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UPGRADABLE MASTER PLANS OF DRAINAGE FOR ARID COMMUNITIES USING A GIS

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ABSTRACT

A Graphics Data Base Management System is developed for use with computerized Master Plans of Drainage. The Master Plans are prepared according to Agency specifications involving multiple hydrologic and hydraulic modeling options, integrated into a single software package. Data bases are prepared for graphical representation of streets, land uses, hydrologic data, as well as computational results developed from the Master Plan of Drainage computer model. Two applications are available; an integrated package enabling editing and upgrading of the Master Plan, and another package designed to publish and distribute the Graphics and the Master Plan of Drainage data bases to the public in an access-only data base retrieval environment. The opportunities provided by such public information programs are significant, in that the entire Master Plan becomes available to the public in an easy-to-read and easy-to-use environment. The public therefore becomes an integral and important member of the Master Plan team, exchanging input and easing the way for acceptance of the project.

INTRODUCTION

An integrated hydrology/hydraulics/planning/deficiency-analysis Master Plan of Drainage computer model is developed which performs several master planning and engineering analysis tasks simultaneously. The computer modeling approach evaluates each link of the Master Plan of Drainage for deficiencies with respect to several defined street flow criteria, and determines mitigation measures of parallel and replacement systems. Because different hydraulic systems have different flow velocity characteristics, hydrology estimates are recomputed as the master plan is developed. Although small areas (less than about one square mile) are modeled by a rational method technique, the computer model integrates the small area hydrology techniques with the unit hydrograph technique for areas greater than one square mile.

The entire Master Plan is represented by a HydroGraphic Management System (or HMS) which allows for rapid communication of master plan data and estimates in graphical form. Two applications are developed:

Application 1: Graphical representation of data, and access to a data base retrieval system, which is noneditable, and which can be published and distributed to the public.

Application 2: Graphical database storage, and editing via an AutoCAD environment, wherein hydrologic, planning, topographic, and geographic data are accessible for processing in AutoCAD, and thence transferable to the Master Plan of Drainage computer model, with access to a data base retrieval system;

In the following, each major element of the above described HMS will be discussed. An application of HMS to an example Master Plan of Drainage will be used to demonstrate graphical display opportunities.

COMPUTERIZED MASTER PLAN OF DRAINAGE AND GRAPHICS DATA BASE MANAGEMENT SYSTEM

The total Master Plan of Drainage software package and data base system contains numerous elements and components that span several technical fields including data base management, geographic information systems (or GIS), hydrologic/hydraulic computer modeling, graphical data base management, flood control engineering and planning, among others. In the following is provided a brief survey of the key elements of the total software package.

Coupled Hydrologic Modeling Technique

Most flood control agencies at city, county or state level require specific procedures for the calculation of flood flow quantities. Often the procedure may involve the use of two or more estimates, depending on conditions such as watershed size. In Southern California, several county flood control districts require use of two floodflow estimation techniques dependent on catchment area; namely, the rational method for areas smaller than about one square mile, and the design storm unit hydrograph method for areas larger than about one square mile. The transition between techniques has been coupled into an integrated computerized Master Plan of Drainage model, enabling the development, for the first time, of an integrated hydrologic computer model with one pass of the analysis, rather than two separate studies. As a result of coupling hydrologic techniques into just one computer model, a single system analysis is available for use in preparing Master Plans of Drainage and upgrading the master plan, thereby greatly reducing the complexity, review process and cost involved.

Additionally, the new software enables all files to be linked so that an entire Master Plan of Drainage may be updated in literally minutes after the proper changes have been made. This advance means that new peak flows, tributary areas, and even cost estimates and drainage fee assessments can be easily updated to reflect any changes that occur to the study area.

The Master Plan of Drainage software contains internal editing and computational elements that involve 152 hydraulic and hydrologic submodels and global modeling commands. The software enables analysis of an integrated open channel or closed conduit flood control system on a study-wide basis.

Graphical Data Base

Several data base layers will be required to complete any hydrologic study. These layers will be created individually, however, they may be viewed simultaneously to show any hydrologic information desired. These layers include:

1) Base Map consisting of contours and streets right-of-way.
2) Watershed Boundary to define study boundaries.
3) Drainage Reservations to define alignments.
4) Existing Facilities to define alignments.
5) Street Flow to determine existing flows.
6) Alignments defined by layers 3, 4, and 5.
7) Subarea Boundaries defined by layers 5 and 6.
8) Overall Mapping Divides for Final Report.
9) Land Use Map.
10) Hydrologic Soil Group Map.
11) Rainfall Isohyetal Map.
12) Hydrologic Nodal Points defined by layers 6 and 7.
13) Hydrologic Element Type to define routing parameters.

Some layers, such as the base map, drainage reservations, existing facilities, land use, hydrologic soil group, and rainfall isohyetal maps may be available in digital form. If these layers are not available in digital form then they can either be digitized or scanned. The layers specifically related to the development of a Master Plan of Drainage can either be digitized from a marked up copy or directly drafted using AutoCAD.

Primary hydrologic parameters used in the Master Plan of Drainage computer model are land use, hydrologic soil group, rainfall, and hydrologic subarea topographic data such as area, length of water course, and elevation. In general, a study is discretized into subareas that are 10 to 20 acres in size. These subareas require definition as to each of the parameters listed above. Additionally, maps are needed in order to communicate these data. By obtaining in digital form or actually digitizing the land use maps, hydrologic soil group maps, rainfall maps, and subarea maps, not only is a digital/graphical representation available for display, but the data can then be processed by a "polygon processor" in order to partition the subareas into the intersection of all of the graphical layers. Geographic location is provided by use of street layout layers, right-of-way maps and freeway maps. The graphics data base is used to prepare hard-copy maps for reports, as well as graphical layers for display on the computer monitor. Figures 1 and 2 show hard copies of example graphical layers for a Master Plan of Drainage. Figure 1 depicts the land use map and Figure 2 depicts the hydrologic soil group map.

An acceptable base map is chosen and information such as subarea boundaries, alignments, and node numbers are added. This information is entered on a watershed basis. Once all this information is added, any desired layers are overlaid to create a hydrology map. Since these maps are created using AutoCAD, they can be reproduced at any scale. Additionally, each hydrology map becomes a "mapview" of the HMS, and thus, serves two purposes.

From each watershed map, the boundary is taken and overlaid with other watershed boundaries to create quadrant maps. These quadrant maps along with an index map are the navigational tools by which the user can locate any specific location in the study area.

There are also several byproducts that are created and updated throughout the entire duration of the MPD development process or prepared in advance.

1. Drawing database file (.DWG type) - used to create the slides of the index map and quadrants. It contains street information and outlines of all individual watersheds with their corresponding numbers, and project boundary.

2. Drawing database file (.DWG type) - containing hydrologic land use information; color-coded with unique hatch patterns for every land use type.

3. Drawing database file (.DWG type) - containing hydrologic soil group information; color-coded with unique hatch patterns for every soil group.

4. Drawing database file (.DWG type) - containing isohyetal rainfall information used in the hydrologic software. This is an option which is not necessary in all projects.

5. Polygon Processor output files (.OUT type) - for each watershed processed by this program. It includes information on every subarea in the watershed, in easy to read, space efficient, tabulated form.

Polygon Processor

The use of geographic information systems (GIS) has become widespread in many facets of engineering and planning, among other fields. A key element of a GIS is the ability to intersect graphical layers so that the several forms of information are resolved into "cells" wherein all parameters are constant. Figure 3 depicts the resolution of several graphical layers of information into homogeneous cells.

In the Master Plan of Drainage, each subarea requires definition of land use, hydrologic soil group, and rainfall, and the proportions of each within the subarea. The polygon processor performs this important task, and then develops a data base for use in the Master Plan of Drainage computer model. The subarea data are stored in tabled formats, on a subarea basis, indexed according to subarea number. Thus, the retrieval of a specific subarea number will access these several data, automatically developed by the polygon processor. This GIS related processing is based upon software developed for this application, and is part of the HydroGraphics Management System; that is, another GIS proprietary package is not required.

Master Plan of Drainage Data Base

The Master Plan of Drainage may be represented, in a data base form, as a collection of nodes (specific points along the catchment flood control system), and subareas (10 to 20 acres in size). All information computed by the Master plan of Drainage, such as deficiency system mitigation needs, flow quantities, hydraulic properties, streetflow characteristics, flood control system characteristics, hydrologic

parameters, and costs, among others, are stored in agency-designed tabled form in a data base indexed according to node number, link number, and subarea number. Also stored are data entered directly into the data base such as flood control system history, age, and so forth. Once the data base is assembled, the data base may be linked to the graphical data base which displays the digital graphical layers constructed for the polygon processing (i.e., multiple use of a data base form), while allowing easy access to the Master plan of Drainage data base.

HydroGraphics Management System

The graphical data base and retrieval software and the Master Plan of Drainage hydrologic/hydraulic computer software are coupled together to form the HydroGraphics Management System. Each of the above software packages are developed specifically for this application, and do not require use of other software packages.

Two applications are available:

The first application, or Application 1, enables a publication of the Master Plan data base for distribution to the public. Using "slides" (i.e. monitor images stored in the graphics data base), the entire study can be resolved into graphics slides of about one-half square mile in size, showing hydrologic master plan nodes, subareas, links, streets, land use, hydrologic soil group, among other designed data. Each slide is indexed to successively larger maps so that by selecting quadrants from the monitor, one is able to navigate through the city to a select point. Additionally, each slide is cross-referenced to a Master Plan of Drainage data base map that stores all the data associated to the slide appearing on the monitor. Figure 4 shows a slide of a data base map which appears on the monitor. Data base operating commands are displayed on the monitor screen, enabling the user to access the slide images.

This first application provides significant communication opportunities for the agency to both the public and the technical sectors. The engineering and planning communities can access the data base for other technical needs, and also inspect the Master Plan of Drainage without reviewing the usual report documents (which typically run several volumes). The public can inspect the Master Plan, and access information that would otherwise be unavailable. The cost of Application 1 is simply the cost of a 3.5-inch disk, or a micro-floppy.

Application 2 is the actual HydroGraphics Management System which includes all the features of Application 1, plus the ability to upgrade the Master Plan of Drainage due to changes in system requirements, land use, hydrologic parameters, among other factors. Because the agency can perform the upgrade, the master plan can be kept current, enabling up-to-date drainage fee assessment to be developed on an on-going basis.

The second application allows for graphic editing in the AutoCAD environment, polygon processing of this updated data, and editing of the Master Plan Data Base by both re-execution of the Master Plan and directly re-entered information. Once updated, new slides can be created to revise the first application. The entire update of a Master Plan of Drainage will only require approximately one weeks time, dependent on the extent of the changes.

AutoCAD based application 2 has its own customized AutoCAD style side and top menus. Through these menus the user has access to the set of custom AutoLISP subroutines, which are the tools for the MPD data base drawing creation process. These tools: HYDRO.MNU and 25 AutoLISP subroutines help develop all elements of a hydrologic map without having to worry about switching layers or setting current parameters. The HYDRO.MNU menu is designed to cut down on the keyboard input. Both the menu and the LISP tools, work only inside the prototype drawing, which contains all the text style blocks and layers referenced by AutoLISP functions. Creation of a slide is a very simple process in which the user is required only to "zoom in" to the area of interest and to type the "NSLIDE" command.

The general approach to a project is summarized in Appendix A.

Computer System Requirements

The necessary computer hardware needs for a study of 100 square miles involves the data base of some 5,000 subareas, 6,000 nodes, 5,000 links, and about 250,000 pieces of information. The total graphics and Master Plan data base requirements is in the 40 to 50 megabyte range.

Hard Copy Products and Mapping

Hard copy maps and reports are readily prepared using the several constructed data bases. Consequently, once the graphical data bases are assembled, drafting time is significantly reduced by using hard copy printouts. Similarly, report technical appendices can be prepared using the Master Plan of Drainage data base.

Application to Sewer, Water, Environmental Systems

Extension of the Graphics Data Base Management System to use in sewer, water, and environmental systems is straightforward and has been accomplished in several applications in Orange County, California. Both Applications 1 and 2 follow the procedural steps described for Master Plans of Drainage. A key element to use with other systems is the availability of an integrated processing model -such as readily available integrated sewer and water system models. In the application described herein, the development of an integrated Master Plan of Drainage computer model was a crucial step in the evolution of the Graphics Data Base Management System approach for Master Plans of Drainage.

Conclusions

A graphics data base management system for computerized Master Plans of Drainage is developed. Two applications are prepared which enables the agency to upgrade the Master Plan in the future, and to publish the Master Plan in computer graphics form for distribution to the public. Because of the ease of communication afforded by this approach, the utility in Agency public information programs may be significant.

References

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APPENDIX A

HYDROGRAPHICS GENERAL APPROACH SUMMARY APPLICATIONS 1 & 2

1. REQUIRED IMAGE LAYERS
   - A. STREET - DIGITAL DATA BASE
   - B. LAND USE - DIGITIZED
   - C. HYDROLOGIC SOIL TYPE - DIGITIZED
   - D. RAINFALL ISOHYETAL - DIGITIZED
   - E. SUBAREA - DIGITIZED
   - F. ALIGNMENT - DIGITIZED

2. STEPS FOR GRAPHICS BASE MAP PREPARATION
   - A. TRANSFER DATA BASE FROM VAX TO PC (ALL LAYERS)
   - B. CHECK ALIGNMENT OF LAYERS AND SCALE (ALL LAYERS)
   - C. CHOOSE COLORS FOR LAYERS
   - D. CLOSE LAYERS IN COUNTERCLOCKWISE DIRECTION

3. STEPS FOR CREATING A GRAPHICS WATERSHED MAP
   - A. OUTLINE WATERSHED MAP
   - B. CHOOSE FRAME LOCATION
   - C. TRIM WATERSHED FROM GRAPHICS BASE MAP

4. STEPS FOR PREPARING GRAPHICS WATERSHED MAP
   - A. CLOSE SUBAREAS IN COUNTERCLOCKWISE DIRECTION
   - B. ADD NODE NUMBERS
   - C. ADJUST DRAINAGE ALIGNMENT
   - D. INSERT STREET NAMES
   - E. POLYGON PROCESSING

5. STEPS FOR MODIFYING DATA BASE FORMAT
   - A. DESIGN DATA BANK TO AGENCY REQUIREMENTS
   - B. CUSTOMIZE PROGRAM FOR SPECIFIC MAPS AND DATA BASE
   - C. ASSEMBLE DATA BANK FROM MASTER PLAN SOFTWARE

6. STEPS FOR MAKING GRAPHICS WATERSHED MAP SLIDES
   - A. MERGE APPROPRIATE LAYERS (SELECTED BY AGENCY)
   - B. ADD GRAPHICS WATERSHED NUMBERS

7. STEPS FOR MAKING DATA BANK NAVIGATION MAPS
   - A. MERGE GRAPHICS WATERSHED MAP BOUNDARY AND STREET LAYER
   - B. ADD GRAPHICS WATERSHED NUMBERS
   - C. MAKE SLIDE OF PRODUCT

8. STEPS FOR MAKING OVERALL DATA BANK INDEX MAP
   - A. MERGE STUDY BOUNDARY AND STREET LAYER
   - B. ADD QUADRANT NUMBERS
   - C. MAKE SLIDE OF ENTIRE STUDY AREA

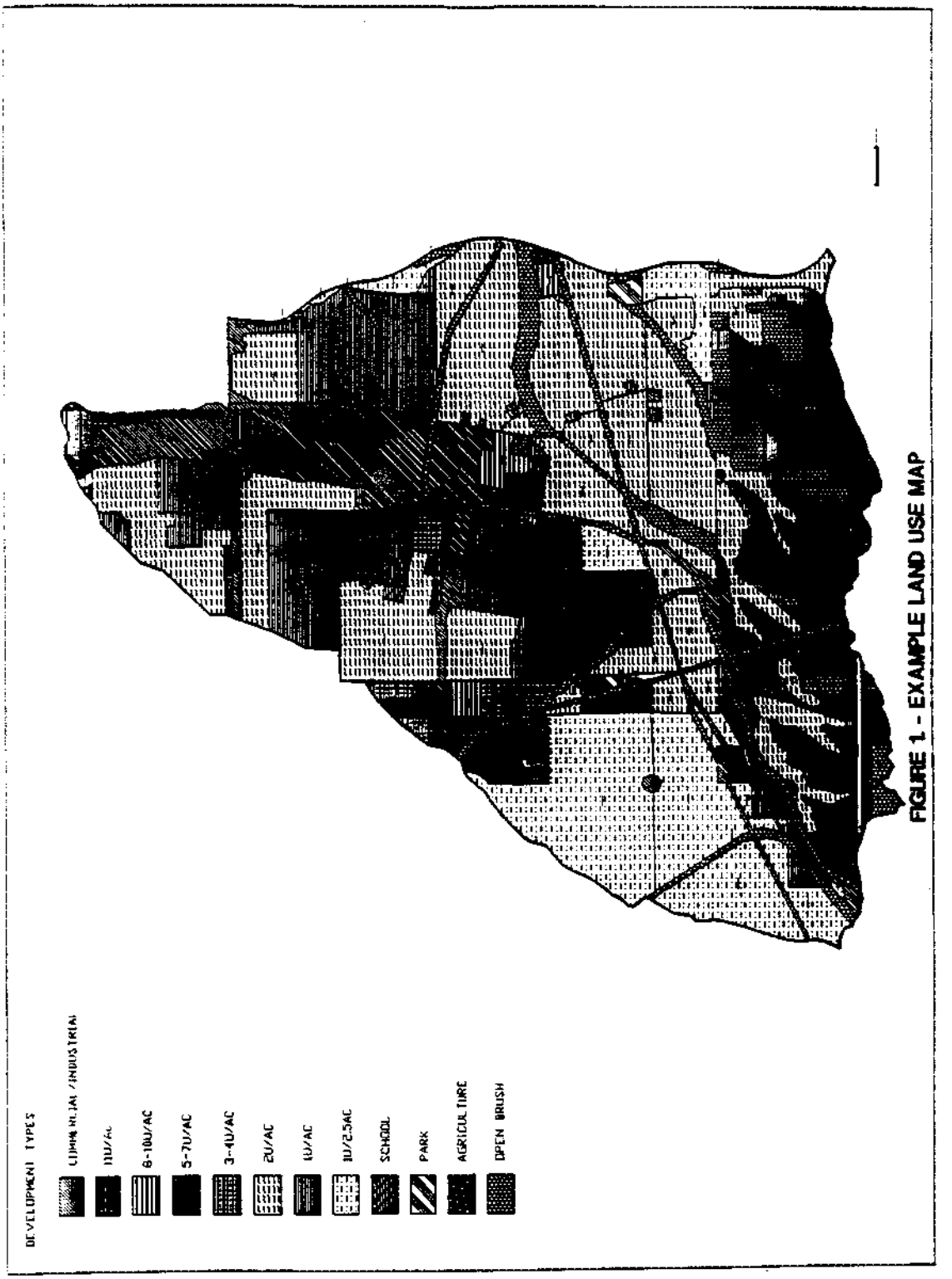

FIGURE 1 - EXAMPLE LAND USE MAP

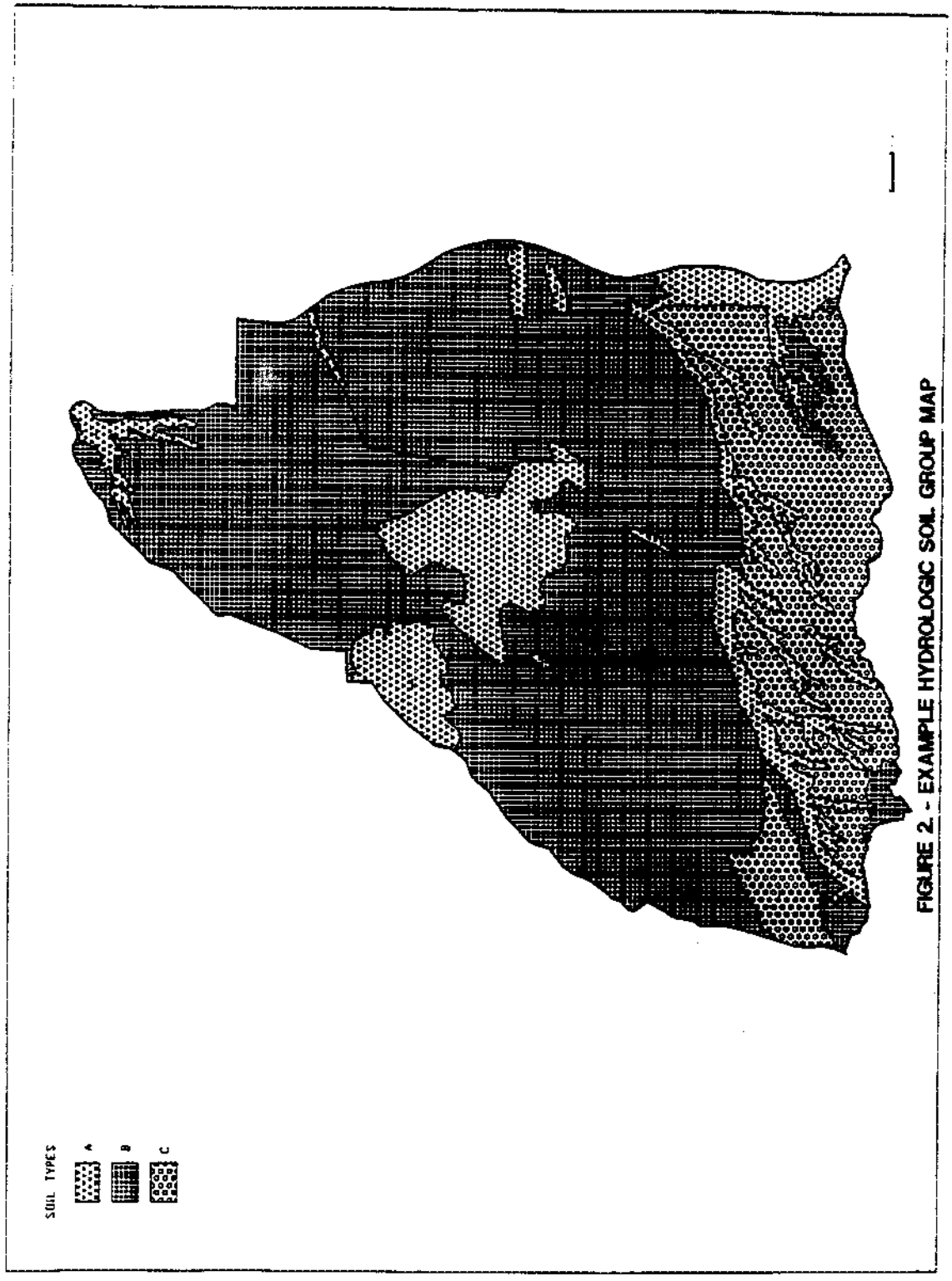

FIGURE 2 - EXAMPLE HYDROLOGIC SOIL GROUP MAP

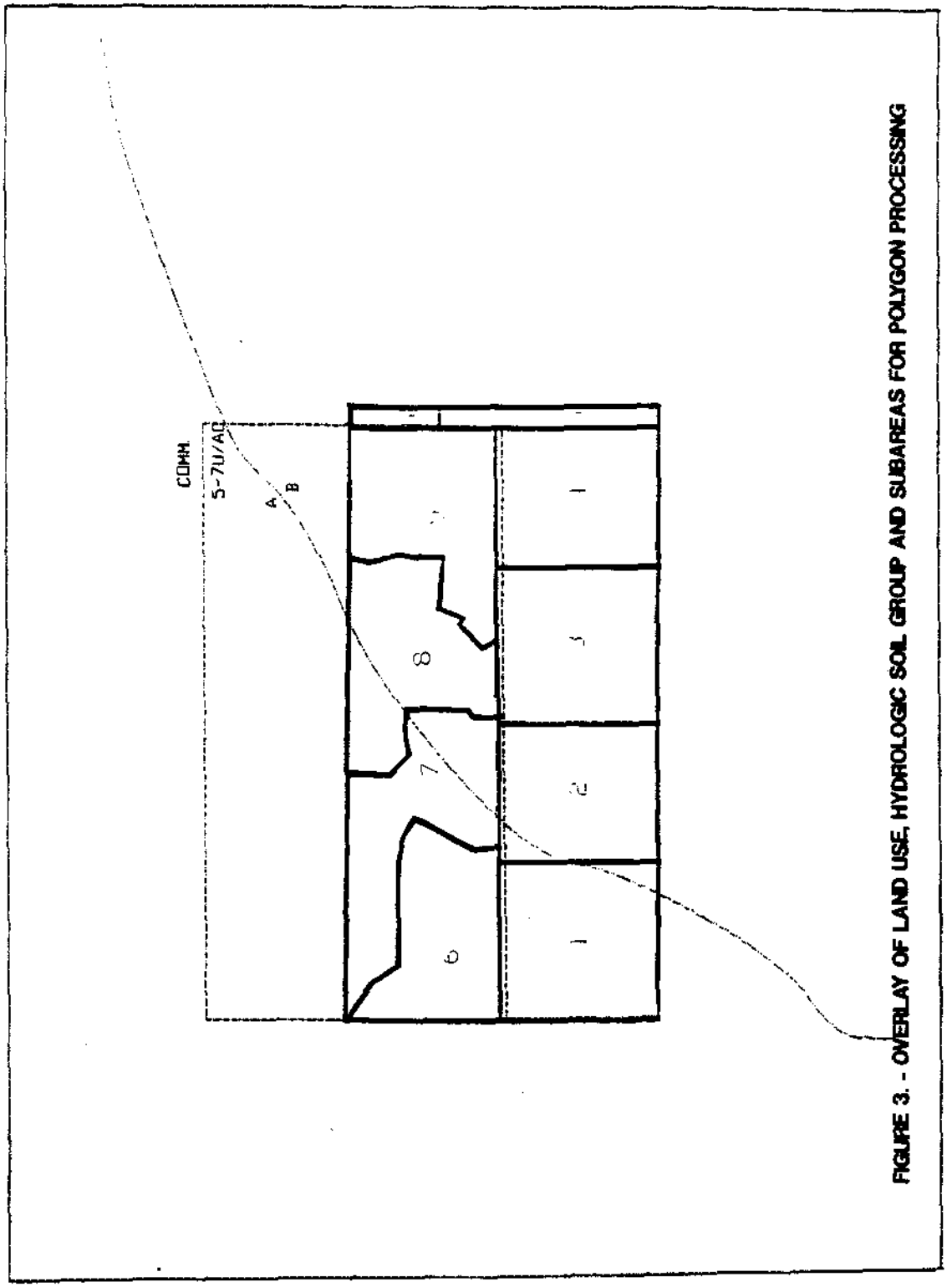

FIGURE 3. - OVERLAY OF LAND USE, HYDROLOGIC SOIL GROUP AND SUBAREAS FOR POLYGON PROCESSING

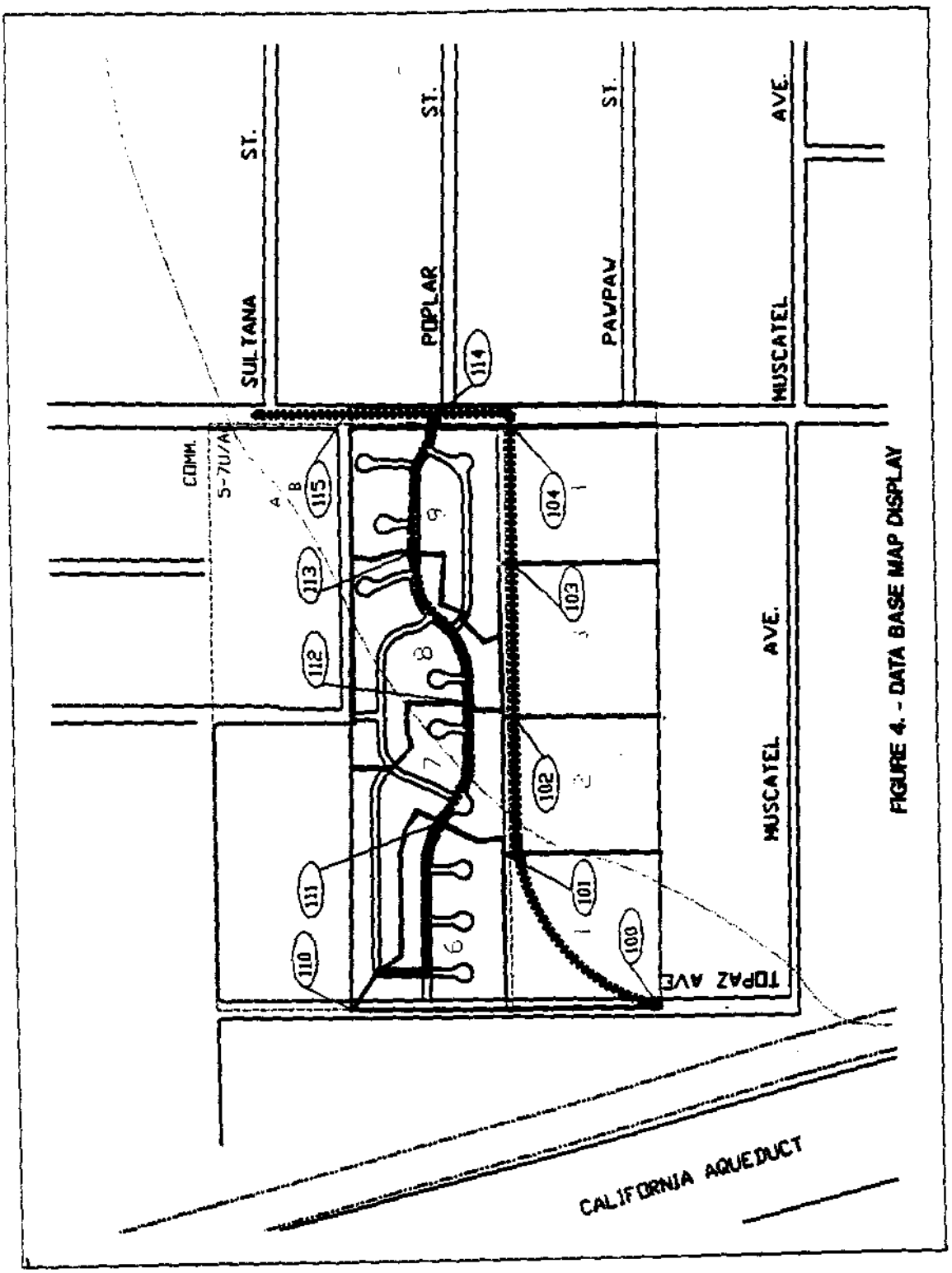

FIGURE 4. - DATA BASE MAP DISPLAY