U-007-303.40

4774

PADDYS RUN FLOW AND INFILTRATION MODEL REPORT: DESCRIPTION AND RESULTS AUGUST 1993

10/01/93

DOE-FN/EPA
175
REPORT

4774

PADDYS RUN FLOW AND INFILTRATION MODEL REPORT: DESCRIPTION AND RESULTS

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

REMEDIAL INVESTIGATION and FEASIBILITY STUDY

PREPARED FOR:

U.S. DEPARTMENT OF ENERGY
FERNALD FIELD OFFICE

PREPARED BY:

IT CORPORATION

August 1993

PRELIMINARY

4774

PADDYS RUN FLOW AND INFILTRATION MODEL REPORT: DESCRIPTION AND RESULTS

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

REMEDIAL INVESTIGATION and FEASIBILITY STUDY

PREPARED FOR:

U.S. DEPARTMENT OF ENERGY
FERNALD FIELD OFFICE

PREPARED BY:

IT CORPORATION

August 1993

DRAFT

DRAFT
4774

PREFACE
PADDYS RUN FLOW AND INFILTRATION MODEL REPORT: DESCRIPTION AND RESULTS

The following report is not intended to be a final, formal report, but is to serve as the basis for a technical discussion on the procedures and techniques used to model the flow and infiltration in Paddys Run. The report's primary purpose, as it stands, is to provide information for the technical discussions. The report is currently undergoing revision to clarify and expand the text of the report, and to increase the areal extent of the infiltration calculations. The following paragraphs will describe these revisions, which are either ongoing or are planned, in further detail.

Generally, the text of the report will be reorganized as well as explanations expanded to make it more readable for individuals who are not closely involved in the modeling tasks. The procedure to integrate the data and results from this report into the groundwater model will be placed in the main body of the text, instead of being a separate document located in Appendix A. Also, the integration procedure will be expanded to include a section on the method which can be used to take the output from a single storm event and determine a yearly loading for use in the Great Miami Aquifer groundwater model. In addition, the calculations and significance of numbers listed in the results section of the report will be more fully explained. Specifically, this involves the percent of infiltration compared to the total runoff, the amount of infiltration in Paddys Run that occurs during the length (time) of the sub-basin hydrograph, and the percent of contaminant washed into Paddys Run which actually enters the Great Miami Aquifer through infiltration.

For this report, no infiltration from the Storm Sewer Outfall Ditch (SSOD) is considered to enter the Great Miami Aquifer, although a portion of the SSOD may also be directly interconnected to the underlying Great Miami Aquifer. The infiltration and flow models will be extended to cover this portion of the SSOD. The current infiltration model stops at Willey Road where the stream is sometimes gaining water from the aquifer and sometimes losing water. The infiltration model will be extended down to 2500 feet south of Willey Road to provide a more conservative calculation of the total infiltration. At this location, the groundwater table is consistently very close (less than one foot) to the stream bed based on the average groundwater elevation. The assumption will be made that no infiltration will take place at this location. The zero infiltration will then be averaged with the upstream cross section infiltration to yield an average infiltration for that stream reach.

PRELIMINARY

DRAFT

The groundwater elevation used in this report was based on a sampling round in March of 1990. The water table elevation is higher than the average groundwater elevation. It was reasoned that more rainfall occurs during the spring months so that a water table elevation from that time of the year would yield more reasonable results for infiltration. An additional sensitivity analysis will be conducted to determine the effect of using the average water table elevation on the total infiltration into the Great Miami Aquifer.

TABLE OF CONTENTS

	Page
LIST OF TABLES	ii
LIST OF FIGURES	ii
1.0 INTRODUCTION	1-1
1.1 Preliminary Technical Specifications	1-2
2.0 MODELING SIMULATIONS	2-1
2.1 PADDYS RUN BASIN	2-1
2.2 PADDYS RUN CROSS SECTIONS	2-1
2.3 STORM AND METEOROLOGIC DATA	2-1
2.4 HEC-1 SIMULATION	2-3
2.5 RATING CURVE CALCULATION	2-4
2.6 INFILTRATION MODEL	2-4
2.7 Verification	2-6
2.8 Sensitivity Analysis	2-8
3.0 RESULTS	3-1
4.0 APPLICATION OF MODEL TO THE FEMP	4-1
Tables	
Figures	
Appendix A - Paddys Run Flow and Infiltration Model Scope	
Appendix B - Paddys Run Flow and Infiltration Model Input Data	
Appendix C - Computer Input Files and Calculations	
Appendix D - Plotted Results	
Appendix E - Predicted Extent of Groundwater Mounding Around Paddys Run and Vertical Cross Section Along Paddys Run	

DRAFT

PRELIMINARY

LIST OF TABLES

Table	Title
1	Depth-Duration Data, 1-year Return Interval Storm Event
2	Subbasin Characteristics (Overland Flow Plane Data)
3	Channel Data
4	SCS Curve Number Calculation Procedure
5	Input Parameters for Infiltration Model
6	Infiltration Model (VS2DT) Mass Balance
7	Summary of Paddys Run Flow and Infiltration Model Results
8	Summary of Modeling Results

LIST OF FIGURES

Figure	Title
1	Paddys Run Drainage Area of HEC-1 Model
2	Diagram of Paddys Run HEC-1 Model

PRELIMINARY

1.0 INTRODUCTION

Paddys Run is an intermittent stream located on the western side of the Fernald Environmental Management Project (FEMP) and is a tributary of the Great Miami River. During the remedial investigation (RI)/feasibility study (FS) conducted at the FEMP, it was discovered that Paddys Run is directly interconnected with the underlying Great Miami Aquifer and that a potential pathway exists for contaminant transport into the aquifer through Paddys Run's streambed. Previously, Paddys Run was only considered as a receptor of contaminants and not as a pathway of contaminants to the Great Miami Aquifer. The scope of this task is to quantify this effect so that it may be incorporated into fate and transport modeling being done at the FEMP for the operable unit studies. This was done using the streamflow model HEC-1, and calculations of head versus flow at points along the stream using Manning's Equation. This task examines the flow duration of Paddys Run during an annual storm event and the subsequent infiltration that is produced. Appendix A includes the overall project scope, of which the information presented in this report is a part. Appendix A also includes correspondence and documentation relevant to this work and a procedure for implementing the data generated in this report.

Input data into the model consisted of geographic information on Paddys Run's drainage basin and stream profile. Stream cross sections were taken at eight locations along Paddys Run from a region just north of the FEMP down to its confluence with the Great Miami River. Topographic maps of Paddys Run Basin were also used to define subbasins for the region of Paddys Run which lies between each pair of stream cross sections. Rainfall data were incorporated using depth-duration maps for given return periods.

Using the input data described above, a streamflow characterization of Paddys Run was done using the HEC-1 modeling code (U.S. Army Corps of Engineers [USACE] 1990a). This code simulates the flow of a storm event in a drainage basin through the drainage basin's channels. It was used to simulate flow and define the resulting stream hydrograph in Paddys Run during an annual storm event. The HEC-1 model was originally developed by the USACE to assist in waterway design projects. As such, it is well documented and has been applied successfully to numerous regions across the United States.

Rating curves were generated using Manning's Equation (Henderson 1966). Manning's Equation was applied along Paddys Run to determine the streamflow velocity at each cross-section location for a given flow rate. This information was used to generate a rating curve (flow versus stream depth) at each cross-section location. To calculate infiltration, the computer code VS2DT (Healy 1990) was applied to determine how much seepage was produced for a given stream head. This information then produced the seepage rate to the Great Miami Aquifer along the length of Paddys Run in contact with the aquifer.

Flow in Paddys Run was assumed to experience no losses to the groundwater system of large enough magnitude to affect streamflow rates or head. Infiltration to the Great Miami Aquifer was simulated using unsaturated flow conditions. Infiltration calculations were limited to the portion of Paddy's Run where infiltration and contaminant loading to the aquifer are known to be significant. The streambed was assumed to consist of the same material as the Great Miami Aquifer where it cut through the glacial overburden and to have permeability and porosity characteristics similar to the aquifer's.

1.1 Preliminary Technical Specifications

The Paddys Run to Great Miami Aquifer Model Preliminary Technical Specifications are presented in Appendix A. All data collection activities were conducted by Fernald Environmental Restoration Management Corporation (FERMCO). These activities included identification of available profile and cross-section information for Paddys Run, determining additional needs, performing limited field surveys as needed, and identification and collection of relevant hydrogeological data.

A portion of the data analysis and model development has been conducted by IT and is presented in this report. The preliminary specifications called for the selection of a representative storm event to cause significant surface runoff and erosion in the study area, determine surface runoff flow rates, determine the average stream flow rates and water elevations, estimate infiltration rate from Paddys Run to the Great Miami Aquifer during the storm event and perform sensitivity analyses. Modification to the procedures specified in the preliminary specification are described in the main text of this report and are summarized in Chapter 3.0.

The preliminary specifications also specify using the results from the streamflow/infiltration analyses as input to the SWIFT III groundwater flow and solute transport model. This task was not included in

4774

the scope of work. During the fate and transport modeling for the RI/FS work , the SWIFT III model will be revised to incorporate the stream flow/infiltration analyses.

DRAFT

2.0 MODELING SIMULATIONS

4774

2.1 PADDYS RUN BASIN

Paddys Run is an intermittent stream which drains a midsize catchment (approximately 15 square miles) which includes most of the FEMP site. It flows only a portion of the year, typically during the late winter and spring months when precipitation events are commonly produced from regional storm events. During the summer and fall months, Paddys Run is generally dry, except during storm events when flow occurs over a space of hours to several days depending on the severity of the storm. The drainage basin extends approximately 8 miles north of its confluence with the Great Miami River and approaches 3 miles in width at its widest point. The majority of the catchment is underlain by relatively impermeable glacial overburden and generates a large percentage of runoff when precipitation occurs. The basin and subbasin boundaries were derived using topographic maps created by the U.S. Geological Survey (USGS). These boundaries were used to calculate runoff parameters for overland flow into Paddys Run and are shown in Figure 1.

2.2 PADDYS RUN CROSS SECTIONS

Cross sections for Paddys Run were produced for 8 locations along Paddys Run, from a point just north of the FEMP to its confluence with the Great Miami River (Figure 1). Cross-section locations were located approximately 2000 feet apart and were spaced to cover the region of Paddys Run which flows in direct contact with the Great Miami Aquifer. These cross sections were used to determine depth-area relationships for points along Paddys Run and were utilized in the calculation of rating curves for Paddys Run. Three of the cross sections were used in the infiltration calculations. The cross sections were supplied by FERMCO and are included in Appendix B.

2.3 STORM AND METEOROLOGIC DATA

The amount of contaminant transport caused by surface water flow is dependent on the rainfall duration, intensity and volume. This report will utilize a single storm event as the tool to represent the yearly flow and infiltration in Paddys Run. This approach will be similar to the approach used in the OU4 RI report. The information in this report will be used by CRUs 1 and 2 in their RI reports. CRU5 is currently evaluating the use of a year long continuous hydrologic simulation to calculate the yearly flow in Paddys Run. The continuous simulation would be based on a typical year of actual rainfall data. Selection of a single representative storm for this report is critical to yield reasonable results. A relatively small, common storm event may not produce erosion and sediment in appreciable

DRAFT

PRELIMINARY

2

quantities, while a large, uncommon event may produce a substantial amount of erosion and sediment but not occur frequently enough to be significant.

Initial attempts to select a representative storm were made using a probability weighting method to incorporate both large and small storm events. The weights were to be based on the return period of the particular storm event. A sensitivity analysis was performed to determine what storm duration would produce the greatest amount of contaminant in the runoff. It was found that as the storm duration increased, the amount of contaminant also increased. A 24-hour storm duration was decided upon, based on its widespread regulatory and design use and availability of rainfall data.

Difficulties arose in weighting the different storm events, and at the decision of FERMCO, the probability weighting method was eventually abandoned. One of the problems was determining a threshold or lower bound below which the storm event would not produce a significant amount of contaminant in the runoff. This threshold was determined by setting the amount of contaminant in the runoff allowable and back calculating the storm event using the Modified Universal Soil Loss Equation (MUSLE, Superfund Exposure Assessment Manual, Environmental Protection Agency [EPA], 1988). The problem was in determining what percentage of the yearly rainfall would fall below this threshold storm. Also a method to accurately account for storm events between the standard storm events presented a problem (for instance, runoff can be calculated and weighted for the standard 5-year and 10-year storms, but the 6.4-year storm event would be neglected).

A storm with a 1-year return period and a 24-hour duration was chosen as the representative storm. This storm was chosen based on the recommendations in the Superfund Exposure Assessment Manual to represent short-term releases of contaminants.

This storm has a small enough return period that it occurs fairly frequently while at the same time it produces a significant amount of runoff from the subbasins. This runoff causes soil loss and contaminant transport through overland flow from the FEMP into Paddys Run. In addition, this size and duration of storm has been utilized in other operable unit studies to define soil losses from individual waste units. This allows consistency between this study and the operable unit fate and transport studies.

2.4 HEC-1 SIMULATION

The HEC-1 model was used to simulate runoff from Paddys Run's drainage basin into Paddys Run. The storm event simulated has a 1-year return period and a duration of 24 hours with a total precipitation depth of 2.5 inches. Depth-duration data required by the HEC-1 model listed in Table 1 were used to produce a synthetic storm for the simulation. The rainfall depths listed in Table 1 were obtained from the rainfall frequency atlas of the United States (Hershfield 1961). As an example, the 1-year, 24-hour rainfall map is presented in Appendix B. The Paddys Run drainage basin was divided into 12 subbasins (Figure 1) for the HEC-1 simulations such that:

- The physical characteristics are similar within each subbasin
- The cross sections where hydrographs are desired are located at the outlet of each subbasin.

Kinematic wave and Muskingum-Cunge methods (USACE 1990a) were employed to calculate subbasin flow and channel routing. In these approaches, the various physical processes of water movement over the basin surface (with attendant infiltration), flow into stream channels, and flow through the channel network are modeled using equations of conservation of mass and energy. Parameters such as channel roughness, slope, catchment lengths and areas, and stream channel dimensions are used to define the processes. In the simulation, various features of irregular surface geometry of the subbasins were read from the USGS topographic map and were approximated by two types of basic elements: (1) an overland flow element and (2) a stream flow or channel flow element. Tables 2 and 3 list all data used to characterize overland flow and channel flow elements for each subbasin. The Soil Conservation Service (SCS) curve number method was utilized to calculate the loss to the overland surface. SCS curve numbers were estimated according to land vegetation cover, soil type, and hydrological characteristics. Table 4 provides the calculation procedure used to determine the SCS curve numbers for the 12 subbasins. The entire basin was modeled by linking the various subbasins together. Figure 2 shows the logical relation of the subbasins, channel routing, and stations in the HEC-1 simulation. The additional assumptions used in the simulation were:

- Baseflow is negligible
- Channel loss is negligible (see Section 2.7 for justification of this assumption).

An example HEC-1 input file is shown in Appendix C.

2.5 RATING CURVE CALCULATION

The HEC-1 model provides hydrographs in terms of discharge rate versus time at each cross-section location. In order to obtain the stream stage for infiltration calculations, rating curves were calculated using Manning's Equation for each cross section. Manning's number and slope for each cross section as listed in Table 3 were also used in the calculation. Appendix B shows the geometries of Cross Sections A-A to H-H. The resulting rating curves are presented in Appendix D.

Use of Manning's Equation instead of the HEC-2 model (USACE 1990b) is a modification to the Preliminary Technical Specifications. The HEC-2 model could not be used because of the large distances between cross sections. It was felt that the additional time required to refine the HEC-2 model would not create a significant change in the calculated stage in Paddys Run versus assuming uniform flow (Mannings Equation).

2.6 INFILTRATION MODEL

Infiltration through the channel of Paddys Run was calculated using a numerical flow model capable of simulating unsaturated and saturated flow in two dimensions. The model was able to take into account the wetting front as it advanced through the vadose zone to the water table once flow in Paddys Run began. Following this, the model simulated the lateral migration of water away from the stream as a mound was formed in the aquifer underneath Paddys Run. A two-dimensional infiltration model was used instead of a one-dimensional model as was originally indicated in the Preliminary Technical Specifications . A two-dimensional model was necessary to estimate the infiltration accurately. Significant lateral flow was found to occur during infiltration (Appendix E).

Paddys Run's streambed is glacial till at Cross Sections A-A and B-B and sand and gravel at Cross Sections C-C through H-H. Where Paddys Run flows on top of the glacial overburden, infiltration is negligible due to the low streambed permeability and infiltration rates were not calculated.

Infiltration calculations were not performed for the cross sections south of the FEMP property line along Wiley Road. It was felt that this was reasonable because the highest concentrations of uranium in the south plume appear to have originated from the area between the storm sewer outfall ditch (SSOD) and Wiley Road. The highest concentrations in the south plume lie south east of the SSOD and Wiley Road (see figure in Appendix E), which is the general direction of groundwater flow in this area. Another reason why infiltration calculations were not performed south of the site is that

groundwater elevation fluctuations south of the site resulting in groundwater flow to Paddys Run during a part of the year.

Infiltration through the streambed was calculated at Cross Sections C-C, D-D, and E-E for a 1-year, 24-hour storm event employing the numerical model VS2DT. VS2DT is a USGS numerical model which simulates water movement through variably saturated porous media. Simulated regions can be one-dimensional columns, two-dimensional vertical cross sections, or axially symmetric, three-dimensional cylinders. In the simulations, the following approaches were used:

- A two-dimensional finite-difference grid was designed to simulate water movement through the cross section under Paddys Run's channel. Only half the cross section was simulated due to the symmetry of the region. The vertical dimension was set from the groundwater table to Paddys Run's streambed. The horizontal dimension was extended far enough such that no water would mound at the boundary at any time during the simulation.

- The simulations assumed there was no baseflow in Paddys Run, and that the sand and gravel formation is unsaturated prior to the storm event. Initial soil moisture contents were initialized by the program after fixing the aquifer's water table elevation and defining a minimum saturation level of 20 percent of full saturation. This allowed the program to create a saturation gradient through the vadose zone.

- The stream was simulated in the model using a constant head boundary at the streambed with a head value equal to the head in the stream at a given time. Since stream head varies during the storm, the simulation was divided into 2-hour periods. In each period, stream head was averaged and the averaged head was used as constant head. This created a total of 10, 2-hour periods for the storm's duration. Estimation of the discrete 2-hour head values used in the model are presented in Appendix C.

- Saturated-unsaturated hydraulic conductivity curves used the Van Genuchten equation to simulate variably saturated aquifer conditions. Fitting parameters were chosen from representative soil types (sand) taken from the VS2DT manual.

- Linear interpolation was used to calculate total infiltration in the reach between cross sections.

Model parameters are listed in Table 5, and the input files for these simulations are shown in Appendix C. The results of the model show a variable infiltration rate depending on the depth to the water table below the channel. Cross Section C-C, which is approximately 14 feet above the water table, experienced an infiltration rate ranging between 13 and 23 inches per hour (in./hr) through the streambed. Cross Section E-E, which is only 0.9 foot above the water table, had an infiltration rate of 0.1 to 0.5 in./hr. This exhibits the difference in thickness of the unsaturated zone which controls the

inflow of water to the aquifer. Cross Section D-D is an intermediate step between Cross Sections C-C and E-E and has a rate of 6-12 in./hr. Total infiltration along Paddys Run for the three sections is approximately 2 million cubic feet for the duration of the storm. This is approximately 25 to 30 percent of the total water flow in Paddys Run during the storm event. Infiltration versus time for the three cross sections and infiltration versus channel length are shown in Appendix D.

In the infiltration calculation, VS2DT model reported cumulative flux entering the streambed and the change of water stored in pore space of the underlying formation. To avoid numerical errors, these two quantities should be near equal within a tolerable error margin. Table 6 summarizes the mass balance for the infiltration runs.

2.7 Verification

In order to make an independent comparison of the volume of water infiltrated into the Paddys Run streambed, a calculation of the volume of voids available to be filled with water under Paddys Run was made. This calculation was intended to check the order of magnitude of water infiltrating into Paddys Run. It assumes that once the volume of void filled under Paddys Run, infiltration would stop. This calculation also assumed that infiltrated water does not travel horizontally.

The total volume under the streambed was calculated by taking the streambed elevation and subtracting the elevation of the groundwater table then multiplying by the length of the stream and an average width of the stream. The streambed elevation information was taken from topographic maps of the site. Because these elevations produce a undulating surface, these elevations were averaged to form a smooth surface for the streambed volume calculations (see figure in Appendix E). The groundwater elevations were based on water surface elevations in the 2000-series wells along Paddys Run. Groundwater elevation data from 1988 to 1993 were averaged to form the groundwater surface elevations used for calculation of the volume. Only well data with 20 or more data points were used in the average. The stream width used was based on the average width (edge of water to edge of water) as shown on the topographic mapping. The average width used was 25 feet.

The groundwater elevations used for the independent calculation of volume were roughly 3 feet lower than the elevations used in this Paddys Run Flow and Infiltration Model report. The groundwater elevations in the Paddys Run Flow and Infiltration Model report are based on a sampling round in the 2000-series wells in March 1990. Since most storm events will occur during the wet season of the

year, it was felt that using the groundwater elevations from that portion of the year would yield more realistic results. The length of stream channel, where infiltration into Paddys Run is believed to be significant, runs from the point where Paddys Run cuts into the Great Miami Aquifer (approximately at Cross Section C-C) to a point where the groundwater intercepts the streambed. Because the groundwater elevation is different between the two methods, the point where the groundwater intercepts the streambed is different by approximately 2500 feet. The independent calculation yielded a total volume of 3.02 million cubic feet. When this is adjusted by the porosity of the Great Miami Aquifer (0.39 [Table 5]) the volume of voids available to accept water is 1.18 million cubic feet. If this is adjusted to only include the length of streambed that the Paddys Run Flow and Infiltration Model included, this volume would be 0.95 million cubic feet.

The VS2DT model allows for lateral flow of water so that the width of saturation under Paddys Run is wider than the width of the stream, forming a mound of saturation beneath the streambed. At the end of the simulation, the width of the groundwater mound is approximately 100 to 400 feet (see figure in Appendix E). The groundwater mound becomes very thin at its outer edges and does not contain a large percentage of the volume. Approximately 2 million cubic feet of infiltration was calculated with the VS2DT model. The saturated mound would account for the difference between the VS2DT model results and the independent volume calculation. While the results of the volume calculation are different for the two methods, they are within an order of magnitude and would indicate that the results from the VS2DT method are reasonable.

IT (1993) observed a high degree of correlation between the Paddys Run and aquifer hydrographs. These data were based on continuous 60-minute readings using pressure transducers and a data logger. The aquifer hydrograph data were measured in Monitoring Well 2014, located approximately 25 feet away from Paddys Run. This monitoring well is located near cross section E-E. On April 14, 1989, a storm event caused a rapid rise in the Paddys Run stage elevation from 526.5 to 531.5 feet. Within two hours, the water level in Monitoring Well 2014 started to rise above its initial elevation of 523.2 feet. Within the following two hour period, the water level rose to its maximum height of 524.2 feet.

It was not possible to compare the results of the infiltration model with the IT (1993) hydrograph data directly, because the magnitude of the storm event and initial conditions were not the same. However, the results from the infiltration model and the field data were compared on a qualitative basis. In the infiltration model (cross section E-E), the stream bed and groundwater elevations were set at 525 and

524.1 feet, respectively. The simulated storm event produced a rapid rise in the Paddys Run stage elevation from 525 to 527.2 feet. The water table elevation at the approximate location of Monitoring Well 2014 rose almost instantaneously and achieved its maximum elevation of 525 feet within one hour.

The difference in response between the infiltration model and the field data may be attributed partially to the difference in the initial water table elevation. In the case of the model, the distance between the stream bed and the initial water table was only 0.9 feet. The high initial water table resulted in less available pore space for infiltrating water, and consequently, a more rapid response in the water table was produced. Although a direct comparison could not be made, in general the response of the infiltration model was similar to the response observed in the field.

2.8 Sensitivity Analysis

Sensitivity analyses of certain parameters used in the Paddys Run Flow and Infiltration Model were performed to determine the model's uncertainty. Three sets of simulations were performed to examine sensitivity of the total infiltration from Paddys Run to the SCS curve number, saturated hydraulic conductivity, and fitting parameters in the Van Genuchten relative hydraulic conductivity equation.

- The computed total runoff for Paddys Run is very sensitive to the SCS curve number. In the analysis, the SCS curve number in each subbasin was increased 5 and 10 percent, respectively. Total calculated runoff volume at Cross Section D-D in the period of subbasin runoff to $t_{subbasin}$ increased from 5 million to 8 million cubic feet for the 5 percent case and to 10 million for the 10 percent case. However, though variation of computed infiltration rate Cross Section D-D in the first 4-hour period was apparent, it was negligible afterwards (Appendix D). The total infiltrated volume per feet of channel at Cross Section D-D was increased from 353 to 357 and 362 cubic feet, respectively.

  This result shows why the assumptions of negligible channel loss used in the HEC-1 Model is valid; large changes in channel flow have a relatively minor effect on infiltration rate.

- Saturated hydraulic conductivity was increased from 450 feet per day to 600 feet per day and decreased to 300 feet per day in the sensitivity analysis. Infiltration volume at Cross Sections C-C, D-D, and E-E corresponding to these values are shown in Appendix D. Infiltration rate was more sensitive to saturated hydraulic conductivity at Cross Section C-C than at Cross Sections D-D and E-E, since more unsaturated pore volume is available at Cross Section C-C. The total infiltration to the streambed in the storm event was increased from 2 million to 2.5 million cubic feet for k = 600 feet per day and decreased to 1.5 million cubic feet for k = 300 feet per day.

- Relative hydraulic conductivity was calculated using Van Genuchten's equation (Healy 1990) in the filtration model. Porosity of the Great Miami Aquifer was considered to be well defined from previous regional groundwater flow model. Other fitting parameters (residual moisture content, scaling length, and pore-size distribution parameter) for sand presented in the VS2DT manual were chosen to vary in the infiltration calculation. In the MATHCAD calculations (Appendix C), relative hydraulic conductivities computed using sand fitting parameters were compared with fitting parameters for Fresno medium sand and fine sand. A small variation of relative hydraulic conductivity computed using three sets of fitting parameters was presented when moisture content was above 0.15. In sensitivity analysis, the fitting parameters for fine sand was input to VS2DT model. Cross Section C-C experienced an increase infiltration from 642 to 780 cubic feet per foot of channel.

The sensitivity analyses for the SCS curve number, the saturated hydraulic conductivity, and the relative hydraulic conductivity all produce a change in the total infiltration of 25 percent or less. Under the possible range of values, 25 percent uncertainty is acceptable for the intended use of the Paddys Run Flow and Infiltration Model.

DRAFT

3.0 RESULTS

Rating curves for each of the Paddys Run cross sections were developed (Appendix D). At Cross Section G-G, Paddys Run is very shallow (0.8 foot in depth) and flow will flood the right bank when the flow rate exceeds 50 cubic feet per second (cfs). Therefore, for discharge rates exceeding 50 cfs, stage elevations for this cross section were fixed at 520 feet. Stream hydrographs were generated using the HEC-1 model for Cross Sections A-A to H-H (Appendix D). A small peak emerges before the larger peak at Cross Section C-C, and continues to grow at the downgradient cross sections. The larger peak corresponds to runoff from the upper stream drainage area (10.5 square mile [mi^2]), and the smaller peak results from the downstream drainage area starting from the FEMP site (Figure 1). Stage versus time curves were determined from the rating curves and hydrograph data (Appendix D). VS2DT-calculated infiltration rates, based on the stage versus time data, were determined (Appendix D). Table 7 lists peak runoff, total runoff, peak stage, peak infiltration rate, and total infiltration at each cross section. Table 8 gives key infiltration results and subbasin summaries for the subbasins that comprise the FEMP. Table 8 gives the values of all the parameters from this report that are needed to use the "Procedure to Implement Additional Paddys Run Data" contained in Appendix A. The duration of the runoff hydrograph (total) presented in Table 8 was defined as the period when discharge is greater than 10 cfs. A 98 percent total runoff volume was discharged in this period (see MATHCAD calculations in Appendix C for details). Duration of FEMP subbasin runoff hydrograph ($t_{subbasin}$) was determined from the Subbasin 80 runoff using the same method.

The following are some of the important results of the Paddys Run Flow and Infiltration Model. The total amount of infiltration is approximately 25 percent of the total amount runoff. The amount of infiltration into Paddys Run which occurs during the runoff hydrograph from the subbasins which contain the site is 73 percent. Only the subbasins which contain the site are considered to be contaminated. The percent of contaminant which is washed into Paddys Run which enters the Great Miami Aquifer through infiltration is approximately 20.5 percent.

Modifications to the Preliminary Specifications included:

- Use of Manning's Equation instead of the HEC-2 model (USACE 1990b). The HEC-2 model could not be used because of the large distances between cross sections. It was felt that the additional time required to refine the HEC-2 Model would not create a significant change in the calculated stage in Paddys Run versus assuming uniform flow (Manning's Equation).

PRELIMINARY

- A two-dimensional infiltration model was used instead of a one-dimensional model. A two-dimensional model was necessary to estimate infiltration accurately. Significant lateral flow was found to occur during infiltration (Appendix E).

DRAFT

4.0 APPLICATION OF MODEL TO THE FEMP

4774

The Paddys Run model provides the total infiltration from Paddys Run streambed to the Great Miami Aquifer underneath. This model also provides the runoff from each subbasin, which can be used to estimate dilution factor for runoff from a specified waste unit in the fate and transport modeling. Table 6 summarizes these results. Given a subbasin along Paddys Run which contains a waste unit, the waste unit's soil loss and flow contribution must first be determined for the storm event. The contaminant concentration contained in the runoff must also be calculated. This runoff is then allowed to mix with the flow in Paddys Run at the subbasin's catchment outlet. Contaminant concentrations in runoff will be modified by the ratio of flow in the subbasin over flow in Paddys Run to derive the concentration in Paddys Run. Once the contamination concentration in Paddys Run is obtained, chemical loading to the aquifer through storm-induced infiltration may be calculated. This is done by assuming instantaneous mixing of the contaminant and allowing a percentage of contaminant to infiltrate into the aquifer. This percentage is the amount of infiltration occurring divided by the total flow in Paddys Run downstream of the subbasin catchment outlet. This chemical loading then becomes a source term into the SWIFT III model of the Great Miami Aquifer.

DRAFT

PRELIMINARY

20

4774

REFERENCES

Healy, R. W., 1990, "Simulation of Solute Transport in Variably Saturated Porous Media with Supplemental Information to the U.S. Geological Survey's Computer Program VS2D," U.S. Geological Survey, ***Water Resources Investigation Report***, 90-4025, Denver, Colorado, pp. 125.

Henderson, F. M., 1966, "Open Channel Flow," McMillian Publishing Co., Inc., New York, pp. 96.

Hershfield, D. M., 1961, ***Rainfall Frequency Atlas of the United States***, Technical Paper No. 40, Department of Commerce, Washington, DC.

IT, 1993, "Groundwater Modeling Report Summary of Model Development," Final, Prepared for the U.S. Department of Energy, April, 1993.

U.S. Army Corps of Engineers, 1990a, ***HEC-1 Flood Hydrograph Package User's Manual***, CPD-1A, Version 4.0.

U.S. Army Corps of Engineers, 1990b, ***HEC-2 Water Surface Profiles User's Manual***, CPD-2A.

U.S. Environmental Protection Agency, 1988, ***Superfund Exposure Assessment Manual***, EPA/540/1-88/001, pp. 28.

DRAFT

PRELIMINARY

-- 4774

DRAFT

TABLES

PRELIMINARY

22

DRAFT

TABLE 1

DEPTH-DURATION DATA*
1-YEAR RETURN INTERVAL STORM EVENT

Duration	Depth (in)
5 minutes	0.33
15 minutes	0.625
60 minutes	1.1
2 hours	1.4
3 hours	1.48
6 hours	1.8
12 hours	2.1
24 hours	2.5

*Hershfield, D. M., 1961, Rainfall Frequency Atlas of the United States. Technical Paper No. 40. Department of Commerce, Washington, D.C.

TABLE 2

SUBBASIN CHARACTERISTICS (OVERLAND FLOW PLANE DATA)

Subbasin	Overland FLow Length[a] (FT)	Overland Flow Slope[a] (ft/ft)	Resistance Factor[b] N	% Subbasin Area[a]	Drain Area[a] (Sq. mile)	SCS Curve Number[c]
10	150	0.07	0.4	100	1.869	65.4
20	200	0.075	0.4	100	1.589	63.7
30	200	0.08	0.4	100	5.188	63
50	200	0.04	0.4	100	1.288	66
60	200	0.08	0.4	100	0.599	59.8
70	150	0.013	0.4	75	0.313	61
	200	0.013	0.15	25		88.8
75	150	0.013	0.4	75	0.408	61
	200	0.013	0.15	25		88
80	200	0.01	0.4	75	1.223	65
	250	0.01	0.15	25		87
100	180	0.1	0.4	30	0.51	62.1
	250	0.018	0.3	70		62.1
110	200	0.2	0.4	50	0.832	61.9
	150	0.03	0.3	50		69
120	100	0.28	0.4	100	0.561	69.4
130	200	0.033	0.4	100	1.385	68.2

[a]Estimated from USGS topographic map, Shandon, Ohio, N3915_W8437.5/7.5, 1981, DMA 4062 ISW-Series V852.

[b]Table 3.5, HEC-1 User's Manual.

[c]See Table 4 for SCS curve number calculation procedure.

TABLE 3

CHANNEL DATA

Element	Length[a] (ft)	Slope[a]	Manning[b] n	Area[a] (sq. mile)	Shape[c]	Width[c] (ft)	Side Slope[c] (ft/ft)	Upstream Flow
Sub 10								
Subcollector Channel	500	0.07	0.045	0.06	TRAP	0	1	
Collector channel	3200	0.05	0.045	0.47	TRAP	0	1	
Main channel	5200	0.015	0.045		TRAP	0	1	No
Sub 20								
Collector channel	4500	0.065	0.045	0.132	TRAP		1	
Main channel	4800	0.015	0.045		TRAP	0	1	Yes
Sub 30								
Subcollector channel	3600	0.05	0.045	0.18	TRAP	0	1	
Collector channel	6000	0.007	0.045	1.297	TRAP	0	1	
Main channel	10800	0.003	0.045		TRAP	20	1	Yes
Sub 50								
Collector channel	5000	0.02	0.045	0.322	TRAP	0	1	
Main channel	2800	0.002	0.035		Irregular	0	1	Yes
Rout 60								
Main channel	1600	0.004	0.035		Irregular		1	Yes
Sub 60								
Collector channel	4500	0.04	0.025	0.15	TRAP	5	1	
Main channel	1600	0.004	0.035		Irregular		1	No
Rout 0								
Main channel	2986	0.004	0.025		Irregular			Yes
Sub 70								
Main channel	4000	0.013	0.045		TRAP	5	1	No

TABLE 3
(CONTINUED)

Element	Length[a] (ft)	Slope[a]	Manning[b] n	Area[a] (sq. mile)	Shape[c]	Width[c] (ft)	Side Slope[c] (ft/ft)	Upstream Flow
Rout 1								
Main channel	3093	0.003	0.025		Irregular			Yes
Sub 75								
Main channel	4000	0.013	0.045		TRAP	5	1	No
Rout 2								
Main channel	2773	0.002	0.025		Irregular			Yes
Sub 80								
Collector channel	6500	0.01	0.045	0.65	TRAP	5	1	
Main channel	5866	0.003	0.025		TRAP	26	0.44	No
Rout 25								
Main channel	2613	0.002	0.025		TRAP	52.8	4.55	Yes
Sub 100								
Collector channel	4000	0.01	0.045	0.412	TRAP	5	1	
Main channel	2773	0.0003	0.025		TRAP	27.2	26.32	Yes
Rout 3								
Main channel	3626	0.0025	0.025		TRAP	63.6	7.3	Yes
Sub 110								
Collector channel	500	0.04	0.045	0.21	TRAP	0	1	
Main channel	10,000	0.009	0.025		TRAP	20	3.33	No
Sub 120								
Collector channel	500	0.2	0.045	0.15	TRAP	0	1	
Main channel	8000	0.021	0.045		TRAP	20	3.33	No

TABLE 3
(CONTINUED)

Element	Length[a] (ft)	Slope[a]	Manning[b] n	Area[a] (sq. mile)	Shape[c]	Width[c] (ft)	Side Slope[c] (ft/ft)	Upstream Flow
Sub 130								
Collector channel	5000	0.016	0.045	0.588	TRAP	5	1	
Main channel	1800	0.02	0.025		TRAP	52.8	4.55	No

[a]Estimated from USGS topographic map, Shandon, Ohio, N3915_W8437.5/7.5, 1981, DMA 4062 ISW-Series V852.

[b]Table 4.2, Henderson F.M., 1966, Open Channel Flow, MacMillan Publishing Co., Inc.

[c]See Appendix B.

DRAFT

TABLE 4

SCS CURVE NUMBER CALCULATION PROCEDURE*

Subbasin	Land Cover[a]	Hydraulic Condition	Hydrologic Soil Group[b]	Weighted SCS Number[c]	Average SCS Number
10	Woods 30%	Good	0.5C + 0.5B	0.5 x 71 + 0.5 x 55	
	Meadow 60%	Good	0.4C + 0.6B	0.4 x 71 + 0.6 x 58	65.4
	Hard surface 10%	--	0.5 C + 0.5B	0.5 x 84 + 0.5 x 90	
20	Woods 15%	Good	0.7C + 0.3B	0.7 x 70 + 0.3 x 55	
	Meadow 80%	Good	0.3C + 0.7B	0.3 x 71 + 0.7 x 58	63.7
	Hard surface 5%	--	0.5C + 0.5B	0.5 x 84 + 0.5 x 90	
30	Woods 10%	Fair	0.4C + 0.6B	0.4 x 73 + 0.6 x 60	
	Meadow 85%	Good	0.25C + 0.75B	0.25 x 71 + 0.75 x 58	63
	Hard surface 5%	--	0.5C + 0.5B	0.5 x 84 + 0.5 x 90	
50	Woods 20%	Fair	0.4C + 0.6B	0.4 x 73 + 0.6 x 60	
	Meadow 70%	Good	0.4C + 0.6B	0.4 x 71 + 0.6 x 58	66
	Hard Surface 10%	--	0.4C + 0.6B	0.4 x 84 + 0.6 x 90	
60	Woods 35%	Good	0.1C + 0.9B	0.1 x 70 + 0.9 x 55	
	Meadow 60%	Good	0.1C + 0.9B	0.1 x 71 + 0.9 x 58	59.8
	Hard surface 5%	--	0.1C + 0.9B	0.1 x 84 + 0.9 x 90	
70	Woods 10%	Fair	0.2C + 0.8B	0.2 x 73 + 0.8 x 60	61
	Meadow 65%	Good	0.2C + 0.8B	0.2 x 71 + 0.8 x 58	
	Hard surface 25%	--	0.2C + 0.8B	0.2 x 84 + 0.8 x 90	88.8
75	Woods 10%	Fair	0.2C + 0.8B	0.2 x 73 + 0.8 x 60	61
	Meadow 65%	Good	0.2C + 0.8B	0.2 x 71 + 0.8 x 58	
	Hard surface 25%	--	0.2C + 0.8B	0.2 x 84 + 0.8 x 90	88.8
80	Woods 10%	Fair	0.5C + 0.5B	0.5 x 73 + 0.5 x 60	65
	Meadow 65%	Good	0.5C + 0.5B	0.5 x 71 + 0.5 x 58	
	Hard surface 25%	--	0.5C + 0.5B	0.5 x 84 + 0.5 x 90	87

4274

28

TABLE 4
(CONTINUED)

Subbasin	Land Cover[a]	Hydraulic Condition	Hydrologic Soil Group[b]	Weighted SCS Number[c]	Average SCS Number
100	Woods 5%	Fair	0.2C + 0.8B	0.2 x 73 + 0.8 x 60	
	Meadow 90%	Good	0.2C + 0.8B	0.2 x 71 + 0.8 x 58	62.1
	Hard surface 5%	--	0.2C + 0.8B	0.2 x 84 + 0.8 x 90	
110	Woods 15%	Fair	0.1C + 0.9B	0.1 x 73 + 0.9 x 60	
	Meadow 75%	Good	0.1C + 0.9B	0.1 x 71 + 0.9 x 58	61.9
	Hard surface 10%	--	0.1C + 0.9B	0.1 x 84 + 0.9 x 90	
120	Woods 85%	Good	0.9C + 0.1B	0.9 x 70 + 0.1 x 55	
	Meadow 10%	Good	0.9C + 0.1B	0.9 x 71 + 0.1 x 58	69.4
	Hard surface 5%	--	0.9C + 0.1B	0.9 x 84 + 0.1 x 90	
130	Woods 10%	Fair	0.7C + 0.3B	0.7 x 73 + 0.3 x 60	
	Meadow 85%	Good	0.7C + 0.3B	0.7 x 71 + 0.3 x 58	68.2
	Hard surface 5%	--	0.7C + 0.3B	0.7 x 84 + 0.3 x 90	

[a]Estimated from USGS Topographic Map, Shandon, Ohio, N3915-W8437. 5/7.5, 1981, DMA 4062 I SW-Series V852.

[b]0.4C and 0.6B means 40% is hydrologic soil group C and 60% is hydrologic soil group B. Percentages of each group were determined from soil survey maps: Soil Survey of Butler Co., Ohio, USDA 1980; Soil Survey of Hamilton Co., Ohio, USDA, 1982.

[c]SCS curve number obtained from G. O. Schwab, R. K. Frevert, T. W. Edminster, and K. K. Barnes, 1981, ***Soil and Water Conservation Engineering***, John Wiley and Sons, Inc., pp. 74.

TABLE 5

INPUT PARAMETERS FOR INFILTRATION MODEL

Cross Section	Distance From Upstream Cross Section (ft)	Groundwater Elevation[a] (ft)	Stream Bed Elevation[b] (ft)	Half Width of Stream Bed (ft)[b]	Vertical Saturated Conductivity[c] (ft/day)	Horizontal Saturated Conductivity[c] (ft/day)	Simulation Time (hour)	Porosity[c] (vol/vol)	Residual Moisture[d] (vol/vol)
C-C	2986	525.83	539.9	12	45	450	18	0.39	0.069
D-D	3093	524.74	531.26	9	45	450	20	0.39	0.069
E-E	2773	524.1	525	13	45	450	20	0.39	0.069
F-F	2613	520.74	520						
G-G	4000	513.5	519						
H-H	3626	505.3	509						

[a]See Appendix A - Groundwater Elevation Map.

[b]See Appendix B.

[c]TT, 1993, "Groundwater Modeling Report Summary of Model Development," Final, Prepared for the U.S. Department of Energy, April, 1993.

[d]Lappola, E.G., R. W. Healy, E. P. Weeks, 1987, "Documentation of Computer Program VS2D to Solve the Equations of Fluid Flow in Variably Saturated Porous Media, U.S. Geological Survey, Water Resources Investigations Report, 83-4099.

TABLE 6

INFILTRATION MODEL (VS2DT) MASS BALANCE

Cross Section	Total Flux* from Stream Channel (ft^3)	Change In Fluid in Underlying Vadose Zone (ft^3)	Fluid Volume Inbalance (ft^3)	Inbalance in Percentage
C-C	321.7	321.0	0.72	0.2
D-D	176.6	176.6	0.03	0.2
E-E	5.34	5.4	0.04	0.7

*Total infiltrated volume per foot of the channel should be doubled due to the symetry of the simulated region.

DRAFT

TABLE 7

SUMMARY OF PADDYS FLOW AND INFILTRATION MODEL RESULTS

Cross Section	Peak Discharge (cfs)	Total Discharge (10^6 ft^3)	Peak Stage (ft)	Peak Infiltration Rate (ft/hr)
A-A	377	6.030	561.4	
B-B	378	6.260	553.9	
C-C	382	6.623	542.3	2.51
D-D	394	7.067	533.9	2.02
E-E	427	8.507	527.7	0.05
F-F	465	9.697	522.0	
G-G	379	9.898	520.0	
H-H	408	11.135	511.5	

DRAFT

DRAFT

TABLE 8

SUMMARY OF MODELING RESULTS

Result	Parameter	Value
Duration of runoff hydrographs	t_{Total}	20 hours
Duration of FEMP subbasin runoff hydrograph	$t_{Subbasin}$	12 hours
Total infiltration from Paddy's Run to Great Miami Aquifer	I_{Total}	2,038,500 ft^3
Percent of total infiltration occurring during FEMP subbasin runoff hydrograph duration	P	73%
Runoff volume from FEMP subbasins:		
Subbasin 60	$V_{r\ subbasin\ 60}$	207,177 ft^3
Subbasin 70	$V_{r\ subbasin\ 70}$	339,623 ft^3
Subbasin 75	$V_{r\ subbasin\ 75}$	425,697 ft^3
Subbasin 80	$V_{r\ subbasin\ 80}$	1,351,285 ft^3
Runoff volume from subbasins upstream of FEMP during $t_{subbasin}$:		
Upstream at Subbasin 60	$V_{r\ paddys\ 60}$	5,160,399 ft^3
Upstream at Subbasin 70	$V_{r\ paddys\ 70}$	5,310,325 ft^3
Upstream at Subbasin 75	$V_{r\ paddys\ 75}$	5,576,240 ft^3
Upstream at Subbasin 80	$V_{r\ paddys\ 80}$	5,910,838 ft^3
Peak discharge from FEMP subbasins:		
Subbasin 60	$Q_{subbasin\ 60}$	10.6 cfs
Subbasin 70	$Q_{subbasin\ 70}$	63.7 cfs
Subbasin 75	$Q_{subbasin\ 75}$	82.7 cfs
Subbasin 80	$Q_{subbasin\ 80}$	173.6 cfs
Discharge rate from Paddys Run when the FEMP subbasin hydrographs are at their peak		
Upstream at subbasin 60	$Q_{paddys\ 60}$	338 cfs
Upstream at subbasin 70	$Q_{paddys\ 70}$	0.1 cfs
Upstream at subbasin 75	$Q_{paddys\ 75}$	28.3 cfs
Upstream at subbasin 80	$Q_{paddys\ 80}$	77.2 cfs

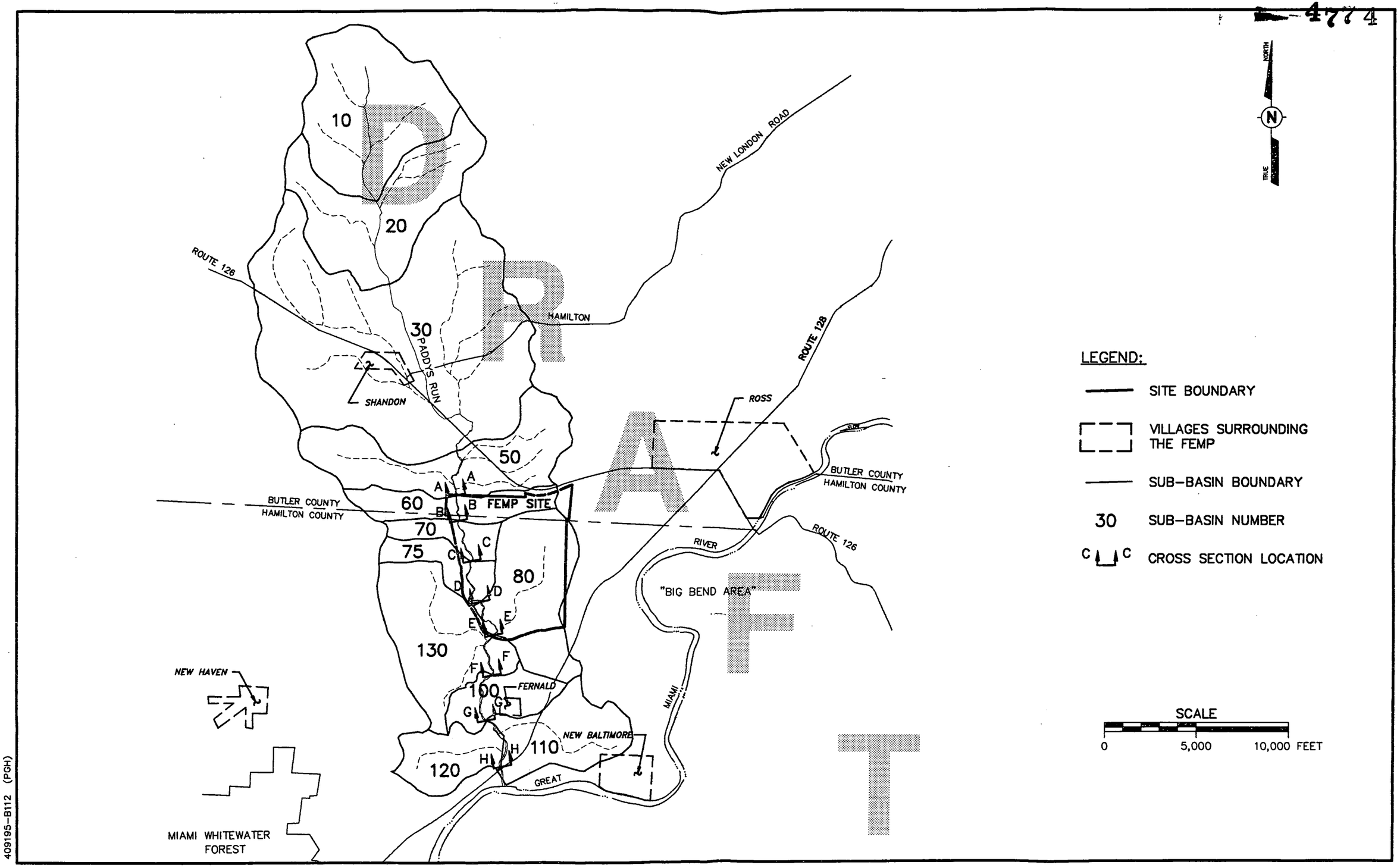
4774

DRAFT

FIGURES

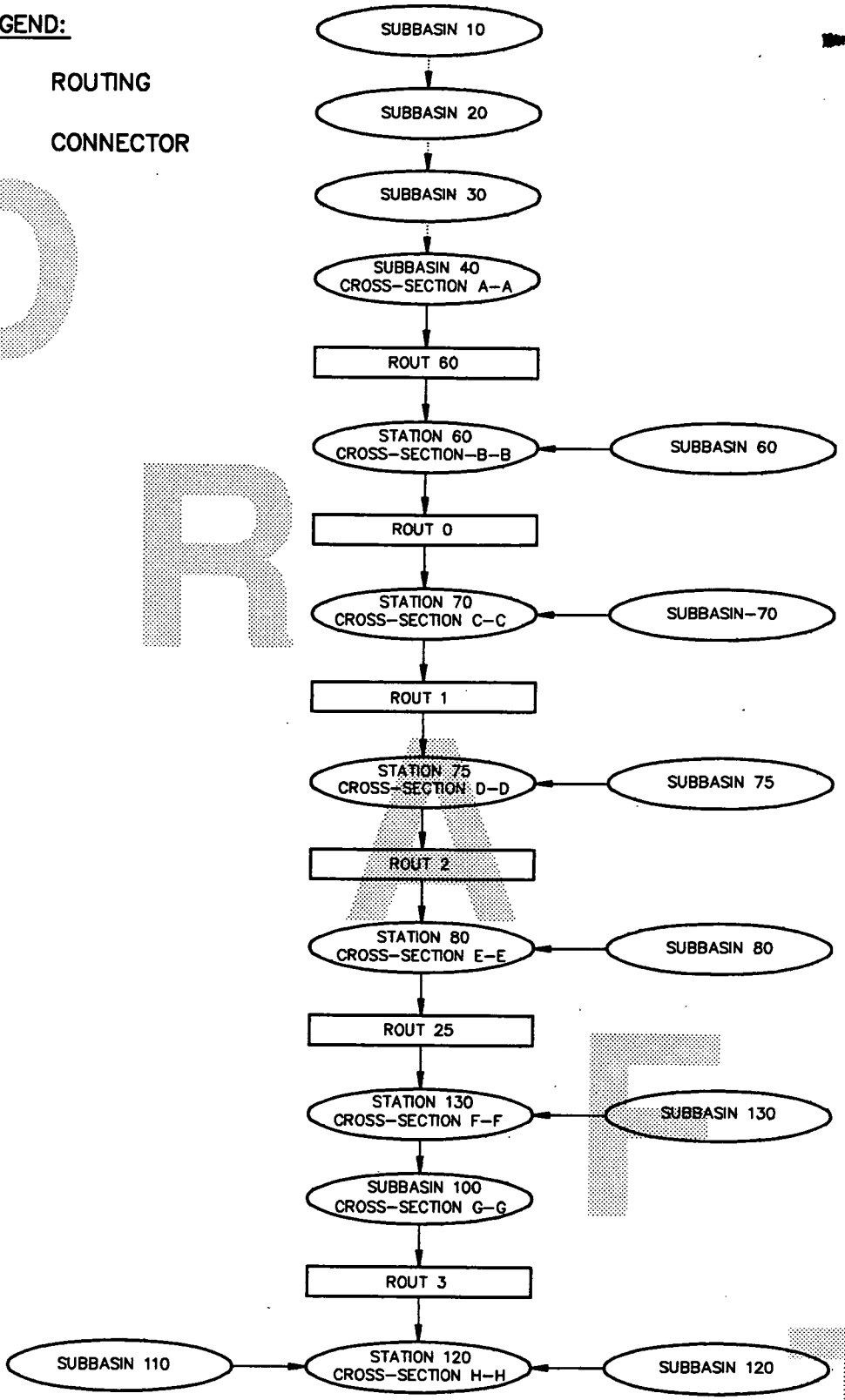
PRELIMINARY

34



409195-B112 (PGH)

FIGURE 1
PADDYS RUN DRAINAGE AREA
OF HEC-1 MODEL



NOTE:
THE CALCULATIONS OF PADDY'S RUN CHANNEL ROUTING AND SUBBASIN RUNOFF WERE COMBINED FOR SUBBASIN 10, 20, 30, AND 40 SINCE NO SUBBASIN RUNOFF HYDROGRAPHS WERE DESIRED FOR THESE SUBBASINS.

419195-A1

FIGURE 2
DIAGRAM OF PADDYS RUN HEC-1 MODEL

4774

DRAFT

APPENDIX A
PADDYS RUN FLOW AND INFILTRATION MODEL SCOPE

PRELIMINARY

PADDY'S RUN TO GREAT MIAMI AQUIFER MODEL PRELIMINARY TECHNICAL SPECIFICATIONS

DATA COLLECTION

- Identify available data on the profile and cross-sections of Paddy's Run.
- Determine additional needs and perform limited field surveys of Paddy's Run if required.
- Identify and collect available rain fall records and other relevant hydrogeological data on Paddy's Run in the vicinity of the FEMP.

DATA ANALYSIS AND MODEL DEVELOPMENT

- Based on the hydrogeological data, select the duration, intensity, and recurrent frequency of a representative storm that is able to cause significant surface runoff and erosion in the study area.
- Conduct HEC1 and HEC2 modeling to establish the average flow rate, water elevation, and flow duration in Paddy's Run caused by the representative storm.
- With the calculated flow rate in Paddy's Run and the flow rate of the surface runoff, the proper contaminant dilution factor to be applied on the contaminated surface runoff can be determined.
- The groundwater flow and elevation will be assumed constant in the model, as in the normal steady state condition, during and after the representative storm.
- Estimate the infiltration rate from Paddy's Run into the GMA during the flow caused by the storm using a 1-dimensional model that can simulate ponding conditions.
- Identify and perform sensitivity analyses on key parameters that affect the infiltration rate.
- Modify the SWIFT model input file to include the developed flow/mass loading from Paddy's Run as a recurrent loading pattern into the GMA due to the selected representative storms.

PROCEDURE TO IMPLEMENT ADDITIONAL PADDYS RUN DATA

The following procedure is the suggested method to implement the data from the Paddys Run flow/infiltration model to improve the modeling connection between Paddys Run and the Great Miami Aquifer for a storm event. The first sections list the available data from IT's Paddys Run Flow and Infiltration model and from the previous RI/FS reports.

Paddys Run basin was modeled by IT using the HEC-1 computer package. The modeled drainage area of Paddys Run is divided into several subbasins. There are three subbasins which contain the FEMP. The operable units are smaller than the subbasins and are contained within them. The IT model did not specifically calculate a runoff hydrograph for each operable unit.

INFORMATION AVAILABLE

1) **INFORMATION FROM PADDYS RUN FLOW/INFILTRATION MODEL (IT 7/93)** For a 1-yr, 24-hr storm, the following information will be provided:

a) The duration (hrs) of the total runoff hydrograph for Paddys Run, t_{total}.
b) The duration (hrs) of the runoff hydrograph for each of the subbasins containing the FEMP, $t_{subbasin}$.
c) Total infiltration volume (m^3) from Paddys Run into the Great Miami Aquifer, I_{total}.
d) The percent of total infiltration which occurs during the runoff hydrographs from the subbasins ($t_{subbasin}$) which contain the FEMP, P.
e) Runoff volume (m^3) from each of the subbasins which contain the FEMP, $V_{rsubbasin}$.
f) Runoff volume (m^3) from each of the runoff hydrographs upstream of the subbasins which contain the FEMP up to $t_{subbasin}$, $V_{rpaddys}$.
g) Peak discharge (m^3/s) from the subbasins which contain the FEMP ($Q_{subbasin}$) and the discharge in Paddys Run when $Q_{subbasin}$ occurs (Q_{paddys}).

2) **PREVIOUS RI/FS APPROACH (USED IN CRU2, 4, AND 1)** The following information was calculated (or will be) with the Modified Universal Soil Loss Equation. The release of contaminants from surface soils due to runoff was calculated based on a 1-yr 24-hour storm event in the previous RI/FS reports. The following parameters are the results of intermediate steps of the previous RI/FS calculations and are not specifically presented in those previous reports.

a) PX_i = sorbed substance loading per event from OU (g)
b) PQ_i = dissolved substance loading per event from OU (g)

c) V_{rou} = volume of runoff from OU (m^3)

PROPOSED PROCEDURE

1) **RUNOFF VOLUME FROM SUBBASINS** The OU will be a part of a larger subbasin as given in IT's data. The total runoff from the subbasin containing the OU can be calculated based on information in the HEC-1 output or on the total rainfall depth and the runoff curve number with the following equations:

$$Q_{rsubbasin} = (R_t - 0.2S_w)^2 / (R_t + 0.8S_w)$$

where $Q_{rsubbasin}$ = runoff depth from subbasin (cm)
R_t = rainfall depth (cm)
S_w = water retention factor (cm)
= ((1000/CN) -10)2.54
CN = curve number

The total volume of runoff from the subbasin is then

$$V_{rsubbasin} = Q_{rsubbasin} A_{subbasin} 100$$

where $A_{subbasin}$ = subbasin area (Ha)
100 = conversion factor

2) **CONCENTRATION IN RUNOFF FROM SUBBASINS** The concentration of dissolved contaminants in runoff from each subbasin can be calculated by the following equation.

$$C_{csubbasin} = PQ_i / V_{rsubbasin}$$

where $C_{csubbasin}$ = concentration in runoff from subbasin (g/m^3)

This assumes that all the flow from the subbasin is completely mixed and the time of the peak flow from the OU hydrograph matches the time of the peak flow from the subbasin hydrograph.

3) **CONCENTRATION IN PADDYS RUN** The concentration in Paddys Run can then be calculated based on the following procedure.

The HEC-1 results indicate that the runoff from the subbasins which contain the FEMP peak before the runoff from all of the upstream hydrographs. The flow of the subbasin hydrograph should not be added to the entire upstream hydrograph to calculate the dilution in Paddys Run since the flow from the subbasin will be over before the upstream

hydrographs are completed. The concentration in Paddys Run should then be calculated by mixing the peak discharge from the subbasin with the discharge in the upstream hydrograph which coincides with the peak discharge of the subbasin hydrograph. The "maximum" dissolved concentration of contaminants can then be calculated as follows:

$$C_{epaddys} = C_{esubbasin}\, Q_{rsubbasin} / (Q_{rpaddys} + Q_{rsubbasin})$$

where $C_{epaddys}$ = concentration in Paddys Run (g/m^3)
$Q_{rpaddys}$ = flow rate of upstream hydrograph coinciding with peak flow rate of the subbasin hydrograph (m^3/s)
$Q_{rsubbasin}$ = peak flow rate of the subbasin hydrograph (m^3/s)

4) **MASS LOADINGS TO THE GREAT MIAMI AQUIFER** The contaminant loading to the Great Miami Aquifer can be calculated with the following equations.

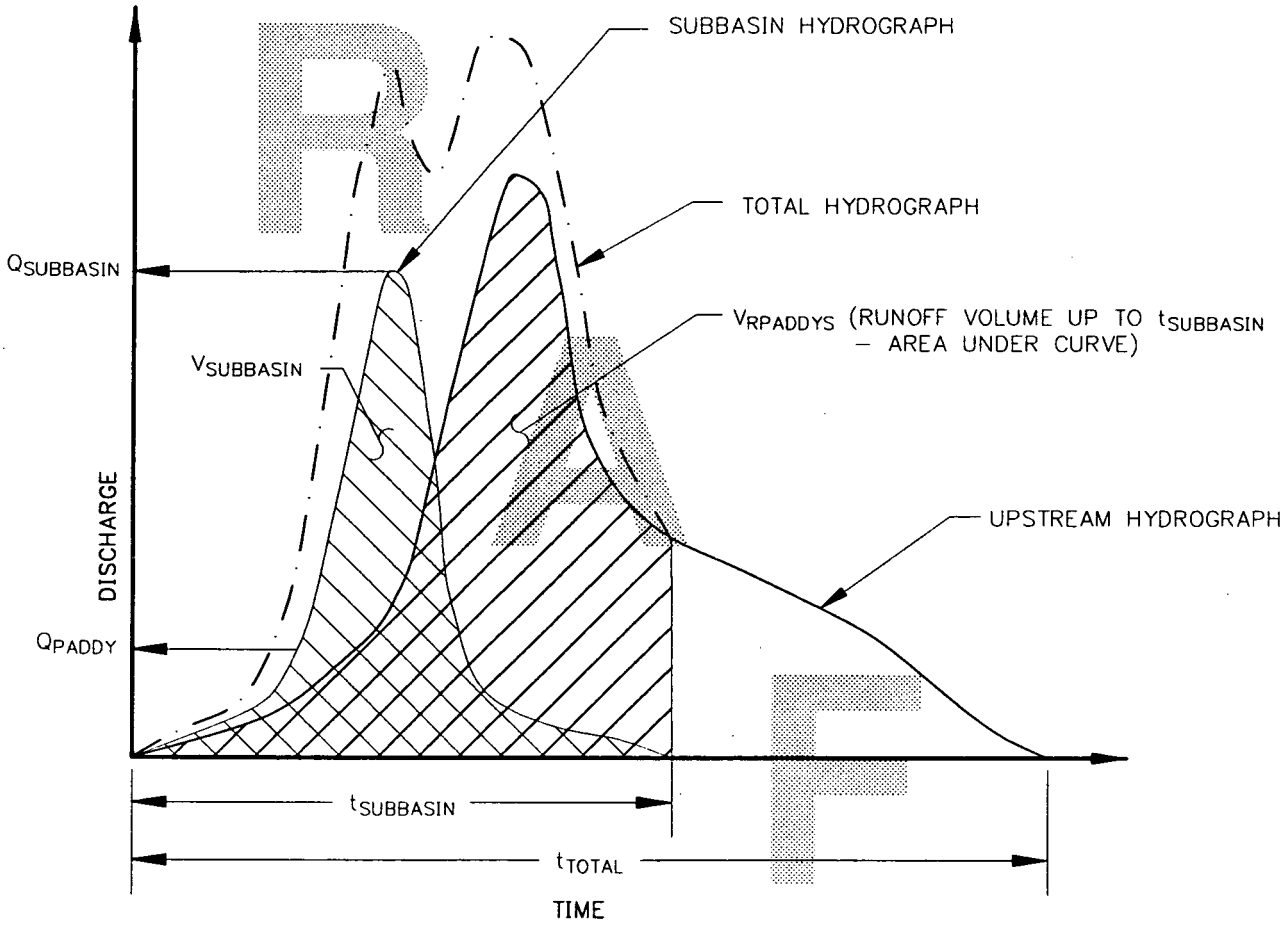
Percent of contaminant in runoff which will enter the Great Miami Aquifer. $= (I_{total}\, P) / (V_{rpaddys} + V_{rsubbasin})$

Time of duration of loading $= t_{subbasin}$

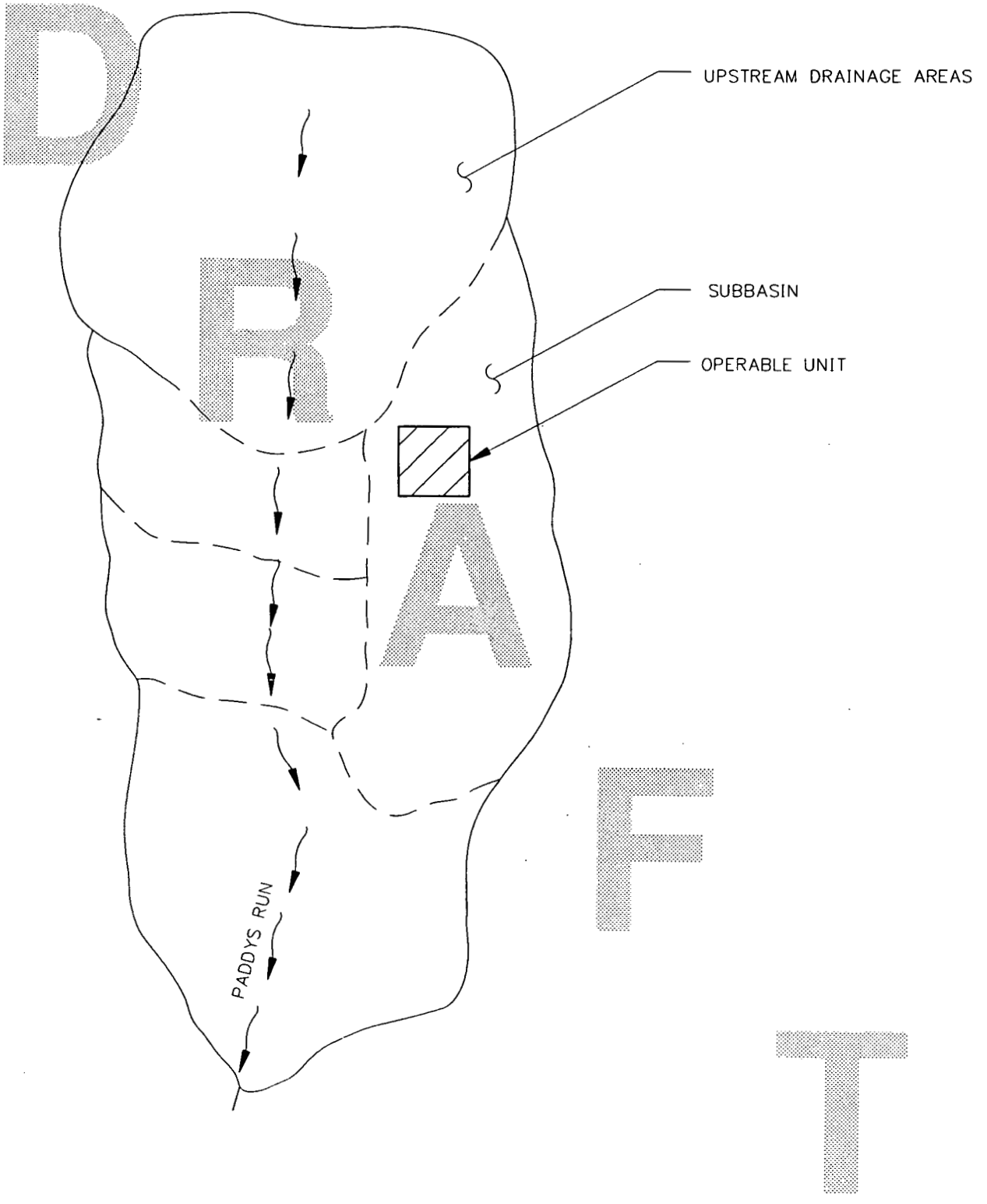
Total mass $= (PQ_i\, I_{total}\, P) / (V_{rpaddys} + V_{rsubbasin})$

DRAFT

DRAFT



RUNOFF HYDROGRAPH RELATIONS



DIVISIONS OF PADDYS RUN DRAINAGE BASIN

ACAD: C:\4P94\RUN.DWG MB 8/3/93 (PLOT1)

4774

MAR 3 1 1993

IT Corporation

Fernald Environmental

FERMCO

Restoration Management Corporation P.O. Box 398704 Cincinnati, Ohio 45239-8704 (513) 738-6200

DRAFT

March 26, 1993

U. S. Department of Energy
Fernald Environmental Management Project
Letter No. C:CRU5:93-045

Jerry Z. Klein, P.G.
Project Manager
IT Corporation
William Penn Plaza
2790 Mosside Blvd.
Monroeville, Pennsylvania 15146-2792

Dear Mr. Klein:

RAINFALL DATA FOR PADDYS RUN TO GMA MODELING EFFORT

In response to the March 12th kick-off meeting for the development of a Paddys Run to GMA model and as part of the Data Collection Activity agreed to by FERMCO, please find enclosed:

- Rainfall Intensity-Duration Frequency Curves from the U.S. Department of Commerce
- Total Monthly Precipitation data for the Cincinnati Airport in Boone County, Kentucky
- A copy of a memorandum indicating that channel data on Paddys Run has already been submitted to Jeff Schubert of IT

Since we will be meeting with you on March 29 in Pittsburgh to discuss the comments on the Groundwater Modeling Report, we can also address any issues relating to the precipitation data at that time. In the meantime, should you have any questions please contact Ken Broberg at (513) 738-6146 or Ron White at (513) 738-8982.

44

Fernald Environmental
FERMCO
Restoration Management Corporation

Sincerely,

James Skridulis, Ph.D.
Environmental Manager, CRU5

JCS:RDW:dah
Enclosure

c: K. A. Broberg
M. J. Cherry
J. D. Chiou
W. A. Hertel
R. M. Ninesteel
R. D. White
File Record Storage Copy 120.3.1

DRAFT

4764

Profile has already been sent

MEMORANDUM

To: Jeff Schubert
From: Bill Hertel WAH
Date: November 4, 1992
Subject: Transmittal of Data Related to the Paddys Run South (PRS) Investigation in Support of the Update to the Surface Water Section of the OU5 RI

Attached you will find information that was generated as part of the PRS Investigation. Most of this information will be useful in updating the surface water section of chapter 3 of our RI.

- Attachment 1 contains field notes and field instrument readings (temperature, pH, and specific conductance) taken during a walk up the creek on July 26, 1990. The walk was from the confluence of Paddys Run and the Great Miami River to the bridge where Willey Road crosses Paddys Run. Notes and field readings were taken at 15 locations. several photographs were also taken and are included. A map depicting the 15 locations is also included. The notes and field readings were taken by me and John Mason (ASI).

- Attachment 2 contains flow measurements taken at 3 locations in Paddys Run, south of the FEMP. A map is also included depicting the 3 locations.

- Attachment 3 contains monthly water level maps of 2000 series wells for calendar year 1990. Superimposed on these maps are the losing and gaining sections of Paddys Run. The gaining/losing sections of Paddys Run were determined by comparing the water level contours with the elevation of the stream channel. Locations where the stream channel elevations were determined by survey are included in a table and on a figure. IT surveyor Bill Church was in charge of all the survey work. If you have specific questions regarding the survey contact Mr. Church at 513-738-0430.

Water level data from locations 0125 and 0126 is being compiled and will be forthcoming in the next couple of weeks.

The information contained in these attachments is crucial to updating the surface water section of chapter 3. Please pass this information along to those individuals completing the surface water sections of the RI (J. Zhang and E. Harmsen).

Mark Hardner contacted me on November 2 and requested that I provide him with a copy of the field notes in Attachment 1. Please ensure that he gets a copy of those notes and he has an opportunity to view the pictures in Attachment 1. The notes / pictures provide descriptions of bedrock outcrops in the creek near its' intersection with state highway 128.

ou5memo.js

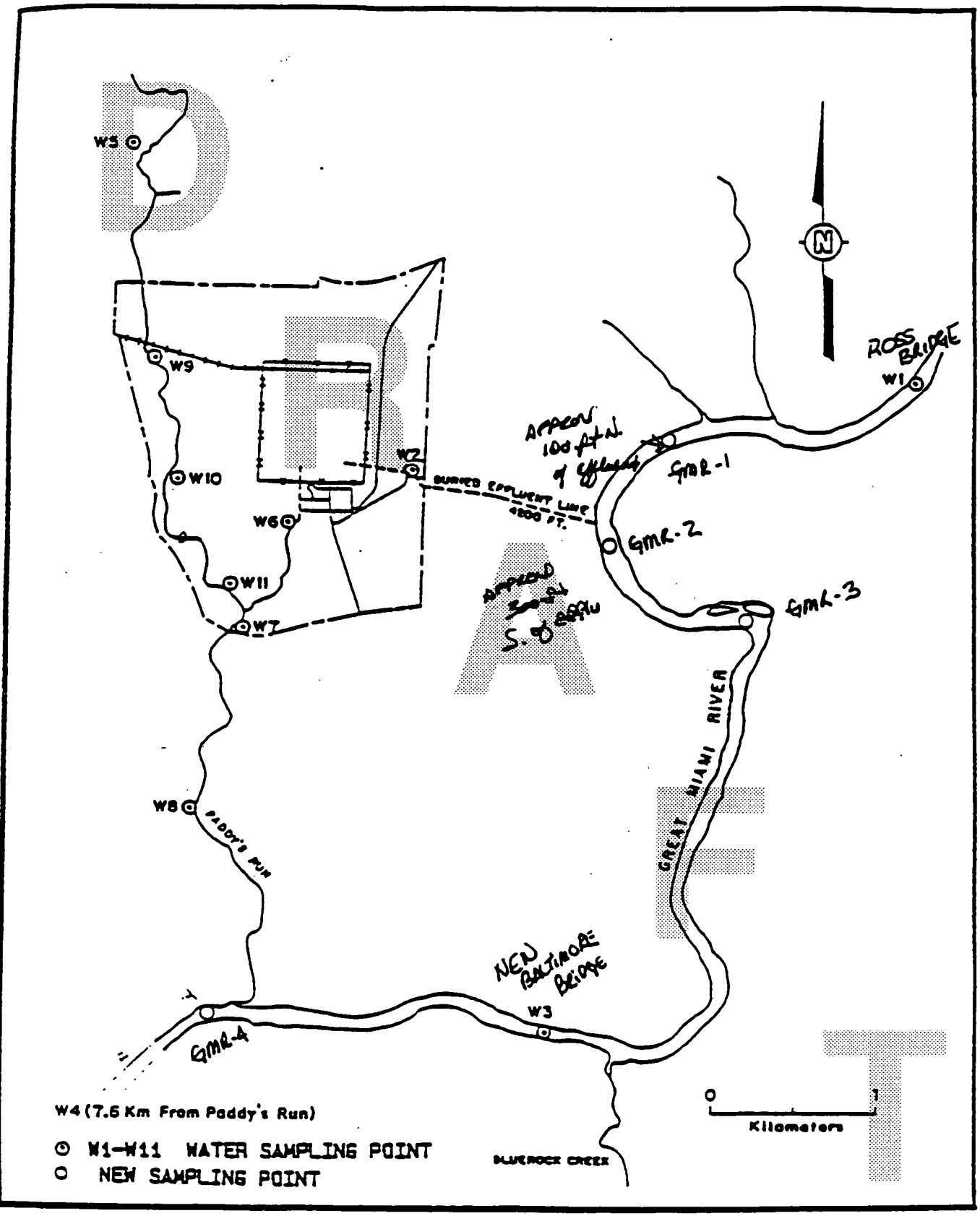


FIGURE 5-1

SURFACE WATER SAMPLING LOCATIONS

INTERNATIONAL TECHNOLOGY CORPORATION

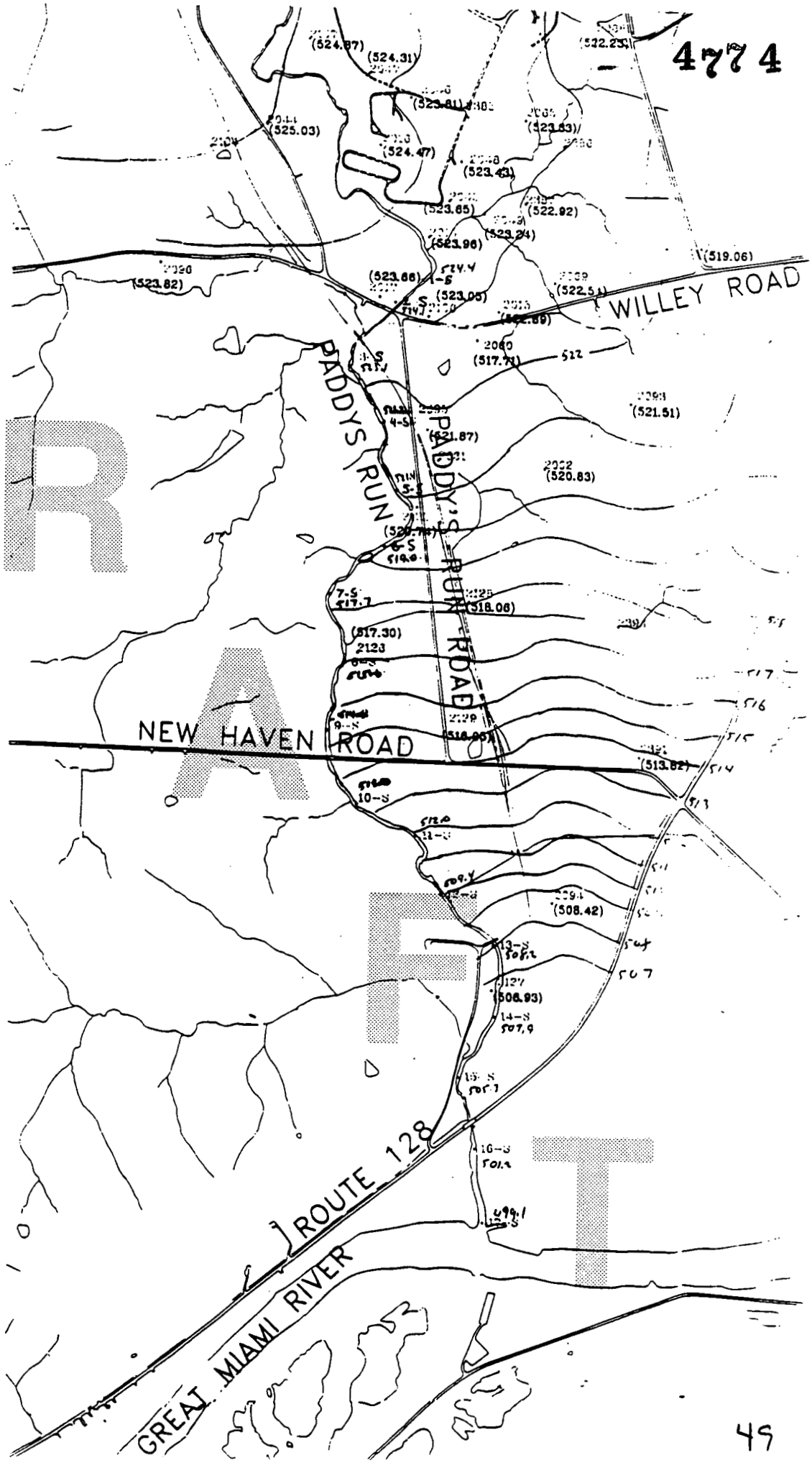
4774

By WEJ Date 4-1-89 Subject ASI-FERNALD Sheet No. 1 of
Chkd. By JK Date 5-11-89 WATER SAMPLE LOCATION Proj. No. 303317

SAMPLE NUMBER	NORTH COOR.	EAST COOR.	GROUND ELEV.	DESCRIPTION
GMR-1	478,732.8	1,387,205.1		℄ Great Miami River
GMR-2	478,318.2	1,387,183.7		" " "
GMR-3	476,058.0	1,390,412.4		" " "
GMR-4	467,750.2	1,379,942.8		" " "
W-1	481,943.7	1,393,681.9		" " "
W-2	479,893.2	1,382,969.4	597.75	Mt #175 Water Treatment Plant.
W-3	467,397.8	1,386,321.6		℄ Great Miami River
W-4	450,969.7	1,375,762.4		" " "
W-5	487,195.0	1,377,526.7	564.15	℄ Paddy's Run. 100' North from concrete bridge @ SR road 126
W-6	478,250.3	1,380,441.2	549.60	outfall from storm water Storage Lake - South Park Lot
W-7	476,200.0	1,379,278.0	524.14	℄ Paddy's Run @ Willey Rd
W-8	472,161.8	1,378,716.0	513.98	Paddys Run - New Bridge West of Fernald New Haven
W-9	482,525.4	1,377,345.5	551.67	℄ Paddy's Run @ R.R. Bridge
W-10	479,607.0	1,379,902.9	540.71	℄ Paddy's Run
W-11	476,956.4	1,379,379.6	526.70	℄ Paddy's Run - 1st Sample Point N. Storm Water outfall

48.

108-11


WILLEY ROAD
PADDYS RUN
PADDY'S RUN ROAD
NEW HAVEN ROAD
ROUTE 128
GREAT MIAMI RIVER

DRAFT

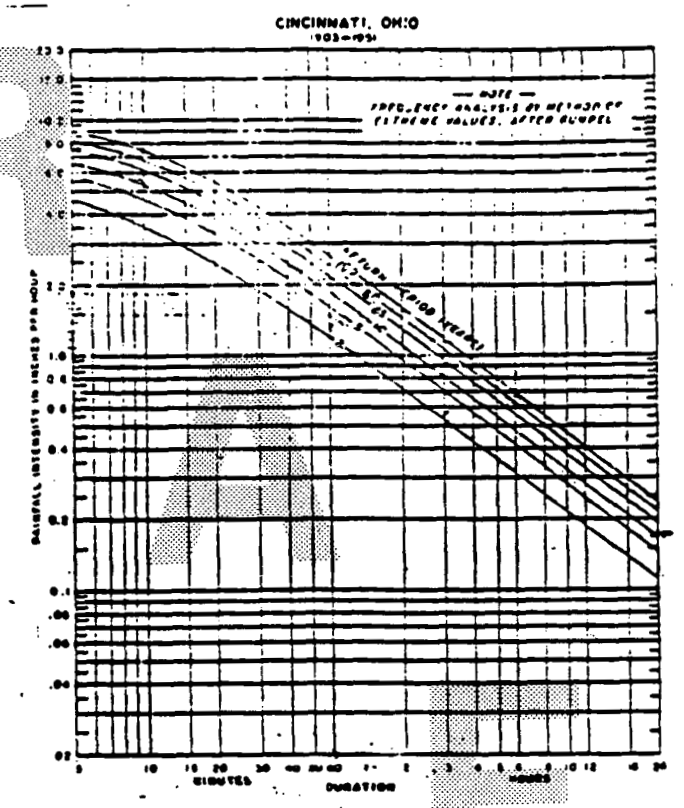
INTERNATIONAL TECHNOLOGY CORPORATION

By WEIK Date _____ Subject ASI-FERNALD Sheet No. ____ of ____

Chkd. By ____ Date _____ Sediment Sample Loc. - Paddys Run Proj. No. 303317

SAMPLE No	NORTH COOR	EAST COOR	ELEV.	DESCRIPTION
1-S	476,414.7	1,379,529.8	524.4	
2-S	476,200.0	1,379,278.0	524.1	
3-S	475,680.0	1,378,910.0	523.1	
4-S	475,112.0	1,379,178.0	521.2	
5-S	474,495.0	1,379,295.0	521.4	
6-S	473,995.0	1,379,185.0	519.0	
7-S	473,565.0	1,378,725.0	517.7	
8-S	472,950.0	1,378,845.0	515.6	
9-S	472,340.0	1,378,710.0	514.8	
10-S	471,735.0	1,378,920.0	513.2	
11-S	471,408.0	1,379,465.0	512.0	
12-S	470,900.0	1,379,715.0	509.4	
13-S	470,458.0	1,380,188.0	508.2	
14-S	469,814.0	1,380,183.0	507.9	
15-S	469,258.0	1,379,860.0	505.3	
16-S	468,625.0	1,380,000.0	501.2	
17-S	467,975.0	1,380,080.0	499.1	

RAINFALL INTENSITY-DURATION-FREQUENCY CURVES



Ref: U.S. Department of Commerce, Rainfall Intensity-Duration-Frequency Curves, Technical Paper No. 25.

24-hour rainfall already determined by U.S. Dept. of Com.

4774

TABLE OH-1

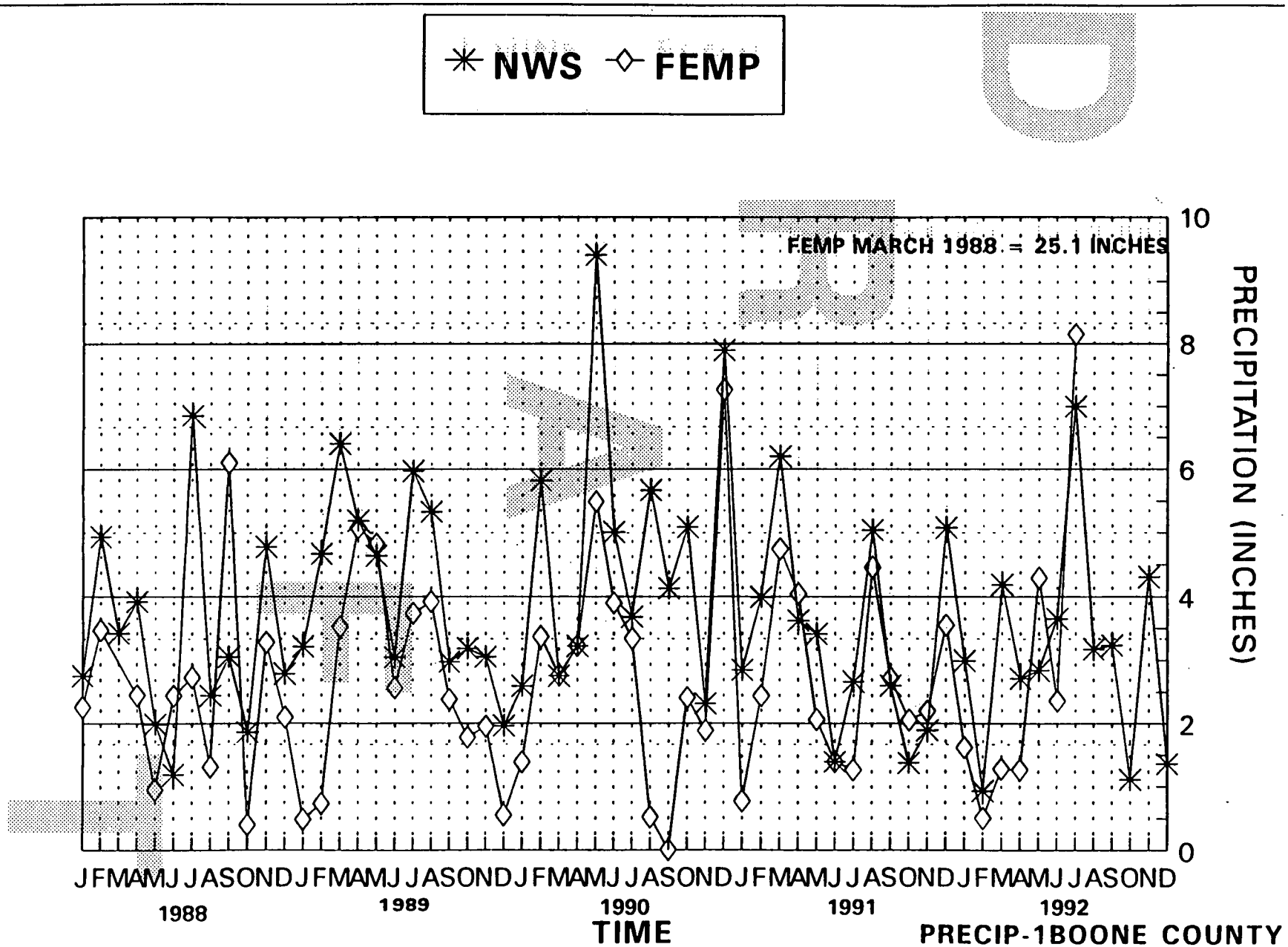
OHIO
24-HOUR RAINFALL (inches)

County	Frequency 1	2	5	10	25	50	100
Adams	2.5	2.8	3.5	4.0	4.6	5.0	5.5
Allen	2.3	2.7	3.3	3.8	4.3	4.8	5.2
Ashland	2.2	2.4	3.1	3.5	4.0	4.5	4.7
Ashtabula	2.1	2.3	3.0	3.5	4.0	4.5	4.7
Athens	2.3	2.5	3.3	3.8	4.3	4.7	4.9
Auglaize	2.4	2.7	3.4	3.9	4.4	4.9	5.2
Belmont	2.2	2.5	3.2	3.7	4.3	4.7	4.9
Brown	2.5	2.9	3.6	4.1	4.7	5.1	5.6
Butler	2.5	2.9	3.6	4.1	4.7	5.2	5.6
Carroll	2.2	2.4	3.1	3.6	4.1	4.6	4.8
Champaign	2.4	2.7	3.4	3.9	4.4	4.9	5.2
Clark	2.4	2.7	3.4	3.9	4.5	4.9	5.3
Clermont	2.5	2.9	3.6	4.1	4.7	5.1	5.6
Clinton	2.5	2.8	3.5	4.0	4.6	5.0	5.4
Columbiana	2.2	2.4	3.2	3.7	4.2	4.6	4.8
Coshocton	2.2	2.4	3.2	3.6	4.1	4.6	4.8
Crawford	2.2	2.5	3.2	3.6	4.1	4.6	4.8
Cuyahoga	2.1	2.2	3.0	3.4	3.9	4.4	4.6
Darke	2.4	2.8	3.5	4.0	4.5	5.0	5.5
Defiance	2.3	2.6	3.3	3.8	4.3	4.8	5.[illegible]
Delaware	2.3	2.5	3.3	3.7	4.2	4.7	4.9
Erie	2.2	2.4	3.1	3.5	3.9	4.4	4.7
Fairfield	2.3	2.5	3.3	3.7	4.3	4.7	4.9
Fayette	2.4	2.7	3.4	3.9	4.5	4.9	5.2
Franklin	2.3	2.6	3.3	3.8	4.3	4.7	5.0
Fulton	2.2	2.6	3.2	3.7	4.2	4.6	5.0
Gallia	2.4	2.6	3.4	3.8	4.4	4.9	5.1
Geauga	2.1	2.3	3.0	3.5	3.9	4.4	4.6
Greene	2.4	2.8	3.5	4.0	4.6	5.0	5.4
Guernsey	2.2	2.4	3.2	3.7	4.2	4.6	4.8
Hamilton	2.5	3.0	3.6	4.1	4.8	5.2	5.7
Hancock	2.3	2.6	3.3	3.7	4.2	4.7	5.0
Hardin	2.3	2.7	3.3	3.8	4.3	4.8	5.1
Harrison	2.2	2.4	3.2	3.7	4.2	4.7	4.9
Henry	2.3	2.6	3.3	3.7	4.2	4.7	5.0
Highland	2.5	2.8	3.5	4.0	4.6	5.0	5.4
Hocking	2.3	2.5	3.3	3.8	4.3	4.8	4.9
Holmes	2.2	2.4	3.1	3.5	4.0	4.5	4.7
Huron	2.2	2.4	3.1	3.5	4.0	4.5	4.7
Jackson	2.4	2.6	3.4	3.8	4.4	4.9	5.1
Jefferson	2.2	2.5	3.2	3.7	4.2	4.7	4.9
Knox	2.2	2.4	3.2	3.6	4.1	4.6	4.8
Lake	2.1	2.2	3.0	3.4	3.9	4.4	4.6
Lawrence	2.4	2.7	3.4	3.9	4.5	4.9	5.2
Licking	2.3	2.5	3.2	3.7	4.2	4.6	4.8
Logan	2.3	2.7	3.4	3.8	4.4	4.8	5.2

THE FMPC SITE IS LOCATED ON THE BORDER BETWEEN HAMILTON AND BUTLER COUNTIES

DRAFT

TOTAL MONTHLY PRECIPITATION IN INCHES
1000-SERIES



4224

35

PRECBOTH.CH3 XY Chart

F1-Help F2-Show chart F4-Draw F5-Mark
F6-Main Menu F7-Spell/Text F8-Options F9-XY data F10-Continue

Title:
Subtitle: 1000-SERIES
Footnote: PRECIP-1BOONE COUNTY

Data Pt	X Axis Name	1 NWS	2 FEMP	3 Series 3	4 Series 4
1	J	2.75	2.7		
2	F	4.94	4.16		
3	M	3.42			
4	A	3.92	2.93		
5	M	1.99	1.14		
6	J	1.19	2.92		
7	J	6.85	3.27		
8	A	2.44	1.57		
9	S	3.05	7.32		
10	O	1.86	0.48		
11	N	4.78	3.93		
12	D	2.78	2.51		

1988

PRECBOTH.CH3 XY Chart

F1-Help F2-Show chart F4-Draw F5-Mark
F6-Main Menu F7-Spell/Text F8-Options F9-XY data F10-Continue

Title:
Subtitle: 1000-SERIES
Footnote: PRECIP-1BOONE COUNTY

Data Pt	X Axis Name	1 NWS	2 FEMP	3 Series 3	4 Series 4
3	J	3.21	0.58		
4	F	4.67	0.88		
5	M	6.4	4.22		
6	A	5.19	6.09		
7	M	4.64	5.79		
8	J	3.04	3.07		
9	J	5.97	4.48		
0	A	5.33	4.7		
1	S	2.97	2.85		
2	O	3.18	2.13		
3	N	3.05	2.34		
4	D	1.96	0.66		

1989

RECBOTH.CH3 XY Chart

F1-Help F2-Show chart F4-Draw F5-Mark
F6-Main Menu F7-Spell/Text F8-Options F9-XY data F10-Continue

itle:
ubtitle: 1000-SERIES
ootnote: PRECIP-1BOONE COUNTY

1 2 3 4

DRAFT

Data Pt	X Axis Name	NWS	FEMP	Series 3	Series 4
25	J	2.59	1.66		
26	F	5.82	4.04		
27	M	2.75	3.31		
28	A	3.22	3.87		
29	M	9.41	6.59		
30	J	5.01	4.68		
31	J	3.68	4		
32	A	5.67	0.62		
33	S	4.13	0		
34	O	5.09	2.89		
35	N	2.31	2.26		
36	D	7.9	8.72		

1990

PRECBOTH.CH3 XY Chart

F1-Help F2-Show chart F4-Draw F5-Mark
F6-Main Menu F7-Spell/Text F8-Options F9-XY data F10-Continue

Title:
Subtitle: 1000-SERIES
Footnote: PRECIP-1BOONE COUNTY

		1	2	3	4
Data Pt	X Axis Name	NWS	FEMP	Series 3	Series 4
37	J	2.84	0.92		
38	F	3.99	2.92		
39	M	6.2	5.69		
40	A	3.62	4.85		
41	M	3.41	2.47		
42	J	1.39	1.67		
43	J	2.66	1.51		
44	A	5.04	5.35		
45	S	2.6	3.26		
46	O	1.37	2.46		
47	N	1.89	2.63		
48	D	5.08	4.26		

1991

PRECBOTH.CH3 XY Chart

F1-Help F2-Show chart F4-Draw F5-Mark
F6-Main Menu F7-Spell/Text F8-Options F9-XY data F10-Continue

Title:
Subtitle: 1000-SERIES
Footnote: PRECIP-1BOONE COUNTY

		1	2	3	4
Data Pt	X Axis Name	NWS	FEMP	Series 3	Series 4
49	J	2.99	1.94		
50	F	0.93	0.6		
51	M	4.19	1.53		
52	A	2.71	1.51		
53	M	2.84	5.15		
54	J	3.65	2.83		
55	J	7	9.78		

1992

DRAFT

4774

56	A	3.17
57	S	3.23
58	O	1.11
59	N	4.31
60	D	1.36

DRAFT

4774

INTERNATIONAL TECHNOLOGY CORPORATION

DRAFT

June 17, 1993

Mr. James Skridulis
FERMCO
Trailer 80
7400 Willey Road
Fernald, Ohio 45030

Dear Mr. Skridulis:

Enclosed is the scope and manhours that J. D. Chiou requested for additional work on the Paddys Run flow model. This task is beyond the original model scope but can be covered under the remaining budget. IT Corporation (IT) is prepared to begin work on this task on June 21, 1993, and have it completed on June 30, 1993, as requested by J. D. Chiou. Please contact either of the undersigned if you have any questions or comments.

Sincerely,

Jerry Z Klein

Jerry Z. Klein - FXM
OU5 Manager

Francis X. Markert

Francis X. Markert
Project Hydrogeologist

JZK:FXM:jar

cc: J. D. Chiou
D. Witt
Central Files

Regional Office
William Penn Plaza • 2790 Mosside Boulevard • Monroeville, Pennsylvania 15146-2792 • 412-372-7701

IT Corporation is a wholly owned subsidiary of International Technology Corporation

PADDYS RUN INFILTRATION MODEL: SCOPE AND MANHOURS

Scope: Create a more realistic infiltration model than was originally scoped as part of the Paddys Run Flow Model Study. The infiltration model is to take into account the mass balance of water in Paddys Run vs. water infiltrating and flow in the unsaturated and saturated zones below Paddys Run. Document and append to the existing report.

Method: The modeling will consist of two parts:

-An unsaturated infiltration model using a unit gradient and Darcy's Law modified for unsaturated conditions. The hydraulic conductivity will be assumed to vary as a function of soils moisture similar to the method used by the HELP model.

-A saturated infiltration model which will begin once the vadose zone below Paddys Run is fully saturated. This model will take into account lateral movement of water and the formation of a mound and will use an analytical solution for determining groundwater flow.

Both models will be constructed and documented for each cross-section location along Paddys Run presented in the original report. Results will be presented in the present report tables and will include the volume and percent of infiltration occurring along each reach of Paddys Run. Infiltration times and basin concentration times will also be documented, with particular emphasis on times from the FEMP.

Manhours: This task has been scheduled to be completed within 1.5 weeks after receiving the notice to proceed. Assuming the notice to proceed is received on or by June 21, the modeling work and documentation will be completed on June 30. The manhours and computer hours are listed below:

Jerry Klein (E10):	8 hours
Eric Harmsen (E10):	16 hours
Jian Zhang (E8):	40 hours
Frank Markert (E8):	32 hours
Wei Hua Li (E6):	64 hours
Computer Time:	120 hours

DRAFT

Summary of IT/FERMCO Meeting
June 14, 1993

Meeting Attendees: J.D. Chiou (FERMCO)
Dan Witt (FERMCO)
Eric Harmsen (IT)
Jerry Klein (IT)
Frank Markert (IT)
Jian Zhang (IT)

Issue 1: The Paddys Run Flow Model: Description and Results Report was submitted to FERMCO in draft form for their review.

Issue 2: FERMCO and IT discussed the results of the infiltration model used in the Paddys Run simulations. Both agreed that the approach used by the task scope resulted in a simplistic model which was not yielding realistic results. Discussion was held on how to improve the infiltration model. IT agreed to prepare a work scope for transmittal to FERMCO by June 17, 1993. IT would also examine the task budget to determine if additional funds would be necessary. FERMCO requested that the additional modeling scope be completed by the end of June.

Issue 3: A technical discussion on the infiltration model developed the items that FERMCO wished to have addressed by the new model. These include:

- Checking the water balance in Paddys Run to determine if excessive infiltration is occurring
- Using an infiltration calculation similar to the HELP model
- Potentially allowing both an unsaturated and saturated flow component of infiltration in the new model.

In addition, FERMCO requested output results showing the volume and percent of infiltration at each cross section. FERMCO is also interested in the infiltration and travel times from runoff from the FEMP site.

DRAFT

Summary of IT/FERMCO Meeting
June 21, 1993

4774

Meeting Attendees: Dan Witt (FERMCO)
Eric Harmsen (IT)
Frank Markert (IT)
Jian Zhang (IT)

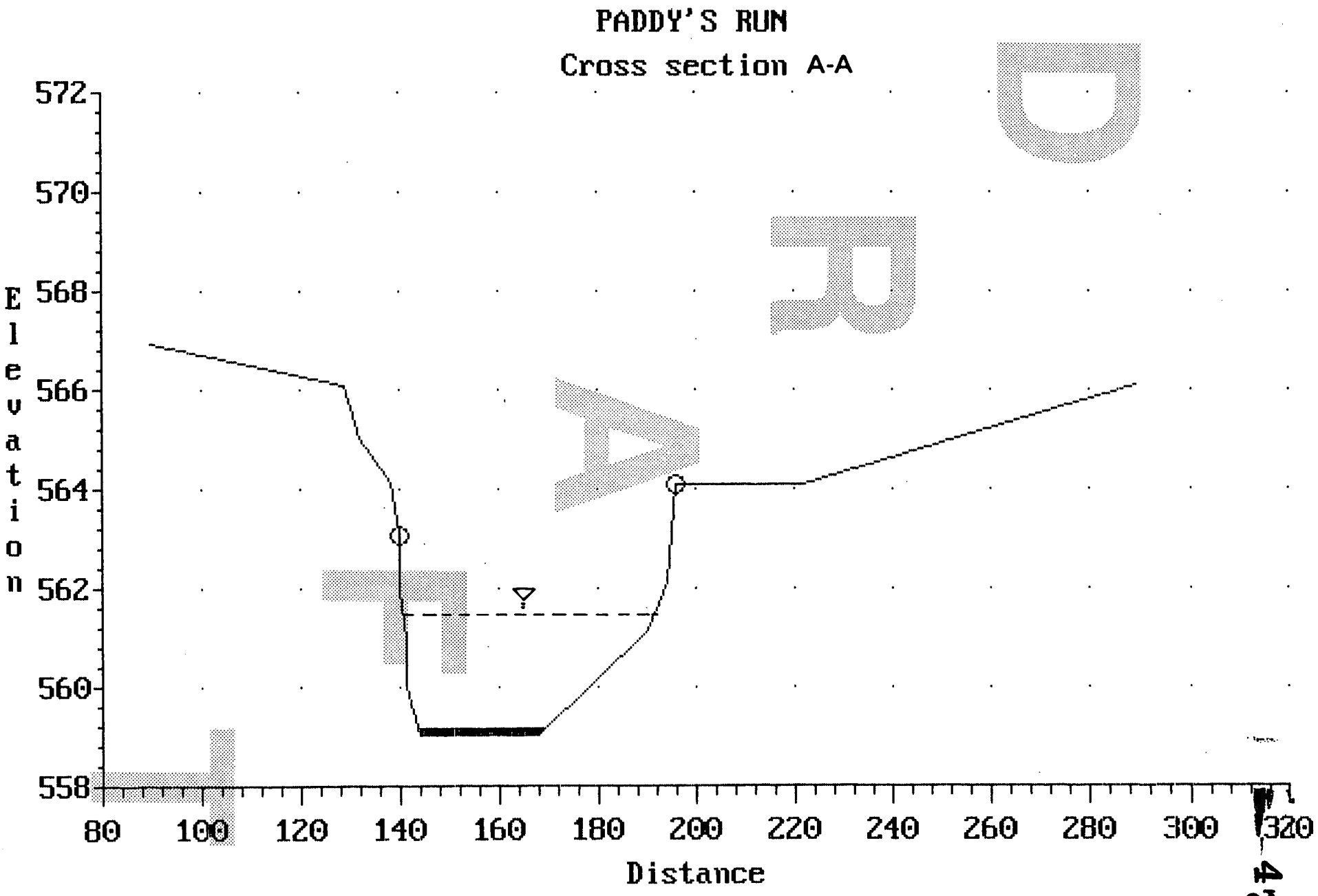
Issue 1: The comments provided by FERMCO on the Paddys Run Flow Model Report were reviewed and clarified by FERMCO. IT agreed to address all comments.

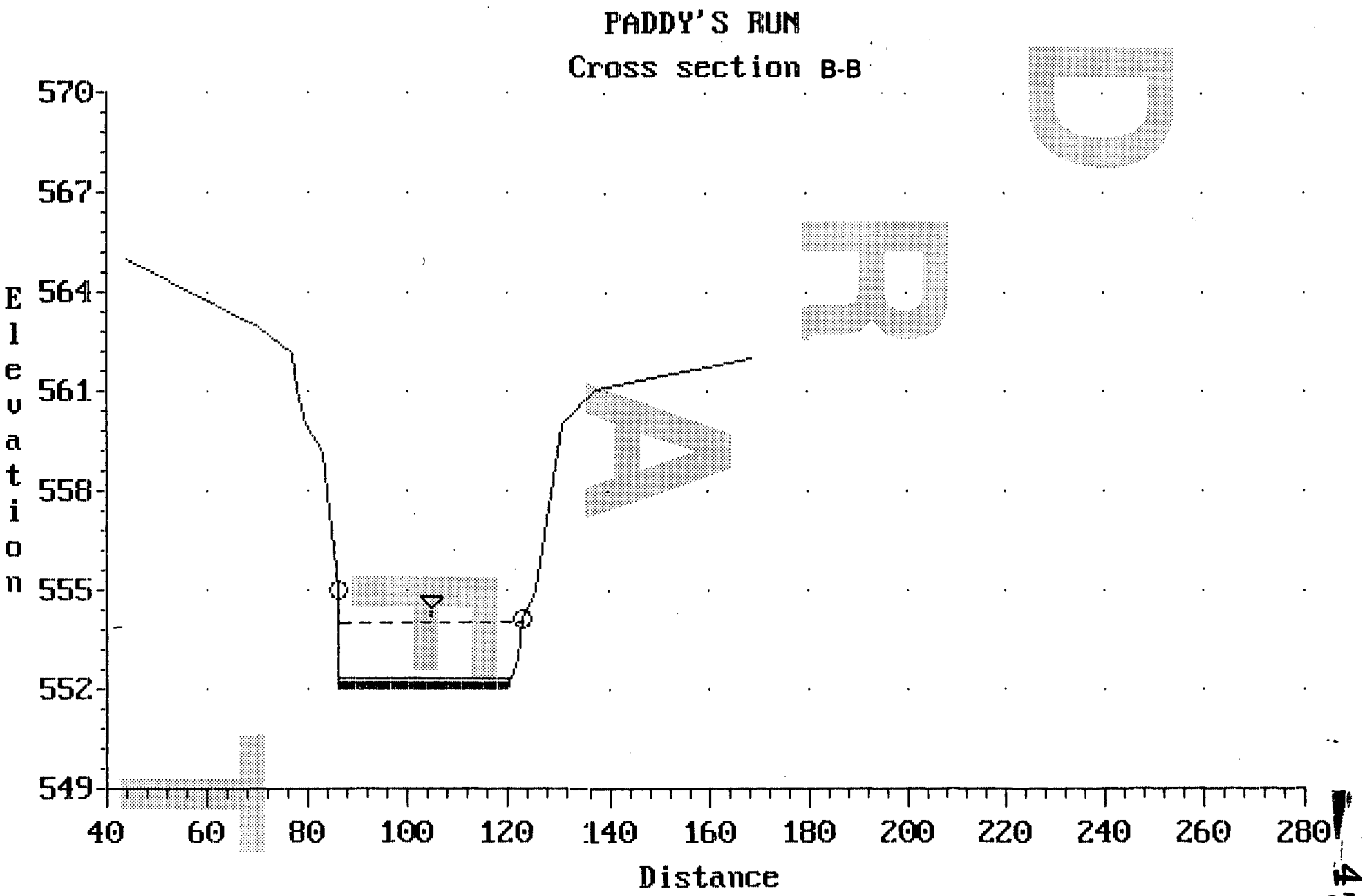
Issue 2: FERMCO requested the final report be provided in a bound, formal report format. IT agreed, but stipulated that the current schedule would not accommodate this change. Upon further discussion, it was agreed that IT would provide a letter report on July 1 followed by a formal final report submittal the week of July 5th. Dan Witt stated that this was agreeable but that he would have to verify this with J.D. Chiou.

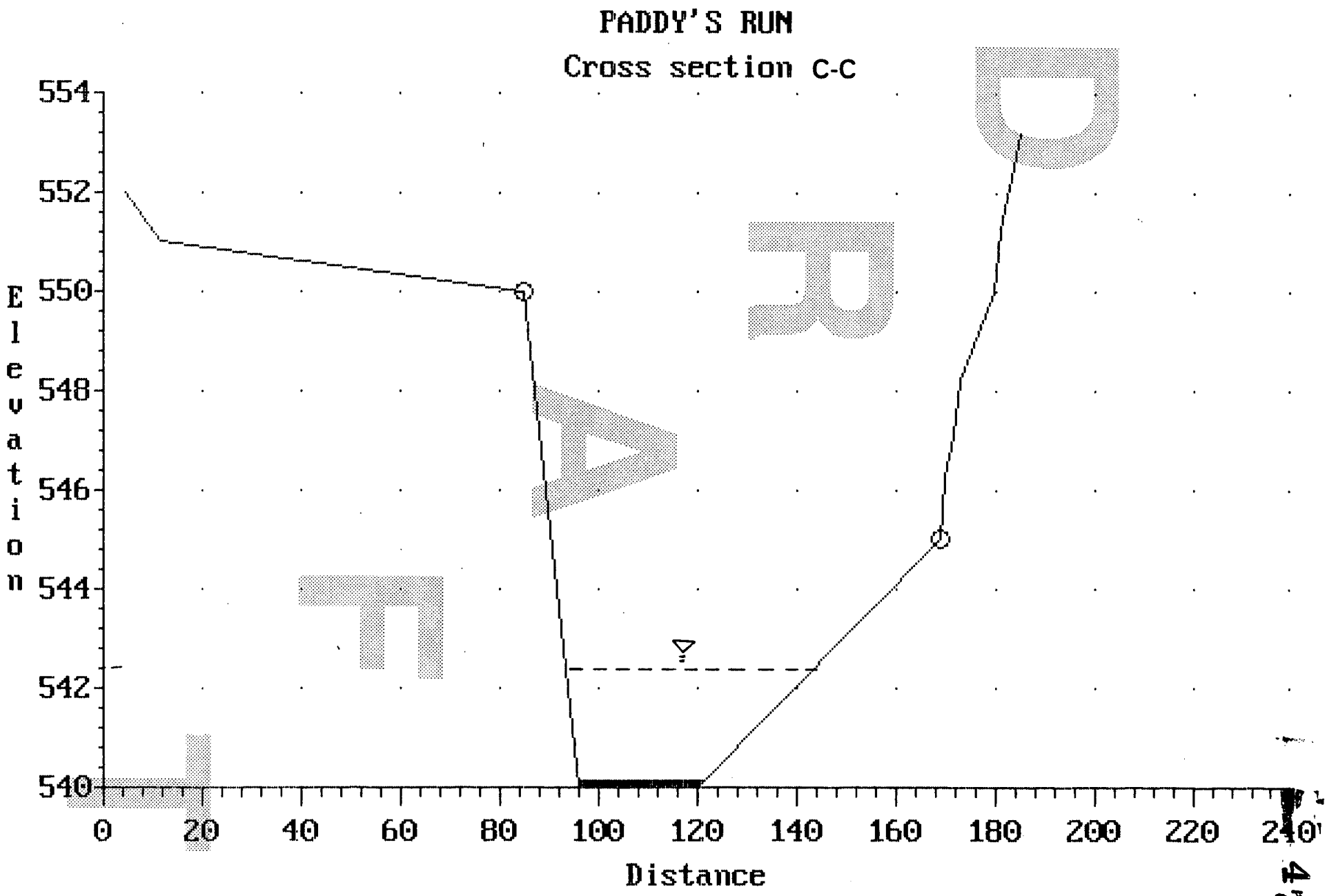
Issue 3: A discussion was held on the infiltration model to be created for Paddys Run. It was agreed that the model should be able to simulate both vertical and lateral movement of water to be realistic. A numeric model will be used to simulate vadose zone movement and an analytical solution will be used for the mounding portion. IT agreed to have a model solution selected by June 24 for review by FERMCO.

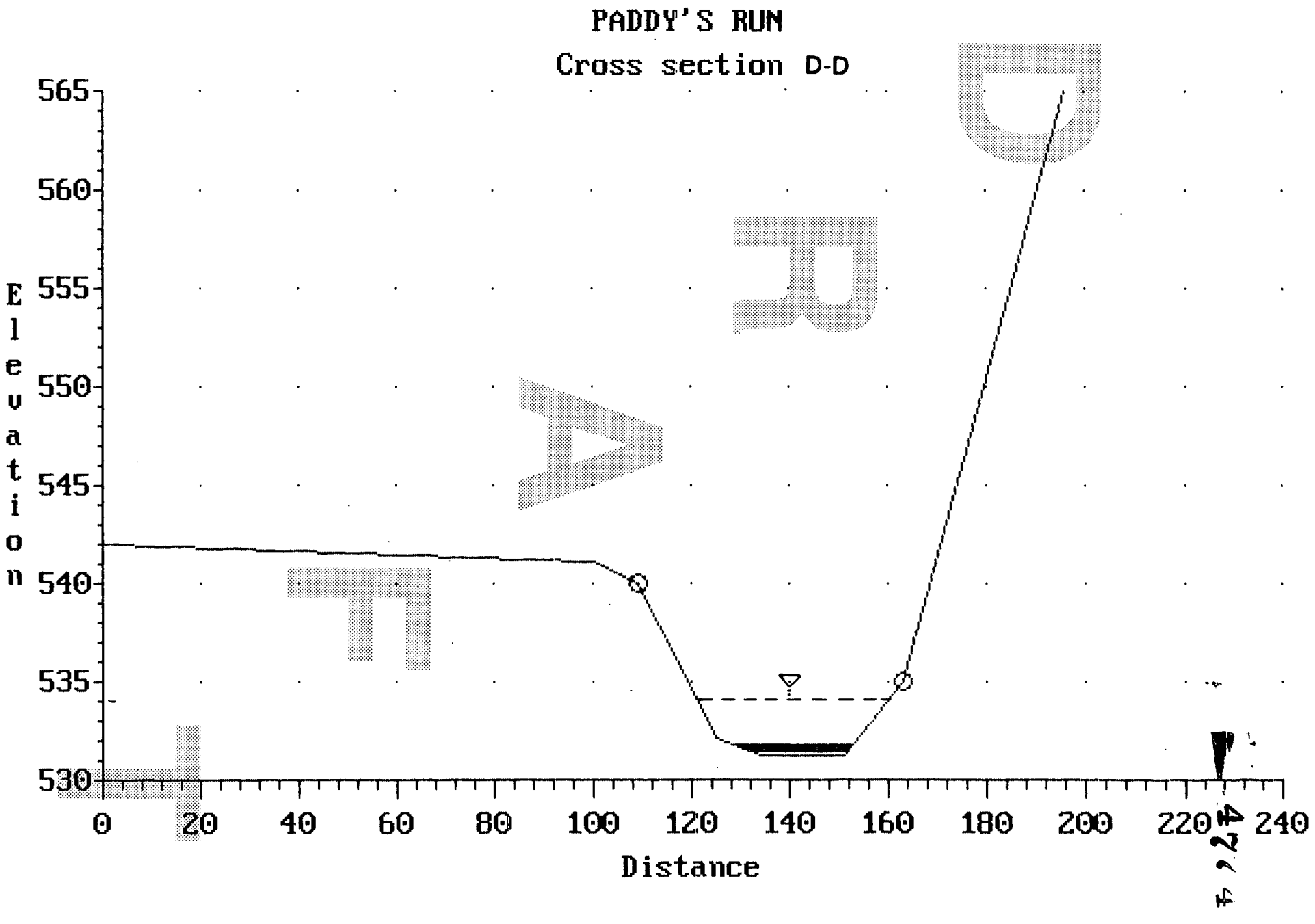
DRAFT

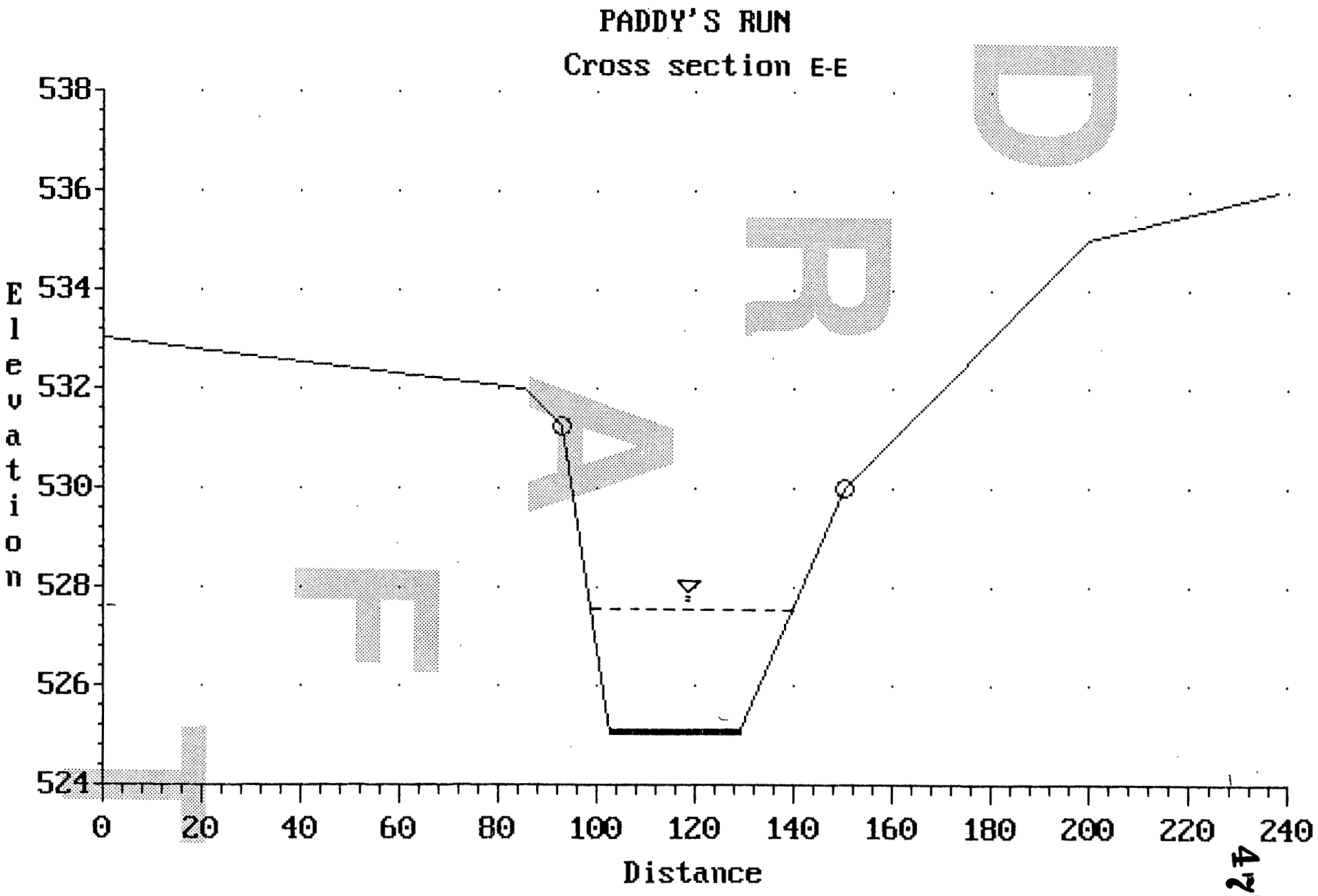
60


PADDY'S RUN
Cross section A-A
Elevation
572
570
568
566
564
562
560
558
80
100
120
140
160
180
200
220
240
260
280
300
320
Distance


PADDY'S RUN
Cross section B-B
Elevation
570
567
564
561
558
555
552
549
40
60
80
100
120
140
160
180
200
220
240
260
280
Distance


PADDY'S RUN
Cross section C-C
Elevation
554
552
550
548
546
544
542
540
0
20
40
60
80
100
120
140
160
180
200
220
240
Distance


PADDY'S RUN
Cross section D-D
Elevation
565
560
555
550
545
540
535
530
0
20
40
60
80
100
120
140
160
180
200
220
240
Distance
427.4


PADDY'S RUN
Cross section E-E
Elevation
538
536
534
532
530
528
526
524
0
20
40
60
80
100
120
140
160
180
200
220
240
Distance

4224

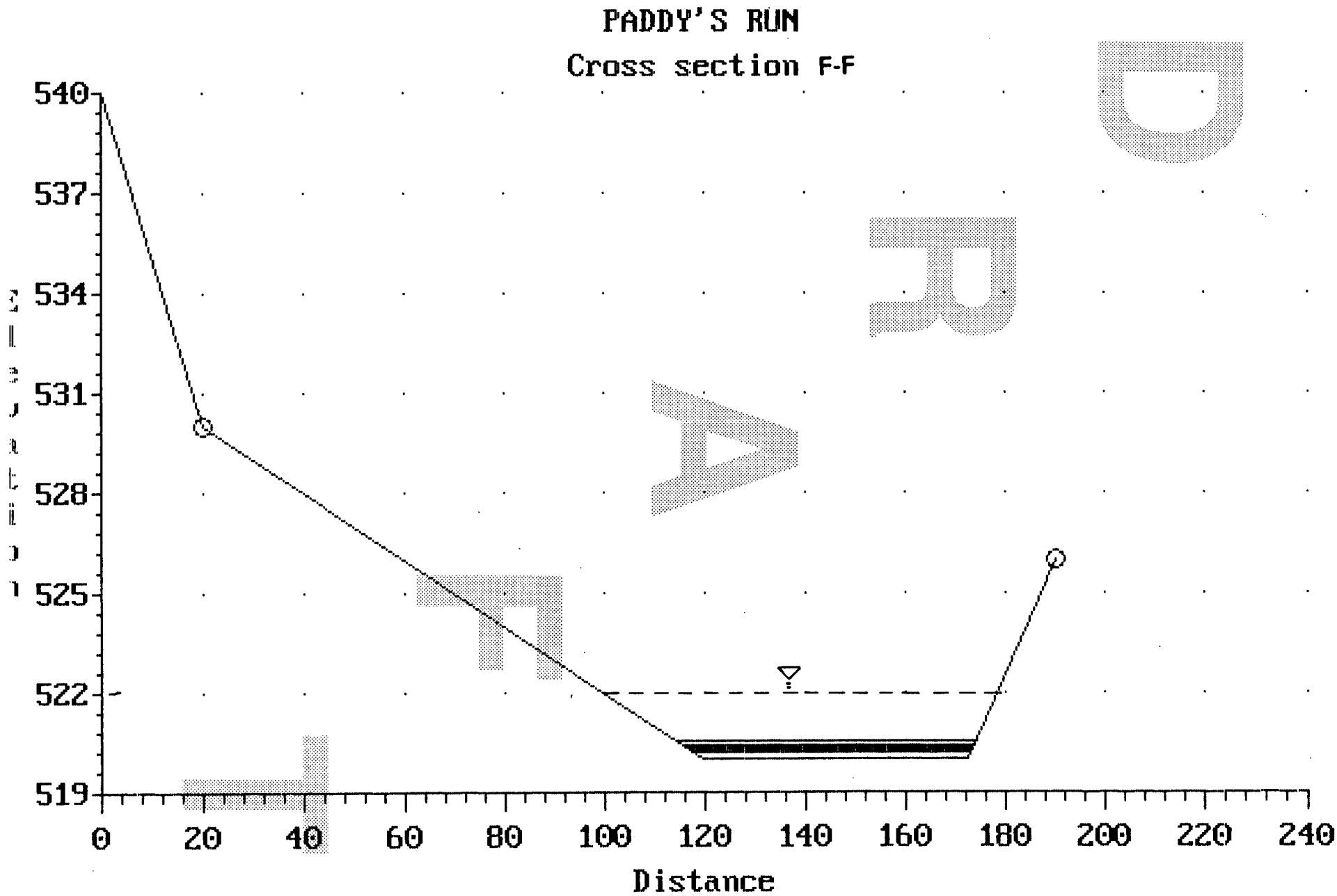
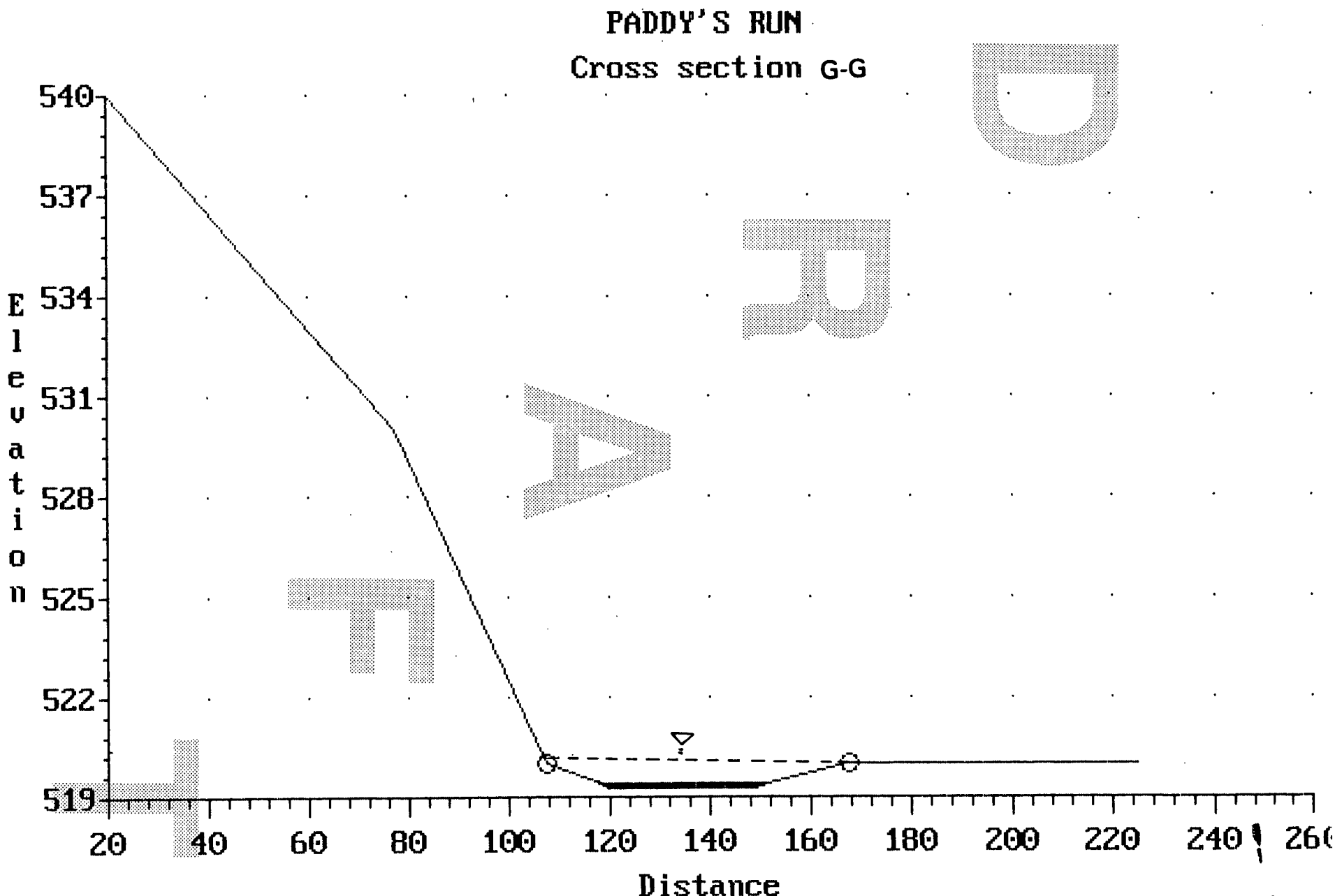
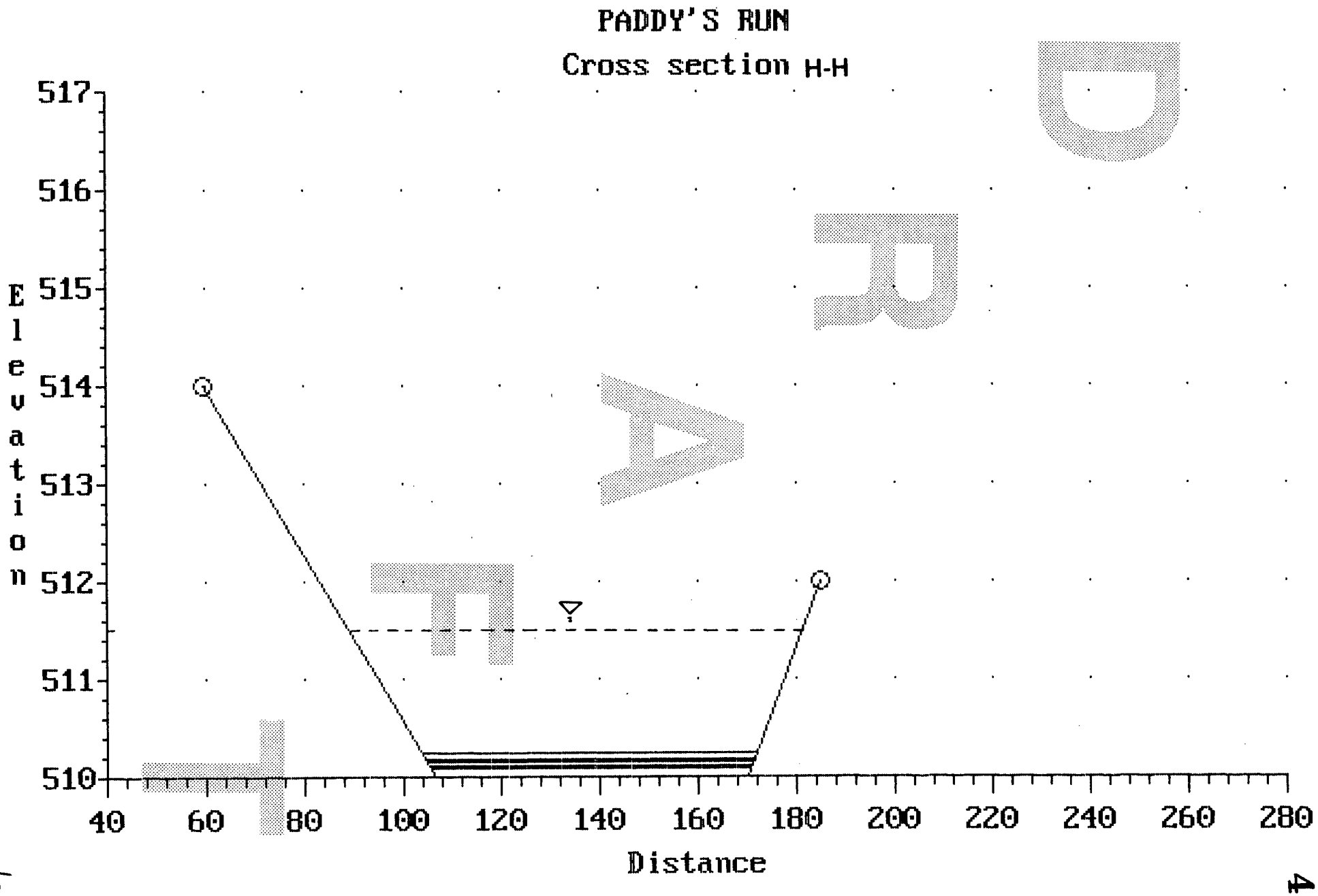
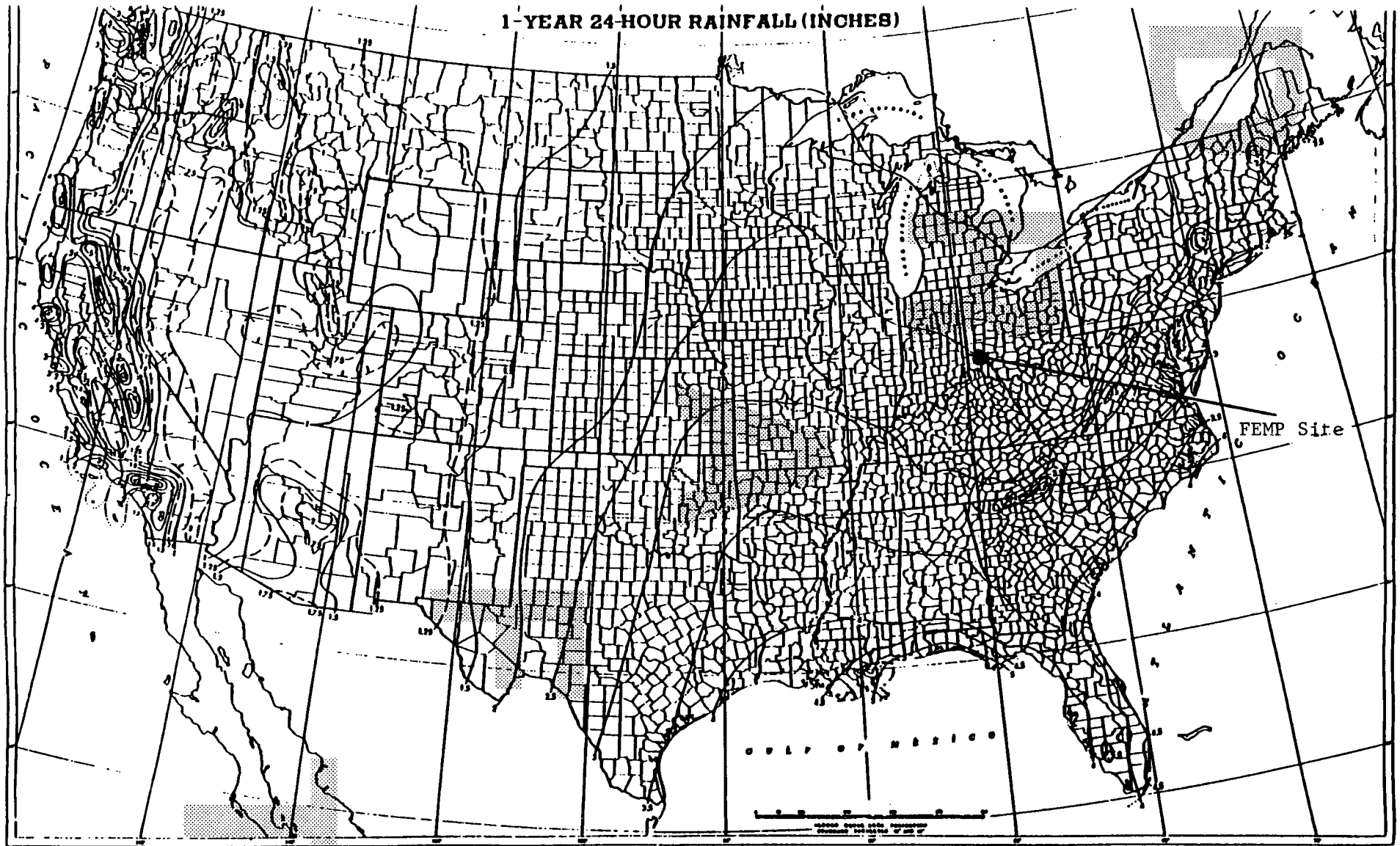

PADDY'S RUN
Cross section F-F
540
537
534
531
528
525
522
519
0
20
40
60
80
100
120
140
160
180
200
220
240
Distance

Fig 4.2.4


PADDY'S RUN
Cross section G-G
Elevation
540
537
534
531
528
525
522
519
20
40
60
80
100
120
140
160
180
200
220
240
260
Distance


PADDY'S RUN
Cross section H-H
Elevation
517
516
515
514
513
512
511
510
40
60
80
100
120
140
160
180
200
220
240
260
280
Distance

4272 4



Ref: Hershfield, D.M., 1961, "Rainfall Frequency Atlas of the United States," Technical Paper No. 40, Department of Commerce, Washington, DC.

4774

DRAFT

APPENDIX C
COMPUTER INPUT FILES AND CALCULATIONS

PRELIMINARY

71

DRAFT

APPENDIX C-1
HEC-1 RUNOFF MODEL INPUT FILE

4774

```
ID          Paddy's Run Simulation (07-17-1993/WHL)
ID          Storm Size: 24-hour and 1 YEAR RETURN PERIOD
*DIAGRAM
IT     10 01JAN93     1200      300
IO      3         0
*
KK SUB10
KM  RUNOFF FROM SUBBASIN 10
KO      1
BA 1.869
PH                 0.333    0.625    1.100    1.400    1.480    1.800      2.1      2.5
LS            65.4
UK  150.      0.07      0.4      100
RK   500      0.07    0.045     0.06     TRAP        0        1
RK  3200      0.05    0.045     0.47     TRAP        0        1       NO
RK 5200.     0.015    0.045              TRAP        0        1
*
KK SUB20
KM RUNOFF FROM SUBBASIN 20
BA 1.589
LS            63.7
UK   200     0.075      0.4      100
RK  4500     0.065    0.045    0.132     TRAP        0        1
RK 4800.     0.015    0.045              TRAP                 1      YES
*
KK SUB30
KM RUNOFF FROM SUBBASIN 30 40 AND 41
BA 5.188
LS              63
UK   200      0.08      0.4      100
RK  3600      0.05    0.045     0.18     TRAP        0        1
RK  6000     0.007    0.045    1.297     TRAP        0        1
RK 10800     0.003    0.045              TRAP       20        1      YES
*
KK SUB50
KO               0                 1       21
KF   YES(f12.4)
BA 1.288
LS              66
UK   200      0.04      0.4      100
RD  5000      0.02    0.045    0.322     TRAP        0        1
KD                                                                   YES
KC 0.045     0.035    0.045     2800    0.002
KX   129       140    141.1    144.1    168.1      190    194.1    196.2
KY566.08   563.07      560   559.03   559.03   561.17   562.12   564.07
*
KROUT60
KO               0                 1       21
KD                                                                   YES
KC 0.045     0.035    0.045   1599.8    0.004
KX    77        83       86     86.5    120.1      123      126    130.1
KY562.16   559.17      555   551.98   551.98   554.16      555      560
*
KK SUB60
KO               0                 1       21
BA 0.599
LS            59.8
UK   200      0.08      0.4      100
```

DRAFT

```
D  4500    0.04    0.02    0.15    TRAP       5       1      NO
D                                                            NO
C 0.045   0.035   0.045  1599.8   0.004
X    77      83      86    86.5   120.1     123     126   130.1
Y562.16  559.17     555  551.98  551.98  554.16     555     560

K  ST60
M COMBINE RUNOFF FROM SUB60
O            0                1      21
C     2

K ROUT0
MROUTE FROM CROSS SECTION B-B TO C-C
O            0                1      21
D                                                            NO
C 0.045   0.025   0.045    2986   0.004
X  11.3    53.7      85    95.9   119.8   168.8   179.7   194.6
Y   551     551     550     540     540     545     550     555

K SUB70
O            0                1      21
A 0.313
S           61                     88.8
K   150   0.013     0.4      75
K   200   0.013    0.15      25
D  4000   0.013   0.045    0.13    TRAP       5       1

K  ST70
M COMBINE RUNOFF FROM SUB70
O            0                1      21
C     2

K ROUT1
M ROUTE FROM CROSS SECTION C-C TO D-D
O            0                1      21
D                                                           YES
C 0.045   0.025   0.045    3093   0.003
X   100   109.2    125.   134.2   151.1     163   195.9     200
Y541.07    540.   532.1   531.3   531.3     535     565   566.4

K SUB75
O            0                1      21
A 0.408
S           61                     88.8
K   150   0.013     0.4      75
K   200   0.013    0.15      25
D  4000   0.013   0.045    0.13    TRAP       5       1

K  ST75
M COMBINE RUNOFF FROM SUB75
O            0                1      21
C     2

K ROUT2
M  ROUTE FROM CROSS SECTION D-D TO E-E
O            0                1      21
D                                                           YES
C 0.045   0.025   0.045    2773   0.002
```

DRAFT

```
     0    82.3      93   102.9     129     150     200   237.8
   533     532   531.2     525     525     530     535     536

K SUB80
M RUNOFF FROM SUB80 (STORM SEWER OUTFALL DITCH)
O            0                1      21
A 1.223
S           65                      87
K   200    0.01     0.4      75      50
K   250    0.01    0.15      25      50
D  6500    0.01   0.045    0.65    TRAP       5       1
D  5866   0.003   0.025            TRAP      26    2.27

K  ST80
M COMBINE RUNOFF FROM STORM SEWER OUTFALL DITCH TO PADDY'S RUN
O            0                1      21
C     2

KROUT25
M ROUTE FROM CROSS SECTION E-E TO F-F
O            0                1      21
D  2613   0.002   0.025            TRAP    52.8    4.55     YES

KSUB130
M RUNOFF FROM SUBBASIN 130
O            0                1      21
A 1.385
S         68.2
K   200   0.033     0.4     100
D  5000   0.016   0.045   0.588    TRAP       5       1
D  1800    0.02   0.025            TRAP    52.8    4.55

K ST130
M  COMBINE RUNOFF FROM FROM SUB130 TO PADDY'S RUN.
O            0                1      21
C     2

KSUB100
M RUNOFF FROM SUB100 AND ROUTE FROM CROSS SECTION F-F TO G-G
O            0                1      21
A 0.510
S         62.1                   62.11
K   180     0.1     0.4      30
K   250   0.018     0.3      70
D  4000    0.01   0.045   0.412    TRAP       5       1
D  2773  0.0003   0.025            TRAP    27.2   26.32     YES

K ROUT3
M ROUTE FROM CROSS SECTION G-G TO H-H
D  3626  0.0025   0.025            TRAP    63.6    7.30     YES

KSUB110
MRUNOFF FROM SUB110
A 0.823
S         61.9                      69
K   200     0.2     0.4      50
K   150    0.03     0.3      50
D   500    0.04   0.045    0.21    TRAP       0       1
```

DRAFT

```
 10000   0.009   0.025            TRAP      20     3.33

SUB120
 RUNOFF FROM SUB120
 0.561
          69.4
   100    0.28     0.4     100
   500     0.2   0.045    0.15    TRAP       0       1
  8000   0.021   0.045            TRAP      20    3.33

 ST120
 COMBINE RUNOFF FROM SUB110 AND SUB220 TO PADDY'S RUN
              0                 1      21
     3
```

DRAFT

DRAFT

APPENDIX C-2
VS2DT INFILTRATION MODEL INPUT FILES

4774

```
nfiltration through cross section C-C simulation  7/1/93
8 0.  0.
EETHOUR LBS
6  23
0  50000000
 F F
 F T T F
 T T T T
 3.5
.4 70
 0.1
.3 1.
8
 2 3 4 5 6. 7  8. 9 10. 11 12. 13 14. 15 16. 17. 18.

1  32
.E-5 0.15 0.0
5 999

 6

.1 18.75  0.0001  0.39 -1.079 0.069  3.9

 20  23 1
  0.
4 -3.
 F
  0.001                    C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 3 4 0.74
99999 /
  0.001                    C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 3 4 2.
99999 /
  0.001                    C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 3 4 1.5
99999 /
  0.0005                   C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.
```

DRAFT

```
 F F

 2 1 3 4 1.2
99999 /
  0.0005                    C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 3 4 1.1
99999 /
  0.0005                    C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 3 4 1.
99999 /
  0.0005                    C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 3 4 0.96
99999 /
  0.0005                    C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 3 4 0.7
99999 /
  0.0005                    C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 3 4 0.34
99999 /
  0.0005                    C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 3 4 0.16
```

DRAFT

)9999 /
)9999 /

DRAFT

```
filtration through cross section D-D simulation  7/1/93
. 0.  0.
ETHOUR LBS
  18
  50000000
F F
F T T F
T T T T
1.68
4 70
0.05
3 1.
0
2 3 4 5 6. 7  8. 9 10. 11 12. 13 14. 15 16. 17. 18. 19. 20.

1  32
E-5 0.25 0.0
5 999

6

.1 18.75  0.0001  0.39 -1.079 0.069  3.9

20  18 1
 0.
.52 -3.
F
 0.001                          C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

F F

2 1 4 4 0.96
99999 /
 0.001                          C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

F F

2 1 4 4 2.2
99999 /
 0.001                          C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

F F

2 1 4 4 1.69
99999 /
 0.0005                         C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.
```

DRAFT

```
 F F

 2 1 4 4 1.4
99999 /
  0.0005                    C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0

 F F

 2 1 4 4 1.2
99999 /
  0.0005                    C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 4 4 1.2
99999 /
  0.0005                    C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 4 4 1.1
99999 /
  0.0005                    C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 4 4 0.84
99999 /
  0.0005                    C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 4 4 0.44
99999 /
  0.0005                    C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 4 4 0.2
```

DRAFT

99999 /
99999 /

DRAFT

774

```
nfiltration through cross section E-E simulation  7/5/93
0.  0.   0.
EETHOUR LBS
5   10
0   50000000
 F F
 F T T F
 T T T T
 1.6
.4 30
 0.05
.3 1.
0
 2 3 4 5 6. 7  8. 9 10. 11 12. 13 14. 15 16. 17. 18. 19. 20.

1   32
.E-5 0.25 0.0
5 999

 6

.1 18.75  0.0001  0.39 -1.079 0.069  3.9

 26  10 1
  0.
.9 -1.
 F
.  0.001                          C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 5 4 1.32
99999 /
  0.001                          C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 5 4 2.23
99999 /
  0.001                          C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 5 4 1.77
99999 /
  0.0005                         C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.
```

DRAFT

4774

```
 F F

 2 1 5 4 1.39
99999 /
  0.0005                          C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 5 4 1.23
99999 /
  0.0005                          C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 5 4 1.15
99999 /
  0.0005                          C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 5 4 1.05
99999 /
  0.0005                          C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 5 4 0.82
99999 /
  0.0005                          C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 5 4 0.46
99999 /
  0.0005                          C-1   New Recharge Period
.05 0.01  0.0001  0.1
.05 0.0
.

 F F

 2 1 5 4 0.21
```

DRAFT

9999 /
9999 /

DRAFT

86

4774

DRAFT

APPENDIX C-3
PADDYS RUN STAGE VERSUS TIME, TOTAL SUBBASIN RUNOFF VOLUME AND RELATIVE HYDRAULIC CONDUCTIVITY CALCULATIONS

Program: MATHCAD v.4.0

4774

Objective:

Using hydrographs created by the HEC-1 model and the rating curves resulting from the normal depth calculation (see Appendix C) to calculate river stage versus time at each cross section.

Calculate average stream heads to be used in the infiltration model.

Calculate total runoff from each subbasin containing FEMP.

The calculations presented in this section were performed using MATHCAD 4.0. For more information on MATHCAD 4.0 procedures and syntax, see MATHCAD 4.0 using guide, Math Soft Inc.

Calculation:

Input rating curves for each cross section,

$RTA := READPRN(ecaa)$ $RTB := READPRN(ecbb)$ $RTC := READPRN(eccc)$

$RTD := READPRN(ecdd)$ $RTE := READPRN(ecee)$ $RTF := READPRN(ecff)$

$RTG := READPRN(ecgg)$ $RTH := READPRN(echh)$

$Qr := RTA^{<0>}$ (Discharge rate in cfs, column 1 of the input rating curve)

$STa := RTA^{<1>}$ (Stage of Paddys Run at crossection A-A, column 2)

$STb := RTB^{<1>}$ (Stage of Paddys Run at crossection B-B in feet)

$STc := RTC^{<1>}$ (Stage of Paddys Run at crossection C-C in feet)

$STd := RTD^{<1>}$ (Stage of Paddys Run at crossection D-D in feet)

$STe := RTE^{<1>}$ (Stage of Paddys Run at crossection E-E in feet)

$STf := RTF^{<1>}$ (Stage of Paddys Run at crossection F-F in feet)

$STg := RTG^{<1>}$ (Stage of Paddys Run at crossection G-G in feet)

$STh := RTH^{<1>}$ (Stage of Paddys Run at crossection H-H in feet)

Using interpolation method, produce a function which represents a continuous rating curve.

DRAFT

$vsa := cspline(Qr, STa)$ $vsb := cspline(Qr, STb)$ $vsc := cspline(Qr, STc)$

$vsd := cspline(Qr, STd)$ $vse := cspline(Qr, STe)$ $vsf := cspline(Qr, STf)$

$vsg := cspline(RTG^{<0>}, STg)$ $vsh := cspline(Qr, STh)$

$STaa(Qra) := interp(vsa, Qr, STa, Qra)$ (rating curve function for cross section A-A, QRaa is discharge rate and STaa is stage)

$STbb(Qrb) := interp(vsb, Qr, STb, Qrb)$

$STcc(Qrc) := interp(vsc, Qr, STc, Qrc)$

$STdd(Qrd) := interp(vsd, Qr, STd, Qrd)$

$STee(Qre) := interp(vse, Qr, STe, Qre)$

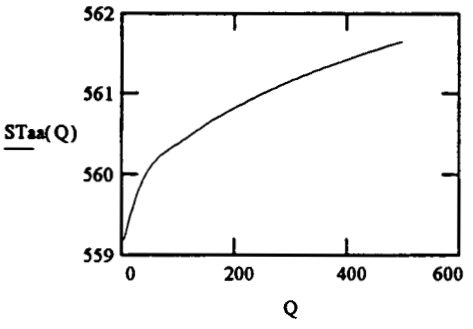
$STff(Qrf) := interp(vsf, Qr, STf, Qrf)$

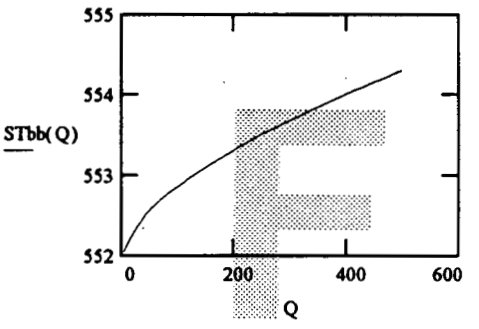
$STgg(Qrg) := if(Qrg<50, interp(vsf, RTG^{<0>}, STg, Qrg), 520)$

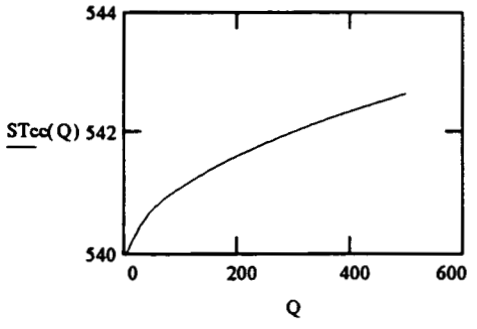
$SThh(Qrh) := interp(vsh, Qr, STh, Qrh)$

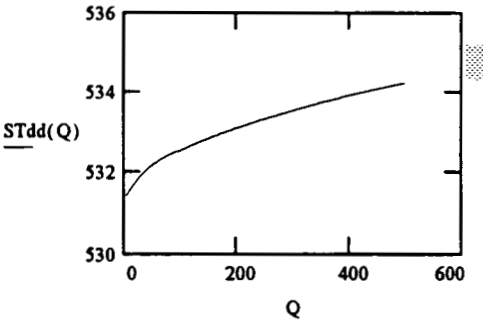
Plot all rating curves in the following figures,

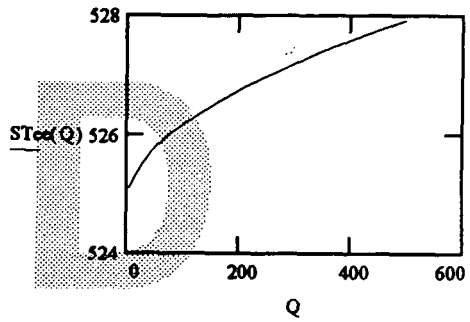
$Q := 5, 10 .. 500$ discharge rate ranges from 5 to 500 cfs

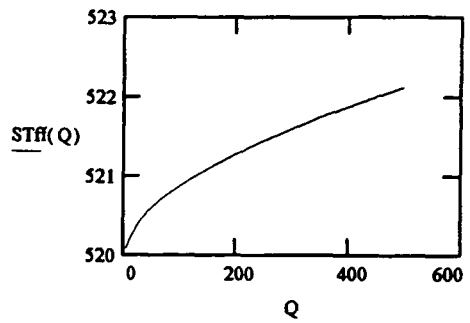


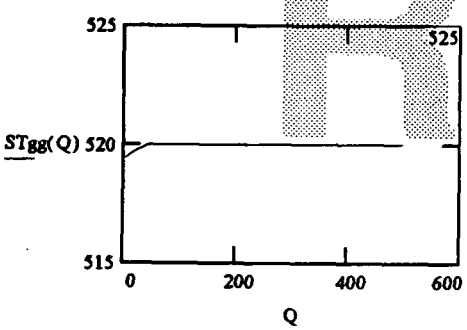


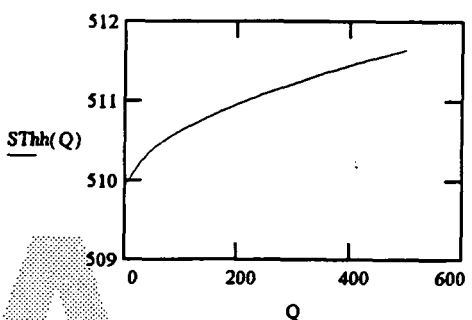












Hydrographs at each cross section were calculated using HEC-1 model for a 24-hour 1-year storm.

$i := 0, 1 .. 299$ each hydrograph contains 300 data points

$dt := \frac{10}{60}$ time interval for hydrograph calculation (hour)

$t_i := (i + 1) \cdot dt$ elapsed time (hour)

input all hydrographs for eight cross-sections

$Qaa := READPRN(hydraa)$ discharge rate (cfs)

$Qbb := READPRN(hydrbb)$ $Q60 := READPRN(sub60)$

$Qcc := READPRN(hydrcc)$ $Q70 := READPRN(sub70)$

$Qdd := READPRN(hydrdd)$ $Q75 := READPRN(sub75)$

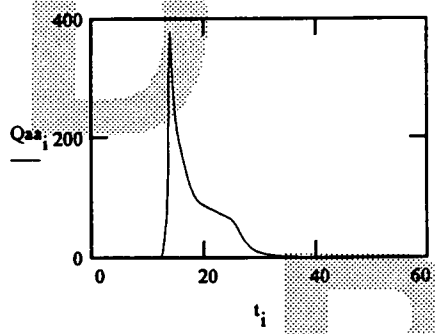
$Qee := READPRN(hydree)$ $Q80 := READPRN(sub80)$

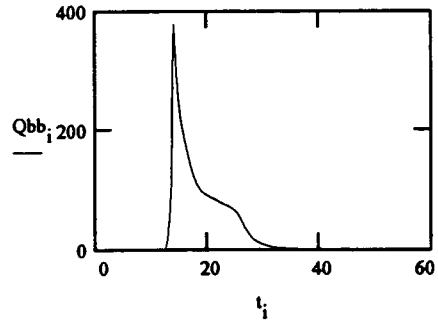
$Qff := READPRN(hydrff)$

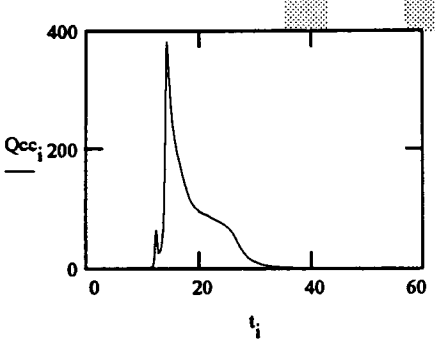
Qgg := READPRN(hydrgg)

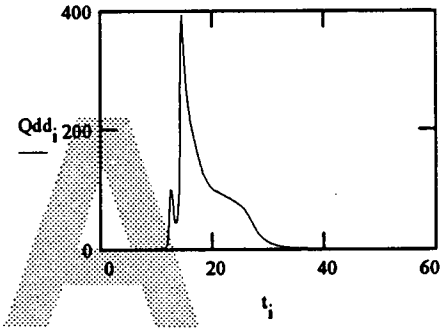
Qhh := READPRN(hydrhh)

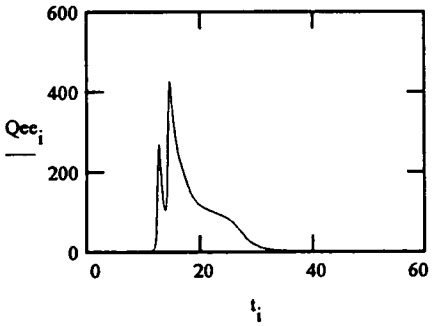
Plot all hydrographs in the following figures:

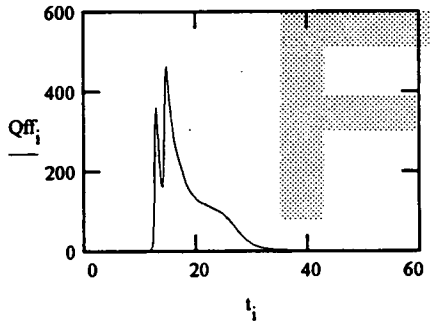


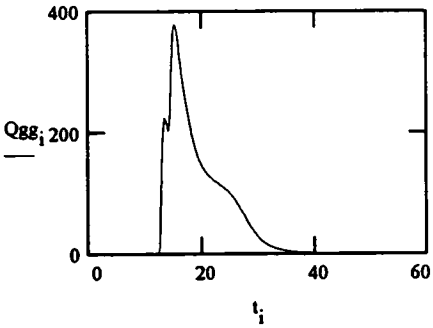


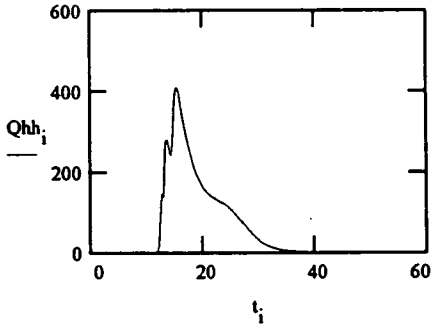


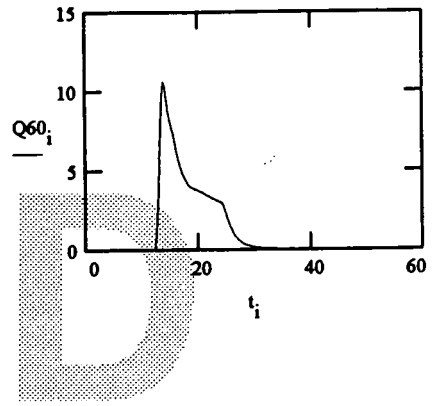


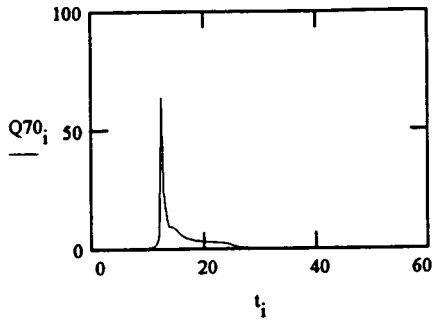


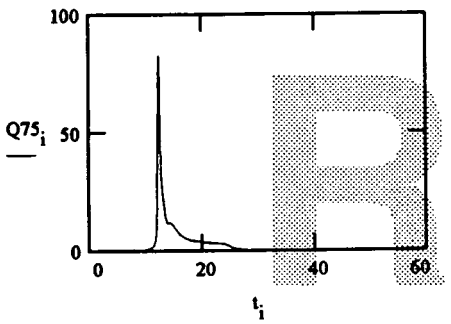


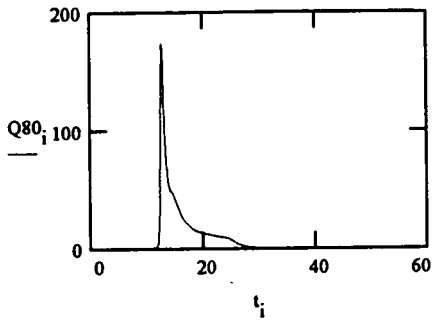










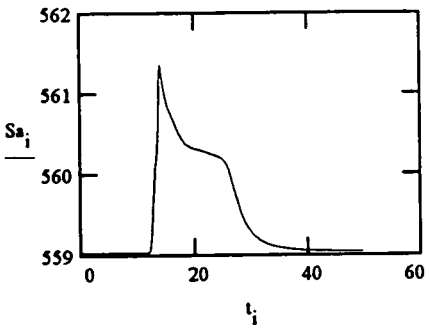


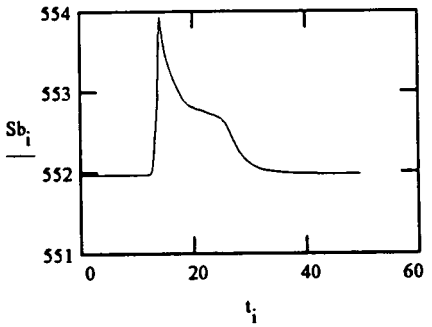
Use rating curve and hydrograph to obtain stage versus time at each cross section.

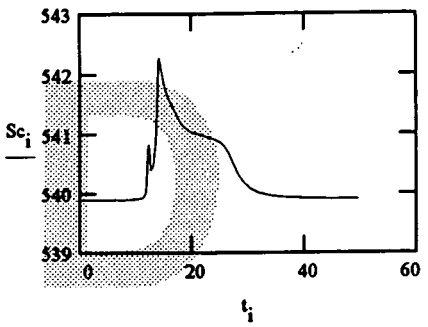
$Sa_i := STaa(Qaa_i)$ $Sb_i := STbb(Qbb_i)$ $Sc_i := STcc(Qcc_i)$ $Sd_i := STdd(Qdd_i)$

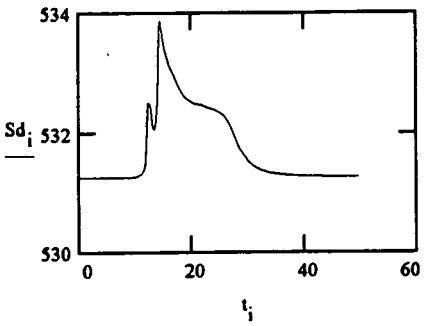
$Se_i := STee(Qee_i)$ $Sf_i := STff(Qff_i)$ $Sg_i := STgg(Qgg_i)$ $Sh_i := SThh(Qhh_i)$

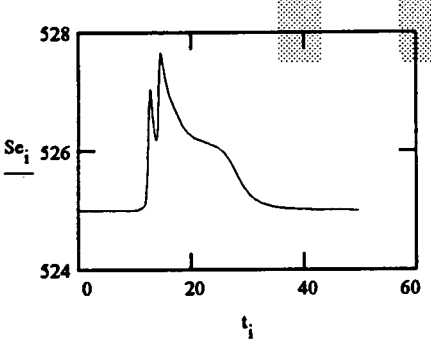
Plot stage versus time curves in the following figures:

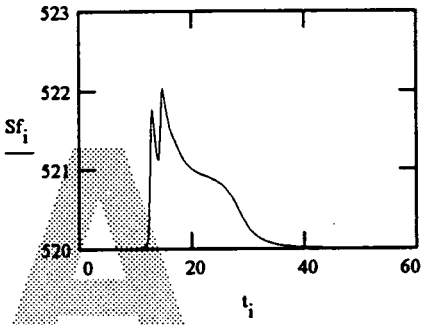


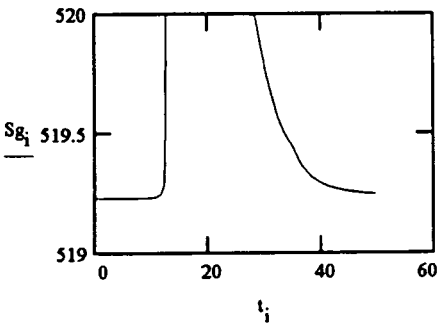


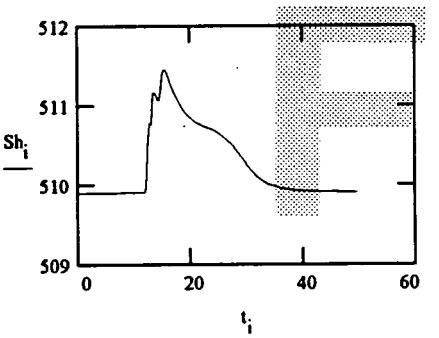












Use interpolation method to produce a continuous function for stage versus time for cross section C-C, D-D and E-E.

vstc := cspline(t, Sc) vstd := cspline(t, Sd) vste := cspline(t, Se)

vstcc(t') := interp(vstc, t, Sc, t') vstdd(t') := interp(vstd, t, Sd, t') vstee(t') := interp(vste, t, Se, t')

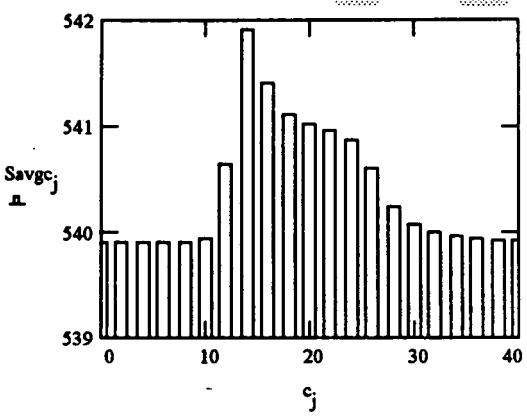
Use time weighted average method to calculate average stage for each two-hour time interval,

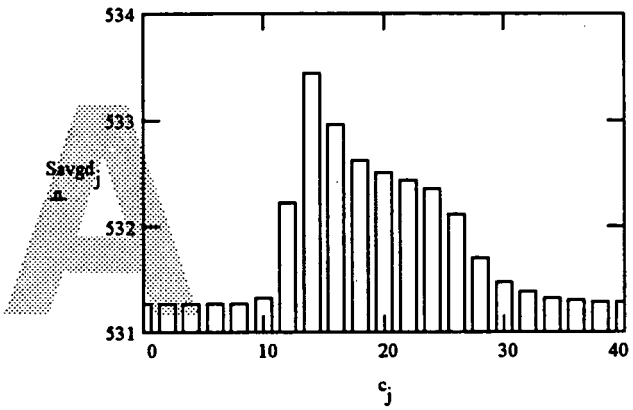
$j := 0, 1 .. 20$

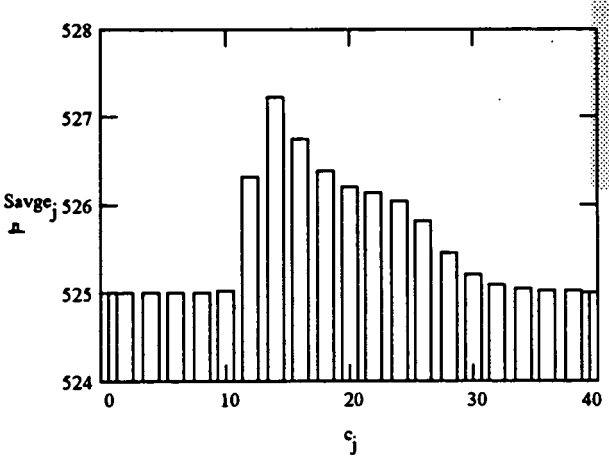
$c_j := 2 \cdot j$

$$Savgc_j := \int_{c_j}^{c_j + 2} \frac{vstcc(t')}{2}\, dt' \qquad Savgd_j := \int_{c_j}^{c_j + 2} \frac{vstdd(t')}{2}\, dt' \qquad Savge_j := \int_{c_j}^{c_j + 2} \frac{vstee(t')}{2}\, dt'$$

Plot the results in the following bar plots







These two-hour average stages will be used in the VS2DT model as constant head during each two hour interval.

Next, calculate the total volume of runoff from the subbasins containing the FEMP and at each cross section. Build a continuous function by interpolation to represent the hydrograph.

$Vqa := cspline(t, Qaa)$ $Vqb := cspline(t, Qbb)$ $Vqc := cspline(t, Qcc)$

$Vqd := cspline(t, Qdd)$ $Vqe := cspline(t, Qee)$ $Vq60 := cspline(t, Q60)$

$Vq70 := cspline(t, Q70)$ $Vq75 := cspline(t, Q75)$ $Vq80 := cspline(t, Q80)$

$Qqa(t') := interp(Vqa, t, Qaa, t')$ $Qqb(t') := interp(Vqb, t, Qbb, t')$

$Qqc(t') := interp(Vqc, t, Qcc, t')$ $Qqd(t') := interp(Vqd, t, Qdd, t')$

$Qqe(t') := interp(Vqe, t, Qee, t')$ $Qq60(t') := interp(Vq60, t, Q60, t')$

$Qq70(t') := interp(Vq70, t, Q70, t')$ $Qq75(t') := interp(Vq75, t, Q75, t')$

$Qq80(t') := interp(Vq80, t, Q80, t')$

Total runoff from subbasin 60, 70, 75, and 80 is given as

$$\int_0^{24} Qq60(t') \cdot 3600\, dt' = 2.07177 \cdot 10^5$$ (cubic feet, subbasin 60)

$$\int_0^{24} Qq70(t') \cdot 3600\, dt' = 3.39623 \cdot 10^5$$ (cubic feet, subbasin 70)

$$\int_0^{24} Qq75(t') \cdot 3600\, dt' = 4.256974 \cdot 10^5$$ (cubic feet, subbasin 75)

$$\int_0^{24} Qq80(t') \cdot 3600\, dt' = 1.351285 \cdot 10^6$$ (cubic feet, subbasin 80)

Calculate runoff volume from the upstream end of each subbasin containing FEMP, up to the time when runoff from the subbasin vanishes.

$$\int_0^{24} Qqa(t')\cdot 3600\,dt' = 5.160399\cdot 10^6$$ (cubic feet, upstream of subbasin 60)

$$\int_0^{24} Qqb(t')\cdot 3600\,dt' = 5.310325\cdot 10^6$$ (cubic feet, upstream of subbasin 70)

$$\int_0^{24} Qqc(t')\cdot 3600\,dt' = 5.57624\cdot 10^6$$ (cubic feet, upstream of subbasin 75)

$$\int_0^{24} Qqd(t')\cdot 3600\,dt' = 5.910838\cdot 10^6$$ (cubic feet, upstream of subbasin 80)

$$\int_0^{32} Qqd(t')\cdot 3600\,dt' = 6.982281\cdot 10^6 \qquad \int_0^{48} Qqd(t')\cdot 3600\,dt' = 7.066775\cdot 10^6$$

$$\frac{7.066775\cdot 10^6 - 6.982281\cdot 10^6}{7.066775\cdot 10^6} = 1.195651\cdot 10^{-2}$$

Duration of runoff is defined as the period when runoff is greater than 10 cfs. Duration of runoff is about 20 hours (from 12 to 32). Calculation above shows that only 1.2 percent of the total volume of runoff is neglected by using 20 hour runoff duration.

DRAFT

Program: MATHCAD 4.0

Objective

Using Van Genuchten Method to calculate the relation of moisture content, hydraulic conductivity and pressure head for the porous medium under Paddys Run channel bed.

Approach:

Fitting parameters for sand obtained from the VST2DT manual were chosen to calculate relative hydraulic conductivity for infiltration model. Calculation of relative hydraulic conductivity using fitting parameters for fine sand and Fresno medium sand were also performed for comparison. For the results of the infiltration analysis see Appdedix D-6 sensitivity analysis results. Parameters used in calculation are defined as the following,

$\theta s := 0.39$ porosity

θr residual moisture content

β fitting parameter

α characteristic length of the porous medium (meters)

$\gamma(\beta) := 1 - \frac{1}{\beta}$

$h := 0.01, 0.02 .. 5$ range of the head (meter) in the calculation (negtive)

$$\theta(h,\theta r,\alpha,\beta) := \theta r + \left[(\theta s - \theta r)\cdot\left[\frac{1}{1+\left(\frac{h}{\alpha}\right)^{\beta}}\right]^{\gamma(\beta)}\right]$$ moisture content as a function of total head

$$Kr(h,\alpha,\beta) := \frac{\left[1-\left(\frac{h}{\alpha}\right)^{\beta-1}\cdot\left[1+\left(\frac{h}{\alpha}\right)^{\beta}\right]^{-\gamma(\beta)}\right]^{2}}{\left[1+\left(\frac{h}{\alpha}\right)^{\beta}\right]^{\frac{\gamma(\beta)}{2}}}$$ relative hydraulic conductivity as a function of total head

$\theta 1(h) := \theta(h,0.02,0.232,3.1)$	$Kr1(h) := Kr(h,0.232,3.1)$	Fresno medium sand
$\theta 3(h) := \theta(h,0.069,0.326,3.9)$	$Kr3(h) := Kr(h,0.326,3.9)$	Sand
$\theta 4(h) := \theta(h,0.072,0.96,6.9)$	$Kr4(h) := Kr(h,0.96,6.9)$	Fine Sand

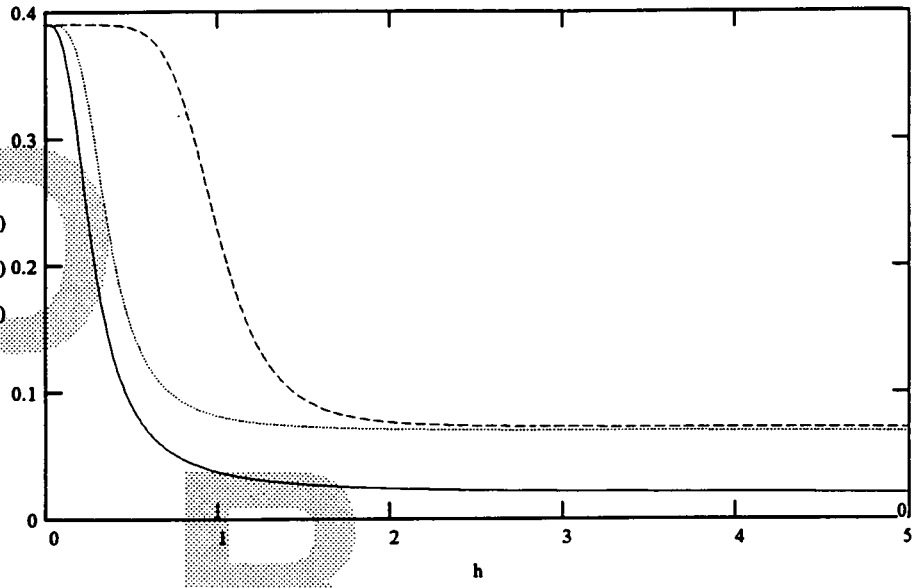


Figure 1: Moisture-characteristic curve (moisture as a function of pressure head).
Solid line - Fresno medium sand
Dotted line - Sand
Dashed line - Fine sand

DRAFT

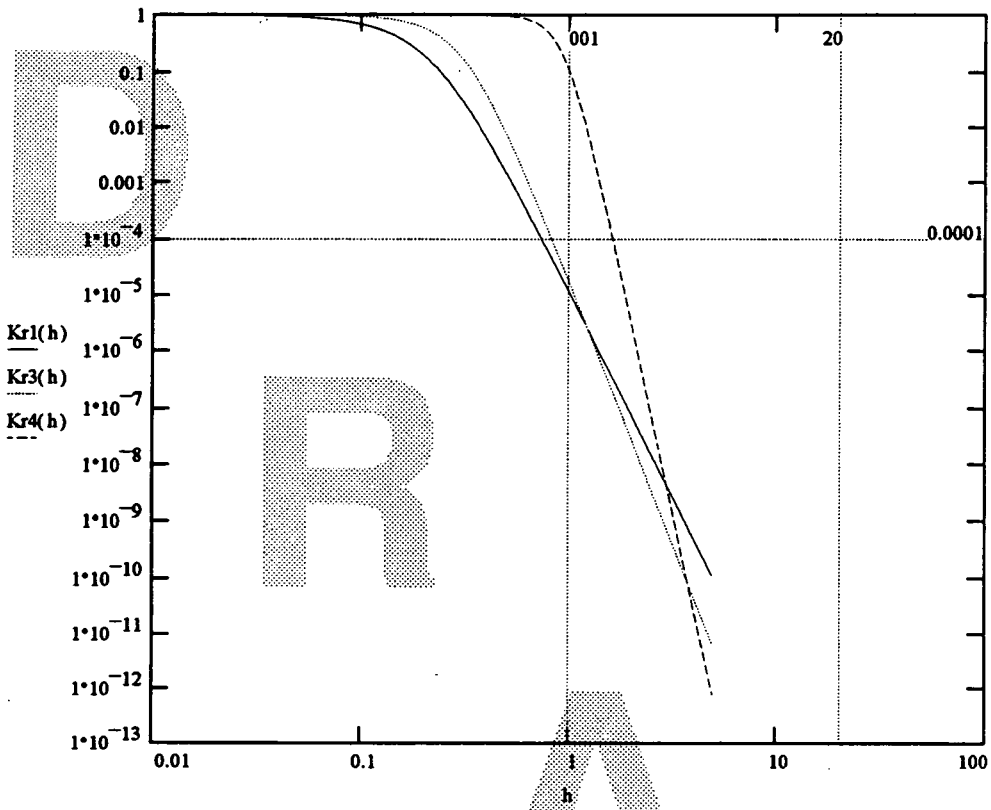


Figure 2: Relative hydraulic conductivity as a function of pressure head.
Solid line - Fresno medium sand
Dotted line - sand
Dashed line - Fine sand

DRAFT

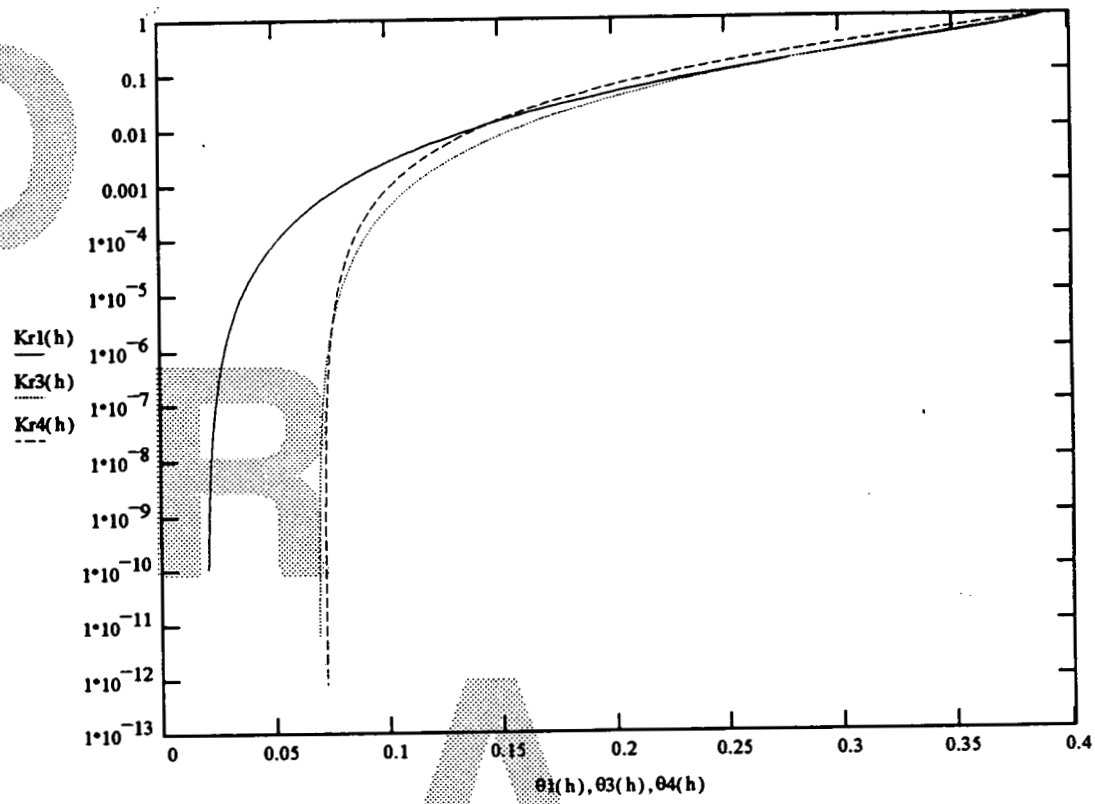


Figure 3: Relative hydraulic conductivity as a function of moisture content.
Solid line - Fresno medium sand
Dotted line - Sand
Dashed line - Fine sand

DRAFT

DRAFT

APPENDIX D
PLOTTED RESULTS

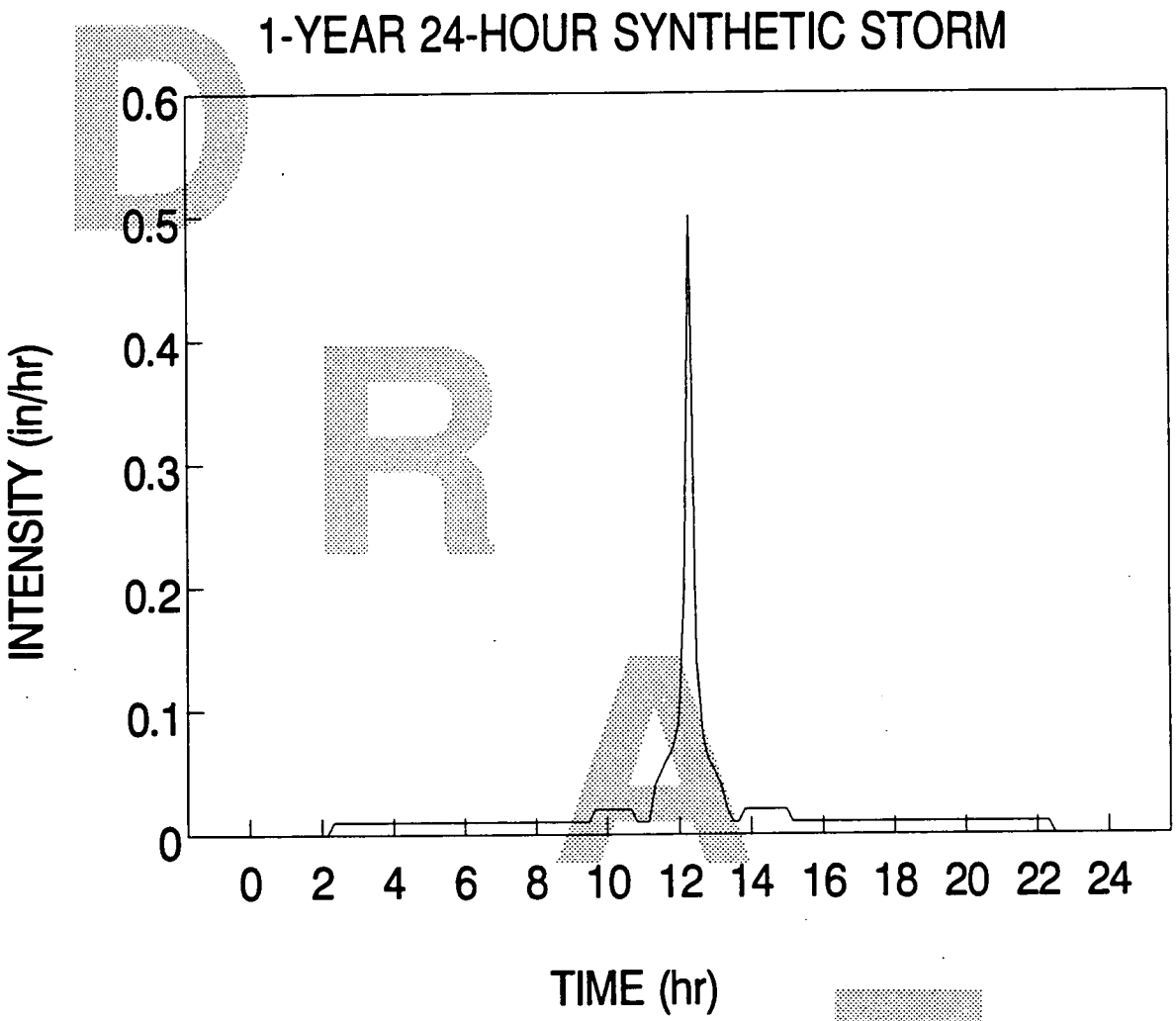
PRELIMINARY

DRAFT

APPENDIX D-1
RAINFALL HYETOGRAPH

RAINFALL HYETOGRAPH

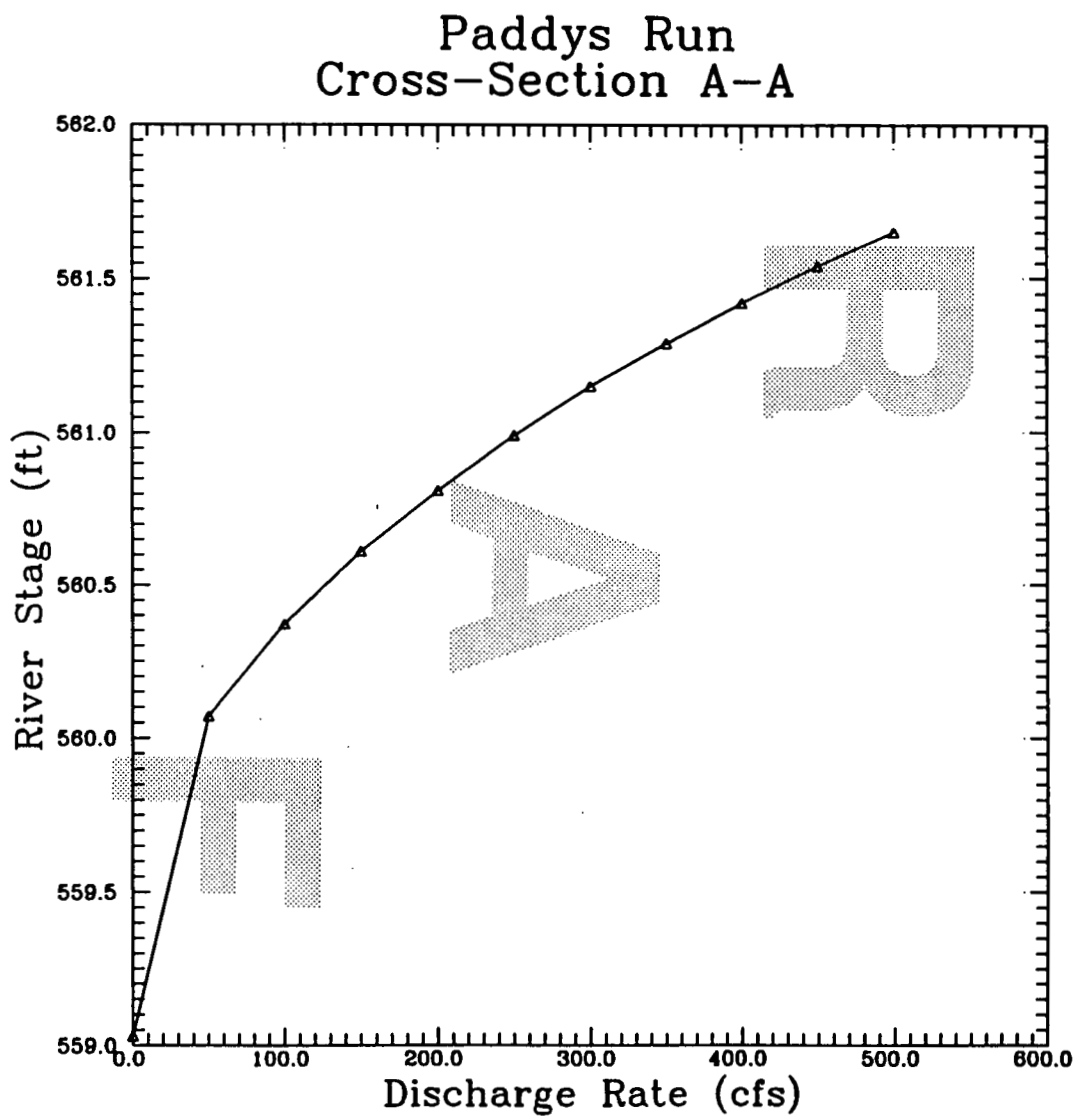
4774



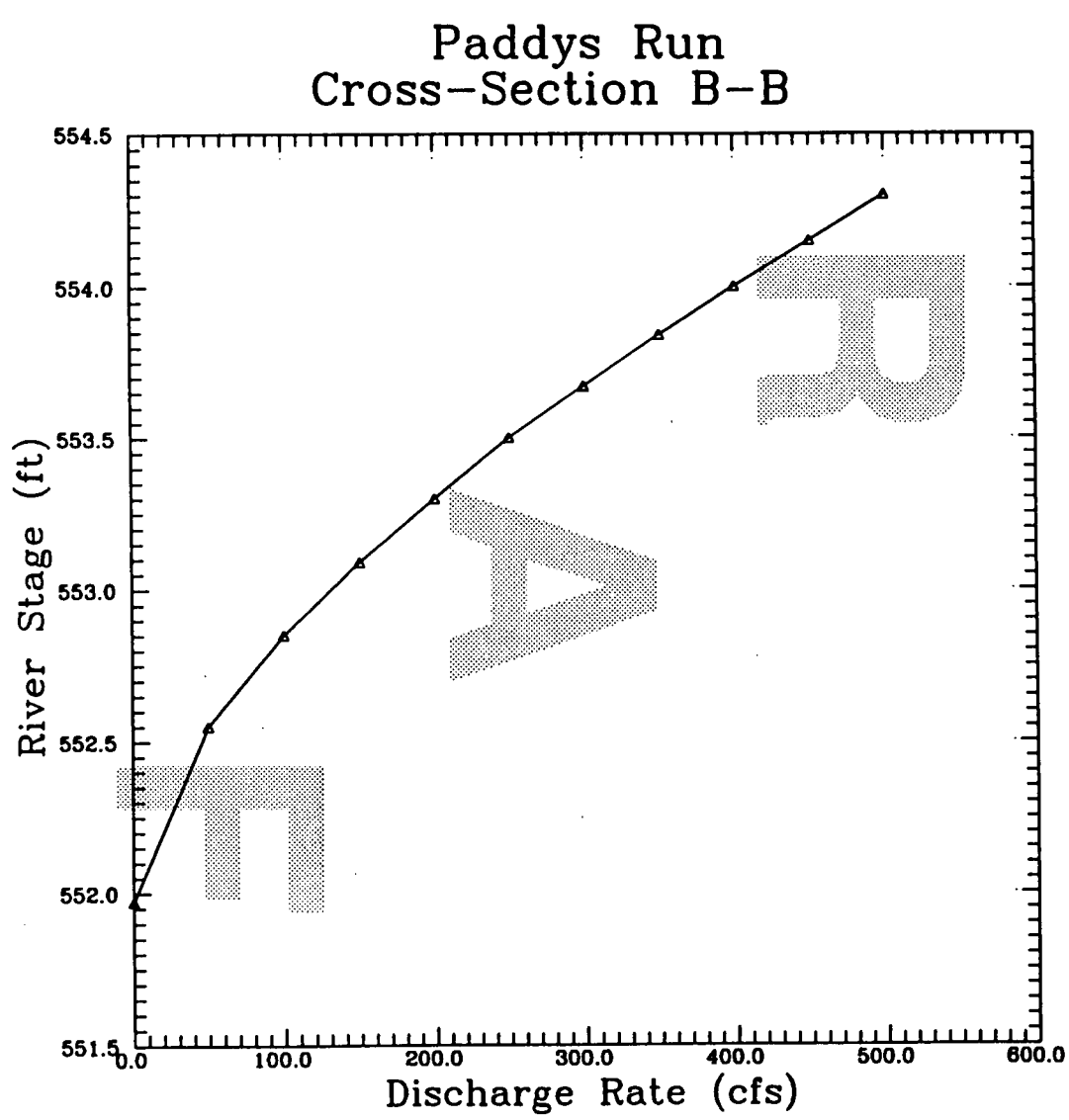
DRAFT

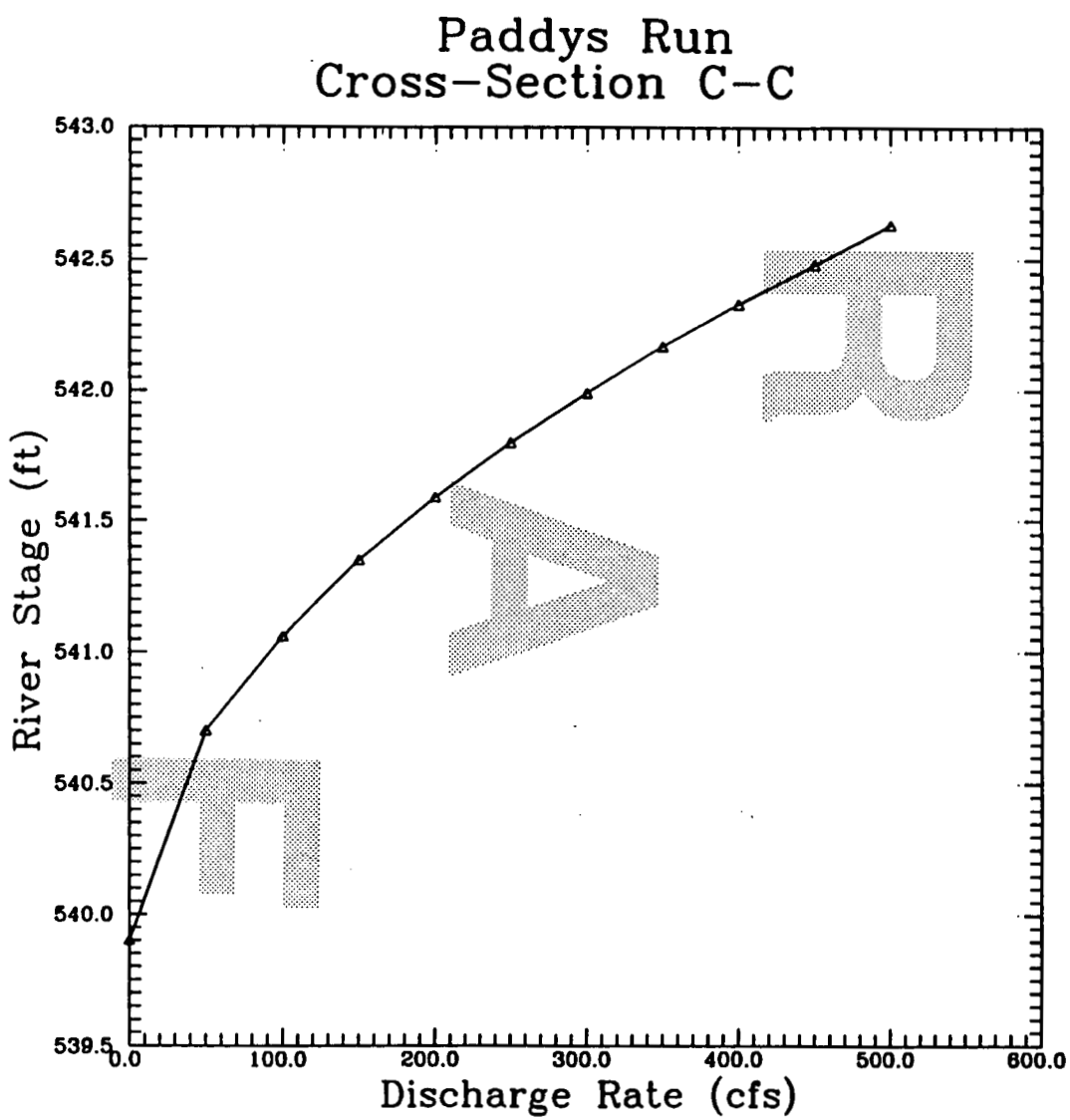
DRAFT

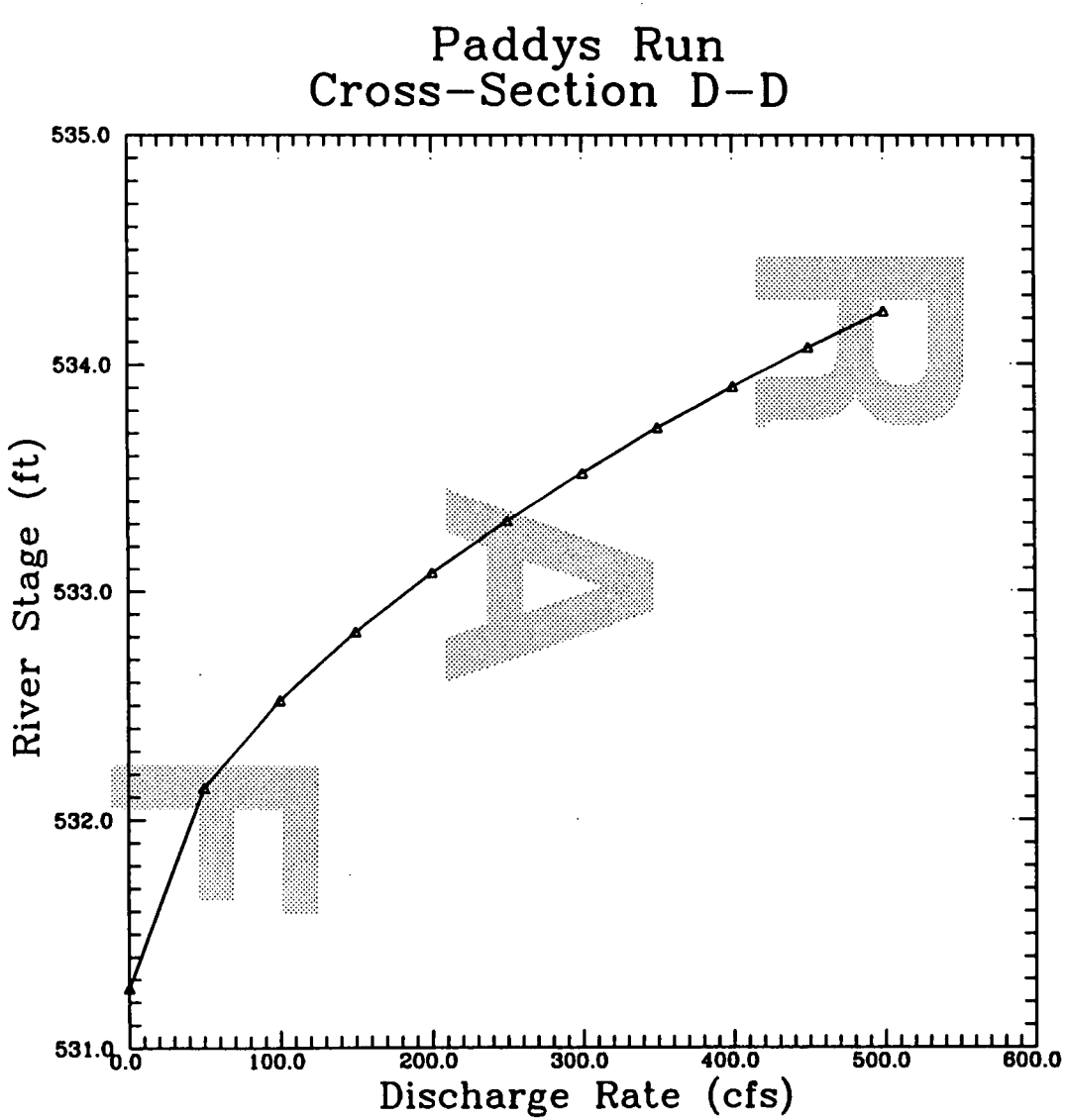
APPENDIX D-2
PADDYS RUN RATINGS CURVES

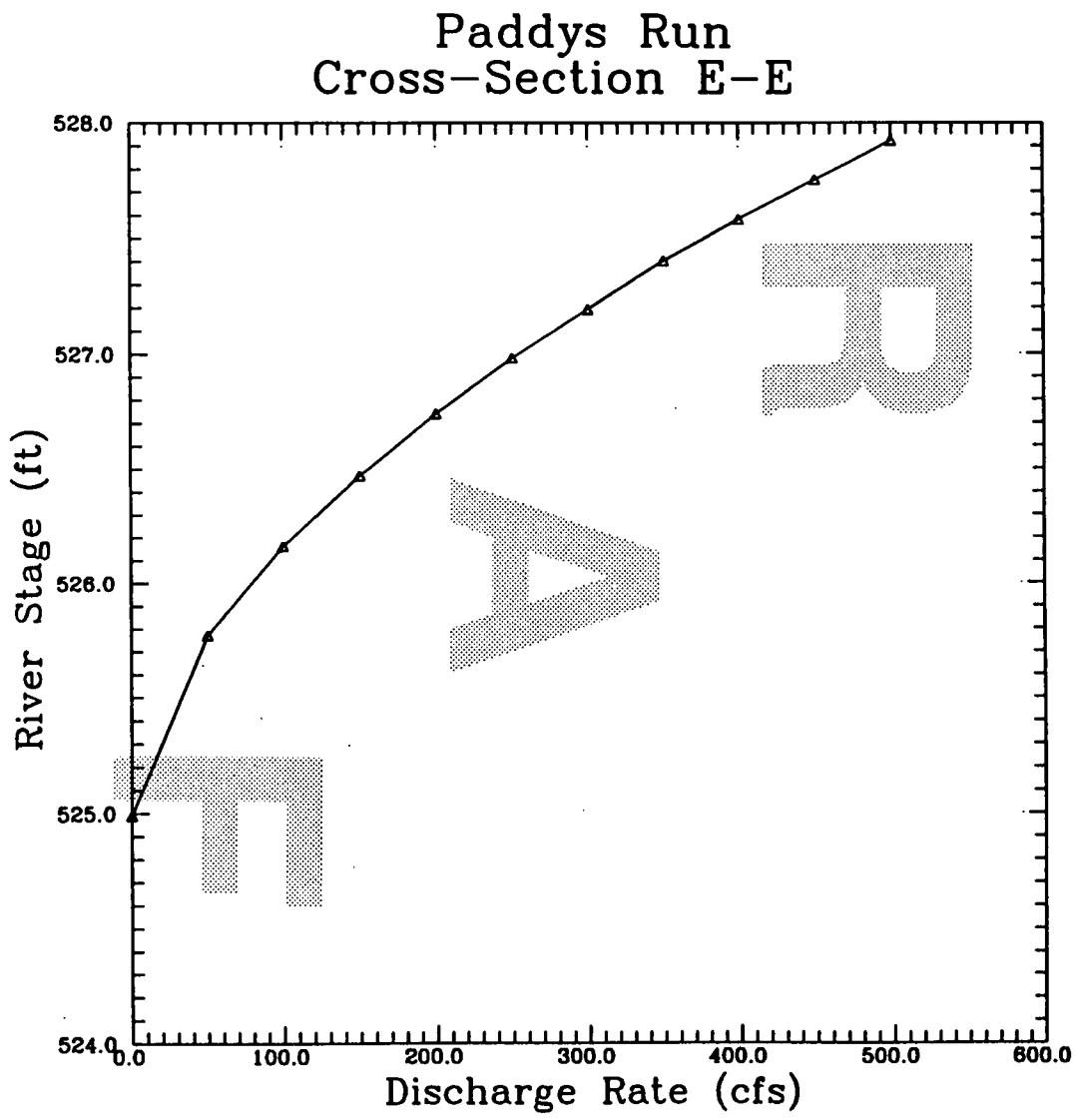

Paddys Run
Cross-Section A-A
River Stage (ft)
562.0
561.5
561.0
560.5
560.0
559.5
559.0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Discharge Rate (cfs)

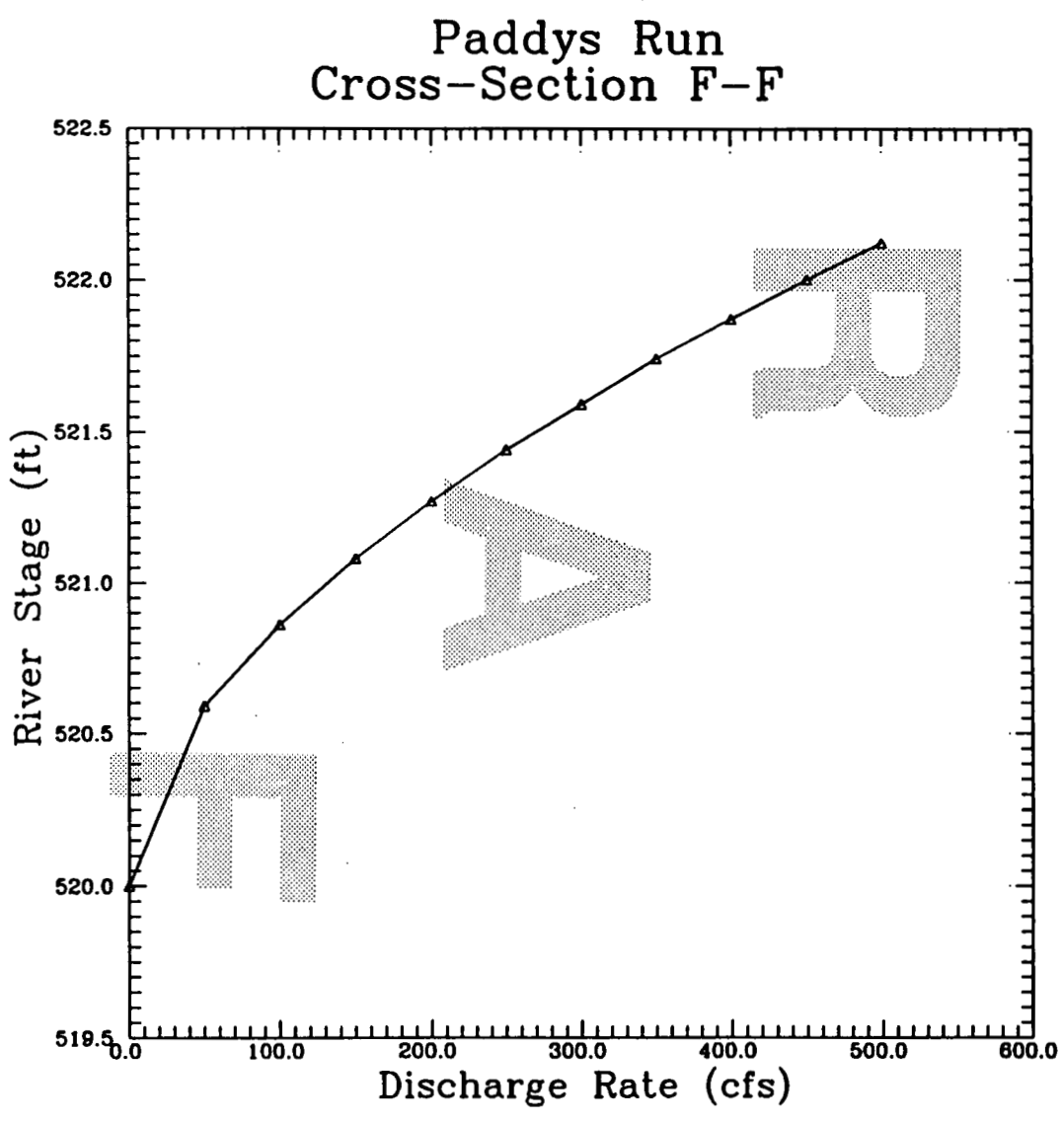
DRAFT

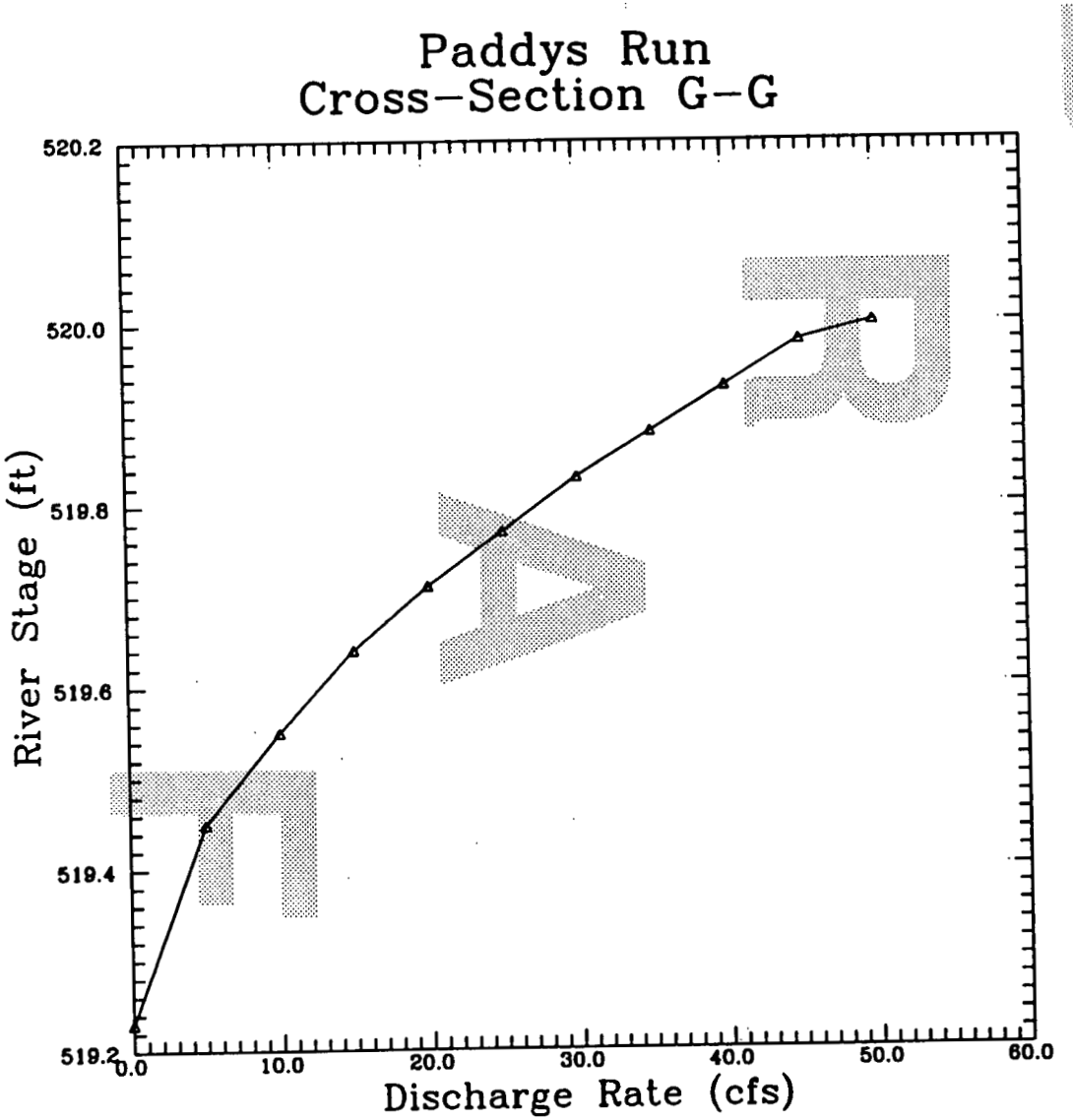

Paddys Run
Cross-Section B-B
River Stage (ft)
554.5
554.0
553.5
553.0
552.5
552.0
551.5
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Discharge Rate (cfs)


Paddys Run
Cross-Section C-C
River Stage (ft)
543.0
542.5
542.0
541.5
541.0
540.5
540.0
539.5
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Discharge Rate (cfs)

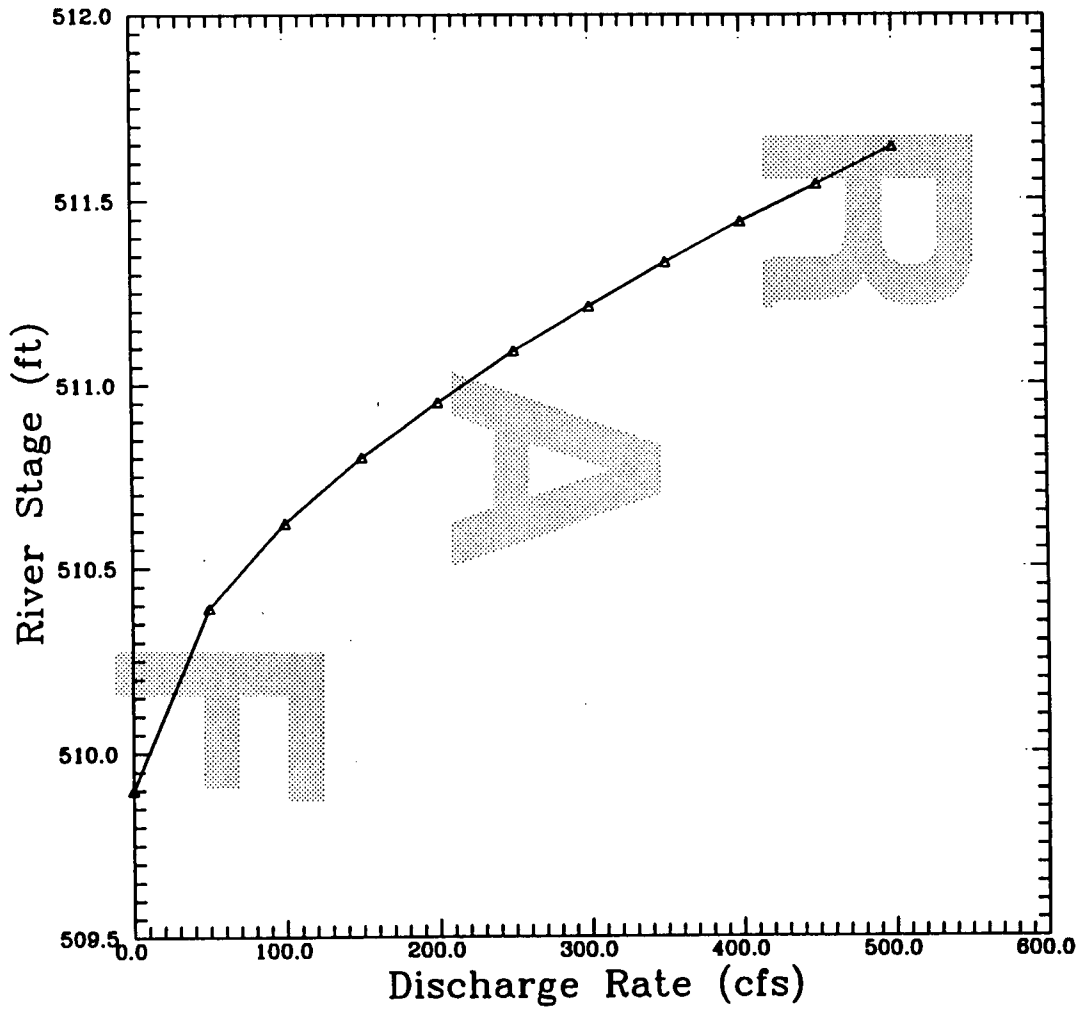

Paddys Run
Cross-Section D-D
River Stage (ft)
535.0
534.0
533.0
532.0
531.0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Discharge Rate (cfs)


Paddys Run
Cross-Section E-E
River Stage (ft)
528.0
527.0
526.0
525.0
524.0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Discharge Rate (cfs)


Paddys Run
Cross-Section F-F
River Stage (ft)
522.5
522.0
521.5
521.0
520.5
520.0
519.5
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Discharge Rate (cfs)


Paddys Run
Cross-Section G-G
River Stage (ft)
520.2
520.0
519.8
519.6
519.4
519.2
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Discharge Rate (cfs)

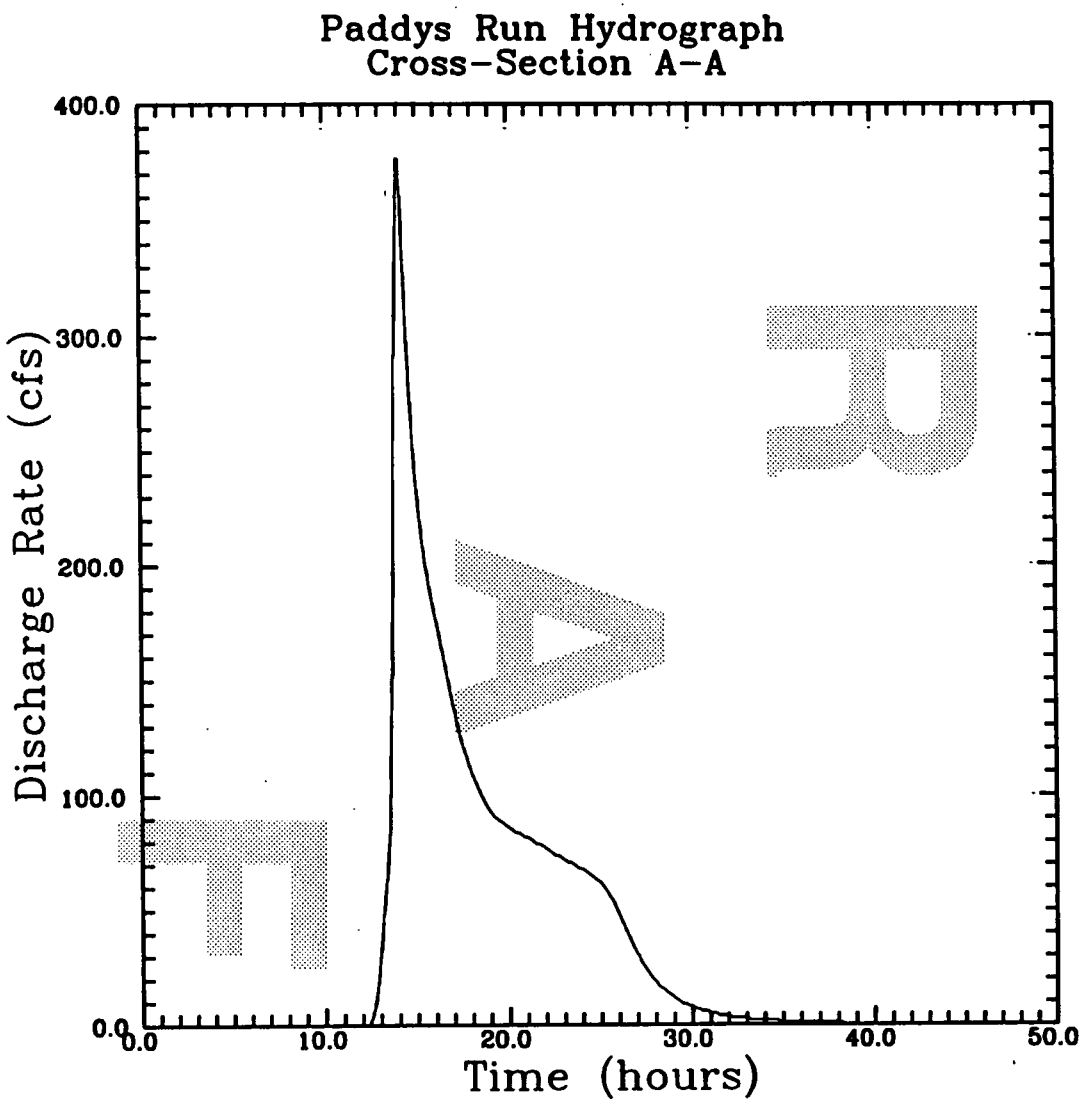
Paddys Run
Cross-Section H-H



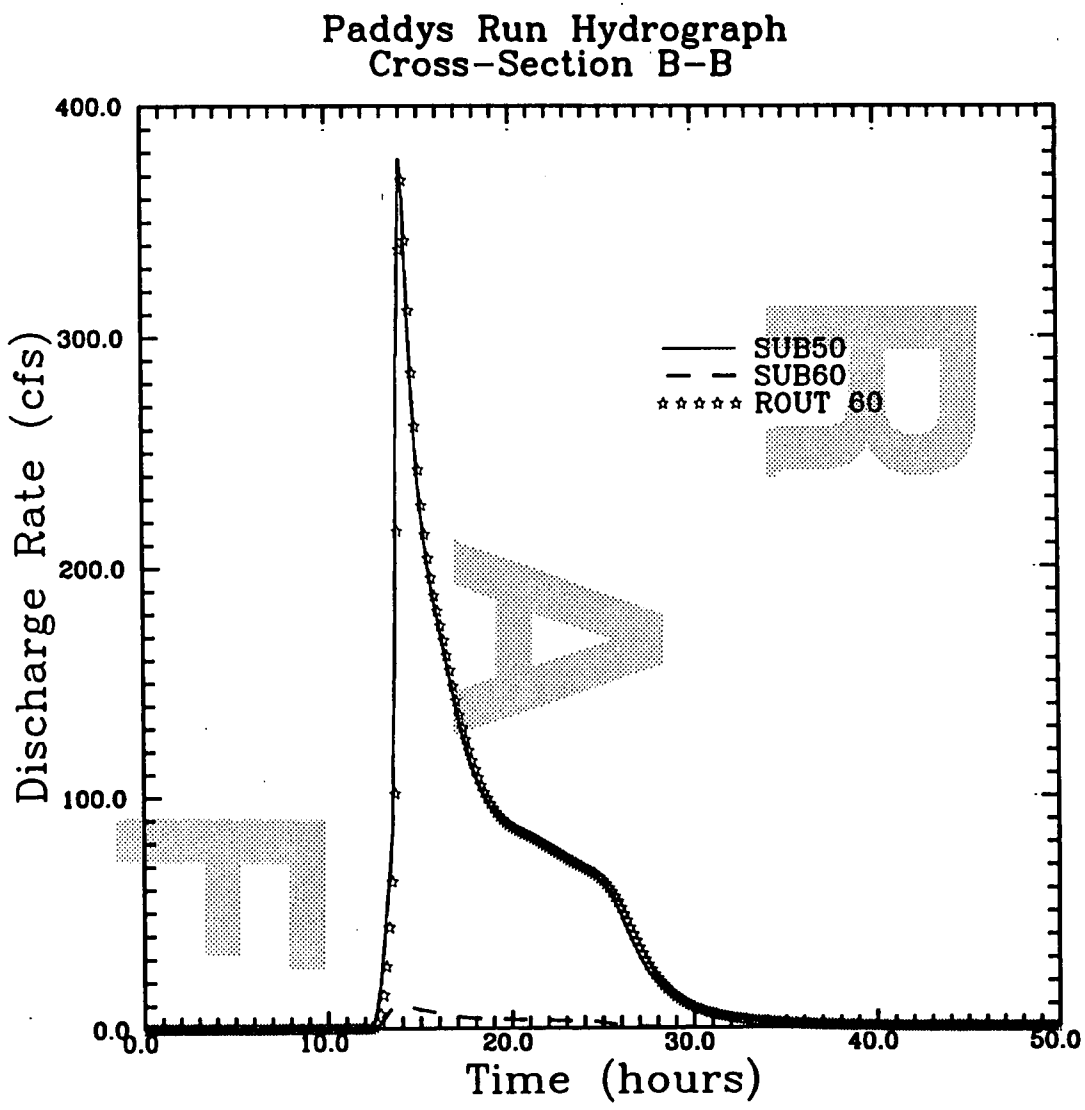
427224

DRAFT

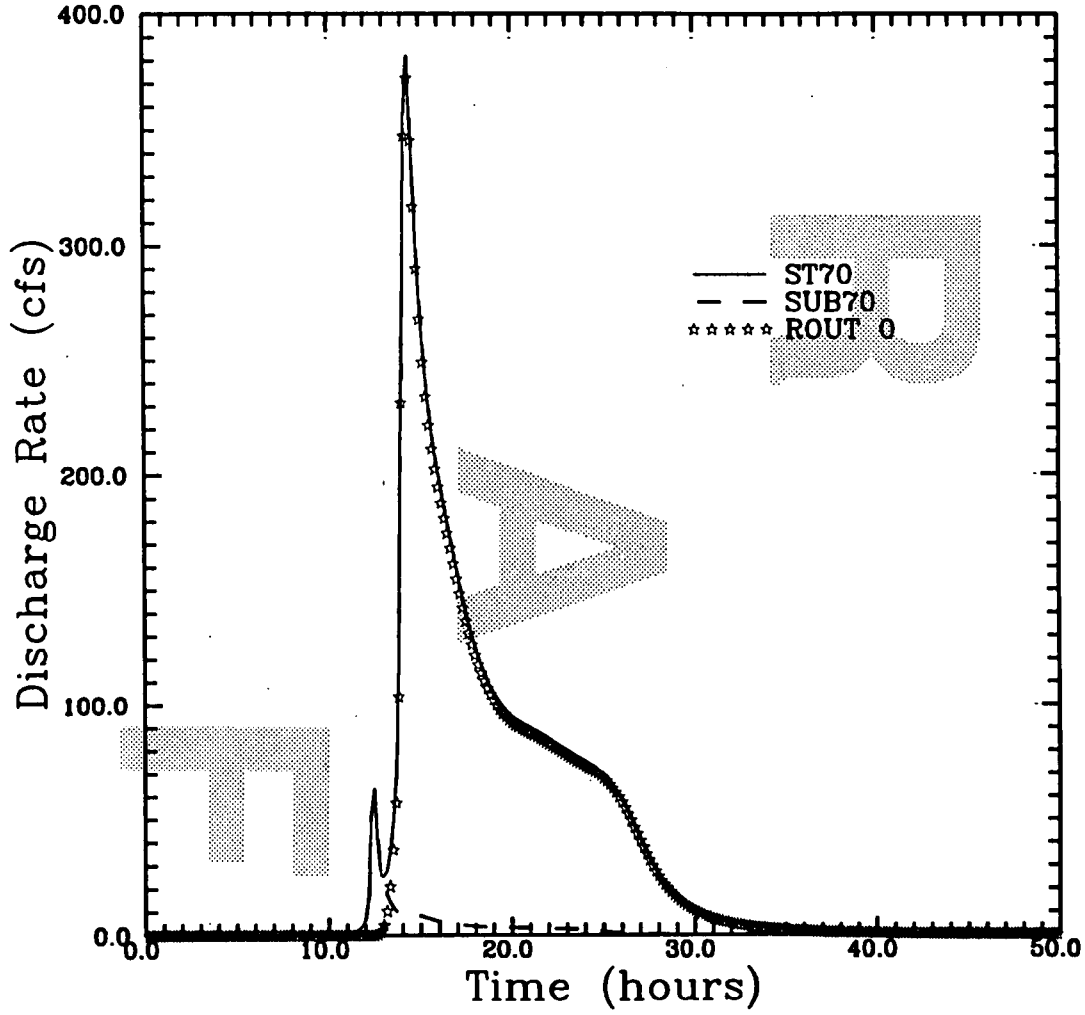
APPENDIX D-3
PADDYS RUN FLOOD HYDROGRAPHS
FOR 24-HOUR, 1-YEAR RETURN PERIOD STORM


Paddys Run Hydrograph
Cross-Section A-A
Discharge Rate (cfs)
400.0
300.0
200.0
100.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0
Time (hours)

DRAFT

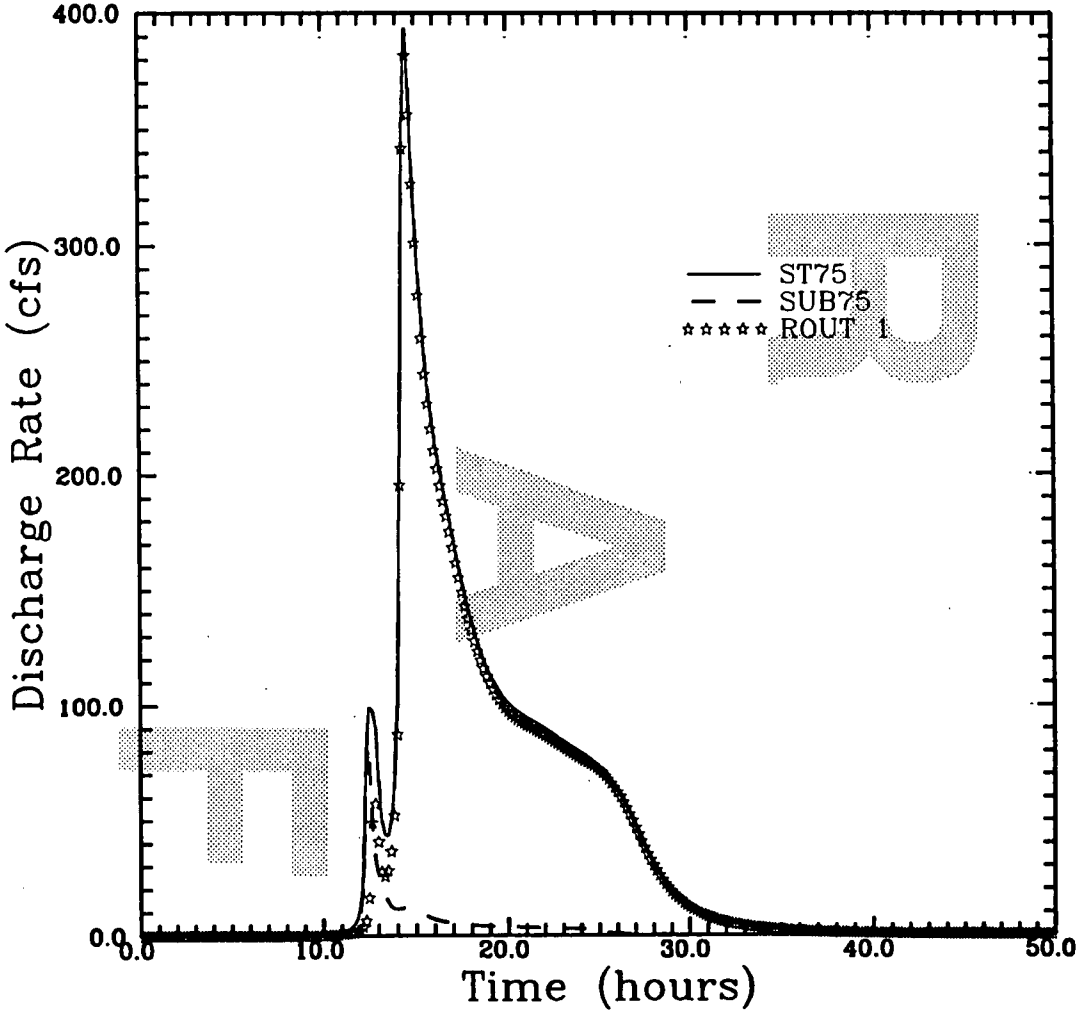

Paddys Run Hydrograph
Cross-Section B-B
Discharge Rate (cfs)
Time (hours)
SUB50
SUB60
ROUT 60
400.0
300.0
200.0
100.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0

Paddys Run Hydrograph
Cross-Section C-C



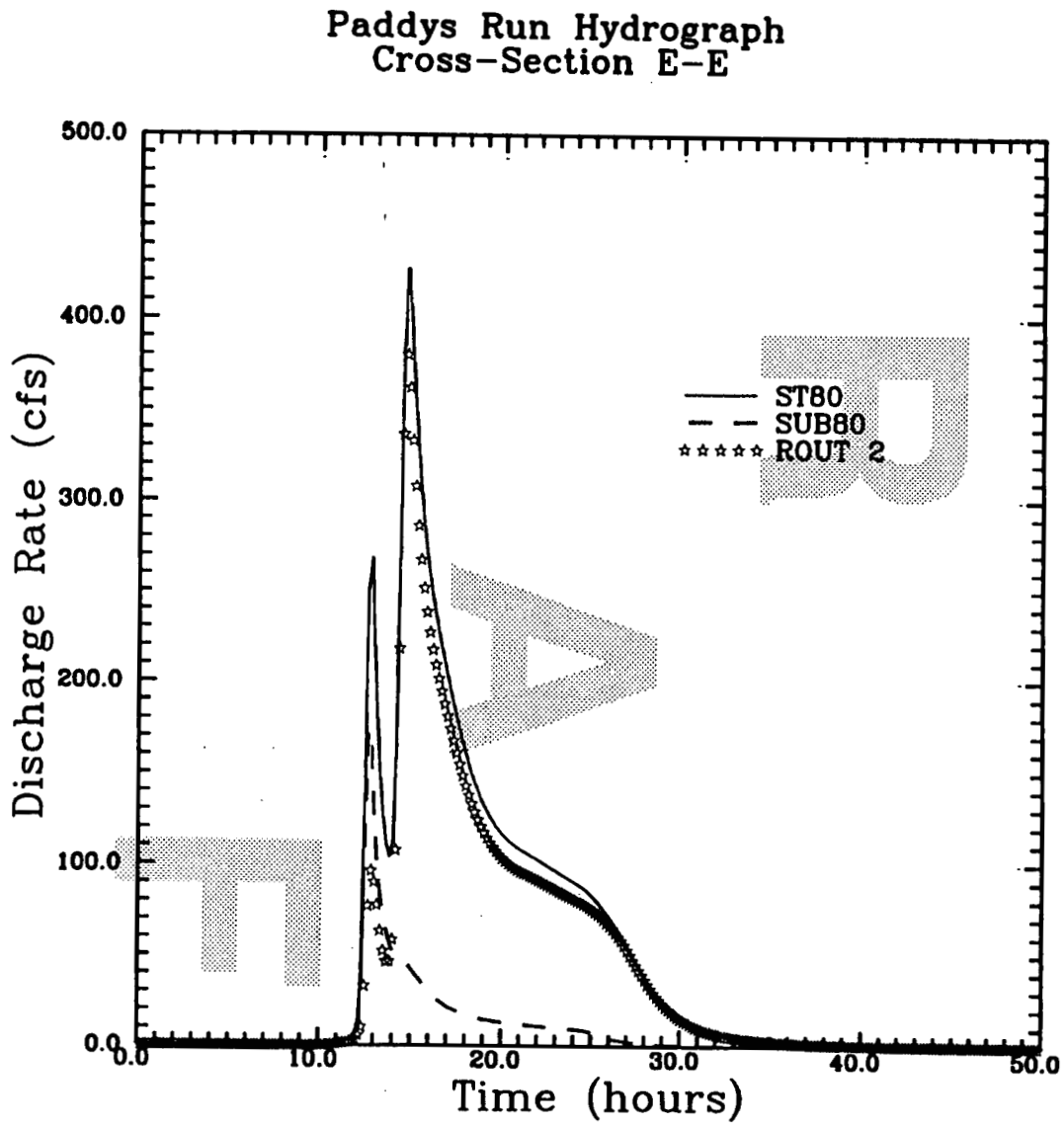
DRAFT

Paddys Run Hydrograph
Cross-Section D-D

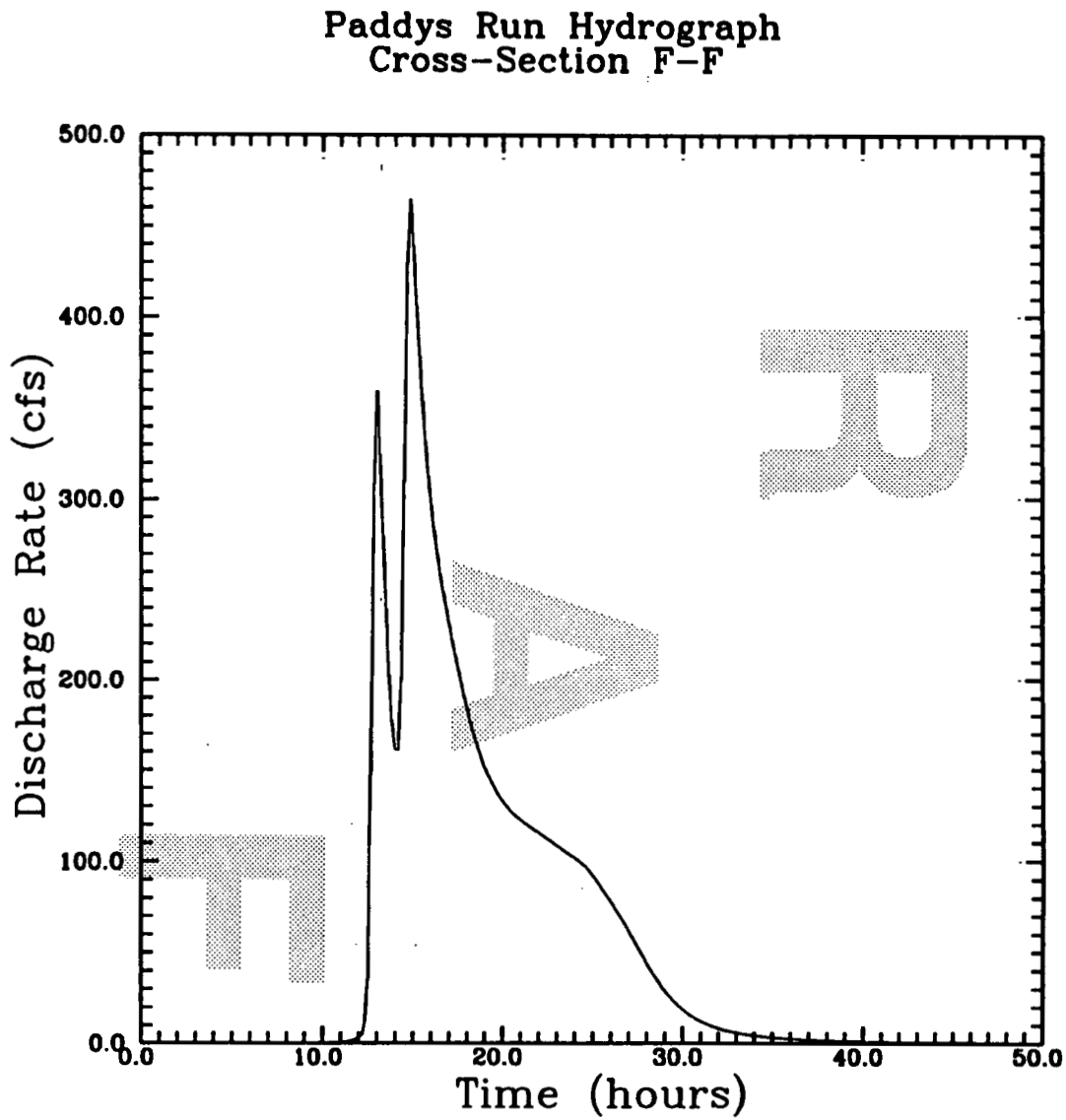


DRAFT

4274


Paddys Run Hydrograph
Cross-Section E-E
Discharge Rate (cfs)
Time (hours)
ST80
SUB80
ROUT 2
0.0
100.0
200.0
300.0
400.0
500.0
0.0
10.0
20.0
30.0
40.0
50.0

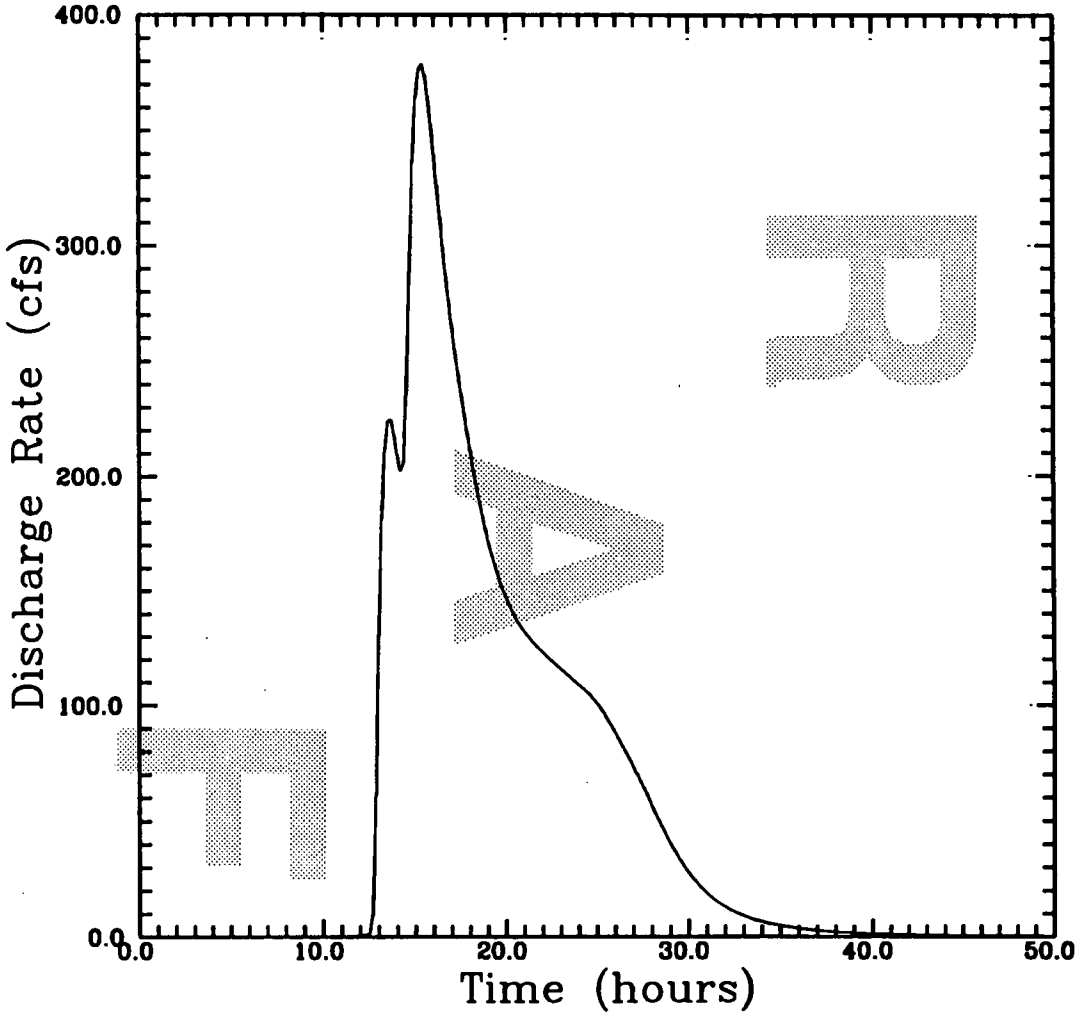
42724


Paddys Run Hydrograph
Cross-Section F-F
Discharge Rate (cfs)
500.0
400.0
300.0
200.0
100.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0
Time (hours)

DRAFT

427-24

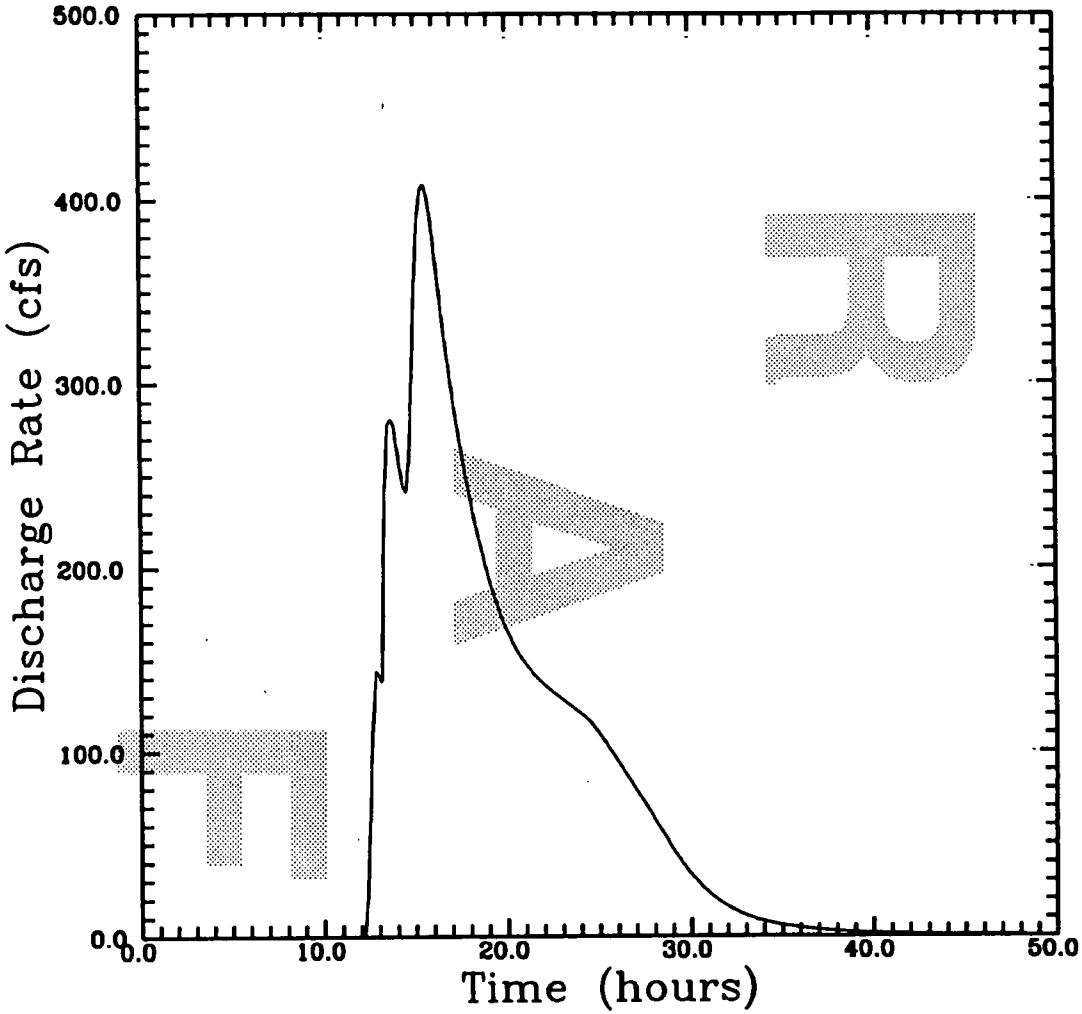
Paddys Run Hydrograph
Cross-Section G-G



DRAFT

427274

Paddys Run Hydrograph
Cross-Section H-H



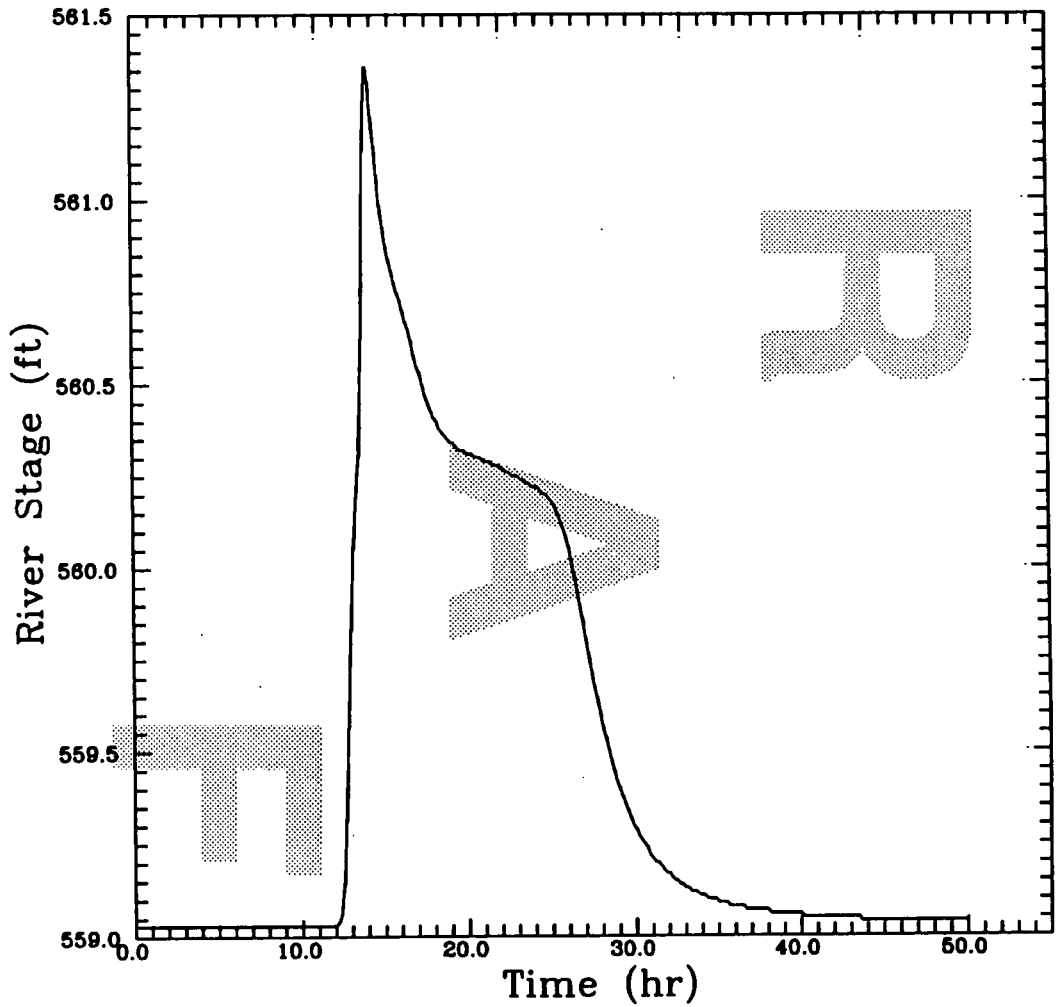
DRAFT

4224

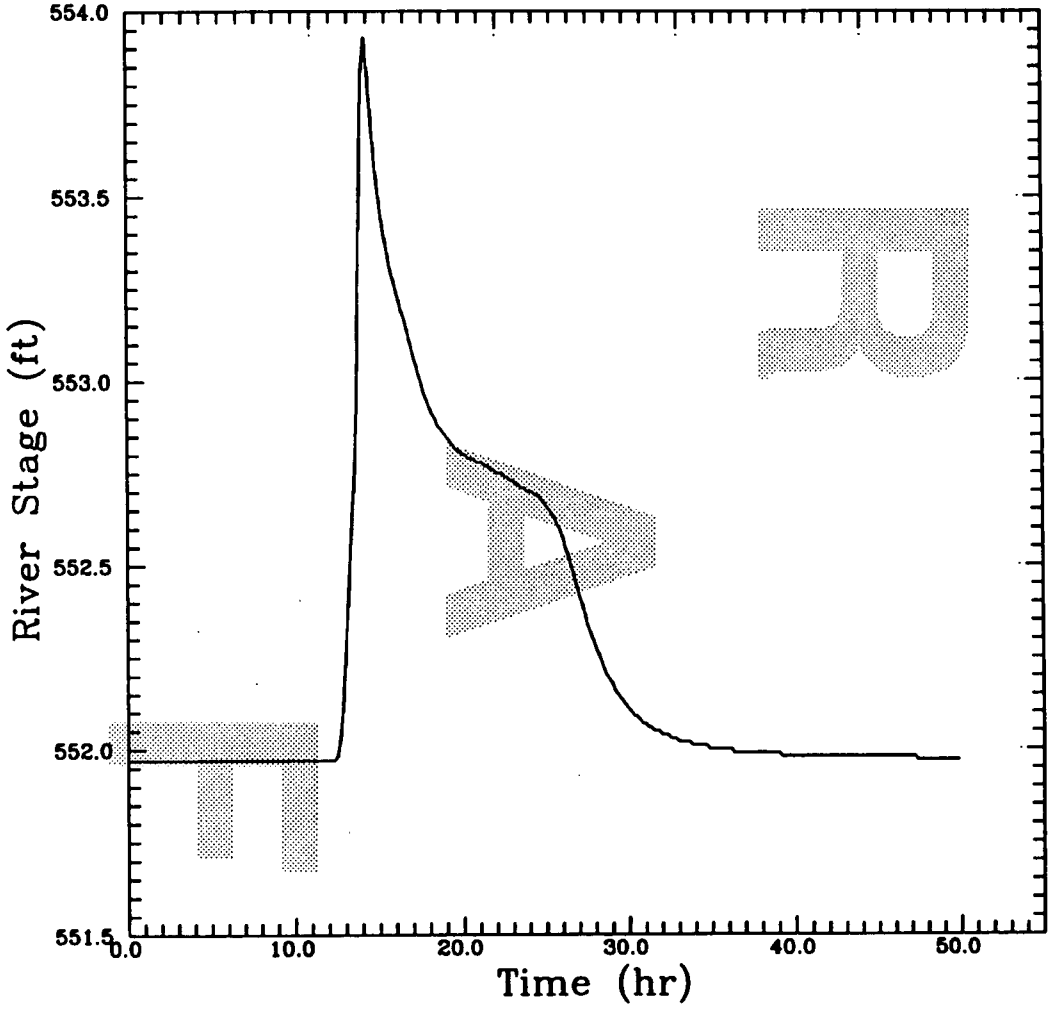
DRAFT

APPENDIX D-4
PADDYS RUN STAGE VS TIME HYDROGRAPHS
FOR 24-HOUR, 1 YEAR RETURN PERIOD STORM

Paddys Run Stage vs Time
Cross-Section A-A



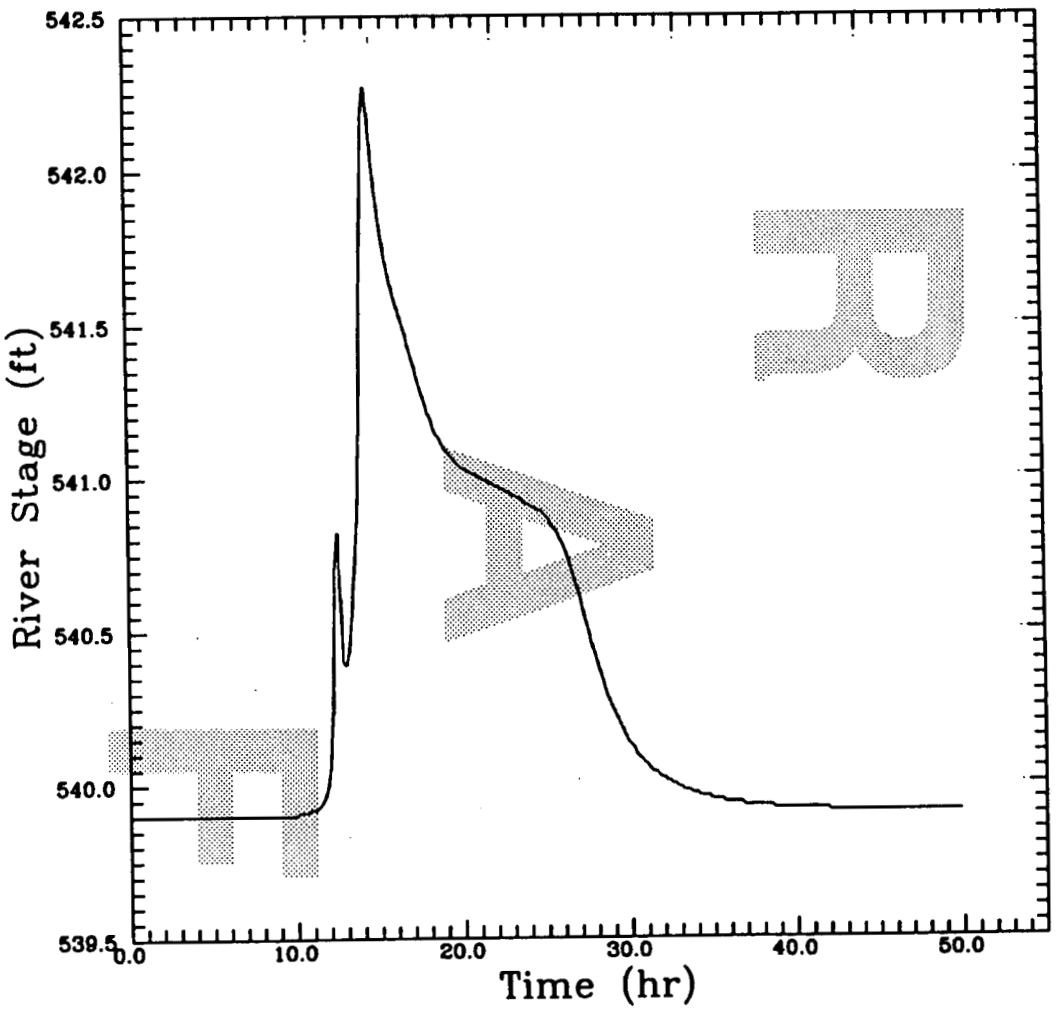
Paddys Run Stage vs Time
Cross-Section B-B



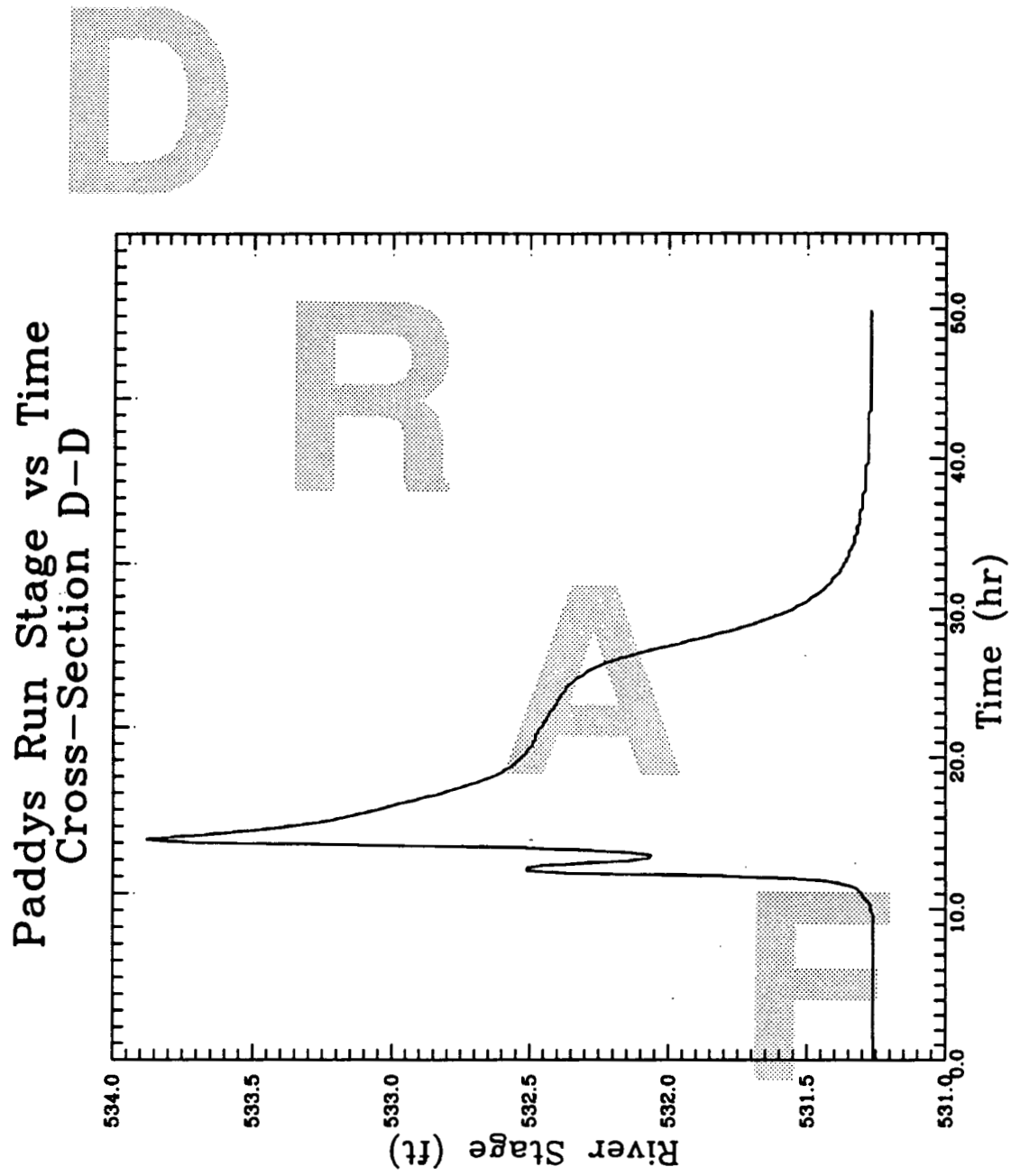
DRAFT

hel

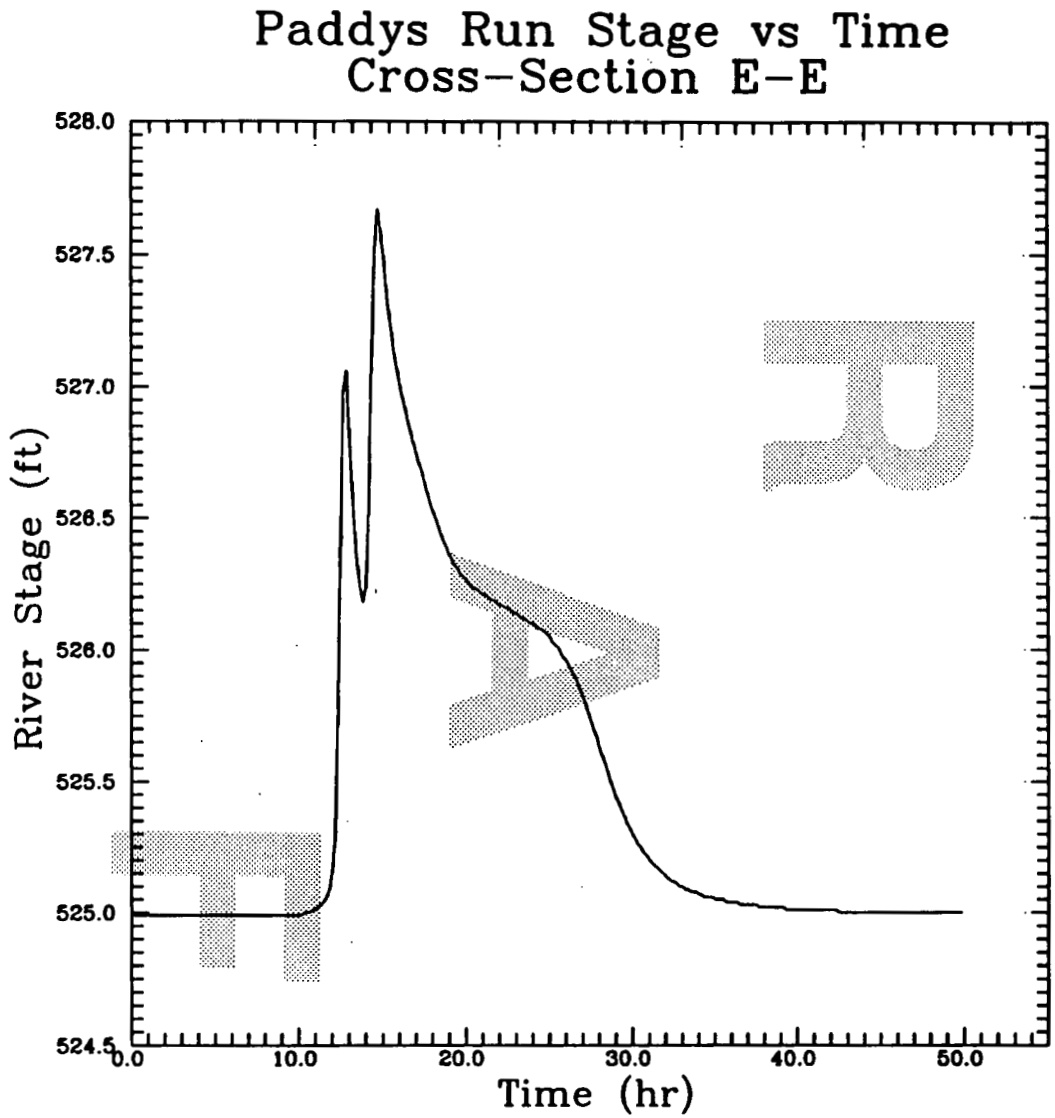
Paddys Run Stage vs Time
Cross-Section C-C



DRAFT

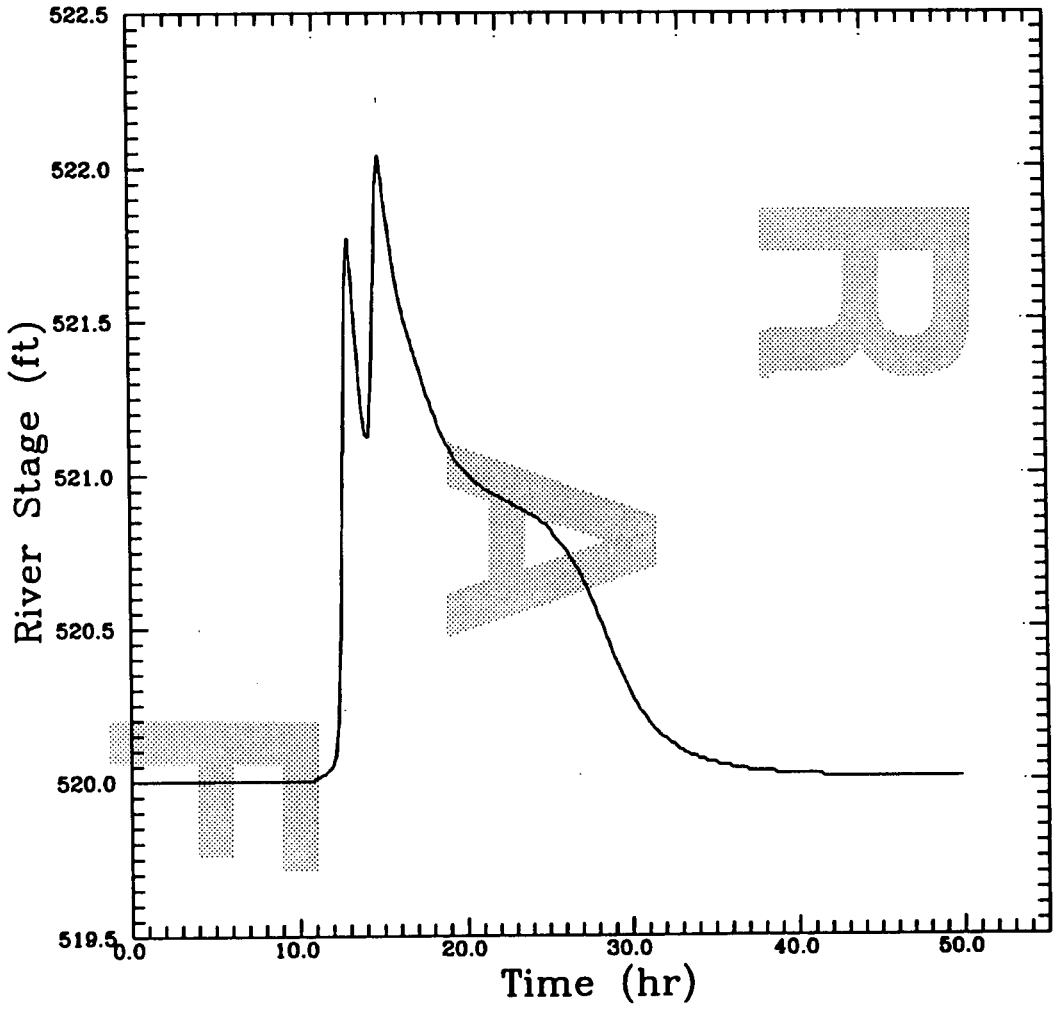

Paddys Run Stage vs Time
Cross-Section D-D
River Stage (ft)
534.0
533.5
533.0
532.5
532.0
531.5
531.0
Time (hr)
0.0
10.0
20.0
30.0
40.0
50.0

DRAFT


Paddys Run Stage vs Time
Cross-Section E-E
River Stage (ft)
528.0
527.5
527.0
526.5
526.0
525.5
525.0
524.5
0.0
10.0
20.0
30.0
40.0
50.0
Time (hr)

DRAFT

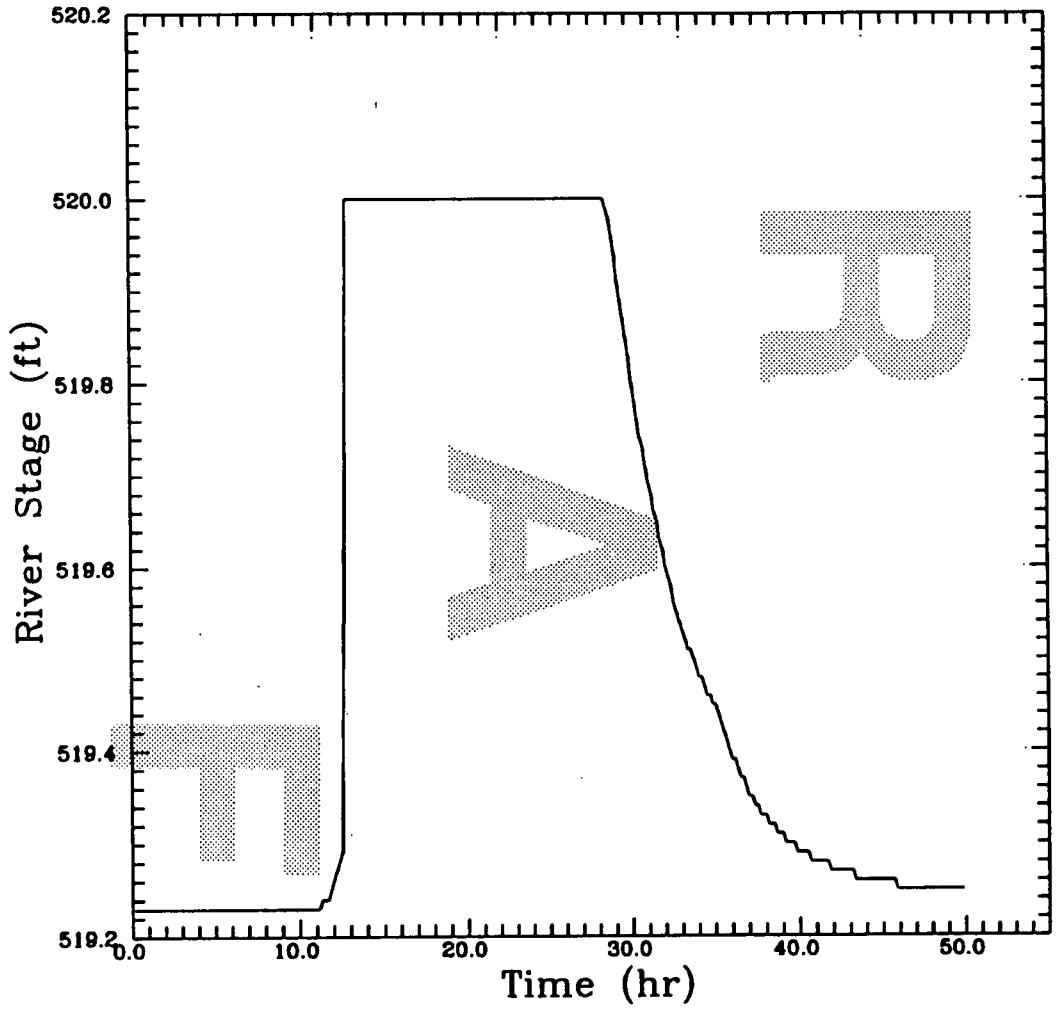
Paddys Run Stage vs Time
Cross-Section F-F



DRAFT

4264

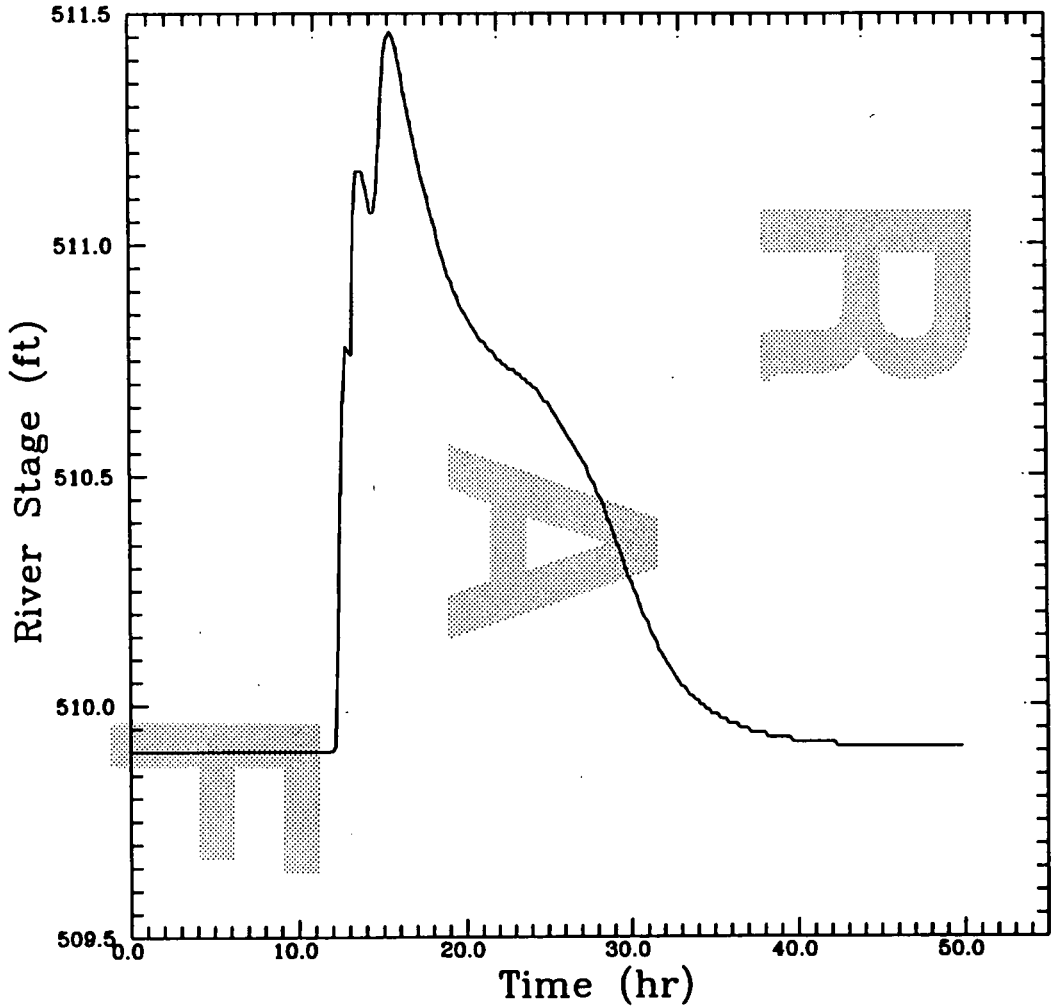
Paddys Run Stage vs Time
Cross-Section G-G



DRAFT

4274

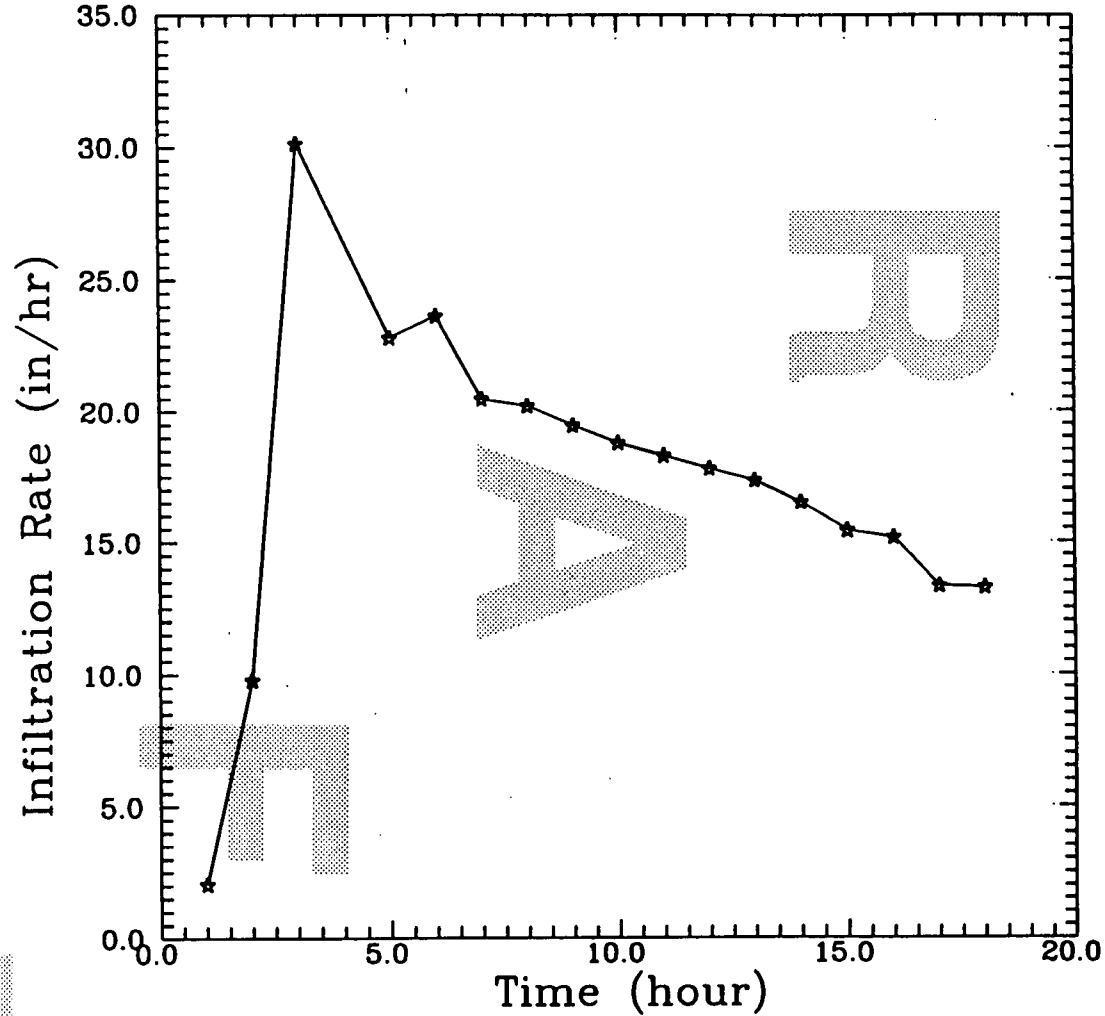
Paddys Run Stage vs Time
Cross-Section H-H



DRAFT

APPENDIX D-5
PADDYS RUN INFILTRATION VS TIME
FOR 24-HOUR, 1-YEAR RETURN PERIOD STORM

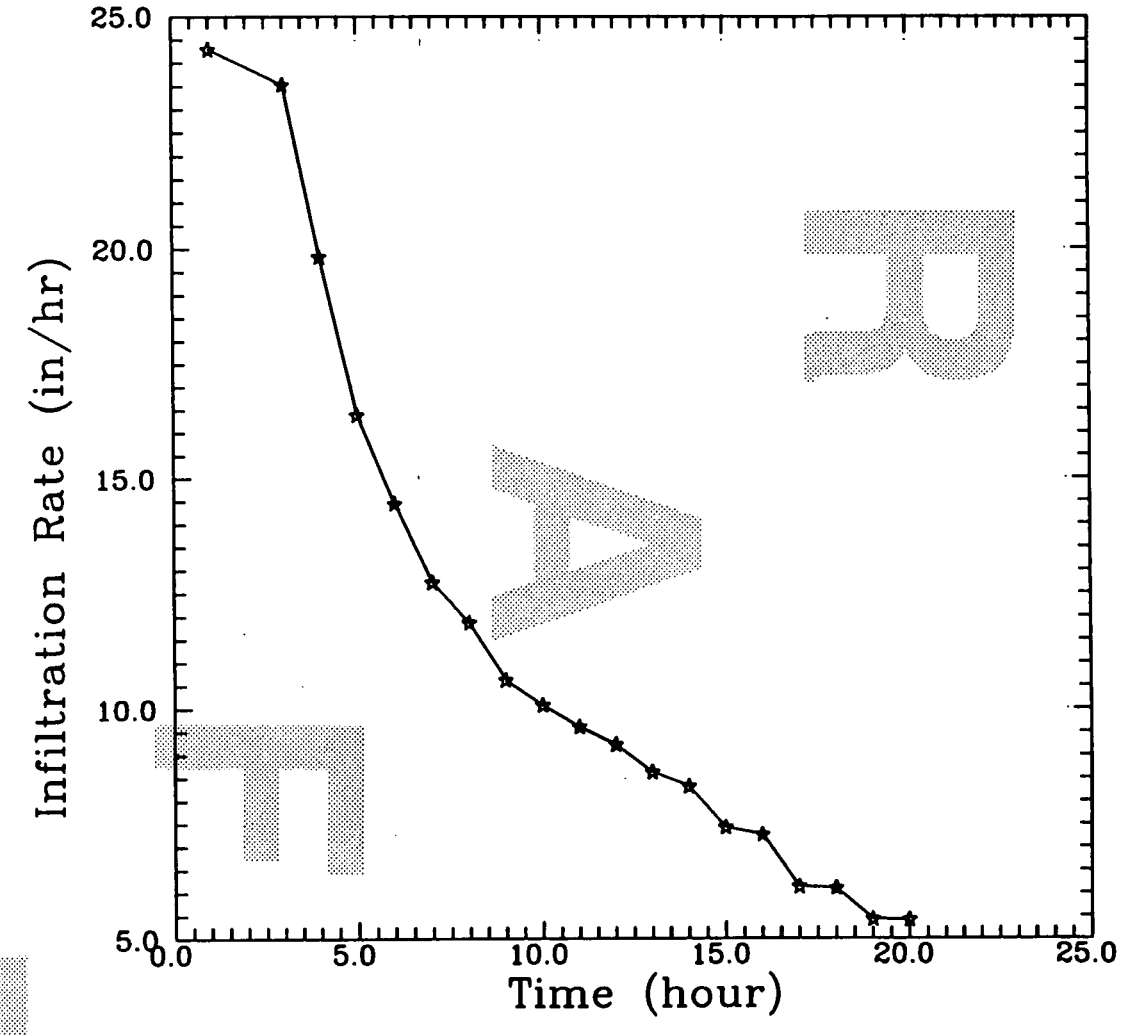
Infiltration Rate At Cross-Section C-C



DRAFT

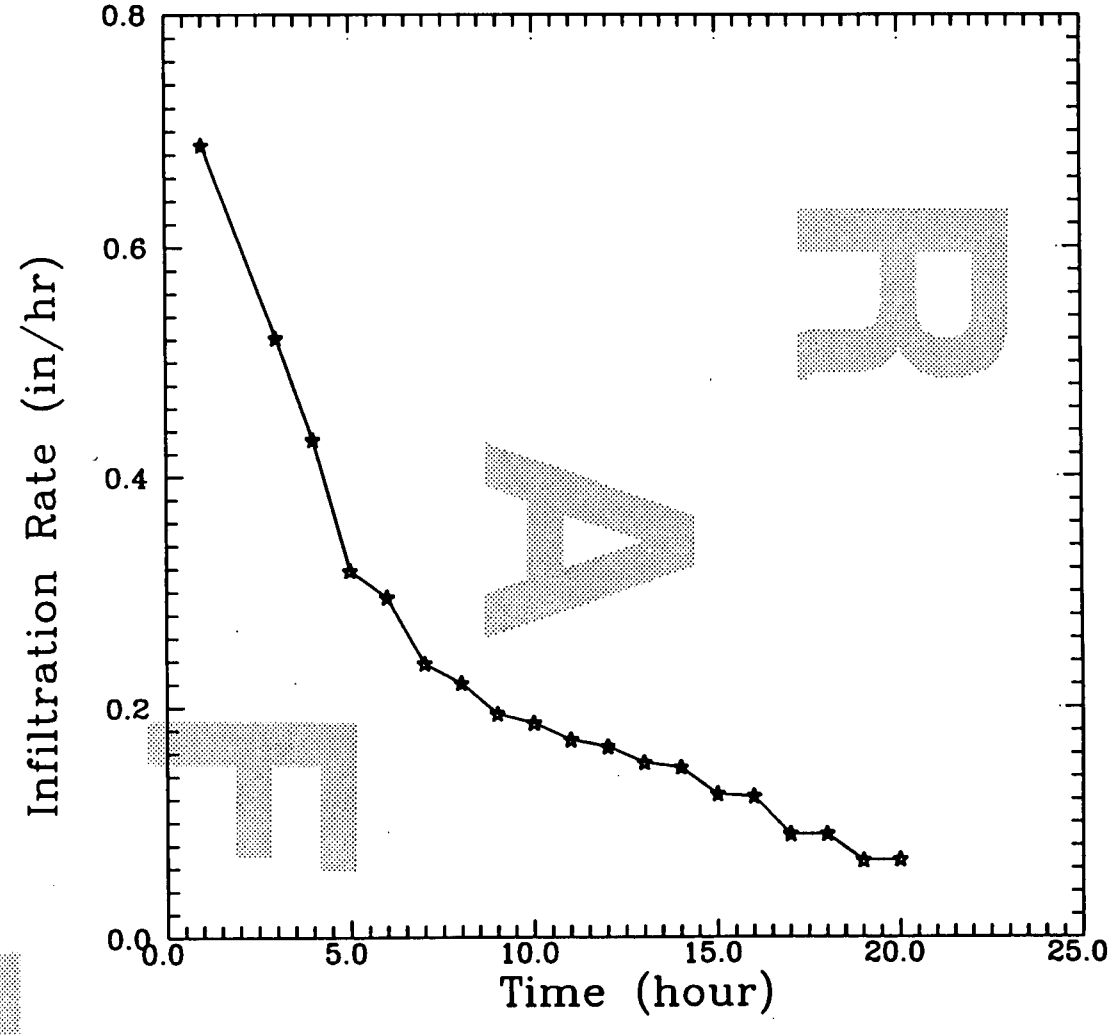
42724

Infiltration Rate At Cross-Section D-D



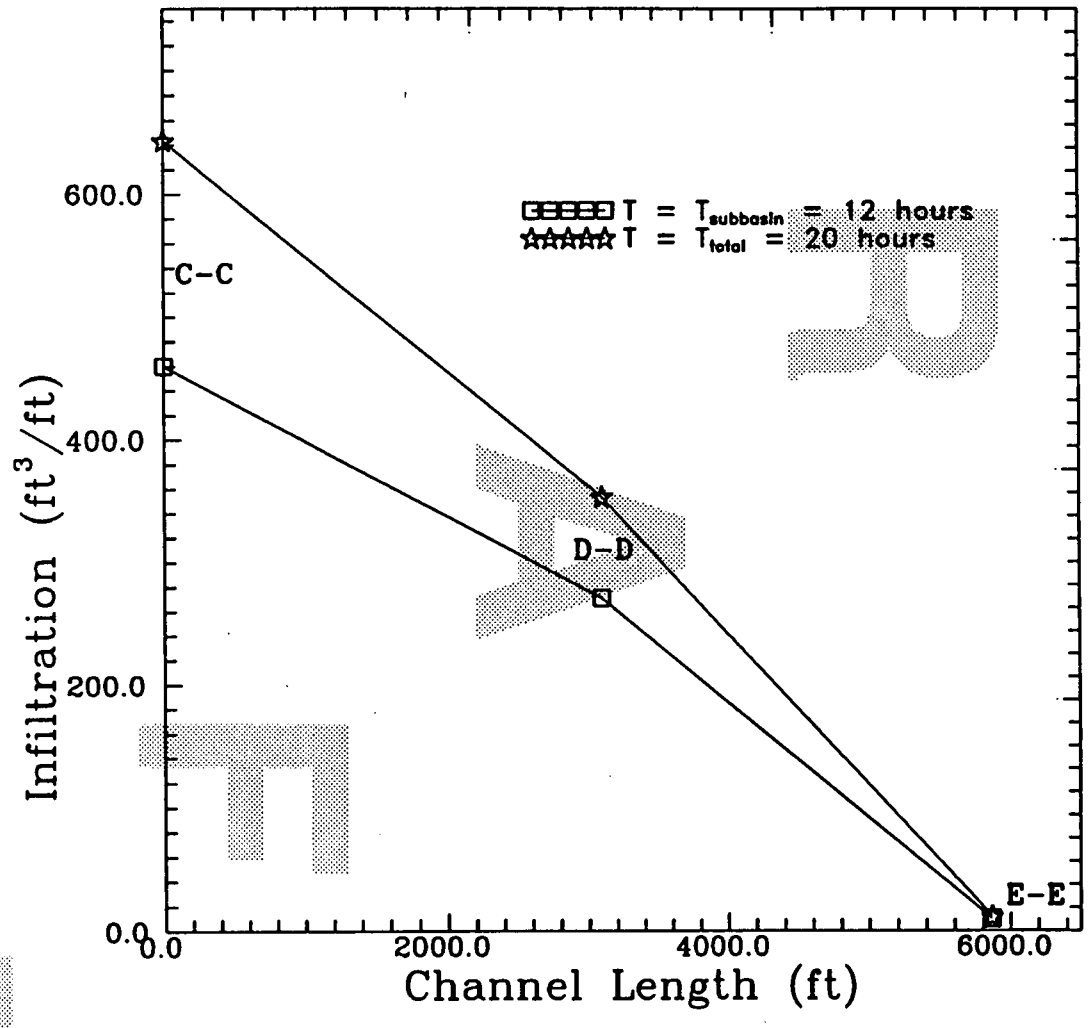
4274

Infiltration Rate At Cross-Section E-E



DRAFT

Linear Infiltration for Cross-Sections
C-C, D-D and, E-E



4224

D

R

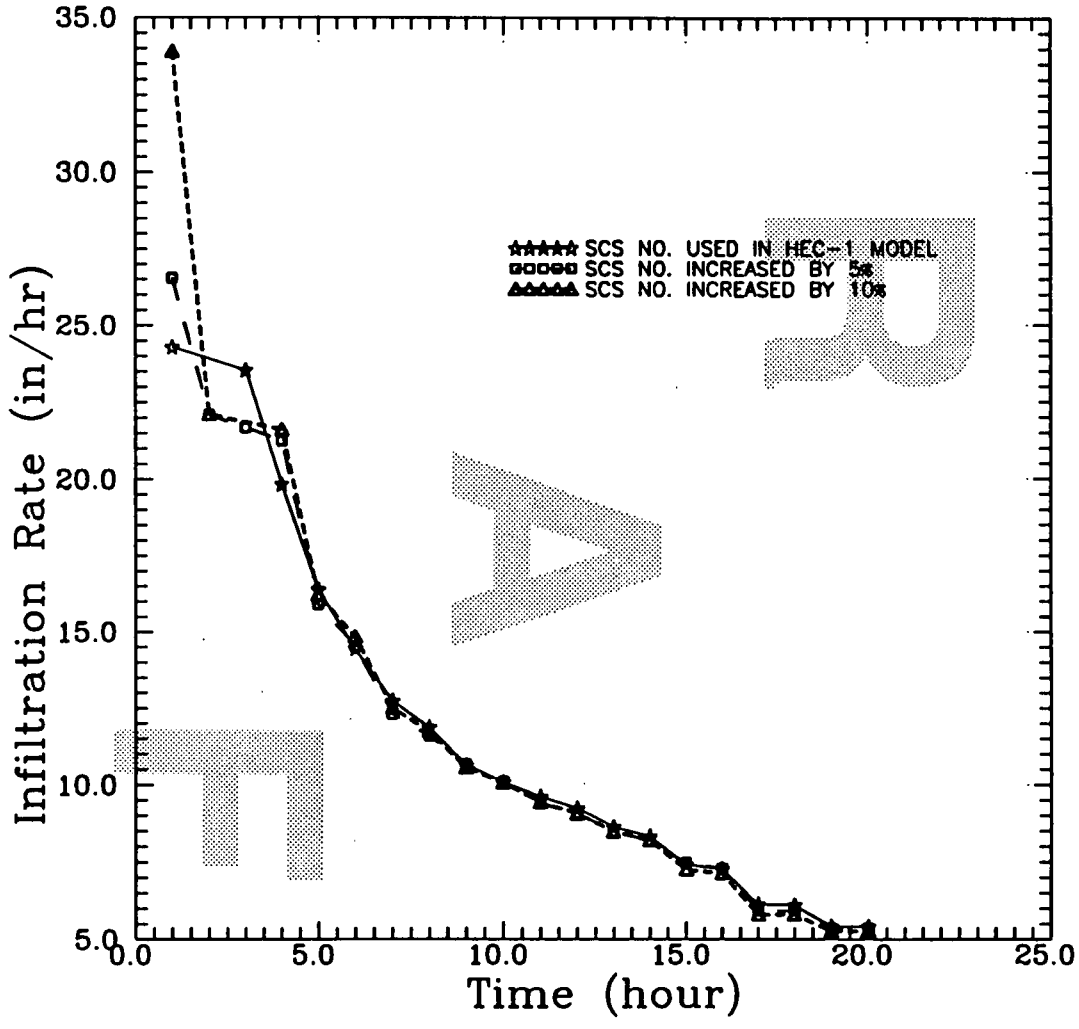
A

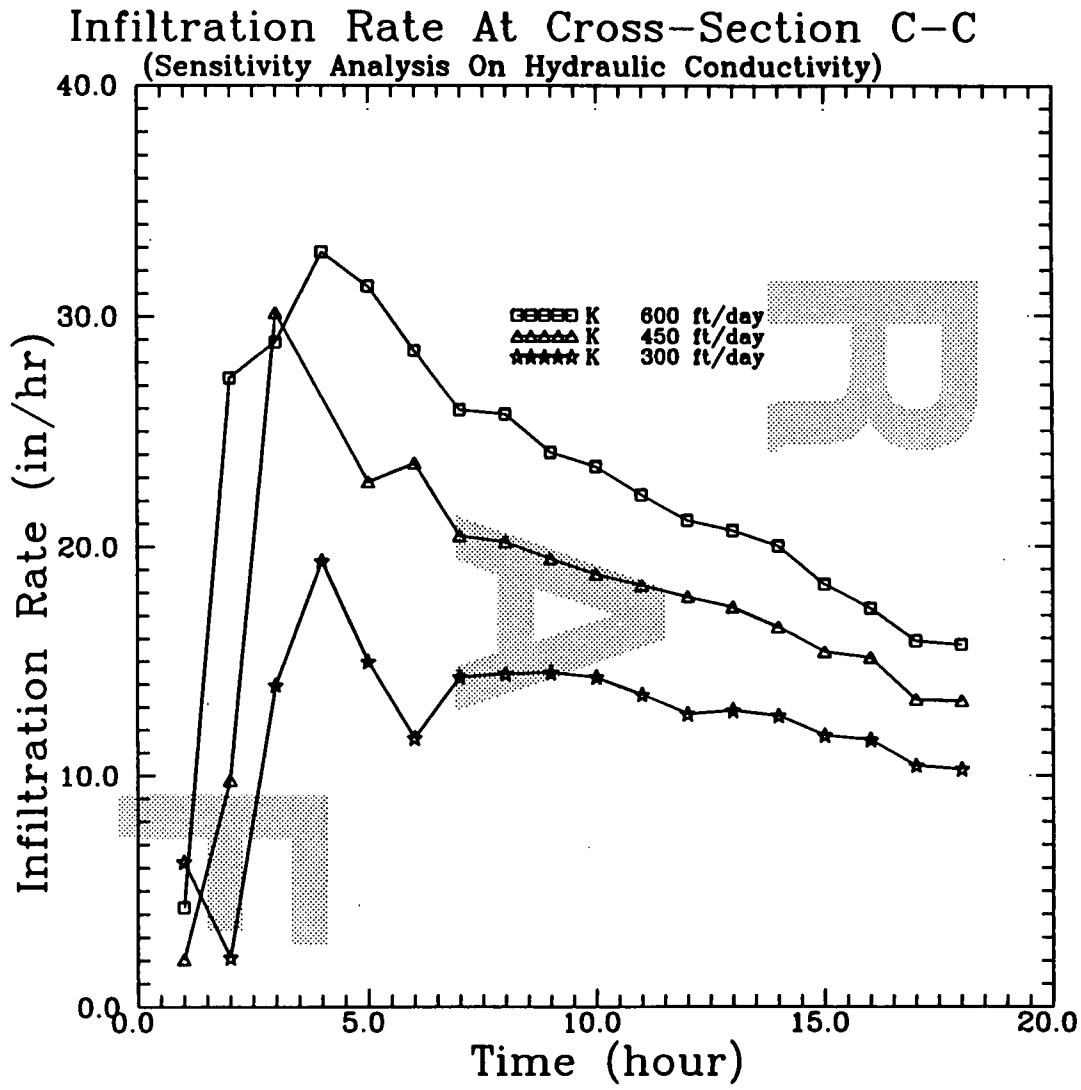
APPENDIX D-6
SENSITIVITY ANALYSIS RESULTS

F

T

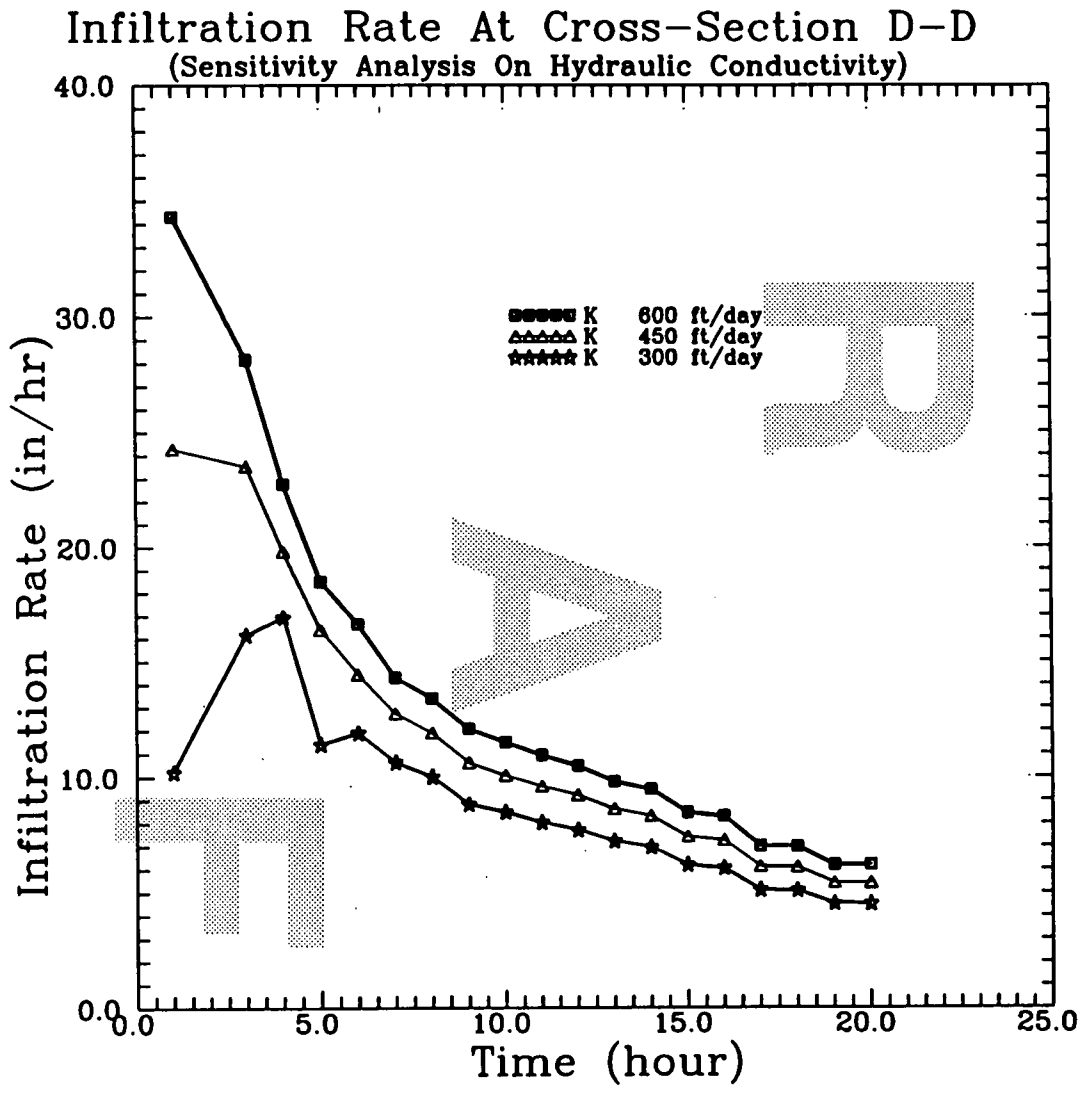
Infiltration Rate At Cross-Section D-D
(Sensitivity Analysis On SCS No.)

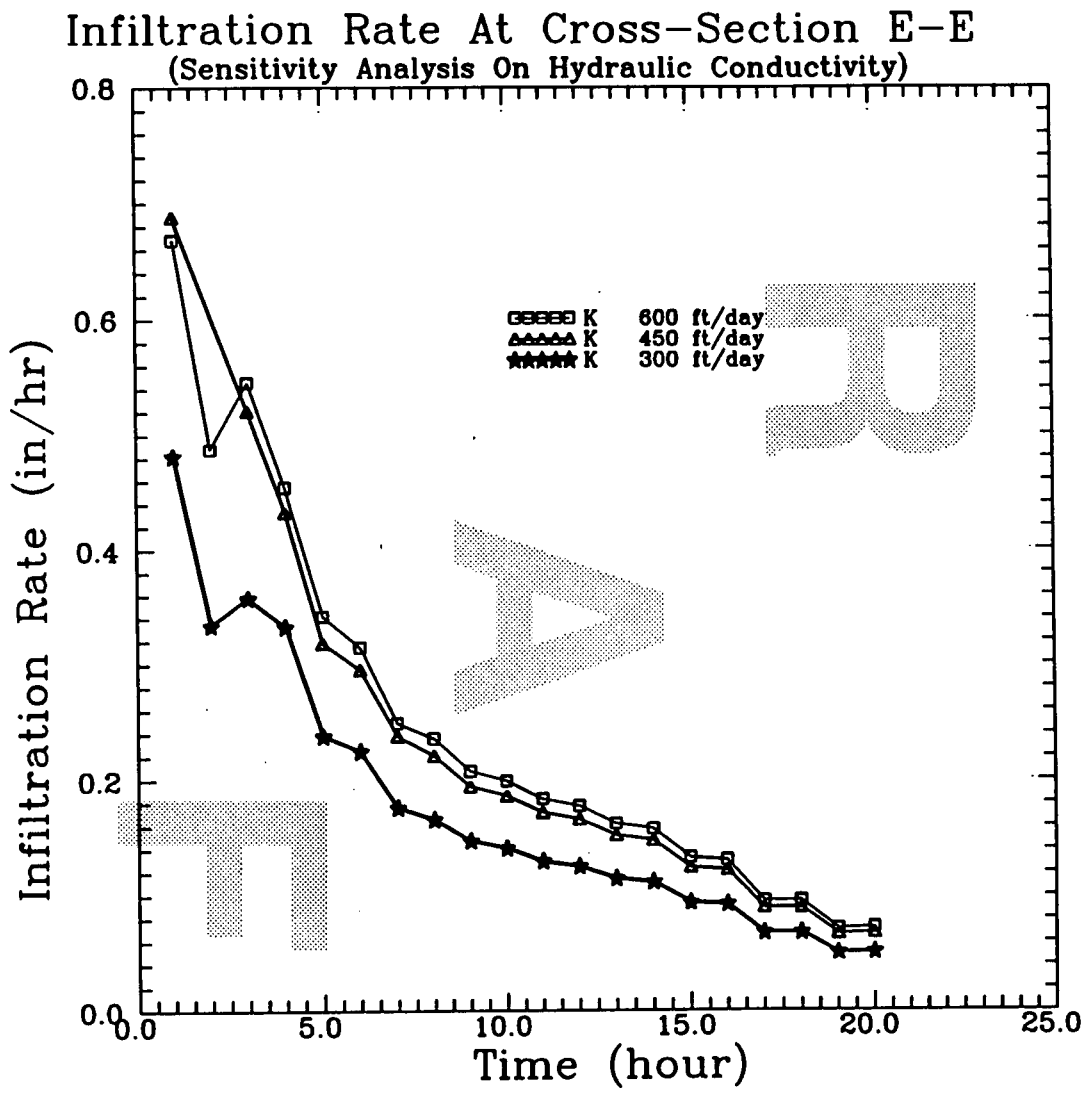


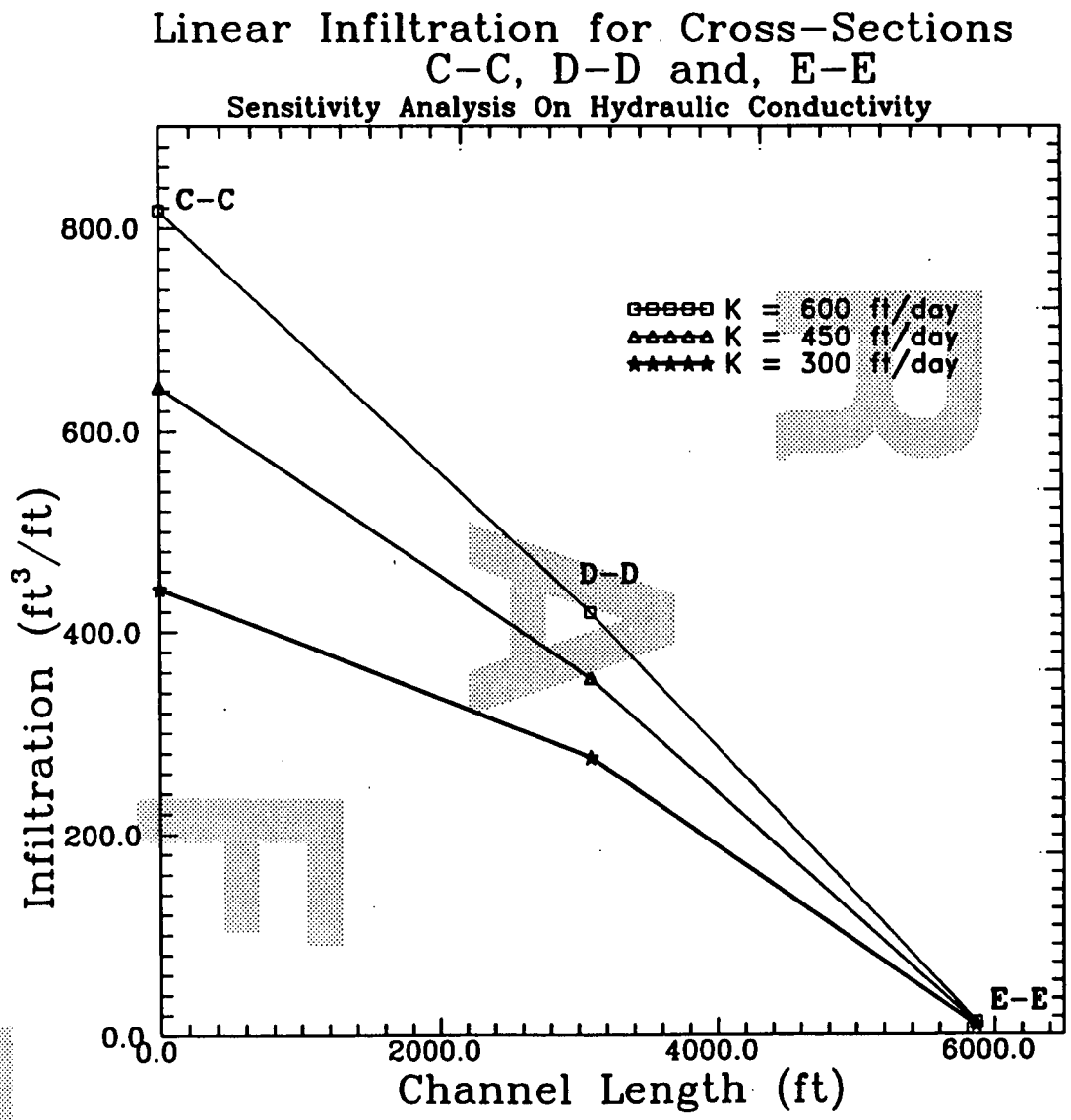

Infiltration Rate At Cross-Section C-C
(Sensitivity Analysis On Hydraulic Conductivity)
K 600 ft/day
K 450 ft/day
K 300 ft/day
Infiltration Rate (in/hr)
Time (hour)
0.0
10.0
20.0
30.0
40.0
5.0
15.0
20.0

4224

138


Infiltration Rate At Cross-Section D-D
(Sensitivity Analysis On Hydraulic Conductivity)
K 600 ft/day
K 450 ft/day
K 300 ft/day
Infiltration Rate (in/hr)
Time (hour)
0.0
10.0
20.0
30.0
40.0
5.0
15.0
25.0


Infiltration Rate At Cross-Section E-E
(Sensitivity Analysis On Hydraulic Conductivity)
K 600 ft/day
K 450 ft/day
K 300 ft/day
Infiltration Rate (in/hr)
Time (hour)
0.0
0.2
0.4
0.6
0.8
5.0
10.0
15.0
20.0
25.0


Linear Infiltration for Cross-Sections
C-C, D-D and, E-E
Sensitivity Analysis On Hydraulic Conductivity
C-C
D-D
E-E
K = 600 ft/day
K = 450 ft/day
K = 300 ft/day
Infiltration (ft³/ft)
Channel Length (ft)
0.0
200.0
400.0
600.0
800.0
0.0
2000.0
4000.0
6000.0

141

4774

D

R

A

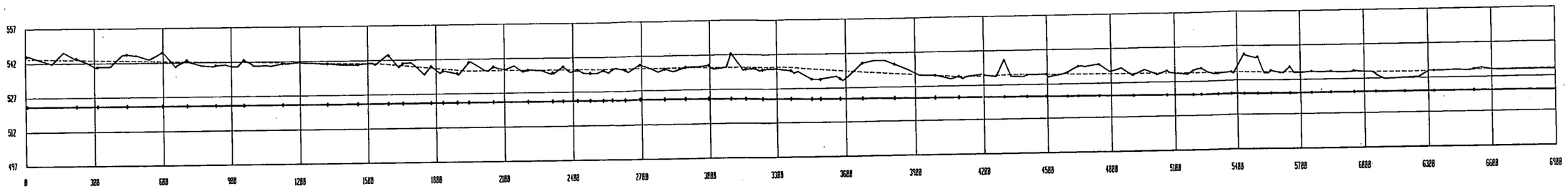
F

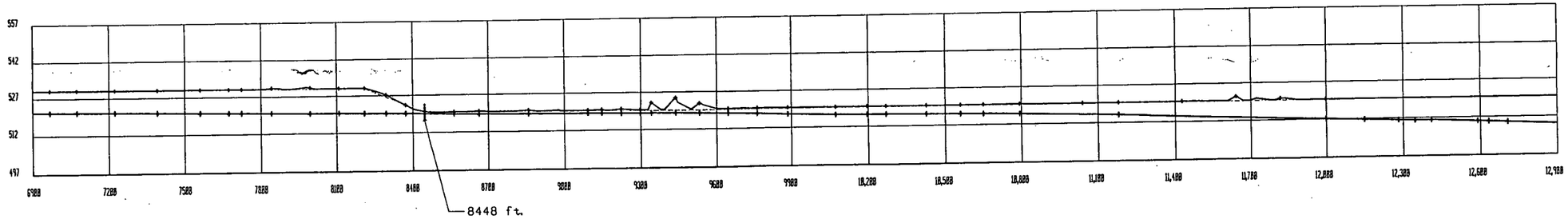
T

APPENDIX E
PREDICTED EXTENT OF GROUNDWATER MOUNDING AROUND PADDYS RUN AND VERTICAL CROSS SECTION ALONG PADDYS RUN

PRELIMINARY

141A





DRAFT

FERNALD ENVIRONMENTAL
FERMCO
RESTORATION MANAGEMENT CORPORATION

REF. NO.:	DATE:	APPROVED:	DATE:
REF. NO.:	DATE:	APPROVED:	DATE:
REF. NO.:	DATE:	APPROVED:	DATE:
REF. NO.:	DATE:	APPROVED:	DATE:

NOTES:
- PADDYS RUN PROFILE
- AVERAGED PADDYS RUN PROFILE
- GROUNDWATER PROFILE BASED ON 2000 SERIES WELL READINGS

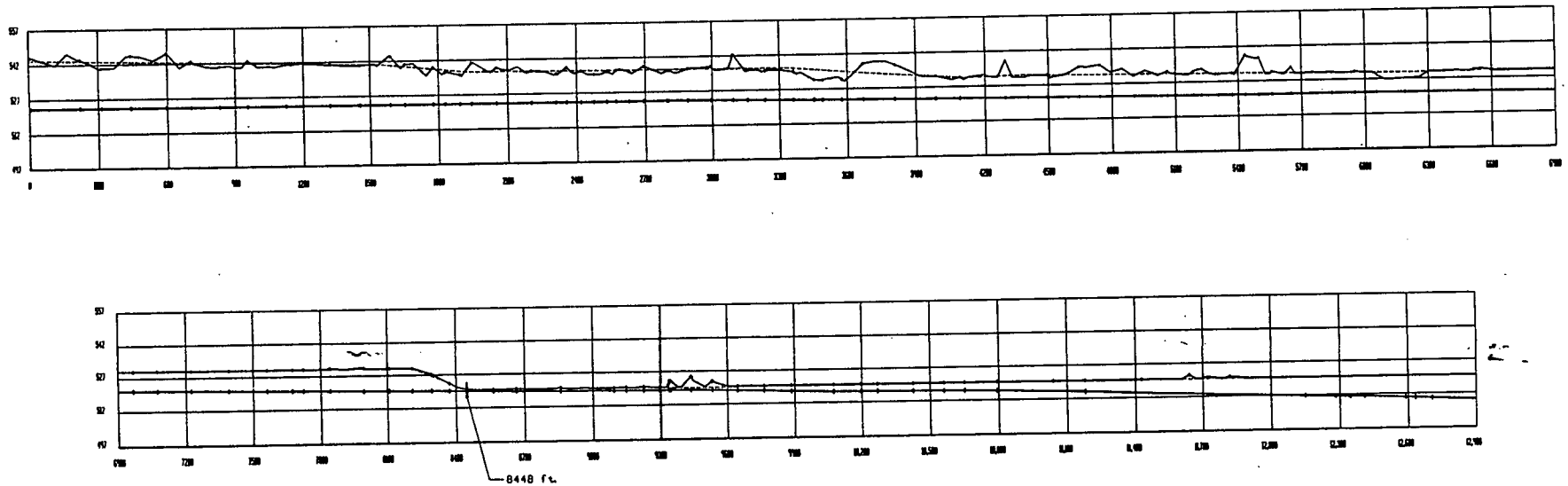
PROFILE BEGINS AT WELL #1408
DISTANCES AND ELEVATIONS ARE IN FEET

DRAFTER:	TLH
DESIGN FILE:	/usr/ermal/cru5/dgn/prsect.dgn
DEPARTMENT:	GIS
DWG. NO.:	6 of 6
DATE:	7/14/93

PADDYS RUN PROFILE

BASED ON 1992 TOPOGRAPHIC DATA

REV



DRAFT

FERMCO
RESTORATION MANAGEMENT CORPORATION

REF. NO.:	DATE:	APPROVED:	DATE:
REF. NO.:	DATE:	APPROVED:	DATE:
REF. NO.:	DATE:	APPROVED:	DATE:
REF. NO.:	DATE:	APPROVED:	DATE:

NOTES:
- PADDYS RUN PROFILE
- AVERAGED PADDYS RUN PROFILE
- GROUNDWATER PROFILE BASED ON 2000 SERIES WELL READINGS

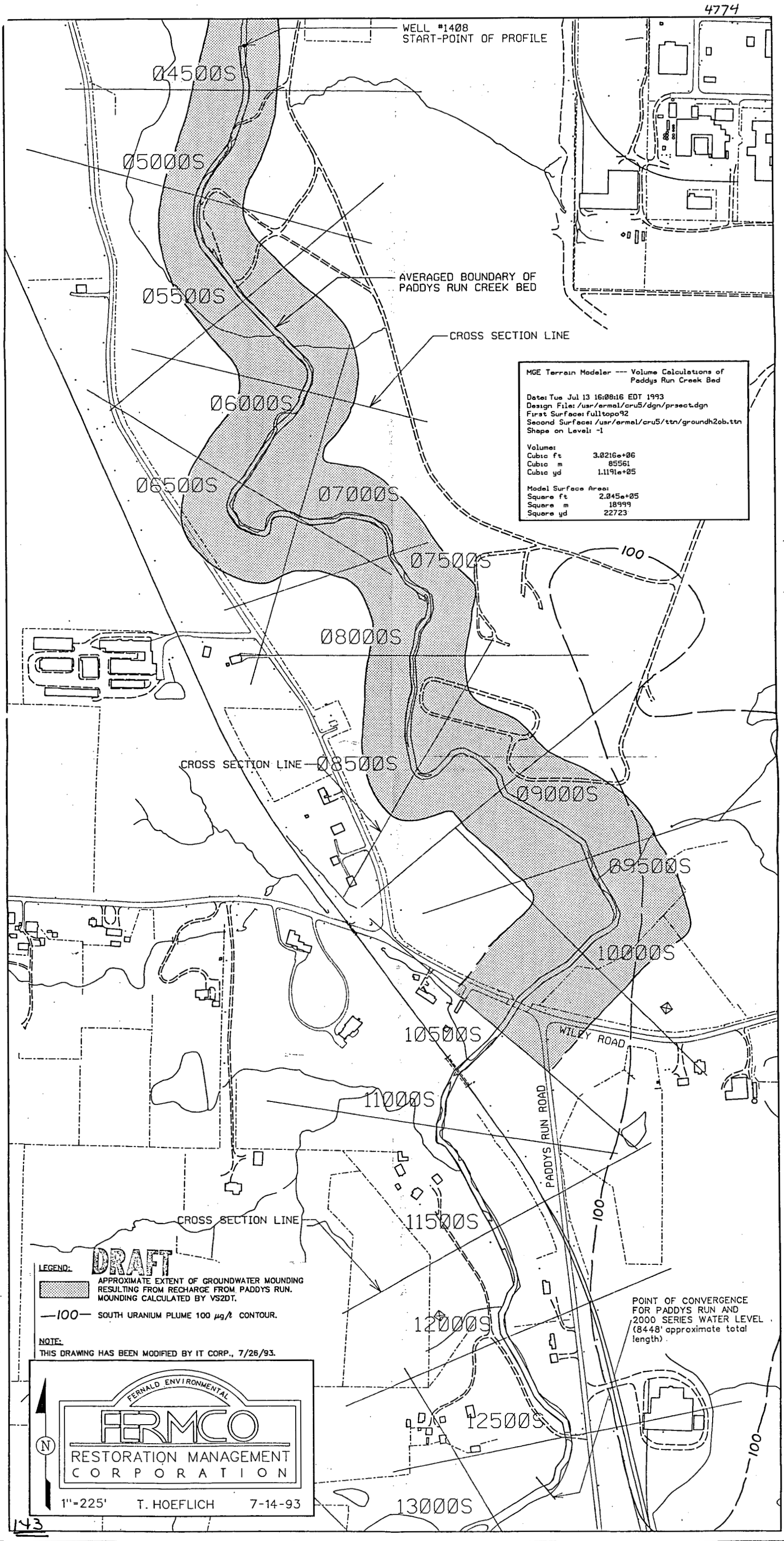
PROFILE BEGINS AT WELL #1488
DISTANCES AND ELEVATIONS ARE IN FEET

DRAFTER:	TLH
DESIGN FILE:	/usr/ermsl/oru5/dgn/prseot.dgn
DEPARTMENT:	GIS
DWG. NO.:	6 of 6
DATE:	7/14/93

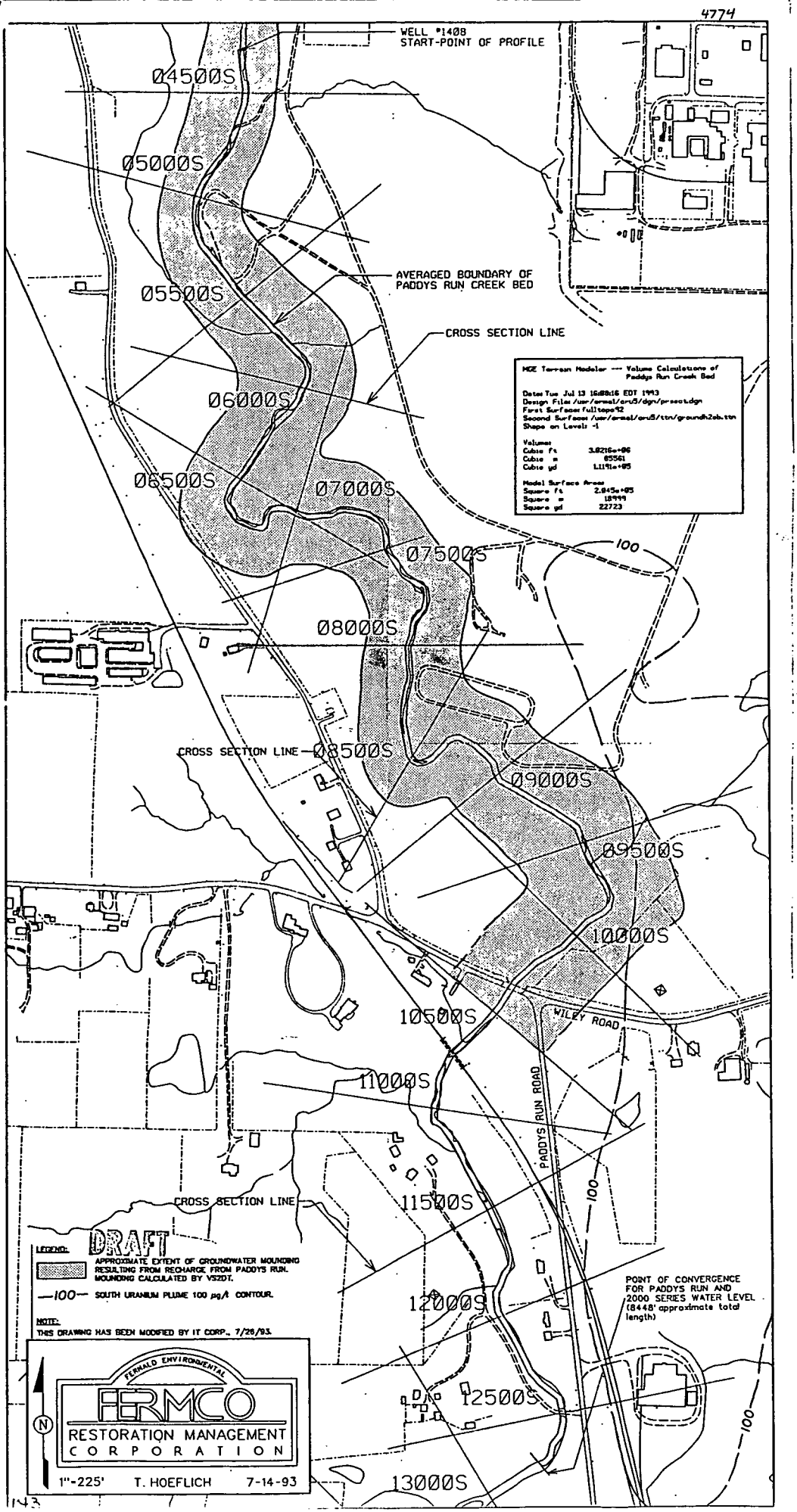
PADDYS RUN PROFILE

BASED ON 1992 TOPOGRAPHIC DATA

REV



~ma1/cru5/dgn/prsect.dgn Jul. 14, 1993 12:05:48 PADDYS RUN PROFILES AND VOLUMETRIC/AREAL CALCULATIONS


4774
WELL #1408
START-POINT OF PROFILE
04500S
05000S
05500S
06000S
06500S
07000S
07500S
08000S
08500S
09000S
09500S
10000S
10500S
11000S
11500S
12000S
12500S
13000S
AVERAGED BOUNDARY OF
PADDYS RUN CREEK BED
CROSS SECTION LINE
CROSS SECTION LINE
CROSS SECTION LINE
MGE Terrain Modeler --- Volume Calculations of
Paddys Run Creek Bed
Date: Tue Jul 13 16:08:16 EDT 1993
Design File: /usr/ernsel/ar05/dgn/prsect.dgn
First Surface: fulltape92
Second Surface: /usr/ernsel/ar05/ttn/groundh2ob.ttn
Shape on Level: -1
Volumes
Cubic ft 3.8216e+06
Cubic m 85561
Cubic yd 1.1191e+05
Model Surface Areas
Square ft 2.845e+05
Square m 18999
Square yd 22723
100
WILEY ROAD
PADDYS RUN ROAD
100
100
POINT OF CONVERGENCE
FOR PADDYS RUN AND
2000 SERIES WATER LEVEL
(8448' approximate total
length)
DRAFT
LEGEND:
APPROXIMATE EXTENT OF GROUNDWATER MOUNDING
RESULTING FROM RECHARGE FROM PADDYS RUN.
MOUNDING CALCULATED BY VS2DT.
—100— SOUTH URANIUM PLUME 100 µg/l CONTOUR.
NOTE:
THIS DRAWING HAS BEEN MODIFIED BY IT CORP., 7/28/93.
FERNALD ENVIRONMENTAL
FERMCO
RESTORATION MANAGEMENT
CORPORATION
N
1"=225'
T. HOEFLICH
7-14-93