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An Integrated Software Package for Flood Damage Analysis

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14. ABSTRACT
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AN INTEGRATED SOFTWARE PACKAGE FOR FLOOD DAMAGE ANALYSIS

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AN INTEGRATED SOFTWARE PACKAGE FOR FLOOD DAMAGE ANALYSIS

By Robert D. Carl and Darryl W. Davis[1]

Abstract

The U.S. Army Corps of Engineers has nationwide responsibilities in water resources planning and management. The Corp's Hydrologic Engineering Center (HEC) develops and supports many computer programs to aid in the analysis of water resource problems. An important task is to evaluate damage potential due to flooding with and without proposed plans of improvement. The computation capabilities required to meet this purpose include hydrologic modeling of flood events, inventorying of structures subject to flood threat, and economic analyses of damage potential of threatened structures. Computer programs, available from HEC, historically have been used to perform these analyses. Often, results from one program are manually entered as input to another. The HEC recently developed a data base system and modified computer programs to automatically transfer data between programs and allows the professional to edit, display, and archive the data. Referred to as the Flood Damage Analysis Package, this system of programs has existed for several years for large mainframe and minicomputers. A full implementation of the system of programs is now available for MS-DOS compatible microcomputers. The microcomputer version of the FDA Package includes a shell menu feature which facilitates program execution and improves data file management and selection. The Flood Damage Analysis Package is described and its application illustrated.

Purpose of the FDA Package

The Flood Damage Analysis (FDA) Package enables a variety of flood damage computations to be performed using linked hydrologic and flood damage computer programs developed by the Hydrologic Engineering Center (HEC). A data storage system links the programs and allows the almost automatic transfer of data from one program to another. HEC developed this data storage system and calls it the Hydrologic Engineering Center's Data Storage System (HECDSS). Data is identified by an alphanumeric label. Simulation programs store or retrieve data using this label as the user identifier. It relieves the analyst from manually keying results from one computer model as input to another model. This Package of programs has existed for several years on mainframe computers. Recently, it has been adapted to MS-DOS microcomputers.

Background of the FDA Calculations

Flood damage analysis is performed for a variety of reasons including:

- determining costs of flooding
- formulating and evaluating plans for flood damage reduction
- implementing projects and management decisions
- identifying critical problem areas
- developing actuarial insurance premiums
- performing a post flood analysis
- evaluating future growth in respect to land use planning and associated flood hazards

Historically, water resource computer programs have been applied in an isolated fashion. One program was expected to perform all of the required calculations. If the selected model did not contain the required analysis options, the user was required to either calculate additional results by hand, modify the computer code for the selected model, or manually code results from the model as

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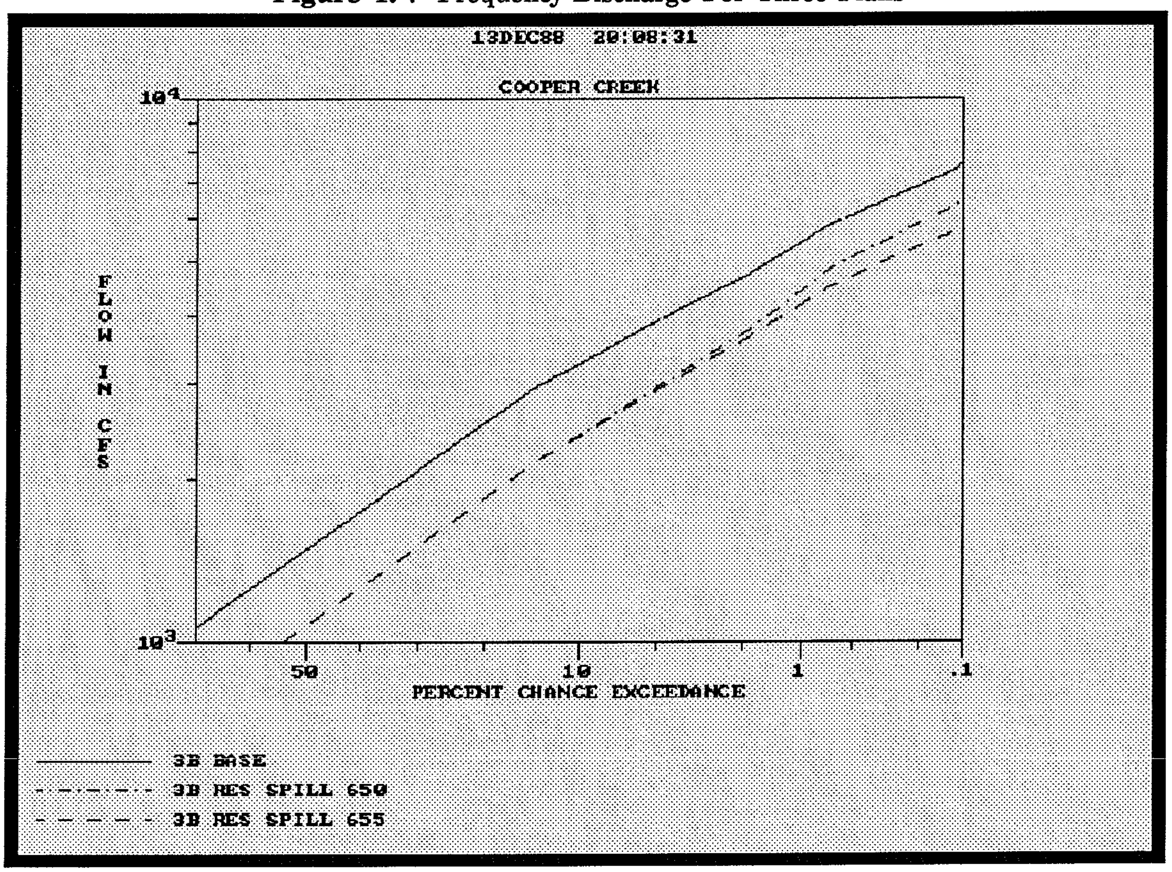
input to another model which contained the required capabilities. With the recent developments in data management software, these programs are now linked through data management software and associated files. This reduces manual keying of data, allows models to maintain their separate, logical capabilities, and eliminates duplication of computer code amongst the programs.

The FDA Package provides a full range of flood damage analysis capability including structural and nonstructural flood plain management measures. Presently, the Package includes three hydrologic and hydraulic engineering programs, five flood damage analysis programs, three data management programs, and a library of data management software.

Overview of Calculation Components

The FDA Package utilizes the "frequency method" for the expected annual damage calculation procedure. The Package calculates damage potential for specific flood magnitudes and then weights the damage values with the probability that these events might be exceeded. The result is the expected annual (or average annual) damage. The probability-damage calculation points may be characterized as a curve. The area under the curve for annual probability points is the expected annual damage. Projects and/or management plans are evaluated by comparing their associated expected annual damage with that computed for base (existing) conditions. For example, to evaluate a reservoir, the expected annual damage is calculated under without reservoir conditions and then with reservoir conditions. The difference between the two values is the "inundation reduction benefit" and represents the expected annual damage reduction which can be achieved by constructing the reservoir.

Figure 1: : Frequency-Discharge For Three Plans

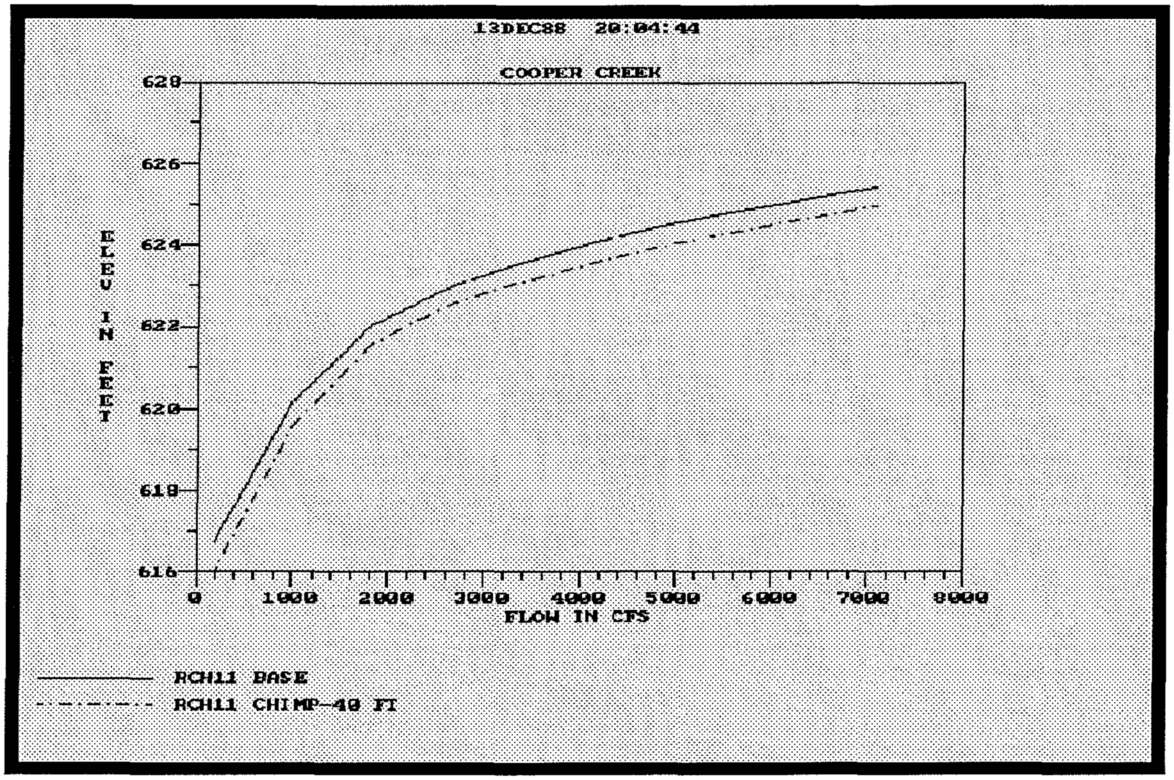


Generally, expected annual damage computation utilizes three basic parametric relationships: frequency-discharge, elevation-discharge, and elevation-damage. From these, the frequency-damage curve is derived. The frequency-discharge curves are usually derived first, followed by the elevation-discharge rating curves, and then followed by the elevation-damage curves. Once the three basic curves are calculated, the derived curves are computed. Typically, the analyst follows this procedure first for base (existing) conditions only. Once the expected annual damage is computed for the base condition, the analyst restarts the procedure for each damage reduction measure. Although the base condition is usually evaluated by itself, two or more plans may be evaluated simultaneously.

The first step is to compute a frequency-discharge curve for base (existing) conditions. A variety of methods may be invoked and the method is dependent upon many factors including data availability and basin development. If proposed damage reduction measures affect the frequency curve, then modified curves are developed for each proposed measure. This may be done at the same time the base condition is evaluated or at a later time. These measures include reservoirs, diversions, flood forecasting, and land use control. Figure 1 depicts three frequency curves - one is for the base condition and the others represent conditions with two different reservoir sizes.

The next step is to compute an elevation-discharge rating curve for base conditions. Typically, it is developed by calculating water surface profiles for a wide range of discharge. It is advantageous to select the discharges from the frequency-discharge curves. The analyst is then assured that the computed rating curve extends to very frequent events (e.g. 50 percent chance exceedance) as well as to very rare events (e.g. 0.2 percent chance exceedance). In addition, the water surface profiles

Figure 2: Elevation-Discharge For Two Plans



(and the associated coordinate points on the rating curves) may be calculated for specific exceedance frequencies such as 50, 20, 10, 5, 2, etc. per cent chance exceedance. If proposed measures affect the rating curves, then modified curves are developed for each proposed measure. This may be done at the same time the base condition is evaluated or at a later time. These measures include levees, floodwalls, and channel modifications. Figure 2 depicts two different rating curves for the same reach - one is for the existing condition and the other represents a channel improvement condition.

The next step is to derive a frequency-elevation curve from the basic relationships of frequency-discharge and elevation-discharge. For selected values of exceedance frequency, a corresponding value of discharge is interpolated from the frequency-discharge curve. Using this interpolated discharge value, a corresponding elevation is interpolated from the elevation-discharge rating curve. Using this procedure, the analyst derives a frequency-elevation curve. Figure 3 depicts this interpolation process.

The next step is to derive an elevation-damage curve for base conditions. It may be developed independently of the frequency-discharge and elevation-discharge curves although information from those curves is helpful. The FDA Package computes an aggregated elevation-damage curve from which it derives a frequency-damage curve for each damage reach. Other methodologies compute expected annual damage at each structure and then aggregate expected annual damage for each reach and/or study. If proposed damage reduction measures affect the elevation-damage curve, then modified curves are developed for each proposed measure. These measures include levees, floodwalls, flood proofing, relocation of structures, flood warning, and land use control. Figure 4 depicts two different elevation-damage curves for the same reach - one is for the existing condition and the other represents a flood proofing condition.

Figure 3: Derivation of Frequency-Elevation

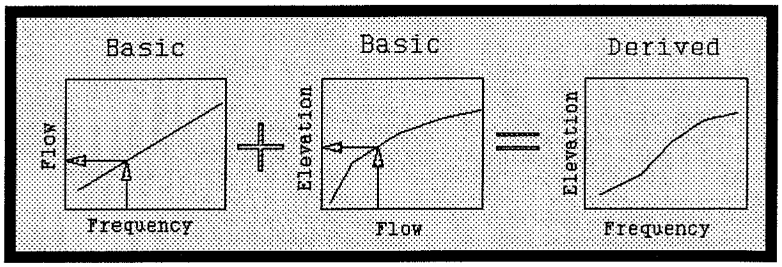


Figure 4: Elevation-Damage For Two Plans

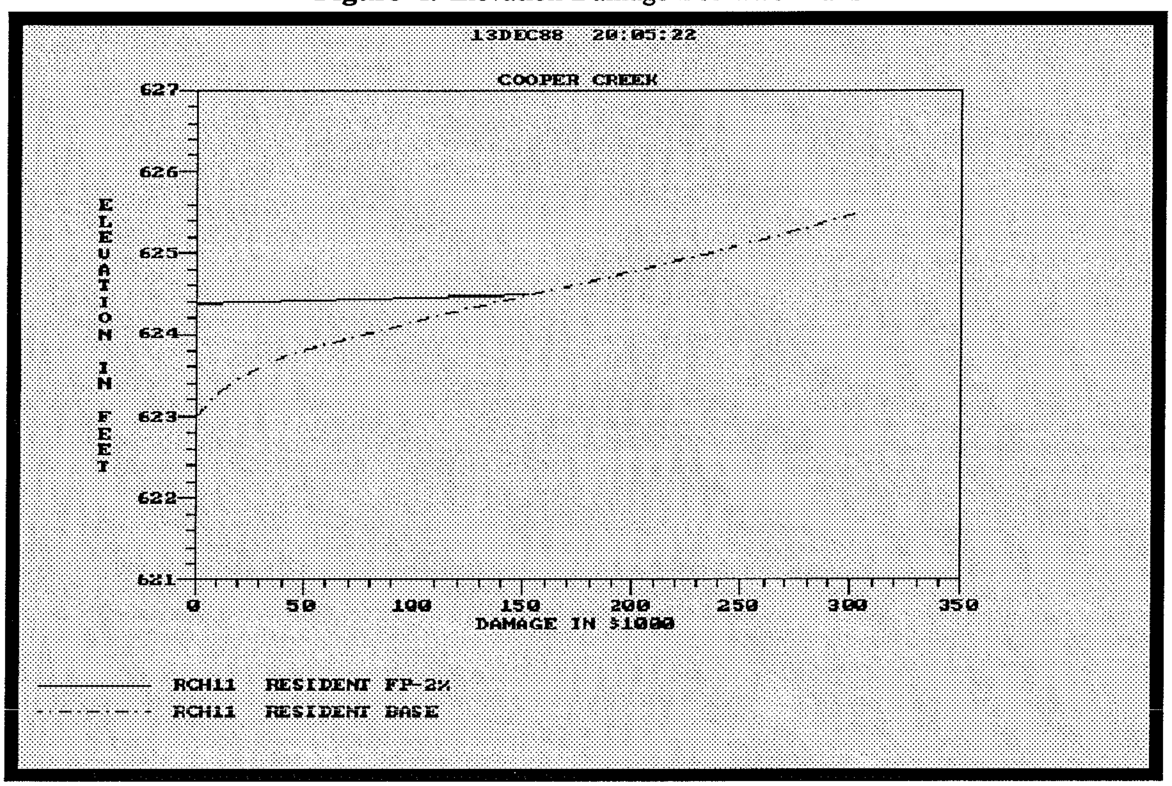
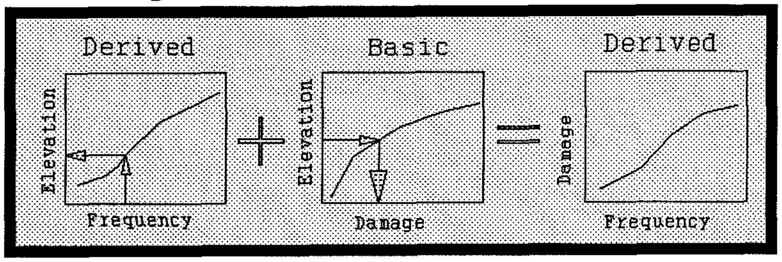
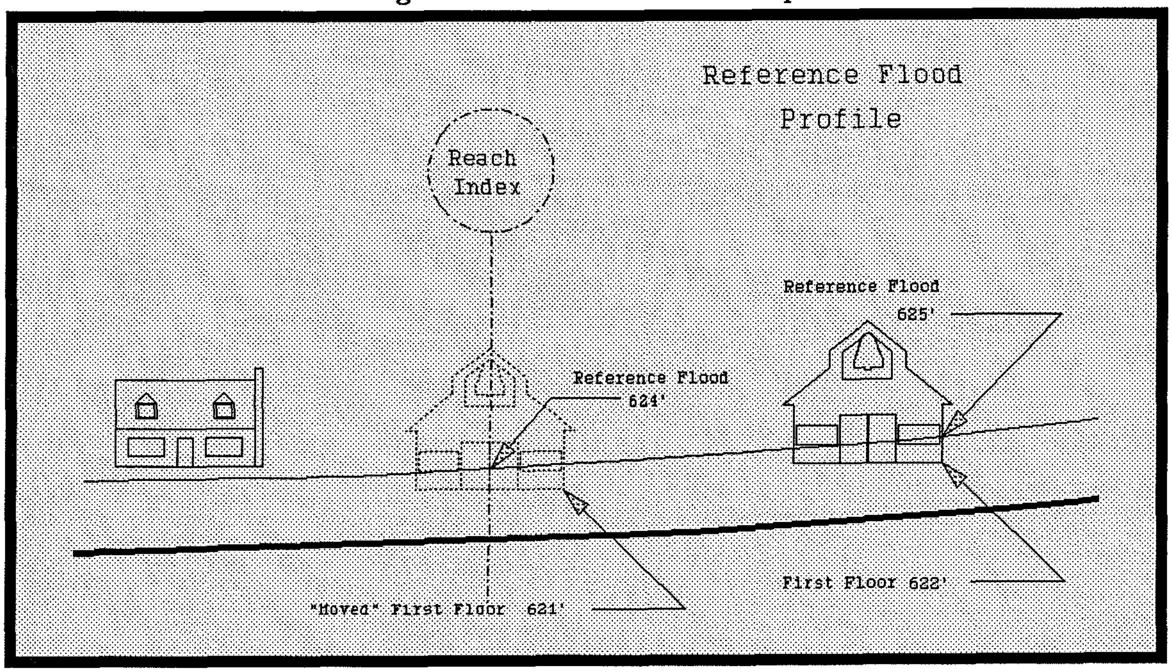


Figure 5: Derivation of Frequency-Damage



The final step is to derive a frequency-damage curve from the derived frequency-elevation curve and the basic elevation-damage curve. For selected values of exceedance frequency, a corresponding value of elevation is interpolated from the frequency-elevation curve. Using this elevation value, a corresponding damage is interpolated from the elevation-damage curve. By following this procedure, the analyst derives a frequency-damage curve. Figure 5 depicts this interpolation procedure. Typically, multiple frequency-damage curves are derived for each damage reach and each condition (e.g. base condition). Each curve represents different damage categories which might include single family residential, light commercial, public building, light commercial, heavy industrial, etc. In addition, separate curves may be computed for structural and content damage. For example, expected annual damage to single family residential structures may be calculated separately from the damage to the contents within the structures. In addition, the damage to single family structures may be subdivided into smaller categories such as single story homes, two story homes, and duplexes. Conversely, subsets of damage categories may be aggregated into more general category sets.

Figure 6: Reference Flood Concept



The FDA Package requires the user to divide the study area into damage reaches because the stage, flow, frequency, and damage relationships vary along a river. The user selects a damage index location within each reach. It should coincide with a geometric cross-section used in the water surface profile computations. There is one frequency-discharge curve and one elevation-discharge curve at the index location and they represent the entire reach. Similarly, there is one aggregated elevation-damage curve for each user selected damage category and it represents all structures and their associated contents within each reach.

Due to the nature of hydrologic and hydraulic modeling, it is relatively simple to obtain the flow-frequency and elevation-discharge curves at the index location. However, it is more complicated to derive the aggregated elevation-damage curve because the structures which are subject to damage are spatially distributed in three dimensions within the damage reach. Conceptually, the FDA Package "moves" all of the structures within a damage reach to the index location and aggregates the depth-damage for each structure into an elevation-damage curve which represents all structures within the damage reach. It "moves" the structures by utilizing a "reference flood" water surface profile. For this profile, it assumes that damage is a function only of the depth to which a structure is flooded and not a function of its distance from the river or index location. In other words, if the reference flood profile inundates a structure to a depth of two feet at some location along the damage reach, then the same structure would suffer exactly the same amount of damage for all events if it were instead moved to the index location and was positioned such that it is flooded to a depth of two feet by the reference flood water surface profile. For accurate calculations, the water surface profiles for all exceedance frequencies should be close to parallel. Figure 6 depicts the reference flood concept. Structure 571, a school, is conceptually moved from its physical location to the damage reach index location.

To compute the aggregated elevation-damage curve for each damage category, the user must supply several data items. For the damage index location within the reach, the user must define the elevation of the reference flood water surface profile. For each structure, the user must define the first floor elevation, the value of the structure (in $1,000), the value of the contents (in $1,000 or percent of structure value), the reference flood profile elevation, the damage category to which it will be aggregated, and the depth-damage function identification code for the structure and content damage. The depth-damage identification code identifies a depth-damage curve. This curve defines damage as a function of the depth to which the structure is flooded. The damage may be expressed as either a percentage of the structure value or as direct dollar damage. A depth of zero feet corresponds to the first floor elevation. If a structure suffers damage when flooded below the first floor, the depth-damage curve starts with a depth less than zero. Separate depth-damage functions may be defined for each structure. However, if more than one structure uses a common depth-damage curve, the function is entered only once. Figure 6 and Tables 1 through 3 depict the calculation of the aggregated elevation-damage curve. In this example, the damage reach contains two structures - one residential structure (structure 311) and one school (structure 571). Table 1 tabulates the depth-damage functions where depth is in feet above the first floor elevation and damage is in percent of total structure value.

Table 1: Depth-Damage Functions

Depth (in feet)	Damage (in percent of structure value)	
	residential	school
0	0	0
1	10	10
2	15	11
3	28	12
4	32	13
5	39	15
6	43	18

The "school" function is used for all schools. From Table 1 in this example, if a school is flooded two feet above the first floor, it suffers damage equal to eleven percent of the total value of the structure. Table 2 gives pertinent information about the structures and the damage reach index location. The school has a first floor elevation of 622. The reference flood elevation at the school is 625 feet and at the index location is 624 feet. The school is conceptually moved to the index location by lowering the first floor elevation by one foot and it becomes elevation 621 feet at the index (the difference in elevation of the reference flood water surface profile at the index minus that at the school). Table 2 describes this new first floor elevation as the "transformed first floor elevation". Figure 6 depicts this transformation. A similar procedure is followed for residential structure 311.

The depth-damage functions are then used to compute the aggregated elevation-damage relationship at the index location as shown in Table 3. The extreme left column entitled "Elevation at Index" contains elevation coordinates and the extreme right column entitled "Index damage" contains aggregated damage coordinates for the two structures. The aggregated elevation-damage

Table 2: : Structure and Index Location Information

Structure and Index Location Information				
location	reference flood elevation	first floor elevation	Structure Value ($1,000)	Transformed first floor elev.
index location	624	---	---	---
Structure 311	622	623	100	625
Structure 571	625	622	200	621

curve is comprised of these two columns. In this example, there is only one elevation-damage curve for this reach and it reflects damage to all structures. Typically, the residential and school structures are aggregated into separate curves.

Table 3: : Aggregation To Index Location

Aggregation To Index Location							
Elevation	Structure 311			Structure 571			Index
at Index (feet)	depth (feet)	damage (%)	damage ($1,000)	depth (feet)	damage (%)	damage ($1,000)	damage ($1,000)
621	-	-	0	0	0	0	0
622	-	-	0	1	10	20	20
623	-	-	0	2	11	22	22
624	-	-	0	3	12	24	24
625	0	0	0	4	13	26	26
626	1	10	10	5	15	30	40
627	2	15	15	6	18	36	51
...	...	...	...	...	...	...	...

Once the three basic parametric relationships (frequency-discharge, elevation-discharge, and elevation-damage) are computed, the frequency-damage curve is derived and then integrated to determine the expected annual damage. Often, this is done first for the base (or existing) condition. Proposed flood damage reduction measures are then evaluated. The analyst computes modified parametric relationships, derives new frequency-damage curves, and integrates the frequency-damage curves to determine the expected annual damage. Examples of this include evaluation of reservoirs, channel modifications, and structure flood proofing. Table 4 summarizes several damage reduction measures and the parametric relationships which they modify. If only one measure is evaluated, then only the parametric relationship(s) affected by this measure change. For example, if a reservoir is evaluated, a new flow-frequency curve is computed, the elevation-flow rating curves and the elevation damage curves would remain the same. The benefit of the proposed measures is determined by subtracting the expected annual damage for each measure from the base condition expected annual damage. This difference is labeled the "inundation reduction benefit". The analyst would complete the analysis by determining the cost associated with each measure and computing a benefit-cost ratio. The FDA Package does not contain capabilities for evaluating the cost of implementing proposed measures.

Table 4: : Effect of Flood Plain Management Measures

Measure	Impacted Relationship[1] Stage-flow	Stage-Damage	Flow-Damage	Flow-Frequency	Damage-Frequency
Reservoir[2]	NC	NC	NC	M	M
Levee or floodwall[2]	M	M	M	M[3]	M
Channel Modification[2]	M	NC	M	M[3]	M
Diversion[2]	NC	NC	NC	M	M
Flood Forecasting	NC	NC	NC	M	M
Flood Proofing	NC	M	M	NC	M
Relocation	NC	M	M	NC	M
Flood Warning	NC	M	M	NC	M
Land Use Control[4]	NC	M	M	M	M

1 The following codes apply to the table above:

NC = No Change in parametric relationship
M = Modification to parametric relationship

2 Long-term effects resulting from a change in stream regime induced by these measures could affect the basic stage-flow relationship and thus other derived relationships at some future date.

3 Elimination of significant amounts of flood plain storage can result in downstream effects on flow-frequency relationship.

4 The impact indicated is that which would occur to a future condition in the absence of the measure.

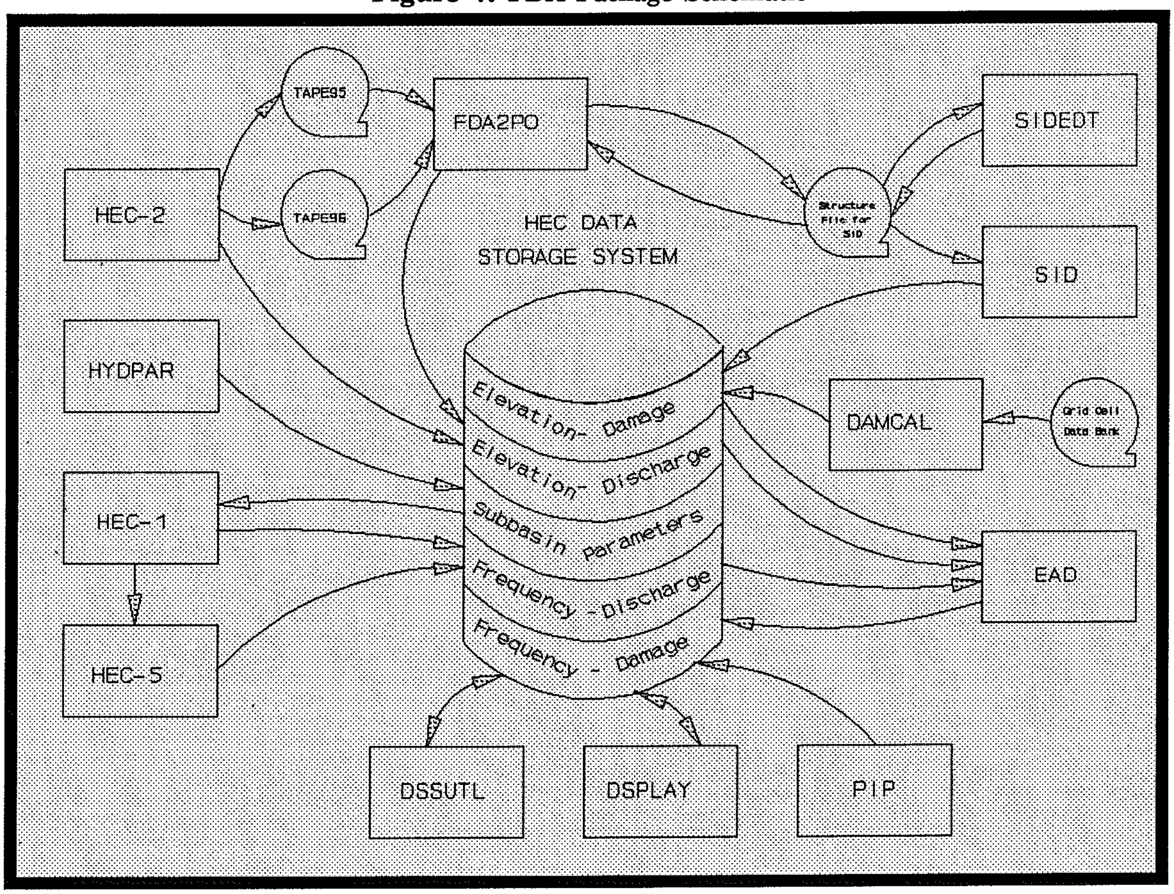
In most study areas, the parametric relationships which are used to compute expected annual damage will not remain constant during a proposed project's life. For example, a proposed reservoir may have an expected serviceable life of 100 years. If it is built above a large metropolitan city (or cities), the urban areas below it will likely grow in size within that 100 year time period. The growth will likely occur (within land use restrictions) under with as well as without reservoir conditions and the aggregated elevation-damage curves will change as a function of this growth. For a given level of flooding (for example, the 0.5% chance exceedance flood elevation), more damage occurs because there are more structures located within the 0.5% chance exceedance (sometimes called the "200 year recurrence interval") flood plain. The FDA Package utilizes a procedure called the "Equivalent Expected Annual Damage" computation to evaluate changing parametric relationships. The user may compute several aggregated elevation-damage relationships during the projects serviceable life at significant years. Expected annual damage is computed for each of these years. For years between the input elevation-damage curves, the expected annual damage is linearly interpolated. The "present worth" of all values of expected annual damage is discounted to the base year using a discount interest rate. The total "present worth" for all years is then amortized over the expected serviceable life of the project to determine the equivalent expected annual damage.

Another example of a changing parametric relationship is the flow-frequency curve in an urbanizing study area. Urbanization of an area requires the paving of natural lands. Instead of rainfall infiltrating the ground, it rushes into storm sewer systems and into the stream channels. This creates a steeper hydrograph with a higher peak discharge compared to pre-growth conditions. As a result, for the same exceedance frequency, a higher peak discharge occurs and the frequency curve must be modified. Again, the analysis requires the application of "equivalent annual damage".

A final example of a changing parametric relationship is "affluence". It is possible to assume that during the serviceable life of a proposed project, the contents within a structure will increase in value relative to the value of the structure in which they are housed. Typically, this applies to residential structures. For example, some homeowners have taken advantage of the current explosion in consumer electronic goods and have filled their house with computers, VCR's, big screen television sets, etc. Other homeowners have improved the quality of their carpeting and furniture. The analyst may be able to forecast similar future increases in content value. For these cases, the depth-damage function may be modified and / or the content value may be redefined either in thousands of dollars or in percent of structure value. The content value would increase during the serviceable project life and the user would apply the "equivalent annual damage" computations.

The "equivalent annual damage" calculation should not be confused with adjustments for inflation. Corps of Engineers regulations prohibit the inclusion of inflation (or deflation) in the flood damage evaluations. It must be assumed that a house that costs $125,000 in 1988 dollars today will still cost $125,000 in 1988 dollars at the end of the projects serviceable life (for example, 50 years from now). The intent is to apply equivalent annual damage only to those cases in which the basic parametric relationship changes due to non-inflationary (or deflationary) items.

Figure 7: FDA Package Schematic



Computer Programs in the Package

The FDA Package includes computer programs in hydrologic and hydraulic engineering, flood damage analysis, and data management. Figure 7 depicts the relationship of these programs to the data management system (HECDSS). The hydrologic and hydraulic engineering application programs used in the Package are:

- HEC-1 Flood Hydrograph Package; simulates rainfall-runoff, ungated reservoirs and hydrologic channel routing; it is used to develop existing, without condition, and modified condition flow-frequency curves.

- HEC-2 Water Surface Profiles; computes steady-state, uniform water surface profiles; it is used to develop existing, without condition, and modified condition elevation-flow rating curves.

- HEC-5 Simulation of Flood Control and Conservation Systems; simulates complex reservoir systems; it is used to develop existing, without condition, and modified flow-frequency curves.

The flood damage analysis application programs used in the Package are:

- SID, Structure Inventory For Damage Analysis; processes inventories of structures located in the flood plain; it is used to develop aggregated elevation-damage relationships.

- SIDEDT, Structure Inventory For Damage Analysis Edit Program; edits and manipulates structure inventory and damage function files used for the SID program.

- DAMCAL, Damage Reach Stage-Damage Calculation; performs same analysis as SID except DAMCAL is based on a geographic (spatial) unit; it is used to develop aggregated elevation-damage relationships.

- EAD, Expected Annual Damage Computation; computes expected (or equivalent) annual damage and inundation reduction benefits; it is used to compare flood damage mitigation plans.

- FDA2PO, HEC-2 post-processor program; computes the reference flood elevation at structures and stores elevation-discharge rating curves in a HECDSS data file.

The data management programs used in the Package are:

- PIP, Interactive Paired-Function Input Program; directly stores paired function relationships in a DSS data file; for example, the user may enter an elevation-damage or flow-frequency relationship derived by hand from field data.

- DSSUTL, HEC-DSS Utility Program; provides the means of performing utility functions on data stored in the HEC-DSS data file; for example, the user may catalog the DSS file, or edit and delete data.

- DSPLAY, HEC-DSS Display Program; Provides the means to tabulate and plot data stored in a HEC-DSS data file.

Either HEC-1 or other tools may be used to develop base condition frequency-discharge curves. To evaluate structural alternatives, HEC-1 is applied in the "multi-plan" - "multi-ratio" mode. The user develops simulation input data containing the basin configuration, the base condition frequency curve, and either rainfall amounts and distributions or basin runoff hydrographs. The user also includes a maximum of nine ratios which are multiplied by either the precipitation or runoff hydrographs. Finally, the user includes input describing proposed damage reduction measures (such as an ungated reservoir). The first plan entered in the simulation input must be the base condition plan corresponding to the base condition frequency curve. HEC-1 computes separate peak discharges (and associated hydrographs) for each ratio and for each plan. It then derives modified condition frequency curves by interpolation. If the user enters appropriate input data, the frequency-discharge curves are written to the data base (HECDSS data file).

HEC-5 is applied in a fashion similar to HEC-1. There are two primary differences between the programs:

(1) HEC-1 models the rainfall-runoff process whereas HEC-5 does not.

(2) HEC-5 simulates gated reservoirs whereas HEC-1 simulates only ungated reservoirs.

HEC-5 is run in the "multi-ratio" and "multi-plan" mode similar to HEC-1 and the modified frequency curves are written to the HECDSS data file.

HEC-2 computes steady-state, uniform flow profiles. A range of discharge is input to the model in order to simulate water surface profiles from very frequent (50% chance exceedance frequency or less) to very infrequent (0.2% chance exceedance frequency) events. Usually, the calculated frequency-discharge curves from HEC-1 simulations are used as a guide in selecting the discharges which are input to HEC-2. Currently, only the versions of HEC-2 which reside on mainframe computers are able to write rating curves to the HECDSS data file. If one of the output disk files (either "TAPE95" or "TAPE96") containing HEC-2 computed results is saved, then the utility program FDA2PO may be invoked to store the rating curves in the HECDSS data file and compute reference flood elevations at each structure.

The SID and DAMCAL programs compute aggregated elevation-damage curves for each damage reach. In a given study, either the SID or the DAMCAL program is used, not both. DAMCAL is used in conjunction with spatial data analysis techniques. SID is used with structure inventories in cases where no spatial analysis is needed. SID performs the functions described earlier under the aggregation of structure damage data. SID input data includes:

- depth-damage functions for all structures, structure contents, and "other" improvements.
- structure inventories for all structures residing in all analysis reaches. The structure inventories include structure and content value, damage function identification, first floor elevation, and reference flood elevation.
- job information which comprises of many items and includes: non-structural flood damage reduction measures (flood proofing, raise-to-target, or relocation), damage reach identification, damage category identification, and output control parameters.

SID performs nonstructural flood damage analysis. The user may define a wide variety of options. For example, the analyst may flood proof all structures to a given elevation (such as the 2% chance exceedance), specify a maximum limit to the flood proofing (such as 2 feet), flood proof individual structures, or flood proof all structures to a specific height above the first floor elevation. Similar options exist for the raise-to-target and relocation measures. SID is invoked once for each measure and the resulting elevation-damage curves are stored in the HECDSS data file. SID analyzes any or all damage reaches at one time for one plan. Separate runs are required for each plan (damage reduction measure). It is most efficient to maintain the depth-damage curves and the structure inventories in separate files. The main SID input data file would then contain only job requirements such as any non-structural analysis criteria, output options, and damage reach identifications.

SIDEDT allows the user to manage and manipulate SID depth-damage curves and structure inventories. Typical applications include generating direct access files for depth-damage functions, performing arithmetic operations on structure data, and selecting structures for analyses based on Boolean logical operations. For example, the analyst may evaluate a subset of the structure inventory by extracting structures for selected reaches and damage categories. An example command to perform this is:

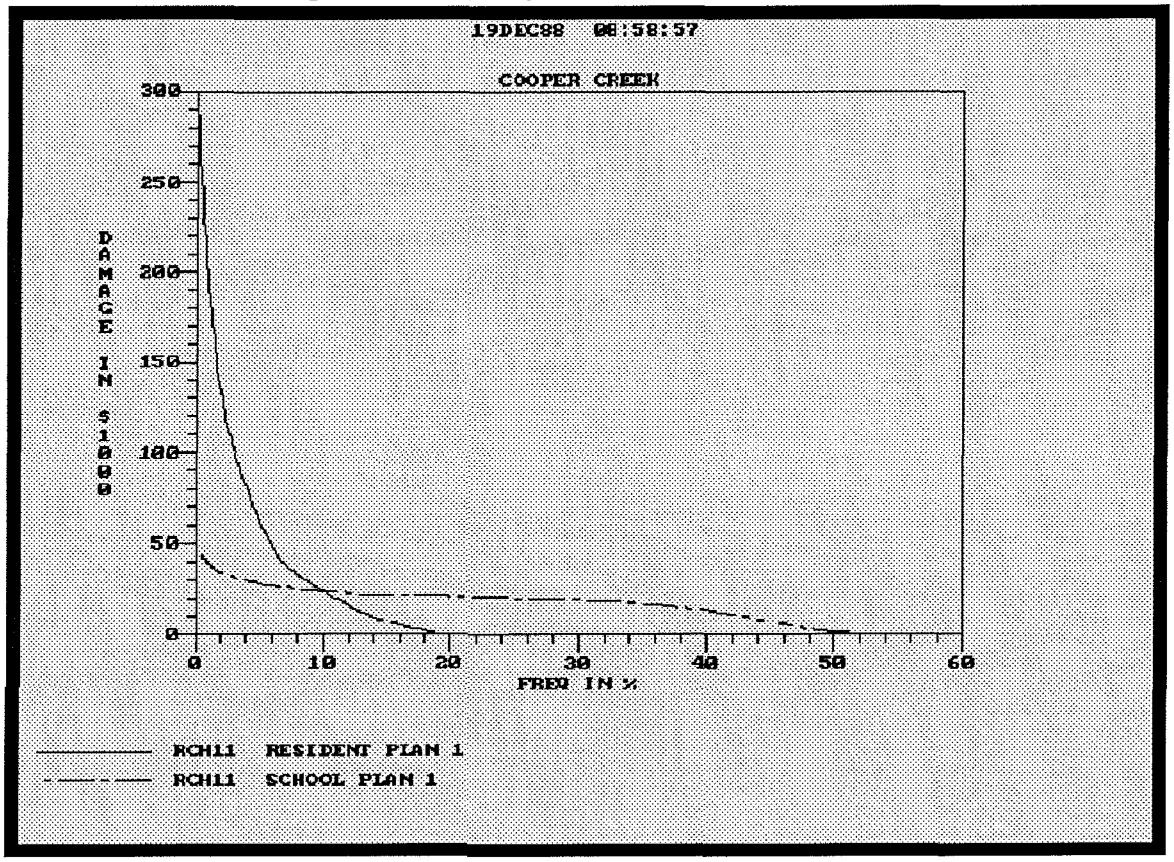
```
PULL FROM 8 TO 12 BY IF IDRCH1 EQ '    DR1' AND IDCAT EQ 'RESIDNTL'
```

SIDEDT moves from one data file to another all structures that are in reach DR1 and the residential damage category "RESIDNTL".

FDA2PO provides a link between the hydrologic/hydraulic engineering and the flood damage analysis programs. It will store rating curves in the HECDSS data file for selected damage reach index locations. It will also compute the reference flood elevations at each structure in the SID inventory as well as at the index location. To compute the reference flood profile elevations, the user must select one of the HEC-2 water surface profiles as the reference flood profile and must identify the stream location (e.g. river mile) at which each structure is located.

EAD is the "bottom line" program in the FDA Package. It merges all of the basic parametric relationships computed by HEC-1, HEC-2, HEC-5, SID, DAMCAL, and FDA2PO. It derives the frequency-damage curve from the frequency curves computed by HEC-1 and HEC-5, the rating curves computed by HEC-2, and the elevation-damage curves computed by SID or DAMCAL. Figure 8 depicts the frequency-damage curves for one reach and two damage categories. The EAD program calculates the expected annual damage by integrating the frequency-damage curve. It performs the equivalent annual damage computation procedure as described earlier. It computes the

Figure 8: *Frequency-Damage For Two Categories*



innundation reduction benefit for all plans and sumarizes the expected annual damage by category, reach, and plan. Table 5 exemplifies the final EAD summary table.

Table 5: : Summary EAD Output

```
** GRAND SUMMARY BY CATEGORY **

** FLOOD PLAIN MANAGEMENT PLANS
       1 -        EXISTING COND. - USES BASE QF,QS,DG DATA
       2 -        RESERVOIR - USES BASE QS,DG DATA - UNGTD RES (650) QF DATA
       3 -        RESERVOIR - USES BASE QS,DG DATA - UNGTD RES (655) QF DATA
       5 -        CHANNEL - USES BASE QF,DG DATA - CHANNEL QS DATA
       6 -        FLOOD-PROOFING-USES BASE QF,QS DATA-FLOODPROOFING DG DATA

GRAND SUMMARY - ALL DAMAGE CATEGORIES
------------------------------------------------------------------------------------------
              . . . . . . . . . . . . . EXPECTED ANNUAL DAMAGE

  DAMAGE      BASE     .... PLAN  2....   .... PLAN  3....   .... PLAN  5....   .... PLAN  6....
 CATEGORY   CONDITION  DAMAGE    DAMAGE   DAMAGE    DAMAGE   DAMAGE    DAMAGE   DAMAGE    DAMAGE
            (PLAN  1)  W/PLAN   REDUCED   W/PLAN   REDUCED   W/PLAN   REDUCED   W/PLAN   REDUCED
------------------------------------------------------------------------------------------
  RESIDENT    33.34     8.84     24.50     7.06     26.28    18.12     15.22    10.05     23.28
  GAS STAT      .73      .14       .59      .10       .63      .50       .23      .73       .00
  SCHOOL       9.78     5.13      4.64     5.10      4.67     7.21      2.57     9.77       .00
  CHURCH        .92      .32       .60      .22       .70      .39       .53      .92       .00
  OTHER         .00      .00       .00      .00       .00      .00       .00      .00       .00
------------------------------------------------------------------------------------------

     TOTAL    44.76    14.43     30.33    12.49     32.27    26.22     18.54    21.47     23.29

------------------------------------------------------------------------------------------

-----DSS---ZWRITE Unit  71; Vers.   14:  /COOPER CREEK//PLAN-EAD////
```

Coordination of Analysis

Typically, in the U.S. Army Corps of Engineers, flood damage studies involve at least three people - a study manager, an engineer, and an economist. The engineer is usually a civil or hydraulic engineer working in the Engineering Division and is responsible for the hydrologic and hydraulic computations. These involve the application of HEC-1, HEC-5, and/or HEC-2 to model rainfall-runoff processes and compute water surface profiles. The economist works in the Planning Division and is responsible for the flood damage calculations. These involve the application of FDA2PO, SID, SIDEDT, DAMCAL, and EAD. The economist must compile an inventory of structures, a table of depth-damage functions, coordinate the inventory with the hydrologic and hydraulic information, and compute the expected annual damage. Both the engineer and the economist must understand and apply data base utilities. Finally, the study manager must coordinate work performed by the Engineering and Planning Divisions and accurately report the study results. Figure 7 depicts these component parts --- basically, the Engineering Division is responsible for programs on the left and the Planning Division is responsible for programs on the right. The HECDSS data file acts as an information conveyer between Divisions. Study personnel can make their studies more efficient and of a higher quality by carefully coordinating their work. The utilization of the HECDSS requires the two Divisions to communicate more since results from Engineering are now given to Planning in an electronic format rather than on paper. The two parties must agree on such things as data naming conventions, locations where parametric relationships are computed, and the types of required results. The outcome of using the data base as an information conveyer is better communication between Engineering and Planning Divisions with the result of a more efficient and a higher quality study.

HECDSS Data Base

The application of the FDA Package requires the user to be knowledgeable in both the application programs as well as the data management conventions and procedures. The HECDSS system allows the analyst to generate one or more data files which contain analysis results. The basic purpose of the Package is to transfer data between programs with little intervention by the analyst. The data storage system provides the vehicle for accomplishing this. There are "spin-off" benefits such as separate data management functions of graphing, tabulating, archiving, and editing.

The HECDSS is a set of software which allows the analyst to generate and store data in a disk file. Although virtually any type of data may be stored, there are several standard data "conventions" which the utility programs recognize. The adoption of these data conventions simplifies software development and allows standard treatment by application and utility programs.

The HECDSS recognizes the conventions of regular time series, irregular time series, and paired function data. The time series convention facilitates efficient storage of data which is measured (or computed) frequently in time for one parameter and one location. An example of such data is the period-of-record eight A.M. stages at a stream gage.

The paired function convention facilitates the storage of a matrix of data consisting of data arranged in rows and columns. One record in the HECDSS data file contains data for one location, one type of relationship, and two variables (or parameters). The FDA Package uses this convention exclusively to transfer results from one application program to the data base file from which a subsequent analysis program retrieves it. A minimum of two columns is required to define a curve of independent and dependent coordinate points. An example of such data is the elevation-discharge rating curve. One variable is elevation and the other is discharge. One record in the HECDSS data file represents the rating curve at one cross-section for one condition (e.g. base condition). The paired function convention also allows one variable to have more than one column of data. An example of such data is a matrix of elevation-damage data. The first column of data is a set of elevations. Each subsequent column contains damage associated with one damage category and corresponds to the elevations in the first column.

The HECDSS software generates an unformatted (or binary), direct access data file. The analyst needs to know only two things about such files:

(1) The file is formatted such that the analyst cannot directly "list" or read the file. To examine data, a utility program must be invoked to tabulate data.

(2) Any record may be accessed directly (as opposed to sequentially). To read a data record at the end of the file, the software reads the record directly as opposed to starting at the front of the file and reading all records which precede the desired record. This makes data access very efficient.

The utility programs (such as DSPLAY and DSSUTL) allow the analyst to archive, edit, tabulate, and plot data stored in the HECDSS file. Data may be archived in a "human readable" (or ASCII) format or in an archive HECDSS data file. Other utility program functions allow the analyst to get an index of data stored in the file. This index is called a data file catalog or catalog listing. The user may selectively catalog the file in order to find (for example) all frequency-discharge curves.

The "catalog" of a HECDSS file is analogous to the table of contents of a book. An alphanumeric label (called a pathname) identifies one record of data. The pathname contains six parts and each part represents certain items for paired function data as described in Table 6. Example pathnames include the following:

/SILVER CREEK/RCH22A/FREQ-FLOW//1990/BASE/
/SILVER CREEK/RCH22A/ELEV-FLOW///BASE/
/SILVER CREEK/RCH22A/ELEVATION-DAMAGE//1990/BASE/

Table 6: : Pathname Part Conventions

Part	Description
A	Study name or river basin.
B	Geographic location such as the damage reach identification.
C	The type of data such as frequency-discharge, elevation-discharge, or elevation-damage.
D	Usually not used.
E	The year associated with the data. This is used for equivalent annual damage analysis.
F	The flood damage reduction plan or measure.

The pathnames above represent the frequency-discharge, elevation-discharge, and elevation-damage curves for damage reach 22A in the Silver Creek river basin for base conditions. The year 1990 is entered for the frequency-discharge and elevation-damage curves because these curves change in time due to development in the basin. One or more additional curves are input to represent future conditions and to facilitate computation of equivalent annual damage. These years may be at any interval but typically represent decade years.

The application programs must be modified to connect with the HECDSS software. They must access the software routines which read and write to the data file. They must also accept input from the user which allows the user to identify the pathname associated with the curves which are retrieved from or stored in the data file. Application programs such as SID accept the entry of a "ZW" record which directs it to write data to the HECDSS data file. Other application programs such as the EAD program accept the entry of a "ZR" record which directs it to read data from a HECDSS data file. The "ZW" and "ZR" records contain some of the pathname parts which are entered in "free-format". For example, the analyst may enter the following record in the SID input data record:

ZW A=SILVER CREEK E=1990 F=FP-2%

This record provides SID with pathname parts A, E, and F for the elevation damage data. Pathname part B is defined by the normal input data which define the damage reaches and their identification codes. The SID program always assigns pathname part C as "ELEVATION-DAMAGE". If the SID input data includes reach 22A, then the aggregated elevation-damage data would be written to the file with the pathname label:

/SILVER CREEK/22A/ELEVATION-DAMAGE//1990/FP-2%/

Microcomputer Package

Adaptation of the FDA Package to the microcomputer (MS-DOS, IBM compatible) has allowed the implementation of several enhancements. These include the creation of a menu program which allows the analyst to manage the structure of the fixed disk drive, select, edit, and list data files, and generate the Job Control Language (JCL) which is required to execute the program. Editing with the Corps of Engineers data editor COED is easier because of the standard keyboards. The HECDSS contains specialized, computer dependent software code. Adaptation to the microcomputer facilitates the distribution of the HECDSS software to a large segment of the professional population in an operational and tested condition. Finally, microcomputers require substantially fewer resources than larger computers (such as mainframe or minicomputers) and makes the use of the Package affordable to more users. Without the extensive acceptance and standardization of the microcomputer, the widespread distribution of the Package in an operational format is impossible.

The FDA Package is distributed for the microcomputer and contains the flood damage analysis computer programs SID, SIDEDT, EAD, and FDA2PO, and the data management utility programs DSSUTL, DSPLAY, and PIP. The FDA2PO program is compatible with both old and new versions of HEC-2. The current microcomputer distribution versions of the hydrologic engineering programs HEC-1 and HEC-5 do not contain linkages to the HECDSS. However, the next releases will contain the HECDSS capability and they will be released in calendar year 1989.

The microcomputer version of the FDA Package consists of nine 360Kb diskettes. It includes an installation program, the FDA Package menu program, utilities to list, print, and edit input and output data, application and data management programs listed earlier, and graphics device drivers. The utility program HECDSS-DSPLAY graphs data which is stored in HECDSS data files. It plots on dot matrix printers, laser jet printers, pen plotters, and video monitors. It requires the use of proprietary device drivers. Two of the distribution diskettes contain a set of device drivers which represent the most common hardware devices.

The FDA Package menu program consist of the following screens or menus: banner screen, select and/or edit study name menu, program selection menu, and a data file selection menu with an optional data file list screen. Each of these screens and/or menus are described.

The banner screen identifies the Package and a menu program version date. It appears briefly when the menu program is first invoked. The next menu replaces it either after ten seconds or if the analyst presses any key.

The select and/or edit study name menu allows the analyst to manage the fixed disk by assigning a subdirectory to each study. The user selects (or creates) a study and the menu program moves the user into the appropriate subdirectory. Figure 9 depicts the screen when the analyst is editing or defining the Cooper Creek study and associated subdirectory. All data for Cooper Creek will reside on the "D:" fixed disk drive in the subdirectory "\DATA\FDA\WORKSHOP".

The program selection menu lists all of the programs which are distributed with the FDA Package. Other related programs (such as HEC-2) have their own menu program. The user may select a program for execution or for defining desired data files. Figure 10 depicts this screen. In this case, the EAD program has been selected. The user may execute a program by moving the highlighted cursor to the desired program and then pressing the Alt-X key combination. Otherwise, the analyst defines data files for the selected program by pressing the "Enter" key or by entering the integer program number ("1" for the EAD program).

The data file selection menu lists the possible FORTRAN file assignments for each program and allows the analyst to define appropriate file names. The menu program assigns default file extensions for different types of files. For example, it assigns the extension ".E" and ".EO" for the input and output data files respectively for the Expected Annual Damage Program. The user obtains a list of all EAD input data files by entering a question mark when defining the input data file name. The menu program will then list all files which have the extension ".E". In figure 11 the analyst has entered a question mark for the input data file name for the EAD program for Cooper Creek. The menu program has interrogated the subdirectory "\DATA\FDA\WORKSHOP" on the

Figure 9: Edit Study Name Menu

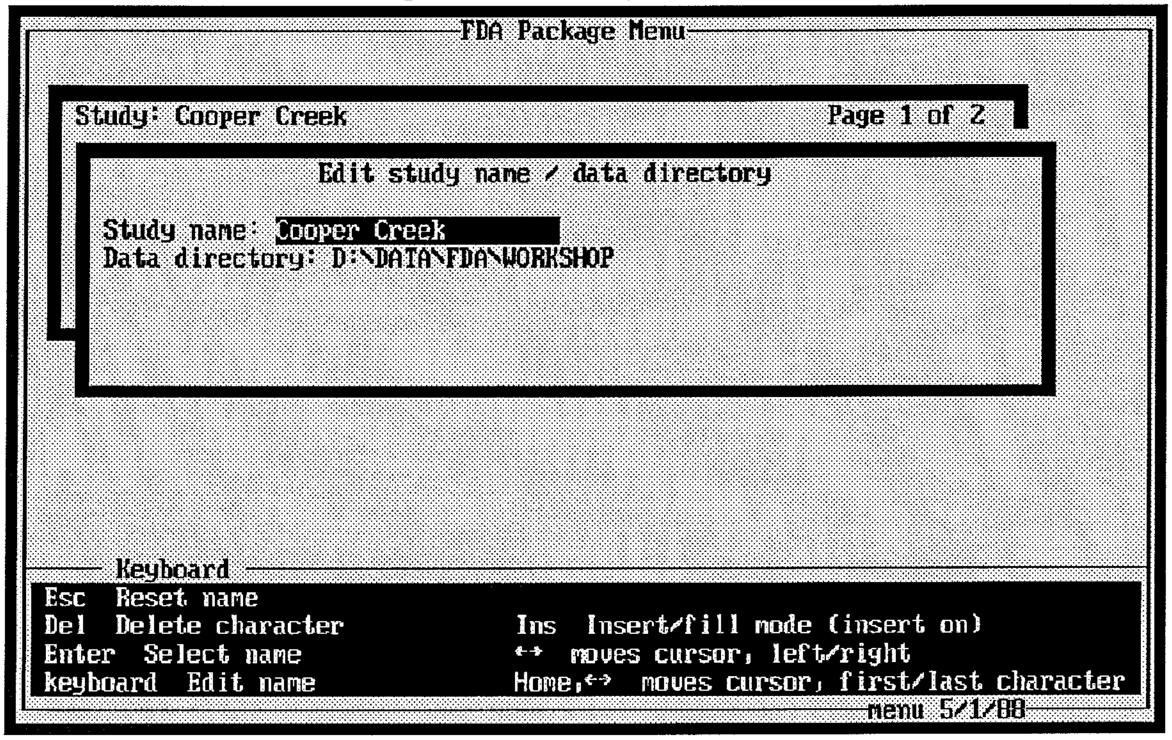
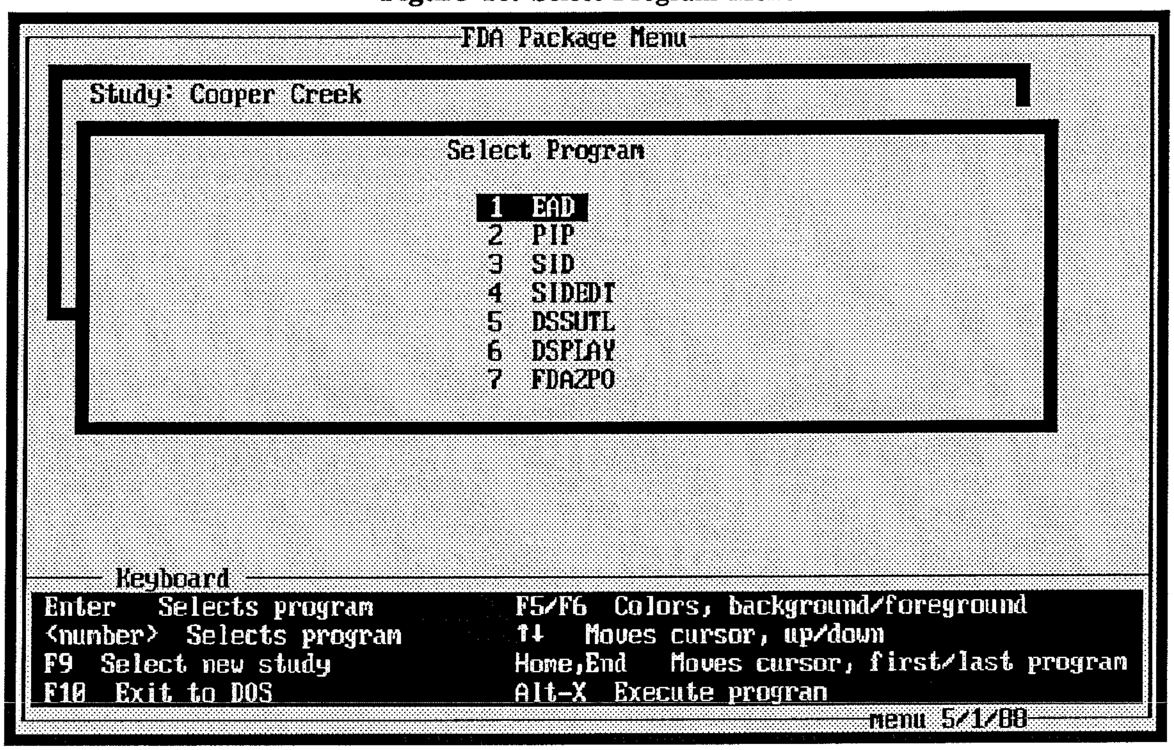
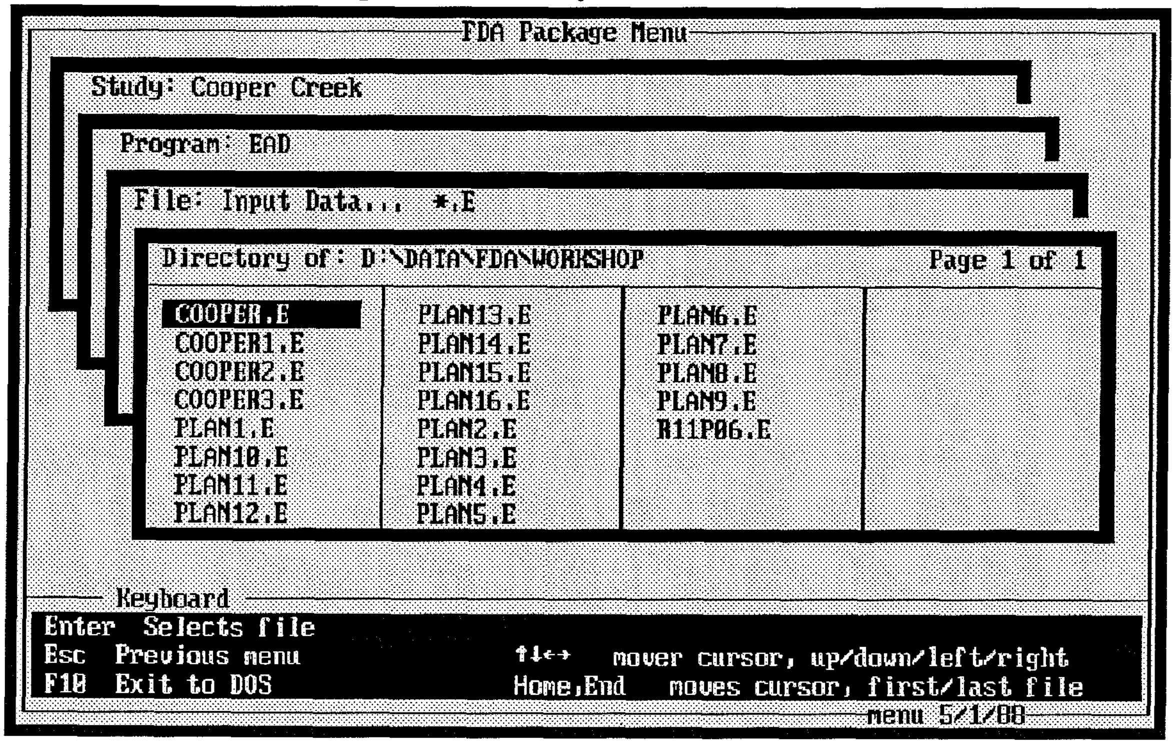


Figure 10: Select Program Menu



fixed disk drive "D:" for all files matching the file mask "*.E" and has displayed a list of those files on the screen.

Figure 11: Directory of Files From Menu



Once the data file is defined, the user may delete, edit, list, or print any file from the "Define data files" menu by moving a cursor to the desired file and pressing the key combinations of Alt-D, Alt-E, Alt-L, or Alt-P respectively. Figure 12 depicts the "Define data files" menu. Help instructions are summarized at the bottom of the screen. The last line reflects the options available and their associated key combinations when using the "Alt" key. Once all of the required files are defined, the user executes the selected computer program by pressing the Alt-X key combination.

The user edits input data by invoking the COED editor from the FDA menu program. For the EAD and SID programs, the selected data file is edited in the "full screen" mode (as opposed to a line edit mode). The editor right justifies all data in the required columns and verifies that numeric data is entered in numeric fields. It will not allow the user to enter alpha characters in numeric fields. The user may also obtain on-line help for the editor and for the EAD and SID programs. The on-line help for EAD and SID is called the "help program" feature. For both programs, the user may access the input data description while in the editor. It has been extracted from their user's manuals and modified for use by the COED editor. For each field, the analyst presses the Alt-F1 key combination to obtain a description of the variable associated with that field. A general description of a given record is obtained by moving the cursor to the first two columns of the data record which contain a record identifier and pressing the Alt-F1 key combination. Figure 13 depicts the computer screen when this is done.

Figure 12: Define Data Files Menu

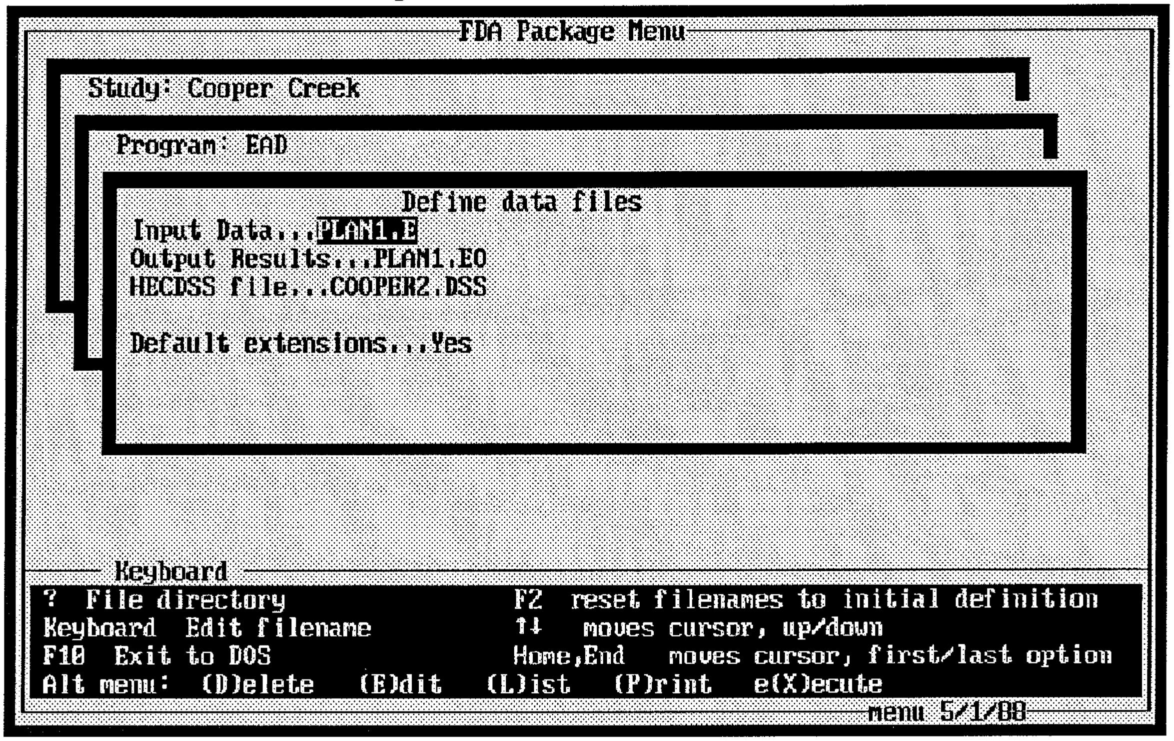
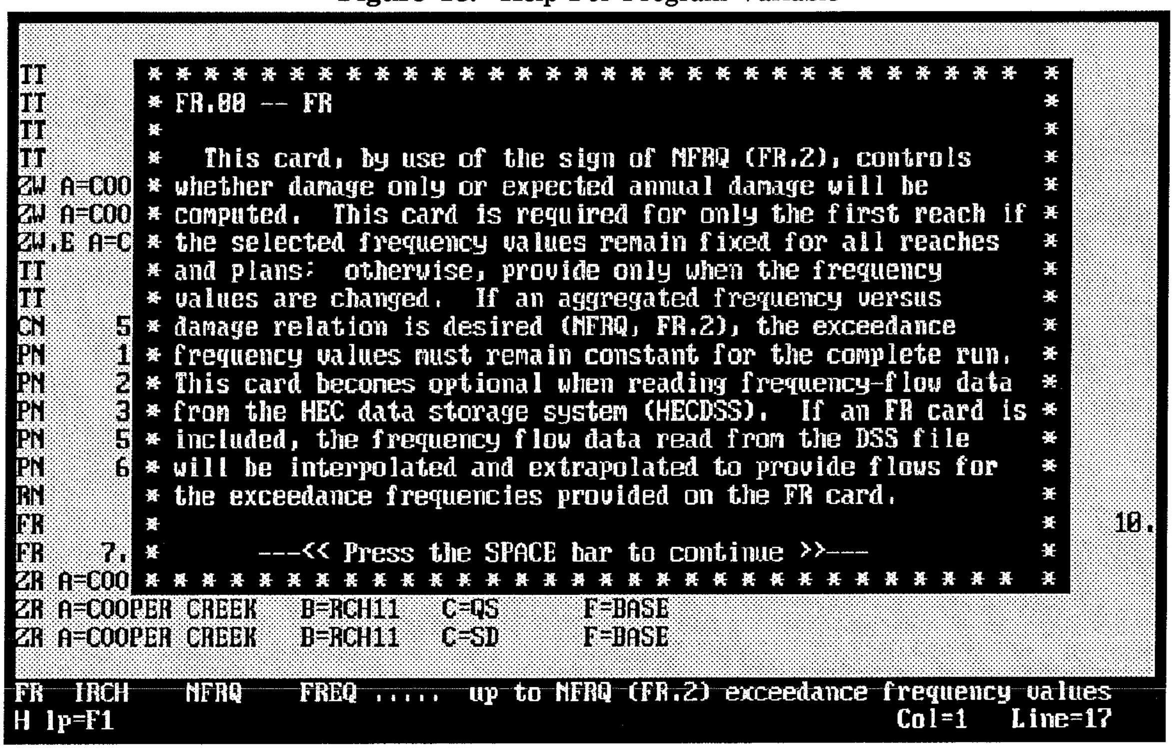


Figure 13: Help For Program Variable



Computer Requirements

The FDA Package requires the following software and hardware:

- MS-DOS computer, IBM compatible.
- MS-DOS version 2.1 or greater.
- 640Kb of RAM
- One 5¼ inch floppy diskette capable of reading 360Kb diskettes.
- Fixed (hard) disk

In addition, the following are recommended:

- MS-DOS version 3.1 or greater.
- Graphics monitor and adapter card (EGA or VGA recommended).
- A minimum of the 80286 (AT level) processor.
- The math co-processor (80287 or 80387).
- A large fixed disk drive. The size depends upon the analyst's data requirements, and should range from 40Mb to 300Mb. The FDA Package of software requires about 2.7Mb of disk space exclusive of input data.
- Cassette tape backup for large studies. Normal "floppy" diskette backup is sufficient for small studies.

If the computer is shared by more than one person and/or the analyst is involved in many studies and/or large studies, then it is desireable to acquire a high-end computer. It would have the following specifications:

- MS-DOS version 3.3 or newer.
- 2Mb or more of memory.
- Fixed disk drive of 300Mb.
- The 80386 and 80387 processing chips operating at 20mhz or faster.
- One 1.2Mb 5¼ inch floppy diskette drive.
- One 1.4Mb 3½ inch floppy diskette drive. This is required if the analyst utilizes a lap top computer in addition to a standard desktop computer.
- A VGA graphics card and monitor.
- A cassette backup card and compatible tape machine.
- A penplotter and/or laserjet printer for producing graphics for documentation.

Microcomputer Package Application

The first version of the HECDSS was created more than eight years ago. In the last six years, the FDA Package has been used on minicomputers for both large and small studies. The application programs (HEC-1, SID, EAD, etc.) have been used individually for several years on MS-DOS computers. They were used primarily on small studies. Within the last two years, one of the Corps of Engineers District offices used a limited, preliminary version of the FDA Package on the microcomputer for a large study in the Amite River basin.

The Amite River study area encompasses 2,000 square miles. A major flood in 1983 caused 172 million dollars in damage. A fifteen year study has been initialized at a cost of 3.5 million dollars. The District is considering at least forty-four different flood damage reduction plans which include channel enlargements, reservoirs, floodproofing, and diversions. As a part of the study, the District contracted with a private firm to inventory all structures within the 0.2 percent chance exceedance frequency (500 year recurrence interval) flood plain. This included about 42,000 residential and 5,900 commercial structures.

The District's economist preferred using a microcomputer instead of a minicomputer. This is the typical preference of casual to moderate users of computers. They feel uncomfortable with mainframe computers and feel that they suffer less outside interference on the microcomputer. Use of the microcomputer also reduces other problems associated with mainframe or minicomputer use such as communication failures (phone or modem problems), mainframe system crashes, overloaded mainframe systems, high processing costs, and more complex management. Although the analyst may "crash" or overload the microcomputer, the analyst is acutely and immediately aware of the problem and normally can fix the problem immediately. If there is a major hardware malfunction of the microcomputer, most offices contain additional computers which the analyst may use with little delay. In contrast, the minicomputer supports many users and is located in a secure area where users are prohibited. There is usually a significant delay between the time the problem occurs until the user is informed as to the nature of the problem and to the resolution of the problem. Thus, the casual to moderate user normally prefers the microcomputer to the mainframe. If today's high-end microcomputers are available (80386 / 80387 processors operating at 20 to 25 Mhz), even experienced users prefer microcomputer use.

For the Amite River study, the economist used an "AT" (80286 chip) computer which had a math co-processor chip (80287), a 32Mb fixed disk, and a 1.2Mb floppy diskette drive. Several people shared the computer. This machine is undersized for a study of this magnitude. To maintain disk space, it required the analyst to constantly move data between diskettes and the fixed disk drive. The use of archiving software diminished the effort and reduced the number of diskettes required to store data on diskettes. For a study of this size, the analyst should acquire a 80386 based machine with a 80387 math co-processor, and a fixed disk drive in the range of 100Mb to 300Mb. However, the analyst was able to effectively perform this study although less efficiently than if a more powerful personal computer were used. Separate structure inventory data files were created for each damage reach. At the time, HEC-2 was not connected to the FDA Package. The Hydraulics and Hydrology section provided frequency-elevation curves for each damage reach. These curves were manually entered into the HECDSS data base using the PIP data entry program. The SID program was run once for each damage reach and the aggregated elevation-damage curves were stored in the HECDSS data file. The EAD program was run to compute the expected annual damage for all damage reaches by deriving a frequency-damage curve from the frequency-elevation and elevation-damage curves which were stored in the HECDSS data file. Generally, the EAD program evaluated ten to twelve plans in one execution.

Representative Execution Times

The amount of time required to process a set of input is dependent upon several things including the computer configuration, the amount of data, the type of analysis, and the amount of output. Table 7 lists representative times for the execution of the SID computer program. All of the computers except the first one have math co-processors. The SID program had to process 1,000 structures and almost all program output was suppressed. If the same data set were run on the 80386 / 25Mhz machine and the user requested the maximum allowable output, the elapsed time would jump from 35 to 145 seconds and the disk output would jump from .01 to 3.4Mb.

Table 7: : Example Execution Times For SID

(1,000 structures)

Computer	Elapsed time (seconds)
XT (without 8087 processor)	5,795
XT (8088 processor)	528
AT (80286 processor at 8Mhz)	235
XT with 80386 add-on board	66
80386 / 16Mhz	63
80386 / 20Mhz	43
80386 / 25Mhz	35
Empty minicomputer	29

Summary

The FDA Package provides the analyst with a wide range of flood damage analysis tools. The development of a data base management system (HECDSS), which addresses the unique nature of hydrologic data needs, provides an effective and efficient vehicle for transporting data between analysis programs. This reduces redundant computer code within the analysis programs and eliminates manual data entry of results from one model as input to another model. The HECDSS also provides tools to tabulate, plot, and edit the data results. It provides a sound and organized method of maintaining and managing study results during as well as after the study. It also acts as a focal point of interaction between the hydrologic and hydraulic engineers and the economists. This encourages better communication amongst study team members and results in more efficient and higher quality studies. Finally, the introduction of low cost microcomputers, which have a standard software operating system and keyboard, has facilitated the distribution of powerful but highly computer system dependent software to the general professional community. The result is a more powerful analysis capability and a friendlier user interface.

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