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Hydrologic Engineering Center

Evolution in Computer Programs Causes Evolution in Training Needs: The Hydrologic Engineering Center Experience

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Papers in this series have resulted from technical activities of the Hydrologic Engineering Center. Versions of some of these have been published in technical journals or in conference proceedings. The purpose of this series is to make the information available for use in the Center's training program and for distribution with the Corps of Engineers.

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Evolution in Computer Programs Causes Evolution in Training Needs:
The Hydrologic Engineering Center Experience¹

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ABSTRACT

Since the Hydrologic Engineering Center (HEC) was established in 1964, it has provided training in hydrologic engineering for the Corps of Engineers. The Center has also been responsible for "computerizing" hydrologic methods and making those programs available to the Corps as well as the general public. These computerized procedures and the required information for project investigations have grown to the point that the program user requires an understanding of a multitude of technical fields. The development of comprehensive computer programs provides an opportunity to bring together previously fragmented technical studies into one integrated study. Several examples of the coordinated program packages and their impact on the evolving training program of the HEC are presented to illustrate the developing technology and its impact on the training and education needs of engineers in the Corps.

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INTRODUCTION

In a paper entitled "Training the Practitioner" (6), Bill Johnson, described the Hydrologic Engineering Center Training Program. While training is provided a number of ways, the primary thrust is through a series of formal courses presented on a rotating schedule at HEC offices in Davis, California. Table 1 lists the courses presently available. An average of 12 of the courses are given each year.

Each course is one or two weeks in length and most feature one or more of our computer programs. The daily schedule generally features a review of the previous day's material, three lectures, and a workshop problem designed to provide participants an opportunity to apply the concepts or procedures presented that day. The next morning review will focus on the solution to the workshop problem and a general review of the previous day's lectures.

Mr. Johnson's paper also presented the growth in the number and variety of courses in our training program. Table 2 lists the courses available over five-year intervals from 1965 to 1980. Obviously the technical topics covered under hydrologic engineering have increased and so has the burden of providing the technical training to Corps' personnel.

The core of the HEC program has always been the computer models in hydrology, hydraulics and reservoir system analysis. More recently, economic analysis, spatial data management, and structural and nonstructural planning

TABLE 1*

HYDROLOGIC ENGINEERING CENTER

TRAINING COURSES

Course Title

- o Analytical Techniques for Formulation of Nonstructural Plans
- o Dam-Break Analysis
- o Flood Frequency Analysis
- o Flood Plain Hydrology and Hydraulics
- o Flood Plain Management Planning

- o Ground Water Hydrology
- o Hydrologic Analysis of Floods
- o Hydrologic Aspects of Hydropower
- o Hydrologic Engineering for Planning
- o Hydropower Planning

- o Interior Flooding Hydrology
- o Planning for Hydrologic Engineers
- o Real Time Water Control
- o Reservoir System Analysis
- o Sediment Transports in Rivers and Reservoirs

- o Spatial Data Management Techniques
- o Statistical Methods in Hydrology
- o Unsteady Flow Analysis
- o Water Quality Aspects of Water Control
- o Water Quality Modeling of Rivers and Reservoirs

- o Water Supply Hydrology
- o Water Surface Profile Computation Using HEC-2 (Advanced)
- o Water Surface Profile Computating Using HEC-2 (Basic)

*Reprinted from Reference 6

TABLE 2*

COURSES IN HEC TRAINING PROGRAM
FY 1965, 70, 75, 80

<u>1965</u>	<u>1970</u>	<u>1975</u>	<u>1980</u>
Hydrologic Probabilities Hydrograph Analysis	Hydrologic Probabilities Hydrograph Analysis * * *	Hydrologic Probabilities Hydrograph Analysis Reservoir System Analysis Water Surface Profile Computations Water Quality Management Flood Plain Hydrology Ground Water Hydrology * * *	Hydrologic Probabilities Hydrograph Analysis Reservoir System Analysis Water Surface Profile Computations Water Quality Management Flood Plain Hydrology Ground Water Hydrology Hydrologic Aspects of Hydropower
	Reservoir System Analysis Water Surface Profile Computations Water Quality Management Flood Plain Hydrology Ground Water Hydrology	Hydrologic Aspects of Hydropower Hydrologic Engineering for Planning Sediment Transport Urban Hydrology Water Quality Modeling	Hydrologic Engineering for Planning Sediment Transport Urban Hydrology Water Quality Modeling * * *
			Unsteady Flow Analysis Analytical Planning Techniques WRC Frequency Analysis Real Time Control of Water Resource Projects Interior Drainage Hydrology Dam Break Analysis Water Supply Potential Spatial Data Management Nonstructural Flood Control Advanced HEC-2

*Reprint of Table 3 from Reference 6

have been added. Not only has the growth of such technical topics had a direct impact on our training program, but the nature of our computer programs and computer environment has also had a major impact on the training mission.

EVOLUTION OF COMPUTER PROGRAMS

Single purpose programs were the norm when the HEC was just starting. For example, there was a separate program for each component of the computation in the rainfall-runoff process. The list below, taken from our publications catalog (4), contains examples of these early programs.

- Basin Rainfall and Snowmelt Computation (BASINC)
Users Manual, Jul 66, 24 pp.
- Unit Graph and Hydrograph Compuation (UHHC)
Users Manual, Jul 66, 31 pp.
- Unit Graph and Loss Rate Optimization (UHLRO)
Users Manual, Aug 66, 37 pp.
- Hydrograph Combining and Routing (HYDCR)
Users Manual, Aug 66, 34 pp.
- Streamflow Routing Optimization (SFRO)
Users Manual, Nov 66, 34 pp.
- Balanced Hydrograph (BALHYD)
Users Manual, Nov 66, 15 pp.
- Spillway Rating and Flood Routing (SWRFR)
Users Manual, Oct 66, 89 pp.
- Spillway Rating - Partial Tainter Gate Openings (SWRPTG)
Users Manual, Jul 66, 34 pp.
- Spillway Gate Regulation Curve (SWGRC)
Users Manual, Feb 66, 26 pp.
- Reservoir Yield (RESYLD)
Users Manual, Aug 66, 42 pp.
- Reservoir Area-Capacity Tables by Conic Method (REACT)
Users Manual, Jul 66, 25 pp.

Because each program is generally single purpose, it is a relatively easy task to review the theory and to show how it is utilized in a computer program to accomplish a task. The programs are small, so input/output specification are also relatively easy. Also the program user still has close ties with the overall computation procedure because he is forced to deal with the output from each program in the computation.

By 1970, separate small programs were being assembled into package programs. The HEC-1 Flood Hydrograph Package combined the features of the first six programs on the program list. Now, in a single computer program, the entire computation sequence could be accomplished in a single computer run. Also during this period, the HEC-2 Water Surface Profiles and HEC-3 Reservoir System Analysis programs were developed.

Obviously, the input specifications and computation alternatives have become more complex. Users must cope with an array of choices, plus learn more input specifications and output options. Given a fixed training course length, there already seems to be an increasing amount of information to process and understand. There becomes a growing concern that more focus is being placed on getting the program to run rather than the computation process and assumptions of the theory.

Over the next decade the programs continued to expand with more options and features. Continuing research and project work activities created new opportunities and demands for the programs to perform more functions. For example, the Flood Hydrograph Package has new options added for dam break analysis. A new version is developed for kinematic wave runoff calculations.

A third version is developed with options to select features for flood control in a system search procedure. The package programs become powerful, complex tools.

EVOLUTION OF TRAINING COURSES

From 1964 to 1980 the number of subjects provided has increased, reflecting the growing field of technical activities of the Corps. Simultaneously, the nature or goals of the individual courses have changed. The early courses reflected the nature of the early computer programs. Small, single purpose programs were the basis of courses on the technical topics. For example, the Hydrograph Analysis course of 1965 could present the theory and application of unit hydrographs and demonstrate the application through a computer program.

By 1970, the Hydrograph Analysis course would be based on a Flood Hydrograph Package. The combination of related tasks into a complete program for rainfall-runoff calculations provides a good basis for a two-week training course. The various components of the computation sequence can be developed until a complete watershed runoff model is developed.

The Flood Hydrograph Package of 1980 presented a larger challenge for the training function. Given a two-week course, there are now some half dozen methods for specifying runoff calculations plus a multitude of loss rate and channel routing methods. There is the realistic goal of familiarizing the new program user with the capabilities and application of the program. But, with such limited time, how much can be spent on the review of fundamentals?

Course design must reflect the competition between theory and utility. There is time to review unit hydrograph theory, but review of the various methods of developing unit hydrographs must be compressed. The various unit graph methods are presented in a single lecture instead of one lecture for each method. There are too many methods available to cover in detail. The hand calculation workshops applying each method must be dropped because there are more computer workshops required to demonstrate the multitude of program features. And the students tend to ask for more computer time and less theory.

Written and open oral critique are held at the end of each course. Over the years, there has been a continued request to spend more time on the practical solution and less on the theory. As the number of program features increase, this attitude seems more pronounced. If we cut back on the time we spend on theory, we could have more time using the program and trying program features not presently covered.

The experienced professionals express their concern about young engineers who make programs work but don't necessarily have a feel for the computation process or the scale of the answers. What is a reasonable value for this coefficient or that parameter? As the programs grow with options and capabilities, there seems to be a growing uncertainty about their application.

In spite of student comments, we have continued the practice of reviewing the theory in lectures and providing hand calculation workshop problems, although less time is available to spend in this way. Two methods for squeezing the theory and hand calculations into the course are precourse reading and problem assignments and computer workshops combined with hand calculation tasks.

Students often request precourse material as a means of "coming up to speed" for a course. While many may not take advantage of the opportunity, we usually provide material and reading assignments to the students prior to the course. Usually the first day's reference material is assigned as precourse reading. In some cases, precourse problem assignments are given.

Hand calculations to check or verify the computer results are sometimes used. Also, the assignment of separate hand calculation problems to work on while waiting for output is a good way to squeeze in the direct application of the procedures used by the programs. For many, however, the computer workshop is the focus and concern about getting output tends to dominate.

Since 1980, we've had to deal with more changes in our computer program environment, and we haven't directly dealt with the impact of microcomputers. On the computer hardware side, we have moved into the interactive terminal environment for our work. Now the students are entering their data by terminal to a disc file. The course participant has to deal with the terminal hardware, data entry, and how to submit jobs for execution. The old keypunch errors are now the engineer's responsibility. Also, the unforgiving computer program becomes a real problem. Input data, off by just one column, create all kinds of problems. We also have to deal with learning the syntax of the text editor. The ADP function has moved a little closer to the engineer. We have better access, but we also have a greater burden of information and procedures to learn.

Another change in our computing environment involved the linking of our package programs through a random access data storage system, HECDSS (3), into a system of programs. Two major systems of programs have been developed for real-time water control and for flood control planning. A review of those two systems will illustrate the problems facing our training function today.

REAL-TIME WATER CONTROL PACKAGE

A large number of separate tasks are required to develop a flood forecast and water control operating strategy. The HEC has been developing and applying a system of software for that purpose (1 and 7). Our training program has adjusted and redesigned the two-week training course, Real-Time Water Control, to present and transfer this emerging technology.

The water control system has been developed with functional modules for major steps in the computation sequence, Figure 1. The data management module decodes raw data and converts it to engineering units. Simple range checks on data validity are also performed. Software for basic data file maintenance is provided to allow hand-entry and editing of the basic data file.

In the water control module, the basic functions include flood forecasting, reservoir regulation simulation and data display. The flood forecast model is a special version of the HEC-1 Flood Hydrograph Package previously discussed. The regulation simulation is provided by the HEC-5 Simulation of Flood Control and Conservation Systems Computer Program. Both programs are represented in two week training courses at the HEC. The display submodule is a graphics package providing for data retrieval and display

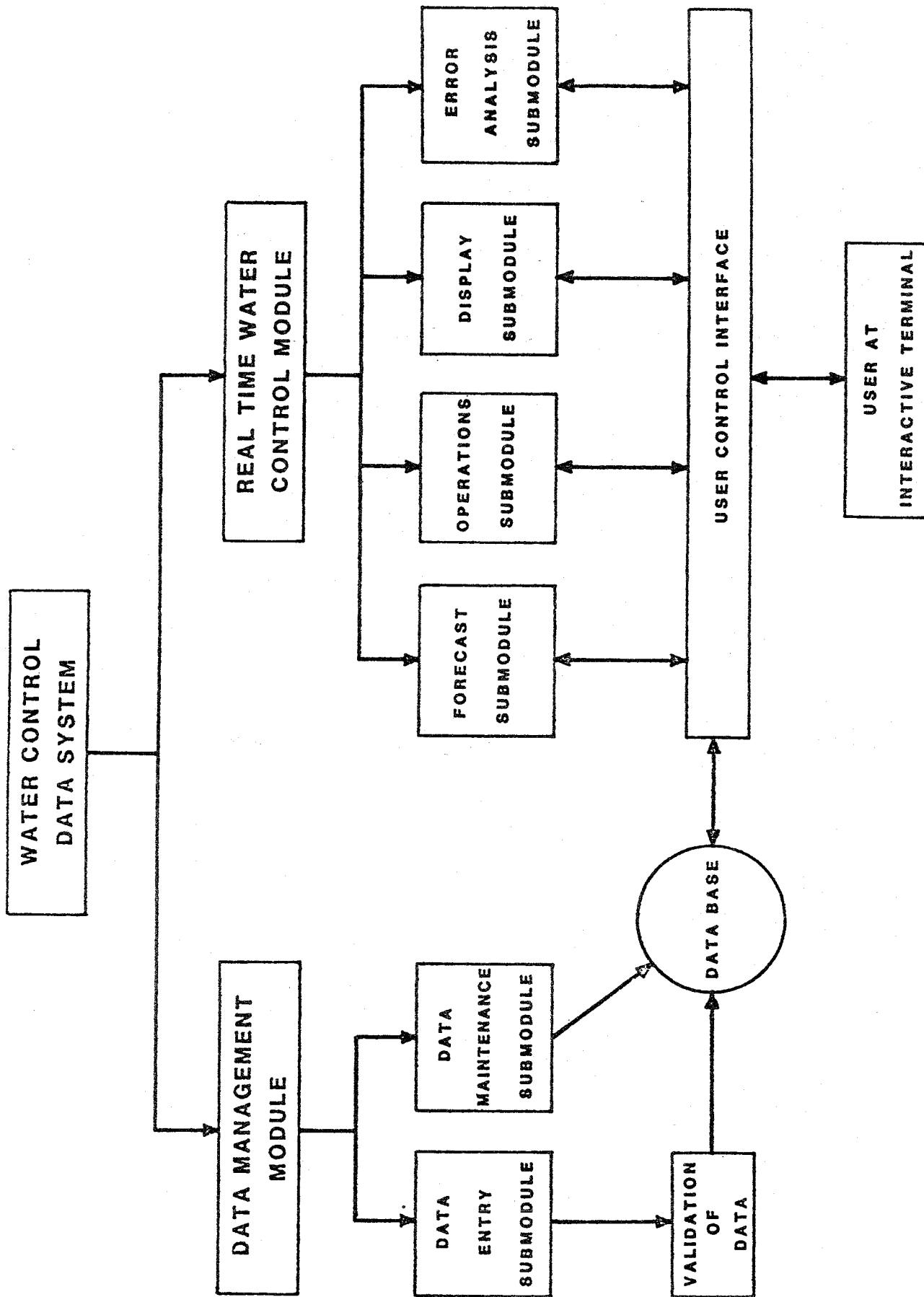


Figure 1* Real-Time Software Diagram

*Reprinted from Reference 1

with a multitude of convenient options. The entire module is managed through an interactive program that automatically provides for file retrieval and linkage with computer programs and the program execution.

Consider the technical topics to cover in a Real-Time Water Control Course. Within this class, there are the problems dealing with acquiring, checking and converting basic data. There are the array of tasks to calibrate and apply the flood forecast model, and then the reservoir operation strategy. In many offices, these tasks are performed by different engineers who do not necessarily see the whole problem. Now the package of programs has been integrated into a single system, and the course participants are required to work through the entire problem from rainfall data to reservoir release decisions.

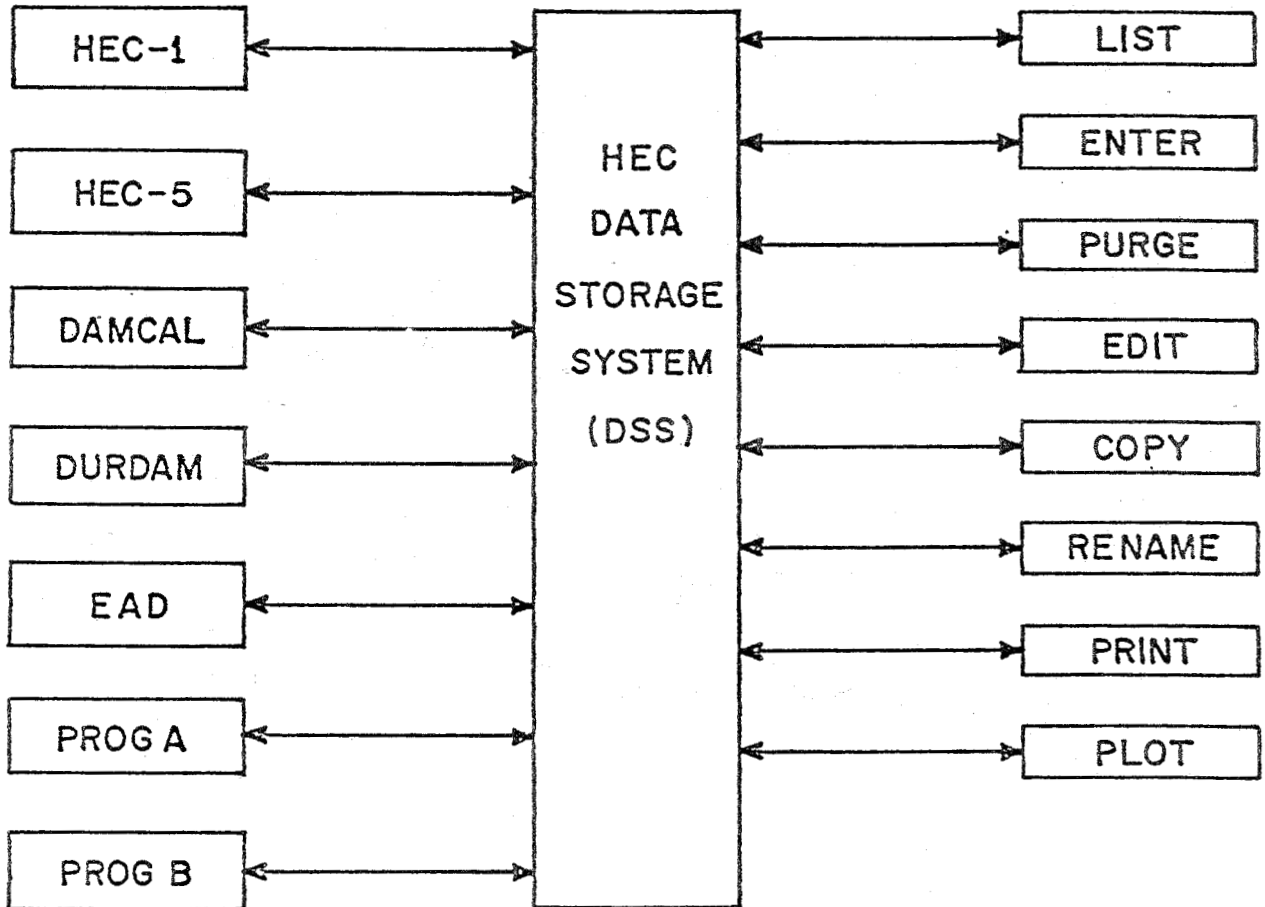
The data storage system (HECDSS) links the programs together. Figure 2 from Reference 1 illustrates the concept. The application programs on the left extract input data (primarily time series data) from the file and write results, back to the file which can be used by other programs. On the right are the utility functions. Associated with those utility purposes are more programs with new commands and limitations. To effectively use the package, the entire set of application and utility programs should be understood. This means more time in the training course must be spent in teaching people how to make programs work.

Figure *2

HEC DATA STORAGE SYSTEM

APPLICATION PROGRAMS

UTILITY PROGRAMS



FLOOD CONTROL PLANNING PACKAGE

The development of an integrated system of models for water resource planning has been a major goal of our Planning Analysis Branch. Recent efforts have focussed on flood control planning, which has produced an integrated set of computer programs (2). Again the key to linking the programs has been the data storage system that provides for automatic passage of data into and out of the various computer programs.

For flood damage evaluation and evaluation of alternative flood loss reduction measures, an integrated sequence of computations must be performed. Figure 3 from Reference 2 provides an illustration of the various programs involved and their linkage through the data storage system. The index numbers by the computer program labels indicate the various steps involved.

The flood hydrology is developed using steps 1, 2, and 3. The HYDPAR program develops the runoff parameters for HEC-1 based on land-based data in a spatial-data file. Programs like DWOPER may be required for dynamic routing because the HEC-1 program is limited to hydrologic routing procedures. The results from the hydrologic computations are discharge-frequency data.

To convert discharge to stage or elevation, the HEC-2 Water Surface Profile Program is applied to the various channel definitions being considered. The steady flow profile results may also be applied in the hydrologic model to define channel routing criteria in the form of storage-discharge functions.

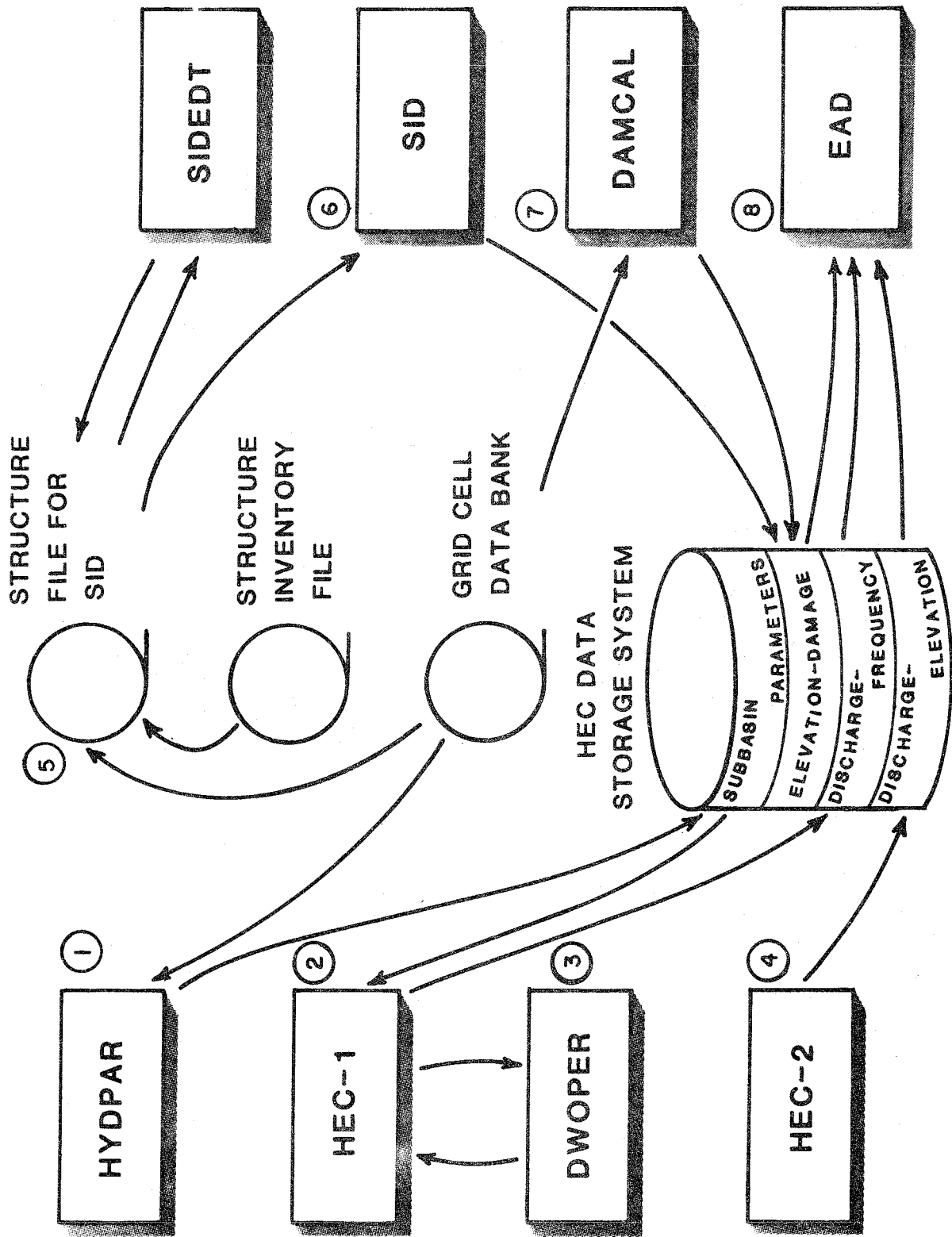


FIG. 3* - Passaic River Study Planning Model Use

* Reprinted from Reference 2.

Flood damage data are developed using structure inventory data files and the file management program SIDEDT, Computer program SID is used to develop damage functions by aggregating the depth-damage relationships for individual structures in a reach of the flood plain. Also the programs can be used to evaluate future land use conditions and nonstructural measures for specific structures of interest. The resulting damage-elevation functions are returned to the data storage system.

An alternative to developing damage functions based on individual structures is the use of land use data. Computer program DAMCAL obtains the land use data stored in the grid cell data bank and develops damage functions which are returned to the data storage system.

The final step is the computation of the expected annual damages for the alternatives considered. The Expected Annual Damages (EAD) program was developed to compute the expected annual flood damages at a location in a specific year with given hydrologic, hydraulic, and economic conditions in that year, or for a series of future years. The EAD program is applied to the results from the simulated basin response to various flood damage reduction measures.

The package of programs brings together all the computation processes to evaluate various flood control measures to reduce flood damages. The processes involve hydrology, hydraulics, land-based data files, structure based data files, engineering economics, and the coordination of computer programs, files, and data base management information.

TRAINING RESPONSE

The development of more complete software systems has provided the opportunity to accomplish complex multi-stepped analysis with apparent ease. The HEC systems for real-time water control and for flood control planning are examples of the HEC systems. The development of "friendly" interactive programs and automatic program job control has made it easier for anyone to use the systems. For the knowledgeable program user, the improved environment is a welcomed relief. However, the program user is getting farther away from the analysis activity; and when that user is not well trained in the fundamentals of each program and its application, the risk of misuse is great. There is an increasing need for the training function to keep the focus on the fundamental process.

Providing training within a common organization makes the task a little easier. Most Corps offices are using the same computer system; therefore, software can be designed to utilize the features of that system. While we have continued to keep our application programs machine independent, our linking software packages require some system dependent statements. The course participants learning to use these packages can return to their offices and use them in the same way. Therefore, the time spent learning to use the utility programs will be applicable to the participant's daily work.

We have recently added a dozen graphics terminals and graphics tablets to our classroom. This equipment allows the students to operate in the classroom, during workshop sessions, in an environment similar to the office.

We give training the priority on our computer, so that computer based workshops can be completed as efficiently as possible. This allows more time for analysis of results.

Because the software packages are designed and developed to apply to Corps field problems, the training courses designed around the programs will tend to directly relate to the participant's needs. However, when the packages are large and complex, it is difficult to present the underlying theory. The fundamentals must be provided in the students' prior education and in the more basic training courses provided at the HEC.

Many of our programs are being used outside the Corps. These other program users face the same hurdles to fully understanding and using the large package programs. We provide user support for our programs which includes answering many questions over the phone. Having provided that type of service for several programs over the last ten years, I know that there are many program users that really don't know how to use the programs they are running. Many "experienced" program users have acquired incorrect notions about the program and they in turn pass it on to the newer program users.

We have attempted to provide alternatives to the many program users unable to attend training courses. Our program user manuals have been updated and expanded to provide a complete description of the theoretical basis, data requirements, and optional capabilities of the program. Also, example input and output are provided. For some program applications, separate training documents have been written to explain and demonstrate the program's features for that purpose. Additionally, over the last ten years, we have selectively video taped lectures in our training courses. While these tapes are far less

attractive than the produced television shows we are familiar with, they do provide supplemental information to those unable to attend the course. We loan these tapes through a commercial service, Modern Talking Pictures (5).

This year we are assembling a set of video tapes to cover our one week basic course on the HEC-2 Water Surface Profiles program. We have taped the lectures during previous presentations of the course. Now we are taping the workshop reviews, which we see as an important part of the course. When completed, the course manual and video tapes will allow a program user to obtain part of the benefit of the one week course. Missing will be the opportunity to ask the instructor questions.

There still needs to be greater opportunity for engineers in the field to become familiar with the computer programs used in their profession. The university students should get the opportunity to see and use programs that are based on the theoretical topics studied in class. The working field engineer needs the computer application workshops to promote the knowledgeable application of the programs. The extension classes provided at some of the universities are ideal for this purpose. There should be more incentive for academics and field engineers to be involved in these workshops. Without more training opportunities, the gap between the available technology and the number of knowledgeable users will grow.

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