2. Literature Review and Questionnaire

Geographic information systems have been implemented mostly by large entities such as Federal, State, and local government agencies. The predominant use is for mapping and management of spatial data. However, there is increasing interest in the potential application of GIS in engineering design and analysis, especially in hydrology and hydraulics. The goal of this work is to establish and demonstrate a means by which GIS can be used to support the determination of flood frequency relationships for use in the hydraulic design of highway drainage structures, especially for bridges and culverts draining large, mostly rural areas.

Several pioneers are worthy of note for their foresight and work in the development of hydrology-related application of GIS for engineering applications. The initial focus seems to have been on the delineation of drainage boundaries and runoff flow paths using digital terrain data. Jensen and Domingue (1988) and Jensen (1991) outlined a grid scheme to delineate watershed boundaries and stream networks to defined outfalls (pour points). The scheme uses digital elevation data to determine the hypothetical direction of flow from each cell in a grid to one of its eight neighboring cells. The cells contributing flow to the pour point can be counted, representing area, and the cells having no contributing flow define drainage boundaries. Cells having a flow accumulation in excess of a threshold establish stream network cells. Tarboton et al. (1991) computed stream slopes and stream lengths using a similar grid system. Jones et al. (1990) employed a triangulation scheme on digital elevation data to determine watershed boundaries and flow paths.

Other investigators have focused attention on employing processes that are unique to GIS. That is, the ability to relate spatial features to their properties and perform overlays of different spatial hydrologic themes. Ragan (1991) developed a personal computer-based GIS named GIS-HYDRO. This allows a user to assemble predetermined land use, soil and slope data clipped within a user-defined boundary. A digitizer is used to delineate the watershed boundary, flow paths, and define land use changes. GIS-HYDRO provides basic file setup for use in the computer program TR 20 (1986). Maidment (1993) provided an intellectual basis for linkage between GIS and hydrologic modeling: a scope within which GIS could be employed for determining parameters for lumped surface hydrologic models, groundwater flow, storm water pollutant and sediment transport, and urban storm drain systems. Additionally, he indicates the potential for development of new spatial hydrologic models, the use of which would not be contemplated without GIS capability. Of specific relevance to this thesis is Maidment's recommendation for development of a new look-up table for using land use types classified by the Anderson system to establish runoff curve numbers for the US Department of Agriculture Soil Conservation Service hydrologic methods. This project provides such tables using existing Anderson Level II codes and by developing new, more detailed level codes that are related to runoff curve numbers based on hydrologic soil groups.

Maidment (1993) outlines a conceptual grid model that incorporates flow direction and a runoff velocity field to develop unit hydrographs from isochrones (areas of equal time of travel to a pour point). This employs the concept of a linear rainfall-runoff response system in which the runoff velocity field is spatially variable but non-temporal and discharge-invariant. Maidment is currently pursuing development and implementation of such a method. Additionally, he is employing GIS to link atmospheric data, surface hydrologic characteristics and subsurface characteristics to create water balance models (Maidment, personal communication, 1994). This may prove to be invaluable for assessing water resources, especially in developing countries.

The work of the aforementioned people and others has encouraged the inclusion of hydrologic tools in GIS software. For example, Arc/Info (ESRI, 1991) incorporates a gridded scheme similar to that described above for delineating drainage boundaries and stream networks. Such features provide the basis for this work.

The dates of the above citations are indicative of the infancy of the hydrologic GIS field. As might be expected, the practicing engineering community has had only limited exposure to such capabilities. As part of this project, a survey was sent out to the fifty state highway agencies to assess the current use (state of the practice) and expected use of GIS for hydraulics-related highway work. Appendix C presents the questions and responses.

Thirty-two states responded to the questionnaire. It is evident from the responses that those state highway agencies who have implemented GIS (10 states) are using it for mapping and data management. Most recognize the potential of GIS for engineering analysis but only one state, Maryland, has implemented a system that supports hydrologic analysis. They employ GIS-HYDRO which was mentioned earlier. To some, the distinction between GIS and Computer Aided Design (CAD) seems to be blurred. GEOPAK, for example, is listed by one responder as a GIS, but is a roadway design CAD package which has digital elevation model capability. However, there is a trend towards integration of CAD and GIS systems. For example, ESRI (1995) is pursuing integrating Arc/Info capabilities with AutoCAD, a commercial CAD package.

Several agencies cite the lack of accurate data and capable software as hindering application of GIS to hydrologic and hydraulic analysis. The Hydrologic Data Development System was developed to demonstrate the potential application of GIS for determining flood frequency relationships and other hydrologic parameters that are used for design of highway drainage facilities. The system employs data that are now widely available or will become more prevalent.