SAND2005-7544P

Potential Site #7 Cover Infiltration - HELP Software

Performance Assessment Workshop

Taiwan Institute of Nuclear Energy Research

December 13, 2005

Bill W. Arnold

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.

Outline

- **Objectives**
- **Introduction:** **Features, Methods, Limitations**
- **Software Installation and Demonstration**
- **Application of HELP to Potential Site #7 cover design to assess infiltration**

Objectives

- Understand the features and limitations of the HELP software code for landfill covers
- Become familiar with use of the HELP software
- Demonstrate application of the HELP software code to the fictitious cover design for disposal cells at potential site #7

Sandia National Laboratories

Introduction

- The Hydrologic Evaluation of Landfill Performance (HELP) software was developed by the U.S. Army Corps of Engineers with support from the U.S. Environmental Protection Agency
- Primary purpose of the HELP code is for comparison of landfill cover design alternatives with regard to water balances
- HELP software is also used to support licensing of disposal facilities that include covers

Sandia National Laboratories

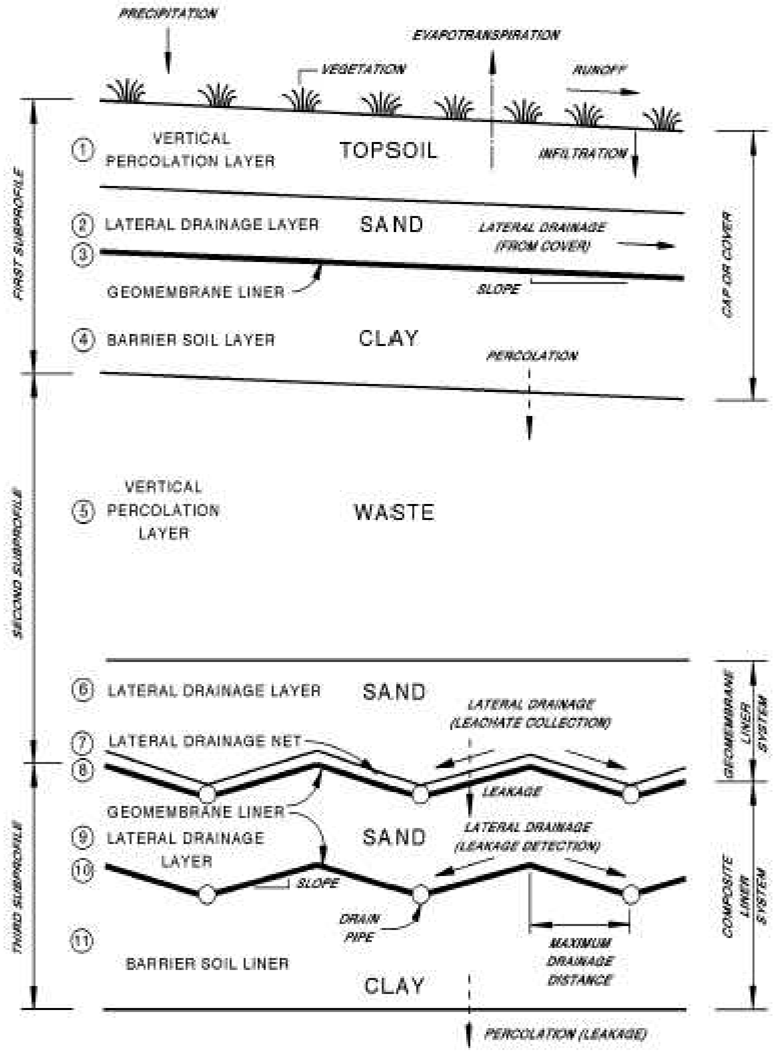
Introduction - Features

- HELP software accounts for processes such as:
  - Variable weather (daily)
  - Surface storage
  - Runoff
  - Infiltration
  - Evapotranspiration
  - Vegetative growth
  - Soil moisture storage
  - Lateral drainage
  - Vertical unsaturated flow
  - Geomembrane liner performance

Introduction - Features

- HELP is a quasi-two-dimensional deterministic water-routing model for landfills
- Components of the landfill that can be modeled include landfill cover, lateral cover drainage, waste zone, landfill liner, and liner leachate collection system
- Stochastic weather record can be generated by HELP or daily weather data can be input directly
- Water balance from simulations can be output on daily, monthly, or annual basis

Introduction - Features



Sandia National Laboratories

Introduction - Methods

- HELP uses a Markov chain model for the generation of synthetic weather data, based on correlations in rainfall data from U.S. locations
- Unsaturated hydraulic conductivity and capillary pressure are calculated using modified versions of the Brooks-Corey relationship
- Evapotranspiration from the upper layer of the model is calculated using the leaf area index and evaporative zone depth

Introduction - Methods

- Surface runoff is computed by the HELP code using the empirical SCS method, based on daily precipitation, soil moisture, surface slope, and vegetative cover
- Potential evapotranspiration is calculated as an empirical function of solar radiation, temperature, wind speed, and relative humidity
- The actual rate of evapotranspiration is treated as a function of the potential evapotranspirtation, vegetation type, vegetation growth stage, and soil moisture content in the HELP software

Sandia National Laboratories

Introduction - Methods

- Vertical drainage in cover layers is calculated using Darcy's law
- For unsaturated layers, the hydraulic gradient is assumed to be 1 and the flux is equal to the unsaturated hydraulic conductivity
- The leakage through installation defects and pinholes in geomembrane layers are approximated in the HELP code
- Lateral drainage in saturated drainage layers is calculated using the Boussinesq equation and the Dupuit-Forcheimer assumptions

Sandia National Laboratories

Important Limitations and Assumptions

- The HELP software code is generally reasonably accurate for humid sites in the U.S., but may be highly inaccurate for arid sites
- The runoff model is based on daily rainfall totals and does not explicitly account for variations in rainfall intensity on shorter time scales
- The potential evapotranspiration model uses quarterly and annual average values for relative humidity and wind speed, respectively and assumes a constant evaporative zone depth
- Vegetative growth is based on a crop growth model

Sandia National Laboratories

Important Limitations and Assumptions

- **Vertical drainage is assumed to occur in soils without the potential effects of heterogeneous medium and flow focusing in cracks, etc.**
- **Vertical drainage in unsaturated medium is driven by gravity only and does not consider capillary forces (upward or downward)**
- **The lateral drainage model in HELP assumes that the head in the drainage layer does not exceed the thickness of the layer**
- **Limitations exist on the number and ordering of layers (e.g., a lateral drainage layer must be underlain by a barrier layer)**

Important Limitations and Assumptions

- Several relations exist between moisture retention properties of a material (e.g., porosity must be greater than field capacity, which must be greater than wilting point) and must be honored in the HELP code inputs
- Simulations can be conducted for periods of 1 to 100 years
- Soil properties, layer thicknesses, etc. are assumed to be constant over the time period of the simulation

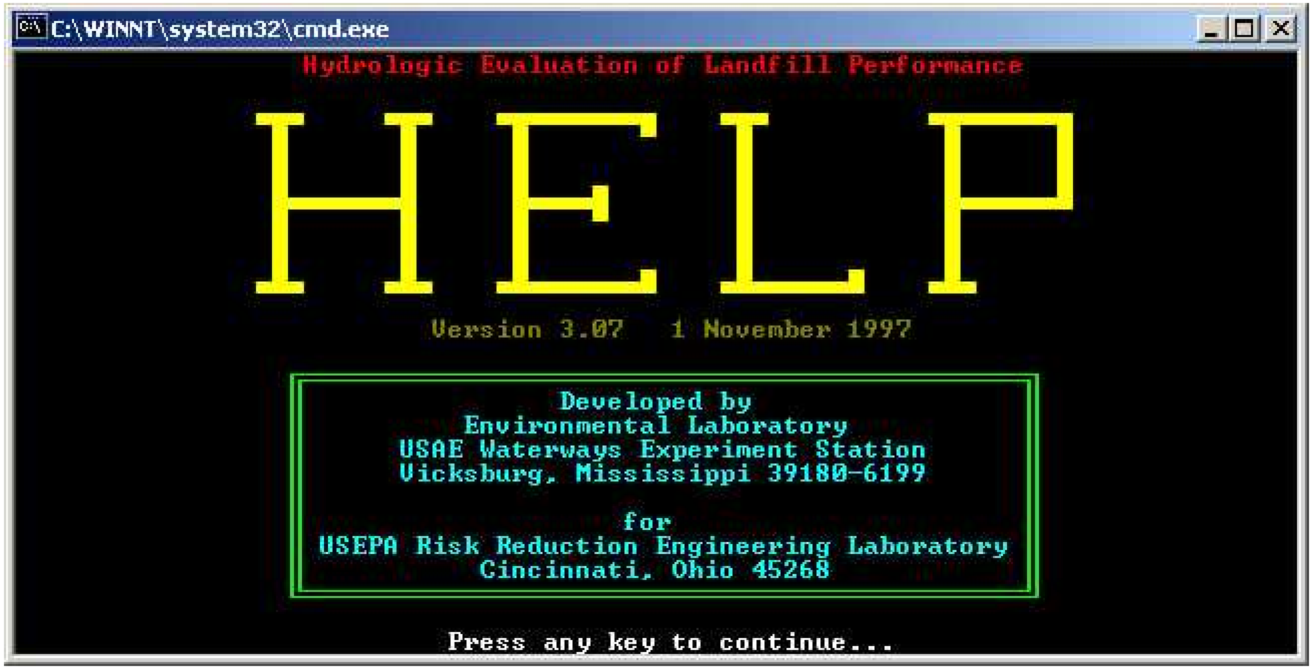
Software Installation

- HELP (Version 3.07) software code and documentation is contained on PA Workshop CD
- HELP software is available on internet from: (http://el.erdc.usace.army.mil/products.cfm?Topic=model&Type=landfill)
- Uncompress all files and install them on hard drive (C:\HELP\ )
- Run Install.exe program

Sandia National Laboratories

Software Use

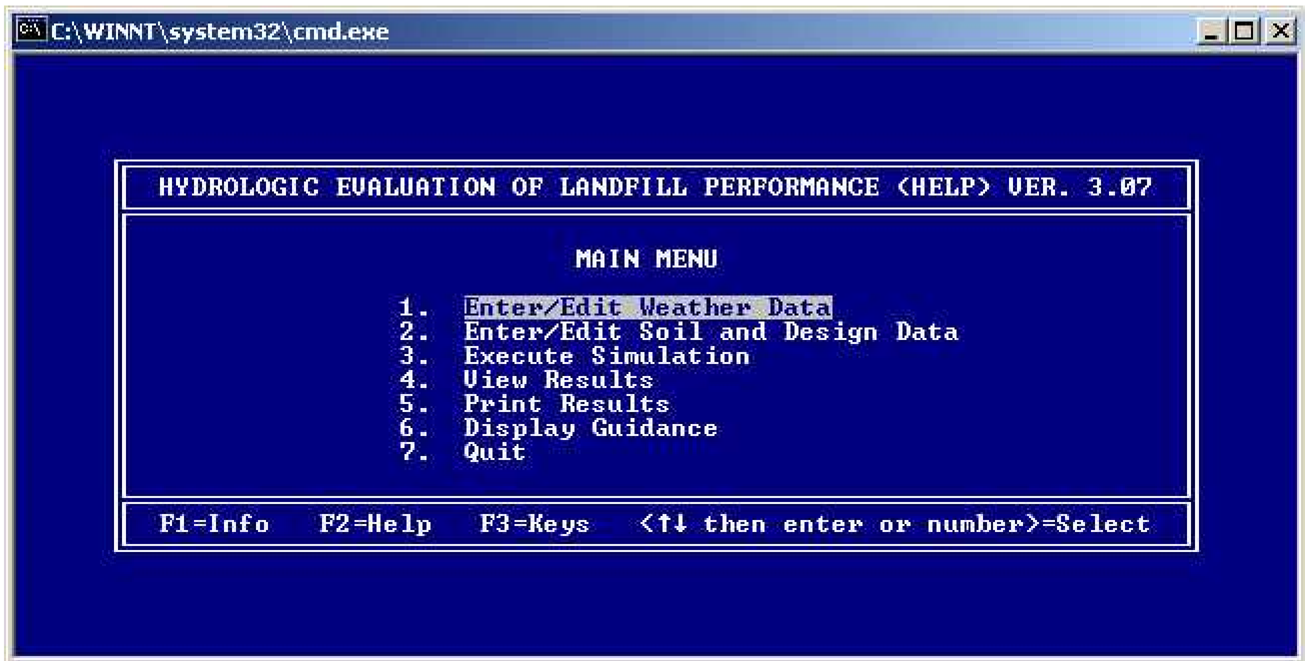
- Launch HELP software from DOS window by typing “HELP3”



Sandia National Laboratories

Software Use

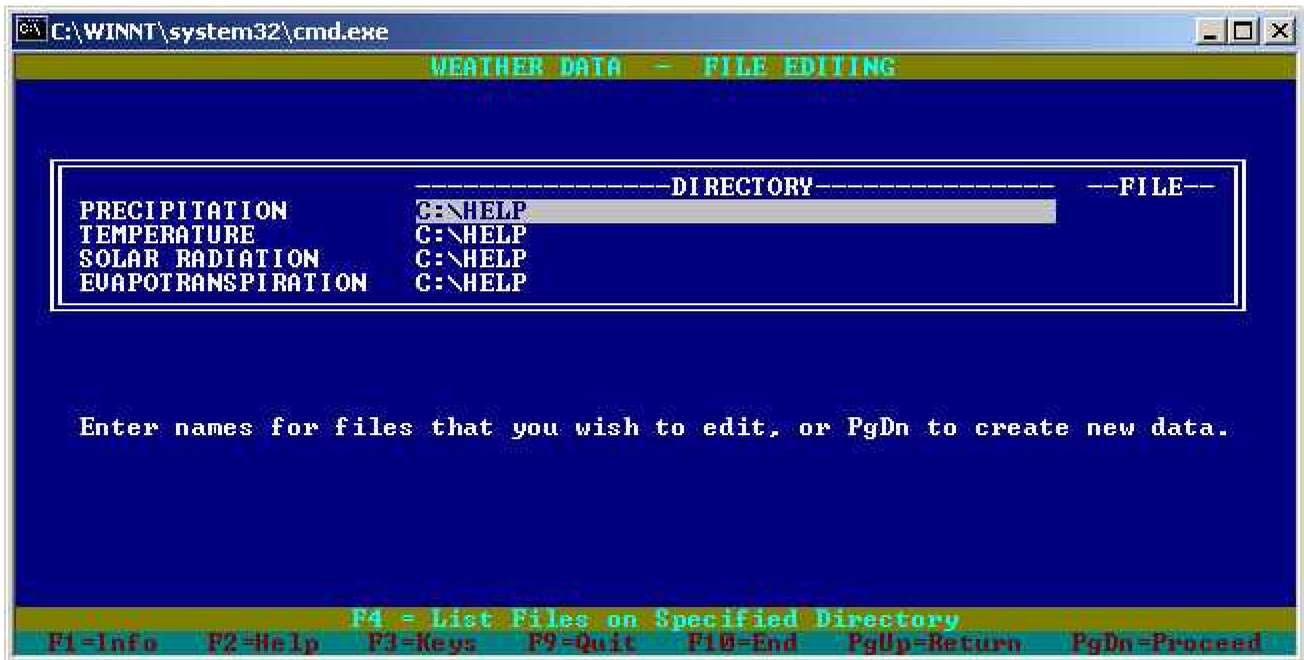
- Input files are read, created, or edited using a series of screens accessed from the main menu



Sandia National Laboratories

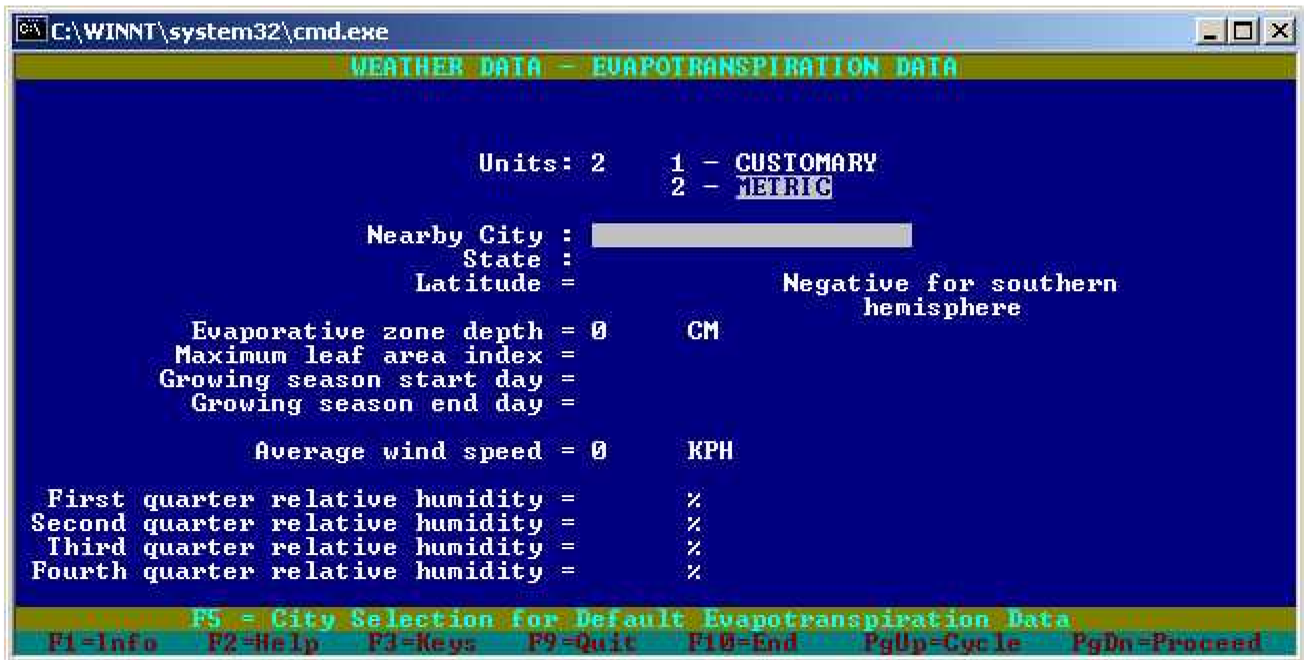
Software Use

- **Enter directory and file names to read in existing input files or proceed to create new input files**



Software Use

- **Enter weather data screen**
- **Input can be customized to a specific site or default data can be read in for U.S. locations**



Software Use

- **Data can be chosen from 139 locations in the U.S.**

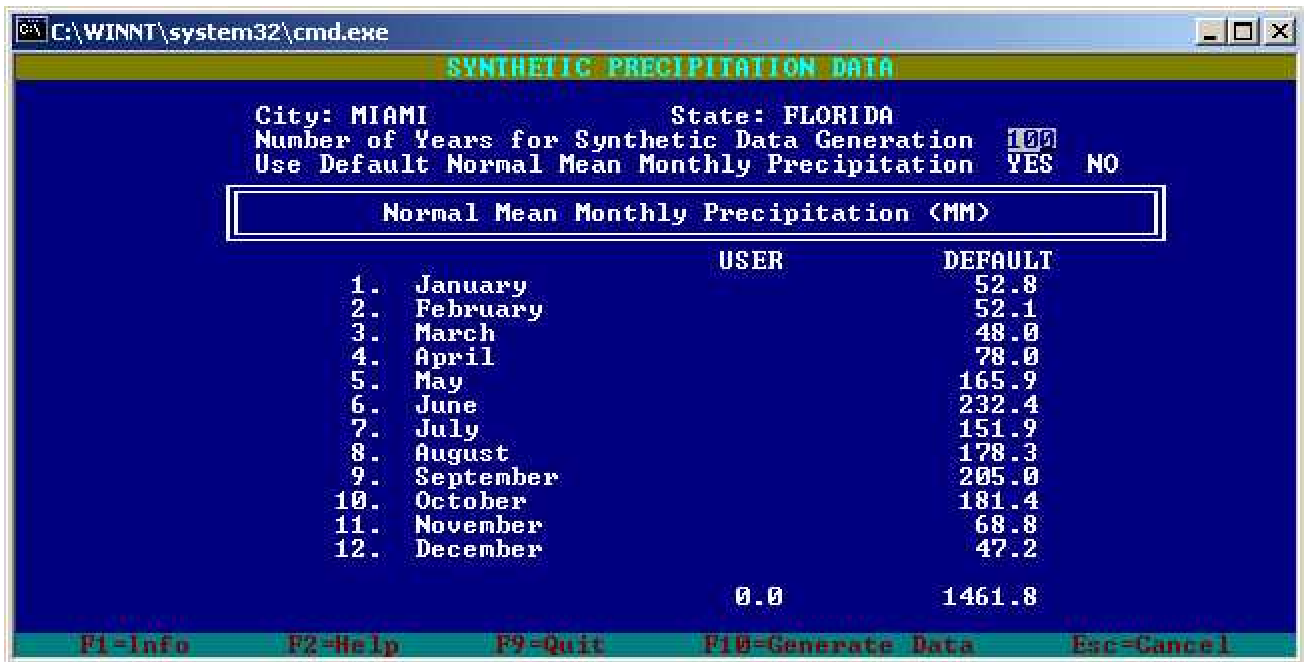
Sandia National Laboratories

Software Use

- **Default data are shown for Orlando, Florida in this example screen**

Software Use

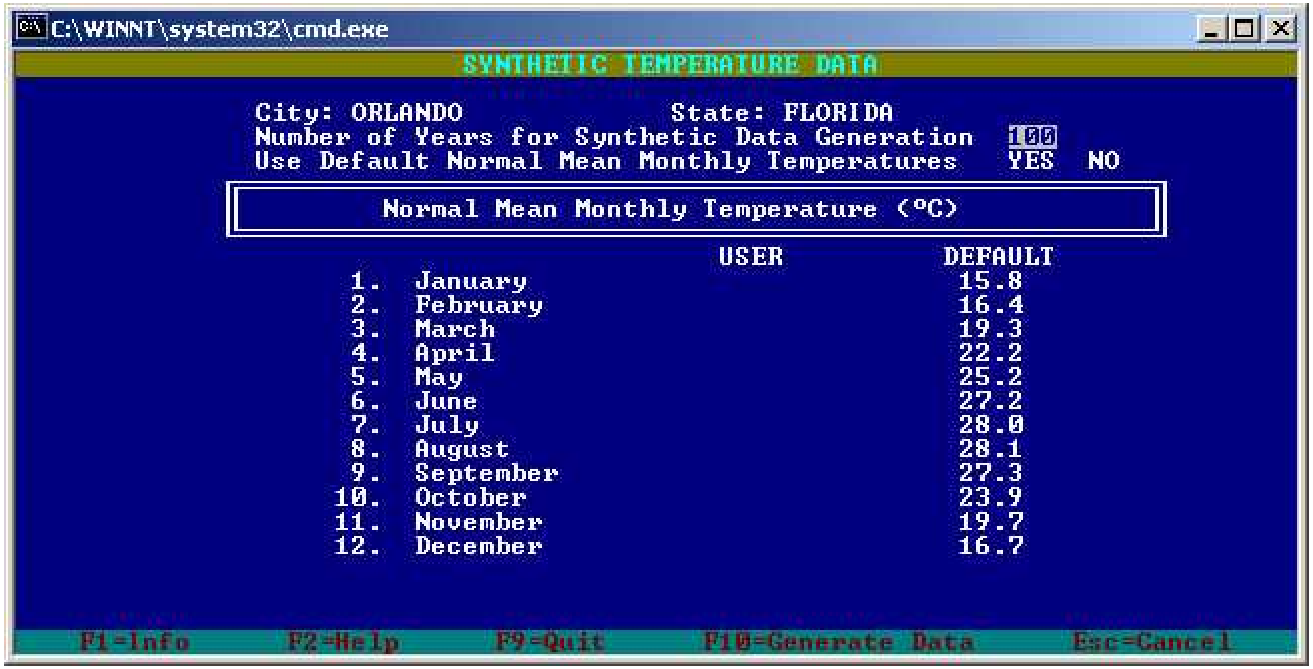
- Default data for precipitation are shown for Miami, Florida in this example screen and used to generate synthetic precipitation record for 100 years



Sandia National Laboratories

Software Use

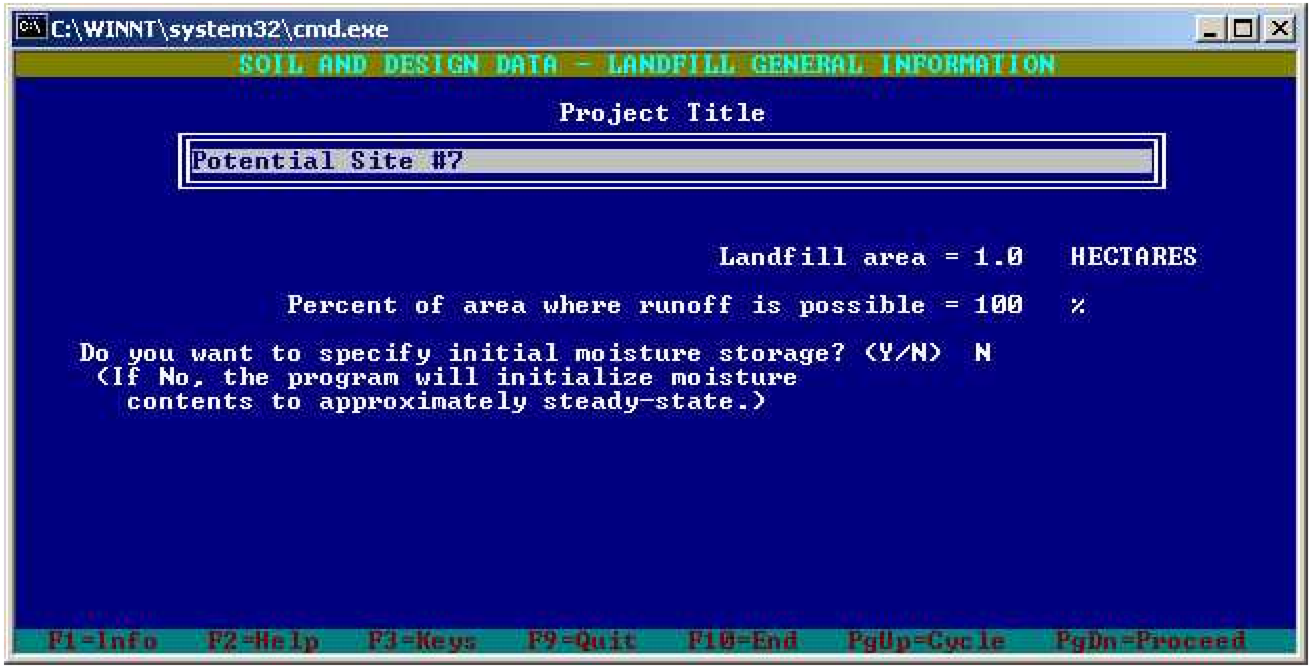
- **Default data for temperature are shown for Orlando, Florida in this example screen and used to generate synthetic precipitation record for 100 years**



Sandia National Laboratories

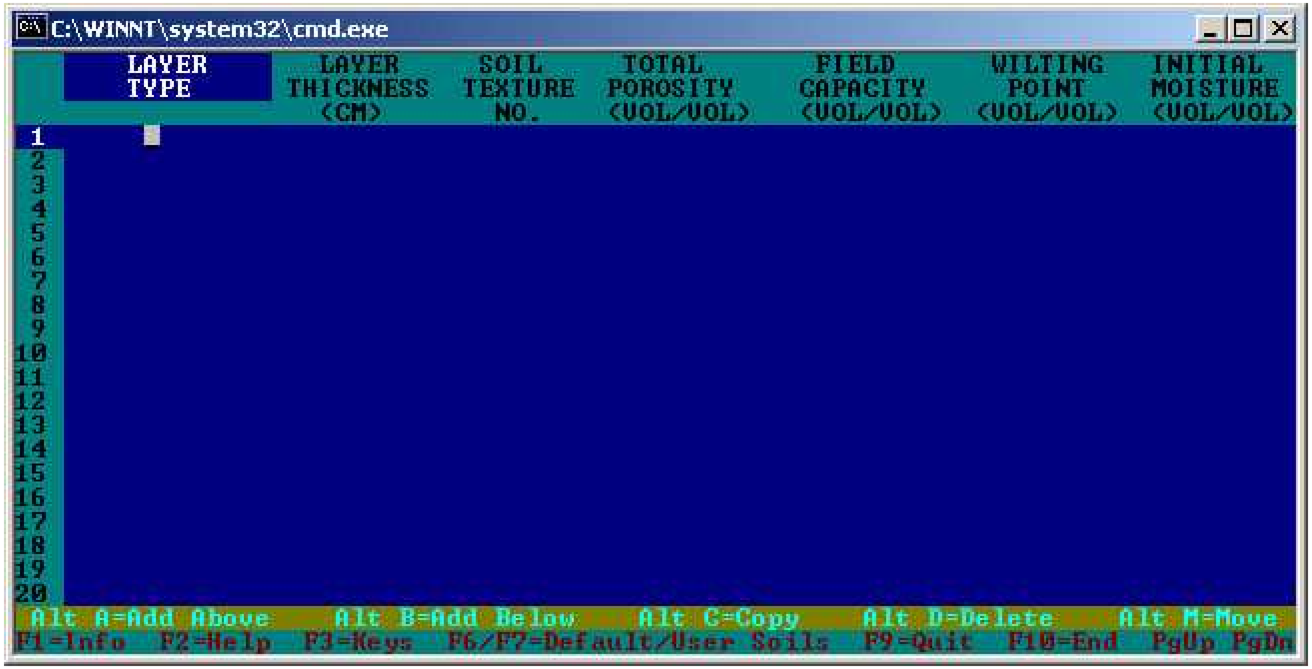
Software Use

- **Begin entering data for the landfill design and soil characteristics**



Software Use

- Data must be entered for each layer in the landfill design, beginning with the uppermost layer



Sandia National Laboratories

Software Use

- **Default soil data for various soil texture types are provided in a database for direct importation into HELP model**

C:\WINNT\system32\cmd.exe

SOIL TEXTURE			POROSITY (VOL/VOL)	FIELD CAPACITY (VOL/VOL)	WILTING POINT (VOL/VOL)	SAT. HYD. CONDUCTIVITY (CM/SEC)
HELP	USDA	USCS				
1	CoS	SP	0.417	0.045	0.018	1.0E-02
2	S	SW	0.437	0.062	0.024	5.8E-03
3	FS	SW	0.457	0.083	0.033	3.1E-03
4	LS	SM	0.437	0.105	0.047	1.7E-03
5	LFS	SM	0.457	0.131	0.058	1.0E-03
6	SL	SM	0.453	0.190	0.085	7.2E-04
7	FSL	SM	0.473	0.222	0.104	5.2E-04
8	L	ML	0.463	0.232	0.116	3.7E-04
9	SiL	ML	0.501	0.284	0.135	1.9E-04
10	SCL	SC	0.398	0.244	0.136	1.2E-04
11	CL	CL	0.464	0.310	0.187	6.4E-05
12	SiCL	CL	0.471	0.342	0.210	4.2E-05
13	SC	CH	0.430	0.321	0.221	3.3E-05
14	SiC	CH	0.479	0.371	0.251	2.5E-05
15	C	CH	0.475	0.378	0.265	1.7E-05
16	Barrier Soil		0.427	0.418	0.367	1.0E-07
17	Bentonite Mat (0.6 cm)		0.750	0.747	0.400	3.0E-09
18	Municipal Waste (900 pcy)		0.671	0.292	0.077	1.0E-03
19	Municipal Waste w/ Channeling		0.168	0.073	0.019	1.0E-03
20	Drainage Net (0.5 cm)		0.850	0.010	0.005	1.0E+01
21	Gravel		0.397	0.032	0.013	3.0E-01

TO SELECT: Cursor ↑↓ then ENTER   PgDn/PgUp = More   Esc = RETURN

Sandia National Laboratories

HELP model – Site #7 Cover Design

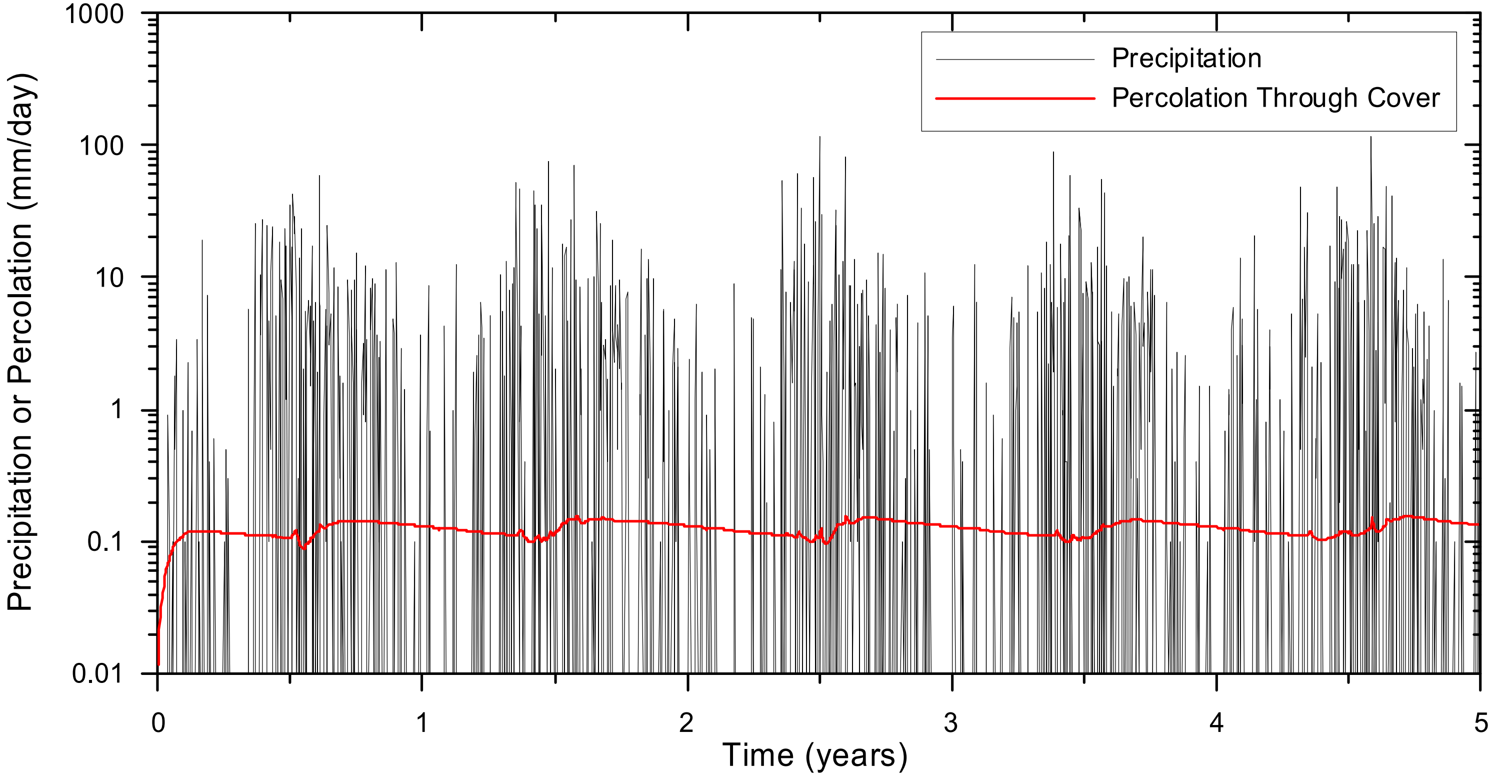
- Preliminary infiltration model for potential site #7 and cover design constructed with HELP code
- Weather data for Orlando and Miami, Florida were modified to be consistent with preliminary data from Penghu Islands area
- Fictitious cover design and alternatives were investigated in sensitivity analyses

HELP model – Site #7 Cover Design

- **Cover design consists of 6 layers above the waste and uses default soil parameters**
- **Drainage layer slope was assumed to be 2%**

Layer #	Soil Type	Saturated Hydraulic Conductivity (cm/s)	Porosity	Field Capacity	Wilting Point
1	Gravel	3.0E-01	0.397	0.032	0.013
2	Gravel	3.0E-01	0.397	0.032	0.013
3	Coarse Sand	1.0E-02	0.417	0.045	0.018
4	Sand	5.8E-03	0.437	0.062	0.024
5	Compacted Clay	1.0E-07	0.451	0.419	0.332
6	Coarse Sand	1.0E-02	0.417	0.417	0.018

HELP model – Site #7 Cover Design

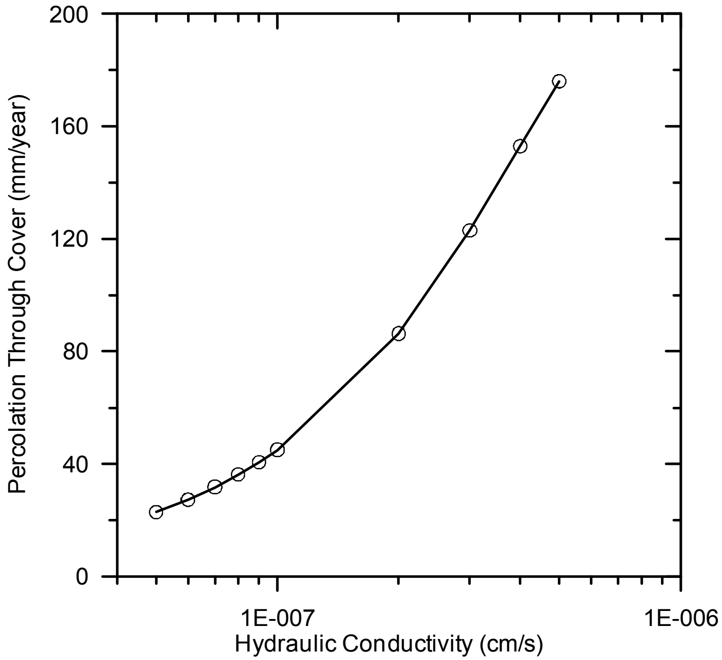


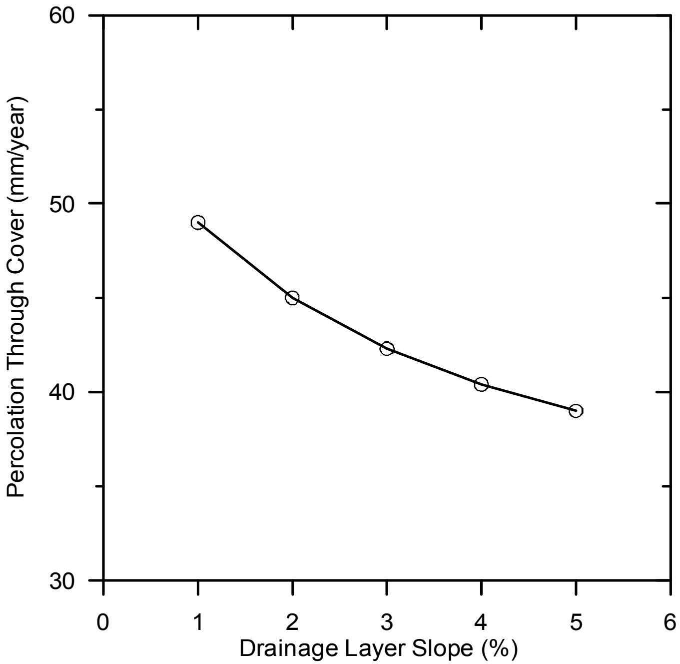
HELP model – Site #7 Cover Design

```
*******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------
                                      MM                CU. METERS     PERCENT
                              --------------------     -----------   ---------
 PRECIPITATION                 938.08    ( 140.168)      75046.2     100.00

 RUNOFF                          0.000   (  0.0000)          0.00      0.000

 EVAPOTRANSPIRATION            675.764   ( 70.0030)      54061.10     72.037

 LATERAL DRAINAGE COLLECTED    217.20668 ( 85.85015)     17376.535   23.15446
   FROM LAYER  4

 PERCOLATION/LEAKAGE THROUGH    44.99475 (  2.10840)      3599.580    4.79649
   LAYER  5

 AVERAGE HEAD ON TOP           382.714 (   60.109)
   OF LAYER  5

 PERCOLATION/LEAKAGE THROUGH    44.97131 (  2.09696)      3597.705    4.79399
   LAYER  6

 CHANGE IN WATER STORAGE         0.135   (  1.1568)         10.82      0.014

*******************************************************************************
```


Sandia National Laboratories

HELP model – Site #7 Cover Design





HELP model – Site #7 Cover Design