7. Assessment and Conclusion

7.1 Software

The intent of this work has not been to evaluate the Arc/Info and ArcView2, however, some comments are provided here:

Arc/Info

1. The use of the Arc/Info subsystem TABLES in the menu system is very slow. Several seconds elapse while just invoking TABLES. The system currently jumps in and out of TABLES as data is created. It would be less time consuming to minimize the number of times TABLES is invoked.
2. The recommended AML writing protocol is to indent each nested level of routine so that it is clear when a loop or conditional routine begins and ends. TABLES does not seem to like this! Indented routines using TABLES would return errors or lock up. This problem was averted by left justifying all TABLES routines.
3. TABS do not seem to be read as spaces on all platforms. On SUN stations, for example, a menu name must be separated from the desired action by at least one space, but a tab might be read as no space such that the menu name appears as the name and action information. All tabs in menus were replaced with spaces to eliminate this problem.
4. In TABLES, to add a new item, the ADDITEM must be invoked without having first selected the file to which the item is to be added. To update, add or alter, the file must first be selected.
5. INFO tables (as opposed to PAT's, AAT's etc.) can be referenced from any workspace, but I have had difficulty in modifying them from anywhere other than the directory in which the tables reside, yet I can modify PAT's or AAT's from anywhere!
6. Tables defined using TABLES or INFO are elusive! The defined table name does not appear in the directory list, therefore, it is hard to keep track of the nomenclature.
7. Using RESELECT in ARCPLOT, it is better to reference an integer id rather than character id: for some reason when I was trying to select Texas, no match was possible (nor Texas,

TEXAS, texas !). Note that the Info tables seem to use upper case, even if the user defined the items using lower case.

8. The integer function (INT) in GRID applied to a zone grid, e.g. ZONALAREA seems to result in fewer zones than the original GRID.

ArcView2

1. On maximizing the layout window, the layout frame remains unchanged. The zoom to page feature must be used to enlarge the frame. In one instance when I minimized the layout window, the frame reduced, but the contents disappeared!
2. Although the data sets are georeferenced, the automatic scale bar option in layouts indicates “unknown” scale.
3. On importing binary Color Graphics Metafile format files into Microsoft Word after having exported them from ArcView2, some data does not show: parts of some coverages do not appear.

7.2 Spatial Data

The means of acquiring and processing the data for HDDS are secure. The main limitations for HDDS were availability, large storage and processing memory requirements, and scale. For simplicity, some data were acquired at only one scale yet were re-sampled for use at other scales. For example, the original highway coverages were based on 1:2 M data yet were re-sampled to the 93 m cell size used for the 1:250 K data. The land use vector coverages were based on 1:250 K data but are re-sampled during execution of HDDS to the resolution of the selected DEM data. Generally, it is satisfactory to re-sample from a high resolution to a lower resolution, however, when re-sampling from a low resolution to high resolution, it should be recognized that the accuracy can be no better than that of the original data. Since HDDS is a prototype and is intended for demonstration of potential applications, the additional effort to create extensive high resolution coverages was not expended.

The sampling frequency and accuracy of the DEM data is the subject of some concern for the author: the delineation of streams from DEM data is sensitive to the resolution of the DEM data. At large cell sizes, chances are high that a stream could be missed entirely. For example, the true location of a 100 m wide stream might be missed by many cells on a 1 km grid resolution. In extreme cases, a flow path represented on a grid might run in a completely different direction to the real stream path. Therefore, it is important to ensure that the resolution of the DEM data is accurate enough for the intended purpose of the analysis. The streams generated from the 500 m DEM grid of Texas show favorable comparison with digitized streams and only a few major drainage basins show discrepancies between the DEM delineated ones and the digitized basins. In some instances, the discrepancies may be attributable to the DEM filling process. Also, in some areas, the topography may be too flat compared with the vertical accuracy of the data. In addition to these possibilities, differences between calculated areas and stream gauged areas could be attributable to the presence of non-contributing area.

Comparison of the analysis of the North Sulphur River at the 1:2 M and 1:250 K scales is favorable. Comparison of may more sites should be made before a more detailed statement can be made, However, the indication is that, for the type of topography existing in Northeast Texas, it may be reasonable to use 1:2 M DEM data for determination of drainage areas, path lengths and average watershed slopes for areas of the order of 800 sq. km and larger. For initial estimates of hydrologic conditions such as those needed for environmental assessment for proposed projects and preliminary sizing estimates, it would appear that verified 1:2 M data may be used for areas as small as a few hundred square kilometers. Also, the speed at which the 1:2 M data can be processed emphasizes the potential use as a first level screening for identification of data needed for higher resolution analysis.

At this stage, no definitive statements can be made as to the lower limits of applicability of the 1:250 K data, but a lower limit of about 1000 cells seems reasonable. This is equivalent to an area of about 10 sq. km at the 1:250 K scale. Also, it is fair to state that the accuracy should be comparable with what might be expected using the same scale paper maps.

7.3 HDDS Procedures

The success of application of HDDS for hydrologic parameter determination is primarily dependent on the accuracy of the base data sets on which the analyses are performed. The procedures incorporated in HDDS attempt to emulate those which have been employed using manual techniques. As such, the procedures should be at least as reliable as those determined by manual procedures. In fact, using a system such as HDDS, it is easier to provide a detailed rendering of features such as land use and reach flow velocities than by manual techniques. For example, for simplicity, a designer might divide a flow path into three reaches for which three average velocities are estimated and applied to calculate a time of concentration. In HDDS, it is not much more time-consuming to define ten or more reaches to accommodate changes in velocity. Also, the user has the ability to add and modify coefficients such as runoff curve numbers and velocity coefficients and simply draw areas to which the values should be assigned. With such capability, a designer is likely to define changes in conditions than that person would if only manual processes were to be employed.

7.4 Limitations and Future Needs

HDDS employs ARC Macro Language, which is powerful and reasonably straight forward. However, it is likely that many of the processes could be made more efficient by the creation of direct functions in the original programming language. Furthermore, the present system is reliant on proprietary software (Arc/Info), which is without doubt a powerful GIS package. However, only a fraction of the Arc/Info functionality is required for HDDS. A self-contained system providing only the desired functions would be much more compact, efficient and possibly more accessible to the engineering community.

As is often the case, time limitations precluded extending the system beyond its current capabilities and extent of data. An immediate data need is to add the highway names to the highway coverages: this would allow easy identification of appropriate sites. Currently, only several arcs have highway names. The process of adding attributes is simple but extremely tedious.

The data developed for HDDS is limited to Texas at the 1:2 M scale and the North Sulphur River at the 1:250 K scale. It would be desirable, and feasible using CDROM, to create 1:250 K scale data for the whole of Texas. 1:24 K scale data is desirable too, however, coverage of Texas at this scale requires over four thousand quadrangles. The DEM data are becoming available at the 1:24 K scale but similar detail would be required of highway data, land use/land cover data, and soil data.

A means of creating a stream network is probably the most needed additional capability: HDDS provides the capability to determine areas, path lengths, times of travel, weighted runoff coefficients and weighted design rainfall. These are the most commonly needed variables for hydrologic analysis. However, at present, the user must visually inspect the resulting data to establish the subarea linkage and stream linkage. It is feasible to employ a grid system or a vector system to generate the stream network by which appropriate connectivity can be established within the system.

This project has focused on establishing a system within which hydrologic data can be established for current lumped hydrologic models: spatial data are drastically reduced to represent average conditions of a given area. The full power of GIS could be utilized with spatially distributed hydrologic models. Some of the methods employed in HDDS could be employed in such models.

7.5 Conclusion

The Hydrologic Data Development System is a prototype package of Arc/Info coverages, AMLS, menus and tables established to indicate the potential of GIS as an engineering analysis tool. Only limited data were available for this project, nevertheless, the system demonstrates the phenomenal speed and precision with hydrologic parameters can be determined.

HDDS allows determination of drainage boundaries, areas, flow path lengths, times of concentration, design rainfall amounts, weighted runoff coefficients, and other important parameters. The system can quickly establish data input sets for THYSYS, invoke THYSYS, and read the resulting design frequency versus discharge data. Data development and analysis times are reduced dramatically from current manual procedures.

Accuracy is probably the biggest concern with this process: no specific accuracy can be stated at this time, however, it is reasonable to say that the primary limit on accuracy of results is the accuracy of the original data coverages, especially the digital elevation models. The larger the scale, the more accurate the data. Comparison of many watersheds would be required for a more definitive statement, but for large areas (say 1000 km^2), use of 1:2 M DEM, 15 arc second data might suffice for all but very rigorous analyses. In any event, as long as the digital data are at least as accurate as paper maps, the results should be as accurate and possibly more accurate than those obtained by manual analysis. Furthermore, the potential for human error may be reduced. At present, the lack of DEM data at the 1:24,000 and larger scales probably precludes use of such a system on areas smaller than a few square kilometers. At the other extreme, it probably is not warranted to employ 1:24,000 scale data for a large area of thousands of square kilometers. The disk storage, random access memory and processing time required increase drastically with increasing area and resolution, yet preliminary indications are that the order of error of estimate of area is small for large areas.

GIS relies absolutely on correct georeferencing: it is paramount that all data are converted into a common projection using the same horizontal and vertical datum. All data employed in HDDS were transposed into a common projection, Albers equal area, to ensure consistency.

Finally, a large initial effort is required to establish suitable coverages for the database and periodic updates may be necessary. However, once the initial data is established, changes are relatively easy and analysis is no longer a chore.