5. Application

The Hydrologic Data Development System has been developed as a prototype package of spatial data and reference data which can be processed within an interactive menu system to determine surface hydrologic parameters for a user-defined site. The system also creates input data files for automatic submission to THYSYS, the Texas Department of Transportation hydrologic and hydraulic analysis computer program. Peak discharge versus frequency relations may be determined using rural regression equations for Texas.

This section provides general instructions for use of the program followed by a sample application.

5.1 User Instructions

HDDS has been set up on Compact Disc Read Only Memory (CDROM) and 4 millimeter Digital Audio Tape (4 mm DAT). The system may be run directly from the CDROM or the data may be installed onto a hard drive.

Two versions of the system are available: a large data set and a small data set. The large set comprises coverage of the State of Texas at the 1:2 M scale, the North Sulphur River watershed in Northeast Texas at the 1:250 K scale, and two tributaries of North Sulphur River at 1:24 K scale. The small data set includes the North Sulphur River watershed, Northeast Texas, at the 1:2 M scale, and the North Sulphur River watershed at the 1:250 K scale.

System Requirements (Hardware and Software)

1. UNIX-based workstation
2. Arc/Info version 7 (or higher)
3. CDROM Drive or 4 mm DAT drive
4. ArcView2 (optional and desirable)
5. Encapsulated Postscript compatible printer (optional, color desirable)
6. THYSYS (optional)

7. Hard drive: The large data set requires about 240 Megabytes of storage if installed on a hard drive. The small data set requires about 40 Megabytes of storage if installed on a hard drive.

Installation

For the CDROM Version, no installation procedures are necessary if HDDS is run from the CDROM drive. The system may be copied directly from the CDROM to any accessible directory level.

The 4 mm DAT version should be installed in the following manner:

1. Set the current directory to any desired location (including the home directory).
2. Load the desired tape. The long version is saved under a main directory "thesis" with several sub-directories (amls, tables, tx, s, and g). Type: “tar xv thesis”. The Short version is saved under a main directory "crp" with several sub-directories (amls, tables, tx, and g). Type: “tar xv crp”.
3. Edit the start up AML using a text editor:

   For the long version, open [your directory]/thesis/amls/hdds.aml and change the line (Appendix A, hdds.aml, line 27) that reads
   "&sv .PTH2 = /usr2/psmith/thesis/" to
   "&sv .PTH2 = [your directory]/thesis/"

   For the short version, open [your directory]/crp/amls/hdds.aml and change the line (Appendix A, hdds.aml, line 27) that reads
   "&sv .PTH2 = /usr2/psmith/crp/" to
   "&sv .PTH2 = [your directory]/crp/"

Running HDDS

The following instructions assume that the large data set version is being run from the hard drive. For the small data set, replace “thesis” with “crp”. To run from the CDROM, replace [your directory] with “/cdrom” and replace “hdds” with “hddscd”.

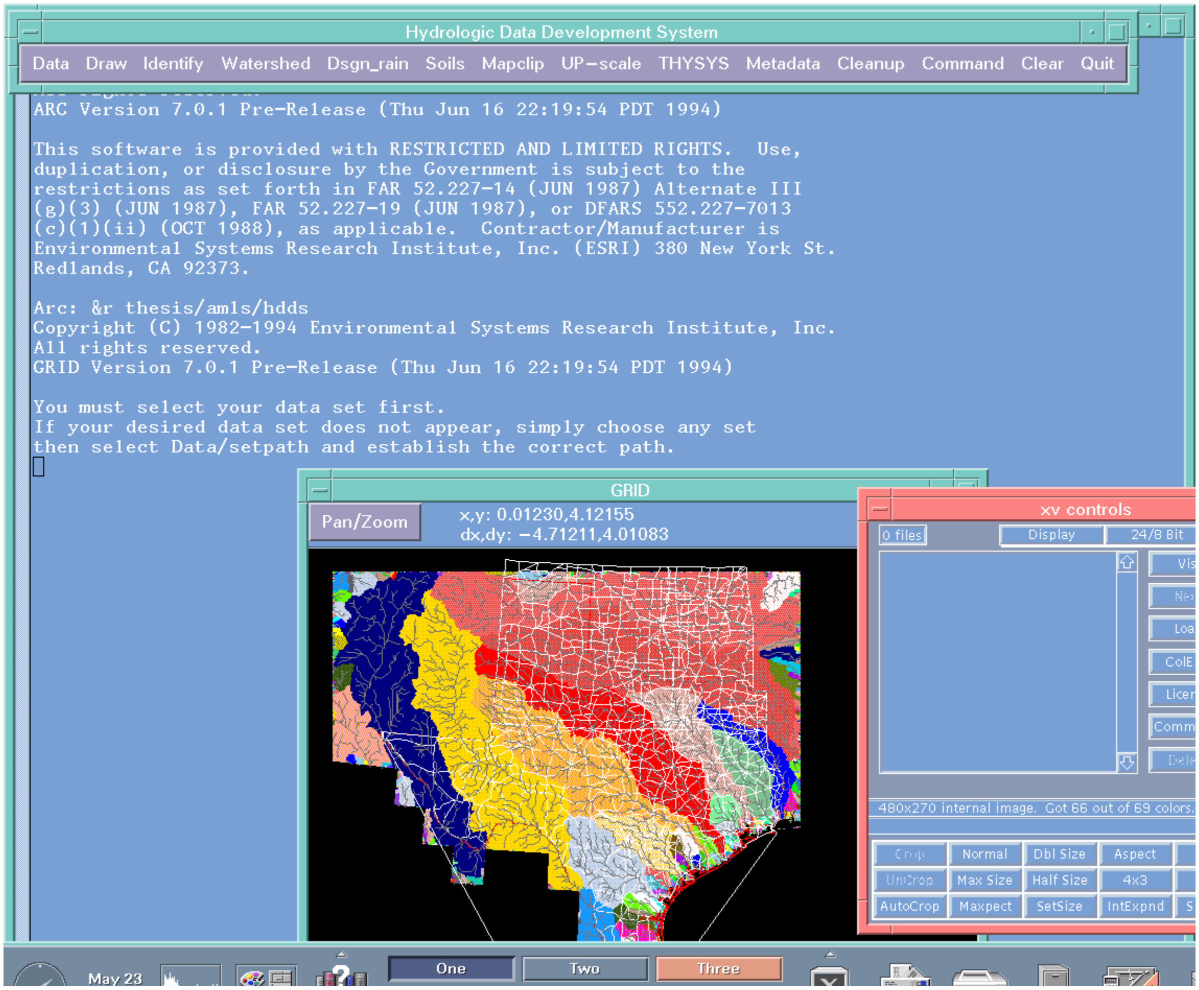

Figure 5-1: Sample menu and display screen

1. Invoke Arc/Info and create a workspace by typing: CREATEWORKSPACE <name>
2. Move to your workspace by typing: &WO <name>

   (There is also an option, “Data/Workspace”, within HDDS that allows designation of a workspace).
3. Enter the following: &r [your directory]/thesis/amls/hdds

   After a few moments, the HDDS menu and start up message will appear.

   Quit out of the start up message by selecting Quit in the bottom right of the message box. *The HDDS menu will become active.*
4. Select “Data/Existing/tx”

   This represents 1:2 M scale coverage of the State of Texas.
5. Select the following in order: (1) “Draw/Basins” (2) “Draw/Roads” (3) “Draw/Streams.”

   *The display window should appear as shown in **Figure 5-1**.*
6. Zoom to an area of interest at which a highway crosses a stream as follows: in the display window click on “Pan/Zoom” (top left). Select “Create.” Identify the opposite corners of a rectangle to define a zoom area. Redo step 5 then bypass step 6 *

   * *This step is necessary because ARCPLOT does not automatically display active views in the zoom window.*
7. Select “Identify/Roads” and click on a road of interest (in the zoom window).
8. Select “Identify/Streams” and click on a the stream over which the selected road crosses.

   It is not necessary to hit the stream and road at their intersection point, however, no nodes must exist between the point selected and the intersection point.
9. Select “Watershed/Area.” At the command line enter a desired suffix that will uniquely identify created files, e.g. a, abc, etc.. Select the opposite corners of a rectangle to include an area larger than the anticipated watershed extent. **

   ***This step helps minimize the amount of data required for processing. The backdrop of basins and streams can be used as a visual aid to approximate the extent of the watershed. The watershed will be delineated and two values of calculated area will appear: the watershed area and the zonal area. These values* *should be the same. However, if the zonal area is smaller than the watershed area, it is likely that the window was set too small such that some of the drainage basin was cropped. The zonal area is appended to the polygon attribute table (PAT) of the delineated watershed.*

10. Select "Watershed/Path_length"

    The path and maximum distance from the outfall (highway crossing) to the watershed boundary will be determined. The length will be added to the watershed coverage attribute table (PAT).

11. Select "Watershed/Av_Slope"

    The path length coverage will be used to determine the average watershed slope. The watershed coverage will be used to determine the hydrologic region (for which specific hydrologic regression equations are valid). The resulting values will be appended to the watershed PAT.

12. The data collected to this stage is sufficient for rural regression equations. Select "THYSYS/USGS" to create a THYSYS input file. At the prompt, enter a four letter file name under which the input data is to be saved, then enter any desired description. THYSYS may then be run by responding "y" at the prompt. If THYSYS is run, the THYSYS output file will be displayed and the frequency discharge data will be read and added to the watershed attribute table.

    Note: THYSYS must be compiled on the user's computer if this option is desired.

13. Select "Watershed/Subareas"

    Quit the message box when it appears and enter a desired area threshold or leave blank to default to 1 sq.km.

14. Select "Watershed/Land"_use for estimation of weighted runoff curve numbers. A pop up window will request selection of "watershed" or "subareas" by which RCN's will be weighted.

    After the desired response, the program will take several minutes while a clip coverage is created based on the current map extent and land use data will be abstracted from the statewide land use coverage using the clip coverage. Then the *vector coverage of land use will be converted into a grid. Also, the hydrologic soil group data will be abstracted from the statewide coverage.*

A command line prompt requests whether modification of land use data is desired. Answer “y” or “n”! If the response to the above is “y”, a new menu will appear and the display area will be cleared. The following steps will establish updated land use coverage and, if desired modified land use code/soil group/RCN relationships.

a) Select “View/Landuse”, “View/Watershed”, and “View/Streams” in order. The land use may look sparse!

b) Select “Check_value” and click on a location for which you wish to determine the assigned land use code. Click on as many locations as desired and enter “9” to stop.

   You may review the land use descriptions and associated RCN’s that are represented by the land use codes by selecting ”List_codes”. At the command line prompt, keep hitting the enter key until you have seen all the records of interest. Type “n” to stop, or scroll to the end of the table. Pay attention to the codes and associated record numbers that you may wish to use to update the coverage and/or modify the land use table.

c) If you wish to modify the land use coverage, select “Setvalue” and, at the command line prompt, enter the numerical land use code to which subsequent user-defined areas will be assigned. Otherwise skip to part (f).

d) Select “Draw_polygon/Land_use” and identify the points to contain the area to which the active land use code value is to be assigned. To complete the polygon, type “9” on the keyboard. If you wish to draw more areas for the same land use category, respond “n” at the “Finished?” prompt and draw your new polygon(s). At the “Finished?” prompt, type “y” when done.

e) To add more areas using different land use codes, redo steps (c) and (d) for each desired land use code.

f) If you desire to add to the land use code table (rcns.dat) or modify the RCN’s to which the land use codes are assigned, select “Add_lucode”. A warning prompt will ask if you are sure changes are to be made because they will be made to the permanent data set. If so, answer "YES" not "y" or "Y" or "yes". A message box will appear with instructions. On closing this box, another menu will appear.

g) To adjust the RCN's assigned to land use codes, select "MODIFY_RCN". Enter the desired record number (from step (b)) at the command line prompt. The existing items and values will be displayed. At the "Edit?" prompt, type in the name of the item followed by a space and the value you wish to assign. You may reassign as many values in a record as you wish. To complete the record hit enter at the "Edit?" prompt. At the "record number" prompt, enter a new record number and repeat the process, or hit enter then type "quit" to finish modifying the table.

h) To add new land use codes and associated RCN's (velocity coefficients too), select "ADD_LUCODE" and type in the values of lucode, RCN's for each hydrologic soil group, and a velocity coefficient when prompted. You may continue to add records at will. To finish, simply hit enter then "quit" at the command prompt.

i) On completion of the above steps (g) and (h) select "Done" from the menu to revert to the previous menu.

j) You may check your updated land use coverage by selecting "View/Landuse". Steps (c) through (i) may be repeated as desired. On completion, select "Done".

Whether or not the land use data were modified, the land use grid and soil grid will be used to determine the weighted runoff curve number for the watershed or for each subarea in the watershed, whichever was requested.

15. Select "Watershed/Travel_time." At the command prompt for use of land use coverage enter "y". You can enter "n" if you wish, in which case the default surface coefficient for grassy waterway is applied to the whole watershed for estimation of velocity. The velocity is determined as a function of cell slope and surface velocity coefficient as described in Section 4.2. At the command prompt for defining velocities you may select "y" to assign velocities interactively by drawing polygons or default to the velocity surface coefficients assigned to the land use categories.

Designation of velocities is similar to land use modification: the same menu will appear and it is necessary to display the land use, watershed boundary and streams as shown in step (14a). Select “Setvalue” and enter a desired velocity (in meters per second). Select Draw_polygon/Velocity and identify the points to contain the area to which the active velocity value is to be assigned. To complete the polygon, type “9” on the keyboard. As many polygons and velocities may be established similar to steps (14c), (14d), and (14e). On completion, select Done. The times of travel will then be computed based on the user-defined velocities and the remaining existing velocity coefficients.

16. Now, if desired, and if higher resolution data have been preprocessed, select “Upscale/Call_data.” At the prompt, type in the name of the higher resolution data set. For example, if the North Sulphur River had been selected from the 1:2 M data set “tx”, the new data set “g” (1:250 K) could be requested. The screen will be updated to reflect the higher resolution data. Steps (7) through (15) may be performed on the new data for comparison.
17. Select “Watershed/Shape_fac” to determine the watershed shape factor.
18. Select “Watershed/Scale_factor” to compute the path length at the surface of the reference ellipsoid. The watershed boundary and flow length must have been established prior to invoking this option.
19. Select “Dsgn_rain/TP40” and choose “watershed” or “subareas” to define the means by which design rainfall data will be weighted. The weighted rainfall for 24 hour duration design frequencies of 2 years, 5 years, 10 years, 25 years, 50 years, and 100 years will be determined and added to the watershed or subarea PAT, as appropriate.
20. The option “Mapclip” will use the watershed boundary to clip any available data such as stream gauges and county boundaries.
21. “Upscale/Find_quads” will determine the name of quadrangles required for retrieval for 1:250 K or 1:24 K DEM's using the current watershed boundary. At the prompt, enter the name under which will be saved an ASCII file containing the names of standard USGS quadrangles in which the delineated watershed is represented. The appropriate DEM data can be acquired and the file can then be used in the preprocessor to establish a new data set for use in HDDS. The DEM data filenames

must match the names in the ASCII file. Thus the 1:2 M data is useful as a first level screening to identify what data is required for higher resolution analysis.

22. Metadata displays some provisional data for two coverages, the 1:250 K scale highway data and the 1:2 M scale hydrologic regions. A series of sub-menus allows the user to view available metadata in any desired order.

Alternate Outfall Designation

The outfall may also be located using “Identify/Cell,” “Identify/Line,” or by using the “Identify/Movegage” option. The use of the “Cell” option usually necessitates a zoom window such that each individual cell can be identified. At the prompt, enter a filename suffix (e.g. a). Then identify the desired outfall locations using the mouse. As many cells as desired may be selected after which the number 9 must be selected on the keyboard. If only one cell is identified, the “Watershed/Area” option must then be selected for subsequent watershed delineation. Otherwise, the “Watershed/Subareas” option should be invoked. The line option is much the same except that a polygon (minimum of three points) must be drawn using the mouse.

Movegage

The “Movegage” option allows the user to create a grid of gauges by selecting an appropriate gauge and then selecting the stream cell at which the gauge should be located. The following steps indicate its use.

1. Invoke HDDS, select a data set, and establish a work space as described earlier.
2. Select “Identify/Movegage.” A new menu will appear.
3. The map extent will have been set to the extent of the selected data set, but may be modified using the “Mapextent” option.
4. Use the “Draw” option to display the streams and gauge locations.
5. Select “Setwindow” and use the mouse to identify an area that encloses the desired gauges. This reduces the amount of data processing required.
6. Select “MOVE.” Use the mouse to hit two points to define a search tolerance, then select a desired gauge. At the prompt, use the mouse to click on the cell in the stream network to which the gauge is to be moved. Hit 9 on the keyboard to complete the move. At the “Finished?” prompt, enter “y” or “n”. As many gauges may be moved as

desired. On completion, a grid of moved gauges is created in which the gauge attributes of the original point coverage are present.

7. Check the distribution of moved gauges using “DRAW/GRDgage” and list the attributes using “LIST.”
8. If the gauge locations are to be used as pour points for area determination, the “PPset” option will create a pour point grid for subsequent use. The window should be reset to the approximate extent of the basins of all selected gauges. If only one pour point has been established, the “Watershed/Area” option should be selected, otherwise choose “Watershed/Subareas.”

Data Preprocessor

The option “Data/Preprocess” invokes the preprocessor routine that prepares DEM data for use in HDDS. Also a user-selected existing highway Arc (vector) coverage is gridded.

The preprocessor requests the following responses at the command line:

1. Prefix name for data set. Enter a short, one or two letter name.
2. Directory path to DEM data files. Type in the full path.
3. Name of highway Arc coverage to be used. Type in the path and file name (e.g. /usr2/psmith/highways).
4. If the “Up-scale/Find_quads” option has been invoked in the current session, the routine requests if the file of quadrangle names is to be used. If not, the user may specify a file containing the names of the DEM data files or the name of a single DEM file should be entered on request.
5. If the “Upscale” option was not used, the routine will request the scale of DEM data used. This assumes the use of USGS DEM’s. The scale value establishes which projection files are to be used to transform the data to the HDDS projection.

On completion of the routine, the data will be available for use in HDDS as a selection option under “Data/Existing.” Currently, the system is limited to use in Texas since the preprocessor does not accommodate land use, soils, and rainfall data.

Creating a New Workspace

The experienced Arc/Info user may create a workspace outside HDDS. Also, there is an option "Data/Workspace" which invokes a small menu: "Create" allows the user to specify the complete path and name of a new workspace. To change workspace, select "Change to" and select a workspace from the given options. The options include the home directory, the newly created workspace name, and "other". "Other" allows the user to specify any existing workspace. The "Cancel" option restores the home directory as the active workspace. "Done" restores the main menu.

Accessing Other Data Sets

Often, the user will work within the preset system which includes data sets and program routines. However, it may be desirable to use the program routines from the hard drive to access data on the CDROM, or vice versa. The option "Data/Set_path" allows the user to override the path to the data sets. At the prompt, the full path to the desired data set must be provided, ending with a slash (/). For example, HDDS is being run from the hard drive but the large data set "tx" is desired from the CDROM. In this case, the path name to enter is "/cdrom/thesis/". This option can be invoked at the beginning of a session or at any time while the main menu is active.

Other Utilities

In addition to displaying basins, roads and streams from the active data set, the main menu "Draw" option includes "other". After selection of this option, the user is requested to select the type of coverage desired (GRID, point, line, or polygon coverage) after which appears a list of appropriate coverages that are available in the current workspace and the option "other". Selection of "other" requires the user to specify the full path and name of the desired coverage.

The "Command" option relinquishes menu control to the user until the command "&return" is entered. This allows a user to perform any Arc/Info operation outside the control of HDDS. One specific use of this is to rename or copy coverages: the option "Cleanup" will delete all coverages created using the active prefix (data set name) and suffix. Prior to invoking "Cleanup", the user may wish to rename specific coverages such as the watershed and subarea polygon coverages. On invoking "Cleanup", the existing files are displayed and the current suffix is displayed. The user may opt to enter another suffix. At the delete prompt, the user should enter "YES" to delete (not "y" nor "yes"). To remove data from previous sessions, select "Data/existing" and choose the appropriate prefix, then select "Cleanup".

The "Clean" option clears the display window and Quit returns the user to the ARC system environment.

5.2 Sample Application

The need to determine frequency versus peak discharge at highway crossings of streams is a common requirement for computation of water surface profiles and flow velocities, hydraulic design of bridges and culverts and channel impact analysis, estimation of sediment transport potential, and estimation of potential scour at bridges.

For existing highway crossings, the potential for local bridge scour and general channel degradation is of concern for the integrity of bridge foundations. The Texas Department of Transportation is currently evaluating thousands of bridges throughout the state for potential scour failure of bridges due to flooding. Generally, the most time-consuming aspect of such evaluations often are the data acquisition and manipulation for hydrologic and subsequent hydraulic analyses.

Any number of sites could have been chosen for which an evaluation is required. However, the North Sulphur River, in Northeast Texas, is of particular concern: prior to the 1930's, the North Sulphur River comprised a shallow, poorly defined, highly sinuous main channel of less than 10 feet deep and an average bank-to-bank width of less than 100 feet. Channel banks were heavily vegetated with trees and dense brush and the flood plain was wide (of the order of 5000 ft.). Local drainage districts, under pressure from farmers, straightened out a 28 mile stretch of the river to create an earthen channel with minimal vegetation on its banks. The farmers subsequently removed much of the dense brush and trees for agricultural use of the land.

Over the last six decades, the river has degraded vertically to depths of about 30 feet below original levels and associated slope failures have widened the main channel to an average of about 300 feet. This is a result of significantly increased stream power from a steeper stream bed and increased runoff, and reduced erosion resistance from exposed soils.

Such unstable channel conditions are a constant threat to the integrity of existing bridge foundations in the stream bed. Also, it is desirable to try to predict the future rate of degradation of the system in order to determine appropriate design measures for bridge replacements and new crossings. The analysis process has been initiated here to the extent that some of the important hydrologic characteristics of this river have been established.

HDDS was applied at State Highway 24 which crosses the North Sulphur River approximately 14 miles south of Paris, Texas. The steps outlined in Section 5.1 were employed to determine the following:

- watershed area, watershed path length, scale-factored length, and average slope using 1:2 M scale data.
- watershed area, path length, and average slope using 1:250 K scale data,
- subareas using 1:250 K data,
- SCS runoff curve numbers, weighted by watershed area and subareas,
- times of travel for main watershed and subareas,
- design 24 hour rainfall weighted by watershed area and subareas, and
- frequency/discharge relationship using regression equations.

The 1:2 M data were used to compare with those taken from the finer resolution 1:250 K data.

In addition to the data determination at the North Sulphur River at SH 24, the 1:2 M scale data contained in the large data set (tx) were used to determine the watershed areas for several locations within the Trinity River watershed at which stream gauge stations are extant. Gage Mover steps (1) to (8) were employed to create a grid of stream gauge locations at the appropriate sites. The area attributes of the stream gauge grid VAT were then compared with the HDDS calculated areas.