiration, lateral drainage, and leakage/percolation through liners, and head on liners. A summary table of annual totals is presented after the daily results for each simulation year.

Averages Annual Totals Summary: Summary of results for the entire simulation period including average annual total rainfall, runoff, evapotranspiration, lateral drainage and drainage recirculation, subsurface inflow, leakage/percolation through liners, head on liners, and change in water storage.

Peak Values Summary: Summary of results for the entire simulation period including peak values for rainfall, runoff, lateral drainage and drainage recirculation, leakage/percolation through liners, head on liners, and location of maximum head on liners.

Final Water Storage: Summary of final water storage in each layer at the end of the simulation period.

REFERENCES

Frye et al. (2016). Daily gridded weather for pesticide exposure modeling. Environmental Modeling & Software. 82(2016):167-173.

Richardson, C. W., and Wright, D. A. (1984). "WGEN: A model for generating daily weather variables," ARS-8, Agricultural Research Service, USDA. 83 pp.

Appendix A
HELP Model Data and Parameter Value Input Requirements

Input Field	Input Options		Required to Run?	Valid values	Comments
	User Input Panel	HELP v3.07 Data File			
Title	General Information	D10	Yes	Any value up to 60 characters	Click **Edit** to enter or edit in pop-up form
Address	General Information	---	No	Any	Click **Edit** to enter or edit in pop-up form
City	General Information	D11	No	Any	Click **Edit** to enter or edit in pop-up form
State	General Information	D11	No	Dropdown list provided	Click **Edit** to enter or edit in pop-up form
ZIP code	General Information	---	No	Validated based on U.S. ZIP codes	Click **Edit** to enter or edit in pop-up form
Latitude (Lat)	General Information	D11	Yes	-14.32 to 71.25	Click **Edit** to enter, find, or edit in pop-up form; value set based on ZIP code if not specified by user
Longitude (Long)	General Information		Yes		Click **Edit** to enter, find, or edit in pop-up form; value set based on ZIP code if not specified by user
Years of Simulation	General Information	---	Yes	1 to ≤ years of weather data (max 100 years)	
Units	General Information	D10	Yes	Dropdown list provided	
Landfill Area (LF Area acres)	General Information	D10	Yes	>0	User prompted to set units if LF Area (acres) is entered before units specified
% Subject to Runoff	General Information	D10	Yes	0 - 100%	
Specify Initial Moisture?	General Information	D10	Yes	Yes/No	
Water/snow storage	General Information	D10	Contingent	≥0	Required if initial moisture specified
Precipitation (daily)	---	D4	Yes		Recommended that data be simulated with WGEN, or imported from NOAA data or HELP v3.07 file
Temperature (daily)	---	D7	Yes		Recommended that data be simulated with WGEN, or imported from NOAA data or HELP v3.07 file

Input Field	Input Options		Required to Run?	Valid values	Comments
	User Input Panel	HELP v3.07 Data File			
Solar Radiation (daily)	---	D13	Yes		Recommended that data be simulated with WGEN, or imported from NOAA data or HELP v3.07 file
Average annual wind speed	Weather	D11	Yes	0-20 MPH (0-32.2 KPH)	Click **Enter or Import** to enter or edit Wind Speed/Rel Humidity in pop-up form; option to import NREL data
Average relative humidity, first quarter	Weather	D11	Yes	>0 - 100%	Click **Enter or Import** to enter or edit Wind Speed/Rel Humidity in pop-up form; option to import NREL data
Average relative humidity, second quarter	Weather	D11	Yes	>0 - 100%	Click **Enter or Import** to enter or edit Wind Speed/Rel Humidity in pop-up form; option to import NREL data
Average relative humidity, third quarter	Weather	D11	Yes	>0 - 100%	Click **Enter or Import** to enter or edit Wind Speed/Rel Humidity in pop-up form; option to import NREL data
Average relative humidity, fourth quarter	Weather	D11	Yes	>0 - 100%	Click **Enter or Import** to enter or edit Wind Speed/Rel Humidity in pop-up form; option to import NREL data
Start of growing season	Weather	D11	Yes	0 - 367	Click **Enter** to enter or edit Other Parameters in pop-up form
End of growing season	Weather	D11	Yes	0 - 367	Click **Enter** to enter or edit Other Parameters in pop-up form
Maximum leaf area index	Weather	D11	Yes	≥0	Click **Enter** to enter or edit Other Parameters in pop-up form; model is insensitive to differences in LAI values >5
Evaporative zone depth	Weather	D11	Yes	>0, cannot exceed depth to top membrane	Click **Enter** to enter or edit Other Parameters in pop-up form
Curve number method	Curve Number	D10	Yes	1-3 Dropdown list provided	

Input Field	Input Options		Required to Run?	Valid values	Comments
	User Input Panel	HELP v3.07 Data File			
CN Method 1, SCS AMCII CN	Curve Number	D10	Contingent	>0	Click **Edit** to enter or edit in pop-up form; required for Method 1
CN Method 2, SCS AMCII CN	Curve Number	D10	Contingent	>0	Click **Edit** to enter or edit in pop-up form; required for Method 2
CN Method 2, slope	Curve Number	D10	Contingent	>0 - 100%	Click **Edit** to enter or edit in pop-up form; required for Method 2
CN Method 2, slope length	Curve Number	D10	Contingent	>0 to effective length calculated at LF width = 10 yds or 10 m	Click **Edit** to enter or edit in pop-up form; required for Method 2
CN Method 3, slope	Curve Number	D10	Contingent	>0 - 100%	Click **Edit** to enter or edit in pop-up form; required for Method 3
CN Method 3, slope length	Curve Number	D10	Contingent	>0 to effective length calculated at LF width = 10 yds or 10 m	Click **Edit** to enter or edit in pop-up form; required for Method 3
CN Method 3, soil texture	---	---	Yes	---	Determined based on topmost landfill layer description
CN Method 3, vegetative cover	Curve Number	D10	Contingent	Dropdown list provided	Click **Edit** to enter or edit in pop-up form; required for Method 3
Layer category	Soil & Design	D10	Yes	Dropdown list provided	Click **Enter/Edit** to enter or edit in pop-up form
Layer description	Soil & Design	D10	Yes	Dropdown list or custom entry	Click **Enter/Edit** to enter or edit in pop-up form
Layer type	---	---	Yes	---	Determined based on layer category
Layer thickness	Soil & Design	D10	Yes	>0	Click **Enter/Edit** to enter or edit in pop-up form
Total porosity	Soil & Design	D10	Contingent	>0 - 1	Click **Enter/Edit** to enter or edit in pop-up form; required for soil, waste, geonets; not required for barrier soil liner unless initial moisture is user-specified; user-defined for custom layers

Input Field	Input Options		Required to Run?	Valid values	Comments
	User Input Panel	HELP v3.07 Data File			
Field capacity	Soil & Design	D10	Contingent	>0 - < porosity	Click **Enter/Edit** to enter or edit in pop-up form; required for soil, waste, geonets; not required for barrier soil liner; user-defined for custom layers
Wilting point	Soil & Design	D10	Contingent	>0 - < field capacity	Click **Enter/Edit** to enter or edit in pop-up form; required for soil, waste, geonets; not required for barrier soil liner; user-defined for custom layers
Saturated hydraulic conductivity	Soil & Design	D10	Yes	>0	Click **Enter/Edit** to enter or edit in pop-up form
Initial moisture	Soil & Design	D10	Contingent	≥ wilting point and ≤ porosity	Click **Enter/Edit** to enter or edit in pop-up form; required if initial moisture is user-specified; not required for barrier soil or geomembrane liners
Drainage length	Soil & Design	D10*	Contingent	>0	Click **Enter/Edit** to enter or edit in pop-up form; required for lateral drainage layers
Drainage slope	Soil & Design	D10	Contingent	0 - 50%	Click **Enter/Edit** to enter or edit in pop-up form; required for lateral drainage layers
Leachate recirculation	Soil & Design	D10	No	0 - 100%	Click **Enter/Edit** to enter or edit in pop-up form
Recirculation to layer	Soil & Design	D10	Contingent	1 - 20; vertical percolation or lateral drainage layer only	Click **Enter/Edit** to enter or edit in pop-up form; required when leachate recirculation is non-zero
Subsurface inflow	Soil & Design	D10	No	≥0	Click **Enter/Edit** to enter or edit in pop-up form
Geomembrane pinhole density	Soil & Design	D10	Contingent	≥0	Click **Enter/Edit** to enter or edit in pop-up form; required for membranes

Input Field	Input Options		Required to Run?	Valid values	Comments
	User Input Panel	HELP v3.07 Data File			
Geomembrane installation defects	Soil & Design	D10	Contingent	≥0	Click **Enter/Edit** to enter or edit in pop-up form; required for membranes
Geomembrane placement quality	Soil & Design	D10	Contingent	Dropdown list provided	Click **Enter/Edit** to enter or edit in pop-up form; required for membranes
Geotextile transmissivity	Soil & Design	D10	Contingent	>0	Click **Enter/Edit** to enter or edit in pop-up form; required if membrane placement quality = 6

* HELP v4.0 requires the user to enter drainage length for all components of a lateral drainage layer, including soil and geosynthetic drainage nets. Some HELP v3.07 files do not contain drainage length for soil lateral drainage layers. If the user imports a HELP v3.07 file without this information, the model will alert the user that the information is missing during data validation (e.g., when the user clicks **Review** or **Run Help Model** from the **Control Panel**).

Appendix B
Weather Simulation in HELP v4.0

HELP v4.0 incorporates the WGEN synthetic weather generator developed by the USDA Agricultural Research Service (Richardson and Wright, 1984). Weather parameter values used in the synthetic weather generator are imported from a dataset of weather parameters for over 13,000 points located on a 0.25 x 0.25 degree (latitude/longitude) grid across the 48 contiguous states of the U.S. developed by EPA's Office of Pesticide Programs (OPP) using two NOAA data products. This appendix provides a brief summary of the WGEN program, OPP gridded weather dataset, and methods used to integrate weather simulation into HELP v4.0.

Weather Generator (WGEN)

The WGEN synthetic weather generator was originally added to Version 2 of the HELP model to provide users with the option of simulating daily values for precipitation, temperature and solar radiation. Prior to this enhancement, the HELP model used mean monthly values. Version 3 of the model maintained this capability, incorporating WGEN for daily weather simulation.

WGEN simulates daily values for precipitation, maximum temperature, minimum temperature, and solar radiation using historical weather data. The model is designed to preserve the dependence in time, the correlation between variables, and the seasonal characteristics in actual weather data for a specified location.

The precipitation component of WGEN is a Markov chain-gamma model. A first-order Markov chain is used to generate the occurrence of wet or dry days. When a wet day is generated, a two-parameter gamma distribution is used to generate the precipitation amount. Precipitation occurrence probabilities are conditioned on whether the previous day was a wet or dry. WGEN uses two precipitation probability values – probability of a wet day following a wet day and probability of a wet day following a dry day – for each month for each location to account for location-specific seasonal characteristics. WGEN uses a two-parameter gamma distribution model, where the probability density function is defined by shape and scale parameters.

Temperature (maximum and minimum) and solar radiation variables are modeled using harmonic equations to simulate seasonal weather patterns. Harmonic equation are defined for each variable (maximum and minimum temperature and solar radiation) using statistically determined parameter values. Daily temperature and solar radiation values are modeled based on precipitation condition (wet or dry) and position on the harmonic, as defined by the day of the year.

In total, WGEN requires 60 parameter values for each location:

- Twelve monthly probability of a wet day given a previous wet day ($P_{W/W}$) values
- Twelve monthly probability of a wet day given a previous dry day ($P_{W/D}$) values
- Twelve monthly shape parameter values (α) to specify the rainfall gamma distribution
- Twelve monthly scale parameter values (β) to describe rainfall distribution

- Five parameters describing the maximum temperature harmonic equation: means for wet and dry days, coefficient of variation, amplitude, and amplitude of coefficient of variation
- Four parameters describing the minimum temperature harmonic equation: mean (wet or dry), coefficient of variation, amplitude, and amplitude of coefficient of variation
- Three parameters describing the solar radiation harmonic equation: means for wet and dry days and amplitude

The version of WGEN incorporated Version 3 of the HELP model in is currently available as a standalone application that can be run on the GoldSim Player.[3] This version of WGEN uses the original parameter values calculated based on weather data for the 20 years from 1951 to 1970. Precipitation parameter values were calculated for 139 locations and temperature and solar radiation parameter values were calculated for 31 locations across the 48 contiguous states of the U.S.

The default application allows the user to specify a latitude for one of the 139 locations with precipitation parameters as the basis for the simulation. The model also allows users to enter precipitation and temperature data to correct for differences in weather between the closest WGEN default location and the actual user location of interest (e.g., landfill site). A separate program, WGEN PAR, is provided to allow users to generate their own parameter values based on actual weather data at a specific location of interest.

For more information, please refer to Richardson and Wright (1984).

Daily Gridded Weather Data

EPA OPP compiled daily precipitation, temperature, wind speed, and solar radiation data for the period 1961 to 2014 using the NOAA products: the NOAA Climate Prediction Center (CPC) Unified Rain Gauge Analysis and National Center for Environmental Prediction (NCEP) and National Center for Atmospheric Research (NCAR) Reanalysis. The NOAA CPC Unified Rain Gauge analysis provides daily precipitation data on a 0.25 x 0.25 degree grid resolution across the 48 contiguous U.S. states. The NCEP/NCAR Reanalysis provides temperature (daily mean, maximum, and minimum), wind speed, and solar radiation data on a 2.5 x 2.5 degree rectilinear global grid.

To assemble a complete dataset, OPP compiled the CPC Unified Rain Gauge data at its native resolution and spatial extent. OPP extracted NCEP/NCAR Reanalysis data for the continental U.S. and interpolated the data from the native 2.5 x 2.5 degree rectilinear grid to the finer 0.25 x 0.25 degree grid used for the CPC Unified Rain Gauge analysis using bilinear interpolation. Bilinear interpolation was first performed in the x direction, followed by the y direction. This interpolation scheme was applied uniformly across the lower 48 contiguous U.S. states for consistency and to limit any data voids.

For more information on the OPP gridded weather dataset, please refer to Frye et al. (2016).

[3] https://support.goldsim.com/hc/en-us/articles/115012797188-WGEN-Weather-Simulator

HELP v4.0 Integration

For HELP v4.0, EPA developed a more spatially resolved and up-to-date application of WGEN using the OPP gridded weather dataset and incorporated this application of WGEN in the HELP model. Daily precipitation, temperature (maximum and minimum), and solar radiation data were downloaded from the OPP dataset. For efficiency, statistical software was used to calculate the 60 parameter values required for WGEN for each of the more than 13,000 grid locations. Parameter values were calculated based on the most recent 30-year period contained in the dataset (1985-2014).

The WGEN PAR program was run for a random sample of grid locations and parameter values calculated using statistical software were compared to results generated by the WGEN PAR program to validate the approach (confirm that the statistical analysis produced the same values as would have been obtained by applying the WGEN PAR program).

To integrate WGEN as a weather simulation tool, the Fortran code described by Richardson and Wright (1984) was reproduced as a VBA module in HELP v4.0. A complete dataset of parameter values was compiled for each grid location and is available to HELP model users for running weather simulation. Weather simulation results obtained using the integrated WGEN model were compared to results obtained using the standalone version of WGEN (GoldSim Player) to confirm that the version integrated in the HELP model conforms with the standalone version of WGEN.

Section 4.3.1 of this User Manual describes the operation of weather simulation using the integrated WGEN model. For weather simulation, the HELP model uses the WGEN parameter values for the grid point closest to the specified landfill location (latitude/longitude). Alternatives to this approach were explored as part of the integration design, including reapplication of bilinear interpolation used to develop the OPP dataset. Given the density of grid locations, it was determined that parameter values calculated using bilinear interpolation would not be significantly different than those of the surrounding grid points. The logic of obtaining values was the closest grid point was implemented to minimize unnecessary data manipulation.

Appendix C
Downloading Precipitation and Temperature Data from the NOAA Website

If you are not using precipitation and temperature data files from HELP model v3.07 or the synthetic weather generation option, you will need to import historical precipitation and temperature data from the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI) from three weather stations near the landfill site. Weather stations occasionally experience data gaps (e.g., during maintenance or due to damage, and, over time, stations are brought on line or retired). The HELP model combines the data from the three selected stations to minimize data gaps.

NOAA provides historical precipitation and air temperature data through the Climate Data Online (CDO) search tool at https://www.ncdc.noaa.gov/cdo-web/search. As noted in **Section 3**, if you choose to import precipitation and temperature data downloaded from the NOAA website, the HELP model will prompt you to identify "primary," "secondary" and "tertiary" data files to be imported. You should select the weather station that balances proximity to your site with relatively complete coverage of precipitation and temperature variables for the date range selected as your "primary" file. Your secondary and tertiary stations should also be located near the site and should provide relatively good coverage.

Please use the following steps to select and download precipitation and temperature data files to be imported to the HELP model:

1. On the *Climate Data Online Search* page (https://www.ncdc.noaa.gov/cdo-web/search):
   a. Under *Select Weather Observation Type/Dataset*, select **Daily Summaries** from the dropdown list
   b. Under *Select Date Range*, select a date range of interest using the calendar feature, and click **Apply** (see text box for important information on specifying the date range)
   c. Under *Search For*, use the default selection, **Stations**
   d. Under *Enter a Search Term*, type location information for the landfill site (e.g., city and state)
   e. Click **Search** and the website will produce a map showing your search results
2. On the *Search Results: Daily Summaries* page (https://www.ncdc.noaa.gov/cdo-web/results)
   a. Zoom-in to your landfill's location

Date Range

You will need to select data for a period (in years) that equals or exceeds the number of years of simulation that you plan to use for the model.

In general, longer periods and more recent data will be more representative of future typical weather conditions, though care should be taken to account for unusual weather periods (e.g., extended drought) when selecting the date range for download.

NOTE: The HELP model requires that you import daily weather data in full year increments (January 1 - December 31). If you attempt to import a partial year of data, the model will interpret the data for the part of the year for which you did not import data as "missing" and the import will fail (you will receive an error message indicating too many missing values).

b. Click on the icon for a station near your site, and the website will provide a pop-up box with *Station Details*

NOAA CDO weather station icon

c. Review the Start/End dates in the Station Details box.

   If the dates do not sufficiently cover the date range of interest or provide relatively poor coverage (e.g., <90%), select another station (Step 2b)

d. If the dates cover the date range of interest or provide relatively good coverage (e.g., ≥90%), click **Full Details**, and the website will take you to a *Station Details* page

e. Scroll down to *Station Data Inventory, Access & History*, and review the information under *Available Data Types*

   If precipitation and/or temperature data are not available for this station, use your browser Back button to return to the *Search Results: Daily Summaries* page, and select another station (Step 2b)

f. If the station provides precipitation and temperature data:

   i. Click on the **Precipitation** link, and review the *Start/End* dates and *Coverage %* information for the variable PRCP

   ii. Click on the **Air Temperature** link, and review the *Start/End* dates and *Coverage %* information for the variables TAVG, TMAX, TMIN and/or TOBS (see text box)

   If the station does not provide precipitation and temperature data with relatively good coverage over the date range of interest, use your browser Back button to return to the *Search Results: Daily Summaries* page, and select another station (Step 2b)

g. If the station provides precipitation and temperature data with relatively good coverage over the date range of interest:

   i. Click **Add to Cart**

   ii. Click on the **Cart (Free Data)** button in the upper right hand corner of the page, and the website will open the Cart for further data download specification

Reviewing and Selecting NOAA Temperature Data

The HELP model is designed to run with the NOAA observed temperature (TOBS) variable alone, average temperature (TAVG) variable alone or maximum and minimum temperature (TMAX, TMIN) variables (combined). The model will review column headers in your NOAA data file. If it detects TOBS, it will use the data from this field. If not, it will use data from the TAVG field. If neither the TOBS or TAVG fields are detected, it will use a combination of TMAX and TMIN data. The model will not independently assess the completeness of the data in each field.

When reviewing temperature data for weather stations near your site (Step 2f), review the start and end dates and coverage for all temperature variables. Try to find three stations that provide good coverage for the date range of interest for the same variable (TOBS or TAVG) or set of variables (TMAX and TMIN). When selecting fields to download (Step 3), select the single variable or set of variables with the best coverage.

3. On the *Cart: Daily Summaries* page (https://www.ncdc.noaa.gov/cdo-web/cart):

   a. Under *Select the Output Format*, select **Custom GHCN-Daily CSV**

b. Under *Select the Date Range*, confirm or modify the date range of interest

c. Click **Continue**, and the website will open a *Custom Options* page

4. On the *Custom Options: Daily Summaries* page (https://www.ncdc.noaa.gov/cdo-web/customoptions):

    a. *Under Station Detail & Data Flag Options*:

        i. Leave the default **Station Name** selected

        ii. Ensure that the **Units** match the units you selected in the *General Information* panel of the HELP model dashboard

    b. Under *Select Data Types for Custom Output*:

        i. Click the plus sign **+** next to *Precipitation* to display the available options and check the box by **Precipitation (PRCP)**

        ii. Click the plus sign **+** next to *Air Temperature* and check the box for either TOBS, TAVG, or both TMAX and TMIN, depending on the variables you identified as providing the best coverage across weather stations in the vicinity of your site (see Additional Notes text box)

    c. Click **Continue**, and the website will open the *Review Order* page

5. On the *Review Order* page (https://www.ncdc.noaa.gov/cdo-web/review):

    a. Enter the email address you would like results delivered

    b. Click **Submit Order**

    c. Scroll down to the bottom of the *Request Submitted* page and beneath *Need more?* click **Go back and complete another search**

6. Repeat Steps 1 - 5 for two more stations

Additional Notes

In some areas, you may have difficulty finding three stations with relatively good precipitation and temperature data coverage over the date range of interest. Try to find at least one station with good data coverage, and make this your primary data file. The model uses your secondary and tertiary data files to fill gaps in the primary file, so data completeness is not as important. At a minimum, try to find stations for your secondary and tertiary data files that include both precipitation and temperature data over a reasonable period of time.

Once data have been requested from the NOAA website, it may take up to a couple hours for you to receive the data. You must download the file within a week.

WARNING: Do not edit the format or contents of the .csv data files received from NOAA/CDO. Doing so will result in errors in running the model.

7. When you receive your files from NOAA/CDO, save them to a file folder as **.csv** files and keep track of which is your primary, secondary and tertiary file

Appendix D
Downloading Solar Radiation Data from the NSRDB

> **NSRDB Compressed Files**
>
> NSRDB provides some compressed data files in a gzip format. Multiple products are available for opening gzip files. To use NSRDB compressed files, save the .gz file to a known directory and use the instructions provided with the selected product to unzip/open the files.

If you are not using solar radiation data files from HELP model v3.07 or the synthetic weather generation option, you will need to import historical solar radiation data from the National Renewable Energy Laboratory's National Solar Radiation Database (NSRDB) website at http://rredc.nrel.gov/solar/old_data/nsrdb.

The NSRDB contains three different datasets, reflecting changes data availability and processing methods over time. HELP v4.0 allows you to download data files from one or more of these datasets to generate a composite solar radiation input file for simulation. Note that the program will only accept one data file per calendar year. Where datasets overlap (i.e., for the years 1998-2010), you should only download the solar radiation data from one NSRDB dataset.

Please use the following steps to select and download solar radiation data files to be imported to the HELP model:

NSRDB 1961 – 1990 (http://rredc.nrel.gov/solar/old_data/nsrdb/1961-1990/)

1. Under Data, click on Hourly Data Files
2. Under Data, click on Compressed Files of All Years for Each Site
3. Find the National Weather Service (NWS) site closest to the landfill and click **Download**
4. Save the resulting folder and unzip the file
5. Save annual data files that you would like to import in the native **.txt** format to the directory from which you will import solar radiation data for the HELP model

NSRDB 1991 – 2010 Update (http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2010/)

1. Under the Data section of the screen, beneath Hourly Solar Data and Statistical Summaries, there is a sub-heading All available solar data and statistical files in compressed site files (gzip compression*) by:. Click on State and Site Name beneath this heading.
2. The Individual Site-Year Files page will display. Find the National Weather Service (NWS) site closest to the landfill and click the site ID link.
3. Save the resulting folder and unzip the file
4. Save annual data files that you would like to import in the native **.csv** format to the directory from which you will import solar radiation data for the HELP model

NSRDB 1998 – 2014 Update (https://maps.nrel.gov/nsrdb-viewer/)

1. Zoom the NSRDB Data Viewer map to the landfill location
2. Select the **Download Data** tab at the upper left corner of the application
3. Select **NSRDB Data Download (Point)** and click on the approximate landfill location
4. Enter name, affiliation, data use and email address in the resulting form
5. In the Data Download Wizard:
    a. Click on the **PSM v3** tab
    b. Under **Select Years**, select the years of data that you wish to download

    NOTE: If you downloaded and wish to use the 1991 – 2010 update, avoid overlapping 1998 – 2010 data by only selecting the year 2011 and years forward.

    c. Under **Select Attributes**, select **GHI** (at a minimum)
    d. Under **Select Download Options**, make sure that Half Hour Intervals is not selected
6. Select **Download Data**, after which you will receive a link to your data files in an email from NREL

NSRDB 1998-2014 Update Data File Attributes

You can select from several attributes for files downloaded via the NSRDB Data Viewer. However, the HELP model will not use any attributes other than GHI. Therefore, it is recommended that you select only the GHI attribute.

Additional User Note

WARNING: Do not edit the file extensions, format or contents of the data files received from NREL/NSRBD. Doing so will result in errors in running the model.

Appendix E
Downloading Wind Speed and Relative Humidity Data from the NSRDB

As an alternative to importing wind speed and relative humidity data from an existing HELP v30.7 data file or entering this information manually, you can import wind speed and relative humidity data from the NSRDB website at https://nsrdb.nrel.gov/data-sets/archives.html. Here you will find typical meteorological year (TMY) data sets for the 1991-2005 timeframe, which provide hourly values of meteorological elements for a typical year for a specific location.

To download wind speed and relative humidity data from this source:

1. Click on the link above and scroll down to the section titled **National Solar Radiation Database 1991-2005**
2. Click on the link for **Download NSRDB 1991-2005 Archive Data** to download the 3 GB file 1020 data stations and save it your computer, un-compress the archive file and open the newly created **1991-2005** folder
3. Navigate into the **tmy3** folder and open the **TMY3_StationsMeta(1).csv** file which contains a listing of the 1020 sites where data has been collected; make a note of the USAF Site ID for the Site Name and state of interest
4. In the same folder, open the archive file **alltmy3a.zip** and look for the file that begins with the USAF Site ID and extract that **.csv** file from the archive. This file contains the wind speed and relative humidity data for selected dates and times.

DO NOT edit the format or contents of the files received. Doing so will result in errors in running the model.

Appendix F
Information and Data Sources for Growing Season, Leaf Area Index and Evaporative Zone Depth

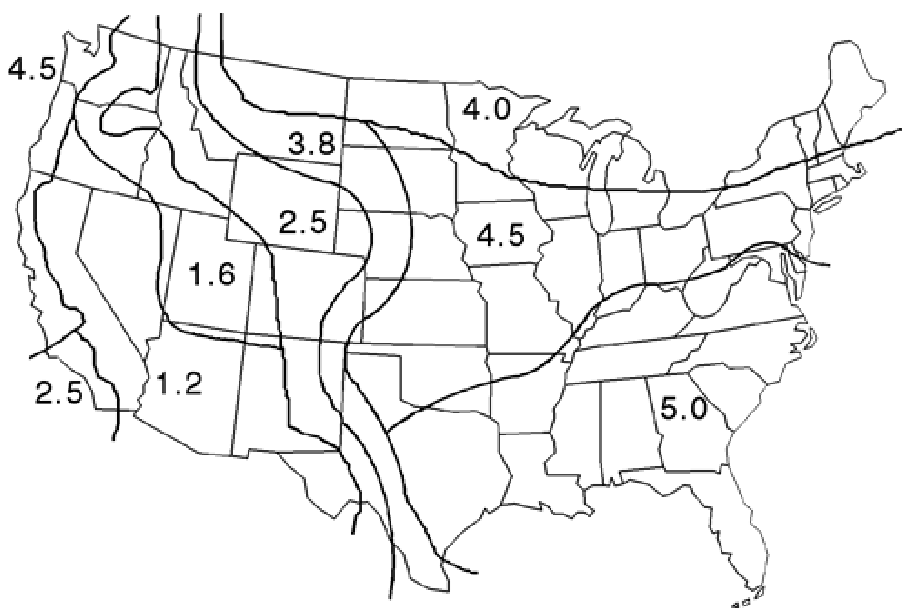
Growing Season

The start of the growing season is based on mean daily temperature and plant species. Typically, the start of the growing season for grasses is the Julian date (day of the year) when the normal mean daily temperature rises above 50 to 55 degrees Fahrenheit. The growing season ends when the normal mean daily temperatures falls below 50 to 55 degrees Fahrenheit. In cooler climates the start and end would be at lower temperatures and in warmer climates at higher temperatures. In locations where the growing season extends year-round, the start of the growing season should be reported as day 0 and the end as day 367.

Maximum Leaf Area Index (LAI)

LAI is the dimensionless ratio of the leaf area of actively transporting vegetation to the nominal surface area of the land on which the vegetation is growing. The maximum LAI for bare ground is zero. For a poor stand of grass the LAI could approach 1.0; for a fair stand of grass, 2.0; for a good stand of grass, 3.5; and for an excellent stand of grass, 5.0. The LAI for dense stands of trees and shrubbery would also approach 5. The model is largely insensitive to values above 5.

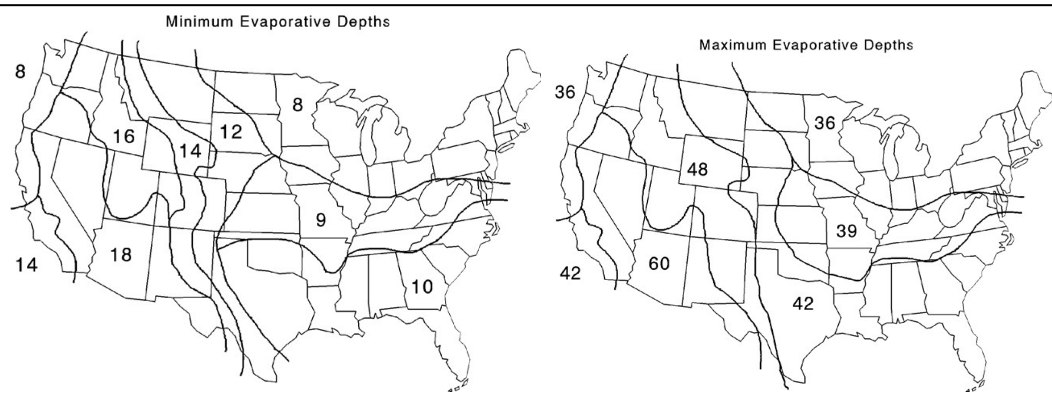
If the vegetative species limit plant transpiration (such as succulent plants), the maximum LAI value should be reduced to a value equivalent of the LAI for a stand of grass that would yield a similar quantity of plant transpiration. Most landfills would tend to have at best a fair stand of grass and often only a poor stand of grass because landfills are not designed as ideal support systems for vegetative growth. Surface soils are commonly shallow and provide little moisture storage for dry periods. See below for appropriate maximum LAI for the geographical location of your site.



Geographic Distribution of Maximum Leaf Area Index

Evaporative Zone Depth

The evaporative zone depth is the maximum depth from which water may be removed by evapotranspiration. HELP requires the ET zone depth to be greater than zero and less than or equal to the depth to the topmost liner. The value specified influences the storage of water near the surface and, therefore, directly affects the computations for evapotranspiration and runoff. Evaporative zone depth value depends on site location and soil type. Below are some default values.



Geographic Distribution of Minimum Evaporative Depth (in) **Geographic Distribution of Maximum Evaporative Depth (in)**

In general, clayey soils would have larger evaporative zone depths since they exert greater capillary suction; analogously, sandy soils would have smaller evaporative zone depths. Shrubs and trees with tap roots would have larger evaporative zone depths than the values presented in the figures above. For bare soil the evaporative depth could be as small as several inches in gravels; in sands the depth may be about 4 to 8 inches, in silts about 8 to 18 inches, and in clays about 12 to 60 inches.

Appendix G
Default Layer Textures and Associated Characteristics

HELP Texture No.	Description	General Material Type	USDA Texture Class	USCS Texture Class	Total Porosity (vol/vol)	Field Capacity (vol/vol)	Wilting Point (vol/vol)	Saturated Hydraulic Conductivity (cm/sec)
1	Coarse Sand	Soil - Low Density	CoS	SP	0.417	0.045	0.018	1.00E-02
2	Sand	Soil - Low Density	S	SW	0.437	0.062	0.024	5.80E-03
3	Fine Sand	Soil - Low Density	FS	SW	0.457	0.083	0.033	3.10E-03
4	Loamy Sand	Soil - Low Density	LS	SM	0.437	0.105	0.047	1.70E-03
5	Loamy Fine Sand	Soil - Low Density	LFS	SM	0.457	0.131	0.058	1.00E-03
6	Sandy Loam	Soil - Low Density	SL	SM	0.453	0.190	0.085	7.20E-04
7	Fine Sandy Loam	Soil - Low Density	FSL	SM	0.473	0.222	0.104	5.20E-04
8	Loam	Soil - Low Density	L	ML	0.463	0.232	0.116	3.70E-04
9	Silty Loam	Soil - Low Density	SiL	ML	0.501	0.284	0.135	1.90E-04
10	Sandy Clay Loam	Soil - Low Density	SCL	SC	0.398	0.244	0.136	1.20E-04
11	Clay Loam	Soil - Low Density	CL	CL	0.464	0.310	0.187	6.40E-05
12	Silty Clay Loam	Soil - Low Density	SiCL	CL	0.471	0.342	0.210	4.20E-05
13	Sandy Clay	Soil - Low Density	SC	SC	0.43	0.321	0.221	3.30E-05
14	Silty Clay	Soil - Low Density	SiC	CH	0.479	0.371	0.251	2.50E-05
15	Clay (Low Density)	Soil - Low Density	C	CH	0.475	0.378	0.265	1.70E-05
16	Liner Soil (High)	Soil - High Density	---	---	0.427	0.418	0.367	1.00E-07
17	Bentonite (High)	Soil - High Density	---	---	0.75	0.747	0.400	3.00E-09
18	Municipal Solid Waste (MSW) (900 pcy)	Waste	---	---	0.671	0.292	0.077	1.00E-03
19	MSW with Channeling	Waste	---	---	0.168	0.073	0.019	1.00E-03
20	Drainage Net (0.5 cm)	Geosynthetic drainage net	---	---	0.850	0.010	0.005	1.00E+01
21	Gravel	Soil - Low Density	G	GP	0.397	0.032	0.013	3.00E-01

HELP Texture No.	Description	General Material Type	USDA Texture Class	USCS Texture Class	Total Porosity (vol/vol)	Field Capacity (vol/vol)	Wilting Point (vol/vol)	Saturated Hydraulic Conductivity (cm/sec)
22	Loam (Moderate)	Soil - Moderate Density	L	ML	0.419	0.307	0.180	1.90E-05
23	Silty Loam(Moderate)	Soil - Moderate Density	SiL	ML	0.461	0.360	0.203	9.00E-06
24	Sandy Clay Loam (Moderate)	Soil - Moderate Density	SCL	SC	0.365	0.305	0.202	2.70E-06
25	Clay Loam (Moderate)	Soil - Moderate Density	CL	CL	0.437	0.373	0.266	3.60E-06
26	Silty Clay Loam (Moderate)	Soil - Moderate Density	SiCL	CL	0.445	0.393	0.277	1.90E-06
27	Sandy Clay (Moderate)	Soil - Moderate Density	SC	SC	0.4	0.366	0.288	7.80E-07
28	Silty Clay (Moderate)	Soil - Moderate Density	SiC	CH	0.452	0.411	0.311	1.20E-06
29	Clay (Moderate)	Soil - Moderate Density	C	CH	0.451	0.419	0.332	6.80E-07
30	High-Density Electric Plant Coal Fly Ash	Waste	---	---	0.541	0.187	0.047	5.00E-05
31	High-Density Electric Plant Coal Bottom Ash	Waste	---	---	0.578	0.076	0.025	4.10E-03
32	High-Density MSW Fly Ash	Waste	---	---	0.450	0.116	0.049	1.00E-02
33	High-Density Copper Slag	Waste	---	---	0.375	0.055	0.020	4.10E-02
34	Drainage Net (0.6 cm)	Geosynthetic drainage net	---	---	0.850	0.010	0.005	3.30E+01
35	HDPE Membrane	Geomembrane liner	---	---				2.00E-13
36	LDPE Membrane	Geomembrane liner	---	---				4.00E-13
37	PVC Membrane	Geomembrane liner	---	---				2.00E-11
38	Butyl Rubber Membrane	Geomembrane liner	---	---				1.00E-12

HELP Texture No.	Description	General Material Type	USDA Texture Class	USCS Texture Class	Total Porosity (vol/vol)	Field Capacity (vol/vol)	Wilting Point (vol/vol)	Saturated Hydraulic Conductivity (cm/sec)
39	Chlorinated Polyethylene (CPE) Membrane	Geomembrane liner	---	---				4.00E-12
40	Hypalon or Chlorosfulfonated Polyethylene (CSPE) Membrane	Geomembrane liner	---	---				3.00E-12
41	Ethylene-Propylene Diene Monomer (EPDM) Membrane	Geomembrane liner	---	---				2.00E-12
42	Neoprene Membrane	Geomembrane liner	---	---				3.00E-12

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