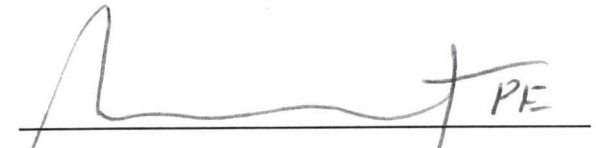


To the Graduate Council:

I am submitting herewith a thesis written by Terry E. Romans entitled, "*Performance Analysis of Constructed Urban Stormwater Detention Ponds.*" I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment for the degree of Master of Science with a major in Environmental Engineering.

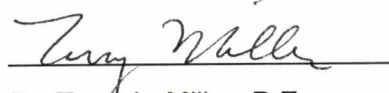


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Associate Vice Chancellor and  
Dean of The Graduate School

**PERFORMANCE ANALYSIS OF  
CONSTRUCTED URBAN  
STORMWATER DETENTION  
PONDS**

A Thesis  
Presented for the  
Master of Science  
Degree  
University of Tennessee, Knoxville

Terry E. Romans  
December 1997

## **DEDICATION**

The author wishes to dedicate this thesis to his wife, Janet M. Romans, for her patience and helpful encouragement during my long years of study and to his deceased but forever remembered grandmother, Ruby Romans, for her support and belief in me many years ago.

## ACKNOWLEDGMENTS

The author wishes to express deep appreciation to the many who helped in the completion of this thesis. My deepest gratitude is expressed to Dr. Bruce A. Tschantz, P.E., Professor of Civil and Environmental Engineering, for his assistance in reviewing the document, developing ideas, serving as my major professor, and advising me and giving me that extra push; to Dr. James L. Smoot, P.E., for his support, advise, and willingness to listen while in class and serving on my committee; and to Dr. Terry L. Miller, P.E. for taking the time to serve on my committee.

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## **ABSTRACT**

The management of stormwater runoff is becoming an increasingly important issue to Tennessee communities as urban development expands. With such development, the amount of stormwater runoff generally increases. Detention ponds are the most common tools used to control excess stormwater caused by increased development. The main components of a detention pond are the storage volume, the dam, and the control outlet. If any of the components are designed or constructed incorrectly there is a possibility of downstream damage and flooding which can result in costly lawsuits.

Twenty ponds in the Knoxville area were analyzed to determine if the ponds were built to the intended design. Constructed detention ponds from five jurisdictions were surveyed and compared to the intended design and design plans.

This study indicated that seventeen of the twenty ponds were not built according to the intended design plans. The ponds have inadequate storage volumes, under-constructed outlets, or a combination of the two. The result is that the ponds are ineffective in reducing the peak runoff to the downstream residents. Recommendations are presented for regulators, designers, and those performing construction. One of the most important recommendations is that the detention ponds should be inspected during and after construction to insure compliance with design plans.

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## CHAPTER I

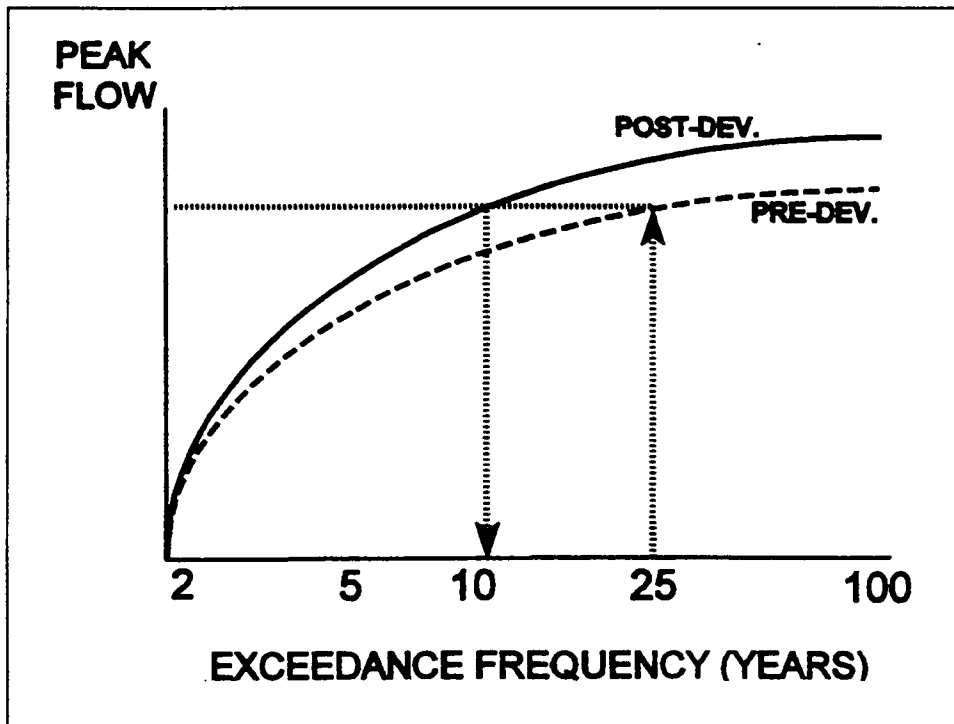
### INTRODUCTION

#### **BACKGROUND**

The management of stormwater runoff is becoming an increasingly important issue to Tennessee communities as urban development expands. With such development, the amount of stormwater runoff generally increases. Urban development converts naturally pervious areas such as pastures and forest lands into residential housing and commercial areas. Whereas grassed and wooded areas allow rainfall to infiltrate the soil, impervious surfaces like asphalt roads and parking lots, concrete drives and sidewalks, and roof tops significantly decrease the area available for infiltration to occur. Natural depressions, sinkholes, and marshy areas where stormwater runoff formerly absorbed are often filled and compacted to facilitate development. Straightened channels and engineered piping systems may replace natural drainage channels.

Urban development generally results in higher peak flows and increased frequency of flooding. Higher peak flows result from decreased time of concentration brought about by the increased imperviousness described above and by more efficient drainage systems. Natural drainage paths that are modified to accommodate development tend to accelerate flow rates. Straightened drainage paths shorten the course of the flow, and lining the paths with smooth materials decreases channel friction and increases the flow rate. The resulting decrease in time of concentration decreases the peak time of the hydrograph so that the peak flow arrives at an earlier time. With less infiltration into the soil, the runoff volume for a given storm is increased. Additionally, the accelerated flow rates can cause streambank erosion and deposit sediment into waterways.

As a result of higher peak flows from urbanization there is a risk of increased frequency of downstream flooding. Figure 1 illustrates how urbanization can increase the frequency of floods. Pre-development (dashed line) and post-development (solid line) peak flow are plotted against exceedance frequency. For example, a 10-year pre-development peak flow



**FIGURE 1. EFFECT OF URBANIZATION ON THE FLOOD FREQUENCY**

can be increased to the peak flow rate of a greater exceedance frequency, such as the 25 year peak flow rate. Thus, urbanization can cause an increase in the frequency of floods. Some of the development related causes of increased downstream flooding are unwise land use and disregard for drainage in planning new developments, inadequate design, lack of enforcement by regulatory agencies, lack of routine maintenance, and rare storm events. Inadequately built drainage facilities, brought about by poor or unsupervised construction, can cause downstream flooding.

Two types of methods used to control and manage stormwater runoff are specification standards and performance standards. Specification standards are stormwater management methods specified by the regulatory agency, such as requiring detention ponds as the only method of managing stormwater. The benefit of specification standards is that specific requirements are set forth. This makes it easier for the regulatory agency to check the designs. However, with specification standards other methods are not considered.

Performance standards are regulations that allow any best management practices (BMP). The engineer is given the flexibility to choose any BMP of their preference as long as the management goal is achieved. For example, an engineer may choose to use porous pavement to increase infiltration and reduce the volume of runoff. The benefit of performance standards is flexibility. The engineer can choose a method that will meet the requirements, satisfy the budget, and reduce detrimental effects on the environment. The problem is that the regulators have many different designs to consider and review.

Because Tennessee is a "home rule" state that encourages stormwater regulation at the local level, many counties and local communities have adopted stormwater policies or ordinances that specify or allow some type of stormwater detention. The local governments have regulatory control and authority over stormwater management. Roman Civil Rule is the basis for drainage law custom in Tennessee. The simple interpretation of the Roman Civil Rule is that upper landowners have an easement right through the lower landowner's property. However, the upper landowners cannot increase the natural flow rate or quantity and discharge it upon the lower land owner.

Most of the regulatory agencies and municipalities in the Knoxville, Tennessee, area have developed specification standards for controlling excess stormwater runoff caused by urbanization. All of the stormwater jurisdictions considered in this study have stormwater ordinances. The excess stormwater runoff brought about by development must be detained and released at a specified pre-development flow rate. A very important issue emerges in regard to the effectiveness of such specification standards. While the standards set forth the desired stormwater management requirements, it remains to be seen if detention ponds in the Knoxville area are designed, constructed, maintained, and performing as the regulatory agencies, engineers, and public intended.

The increase in urbanization makes it difficult to regulate stormwater runoff. Most municipalities do not appear to have the staff to inspect newly-constructed stormwater pond facilities. Even properly constructed facilities may not be adequately maintained or monitored by regulatory agencies. Poorly designed, constructed, or maintained stormwater



facilities can result in many problems including street flooding, roadway washouts, and traffic delays. Personal and property damage from flooding is another effect of poor stormwater management practice. Problems of clogged culverts and dysfunctional storm drainage systems may also arise from inadequate stormwater management. Problems caused from stormwater can ultimately lead to increased litigation and lawsuits.

### ***STUDY SCOPE AND OBJECTIVE***

The purpose of this thesis is to evaluate the performance of constructed detention ponds in the Knoxville area by comparing the intended design and performance to the actual performance of the "as-built" detention pond. Study observations and discussions with regulators and designers indicated an apparent lack of inspection during the construction phase of site development. In this thesis, the following performance components of 20 detention pond designs were analyzed:

1. Three elements of the design calculations were reviewed to determine if the detention ponds are being accurately engineered. In each case the design method was reviewed to determine if there were any obvious errors in calculations for sizing outlet structures, pond volume, and in selecting discharge coefficients.
2. All elements of the constructed detention ponds were field surveyed. The outlet structure, detention volume, dam height, and side slopes were measured and compared to the intended design to determine if the plans were being correctly implemented.
3. The operating condition and maintenance of each pond were inspected to determine if the facility would function as intended.
4. The intended design inflow hydrograph was routed through the actual "as-built" detention pond to determine the actual performance of each. The modeled outflow was compared with the intended outflow and it was determined if any of the ponds would overtop given the selected design storm.

The results of this study will show that there are some significant differences between the actual constructed detention ponds and the intended design and also some design

deficiencies. The study will show that there is a need to improve the design plans/computations review and construction inspection process of stormwater detention facilities in the Knoxville area.

## CHAPTER II

### DETENTION PONDS

#### **GENERAL**

A detention pond is a stormwater management tool used to reduce peak flow caused by increased development. The purpose of a detention pond is to regulate or limit the peak flow for a specific rainfall event to some specified lower discharge. Typically, a detention pond will provide adequate volume and outlet discharge control to store and release post-development runoff at a peak flow rate no greater than that for pre-development conditions. Common practice is to limit the post-development condition peak flow to the pre-development peak for a single rainfall event, such as a specified duration 10-year storm. However, many local governments are beginning to adopt ordinances requiring that post-development discharges not exceed present condition discharges for multiple storm frequencies, such as 10-year and 25-year storms. Some community policies require that the maximum release rate from a developed site not exceed the 10-year pre-development peak flow for an assumed larger (i.e., 50-year) storm event. Figure 2 illustrates the impact and construction of detention ponds. The top figure represents the effect of a detention pond on the inflow hydrograph (flow rate plotted against time). The inflow hydrograph (solid line) represents the post-development condition and the outflow hydrograph (dashed line) represents the pre-development condition. As shown, the peak inflow is attenuated to the pre-development condition but is delayed to a later time. The shaded area represents the required storage volume to meet the pre-development conditions. The bottom of the figure presents a cross-section of a typical detention pond. The shaded areas of the figure represent the detention volume.

A detention pond does not reduce runoff volume but, rather, delays the peak flow and releases it at a lower flow rate. Location of a detention pond is critical. The designer should consider the effect of each new detention pond with respect to the basin-wide impact. If not strategically located within the basin, a detention pond can actually

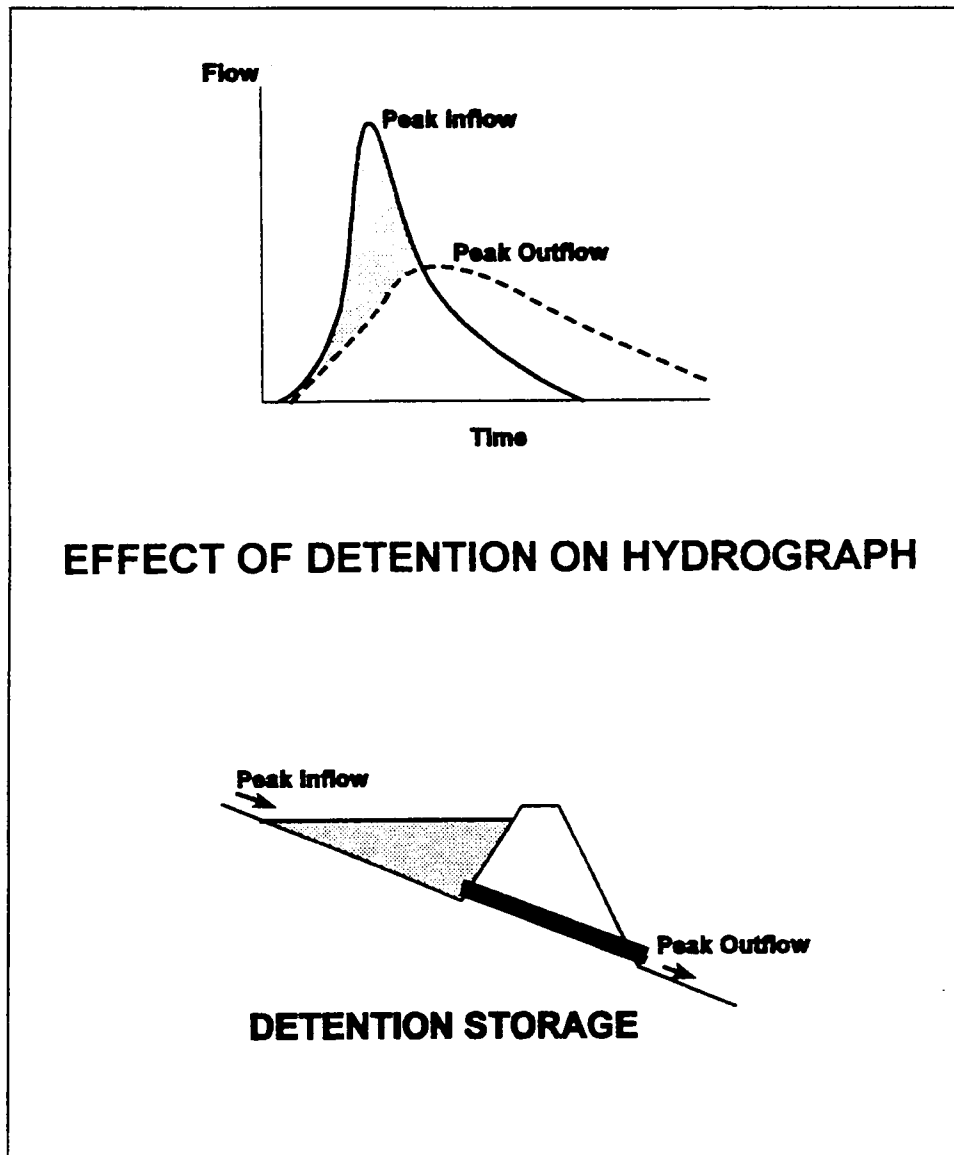


FIGURE 2. DETENTION POND IMPACT

increase downstream flood peaks. Figure 3 illustrates such an effect. This example shows a drainage basin with two developments (A and B) located on different drainage paths but both discharging into the same outlet. The thin solid lines represent the post-development hydrographs with no detention. The thicker solid line represents the combined effects of the hydrographs (A+B) at the outlet with no detention. The thin dashed lines represent the attenuated outflow hydrographs of each development with detention. The thick dashed line is the combined (A+B) attenuated outflow hydrograph at the outlet of the basin with detention. The peak outflow is greater with detention than without detention. In this case would be a lesser effect on the downstream flood peak if no detention were provided at these locations. The placement of detention ponds and a basin wide evaluation of multiple detention ponds is an important design consideration in controlling and managing stormwater.

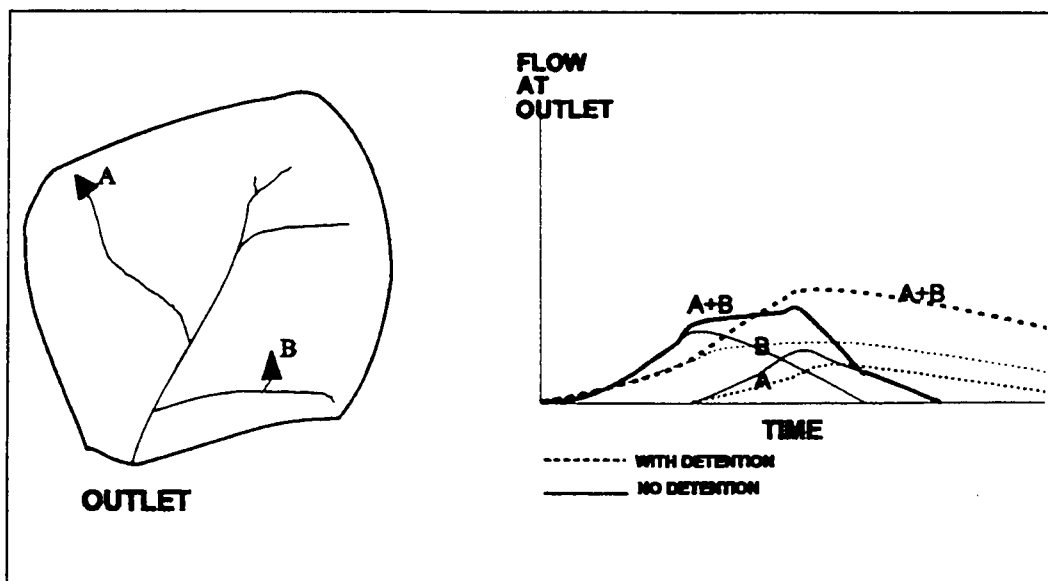


FIGURE 3. DETENTION POND PLACEMENT

## ***ELEMENTS OF A DETENTION POND***

Detention pond facilities are made up of several components. Each component must be designed and built correctly for a detention pond to perform effectively. The basic components of a detention pond are listed below along with the parameters of each component. Figure 4 illustrates these components, and a brief description of each follows.

List of components of a detention pond:

1. Dam (height, stable slopes, erosion protection, crest width)
2. Storage Volume (capacity with freeboard)
3. Principal outlet or outlet works (single or multi-stage outlet, control opening, outlet pipe, trash rack)
4. Emergency spillway
5. Inlets to pond (open channel, pipes with headwalls)
6. Actual pond (side slopes, stage vs. storage relationship, stage vs. discharge relationship)

### **DAM**

Most detention pond dams are earthen barriers constructed across a drainageway for the purpose of storing water. The Tennessee Department of Environment and Conservation defines a dam as having a height of twenty feet or more and storage capacity of thirty acre feet or more. The state also classifies dams according to the hazard potential. A dam is classified as high hazard potential if the failure of the dam will result in possible loss of life and excessive economic loss. A high hazard potential dam must be inspected every year. If there is a remote possibility of loss of life and downstream property damage due to dam failure, it is classified as having significant hazard potential and must be inspected every two years. If dam failure will result in no expected loss of life and damage is limited to the dam owner's property it is classified as low hazard potential and must be inspected every three years. The detention pond dams in this study are not large enough to meet the Tennessee classification of dams. However, failure of a dam can result in downstream damage and other serious problems. For this reason alone, detention pond dams should be inspected and maintained in order to prevent potential problems associated with dam failure.

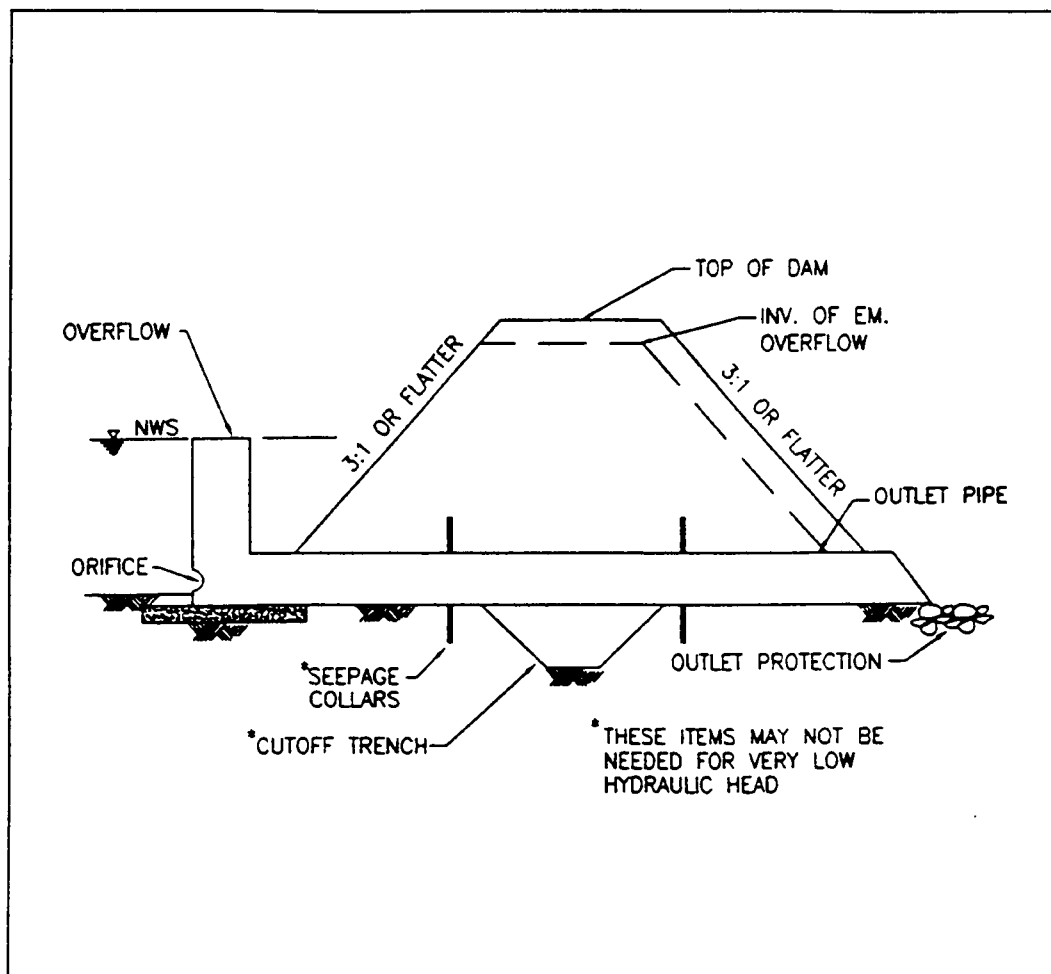


FIGURE 4. BASIC COMPONENTS OF A DETENTION POND

## PRINCIPAL OUTLETS

The principal outlet is a device to provide controlled discharge from the pond. The principal outlet is usually an orifice or weir. Outlet pipes are normally reinforced concrete or corrugated metal. The outlet structure is a key element of a detention pond. If the outlet is not sized correctly the pond will not function as it was intended. Some detention ponds have outlets that will handle multiple storm events (i.e., 10- and 25-year storm events). Figure 5 illustrates how multi-frequency outlet control can be a more effective strategy than single-frequency outlet control in stormwater management. As shown, a multi-frequency outlet can reduce peak flow rates for more than one storm. The outlet control depicted in Figure 5 provides reduction in peak flows for the 10-year and 25-year storm events, and between the two storm events there is partial reduction in peak flow rates. Peak flow is plotted against exceedance frequency (years). The solid line represents the post-development peak flows and the long dashed line is the pre-development peak flows. The shorter dashed line represents the peak outflow for two different storm events. As shown, each post-development storm event is attenuated to the pre-development condition, and in between there is partial reduction of post-development flow.

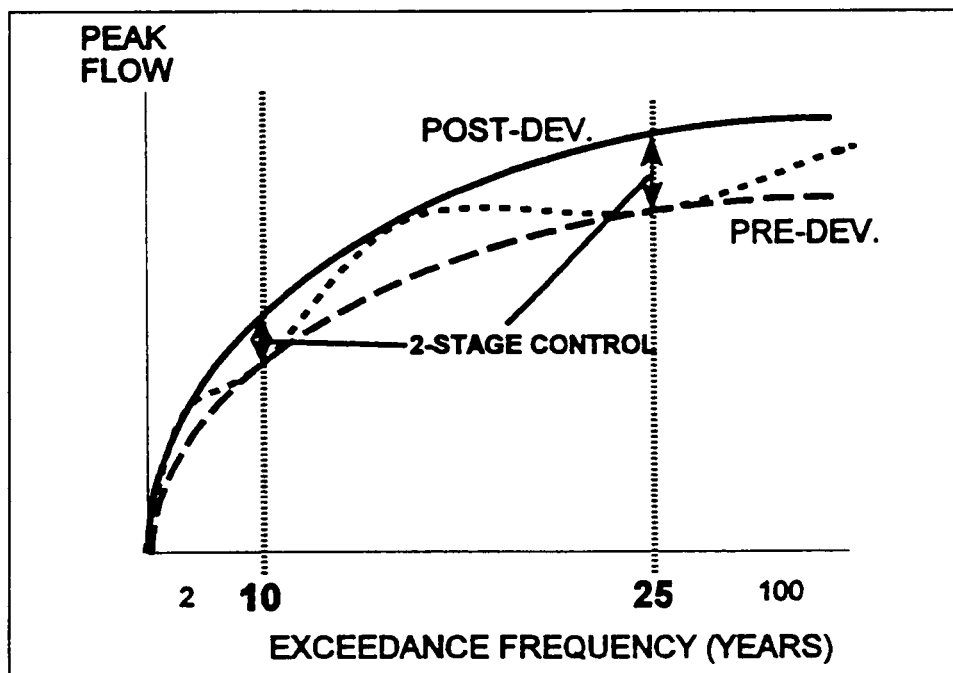


FIGURE 5. MULTI-FREQUENCY OUTLET CONTROL



## **EMERGENCY SPILLWAY**

The emergency spillway is designed to provide relief during rare storms which would otherwise cause damage to the dam, if allowed to overtop. Most spillways for detention ponds are sized to pass the 100-year storm event. The emergency spillway is typically a poured concrete channel, grassy swale, or rip-rapped channel, either over the dam or around one of the abutments.

## **INLETS**

The pond inlets are open channels and ditches, pipes and culverts, or a combination of the two that allow the runoff from development to enter the pond.

## **DESIGN OF DETENTION PONDS**

The methods used by engineers for determining detention pond volume vary, but the Soil Conservation Services TR-55 Urban Hydrology for Small Watersheds (also referred to as SCS TR-55)(1\*) approach appears to be the most favored method in Tennessee. TR-55 (Technical Release 55) was first issued in 1975 by the Soil Conservation Service (SCS) and revised in June 1986. It is applicable in modeling watersheds of less than one square mile, which is the case for most commercial and residential developments. TR-55 provides two methods, Graphical and Tabular, for design engineers to compute peak flows from a drainage basin of known size and hydrologic conditions. TR-55 then allows the engineer to estimate required detention volume from computed peak outflow discharge to peak inflow discharge ratio. However, the TR-55 technical manual warns users to apply the method with caution. Its principle use should be for developing preliminary estimates of storage for small detention ponds and storage volume where errors of 25 percent are acceptable. The TR-55 graphical procedure for storage routing is not sensitive to a particular outlet structure (i.e., weir or orifice or pipe). Therefore, a specific outlet structure and pond configuration can greatly affect the shape of the outflow hydrograph and hence, the amount of storage required to control the outflow discharge. The limitations of the TR-55 method coupled with inadequate as-built inspections can combine to produce either expensive over-designed/over-constructed or deficient under-designed/under-constructed ponds.

\* Number in parenthesis indicates reference number.

The concept of detention pond design is fairly simple and straightforward. However, the design process requires a thorough knowledge of hydrologic and hydraulic engineering. Too frequently, economics of development tend to rush the design process. The goal of developers is often to minimize detention pond area, construction costs and design costs. Most developers regard detention ponds as non-productive overhead because they take up valuable property and do not produce revenue. The tendency by engineers often is to view the regulations as the minimum requirement for obtaining a permit and for design parameters.

Detention pond design basically involves a three-step process. The first step is to determine the existing pre-development hydrologic conditions. Detention pond hydrology requires the use of soils maps, aerial topographic maps, field survey, USGS topographic maps, or a combination of these. Whatever method for obtaining topographic information is used, it is always helpful to visit the site since topographic conditions may have changed since the topographic maps were produced. The use of topographic information and soils maps helps the designer determine drainage paths, non-contributing depressions and sinkholes, slopes of ground surfaces, ground cover, and hydrologic soil types. The second step is to determine the hydrologic conditions of the developed site. The proposed layout of the new development will define new drainage paths, slopes, and surface cover. From these two steps the designer can define the needed data to model the pre-development and post-development conditions using SCS TR-55. The SCS TR-55 program computes a detention volume based on the post-development inflow into the pond and the pre-development outflow release from the pond. For the required storage the designer generally determines the surface area and depth of the detention pond based on the site constraints. The proposed site design will also define the area available for the detention pond and the location of the detention pond. The third step to designing a detention pond is to design the control outlet. The designer sizes the outlet to release the pre-development peak flow at the defined maximum pond depth. Typical outlets used are orifice restrictor plates on pipes, culverts, and weirs (2,3,4,5,6,7,8,9,10,11).

## ***ADVANTAGES AND DISADVANTAGES OF DETENTION PONDS***

Detention ponds are not a "cure-all" for stormwater management, but they can be beneficial if implemented correctly. Detention ponds have advantages and disadvantages. Peak flow rate reduction is the main advantage of detention ponds. Other advantages include preventing downstream drainage problems, replenishing groundwater, decreased soil erosion, sediment trapping, and improved water quality of receiving streams, possibility of multiple use, and aesthetics. In order to achieve these positive aspects a detention pond must be designed and built properly. Also, it must be maintained regularly, especially after a storm event. The high maintenance requirements are a major disadvantage of detention ponds, and there seems to be a continuing question of who is responsible for the maintenance. Another disadvantage of detention ponds is land requirements and availability. Land acquisition is a major expense in development, and developers do not want to give up valuable property for detention ponds. Often, there is inadequate acreage available for a detention pond and the planned development. Other disadvantages of detention ponds include such issues as safety concerns, the potential of shallow ponds to serve as breeding grounds for mosquitoes, and the potential for improperly designed outlet controls to actually increase post-development peak flow rates and volumes at some downstream points.

## **CHAPTER III**

### **STUDY METHOD AND PROCEDURE**

#### **GENERAL**

Twenty stormwater detention ponds representing a cross-section of ponds in the Knoxville area were analyzed. The goal of this thesis was to determine if the detention ponds in the Knoxville area are performing as they were intended. This was achieved by comparing actual field conditions with the engineering design intent. Only ponds were selected where submitted design computation and plan documentation were available on file in the respective regulatory office. Ten older ponds and ten newer ponds (less than a year old) were selected from among the five regulatory jurisdictions of the Town of Farragut, the City of Knoxville, Knox County, the City of Maryville, and the City of Oak Ridge. Ten of the ponds were constructed for residential developments and ten were for commercial developments. These detention ponds, having maximum design storage volumes ranging from 0.1 ac.-ft. to 4 ac.-ft., were surveyed through extensive field work. Hydraulic and hydrologic analysis of the field data were conducted. Further, the "as-built" storage and flow reduction capability of each detention pond were compared with (1) the intended engineered storage and peak flow reduction performance characteristics and (2) the required regulatory storage and performance. Pond characteristics that were examined included pond geometry and capacity, emergency spillways, outlet structures, stage vs. storage relationships, stage vs. discharge relationships, and general condition and maintenance.

#### **METHOD**

The steps involved in the study are as follows:

1. Selection of ponds
2. Review of design plans and computations
3. Field survey of each pond
4. Reduction of field notes
5. Comparison of field survey ("as-built") conditions to intended design and plans

It would be desirable to look at all of the ponds in the Knoxville area, but not practical or realistic, because of the time involved in collecting and interpreting the data for each pond and because not all ponds have adequately documented information to analyze. The goal of the study is to analyze enough detention ponds to provide a representative cross-section in the area. Based on professional judgment of time considerations it was decided that twenty detention ponds would provide an adequate sample of the detention ponds in the Knoxville area. In order to select a representative cross-section of detention ponds the following criteria were used:

1. Design plans and computations had to be available.
2. A reasonable cross-section of designers should be represented.
3. Both commercial and residential developments were to be included.
4. A cross-section of jurisdictions should be represented.

The City of Knoxville and Knox County made available submitted design documentation on which pond selection was based. Engineers for the Town of Farragut, the City of Maryville, and the City of Oak Ridge selected ponds based on the given criteria and provided original design information for each selected detention pond. The design computations were checked using the same method that the designer used. All errors identified in the submitted engineering design documentation materials were corrected for this study.

Field work involved taking photographs, measuring and documenting existing conditions, and doing an "as-built" survey of the ponds and outlet facilities. Survey equipment included a Topcon total station EDM and an HP 48GX data collector. The data collector used the Tri-Data System (TDS) software. The field data was digitally analyzed using AutoCAD 12 and Softdesk 7.2. For each detention pond the stage vs. storage and stage vs. discharge relationship were developed using the field data.

The U.S. Army Corps of Engineers Flood Hydrograph Package, HEC-1(12), was used to route the computed inflow hydrographs through the ponds using the "as-built" pond and outlet geometry conditions to determine whether the actual storage was adequate. If the original designer did not compute an inflow hydrograph, but used the TR-55 Graphical

method to determine peak flow, the TR-55 Tabular method was used in conjunction with the designer's drainage basin parameters to produce the inflow hydrograph before using HEC-1 to route through the actual pond. However, if the original designer computed an inflow hydrograph, HEC-1 was only used to route the hydrograph through the actual pond. Considerable effort was made in the study to understand and to appreciate the design intent of each pond.

### ***SUMMARY OF JURISDICTION REQUIREMENTS***

The drainage ordinances of each jurisdiction were obtained by contacting respective engineering departments. Below are summaries of these ordinances which include only the basic design constraints.

#### **City of Knoxville**

The stormwater requirements are found in Ordinance No. 6191 (13). The purpose of the ordinance is to reduce increases to that of pre-development conditions in peak flow rates caused by urban development. The stormwater ordinance applies to all commercial and industrial developments of one acre or more, multi-family residential developments of two acres or more, and single family residential developments of five and five lots or more.

Ordinance 6191 requires that stormwater computations be in accordance with SCS TR-55 or other methods approved by the City Engineer. The stormwater facility shall be designed to reduce the 10-year post-development runoff rates to the 10-year pre-development runoff rate and control the excess runoff volume. Antecedent Moisture Condition I (AMC I) will be used instead of AMC II (14). The maintenance of detention facilities is the responsibility of the developer or home association. If the developer (engineer) feels that a stormwater facility is not necessary, hydraulic and hydrologic computations to support the decision must be submitted to and approved by the City Engineer. The developer is not required to design a detention facility or submit computations if the runoff from the development is released directly to a main stream.

### **The City of Maryville**

The stormwater requirements are found in the "*Maryville Land Development and Public Works Standards*", Section 112, *DETENTION OF STORMWATER* (15). All developments are required to have an on-site detention facility to store the excess stormwater volume caused by the development. The required design storm is the 24-hour 25-year storm event. The discharge rate from the detention pond shall not exceed the discharge rate prior to development. The outlet structure shall be sized to discharge the pre-development flow rate or less. The outlet structure shall not include any mechanical devices and shall function without assistance. The outlet structures shall be designed so that the water is out of the pond within a 24-hour period. The detention storage facility shall be designed to accept runoff from the entire drainage area, regardless of ownership of land within the drainage area. Detention storage shall have adequate capacity to contain the required volume of runoff with one foot of freeboard. Provisions and allowances shall be made for accumulation and removal of silt. Emergency spillways shall be provided to allow flow to pass from storms producing more runoff than the design storm.

The designer must submit the following information for the City Engineer to approve the drainage design:

1. Runoff hydrographs
2. Stage vs. Storage and Stage vs. Discharge curves
3. Combined inflow and outflow hydrographs showing the attenuation of the post-development peak flow to the pre-development flow rate

### **City of Oak Ridge**

The stormwater requirements for the City of Oak Ridge are found in the "*Erosion Control and Stormwater Management Ordinance*", Ordinance 7-89, Section 9-420, Performance Criteria ( 15). Stormwater discharges from fully developed sites shall not exceed the discharges prior to development. Stormwater plans and calculations shall be formulated using SCS TR-55, Soil Survey of Anderson County, Erosion and Sediment Control Handbook, and the Subdivision Regulations of the City of Oak Ridge. The design shall use the Antecedent Moisture Condition I (AMC I). The post-development peak discharge from

a 25-year 24-hour storm event (5.5-in.) shall not exceed the pre-development discharge from a 10-year 24-hour storm event (4.8-in.). Emergency spillways shall be required to allow safe passage of storm events of greater magnitude than the design storm.

### **Knox County**

The design requirements for Knox County are in the Minimum Subdivision Regulations For Knoxville and Knox County, adopted by the Knoxville-Knox County Metropolitan Planning Commission July 8, 1971 and amended through July 6, 1993 (17). The design criteria does not specify a design storm and it does not give guidelines for the design and construction of detention ponds. Although Knox County does not have a written ordinance the past procedure has been to follow the City of Knoxville stormwater ordinance.

### **Town of Farragut**

The stormwater drainage requirements are found in the *Drainage Ordinance of the Town of Farragut, Tennessee* (Ord. No. 83-1, Sec 1.1) (18). The stormwater management objective for the Town of Farragut is established to reduce off-site flooding caused by development. Farragut's drainage ordinance is performance based in that there is no specified method to achieve the stormwater management objective. The only requirement is to reduce peak runoff from the 50-year storm event at post-development conditions to the 10-year storm event for pre-development conditions. The Town of Farragut must approve whatever stormwater management technique is used to control post-development runoff. A final drainage plan outlining the hydrologic conditions of the site shall be submitted for approval. The plan shall include a topographic map outlining the project site, adjacent areas, location of streams, and any stormwater facility either natural or manmade. The plan shall be accompanied by detailed calculations of pre-development and post-development runoff. An executive summary of the conditions and calculations shall be included in the drainage plan. The following information shall be submitted if a detention pond is used as the means for controlling stormwater runoff:

1. Inflow and outflow hydrographs for 50-year storm event under developed conditions.
2. Calculated 10-year storm peak flow under pre-development conditions.
3. Methods, data, criteria, and calculations for designing inlet and outlet structures.



4. Inflow and outflow hydrographs for the pond.
5. Area-capacity- elevation curves for the detention pond.
6. Discharge rating curves for outlet works.

For areas less than 25 acres the Rational Method can be used to determine peak flows. Areas greater than 25 acres require hydrographs generated by either the method described in the *SCS National Engineering Handbook*, Section 4; *SCS Technical Release 55*; or the *SCS Technical Paper 149*.

### ***IMPACT OF THE STORMWATER ORDINANCES IN THE STUDY***

The Town of Farragut has the most stringent stormwater ordinance of all of the jurisdictions in the study whereby the designer is required to provide for the 50-year storm event. All other jurisdictions in the study specify that the discharge from a newly developed site shall not exceed the pre-development peak flow for a 10-year storm event. The problem with the target 10-year design storm is that smaller storms are not considered. The control outlets are designed to restrict the post-development flow to the 10-year pre-development flow rate and when a storm event of lesser exceedance frequency occurs the runoff passes through the outlet with no attenuation of peak flow. The storms in this region of Tennessee are short and intense often render these detention ponds ineffective. Jurisdictions should consider requirements for smaller storm events such as the 2-year and 5-year storm events.

## **CHAPTER IV**

### **FIELD FINDINGS**

#### ***GENERAL***

In this study the design storm for the initial outlet (first stage) required by the respective jurisdiction was the only storm used for intent versus field comparisons and analyses. For example, if the designer designed for multi-frequency storm events, the only storm used in the analysis was the storm used to design the first stage outlet.

If the inflow hydrograph for the pond was available, HEC-1 was used to route the inflow hydrographs through the actual ponds. If inflow hydrographs were not submitted with design data, but there was enough information given to produce the hydrograph, then TR-55 was used to compute the hydrographs and HEC-1 was used to route the inflow hydrographs through the actual ponds.

Submitted design plans were compared to the intended design calculations as well as the actual field survey if design plans were submitted. The design storms for the ponds are not specified in this paper to help insure anonymity.

The control outlet discharges calculated for the "as-built" ponds occasionally differed from the discharges calculated by the original design engineer because none of the original designs allowed for flow through the outlet before it is submerged. The discharge for an orifice is calculated using the weir equation when the water depth is below or at the center of the outlet. Corrected discharge coefficients were used to calculate discharge for the designs that used incorrect discharge coefficients.

#### **DEFINITIONS**

The definitions of words that are used throughout this thesis are listed below to help the reader understand the analysis.

Intended design - The word "intended design" refers to what the design engineer calculated and expected that the design would ultimately become constructed.

Design plan drawing - The design plan drawing is the topographic site and grading drawing that the designer produced for the contractor to build the intended pond. The volume and depth represented in the design plan drawing should be equal to the design depth and required storage volume in the intended design calculations.

Actual - The word actual refers to the "as-built" condition, or what actually exists in the field and was actually built by the contractor.

Modeled/Predicted - This refers to the use of the HEC-1 model to predict the discharge, depth, and volume of the pond by routing the design storm through the "as-built" pond. Routing the design storm through the pond helps to determine the pond performance.

Under-constructed - Under-constructed means that the pond is not built according to the design plans and specifications and therefore is not performing effectively.

Over-constructed - Over-constructed means, from a performance standpoint, that the pond is built larger than intended, the pond is discharging less than the pre-development flow, or a combination of both.

Perfect Construction - Perfect construction means that the pond volume, depth, outlet, and discharge are constructed to the design plans and specifications. However, earthwork is not an exact science and TR-55 will give a 25 percent error in volume, it is noted that perfect construction is a target value rather than a requirement.

The following information documented for each pond is in Appendix:

- AX\*.1. Photographs of outlet and pond
- AX.2. Submitted design plan drawings
- AX.3. Actual field survey (as-built) drawings

- AX.4. Stage vs. Storage Relationship
- AX.5. Stage vs. Discharge Curve Relationship
- AX.6. Inflow hydrographs
- AX.7. HEC-1 hydrograph routing data input file
- AX.8. HEC-1 routing results summary page

\*(X = Pond number)

## **POND 1**

### **INTENDED DESIGN**

Pond 1, located in a 300-acre commercial development, was designed in 1995 and is classified as "old". The pond is designed to reduce the peak flow from a fully-developed 46.7-acre portion of the 300-acre site. TR-55 graphical procedure was used by the design engineer to compute the peak flows and storage volume. The pre-development peak flow is 13 cfs (cubic feet per second) and the post-development peak flow is 88 cfs.

The outlet structure is a 48-in. diameter, 10.3-ft. high manhole designed to control multiple storm events (10, 25, and 100-year events). The initial outlet was designed to be an 11.5-in. diameter orifice located at the bottom of the structure. A maximum design depth of 8.8 ft. for the inflow peak was used to design the initial outlet for a calculated storage of 2.90 acre-feet (ac.-ft.) at the maximum design depth. The dam was designed for a maximum height of 12.5 ft., a 1.5-ft. freeboard, 3H:1V side slopes, and an available storage volume of 4.67 ac.-ft.

### **ACTUAL SITE CONDITIONS**

The submitted computations are neat, orderly, and clear making it easy to determine the design intent. The stage/storage relationship was calculated incorrectly. The design plan drawings are very detailed, but there is no typical cross-section of the dam.

The dam is built across an existing drainage path. The pond is located in a cleared wooded area. However, the pond area is now covered with weeds and 4-ft. tall undergrowth. The drainage path through the pond is beginning to erode into gullies.

The orifice diameter for the as-built outlet structure is 10.5 in. The actual storage, at a depth of 8.8 ft., is 1.66 ac.-ft. The routed design storm outflow discharge is 16 cfs, causing a maximum pond depth of 9.8 ft. and a maximum storage volume of 1.99 ac.-ft. The actual measured dam height is 11.9 ft. having 3H:1V side slopes, and the storage volume at the top of the dam is 3.39 ac.-ft.

### **SUMMARY OF DISCREPANCIES AND PROBLEMS**

- The plans do not have a typical cross-section of the dam.
- Errors were made in calculating the Stage vs. Storage relationship which resulted in an incorrect design plan drawing.
- The pond bottom is eroding into gullies.
- The initial outlet orifice is constructed smaller than designed, resulting in 14.7% less area.
- The storage volume is inadequate (57% of the intended storage volume) at the maximum design depth. Pond was not built according to the design plan drawing. The design plan was incorrect, but the storage volume was constructed smaller than the storage volume represented on the design plan drawing.
- The dam is constructed 0.6 ft. lower than was intended from design information.
- The discharge from the pond is 3 cfs greater than the intended pre-development peak flow of 13 cfs. The water is spilling over into the overflow because the maximum design depth is being exceeded resulting from the outlet and storage volume being constructed smaller than intended.

### **POND 2**

#### **INTENDED DESIGN**

Pond 2, located in a residential subdivision, was designed in 1995 and is classified as "old". A drainage area of 19.1 acres was used to calculate the pre- and post-development runoff

from the site. Quick TR-55 tabular procedure was used by the design engineer to compute the peak flows and storage volume. The pre-development peak flow is 5 cfs and the post-development peak flow is 48 cfs.

The intended design of the outlet structure was a 5-ft. x 5-ft. concrete open top box 2.8 ft. high with a 12-in. diameter orifice located at the bottom of the structure. The design depth that was used to size the orifice was 2.8 ft. which corresponds to the top of the concrete box. The intended storage volume at the design depth (top of the open concrete box) was 1.1 ac.-ft. The dam was designed for a maximum height of 4.0 ft., 2.5H:1V side slopes and having an available storage volume of 1.95 ac.-ft.

### **ACTUAL SITE CONDITIONS**

The submitted computations are in a logical format, making it easy to determine the design intent. No plan drawing of the pond was submitted with the computations but a hand sketch of the pond cross-section was incorporated. An incorrect discharge coefficient was used in the calculations. The coefficient used to size the orifice was 0.60, which is for a thin plate orifice. However, the orifice is actually the thickness of the wall of the concrete box (8-in.). The correct discharge coefficient is 0.86. Correcting for the thick wall orifice, the actual discharge is expected to be about 43% greater than the calculated flow.

The pond is in excellent condition having a new stand of grass and appeared to be well maintained. The as-built outlet structure is a 5.5-ft. x 5.0-ft. concrete open top box 2.9-ft. high with a 12-in. diameter orifice for the principal outlet located at the bottom of the structure. A 48-in. diameter corrugated metal pipe (CMP) serves as the outlet pipe from the pond. The actual storage at the top of the box is 0.82 ac.-ft. The actual storage at the design depth of 2.8 ft. is 0.76 ac.-ft., about 70% of what was intended.

The routed design storm outflow discharge is 15 cfs, causing a maximum depth of 3.1 ft. and a maximum storage volume of 0.92 ac.-ft. Hence, the discharge from the pond is three

times greater than intended. The water surface elevation is 0.3 ft. higher than intended, and because of this, water is spilling over the concrete box and through the 48-in. CMP. The actual measured dam height is 3.9 ft. and the storage volume at the top of the dam is 1.38 ac.-ft.

### **SUMMARY OF DISCREPANCIES AND PROBLEMS**

- The discharge coefficient used to design the initial outlet is incorrect, which makes the orifice 41% larger than needed.
- The storage volume is inadequate at the design depth (actual = 0.76 ac.-ft. and intended = 1.1 ac.-ft.).
- The routed design storm results in a maximum depth of 3.1 ft. and the intended depth is 2.8-ft. The water depth is greater because the storage volume in the pond is smaller than the intended design.
- The routed design storm results in a peak discharge of 15 cfs and the intended discharge is 5.0 cfs, because the orifice was constructed larger than the intended design and the storage volume was constructed smaller than the intended design. The water is spilling over into the overflow.

### **POND 3**

#### **INTENDED DESIGN**

Pond 3, located in a residential subdivision, was designed in 1996 and is classified as "new". The design drainage area is 3.0 acres. TR-55 graphical procedure was used by the design engineer to compute the peak flows and storage volume. The pre-development peak flow is 0.36 cfs and the post-development peak flow is 6.40 cfs.

The outlet structure consists of an 18-in. diameter CMP with a headwall having a 6 in. orifice restrictor face plate on the upstream side. A maximum design depth of 5.0 ft. for the inflow peak was used to design the initial outlet for a calculated storage volume of 0.19 ac.-ft. at the design depth.

The dam was designed for a maximum height of 6.5 ft., 1.5 ft. of freeboard, and 2H:1V side slopes. Based on the submitted design plan drawing the intended storage available at the top of the dam was 0.27 ac.-ft. An emergency spillway was designed having a length of 5 ft. and a depth of 1 ft.

### **ACTUAL SITE CONDITIONS**

The submitted computations are sloppy and difficult to follow. The data needed for computing the inflow hydrograph was not available so the pond could not be modeled using HEC-1. The storage volume represented by design drawing is not equal to the storage volume indicated by the engineer's design calculations. The design drawings do not have a typical cross-section of the dam. The maximum peak discharge from the pond is 0.36 cfs, but the design engineer calculated an orifice size that would allow 2.1 cfs to allow for siltation.

The condition of the pond is very poor. The pond is filling up with silt from the surrounding construction site due to poor erosion control practices and, as a result, the storage volume is decreasing.

The as-built orifice diameter is 6 in. as intended, but the maximum depth in the pond to the top of the dam is 4.3 ft., 0.7 ft. less than intended for the designed outlet. The emergency spillway was not constructed. The actual measured dam height is 4.3 ft. and the storage volume at the top of the dam is 0.32 ac.-ft.

### **SUMMARY OF DISCREPANCIES AND PROBLEMS**

- The design calculations are sloppy and hard to follow. A summary outlining pre- and post-development conditions, design assumptions, and soil types was not submitted with the calculations. The calculated stage/discharge data is not included in the calculations.
- The design engineer intentionally sized the initial outlet orifice 5.8 times larger than that required to allow for siltation.
- The design calculations do not include a typical cross-section of the dam.



- The design plans do not support the design calculations. The storage volume at the maximum design depth is 0.35 ac.-ft. (design plan drawing) and 0.19 ac.-ft. (design calculations).
- The maximum measured depth in the pond is 4.3 ft. and the intended calculated depth is 5.0 ft.
- The as-built storage volume is 0.32 ac.-ft. and the intended storage volume is 0.19 ac.-ft.
- Pond is filling with silt due to poor watershed erosion control practices on the upstream construction site.
- The design storm could not be routed through the pond because the data needed to produce the post-development hydrograph was not submitted.

#### **POND 4**

##### **INTENDED DESIGN**

Pond 4, located in a residential subdivision, was designed in 1993 and is classified as "old". The drainage area used in the design is 13.2 acres. TR-55 tabular method was used by the design engineer to compute peak flows and storage volume. The pre-development peak flow is 1.0 cfs and post-development peak flow is 6.0 cfs.

The intended outlet structure was a 3-ft. x 2-ft. square x 5.9 ft. high concrete box with a grate on top of the box. The principal outlet in the bottom of the box was designed as a 15-in. diameter CMP having a 4-in. diameter orifice restrictor face plate on the upstream end. A maximum depth of 4.9 ft. (1 ft. below the top of the concrete box) for the inflow peak was used to design the initial outlet for a calculated storage volume of 0.40 ac.-ft.

The dam was designed for a maximum height of 8.9 ft. and an available storage volume of 1.54 ac.-ft. However, the submitted plan drawing indicated 0.16 ac.-ft. of available storage volume.

## **ACTUAL SITE CONDITIONS**

The calculations for the detention pond were submitted along with calculations for a large subdivision which made it difficult to locate the specific calculations for the pond. However, the calculations are neat and easy to follow. The design plan drawing indicates a storage volume of 0.16 ac.-ft. at the top of the dam, but the design calculations show 1.54 ac.-ft. available at the top of the dam.

The pond is well maintained and is covered with grass. A concrete ditch runs through the center from a 30-in. CMP to the outlet structure.

The as-built outlet is a 12-in. diameter CMP at the bottom of a 3-ft. x 2-ft. concrete box with a grate on top of the box. The box is 6.1 ft. high from the invert of the 12-in. diameter CMP to the top of the concrete box. The actual volume at the design depth is 0.64 ac.-ft. The routed design storm outflow discharge is 6.0 cfs, causing a maximum pond depth of 2.6 ft. The actual measured dam height is 5.6 ft., and the storage volume at the top of the dam is 0.89 ac.-ft.

## **SUMMARY OF DISCREPANCIES AND PROBLEMS**

- The design plans do not support the design calculations. The storage volume at the maximum design depth is 0.16 ac.-ft. (design plan drawing) and 1.54 ac.-ft. (design calculations).
- The as-built principal outlet is a 12-in. CMP but the intended outlet was a 15-in. diameter CMP having a 4-in. diameter orifice restrictor face plate. The net result is that the pre-development peak flow is being exceeded.
- The routed design storm results in a peak discharge of 6.0 cfs, causing a maximum depth of 2.6 ft. and a storage volume of 0.89 ac.-ft., but the intended discharge is 1.0 cfs at a depth of 4.9 ft. and a storage volume of 0.40 ac.-ft. The discharge is greater than the pre-development peak flow because the outlet was constructed larger than specified by the design plans.
- The actual measured dam height is 5.6 ft., but the intended dam height is 8.9 ft.

## **POND 5**

### **INTENDED DESIGN**

Pond 5, located in a commercial development, was designed in 1994 and is classified as "old". The drainage area used in the design is 1.17 acres. TR-55 graphical procedure was used by the design engineer to compute peak flows and storage volume. The pre-development peak flow is 1.0 cfs and post-development peak flow is 7.34 cfs. The outlet is an 18-in. diameter CMP riser pipe with a 6-in. CMP at the bottom for the principal outlet. The 18-in. riser serves as the overflow and was designed to be 4.5 ft. high with an anti-vortex device made of a 24-in. diameter CMP over the 18-in. opening. A maximum design depth of 4.5 ft. for the inflow peak was used to design the initial outlet for a calculated storage volume of 0.20 ac.-ft. at the design depth.

The dam was designed for a maximum height of 6.5 ft. and an available storage volume of 0.45 ac.-ft.

### **ACTUAL SITE CONDITIONS**

The calculations are orderly and easy to follow. Calculations include a brief summary of existing and proposed conditions and a plan drawing of the layout of the proposed pond. However, the design plan drawing and design calculations show available storage volumes at the top of the dam to be 0.38 and 0.45 ac.-ft. respectively. The design engineer calculated an orifice size that will discharge twice the pre-development peak flow rate to allow for maintenance.

The pond is along a main roadway is in front of a business and is very well maintained. The actual height of the riser pipe is 2.9 ft., 1.6 ft. lower than the designed height of 4.5 ft. so that water will enter the 18-in. riser before the design depth is reached. The storage volume at the top of the structure is 0.03 ac.-ft. and the storage volume at the maximum design depth of 4.5 ft. (1.6 ft. above the overflow) is 0.09 ac.-ft.

The routed design storm outflow discharge is 6.0 cfs, causing a maximum pond depth of 3.3 ft. and a maximum storage volume of 0.04 ac.-ft. As mentioned above, the 18-in. riser designed as an overflow for more intense storms is 2.9 ft. high. Therefore, water is entering the overflow, which results in increased discharge. The actual measured dam height is 7.5 ft., and the storage volume is 0.32 ac.-ft.

#### **SUMMARY OF DISCREPANCIES AND PROBLEMS**

- The design plan drawing does not support the design calculations. There is a 14.6% difference in the storage volume at the top of the dam between the design plan drawing and the design calculations.
- The design computations lacked the calculated stage/discharge data.
- The design engineer calculated an orifice size that will discharge twice the pre-development flow rate.
- The outlet structure is constructed 1.6 ft. lower than designed.
- The storage volume at the maximum design depth is 55% smaller than intended.
- The discharge is six times greater than the pre-development peak flow of 1 cfs, because the volume is constructed smaller than intended and the overflow is constructed 1.6 ft. lower than the intended design plans.
- The actual measured dam height is 1.0 ft. higher than the intended dam height of 6.5 ft.

#### **POND 6**

##### **INTENDED DESIGN**

Pond 6, located in a commercial development, was designed in 1991 and is classified as "old". It consists of two basins connected in series by an 18-in. diameter CMP 110 ft. in length. The drainage area used in the design is 0.94 acres. TR-55 graphical procedure was used by the design engineer to compute peak flows and storage volume. The pre-development peak flow is 3.0 cfs and post-development peak flow is 7.24 cfs.

The outlet structure is an 18-in. diameter CMP having a 9-in. diameter orifice restrictor face plate on the upstream end as the principal outlet. A 3-ft. long x 1-ft. high emergency spillway was designed. A maximum depth of 1.9 ft. for the peak inflow was used to design the principal outlet for a calculated storage volume of 0.1 ac.-ft. The storage volume is divided between the two basins. The dam was designed for a maximum height of 5.0 ft. and 3H:1V side slopes.

### **ACTUAL SITE CONDITIONS**

The submitted data did not contain a summary describing the pre- and post-development conditions and the intended design. Computations for time of concentration were not submitted. Soil types, slopes, and ground cover of the area were not submitted. The design depth was not clear in the computations but appears to be 1.9 ft. The submitted design plan drawing was not to scale, so it could not be used in comparison to the design calculations and the actual field conditions.

The pond is very well maintained and landscaped. It has 3-ft. wide concrete ditches in the bottom of both basins.

The actual outlet is a 9-in. x 9-in. square, but the intended outlet is a 9-in. diameter orifice. The actual opening area of the outlet is 0.56 sq. ft., and the intended area is 0.44 sq. ft., resulting in the actual outlet being 27% larger than the intended orifice. The second basin contains the outlet structure and emergency spillway.

The first pond has a dam height that is 1.3 ft. *lower* than the emergency spillway, which indicates the first pond will overtop before the water reaches the emergency spillway. The actual measured dam height is only 2.8 ft. instead of the intended 5.0 ft. The measured storage volume at the design depth is 0.01 ac.-ft. The storage volume at the top of the dam (the dam of the first pond is used because it will overtop before the second dam) is 0.03 ac.-ft. The routed design storm outflow discharge is 6 cfs, before the pond overtops.

## **SUMMARY OF DISCREPANCIES AND PROBLEMS**

- The submitted computations were lacking specific design data( e.g., pre- and post-development inflow hydrographs, outflow hydrograph from the pond, stage/ storage and stage/ discharge curves). A summary outlining pre- and post-development conditions, design assumptions, and soil types was not submitted with the calculations.
- The design plan drawing was not to a specific scale and a typical cross-section of the dam was not submitted.
- The dam height is 2.2 ft. lower than intended.
- The outlet is 0.56 sq. ft. and the intended is 0.44 sq. ft.
- The routed design storm overtops the pond because the dam is constructed 2.8 ft. lower than intended.

## **POND 7**

### **INTENDED DESIGN**

Pond 7, located in a commercial development, was designed in 1995 and is classified as "old". The drainage area used in the design is 1.59 acres. The Rational method was used by the design engineer to compute peak flows and storage volume. The method for calculating required detention storage was not specified. The pre-development peak flow is 1.9 cfs and post-development peak flow is 8.3 cfs.

The outlet structure is designed as a pre-cast concrete catch basin (3-ft. x 3-ft. x 3-ft. high) with a grate on top for the overflow. The principal outlet was designed as a 0.15-ft. wide slot weir extending from the bottom of the pond to the top of the structure on one side of the catch basin. The 0.15-ft. wide slot weir is described and analyzed as a "broad crested" weir. A maximum design depth of 2.9 ft. for the peak inflow was used to design the principal outlet for a calculated storage volume of 0.11 ac.-ft. The dam was designed for a maximum height of 5.0 ft. and 3H:1V side slopes.

## **ACTUAL SITE CONDITIONS**

The submitted design data contained computer printouts of flow rates and detention volumes but no explanation or drawings illustrating the pre- and post-development site conditions. The cross-section of the pond was detailed, but the plan drawing was not to any scale. A comparison of plan drawing to intended design and as-built could not be made. An inflow hydrograph was not available so the hydraulic performance could not be modeled.

The pond was built recently and has a fresh stand of grass on the side slopes and a 3-ft. wide concrete swale through the length of the pond. The as-built outlet structure is a 4-ft. x 4-ft. x 3.1-ft. high concrete box with a 0.21-ft. wide slot weir on one side of the box extending from the bottom of the pond to the top of the structure. References for coefficients for calculating flow through narrow slots could not be found and the designer gave no indication or reference for the assumptions used to calculate the flow or size the slot. The designer modeled the slot as a broad crested weir but this is not correct. One problem when using a contracted weir equation to calculate flow for a narrow slot is that the calculations may result in negative flows.

The actual storage volume at a depth of 2.9 ft. is 0.06 ac.-ft., which is about half of the intended 0.11 ac.-ft. The measured dam height is 4.1 ft. and the storage volume at the top of the dam is 0.14 ac.-ft. The intended volume available at the top of the dam was not given, and the plan drawing was not to any scale from which it could be determined.

## **SUMMARY OF DISCREPANCIES AND PROBLEMS**

- The design calculations included computer printouts only. A summary outlining pre- and post-development site conditions, design assumptions, design references, and soil types were not submitted with the calculations. The stage/storage and stage/discharge calculated data does not extend to the top of the dam.
- The design plan drawing was not to any scale.
- The outlet was designed incorrectly. The 0.15-ft wide slot weir was modeled as a "broad crested" weir.
- The slot was constructed 1.4 times wider than the intended design.

- The storage volume is inadequate at the design depth, the actual volume is 0.06 ac.-ft., but the intended volume is 0.11 ac.-ft.
- The design storm could not be routed through the pond because the data needed to produce the post-development inflow hydrograph was not submitted.

## **POND 8**

### **INTENDED DESIGN**

Pond 8, located in a commercial development, was designed in 1994 and is classified as "old". TR-55 graphical procedure was used by the design engineer to compute peak flows and storage volume. The pre-development peak flow is 10.3 cfs and post-development peak flow is 18.3 cfs.

The outlet structure is a 12-in. CMP culvert (assuming outlet control). A 9.6-ft. long x 0.9-ft. deep emergency spillway was designed. A maximum design depth of 5.7 ft. for the peak inflow was used to design the initial outlet for a calculated storage volume of 0.23 ac.-ft. at the design depth. The dam was designed for a maximum height of 5.7 ft.

### **ACTUAL SITE CONDITIONS**

Submitted design data consists of TR-55 work sheets and hydraulic calculations for outlets. Descriptions of pre- and post-development site conditions were not given. The designer assumed outlet control for the culvert design but did not specify a tailwater condition. The pond depth that the designer used to size the outlet structure was 5.7 ft. At that depth, water will be discharging through the emergency spillway and the intended control outlet. The computations appear to have been carelessly done.

The pond is well maintained. It has a 3-ft. wide concrete swale running through the length of the pond.

The as-built outlet is a 15-in. diameter corrugated black plastic pipe with a 10-in. diameter orifice restrictor face plate attached inside the pipe. The pipe will always have water in it



because the orifice is at the top of the pipe rather than at the invert of the pipe. The design of the orifice is not in the design calculations. The orifice plate was added later because the downstream resident was complaining about excess water being discharged onto the property. The emergency spillway is 9 ft. wide and 0.92 ft. deep.

The maximum pond depth at the design flow was 5.7 ft., but the pond is only 2.8 ft. deep to the top of the dam. The storage volume available at the top of the dam is 0.06 ac.-ft., 26 percent of that intended. The routed design storm outflow discharge is 15.0 cfs before the pond overtops.

### **SUMMARY OF DISCREPANCIES AND PROBLEMS**

- A summary outlining pre- and post-development conditions, design assumptions, stage/storage, stage/discharge and soil types was not submitted with the calculations. Poor design assumptions were employed, and calculations were carelessly performed.
- A design plan and a typical cross-section of the dam were not submitted.
- The maximum design depth is 5.7 ft. but the pond has an actual depth of 2.8 ft. to the top of the dam because the pond is not constructed according to the intended design. The net result is inadequate storage volume so that the pond overtops during the design storm.
- The actual measured dam height is 2.9 ft. lower than the intended dam height.
- The downstream landowner is unhappy about the amount of water being discharged onto his property.

### **POND 9**

#### **INTENDED DESIGN**

Pond 9, located in a residential development, was designed in 1992 and is classified as "old". The drainage area used in the design is 16.4 acres. TR-55 tabular procedure was used by the design engineer to compute peak flows and storage volume. The pre-development peak flow is 7 cfs and post-development peak flow is 31 cfs.

The outlet is an 18-in. CMP having a 12-in. diameter orifice restrictor face plate on the upstream end. A 30-ft. long x 1-ft. deep emergency spillway was designed. The emergency spillway was designed to be approximately 12 ft. to the left of the outlet pipe. A maximum design depth of 4.0 ft. for the peak inflow was used to design the principal outlet for a calculated storage volume 1.1 ac.-ft. at the design depth.

The dam was designed for a maximum height of 5.0 ft., 2H:1V side slopes, and an available storage volume of 1.34 ac.-ft.

### **ACTUAL SITE CONDITIONS**

The calculations are in a logical format, and assumptions are stated for pre- and post-development conditions. The calculations included a soils map, a map of the drainage basin, a detailed cross-section of the pond and outlet structure, stage/storage and stage/discharge information, and hydraulic calculations for the outlets. However, the available storage volume at the top of the dam calculated from the design plans is 0.66 ac.-ft., but the design data shows 1.34 ac.-ft. The pond is in a condominium complex and is well maintained.

The as-built outlet is an 18-in. diameter CMP and a 5-in. diameter orifice restrictor face plate on the upstream end. The design calculations indicate a 12-in. diameter orifice. The emergency spillway is 3 ft. long x 0.2 ft. deep and was constructed directly over the outlet pipe. The pond is 3.8 ft. deep and is 1.2 ft. less than the intended design depth.

The routed design storm outflow discharge for design conditions is 20 cfs. The routed design storm overtops the dam. A resident of the complex has seen the pond overtop. The available storage at the top of the dam is 0.54 ac.-ft.

### **SUMMARY OF DISCREPANCIES AND PROBLEMS**

- The design plans do not support the design calculations. The storage volume at the maximum design depth is 0.75 ac.-ft. (design plan drawing) and 1.10 ac.-ft. (design calculations).

- The outlet structure is not constructed according to design plans. The outlet is a 5-in. diameter orifice restrictor face plate on the upstream end of an 18-in. diameter CMP but, the intended orifice plate is a 12-in. diameter orifice.
- The emergency spillway was intended to be 30 ft. long x 1 ft. deep, but it is 3 ft. long x 0.2 ft. deep and it was not constructed in the location indicated on the design plans.
- The maximum design depth is 4.0 ft. but the pond has an actual depth of 3.8 ft. to the top of the dam. The net result is inadequate storage volume so that the pond overtops during the design storm.
- The dam is 1.2 ft. lower than designed.

## **POND 10**

### **INTENDED DESIGN**

Pond 10, located in a commercial development, was designed in 1996 and is classified as "new". The drainage area used in the design is 2.75 acres. The TR-55 graphical procedure was used by the design engineer to compute peak flows and storage volume. The pre-development peak flow is 0.23 cfs, and post-development peak flow is 2.00 cfs.

The outlet structure is designed to have a 2.5-in. diameter orifice restrictor face plate and a 6-in. diameter CMP overflow pipe. The design calculations specify a 3-ft. long x 1-ft. deep emergency spillway. A maximum design depth of 2.0 ft. for the peak inflow was used to design the initial outlet for a calculated storage volume of 0.1 ac.-ft.

### **ACTUAL SITE CONDITIONS**

Submitted design data consist of TR-55 computation computer printouts, a post-development topographic map of the site, and hydraulic calculations for outlets. The design drawing is difficult to read, because it was a very poor xerox copy, and a detailed drawing of the proposed outlet structure was not submitted.

The pond has been recently built and there is nothing to keep silt from the surrounding construction site out of the pond. The as-built outlet structure is a 3-ft. x 3-ft. brick box

3.75 ft. high with a 9-in. vertical slot on one side. The outlet pipe from the box is an 18-in. diameter CMP. The actual storage at a depth of 2 ft. is 0.04 ac.-ft., which is 40 percent of the intended storage volume of 0.1 ac.-ft.

The routed design storm outflow discharge is 1.0 cfs, causing a maximum pond depth of 0.8 ft. The peak outflow is five times greater than the intended design peak outflow.

The actual measured dam height is 3.8 ft. with an available storage volume of 0.15 ac.-ft. The design plan drawing indicates a dam height of 3 ft. and a storage volume of 0.19 ac.-ft.

### **SUMMARY OF DISCREPANCIES AND PROBLEMS**

- The design calculations do not have a summary describing the pre- and post-development conditions. The design plan drawing is difficult to read. Stage/storage and stage/discharge data were not submitted.
- The outlet structure is not constructed to design plans. The intended design is a 6-in. overflow pipe with a 2.5-in. diameter orifice restrictor plate, but the as-built outlet structure is a 3-ft. x 3-ft. brick box with a 9-in. wide x 3.75 ft. high vertical slot on one side of the box. The emergency spillway was not constructed.
- The storage volume at the design depth of 2 ft. is 0.04 ac.-ft.
- The routed design storm results in a maximum pond depth of 0.8 ft. causing, a storage volume of 0.01 ac.-ft., and a discharge 5 times greater than the pre-development, because the outlet is constructed larger than intended.

### **POND 11**

#### **INTENDED DESIGN**

Pond 11, located in a commercial development, was designed in 1992 and is classified as "old". The drainage area used in the design is 24 acres. TR-55 graphical procedure was used by the design engineer to compute peak flows and storage volume. The pre-development peak flow is 8.0 cfs and the post-development peak flow is 13.6 cfs.

The intended outlet structure was an 18-in. diameter CMP having a 13-in. diameter orifice restrictor face plate on the upstream end. A maximum design depth of 3.5 ft. for the inflow peak was used for sizing the principal outlet at a calculated storage of 0.20 ac.-ft. at the design depth. The emergency spillway is a grass swale 5 ft. wide x 2 ft. deep. The dam was designed for a maximum height of 5.5 ft., a 2-ft. freeboard, 2H:1V side slopes, and an available storage volume of 0.38 ac.-ft.

### **ACTUAL SITE CONDITIONS**

The submitted computations are neat, orderly, and clear, making it easy to determine the design intent. No errors were found in design computations. The computations did not have a summary describing the pre- and post-development conditions. A typical cross-section of the dam was not submitted with the design plan drawings. The volume calculated from the design drawing indicates 0.46 ac.-ft. of storage volume and the design calculations show 0.38 ac.-ft. of available storage volume at the top of the dam.

The detention pond is divided by an entrance driveway, so the storage volume is separated between two ponds connected in series with 30 ft. of 18-in. diameter reinforced concrete pipe (RCP). The second basin contains the outlet structure.

The as-built outlet structure is an 18-in. diameter CMP with a head wall. The 13-in. diameter orifice restrictor face plate and the emergency spillway were not constructed. The actual storage at a design depth of 3.5 ft. is 0.16 ac.-ft.

The routed design storm outflow discharge is 11 cfs, corresponding to a maximum pond depth of 2.5 ft., and a maximum storage volume of 0.07 ac.-ft. The actual measured dam height is 4.3 ft., and the storage volume at the top of the dam is 0.24 ac.-ft.

### **SUMMARY OF DISCREPANCIES AND PROBLEMS**

- The design plans are not supported by the design calculations. The storage volume at the maximum design depth is 0.46 ac.-ft. (design plan drawing) and 0.38 ac.-ft. (design calculations).

- The storage at the maximum design depth is 0.16 ac.-ft.
- The intended orifice restrictor face plate and the emergency spillway as given in the design calculations and plans were not constructed. The net effect of this combined with inadequate storage volume is that the pre-development peak flow of 8 cfs is being exceeded.

## **POND 12**

### **INTENDED DESIGN**

Pond 12, located in a residential subdivision, was designed in 1992 and is classified as "old". The drainage area used in the design is 13.4 acres. TR-55 graphical procedure was used by the design engineer to compute peak flows and storage volume. The pre-development peak flow is 30.0 cfs and the post-development peak flow is 54.0 cfs.

The intended outlet structure is an 18-in. diameter CMP. The design engineer assumed inlet control to calculate the discharge. A maximum design depth of 7.0 ft. for the inflow peak was used to size the principal outlet for a calculated storage of 0.75 ac.-ft. at the design depth. A 13-ft. long x 1.5 ft. deep concrete emergency spillway was designed. The dam was designed for a maximum height of 8.5 ft. and 2H:1V side slopes.

### **ACTUAL SITE CONDITIONS**

The design calculations are disorganized and difficult to follow. Changes were apparently made on the calculations and the designer wrote the changes beside the original calculation pages. The calculations are difficult to interpret. A design drawing was not submitted, but a very poor xerox copy of the subdivision layout with unclear contours was submitted. The copy of the site has a circle indicating the location of the proposed detention pond and inside the circle the designer wrote the storage volume (32,880 ft<sup>3</sup>) required for the design storm.

The pond is landscaped with trees around the edges. The grass on the side slopes of the pond and on the pond bottom is about 10 inches high. The 30-in. diameter CMP inlet to the pond has about 12 inches of silt in the bottom of the pipe from the upper construction site erosion.

The actual as-built outlet is an 18-in. diameter black corrugated plastic pipe (HDP) with a flared end section. The actual storage at the design depth of 7.0 ft. is 0.83 ac.-ft. The as-built concrete emergency spillway is 9.8 ft. long x 1.0 ft. deep.

The actual measured dam height is 8.2 ft., and the storage volume at the top of the dam is 1.24 ac.-ft. The routed design storm discharge is 19 cfs, corresponding to a maximum pond depth of 2.5 ft. and a maximum storage volume of 0.47 ac.-ft.

### **SUMMARY OF DISCREPANCIES AND PROBLEMS**

- The design calculations were very sloppy, making the review difficult.
- A design plan drawing and typical cross-section of the dam were not submitted.
- The stage/storage and stage/discharge curves were not submitted.
- The as-built volume is 10.6% larger than intended, resulting in a potential waste of valuable property and developer expense.
- The emergency spillway is constructed 3.2 ft. smaller than the intended spillway, resulting in decreased capacity and overtopping potential.
- The routed design storm results in a peak discharge of 19 cfs, corresponding to a maximum pond depth of 2.5 ft. and a storage volume of 0.47 ac.-ft. The analysis indicates that the pond is over-sized.

### **POND 13**

#### **INTENDED DESIGN**

Pond 13, located in a commercial development, was designed in 1988 and is classified as "old". The drainage area used in the design is 24.8 acres. The TR-55 tabular procedure was used by the design engineer to compute peak flows and storage volume. The pre-development peak flow is 49.0 cfs and the post-development peak flow is 144.0 cfs.

The designed outlet is a 24-in. diameter CMP assuming inlet control. A maximum design depth of 4.0 ft. for the peak inflow was used to design the initial outlet for a calculated storage of 3.73 ac.-ft. at the design depth. The design plans for the pond show a 24-in.

diameter perforated CMP riser for sediment control during construction. Later, a decision was made to leave it in place as part of the outlet control. An emergency spillway 32 ft. long x 1.5 ft. high was designed. The dam was designed for a maximum height of 4.0 ft. and 2H:1V side slopes.

### **ACTUAL SITE CONDITIONS**

The submitted design computations were neat, orderly, and clear. There were no computations provided for the 24-in. diameter riser. The design plan drawings and typical cross-section of the dam are very detailed.

The pond is receiving runoff from a large store and strip shopping center. The pond is grown up with weeds and undergrowth 4 ft. tall, and it is apparent the pond is not maintained regularly. The outlet structure opening is clogged with sticks and other debris.

The actual as-built outlet structure is a 24-in. diameter perforated CMP riser. The actual storage at the design depth of 4.0 ft. is 0.85 ac.-ft. The as-built emergency spillway is 15.5 ft. long x 0.5 ft. high. The actual measured dam height is 6.4 ft. and the storage volume at the top of the dam is 2.38 ac.-ft. The routed design storm outflow discharge is 102 cfs, which would cause the dam to be overtopped.

### **SUMMARY OF DISCREPANCIES AND PROBLEMS**

- The design calculations do not support the need for a 24-in. diameter perforated riser.
- The actual storage volume at the design depth of 4 ft. is 22.7% of the intended storage volume.
- The emergency spillway is not constructed by the intended design.
- The maximum dam height is 6.4 ft., but the intended dam height is 4.0 ft., but the storage volume is less than designed.
- The dam will overtop at the design storm, because of inadequate constructed storage volume.



## **POND 14**

### **INTENDED DESIGN**

Pond 14, located in a commercial development, was designed in 1996 and is classified as "new". The drainage area used in the design is 26 acres. The TR-55 tabular procedure was used by the design engineer to compute peak flows and storage volume. The pre-development peak flow is 7.76 cfs, and the post-development peak flow is 76.0 cfs.

The designed outlet is a 4 ft. x 4 ft. square x 4 ft. high concrete box with a triangular weir (2.5° notch) attached to the upstream side of the box. The downstream side of the outlet structure is a 15-in. diameter RCP having a 10-in. diameter orifice restrictor face plate. A maximum design depth of 9.0 ft. for the peak inflow was used to design the initial outlet for a calculated storage of 4.0 ac.-ft. at the design depth. The dam was designed for a maximum height of 9 ft., 2.5H:1V side slopes and an available storage volume of 4.0 ac.-ft.

### **ACTUAL SITE CONDITIONS**

The design calculations are very difficult to follow. The designer submitted approximately 90 pages of computer printouts with no summary explaining the design logic and methodology. The design plan drawings are very detailed showing the proposed contours and the outlet structure.

The pond has rill erosion around the side slopes because of the lack of slope stabilization. The outlet is clogged with trash and debris.

The as-built inlet for the pond collects runoff from a parking lot. It is a 5 ft. x 5 ft. x 4 ft. high brick box with no outlet. The runoff is conveyed into the box through a 48-in. diameter RCP. For the water to enter the pond it has to fill the box and over flow into the pond. The box stays full of water because it has no outlet or drain in the bottom.

The as-built outlet structure is a 5 ft. x 5 ft. x 3.7 ft. high with a triangular weir plate (2.5° notch) attached to the upstream side of the box. Inside the box on the outlet end is

a 10-in. diameter orifice face plate. The routed design storm outflow is 59.0 cfs, causing the pond to overtop. The actual measured dam height is 6.1 ft. and the storage volume at the top of the dam is 2.7 ac.-ft.

### **SUMMARY OF DISCREPANCIES AND PROBLEMS**

- The design engineer submitted approximately 90 pages of computer printouts without a summary explaining the design.
- The discharge coefficients for the weir are not listed.
- The main inlet to the pond is a 5 ft. x 5 ft. brick box with no drain or outlet in the bottom to release water, so the box stays full of water.
- The invert of the outlet is higher than the pond bottom which is causing water to stand in the bottom of the pond and the pond side slopes are eroding to rills.
- The outlet weir is clogged with debris resulting in decreased capacity of the outlet.
- The as-built storage volume to the top of the dam is 52% of the intended 4.0 ac.-ft.
- The as-built dam height is 68% of the intended 9.0 ft. dam height.
- The routed peak outflow overtops the pond because the constructed storage volume is inadequate.
- Downstream residents are complaining about the pond holding water for long periods.

### **POND 15**

#### **INTENDED DESIGN**

Pond 15, located in a residential development, was designed in 1994 and is classified as "old". The drainage area used in the design is 16 acres. TR-55 tabular procedure was used by the design engineer to compute peak flows and storage volume. The pre-development peak flow is 6.0 cfs, and the post-development peak flow is 25.0 cfs.

The outlet structure is a 48-in. diameter manhole 4.7 ft. high with an 11-in. diameter orifice at the bottom of the structure on the upstream side and a 30-in. diameter CMP at the outlet side. An emergency spillway 20 ft. long and 1.3 ft. high is designed. The required storage

volume for the design storm is 0.4 ac.-ft. The dam was designed for a maximum height of 6.0 ft., 2.5H:1V side slopes, and an available storage volume of 0.59 ac.-ft.

### **ACTUAL SITE CONDITIONS**

The submitted design computations were neat, orderly, and clear. However, the design engineer calculated a maximum peak discharge of 6.0 cfs and a storage volume of 0.4 ac.-ft. but then routed the design storm and calculated a discharge of 6.9 cfs and a storage volume of 0.33 ac.-ft. The designer did not adjust the design to meet the design requirements. The maximum design depth is not specified.

The maximum storage volume at the top of the dam is 0.76 ac.-ft. (design plan drawing), is 0.76 ac.-ft. but the maximum storage volume at the top of the dam is 0.59 ac.-ft. (design calculations).

The pond bottom is eroding into gullies and sediment is entering the pond from the upstream construction. The as-built outlet structure is a 48-in. diameter manhole with an 11-in. diameter orifice at the bottom of the structure on the upstream side and a 30-in. diameter CMP on the outlet side. The actual measured dam height is 6.3 ft. and the storage volume at the top of the dam is 0.31 ac.-ft. The routed design storm peak outflow is 20.0 cfs, causing a maximum pond depth of 5.1 ft. and a maximum storage volume of 0.16 ac.-ft.

### **SUMMARY OF DISCREPANCIES AND PROBLEMS**

- The design engineer calculated a maximum peak discharge of 6.0 cfs and then calculated a routed peak discharge of 6.9 cfs.
- The design engineer calculated a required volume of 0.4 ac.-ft. and then calculated a routed volume of 0.33 ac.-ft.
- The actual available storage volume at the top of the dam is 0.31 ac.-ft. but the intended storage at the top of the dam is 0.59 ac.-ft. (design calculations) and 0.76 ac.-ft. (design plan drawing). The design plan drawing does not support the intended design.
- The pond is receiving sediment from the upstream construction.

- The bottom of the pond is eroding into gullies and the sediment is being discharged downstream.
- The routed peak outflow is 3.3 times greater than the intended 6.0 cfs because the constructed storage volume is inadequate, therefore the maximum design depth is being exceeded and water is discharging through the over flow.

## **POND 16**

### **INTENDED DESIGN**

Pond 16, located in a residential development, was designed in 1996 and is classified as "new". The drainage area used in the design is 2.8 acres. The rational method was used by the design engineer to compute peak flows and storage volume. The pre-development peak flow is 5.9 cfs and the post-development peak flow is 9.7 cfs.

The designed outlet structure is a 3 ft. x 3 ft. x 3.5 ft. high pre-cast or cast in-place concrete box with a grate on top, an 8-in. diameter orifice on the upstream side and a 30-in. diameter CMP at the outlet side. The required storage volume for the design storm is 0.12 ac.-ft. having a maximum depth of 1.3 ft.

### **ACTUAL SITE CONDITIONS**

The submitted design computations were neat, orderly, and clear. However, the orifice discharge was calculated assuming outlet control and using the culvert equation. The actual discharge for the orifice is calculated using the orifice equation and a discharge coefficient of 0.86, and the overflow into the manhole is calculated using the weir equation and a discharge coefficient of 3.33. The design plan drawing of the outlet structure and detention pond is very detailed. The intended stage/storage relationship is calculated from the design plan since it is not given in the design calculations.

The pond has been seeded and mulched and has a new stand of grass. It appears to be very well maintained.

The as-built outlet structure is a 60-in. diameter manhole with a 7-in. diameter orifice at the bottom of the structure on the upstream side and an 18-in. diameter RCP on the outlet side. The actual measured storage volume at the maximum design depth of 1.3 ft. is 0.02 ac.-ft. The maximum storage volume calculated from the design plan drawing is 0.31 ac.-ft. at the top of the dam but the actual measured storage volume at the top of the dam is 0.18 ac.-ft. The actual measured dam, height is 3.5 ft., and the maximum dam height calculated from the design plan drawing is 4.5 ft. The routed design storm peak outflow is 10.0 cfs, causing a maximum pond depth of 2.7 ft. and a maximum storage volume of 0.13 ac.-ft.

### **SUMMARY OF DISCREPANCIES AND PROBLEMS**

- The design plan drawing did not include a typical cross-section of the dam.
- The outlet is designed as a culvert, but it is an orifice.
- The actual storage volume at the design depth is 0.02 ac.-ft. and the intended storage volume at the design depth is 0.12 ac.-ft.
- The actual routed discharge is 10 cfs, but the intended pre-development discharge is 5.9 cfs. The constructed storage volume is inadequate, therefore the maximum design depth is being exceeded and the head on the orifice is greater resulting in an increase in flow.

### **POND 17**

#### **INTENDED DESIGN**

Pond 17, located in a residential development, was designed in 1996 and is classified as "new". The drainage area used in the design is 5.2 acres for the pre-development condition and 10.3 acres for the post-development condition. The rational method was used by the design engineer to compute peak flows and storage volume. The pre-development peak flow is 11.6 cfs and the post-development peak flow is 52.6 cfs.

The designed outlet structure is a 3-ft. x 3-ft. x 6.5-ft. high pre-cast concrete catch basin with a grate on top, a triangular notch weir ( $\theta = 7.2^\circ$ ) bolted to the upstream side, and an 18-in. diameter CMP on the downstream side. A chain link fence is designed around the upstream

side of the catch basin in front of the weir. The required storage volume for the design storm is 1.88 ac.-ft. having a maximum depth of 5.7 ft.

### **ACTUAL SITE CONDITIONS**

The submitted design computations were neat, orderly, and clear. However, the design engineer used  $\theta = 20^\circ$  and a discharge coefficient of 0.6. The actual discharge for the triangular weir is calculated using a discharge coefficient of 0.61 and the overflow into the top of the catch basin is calculated using the weir equation and a discharge coefficient of 3.33.

The pond has been seeded and mulched recently. The as-built outlet structure is a 3-ft. x 3-ft. x 5.6-ft. high pre-cast catch basin with a grate on top and a  $7.5^\circ$  notch triangular weir plate attached to the upstream side. The chain link fence around the upstream side of the outlet structure was not constructed.

The actual measured storage volume at the maximum design depth of 5.7 ft. is 0.24 ac.-ft., but the intended storage volume is 1.88 ac.-ft.

The maximum storage volume at the top of the dam is 1.25 ac.-ft. (design plan drawing) versus 2.75 ac.-ft. (design calculations). The actual measured storage volume to the top of the dam is 0.39 ac.-ft.

The actual measured dam height is 6.9 ft., but the design plan drawing indicates 7.5 ft. and the design calculations show 8.0 ft. for the maximum dam height.

The routed design storm peak outflow is 47.0 cfs, causing a maximum pond depth of 6.4 ft. and a maximum storage volume of 0.33 ac.-ft.

### **SUMMARY OF DISCREPANCIES AND PROBLEMS**

- The design engineer used a discharge coefficient for a  $20^\circ$  triangular notch weir but the weir has a notch of  $7.5^\circ$ .

- Design calculations and the design plan drawing indicated storage volumes at the top of the dam of 2.75 and 1.25 ac.-ft. respectively.
- The actual maximum storage volume at the top of the dam is 0.39 ac.-ft.
- The actual routed discharge is 47 cfs causing, a maximum depth of 6.4 ft. and a storage volume of 0.33 ac.-ft. The excess discharge is caused from inadequate constructed storage volume.

## **POND 18**

### **INTENDED DESIGN**

Pond 18, located in a commercial development, was designed in 1994 and is classified as "old". The drainage area used in the design is 2.85 acres. TR-55 graphical procedure was used by the design engineer to compute peak flows and storage volume. The pre-development peak flow is 1.0 cfs and the post-development peak flow is 7.0 cfs.

The designed outlet structure is an 18-in. diameter riser with a 6-in. diameter orifice face plate attached to the upstream end. The required storage volume for the design storm is 0.3 ac.-ft. The maximum design depth is unclear. The maximum intended dam height is 3.0 ft. having a maximum storage volume of 0.37 ac.-ft.

### **ACTUAL SITE CONDITIONS**

The submitted design computations were neat, orderly, and clear with a complete summary of the design intent. The pond is very well maintained. The as-built outlet structure is an 18-in. diameter CMP riser 2 ft. high with a trash rack, an anti-vortex device, and a 6-in. diameter orifice face plate attached at the bottom of the riser. The actual measured storage volume at the maximum design depth of 1.4 ft. is 0.06 ac.-ft., but the intended storage volume is 0.37 ac.-ft.

The maximum storage volume calculated from the design plan drawing is 0.43 ac.-ft. to the top of the dam, and the design calculations show 0.37 ac.-ft. of available storage to the top of the dam. The actual measured storage volume to the top of the dam is 0.24 ac.-ft.

The actual measured dam height is 2.9 ft. The design plan drawing indicates a dam height of 3.2 ft. having a maximum storage volume of 0.43 ac.-ft., but because of rock outcroppings the capacity is 0.37 ac.-ft.

The routed design storm peak outflow is 2.0 cfs, causing a maximum pond depth of 2.0 ft. and a maximum storage volume of 0.11 ac.-ft.

#### **SUMMARY OF DISCREPANCIES AND PROBLEMS**

- The actual maximum storage volume is 64.8% of the intended 0.37 ac.-ft.
- The actual routed discharge is 2.0 times greater than the intended pre-development peak flow, because the constructed storage volume is inadequate.

#### **POND 19**

##### **INTENDED DESIGN**

Pond 19, located in a residential development, was designed in 1995 and is classified as "old". The detention pond is designed to attenuate the peak flow from an adjacent creek because the topography of nearby parcels will not allow direct runoff into the pond. The creek will flow into the pond over a rectangular weir 20 ft. long x 3 ft. high. TR-55 tabular procedure was used by the design engineer to compute peak flows and storage volume. The pre-development peak flow is 114.0 cfs and the post-development peak flow is 215.0 cfs.

The designed outlet structure is an 8-in. diameter corrugated plastic pipe with headwalls. The required storage volume for the design storm is 3.67 ac.-ft. at a maximum depth of 4.0 ft. The maximum intended dam height is 5.5 ft. (taken from the design stage/storage relationship).

##### **ACTUAL SITE CONDITIONS**

The submitted design computations were complicated and difficult to follow if one is not familiar with the proposed site. However, no errors were discovered in the calculations.



The pond is very well maintained but the outlet was clogged with straw that was used for inlet protection. The as-built outlet structure is an 8-in. diameter corrugated plastic pipe with a headwall. The measured storage volume at the design control depth is 1.95 ac.-ft., but the intended storage volume is 3.67 ac.-ft.

The maximum storage volume calculated from the design plan drawing is 4.84 ac.-ft. to the top of the dam, and the design calculations show 5.57 ac.-ft. of available storage to the top of the dam. The actual measured storage volume to the top of the dam is 2.16 ac.-ft. Because of rock outcroppings in the pond the required storage volume was not available. The designer submitted an as-built survey at a later date wherein the available storage volume was determined to be 2.98 ac.-ft. The actual measured dam height is 4.2 ft. The routed design storm peak overtops the dam.

#### **SUMMARY OF DISCREPANCIES AND PROBLEMS**

- The actual storage volume at the design depth of 4.0 ft. is 1.95 ac.-ft., and the intended storage volume at the design depth is 3.67 ac.-ft. The actual maximum storage at the top of the dam is 2.16 ac.-ft.
- The actual routed design storm overtops the dam because the storage volume is inadequate.

#### **POND 20**

##### **INTENDED DESIGN**

Pond 20, located in a commercial development, was designed in 1995 and is classified as "old". The drainage area used in the design is 1.16 acres. TR-55 graphical procedure was used by the design engineer to compute peak flows and storage volume. The pre-development peak flow is 2.0 cfs and the post-development peak flow is 6.0 cfs.

The designed outlet structure is an 36-in. diameter riser with an 8-in. diameter PVC orifice attached to the upstream end. The required storage volume for the design storm is

0.12 ac.-ft. at a maximum design depth of 2.0 ft. The design plan drawing shows the maximum dam height is 4.9 ft., having a maximum storage volume of 0.30 ac.-ft. The design calculations do not provide a storage volume to the top of the dam.

### **ACTUAL SITE CONDITIONS**

The submitted design computations were brief with a complete summary of the design intent, but the following errors were found in the outlet and discharge calculations. The designer assumed an 8-in. diameter sleeve of PVC pipe to act as an orifice ( $C_d = 0.6$ ). He also incorrectly calculated orifice flow (assuming the head on the orifice to be the depth from the water surface to the invert of the orifice instead of the depth from the water surface to the center of the orifice).

The designer calculated a discharge 30% greater than that required and proceeded with the results of that calculation. The pond is filled with cigarettes, trash, and oils from the parking lot upstream. The pond bottom and sides are sodded, but the sodded grass has died. The as-built outlet structure is a 15-in. diameter CMP. The 36-in. diameter riser and 8-in. diameter orifice were not constructed.

The actual measured storage volume at the maximum design depth of 2.0 ft. is 0.09 ac.-ft., but the intended storage volume is 0.12 ac.-ft. The actual measured dam height is 5.2 ft. having a storage volume of 0.32 ac.-ft. The design plan drawing indicates a dam height of 4.9 ft. having a maximum storage volume of 0.30 ac.-ft. The routed design storm peak outflow is 4.0 cfs, causing a maximum pond depth of 1.5 ft. and a maximum storage volume of 0.04 ac.-ft.

### **SUMMARY OF DISCREPANCIES AND PROBLEMS**

- The orifice discharge was calculated incorrectly. The design engineer calculated the head on the orifice to be the depth of water from the invert to the water surface. The head should be measured from the water surface to the center of the orifice. The design engineer also assumed 2.6 cfs to be approximately equal to 2 cfs.
- The calculations for the intended 15-in. diameter CMP were unclear.

- The pond is receiving oil and trash from the upstream parking lot.
- The outlet is not constructed in accordance with the design plans. The intended outlet structure is a 36-in. diameter riser having an 8-in. diameter CMP orifice on the upstream side, but the as-built outlet is a 15-in. diameter CMP. The net result is that the pre-development peak outflow is being exceeded.
- The routed design storm results in a peak discharge of 4.0 cfs which is twice the permitted pre-development peak flow, because the control outlet is constructed larger than indicated on the design plans.
- The routed design storm causes a maximum depth of 1.5 ft. and a storage volume of 0.04 ac.-ft.
- The modeled storage volume is 33% of the intended 0.127 ac.-ft.

## **CHAPTER V**

### **SUMMARY OF FINDINGS**

#### **GENERAL**

Inspection and analysis of the 20 ponds showed significant differences between what was intended or designed and what actually existed in the field. The findings are summarized as follows:

#### **I. Detention Ponds**

##### **Construction**

- Seventeen of the 20 ponds had storage volumes less than what the design engineer intended at all depths up to the maximum required for controlling the intended peak flow because they were not constructed according to the design plan drawings and calculations.
- At the design flow, 12 ponds had greater depth over the outlet opening than intended by the design engineer because the pond was not constructed according to design plan drawings therefore, the storage volume is inadequate.

##### **Design**

- Engineering plan drawings were submitted 17 of the 20 ponds. Two of the 17 plan drawings were not to scale.

##### **Design/Construction**

- Engineering plan drawings for 5 ponds showed less volume than intended from the calculations by the same engineer.

##### **Maintenance**

- One of the newly constructed ponds had accumulated a large amount of silt due to poor erosion control practices on the surrounding construction site, thus reducing available storage volume and pond performance in lowering peak flow.

## II. Outlet Structures

### Construction

- Twelve of the ponds have control outlet structures that were not built according to the intended design for the following reasons:
  - One control outlet was designed for an 11.5-in. diameter orifice, but a 10.5-in. diameter orifice was constructed.
  - One control outlet structure was designed for a 4-in. diameter orifice, but a 12-in. diameter CMP was constructed.
  - One overflow structure was constructed 1.6 ft. lower than intended by the design engineer.
  - One control outlet structure was designed for a circular orifice diameter of 9 inches, but a 9-in. by 9-in. *square* opening was installed, which is 27% larger than intended by the engineer. This difference will result in pond outflows significantly greater than intended for any pond depth.
  - One control outlet structure was designed for a 0.15-ft. wide slot, but a 0.21-ft. wide slot was constructed. A narrow slot is a non-standard outlet configuration because discharge coefficients are not known.
  - One control outlet was sized for a 12-in. pipe, but a 10-in. orifice plate was installed.
  - One control outlet was designed to have a 12-in. diameter orifice, but a 5-in. diameter orifice was constructed.
  - One control outlet was designed for a 6-in. diameter riser and a 2.5-in. diameter orifice, but a 9-in. wide by 3.75 ft. high slot was constructed.
  - One control outlet was designed for a 15-in. diameter pipe, but an 18-in. diameter pipe was installed.
  - One control outlet was designed to have a 24-in. diameter perforated riser during the construction phase, but it was decided later to leave it in place.
  - One control outlet was designed for an 8-in. diameter orifice, but a 7-in. diameter orifice was constructed.

- One outlet control structure was designed for a 36-in diameter riser with an 8-in. diameter pipe at the bottom of riser, but a 15-in. diameter CMP was installed.
- Four ponds had overflows that were constructed lower than designed, resulting in discharges exceeding the pre-development peak flows.
- Three ponds, calling for an emergency spillway, had none.
  - At one pond, the spillway invert elevation was set higher than intended, resulting in the pond overtopping before the emergency spillway is utilized.
  - One emergency spillway was specified to be 30 ft. long and 1 ft. deep, but the actual spillway was only 3 ft. long and 0.2 ft. deep.

#### Design

- Two ponds have non-standard control outlets (narrow weirs with notches less than 10°).

### III. Dams

#### Construction

- Fifteen of the 20 ponds have lower dams than were intended from design information.

#### Design

- For 9 ponds, no typical dam sections were submitted with plans.

### IV. Performance / Discharge

#### Construction

- Seventeen of the 18 ponds having adequate information for analysis were determined to discharge *more* flow than permitted for the specified design storm, because of a combination of inadequate storage volume and control outlets not being constructed according to design plans. Six of those 17 ponds overtop during the design storm.

#### IV. Computational Methods

##### Design

- One-third of the design computations were difficult to read, follow, or review.
- Hydraulic or hydrologic assumptions, necessary for review, were found to be unclear and/or missing in 4 of the design documents.
- Two designers' calculate control outlets that will discharge more than the required pre-development because of potential maintenance problems.
- One designer used an incorrect discharge coefficient resulting in an oversized control outlet.
- Two designers calculated orifice sizes using the culvert equation.
- Spillway and outlet control computations were confusing and unclear for four of the design computations. Questionable weir or orifice discharge coefficients were used in three design computations.

#### V. Other

##### Design

- Submitted materials for 2 ponds were missing critical design data necessary for review.
- Submitted information for 5 ponds contained no design plans or drawings for construction.

##### Maintenance

- Six of the ponds were observed to lack routine but critical maintenance to ensure intended performance and 5 of those ponds have erosion and sedimentation problems.

Table 1 illustrates the difference between the intended designs and the "as-built" detention ponds. It provides comparisons between design plan drawings, design calculations, and the actual measured elements and quantities of the detention ponds. Table 2 is a summary of the intended designs compared to the actual performance of the detention ponds having the design storm routed through the as-built pond.

**Table 1. Summary of Intended Design vs. Actual Field Survey For Various Pond Elements**

| Pond | Y<br>ft          | <sup>1</sup> V <sub>I</sub><br>ac-ft | <sup>2</sup> V <sub>I</sub><br>ac-ft | V <sub>A</sub><br>ac-ft | <sup>1</sup> V <sub>I-TD</sub><br>ac-ft | <sup>2</sup> V <sub>I-TD</sub><br>ac-ft | V <sub>A-TD</sub><br>ac-ft | Dam <sub>I</sub><br>ft | Dam <sub>A</sub><br>ft | SS <sub>I</sub><br>H:V | SS <sub>A</sub><br>H:V |
|------|------------------|--------------------------------------|--------------------------------------|-------------------------|-----------------------------------------|-----------------------------------------|----------------------------|------------------------|------------------------|------------------------|------------------------|
| 1    | 8.8              | 2.90                                 | 2.10                                 | 1.66                    | 4.67                                    | 4.67                                    | 3.39                       | 12.5                   | 11.9                   | 3 : 1                  | 3 : 1                  |
| 2    | 2.8              | 1.10                                 | N.A.                                 | 0.76                    | 1.95                                    | N.A.                                    | 1.38                       | 4.0                    | 3.9                    | 2.5 : 1                | 2.5 : 1                |
| 3    | 5.0              | 0.19                                 | 0.42                                 | <sup>4</sup> 0.32       | N.A.                                    | 0.27                                    | 0.32                       | 6.5                    | 4.3                    | <sup>3</sup> 2 : 1     | 2 : 1                  |
| 4    | 4.9              | 0.40                                 | 0.40                                 | 0.64                    | 1.54                                    | 0.16                                    | 0.89                       | 8.9                    | 5.6                    | 2 : 1                  | 5 : 1                  |
| 5    | 4.5              | 0.20                                 | 0.20                                 | 0.09                    | 0.45                                    | 0.38                                    | 0.32                       | 6.5                    | 7.5                    | 3 : 1                  | 3 : 1                  |
| 6    | <sup>3</sup> 1.9 | 0.10                                 | N.A.                                 | 0.01                    | N.A.                                    | N.A.                                    | 0.03                       | 5.0                    | 2.5                    | N.A.                   | 2 : 1                  |
| 7    | 2.9              | 0.11                                 | N.A.                                 | 0.06                    | N.A.                                    | N.A.                                    | 0.14                       | 5.0                    | 4.1                    | 3 : 1                  | 3 : 1                  |
| 8    | 5.7              | 0.23                                 | N.A.                                 | <sup>4</sup> 0.06       | N.A.                                    | N.A.                                    | 0.06                       | 5.7                    | 2.5                    | N.A.                   | 2.5 : 1                |
| 9    | 4.0              | 1.10                                 | 0.76                                 | <sup>4</sup> 0.54       | 1.34                                    | 0.66                                    | 0.54                       | 5.0                    | 3.8                    | 2 : 1                  | 2 : 1                  |
| 10   | 2.0              | 0.10                                 | 0.13                                 | 0.04                    | N.A.                                    | 0.19                                    | 0.15                       | 3.0                    | 3.8                    | N.A.                   | 3 : 1                  |
| 11   | 3.5              | 0.20                                 | 0.20                                 | 0.16                    | 0.38                                    | 0.46                                    | 0.24                       | 5.5                    | 4.3                    | 2 : 1                  | 2 : 1                  |
| 12   | 7.0              | 0.75                                 | N.A.                                 | 0.83                    | N.A.                                    | N.A.                                    | 1.24                       | 8.5                    | 8.2                    | N.A.                   | 2 : 1                  |
| 13   | <sup>1</sup> 4.0 | 3.73                                 | 1.65                                 | 0.85                    | N.A.                                    | 3.67                                    | 2.38                       | 4.0                    | 6.4                    | 2 : 1                  | 2 : 1                  |
| 14   | 9.0              | 4.00                                 | 3.90                                 | <sup>4</sup> 2.07       | 4.00                                    | 3.92                                    | 2.07                       | 9.0                    | 6.1                    | 2.5 : 1                | 2.5 : 1                |
| 15   | 5.0              | 0.40                                 | 0.56                                 | 0.15                    | 0.59                                    | 0.76                                    | 0.31                       | 6.0                    | 6.3                    | 2.5 : 1                | 2.5 : 1                |
| 16   | 1.3              | 0.12                                 | 0.03                                 | 0.02                    | N.A.                                    | 0.31                                    | 0.18                       | 4.5                    | 3.5                    | 2 : 1                  | 4 : 1                  |
| 17   | 5.7              | 1.88                                 | 0.58                                 | 0.24                    | 2.75                                    | 1.25                                    | 0.39                       | 7.5                    | 6.9                    | varies                 | varies                 |
| 18   | 1.4              | 0.26                                 | 0.22                                 | 0.06                    | 0.37                                    | 0.43                                    | 0.24                       | 3.2                    | 2.9                    | 2 : 1                  | 2 : 1                  |
| 19   | 4.0              | 3.67                                 | 2.90                                 | 1.95                    | 5.57                                    | 4.84                                    | 2.16                       | 5.6                    | 4.2                    | 3 : 1                  | 3 : 1                  |
| 20   | 2.4              | 0.12                                 | 0.11                                 | 0.09                    | N.A.                                    | 0.30                                    | 0.32                       | 4.9                    | 5.2                    | 2 : 1                  | 2 : 1                  |

**Y** Maximum design depth for detention pond at controlled outflow peak

**<sup>1</sup>V<sub>I</sub>** Intended storage at the maximum design depth for the first stage outlet from submitted design calculations

**<sup>2</sup>V<sub>I</sub>** Intended storage at the maximum design depth for the first stage outlet from submitted design plan drawings

**V<sub>A</sub>** Actual storage from field survey at the maximum design depth for the first stage outlet

**<sup>1</sup>V<sub>I-TD</sub>** Intended storage at the top of the dam as designed from submitted calculations

**<sup>2</sup>V<sub>I-TD</sub>** Intended storage at the top of the dam as designed from submitted design plan drawing

**V<sub>A-TD</sub>** Actual storage at the top of the actual dam

**Dam<sub>I</sub>** Intended design dam height

**Dam<sub>A</sub>** Actual dam height

**SS<sub>I</sub>** Design side slopes

**SS<sub>A</sub>** Actual side slopes

**N.A.** Not Available

**1** Data from design calculations

**2** Data from submitted design drawing

**3** Unclear information in the design calculations

**4** Actual depth in pond is less than the intended design depth



**Table 2. - Comparison of Intended Design vs. Actual  
Routing Flows, Depths, and Storage Volumes**

| POND | Q <sub>I-I</sub><br>(cfs) | Q <sub>I-M</sub><br>(cfs) | Q <sub>O-I</sub><br>(cfs) | Q <sub>O-M</sub><br>(cfs) | Y <sub>I</sub><br>(ft) | Y <sub>M</sub><br>(ft) | V <sub>I</sub><br>(ac-ft) | V <sub>M</sub><br>(ac-ft) |
|------|---------------------------|---------------------------|---------------------------|---------------------------|------------------------|------------------------|---------------------------|---------------------------|
| 1    | 88 (G)                    | 82.0                      | 13.0                      | 16.0                      | 8.8                    | 9.5                    | 2.90                      | 1.99                      |
| 2    | 48 (T)                    | 48.0                      | 5.0                       | 15.0                      | 2.8                    | 3.1                    | 1.10                      | 0.92                      |
| 3    | 6.4 (G)                   | N.A.                      | 0.4                       | N.A.                      | 5.0                    | N.A.                   | 0.19                      | N.A.                      |
| 4    | 6.0 (T)                   | 6.0                       | 1.0                       | 6.0                       | 4.9                    | 1.6                    | 0.40                      | 0.02                      |
| 5    | 7.3 (G)                   | 7.0                       | 1.0                       | 6.0                       | 4.5                    | 3.3                    | 0.20                      | 0.04                      |
| 6    | 7.2 (G)                   | 8.0                       | 3.0                       | 6.0                       | 1.9                    | OT                     | 0.10                      | OT                        |
| 7    | 8.3 (R)                   | 8.3                       | 6.5                       | N.A.                      | 2.9                    | N.A.                   | 0.11                      | N.A.                      |
| 8    | 18.3 (G)                  | 17.0                      | 10.3                      | 15.0                      | 5.7                    | OT                     | 0.23                      | OT                        |
| 9    | 31.0 (T)                  | 31.0                      | 7.0                       | 20.0                      | 4.0                    | OT                     | 1.10                      | OT                        |
| 10   | 2.0 (G)                   | 2.0                       | 0.2                       | 1.0                       | 2.0                    | 0.8                    | 0.10                      | 0.01                      |
| 11   | 13.6 (G)                  | 13.0                      | 8.0                       | 11.0                      | 3.5                    | 2.5                    | 0.20                      | 0.07                      |
| 12   | 54.0 (G)                  | 54.0                      | 30.0                      | 19.0                      | 7.0                    | 5.7                    | 0.75                      | 0.47                      |
| 13   | 144.0 (T)                 | 128.0                     | 49.0                      | 102.0                     | 4.0                    | OT                     | 3.73                      | OT                        |
| 14   | 76.0 (T)                  | 80.0                      | 8.0                       | 59.0                      | 9.0                    | OT                     | 4.00                      | OT                        |
| 15   | 25.0 (T)                  | 25.0                      | 6.0                       | 20.0                      | 5.0                    | 5.1                    | 0.40                      | 0.16                      |
| 16   | 9.7 (R)                   | 9.7                       | 5.9                       | 10.0                      | 1.3                    | 2.7                    | 0.12                      | 0.13                      |
| 17   | 52.6 (R)                  | 52.6                      | 11.6                      | 47.0                      | 5.7                    | 6.4                    | 1.88                      | 0.33                      |
| 18   | 7.0 (G)                   | 7.0                       | 1.0                       | 2.0                       | 1.4                    | 2.0                    | 0.26                      | 0.11                      |
| 19   | 215(T)                    | 215.0                     | 114.0                     | 218.0                     | 4.0                    | 6.2                    | 3.67                      | OT                        |
| 20   | 6.0 (G)                   | 6.0                       | 2.0                       | 4.0                       | 2.4                    | 1.5                    | 0.12                      | 0.04                      |

Q<sub>I-I</sub> Intended design post-development peak inflow (from design engineer's calc's.)

Q<sub>I-M</sub> Modeled/Predicted post-development peak inflow - TR-55 (Tabular Method)

Q<sub>O-I</sub> Intended design pre-development peak outflow (from design engineer's calc's.)

Q<sub>O-M</sub> Modeled/Predicted peak outflow - HEC-1 (Reservoir Routing)

Y<sub>I</sub> Intended design - maximum water depth (from design engineer's calc's.)

Y<sub>M</sub> Modeled/Predicted water depth (HEC-1) for design storm

V<sub>I</sub> Intended design storage volume (from design engineer's calc's.)

V<sub>M</sub> Modeled/Predicted storage volume (HEC-1) for design storm

**Peak Flow Methods:**

1 (G) TR-55 Graphical Method

2 (T) TR-55 Tabular Method

3 (R) Rational Method

HEC-1 The program used to route the design storm through the "as-built" pond.

N.A. Inadequate design information to model

OT Over top

Figure 6 shows pond performance by illustrating the variation in depths between the routed design storm and the intended maximum design depths. The vertical axis represents the maximum depth when design storm is routed through the "as-built" pond. The horizontal axis represents the maximum intended design depth which the design engineer used to size the control outlet. Ponds 3 and 7 did not submit the data to produce inflow hydrographs, so they could not be analyzed through routing and are not represented on the figure. The implication of pond depths being greater than the intended design depth is that water may discharge through the overflows, thus exceeding the pre-development peak flow and possibly causing downstream damage.

Figure 7 shows pond performance by illustrating the extent to which 17 of the 20 ponds have under-constructed storage volumes. The vertical axis represents the storage volume associated with the maximum depth for the routed design storm. The horizontal axis represents the intended storage volume. Ponds 3 and 7 are not shown on this figure (see discussion of Figure 6). The implication of inadequate storage volume is that the pond will probably discharge more than the pre-development peak flow. The pond design depth will be exceeded before the peak inflow is reached, and when the peak flow is achieved, either the head on the outlet will be greater than the design head, or the water will discharge through the overflow. The result will be that the discharge exceeds the pre-development condition. However, it should be pointed out that in defense of the design engineer that the TR-55 manual discusses the limitations of the methods for determining peak flows and storage volumes. For example, TR-55 specifically notes that "it (TR-55 procedure) should not be used to perform final design if an error in storage of 25 percent cannot be tolerated."(1)

Pond discharge performance is shown in Figure 8, which illustrates that 17 of 18 ponds are discharging in excess of the specifications of the respective regulatory agency. The figure shows how a combination of insufficient pond depth, storage volume and inadequate outlet structure can cause a difference between intended and predicted maximum outflows for the required design storm. The vertical axis represents the predicted peak outflows from the ponds. The predicted peak outflows were computed using HEC-1. The horizontal axis represents the intended peak outflows (pre-development peak flow). Ponds 3 and 7 are not shown because were not provided to route the design storm through these ponds.

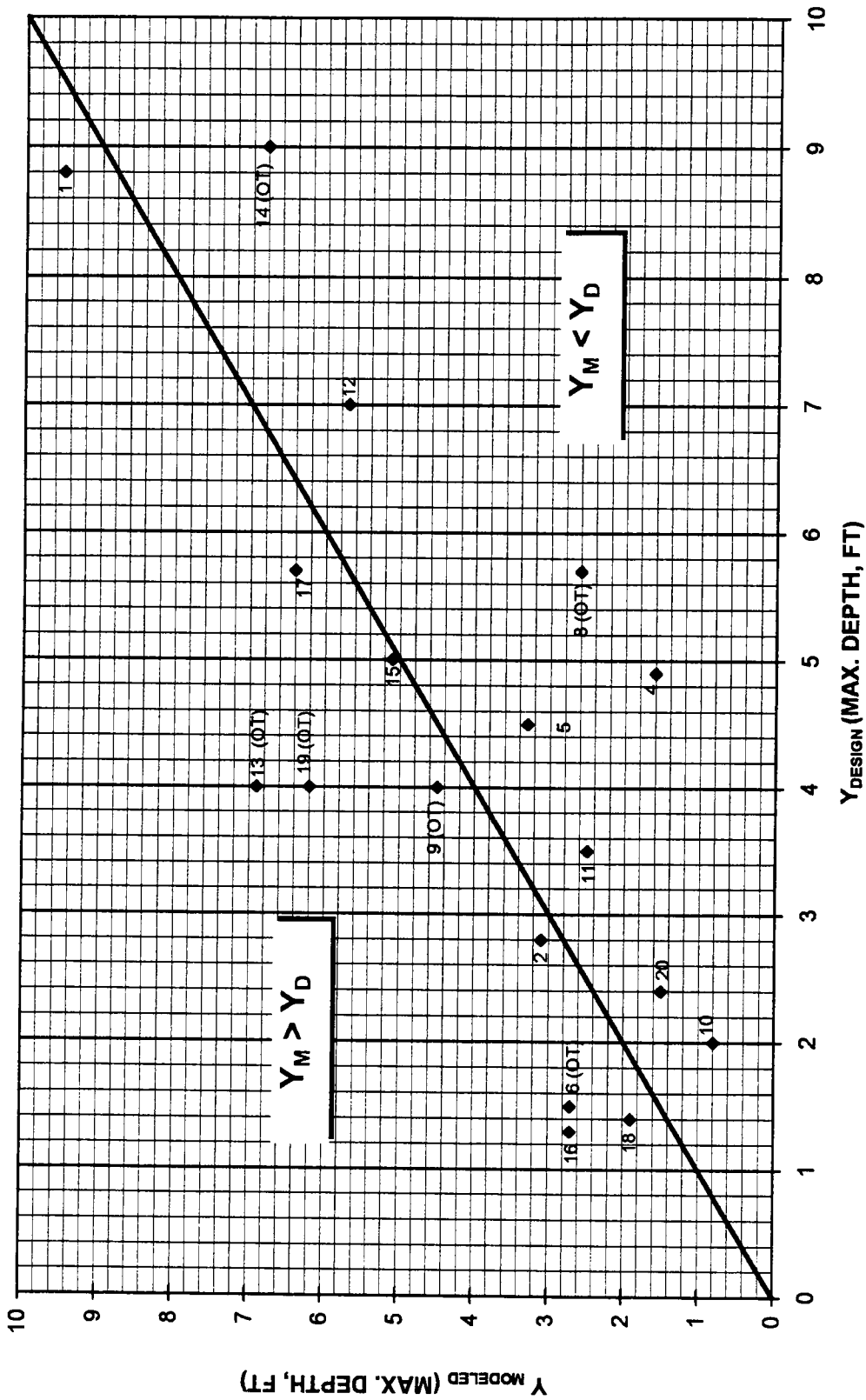


FIGURE 6. COMPARISON OF PREDICTED POND PERFORMANCE vs. DESIGN MAXIMUM DEPTH FOR ROUTED DESIGN STORM.

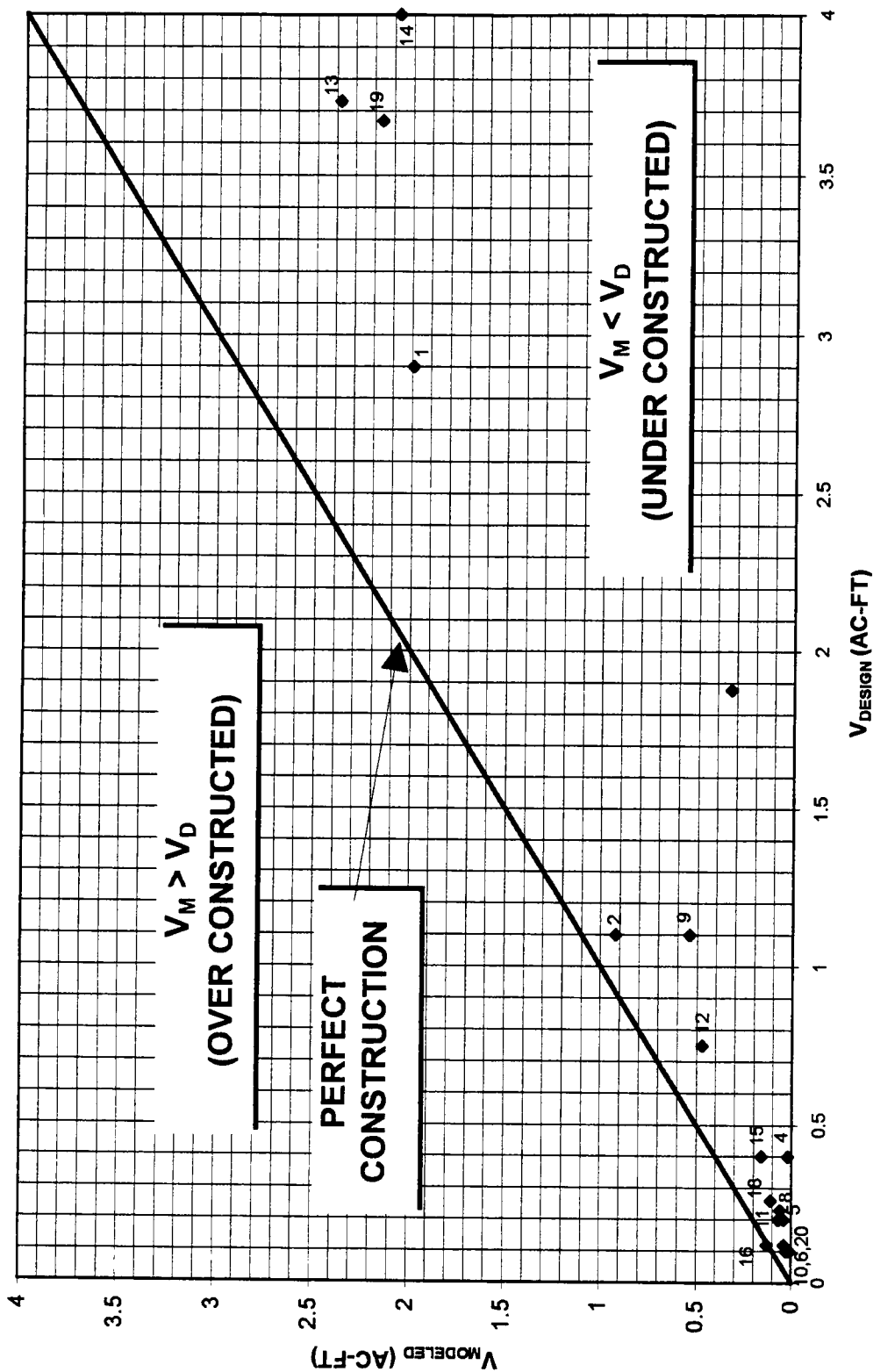


FIGURE 7. COMPARISON OF PREDICTED POND PERFORMANCE vs. DESIGN STORAGE VOLUME FOR ROUTED DESIGN PEAK FLOW.

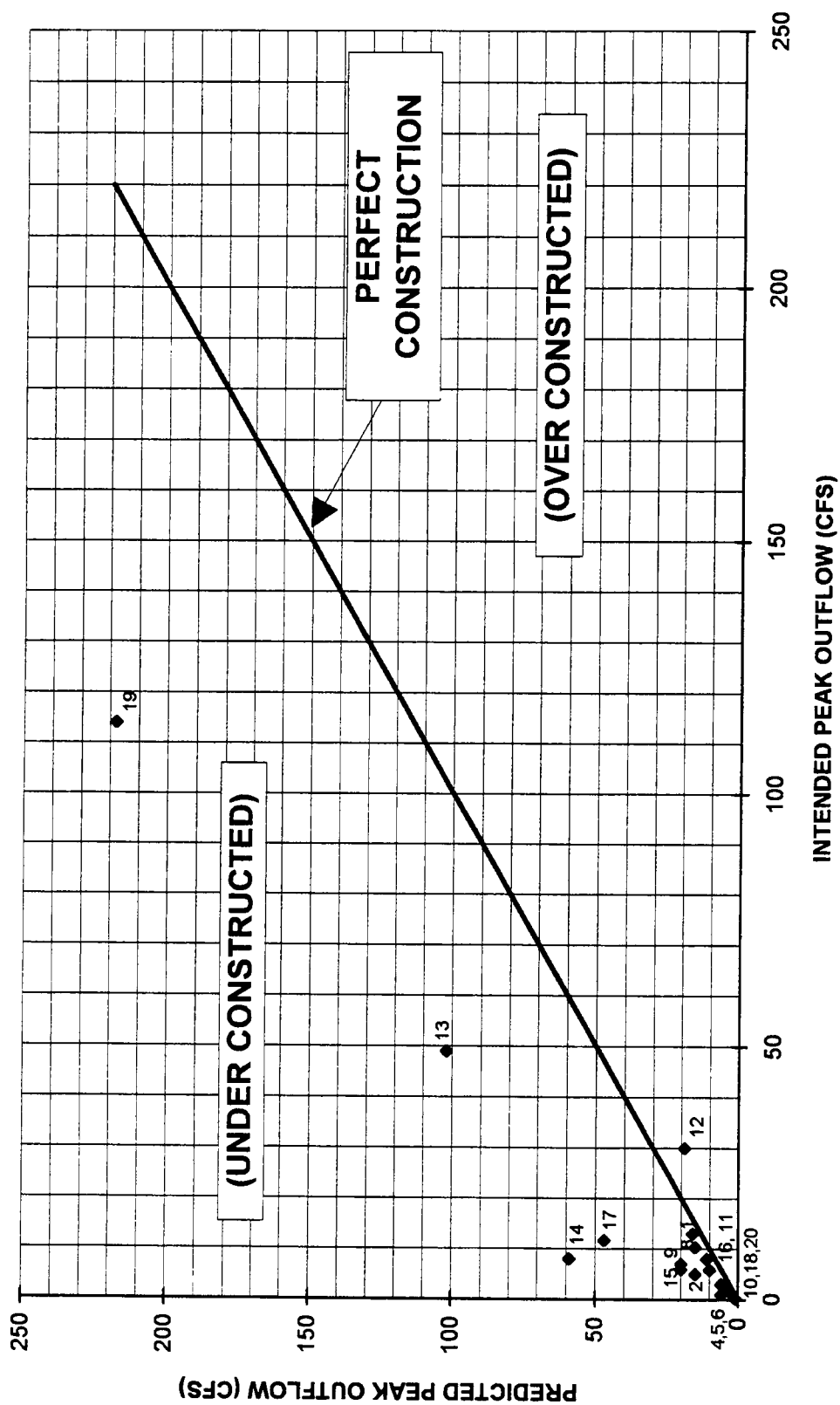


FIGURE 8. COMPARISON OF PREDICTED vs. INTENDED PEAK OUTFLOW FROM SURVEYED PONDS FOR REQUIRED STORM.

Figure 9 illustrates the comparison of designed to constructed detention pond volumes at various pond depths. The ratio of actual volume to intended volume at varying depths is plotted against the ratio of varying depths to maximum design depth to show the inadequate construction of detention ponds. The volume in the 16 of the 18 ponds that were analyzed have inadequate volumes at all depths. The problem associated with inadequate volume are the possibility of overtopping. The water will fill the pond before the peak reaches the pond. Two of the ponds have larger volumes at every depth up to the top of the pond but the maximum depth in the ponds were constructed less than the intended design. The ponds will not perform as intended. Ponds 8 and 12 are not shown on the figure because the stage vs. storage relationships and design plan drawings were not submitted.

Figure 10 extends the interpretation of Figure 9 by illustrating the under- and over-built conditions for the design storm. Quadrant A represents the completely over-built condition, and no pond in this study was over-built for both volume and depth. Quadrant B represents the under-built volume and over-built depth condition. One of the 18 ponds for which the necessary data were provided fits this description. Quadrant C represents the under-built volume and under-built depth condition. Twelve of the 18 ponds (67%) fall into Quadrant C and are totally under-built. The problem associated with under-built ponds is that the ponds are not performing as the intended design which could result in downstream damage due to flooding resulting in possible lawsuits. Two of the 18 ponds have over-built volume and under-built depth.

Figure 11 provides a comparison of actual to intended volumes and outflow discharge for the design storm. This figure shows that 14 out of 16 ponds have under-built volumes and will discharge in excess of the pre-development design storm. The ponds are not performing to the design standards. The deficiencies of inadequate volume combined with outlet structures not being built to design plans result in ponds not performing according to the intended design.

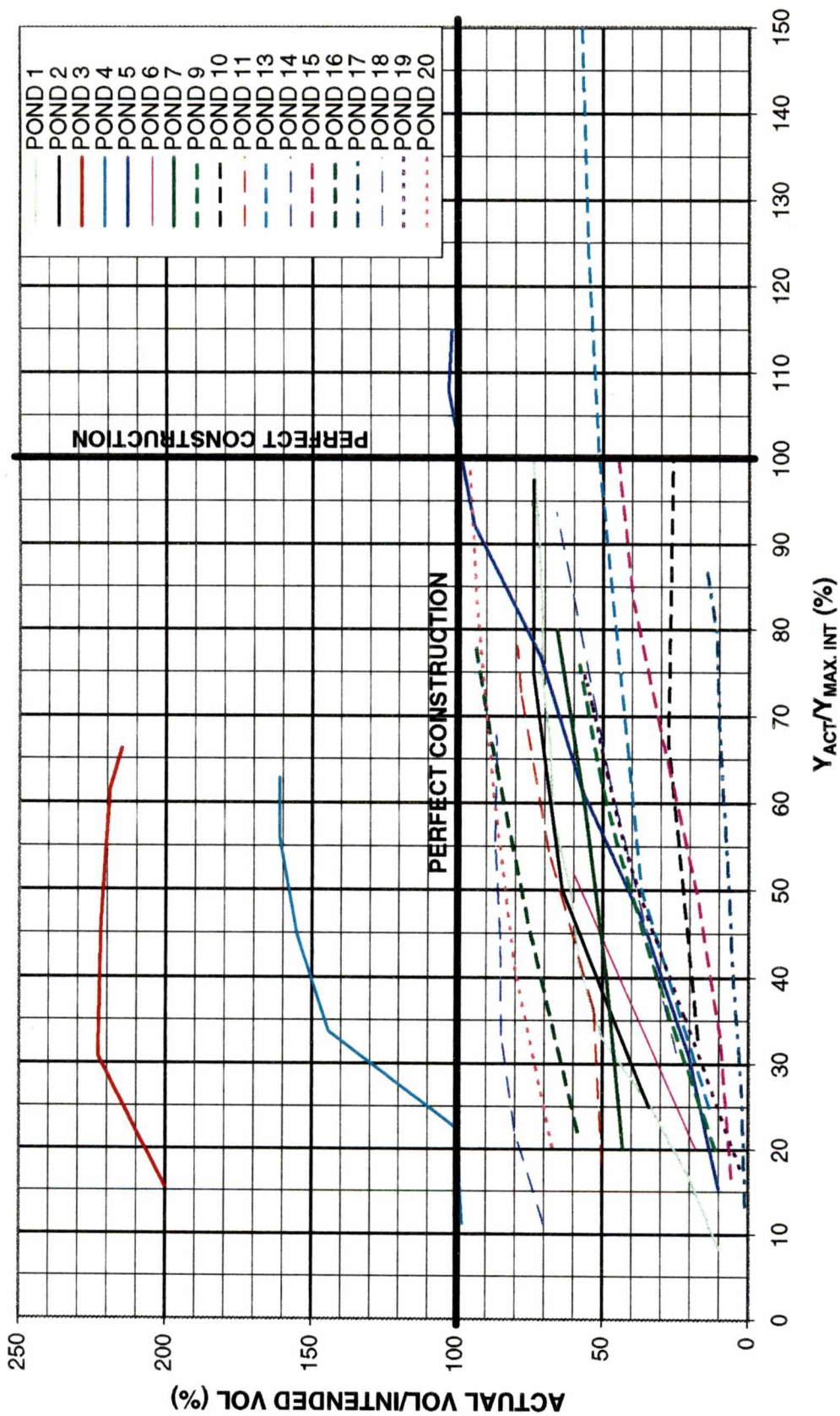


FIGURE 9. COMPARISON OF DESIGNED (INTENDED) vs. CONSTRUCTED (ACTUAL) DETENTION POND VOLUMES FOR VARYING DEPTHS TO MAX. DESIGN DEPTH RATIOS.

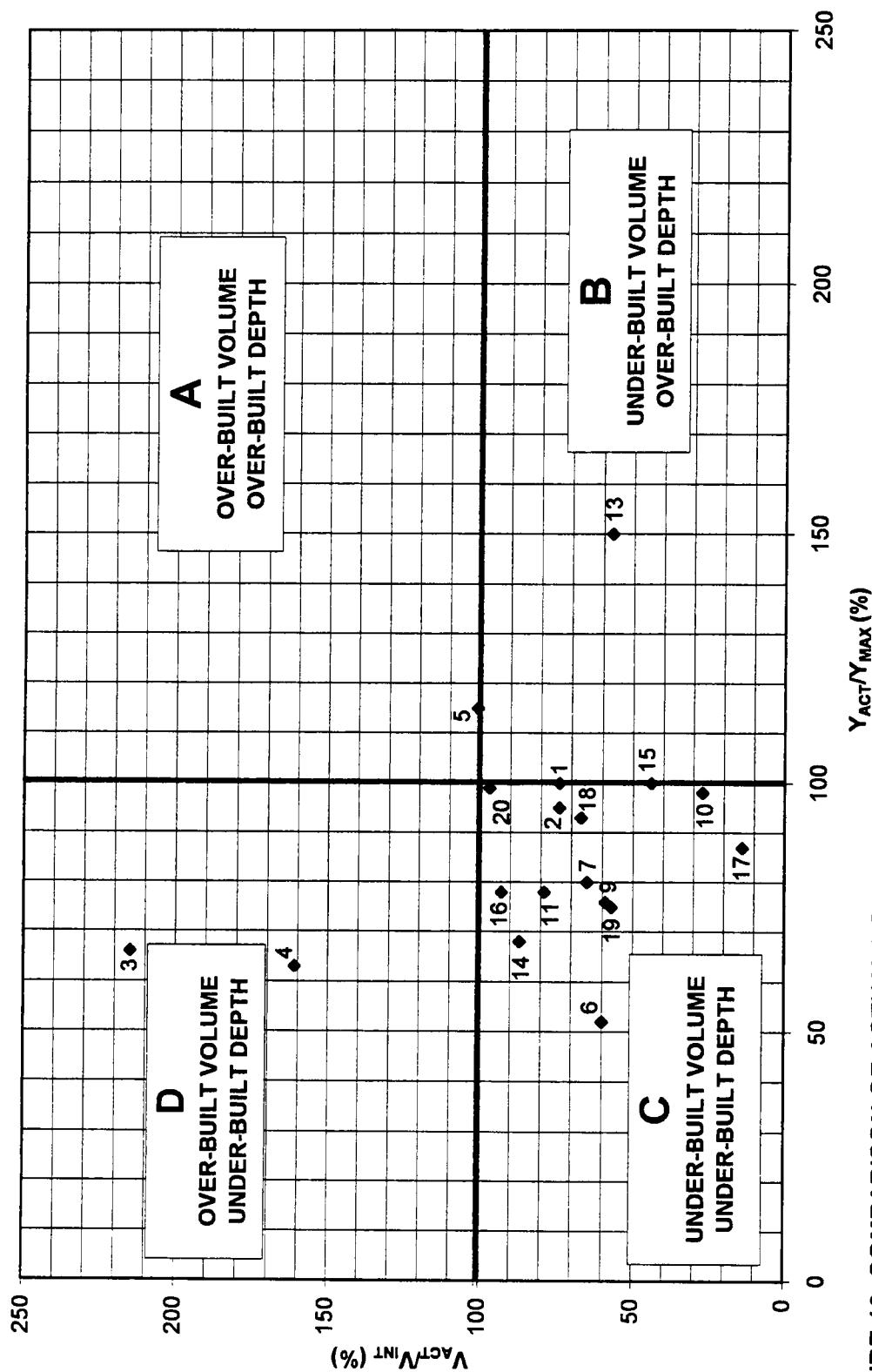


FIGURE 10. COMPARISON OF ACTUAL TO INTENDED POND VOLUMES AND DEPTHS FOR DESIGN STORM TO ILLUSTRATE UNDER- AND OVER-BUILT CONDITIONS.



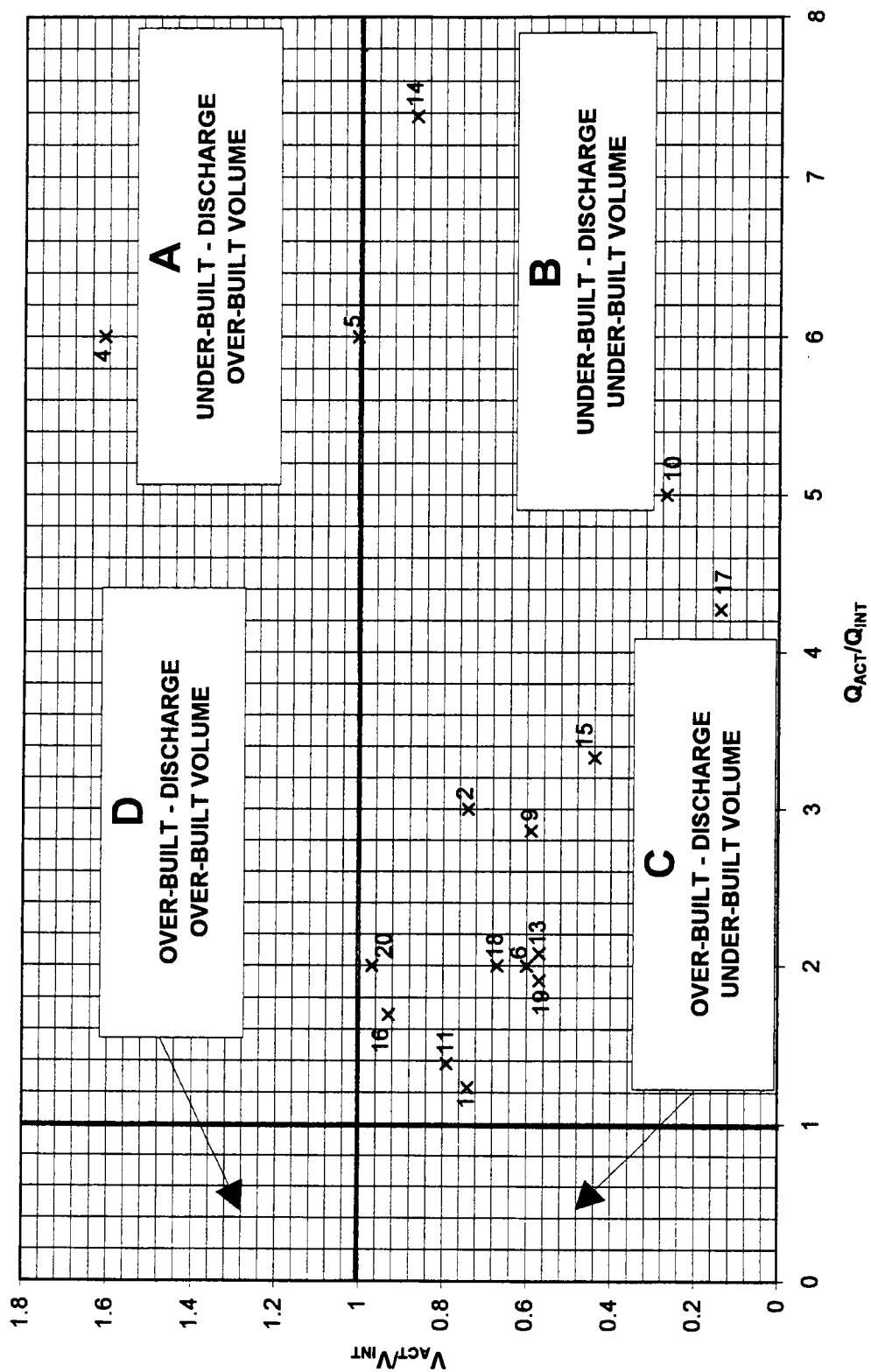


FIGURE 11. COMPARISON OF ACTUAL TO INTENDED POND VOLUMES AND OUTFLOW DISCHARGE FOR DESIGN STORM TO ILLUSTRATE UNDER- AND OVER-BUILT CONDITIONS.

## **SUMMARY**

The results of this study show many deficiencies in the design and construction of detention ponds. The ponds are not performing effectively according to the design standards. The main deficiency is that ponds are not being built according to the intended design. Twelve of the 20 ponds have outlets that are not constructed according to the design plans. Seventeen of the 20 ponds have storage volumes that are less than the intended design, because they were not constructed to the design plans and specifications. Detailed on-site inspection during construction would greatly reduce the construction problems.

Designers need to compare the design calculations to the design plan drawings before submitting them to the regulatory agency. The use of non-standard outlet structures is discouraged. Weir discharge coefficients are not the same for all weirs, and designers should use outlets that have documented data by which the performance may be predicted.

The regulators need to do a more complete and thorough check of the submitted designs. The errors found in the design calculations could have been discovered with simple checks on outlet calculations and comparison of design calculations to the stage/ storage relationships of the design plan drawings. Routine maintenance should be enforced during and after construction.

## CHAPTER VI

### CONCLUSION AND RECOMMENDATIONS

The study findings show that most of the surveyed detention ponds were not constructed according to the indicated design plans and specifications. Sloppy or incomplete design calculations and drawings, computational errors, and poor engineering (judgment) compound this problem. Some of the differences between intended design and field conditions are significant and can have a significant negative effect on pond performance. Findings demonstrate a need for rigid inspection of detention ponds during construction. Furthermore, regulatory review offices need to pay closer attention to design computations. Review offices should issue guidelines to engineers on how drainage calculations and drawings should be submitted so that the reviewers can better follow the designer's assumptions, hydraulic and hydrologic procedures, and intent in order that the developers and their contractors can accurately follow the intended plans. The study clearly points to a serious need for on-site inspection to insure that the ponds are built to the intended design plans and specifications so that the ponds will perform effectively. Regulating offices should establish who is responsible for construction inspections to ensure that intended design plans are followed. Because detention ponds within major watersheds do not reduce the *volume* of stormwater runoff, but do change hydrograph timing, stormwater managers are encouraged to analyze the combined and cumulative effects of detention ponds within a basin on flood depths at different points along the main creek. They should use basin-wide hydrologic models to determine whether or not new detention ponds in some locations are even warranted. In some situations, the use of detention ponds, regardless of the quality of engineering or construction, can actually magnify downstream flood problems.

The implications of the findings in this study should be obvious to engineers who design stormwater detention ponds, developers who are responsible for controlling flows from their developments, stormwater managers who are responsible for reviewing and approving calculations and plans, the ultimate owner(s) responsible for maintenance, and the general public who is impacted by development. The performance of detention ponds depends on the chain of cumulative competence of the design engineers who are expected to practice

within a reasonable degree of engineering certainty, the thoroughness of local reviewers, the quality of construction, and degree of continuous maintenance. If the chain is broken at any stage because of neglect of duty or responsibility, and detention pond performance is unreasonably compromised, the door is open to downstream damage and possible costly litigation. The public rightfully expects nothing less than responsible engineering and development in stormwater management and does not want to shoulder the burden of mismanaged stormwater.

The following is a list of recommendations:

#### Recommendations for reviewers and regulators

- Regulators should require better (more complete and consistent) design documentation from designers.
- Regulators should issue guidelines specifying a format that the designer must follow to submit stormwater calculations, so that all submitted designs will contain the same information. This will make it easier to check the designs. The regulator should formulate a check list of required design information that the designer can that the designer must follow
- The outlet calculations should be checked for correctness.
- The discharge coefficients used in the design of the outlet control device should be checked.
- A minimum of two cross-sections of the intended pond design should be submitted with the design calculations and design plan drawing. (longitudinal and lateral).
- Regular Maintenance should be enforced especially after a storm event. The maintenance responsibility should be clearly specified so that there is no question of who is the responsible party for maintenance.

#### Recommendations for designers

- Designers should clearly and completely document all hydrologic and hydraulic methods, calculations, field conditions, and design assumptions.
- Designers should not use non-standard or non-documented outlet configurations such as narrow weirs (notch less than 20°) and narrow slots unless there is

documented design data (i.e., discharge coefficients).

- Designers should consider designing the outlets to discharge slightly less than the pre-development peak flow and size the storage volume larger than the required storage volume to compensate for possible construction deficiencies.
- Designers should use TR-55 for the preliminary design. The final design should have the design storm routed through the intended pond design to check performance.
- Design plan drawings should be dimensioned.
- The engineer should emphasize to the client the importance of having reliable construction inspection as one means of quality control for assuring that the "as-built" facility will perform as the designer intended. At the same time, the engineer needs to contractually spell out specific duties and responsibilities for construction inspection.

#### Recommendations for construction

- On site inspection is needed during construction.
- As-built surveys should be required to confirm that the designer's plans are constructed according to intent.

## REFERENCES

## REFERENCES

1. U.S. Department of Agriculture, Soil Conservation Service, Technical Release 55 (TR-55), Urban Hydrology for Small Watersheds (Technical Manual), June 1986 and TR-55 Microcomputer Program (v. 2.0), March 1987.
2. American Public Works Association (APWA), Urban Stormwater Management, Special Report No. 49, 1981.
3. Parmley, R. O., Hydraulics Field Manual, McGraw Hill, 1992.
4. Daugherty, R.L., Finnemore, J.E., and Franzini, J.B., Fluid Mechanics with Engineering Applications, Eighth Edition, McGraw Hill, 1985.
5. American Society of Civil Engineers (ASCE), Hydraulics Division, Task Committee on the Design of Outlet Control Structures, Stormwater Detention Outlet Control Structures, 1985, 34 pp.
6. Viessman, W., Lewis, G. L., and Knapp, J. W., Introduction to Hydrology, Harper Collins Publishers, 1989.
7. Stahre, P. and Urbonas, B., Stormwater Detention, Prentice-Hall Publishers, 1990.
8. Grant, D. M., Isco Open Channel Flow Measurement, Third Edition 1989
9. Handbook of Steel Drainage & Highway Construction Products, American Iron and Steel Institute, Fourth Edition 1993.
10. American Society of Civil Engineers (ASCE) and Water Environment Federation (WEF), Design and Construction of Urban Stormwater Management Systems, (ASCE Manual of Practice No. 77 and WEF Manual of Practice FD-20), 1992.

11. McCuen, R. H., Hydrologic Analysis and Design, Prentice-Hall Publishers, 1989.
12. U.S. Army Corps of Engineers, Hydrologic Engineering Center, HEC-1, Flood Hydrograph Package (User's Manual and Computer Program), September 1990, C.D.-1A.
13. Knoxville City Ordinance No. 6191, Sections 1 - 8, Passed October 5, 1976.
14. City Policy Memorandum to Drainage Facility Designers (use of AMC I antecedent moisture condition instead of AMC II for stormwater calculations, including charts and examples), January 31, 1984, 8 pp.
15. Maryville Land Development and Public Works Standards, Section 112, Detention of Stormwater.
16. Erosion Control and Stormwater Management Ordinance, Ordinance 7-89, Section 9-420, Performance Criteria.
17. Minimum Subdivision Regulations For Knoxville and Knox County, adopted by the Knoxville-Knox County Metropolitan Planning Commission July 8, 1971 and amended through July 6, 1993.
18. Farragut Drainage Ordinance (adopted after published in West Side Story on Feb 16, 1983).
19. Policy for Control of Erosion and Stormwater, Knox County, Tennessee, Standards and Procedures for Erosion and Sediment Control and Drainage Structures, August 13, 1984.



20. Tennessee Erosion and Sediment Control Handbook, A Guide for Protection of State Waters through Effective Management Practices during Construction Activities, Tennessee Dept. of Health and Environment, November 1990.
21. Knoxville Code: Article VII. Stormwater Detention, Sections 6-171 to 6-183, pp. 598-600.
22. Tschantz, B.A. and Romans, T.E., Stormwater Detention Pond Discrepancies Can Result In Downstream Damage, Tennessee Public Works, Volume 15 No.2 - July/August 1997, pp 6-11.
23. Romans, T.E. and Tschantz, B.A., Performance Analysis of Constructed Urban Stormwater Detention Ponds, Proceedings and paper presented at the Seventh Tennessee Water Resources Symposium, Tennessee Section of American Water Resources Association, Nashville, Tennessee, February 24-26, 1997, pp 212-217.

**APPENDIX  
SUBMITTED DESIGN DATA  
FIELD FINDINGS  
AND  
ANALYSIS**

## APPENDICES

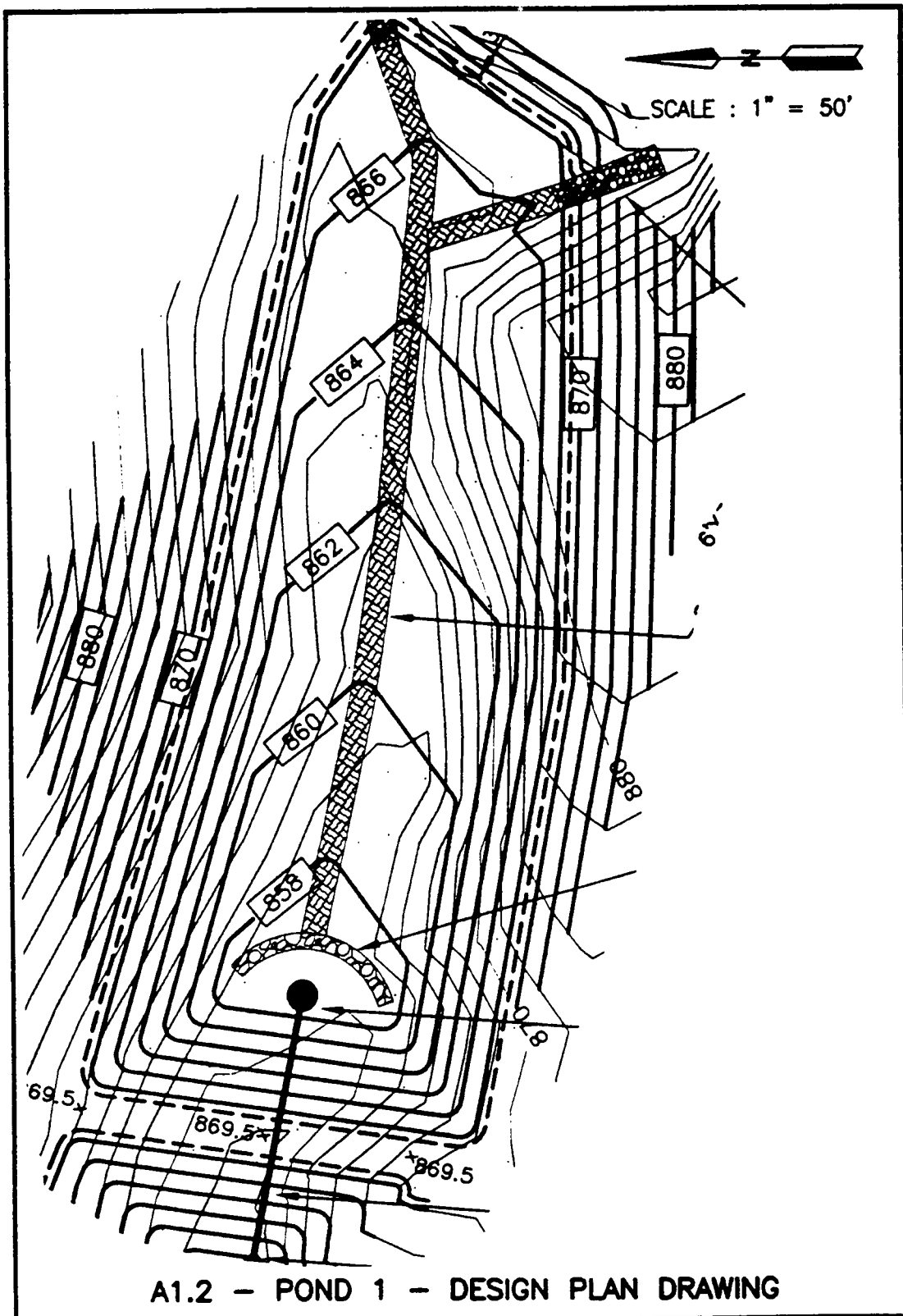
|               |     |
|---------------|-----|
| POND 1 .....  | 79  |
| POND 2 .....  | 87  |
| POND 3 .....  | 96  |
| POND 4 .....  | 104 |
| POND 5 .....  | 112 |
| POND 6 .....  | 120 |
| POND 7 .....  | 129 |
| POND 8 .....  | 137 |
| POND 9 .....  | 146 |
| POND 10 ..... | 155 |
| POND 11 ..... | 164 |
| POND 12 ..... | 173 |
| POND 13 ..... | 182 |
| POND 14 ..... | 190 |
| POND 15 ..... | 199 |
| POND 16 ..... | 207 |
| POND 17 ..... | 215 |
| POND 18 ..... | 223 |
| POND 19 ..... | 232 |
| POND 20 ..... | 241 |

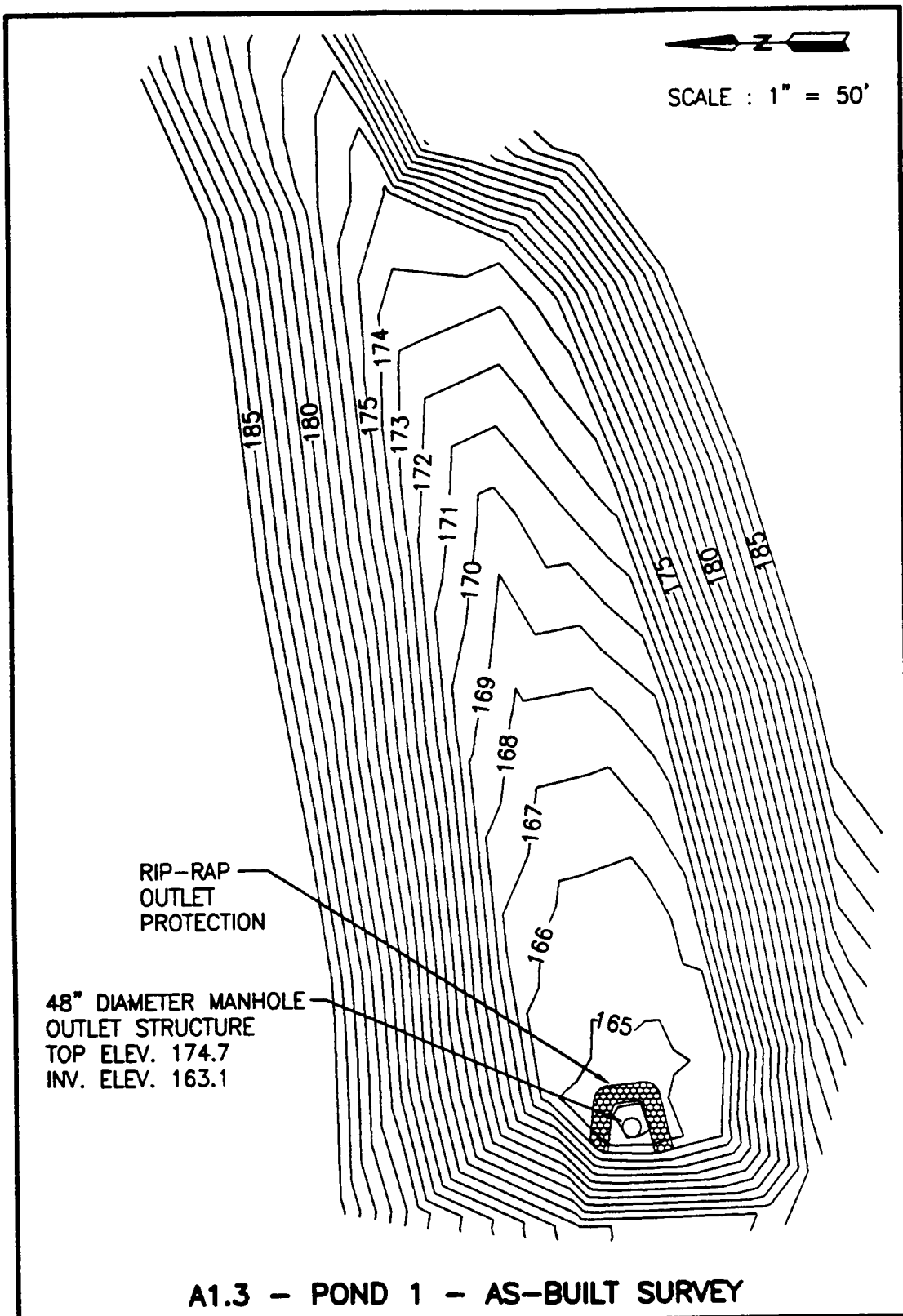


A1.1a - Looking downstream at the outlet structure and dam of Pond 1. The orifice at the bottom of the outlet structure was intended to be a 11.5 in. diameter orifice but, it was constructed as a 10.5 in. diameter orifice.

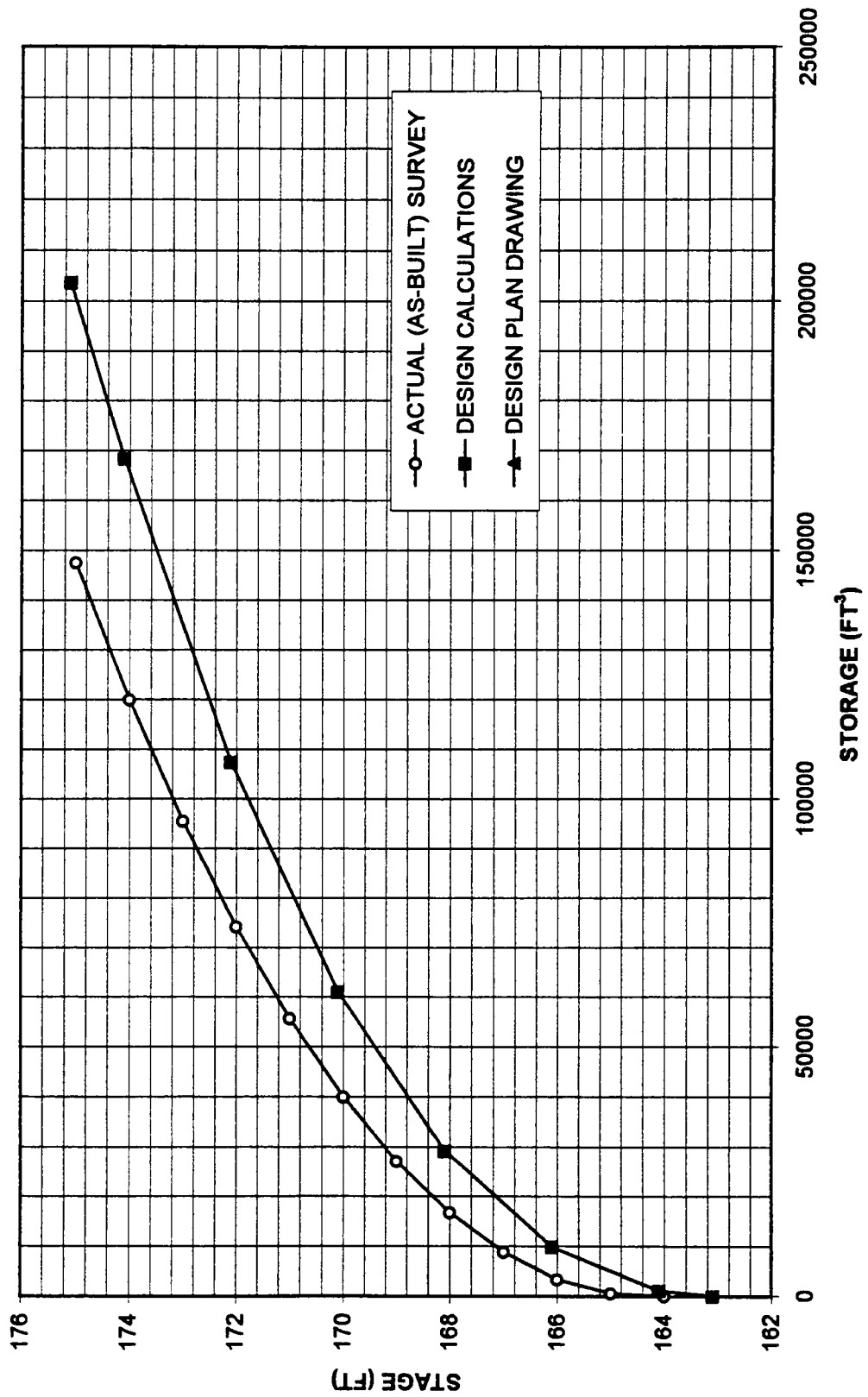


A1.1b - Looking upstream at Pond 1, the area previously wooded, was cleared to build the pond. The bottom of the pond is now eroding into gullies.

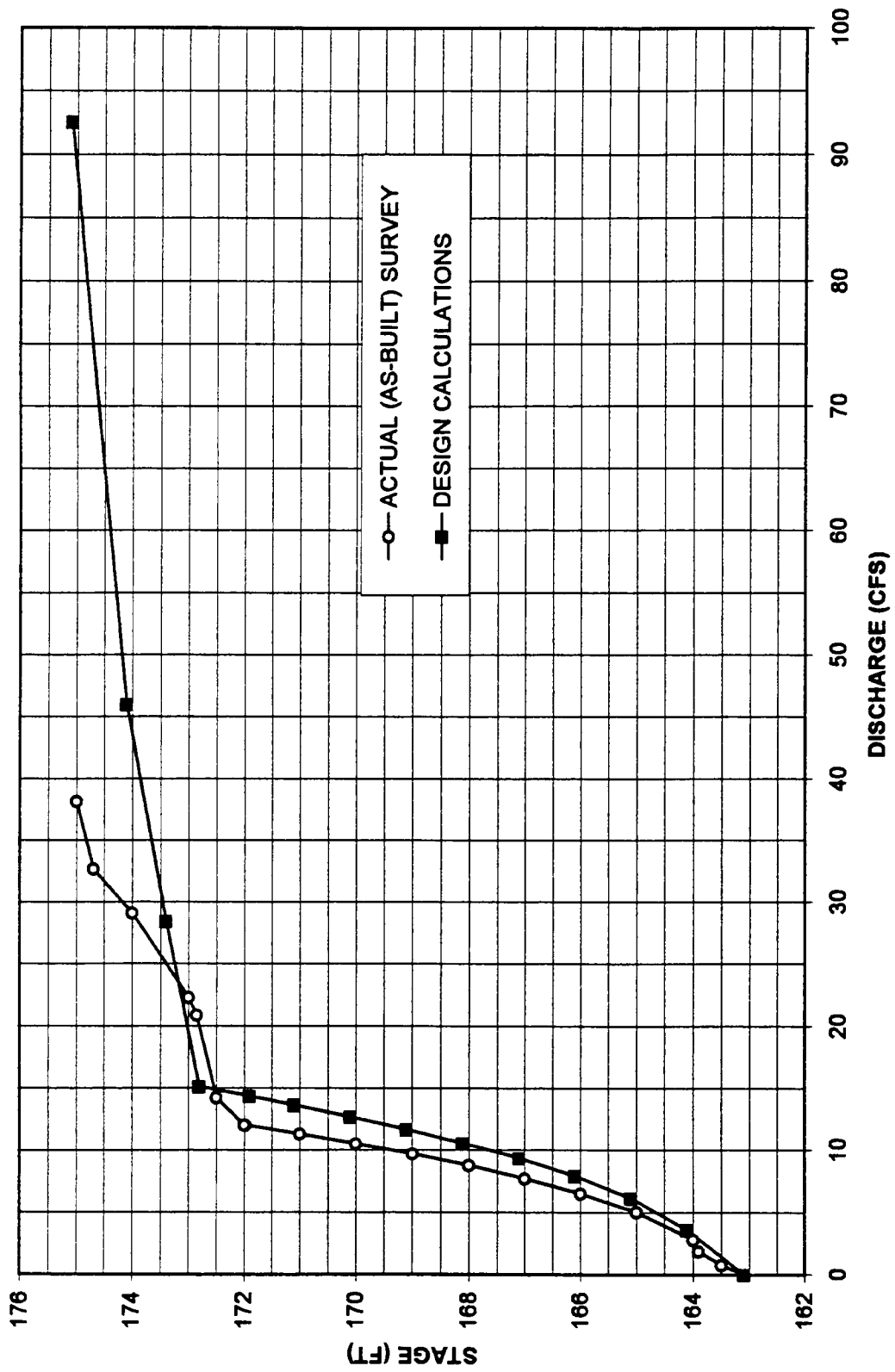




# A1.4 - POND 1 - STAGE vs. STORAGE



# A1.5 - POND 1 - STAGE vs. DISCHARGE





# A1.6 - POND 1 - INFLOW HYDROGRAPH

## TABULAR HYDROGRAPH METHOD

Version 2.00

Project : DETENTION POND ANALYSIS User: TER Date: 04-09-97  
 County : State: TN Checked: Date:   
 Subtitle: POND 1

Total watershed area: 0.057 sq mi Rainfall type: II Frequency: years  
 ----- Subareas -----

Area(sq mi) 0.06  
 Rainfall(in) 4.8  
 Curve number 70  
 Runoff(in) 1.89  
 Tc (hrs) 0.17  
 (Used) 0.20  
 TimeToOutlet 0.00  
 Ia/P 0.18

| Time (hr) | Total Flow | Subarea Contribution to Total Flow (cfs) |
|-----------|------------|------------------------------------------|
| 11.0      | 2          | 2                                        |
| 11.1      | 2          | 2                                        |
| 11.6      | 3          | 3                                        |
| 11.9      | 15         | 15                                       |
| 12.0      | 34         | 34                                       |
| 12.1      | 72         | 72                                       |
| 12.2      | 82P        | 82P                                      |
| 12.3      | 53         | 53                                       |
| 12.4      | 28         | 28                                       |
| 12.5      | 19         | 19                                       |
| 12.6      | 15         | 15                                       |
| 12.7      | 12         | 12                                       |
| 12.8      | 10         | 10                                       |
| 13.0      | 9          | 9                                        |
| 13.2      | 7          | 7                                        |
| 13.4      | 7          | 7                                        |
| 13.6      | 6          | 6                                        |
| 13.8      | 6          | 6                                        |
| 14.0      | 5          | 5                                        |
| 14.3      | 4          | 4                                        |
| 14.5      | 4          | 4                                        |
| 15.0      | 4          | 4                                        |
| 15.5      | 3          | 3                                        |
| 16.0      | 3          | 3                                        |
| 16.5      | 3          | 3                                        |
| 17.0      | 3          | 3                                        |
| 17.5      | 2          | 2                                        |
| 18.0      | 2          | 2                                        |
| 19.0      | 2          | 2                                        |
| 20.0      | 2          | 2                                        |
| 22.0      | 2          | 2                                        |
| 26.0      | 0          | 0                                        |

P - Peak Flow

# A1.7 - POND 1 - HEC-1 INPUT FILE

```

ID
ID POND 1
ID
*FREE
IT 6 0 0 300
IN 6 0 0
IO 2 0 0
KK INFLOW HYDROGRAPH
KM 10 YEAR HYDROGRAPH
QI 0 2 2 2 2 2.3 2.6 3 7 11
QI 15 34 72 82 53 28 19 15 12 10
QI 9.5 9 8 7 7 7 6.5 6 6 6
QI 5.5 5 4.6 4.3 4 4 4 4 4 4
QI 4 4 3.8 3.6 3.4 3.2 3 3 3 3
QI 3 3 3 3 3 3 3 3 3 3
QI 3 3 2.8 2.6 2.4 2.2 2 2 2 2
QI 2 2 2 2 2 2 2 2 2 2
QI 2 2 2 2 2 2 2 2 2 2
QI 2 2 2 2 2 2 2 2 2 2
QI 2 2 2 2 2 2 2 2 2 2
QI 2 2 1 1 1 0 0 0
KK POND1
KM ROUTE 10 YEAR POST DEV HYD
RS 1 ELEV 163.1
SV 0 .0001 .0008 .001 .014 .076 .204 .386 .624 .92
SV 1.28 1.66 1.7 1.88 2.17 2.19 2.75 3.35 3.39
SQ 0 .8 1.9 2.8 5 6.5 7.7 8.8 9.7 10.5
SQ 11.3 12.1 12.2 14.3 20.9 22.3 29.1 32.7 38.2
SE 163.1 163.5 163.9 164 165 166 167 168 169 170
SE 171 171.9 172 172.5 172.9 173 174 174.7 175
ST 175 60 3.3 1.5
ZZ

```

## A1.8 - Pond 1 - HEC-1 SUMMARY OF RESULTS

### RUNOFF SUMMARY FLOW IN CUBIC FEET PER SECOND TIME IN HOURS, AREA IN SQUARE MILES

| + | OPERATION                                                             | STATION | PEAK<br>FLOW | TIME OF<br>PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD |         |         | BASIN<br>AREA | MAXIMUM<br>STAGE | TIME OF<br>MAX STAGE |
|---|-----------------------------------------------------------------------|---------|--------------|-----------------|---------------------------------|---------|---------|---------------|------------------|----------------------|
|   |                                                                       |         |              |                 | 6-HOUR                          | 24-HOUR | 72-HOUR |               |                  |                      |
| + | HYDROGRAPH AT<br>INFLOW                                               |         | 82.          | 1.30            | 9.                              | 3.      | 3.      | .00           |                  |                      |
| + | ROUTED TO<br>POND                                                     |         | 16.          | 1.70            | 9.                              | 3.      | 3.      | .00           | 172.58           | 1.70                 |
| + | SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION POND           |         |              |                 |                                 |         |         |               |                  |                      |
| 1 | (PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION) |         |              |                 |                                 |         |         |               |                  |                      |

| PLAN 1 ..... | INITIAL VALUE | SPILLWAY CREST | TOP OF DAM |
|--------------|---------------|----------------|------------|
| ELEVATION    | 163.1         | 175.00         | 175.00     |
| STORAGE      | 0.            | 3.             | 3.         |
| OUTFLOW      | 0.            | 38.            | 38.        |

| RATIO<br>OF<br>PMF | MAXIMUM<br>RESERVOIR<br>W.S.ELEV | MAXIMUM<br>DEPTH<br>OVER DAM | MAXIMUM<br>STORAGE<br>AC-FT | MAXIMUM<br>OUTFLOW<br>CFS | DURATION<br>OVER TOP<br>HOURS | TIME OF<br>MAX OUTFLOW<br>HOURS | TIME OF<br>FAILURE<br>HOURS |
|--------------------|----------------------------------|------------------------------|-----------------------------|---------------------------|-------------------------------|---------------------------------|-----------------------------|
| 1.00               | 172.58                           | .00                          | 2.                          | 16.                       | .00                           | 1.70                            | .00                         |

\*\*\* NORMAL END OF HEC-1 \*\*\*



A2.1a - Looking downstream at the outlet structure and dam of Pond 2. The outlet structure is a 5 ft. x 5.5 ft. concrete box with a 12 in. diameter orifice. The orifice is constructed from an 8-in. Diameter PVC pipe.



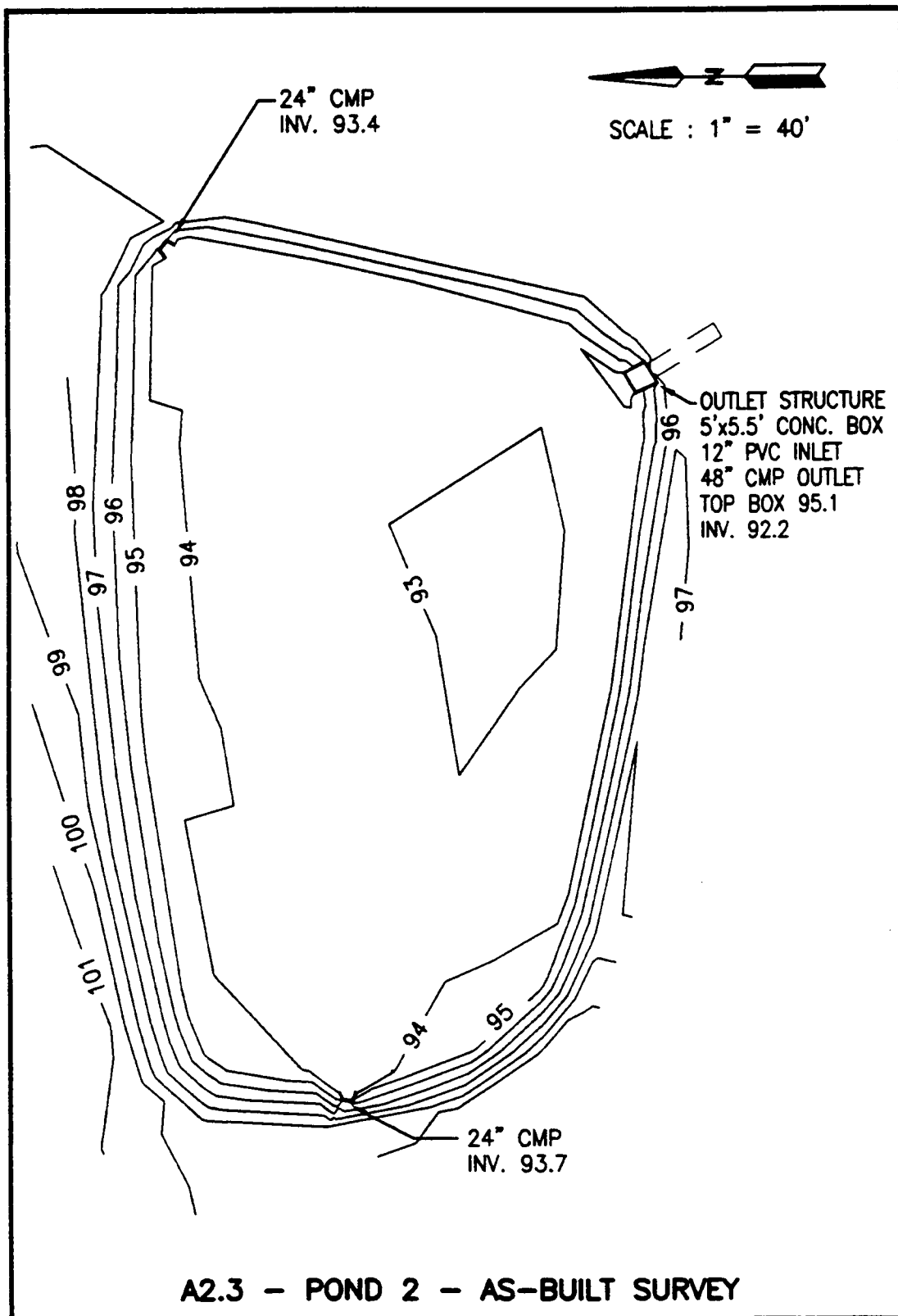
A2.1b - Looking upstream at the 12 in. diameter PVC orifice in the bottom of the concrete box.



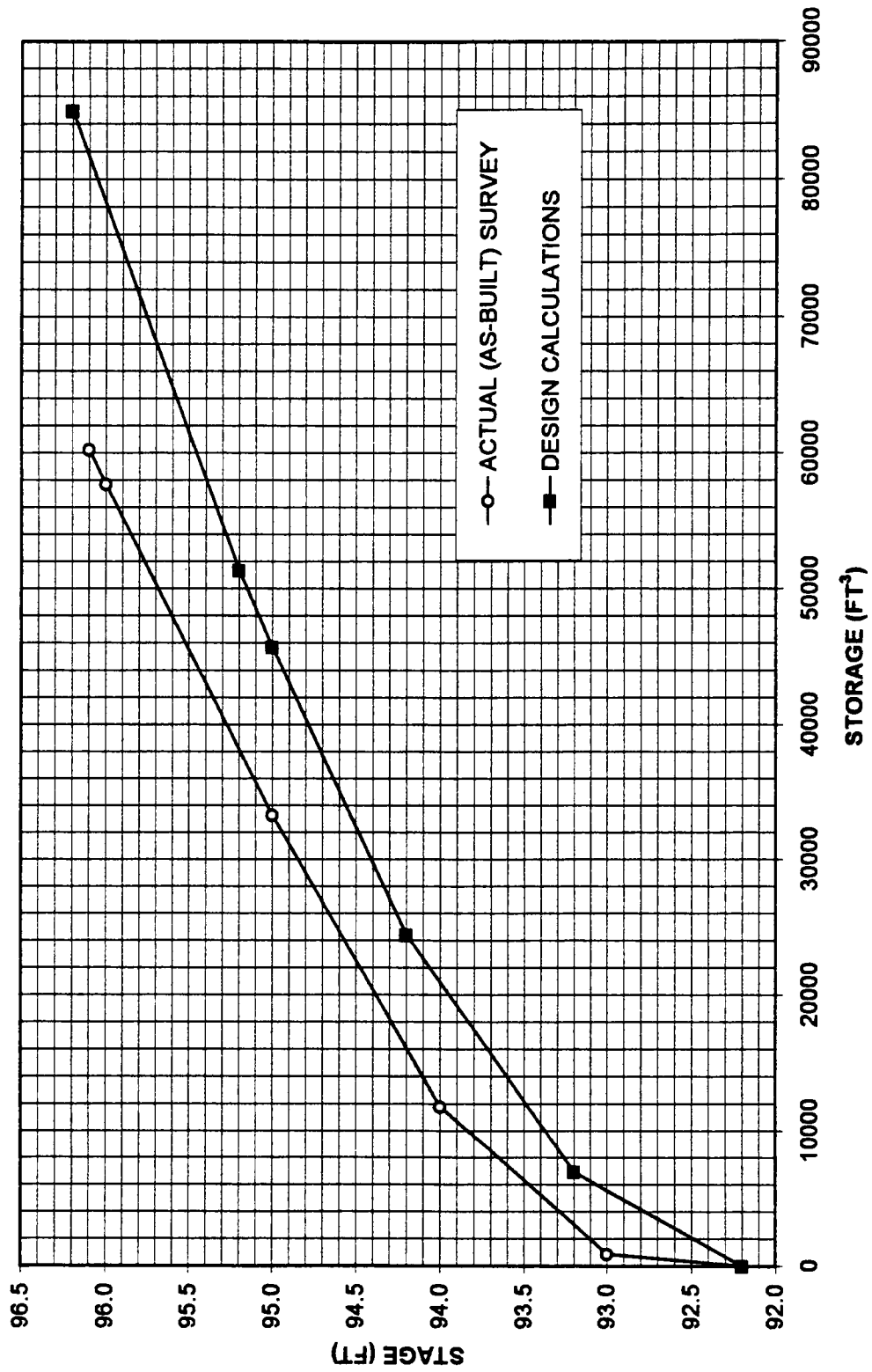
A2.1c - Looking upstream at Pond 2, the pond has been seeded and mulched recently.

**INFORMATION NOT AVAILABLE**

**A2.2 - POND 2 - DESIGN PLAN DRAWING**

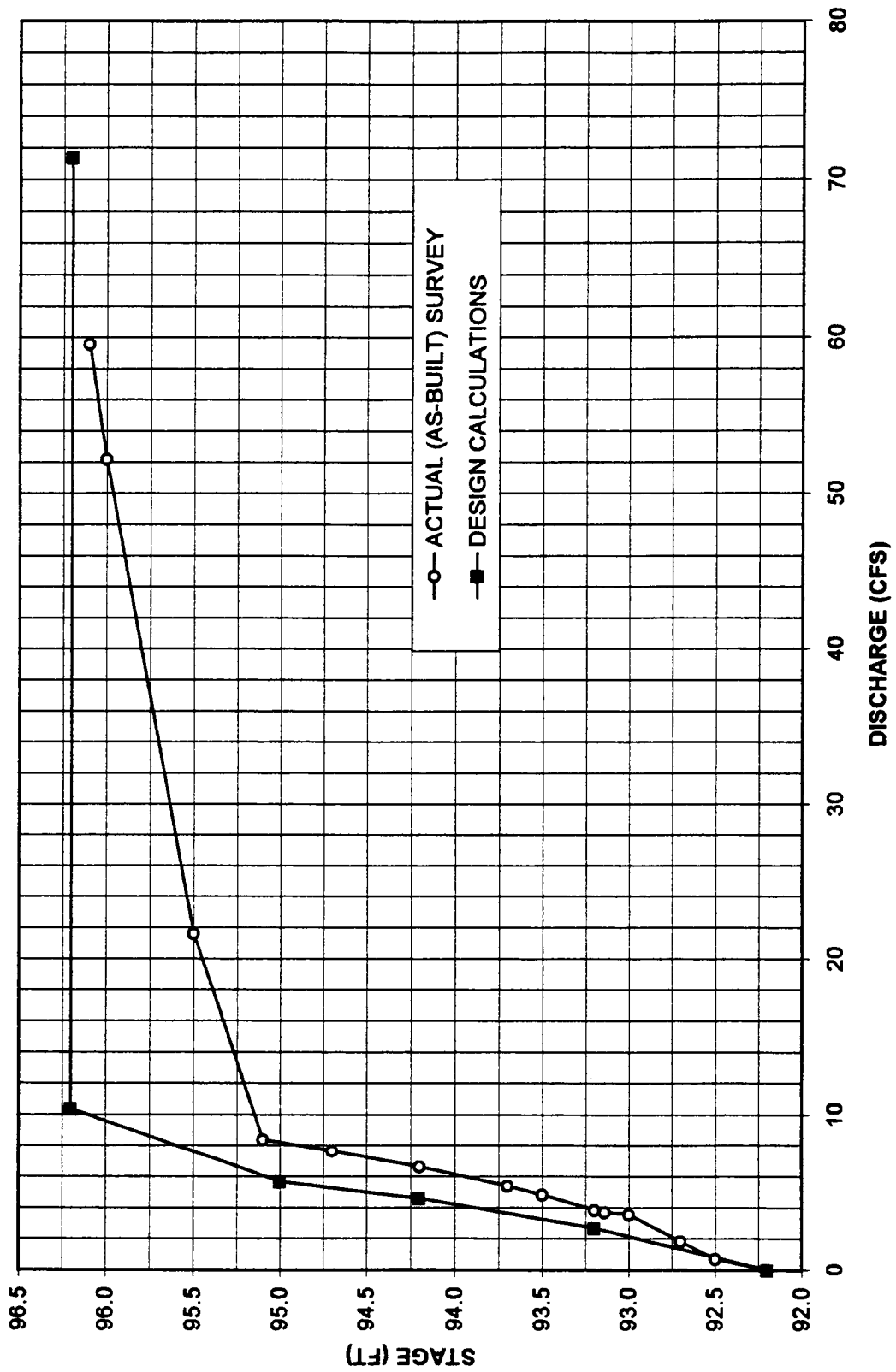


## A2.4 - POND 2 - STAGE vs. STORAGE





# A2.5 - POND 2 - STAGE vs. DISCHARGE



# A2.6 - POND 2 - INFLOW HYDROGRAPH

## TABULAR HYDROGRAPH METHOD

Version 2.00

Project : DETENTION POND ANALYSIS User: TZR Date: 04-09-97  
 County : State: TN Checked: Date:   
 Subtitle: POND 2

Total watershed area: 0.030 sq mi Rainfall type: II Frequency: years  
 ----- Subareas -----

1  
 Area(sq mi) 0.03  
 Rainfall(in) 4.8  
 Curve number 67  
 Runoff(in) 1.67  
 Tc (hrs) 0.10  
 TimeToOutlet 0.00  
 Ia/P 0.21

| Time (hr) | Total Flow | Subarea Contribution to Total Flow (cfs) |
|-----------|------------|------------------------------------------|
|           |            | 1                                        |
| 11.0      | 1          | 1                                        |
| 11.3      | 1          | 1                                        |
| 11.6      | 1          | 1                                        |
| 11.9      | 12         | 12                                       |
| 12.0      | 30         | 30                                       |
| 12.1      | 48P        | 48P                                      |
| 12.2      | 28         | 28                                       |
| 12.3      | 11         | 11                                       |
| 12.4      | 8          | 8                                        |
| 12.5      | 7          | 7                                        |
| 12.6      | 6          | 6                                        |
| 12.7      | 5          | 5                                        |
| 12.8      | 4          | 4                                        |
| 13.0      | 4          | 4                                        |
| 13.2      | 3          | 3                                        |
| 13.4      | 3          | 3                                        |
| 13.6      | 3          | 3                                        |
| 13.8      | 2          | 2                                        |
| 14.0      | 2          | 2                                        |
| 14.3      | 2          | 2                                        |
| 14.6      | 2          | 2                                        |
| 15.0      | 2          | 2                                        |
| 15.5      | 2          | 2                                        |
| 16.0      | 1          | 1                                        |
| 16.5      | 1          | 1                                        |
| 17.0      | 1          | 1                                        |
| 17.5      | 1          | 1                                        |
| 18.0      | 1          | 1                                        |
| 19.0      | 1          | 1                                        |
| 20.0      | 1          | 1                                        |
| 22.0      | 1          | 1                                        |
| 26.0      | 0          | 0                                        |

P - Peak Flow

# A2.7 - POND 2 - HEC-1 INPUT FILE

```

ID
ID POND 2
ID
*FREE
IT 6 0 0 300
IN 6 0 0
IO 2 0 0
KK INFLOW HYDROGRAPH
KM 10 YEAR POST DEV
QI 0 0 1 1 1 1 1 1 1 8.25
QI 15.5 22.75 30 48 28 11 8 7 6 5
QI 4 4 4 3.5 3 3 3 3 3 2.5
QI 2 2 2 2 2 2 2 2 2 2
QI 2 2 2 2 2 2 2 2 1.8 1.6
QI 1.4 1.2 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 .975 .950 .925 .9 .875 .85 .825
QI .8 .775 .75 .725 .7 .675 .65 .625 .6 .575
QI .55 .525 .5 .475 .45 .425 .4 .375 .35 .325
QI .3 .275 .25 .225 .2 .175 .15 .125 .1 .075
QI .05 .025 0 0
KK POND2
KM POND DATA
RS 1 ELEV 92.2
SV 0 .005 .006 .02 .044 .057 .115 .169 .344 .599
SV .815 1.033 1.32 1.38
SQ 0 .7 1.8 3.6 3.7 3.8 4.8 5.4 6.6 7.7
SQ 8.4 21.6 52.2 59.6
SE 92.2 92.5 92.7 93 93.1 93.2 93.5 93.7 94.2 94.7
SE 95.1 95.5 96 96.1
ST 96.1 50 3.3 1.5
ZZ

```

## A2.8 - POND 2 - HEC-1 SUMMARY OF RESULTS

RUNOFF SUMMARY  
FLOW IN CUBIC FEET PER SECOND  
TIME IN HOURS, AREA IN SQUARE MILES

|   | OPERATION               | STATION | PEAK<br>FLOW | TIME OF<br>PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD |         |         | BASIN<br>AREA | MAXIMUM<br>STAGE | TIME OF<br>MAX STAGE |
|---|-------------------------|---------|--------------|-----------------|---------------------------------|---------|---------|---------------|------------------|----------------------|
|   |                         |         |              |                 | 6-HOUR                          | 24-HOUR | 72-HOUR |               |                  |                      |
| + | HYDROGRAPH AT<br>INFLOW |         | 48.          | 1.30            | 5.                              | 1.      | 1.      | .00           |                  |                      |
| + | ROUTED TO<br>POND       |         | 15.          | 1.50            | 5.                              | 1.      | 1.      | .00           | 95.29            | 1.50                 |

SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION POND  
(PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION)

|              |                    |                                  |                              |                             |                           |                               |                                 |                             |
|--------------|--------------------|----------------------------------|------------------------------|-----------------------------|---------------------------|-------------------------------|---------------------------------|-----------------------------|
| PLAN 1 ..... | INITIAL VALUE      |                                  | SPILLWAY CREST               |                             | TOP OF DAM                |                               |                                 |                             |
|              | ELEVATION          | 92.20                            |                              | 96.10                       |                           | 96.10                         |                                 |                             |
|              | STORAGE            | 0.                               |                              | 1.                          |                           | 1.                            |                                 |                             |
|              | OUTFLOW            | 0.                               |                              | 60.                         |                           | 60.                           |                                 |                             |
|              | RATIO<br>OF<br>PMF | MAXIMUM<br>RESERVOIR<br>W.S.ELEV | MAXIMUM<br>DEPTH<br>OVER DAM | MAXIMUM<br>STORAGE<br>AC-FT | MAXIMUM<br>OUTFLOW<br>CFS | DURATION<br>OVER TOP<br>HOURS | TIME OF<br>MAX OUTFLOW<br>HOURS | TIME OF<br>FAILURE<br>HOURS |
|              | 1.00               | 95.29                            | .00                          | 1.                          | 15.                       | .00                           | 1.50                            | .00                         |

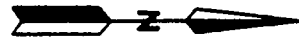
\*\*\* NORMAL END OF HEC-1 \*\*\*



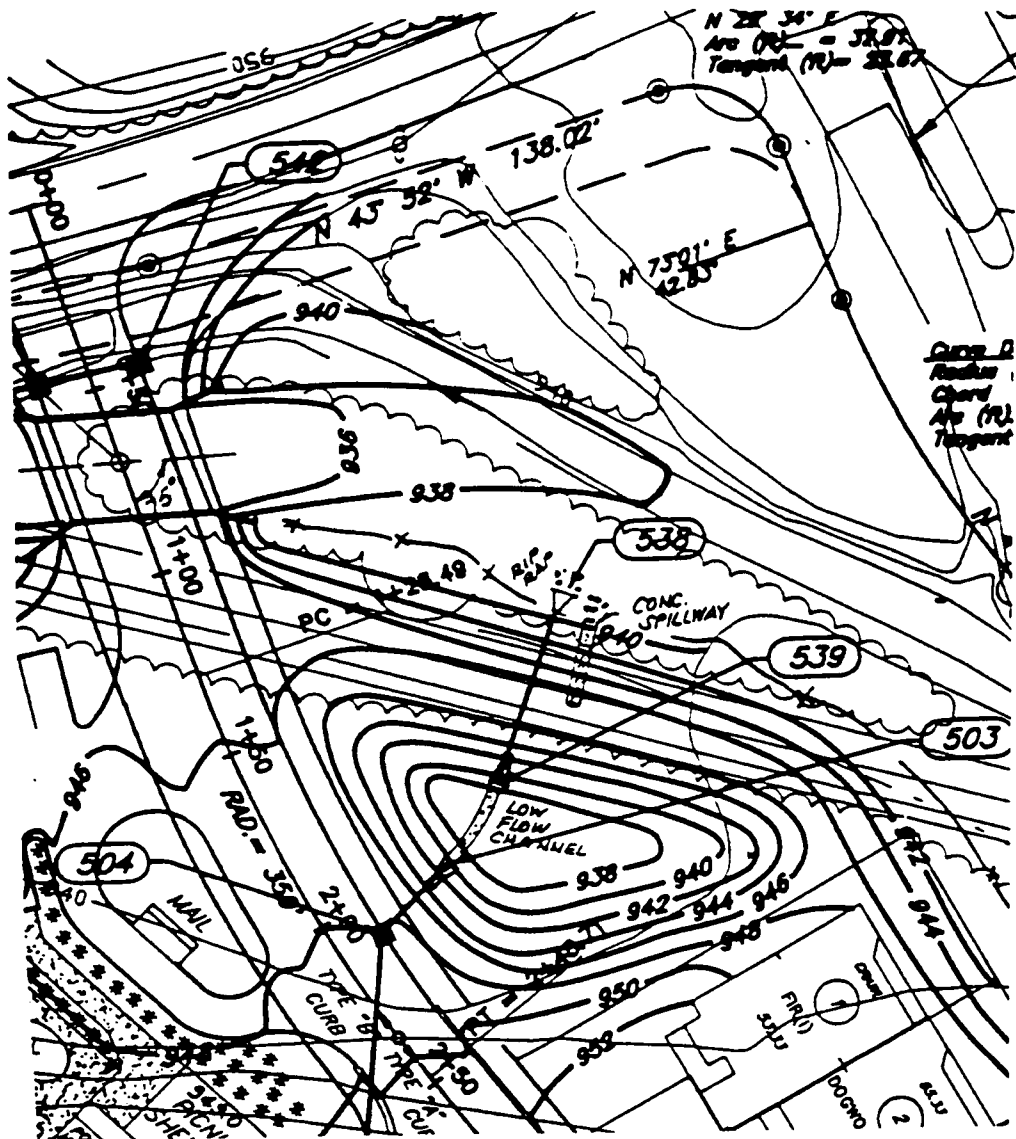
A3.1a - The outlet structure for Pond 3 is a 18 in. diameter CMP having a 6 in. diameter orifice face plate. The pond is filling in with silt from the upstream construction site.



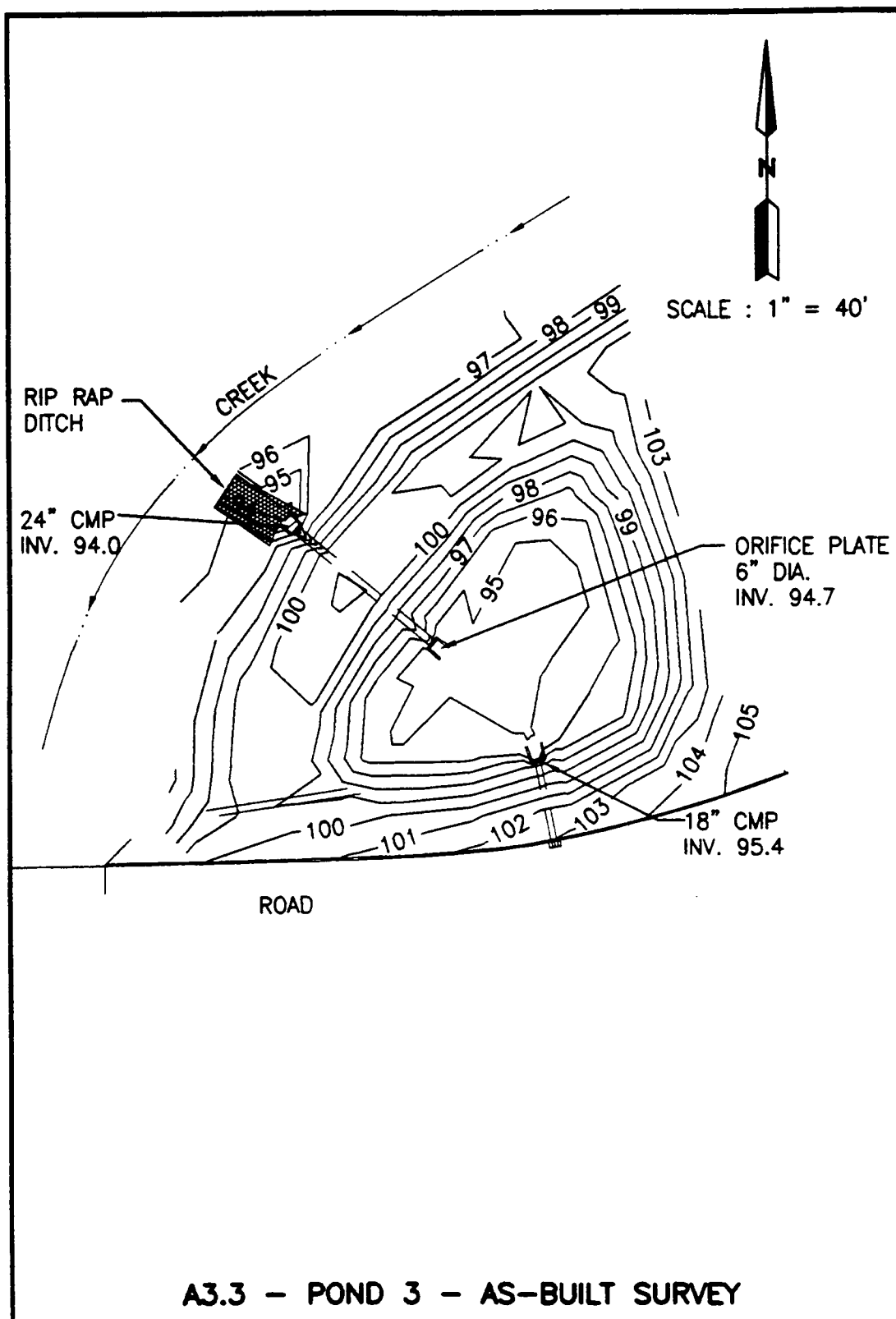
A3.1b - Sediment from this construction site is filling in Pond 3 due to poor erosion control practices.



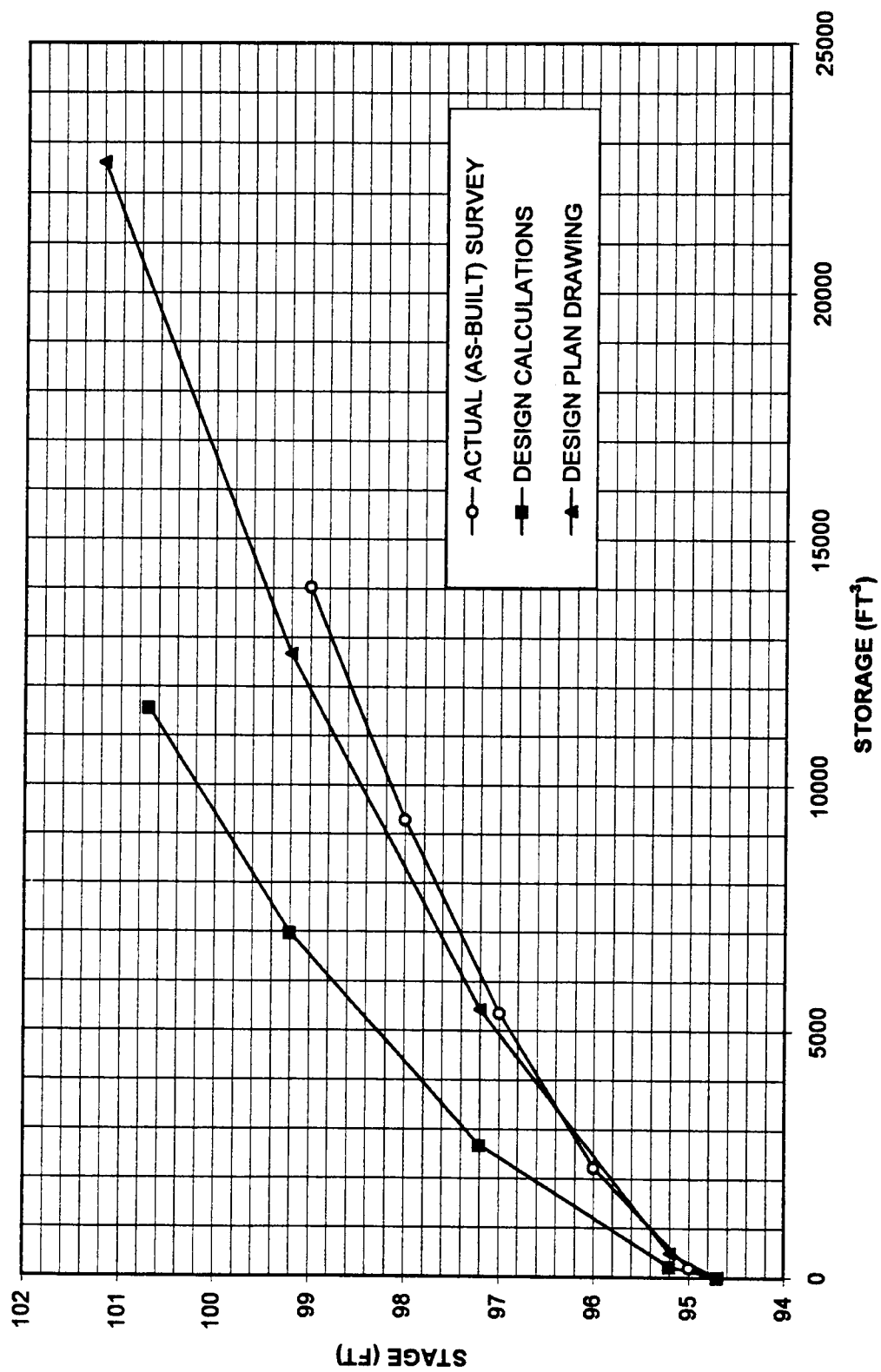
SCALE : 1" = 50'



A3.2 - POND 3 - DESIGN PLAN DRAWING

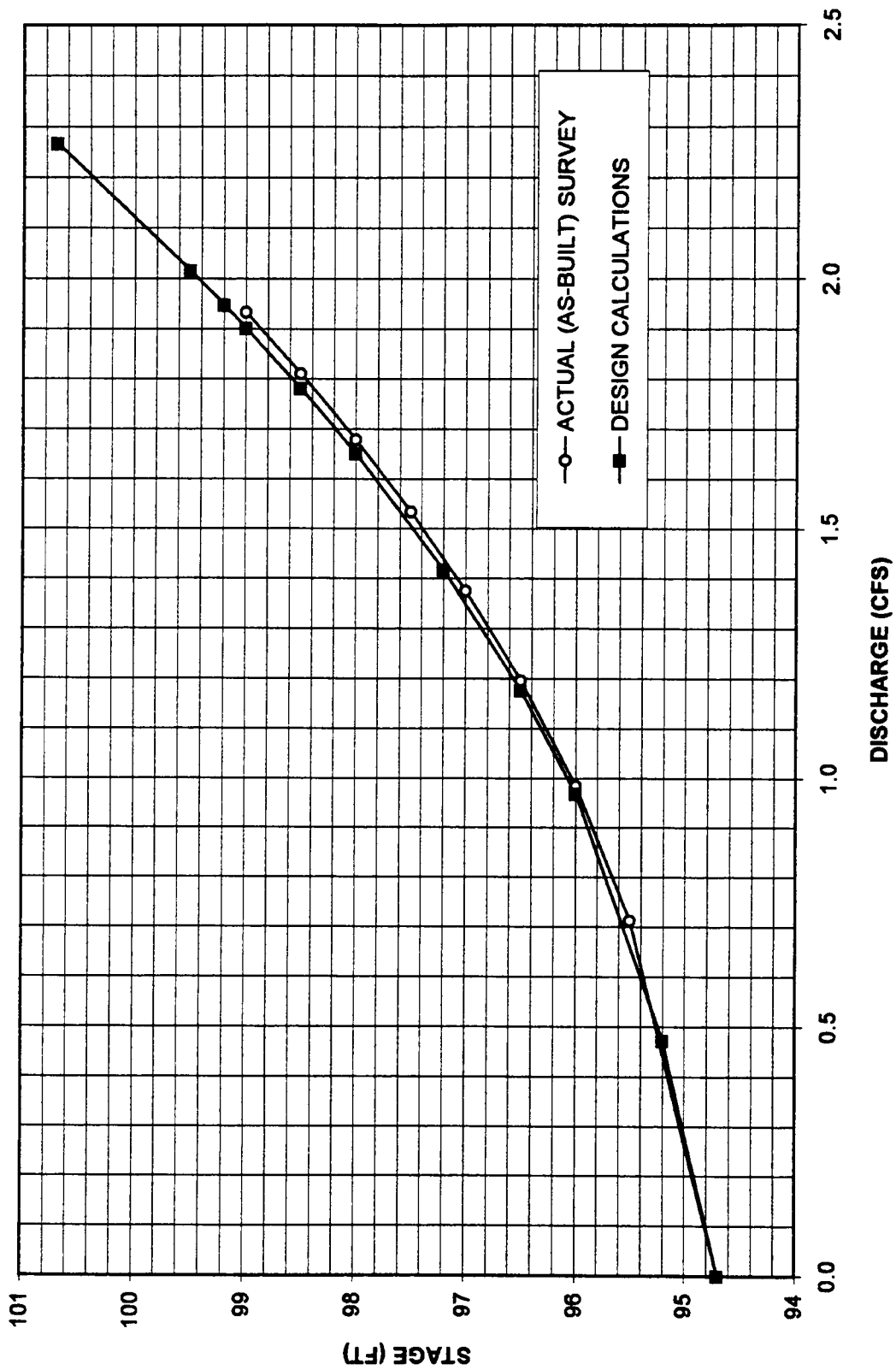


### A3.4 - POND 3 - STAGE vs. STORAGE





# A3.5 - POND 3 - STAGE vs. DISCHARGE



### **A3.6 - POND 3 - INFLOW HYDROGRAPH**

Inadequate Information

### A3.7 - POND 3 - HEC-1 INPUT FILE

Inadequate Information

### A3.8 - POND 3 - HEC-1 SUMMARY OF RESULTS

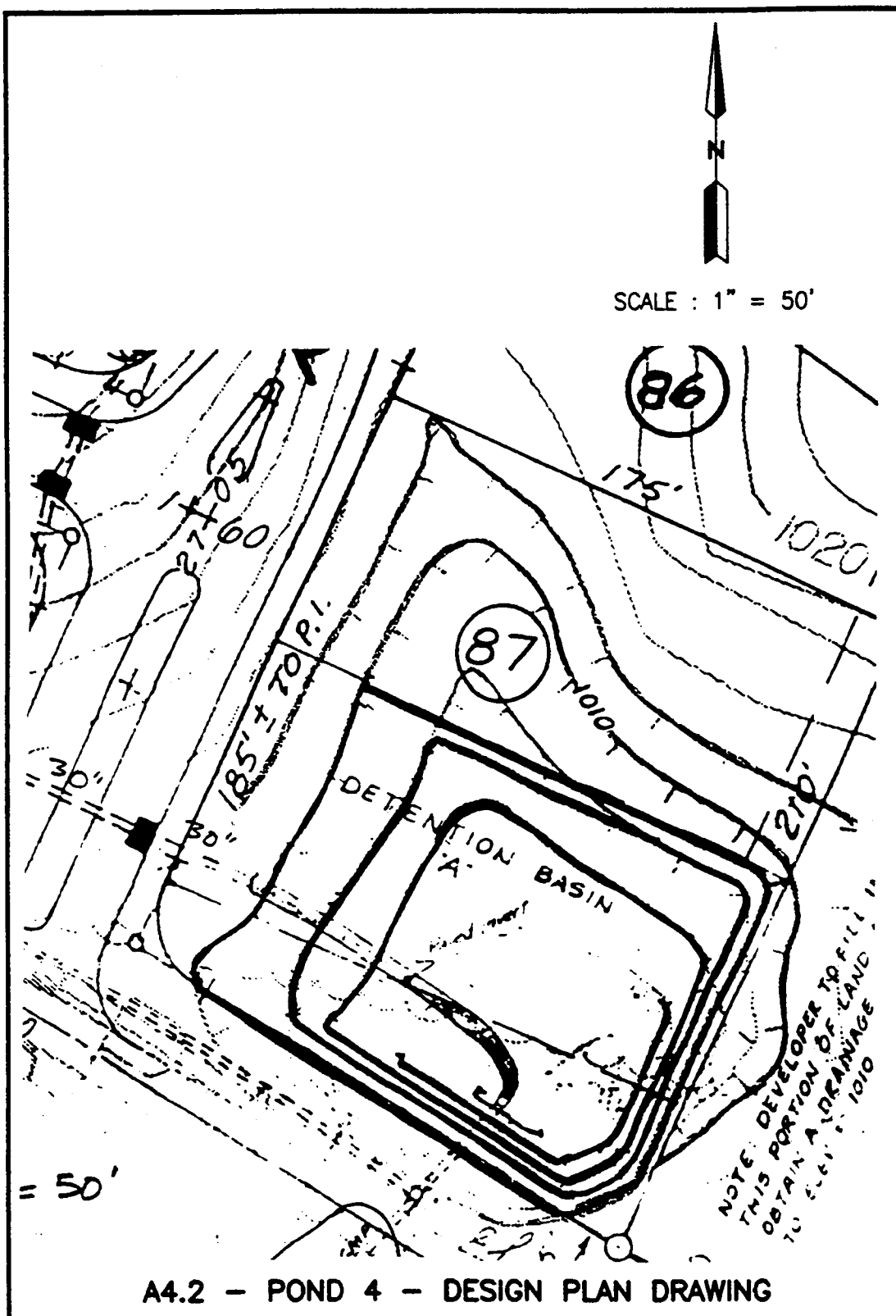
Inadequate Information



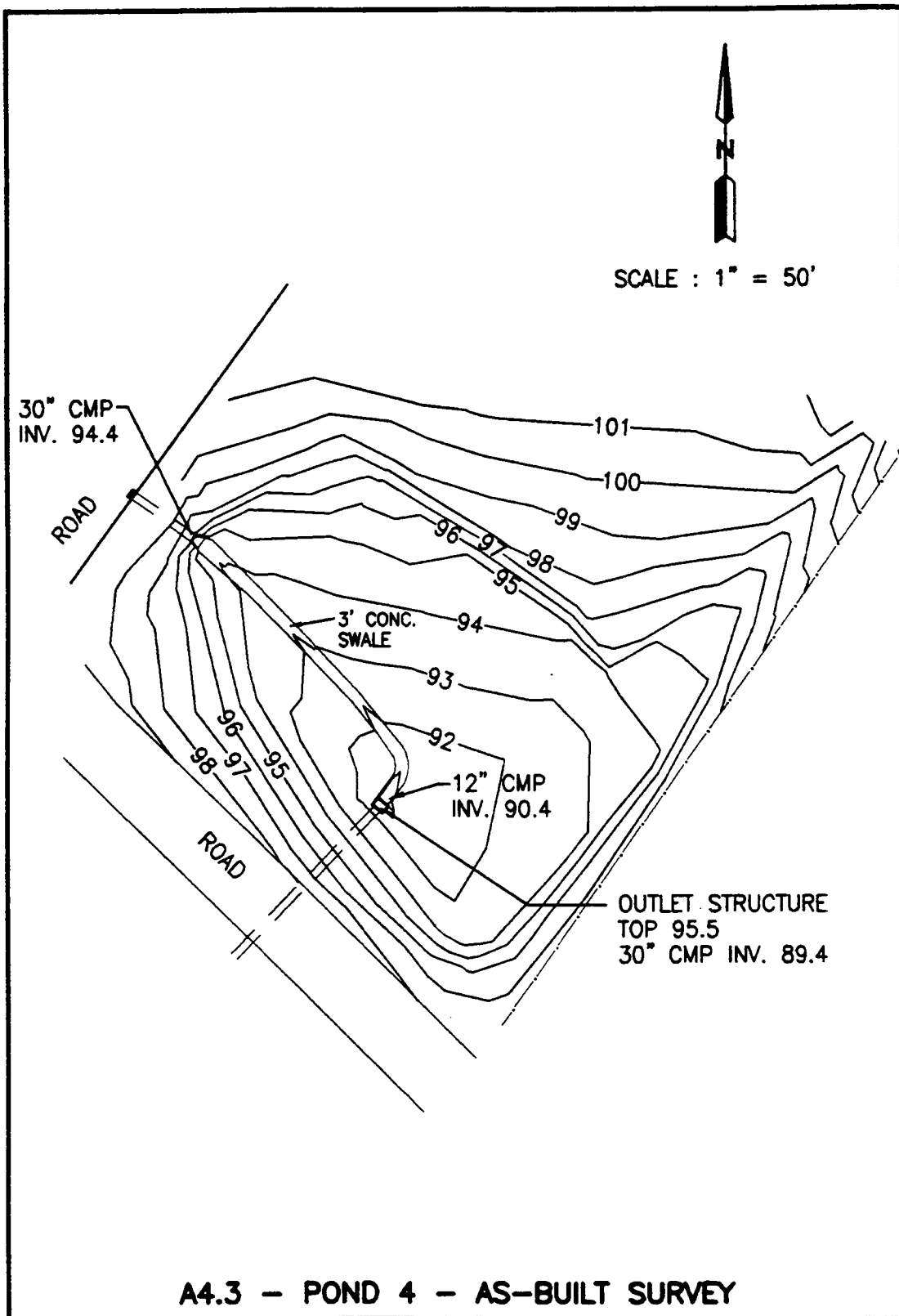
A4.1a - The outlet structure for Pond 4 is a 3-ft. x 2-ft. concrete box having a 12-in. diameter CMP at the bottom of the box for the initial outlet. The initial outlet was intended to be a 4-in. diameter orifice.



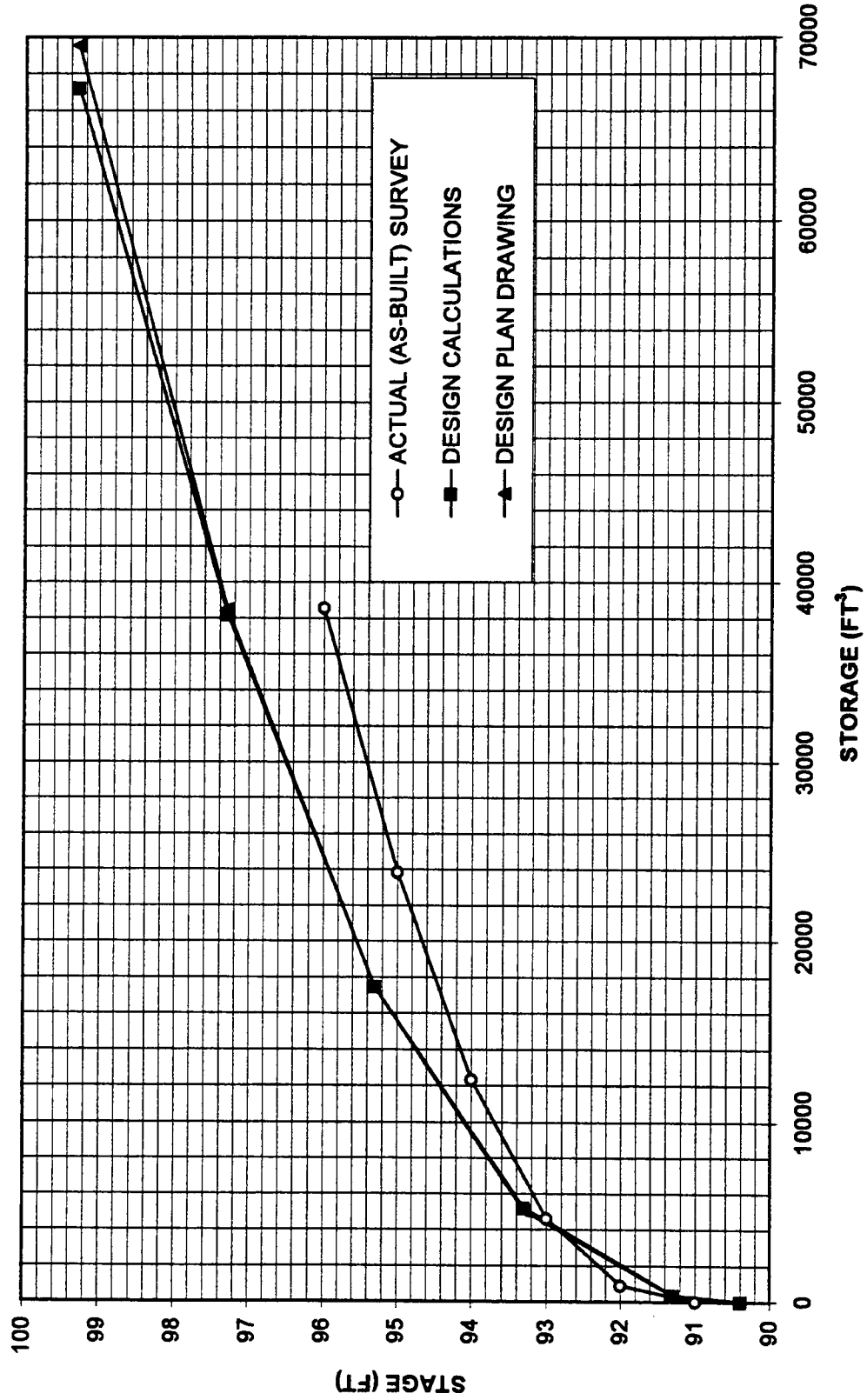
A4.1b - Looking upstream of Pond 4 is an inlet ditch with silt fence erosion protection and check dams. The pond is well maintained.



A4.2 - POND 4 - DESIGN PLAN DRAWING

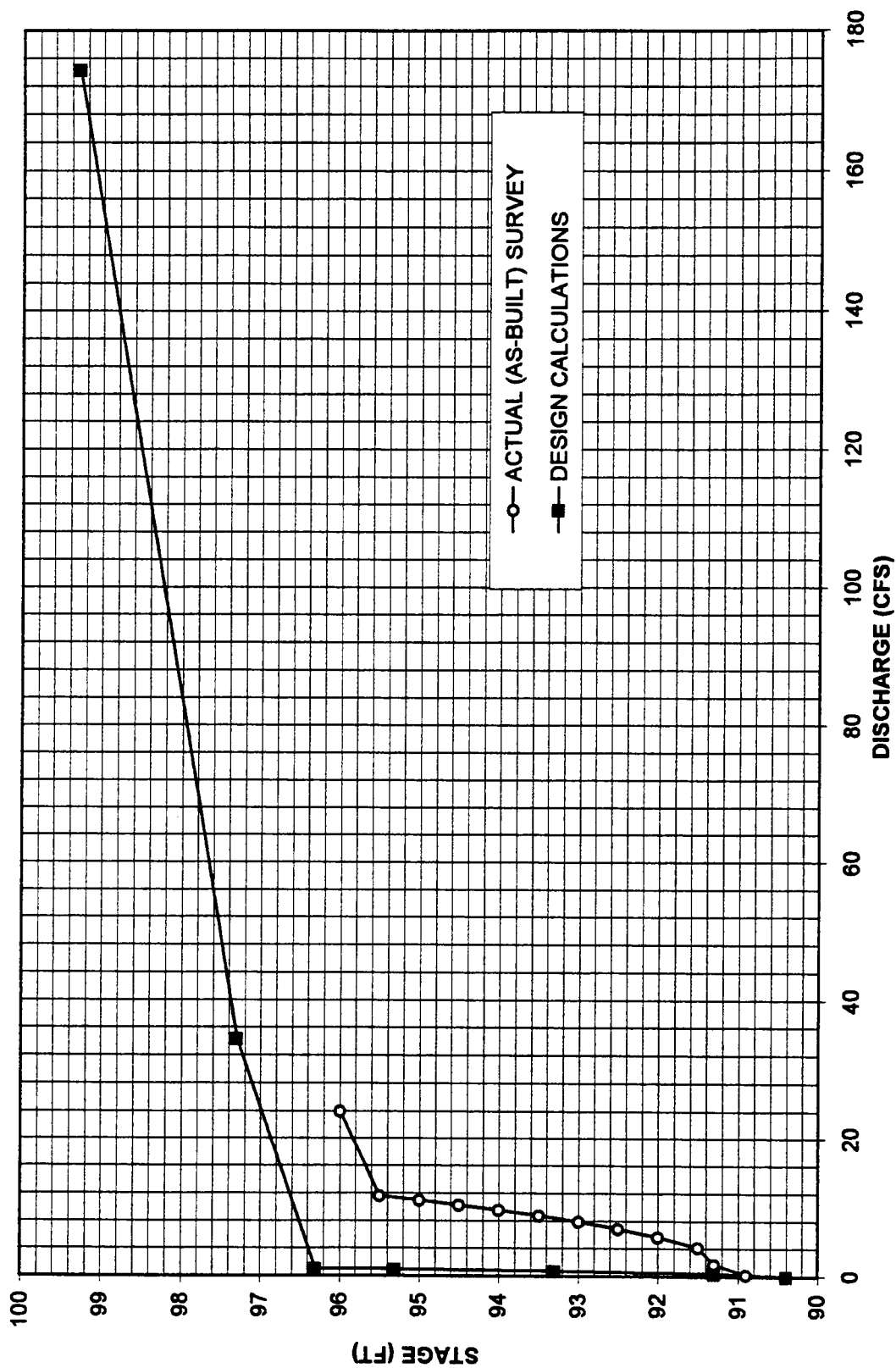


# A4.4 - POND 4 - STAGE vs. STORAGE





# A4.5 - POND 4 - STAGE vs. DISCHARGE



# A4.6 - POND 4 - INFLOW HYDROGRAPH

## TABULAR HYDROGRAPH METHOD

Version 2.00

Project : DETENTION POND ANALYSIS

County :

State: TN

User: TER

Date: 04-09-97

Subtitle: POND 4

Checked: \_\_\_\_\_

Date: \_\_\_\_\_

Total watershed area: 0.020 sq mi Rainfall type: II Frequency: years

----- Subareas -----  
 1  
 Area(sq mi) 0.02  
 Rainfall(in) 4.8  
 Curve number 51  
 Runoff(in) 0.77  
 Tc (hrs) 0.40  
 TimeToOutlet 0.00  
 Ia/P 0.37

| Time (hr) | Total Flow | Subarea Contribution to Total Flow (cfs) |
|-----------|------------|------------------------------------------|
| 11.0      | 0          | 0                                        |
| 11.3      | 0          | 0                                        |
| 11.6      | 0          | 0                                        |
| 11.9      | 0          | 0                                        |
| 12.0      | 0          | 0                                        |
| 12.1      | 1          | 1                                        |
| 12.2      | 3          | 3                                        |
| 12.3      | 67         | 67                                       |
| 12.4      | 6          | 6                                        |
| 12.5      | 6          | 6                                        |
| 12.6      | 4          | 4                                        |
| 12.7      | 3          | 3                                        |
| 12.8      | 3          | 3                                        |
| 13.0      | 2          | 2                                        |
| 13.2      | 2          | 2                                        |
| 13.4      | 1          | 1                                        |
| 13.6      | 1          | 1                                        |
| 13.8      | 1          | 1                                        |
| 14.0      | 1          | 1                                        |
| 14.3      | 1          | 1                                        |
| 14.5      | 1          | 1                                        |
| 15.0      | 1          | 1                                        |
| 15.5      | 1          | 1                                        |
| 16.0      | 1          | 1                                        |
| 16.5      | 1          | 1                                        |
| 17.0      | 1          | 1                                        |
| 17.5      | 1          | 1                                        |
| 18.0      | 0          | 0                                        |
| 19.0      | 0          | 0                                        |
| 20.0      | 0          | 0                                        |
| 22.0      | 0          | 0                                        |
| 26.0      | 0          | 0                                        |

P - Peak Flow

# A4.7 - POND 4 - HEC-1 INPUT FILE

```

ID
ID POND 4
ID
*FREE
IT 6 0 0 300
IN 6 0 0
IO 2 0 0
KK INFLOW HYDROGRAPH SCS TR-55
KM 10 YR POST DEVELOPMENT
QI 0 0 1 3 6 6 6 4 3 3
QI 2.5 2.0 2.0 2.0 1.5 1.0 1.0 1.0 1.0 1.0
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 .8 .6 .4
QI .2 0 0
KK POND 4
KM ROUTE 10 YR POST DEV HYD
RS 1 ELEV 90.4
SV 0 0.0002 0.008 0.016 0.02 0.062 0.106 0.204 0.284 0.413
SV 0.548 0.712 0.89
SQ 0 0.2 1.8 4.2 5.7 6.9 7.9 8.7 9.5 10.3
SQ 11 11.6 23.9
SE 90.4 90.9 91.3 91.5 92.0 92.5 93.0 93.5 94.0 94.5
SE 95.0 95.5 96.0
ST 96.0 70 3.3 1.5
ZZ

```

## A4.8 - POND 4 - HEC-1 SUMMARY OF RESULTS

### RUNOFF SUMMARY FLOW IN CUBIC FEET PER SECOND TIME IN HOURS, AREA IN SQUARE MILES

|   | OPERATION     | STATION | PEAK<br>FLOW | TIME OF<br>PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD |         |         | BASIN<br>AREA | MAXIMUM<br>STAGE | TIME OF<br>MAX STAGE |
|---|---------------|---------|--------------|-----------------|---------------------------------|---------|---------|---------------|------------------|----------------------|
|   |               |         |              |                 | 6-HOUR                          | 24-HOUR | 72-HOUR |               |                  |                      |
| + | HYDROGRAPH AT |         |              |                 |                                 |         |         |               |                  |                      |
| + | INFLOW        |         | 6.           | .40             | 1.                              | 1.      | 0.      | .00           |                  |                      |
| + | ROUTED TO     |         |              |                 |                                 |         |         |               |                  |                      |
| + | POND          |         | 6.           | .60             | 1.                              | 1       | 0.      | .00           |                  |                      |
| 1 |               |         |              |                 |                                 |         |         |               | 92.01            | .60                  |

SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION POND  
(PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION)

| PLAN 1 ..... | INITIAL VALUE | SPILLWAY CREST | TOP OF DAM |
|--------------|---------------|----------------|------------|
| ELEVATION    | 90.40         | 96.00          | 96.00      |
| STORAGE      | 0.            | 1.             | 1.         |
| OUTFLOW      | 0.            | 24.            | 24.        |

| RATIO<br>OF<br>PMF | MAXIMUM<br>RESERVOIR<br>W.S.ELEV | MAXIMUM<br>DEPTH<br>OVER DAM | MAXIMUM<br>STORAGE<br>AC-FT | MAXIMUM<br>OUTFLOW<br>CFS | DURATION<br>OVER TOP<br>HOURS | TIME OF<br>MAX OUTFLOW<br>HOURS | TIME OF<br>FAILURE<br>HOURS |
|--------------------|----------------------------------|------------------------------|-----------------------------|---------------------------|-------------------------------|---------------------------------|-----------------------------|
| 1.00               | 92.01                            | .00                          | 0.                          | 6.                        | .00                           | .60                             | .00                         |

\*\*\* NORMAL END OF HEC-1 \*\*\*



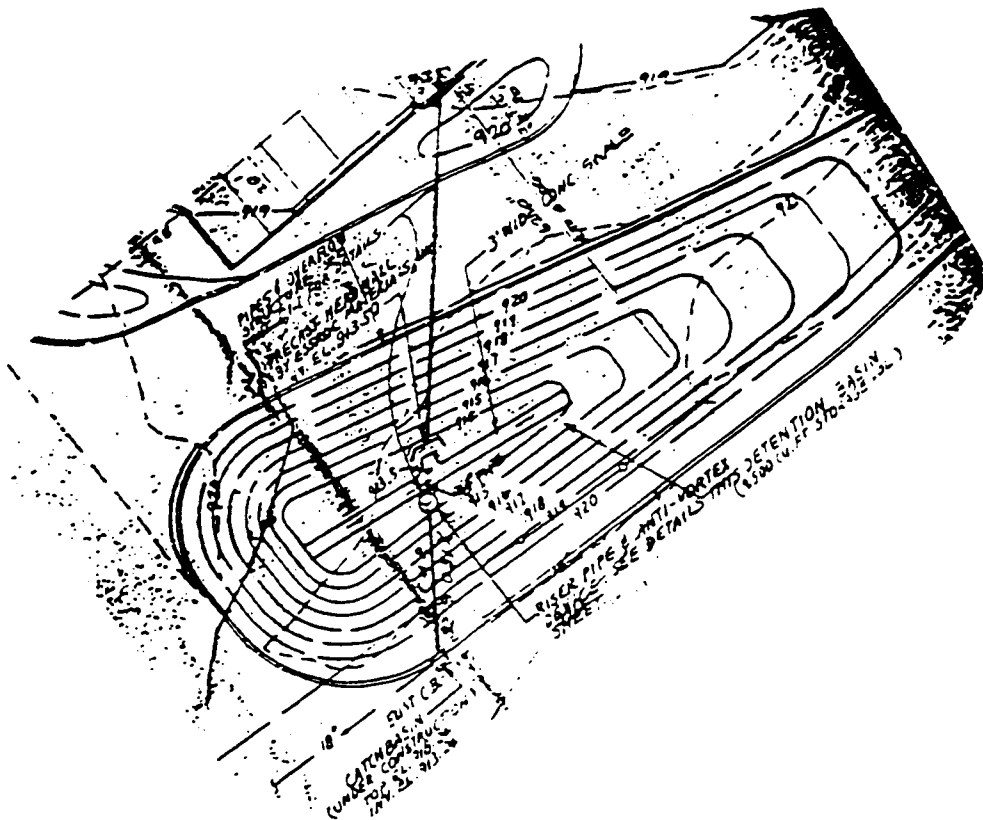
A5.1a - The outlet structure for Pond 5 is an 18-in. diameter CMP riser with a 24-in. diameter CMP anti-vortex device and having a 6-in. diameter CMP at the bottom of the riser. The riser was constructed 1.6 ft. lower than designed.



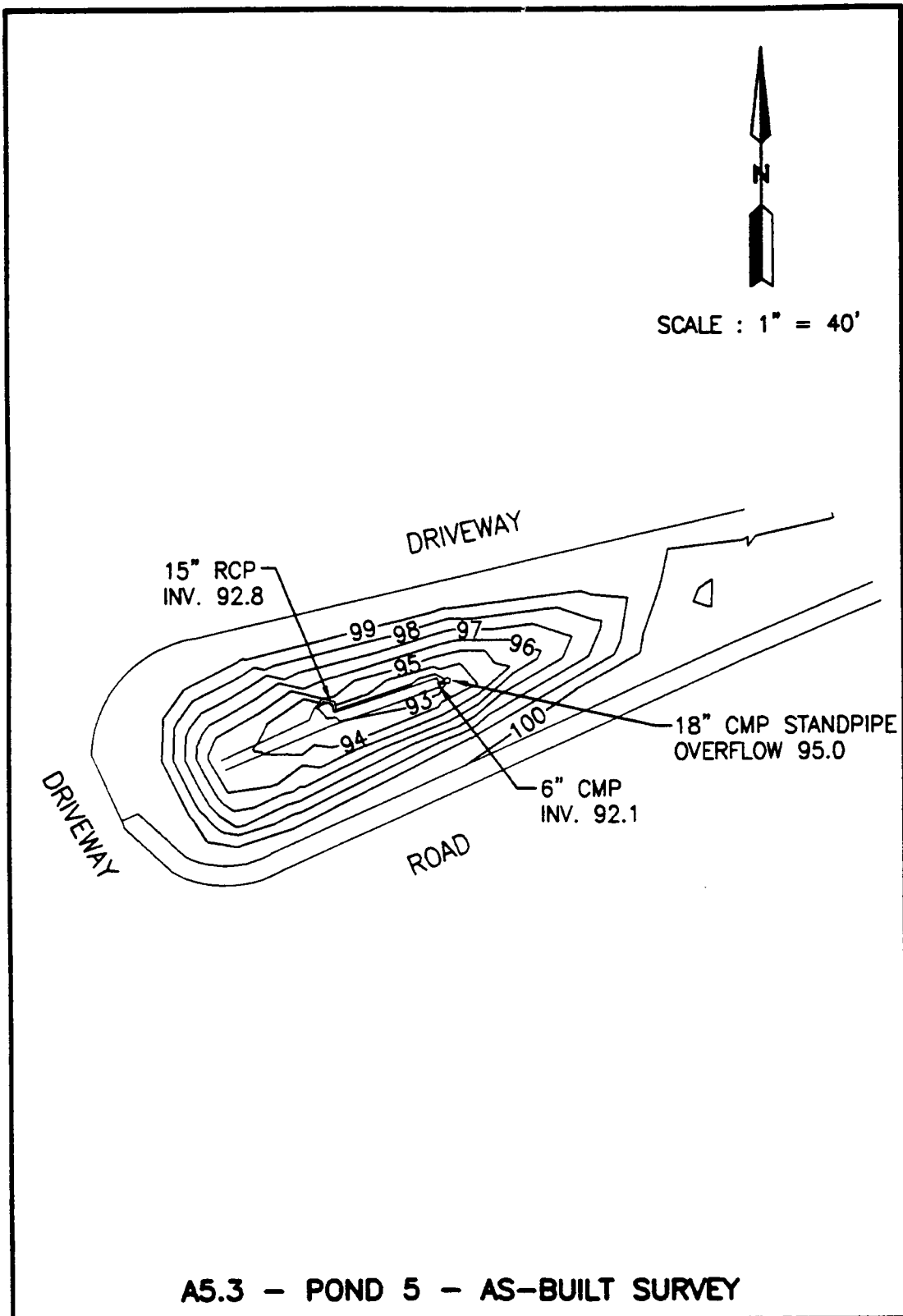
A5.1b - An overall view of Pond 5. The pond is on a main roadway in front of a business and is well maintained.



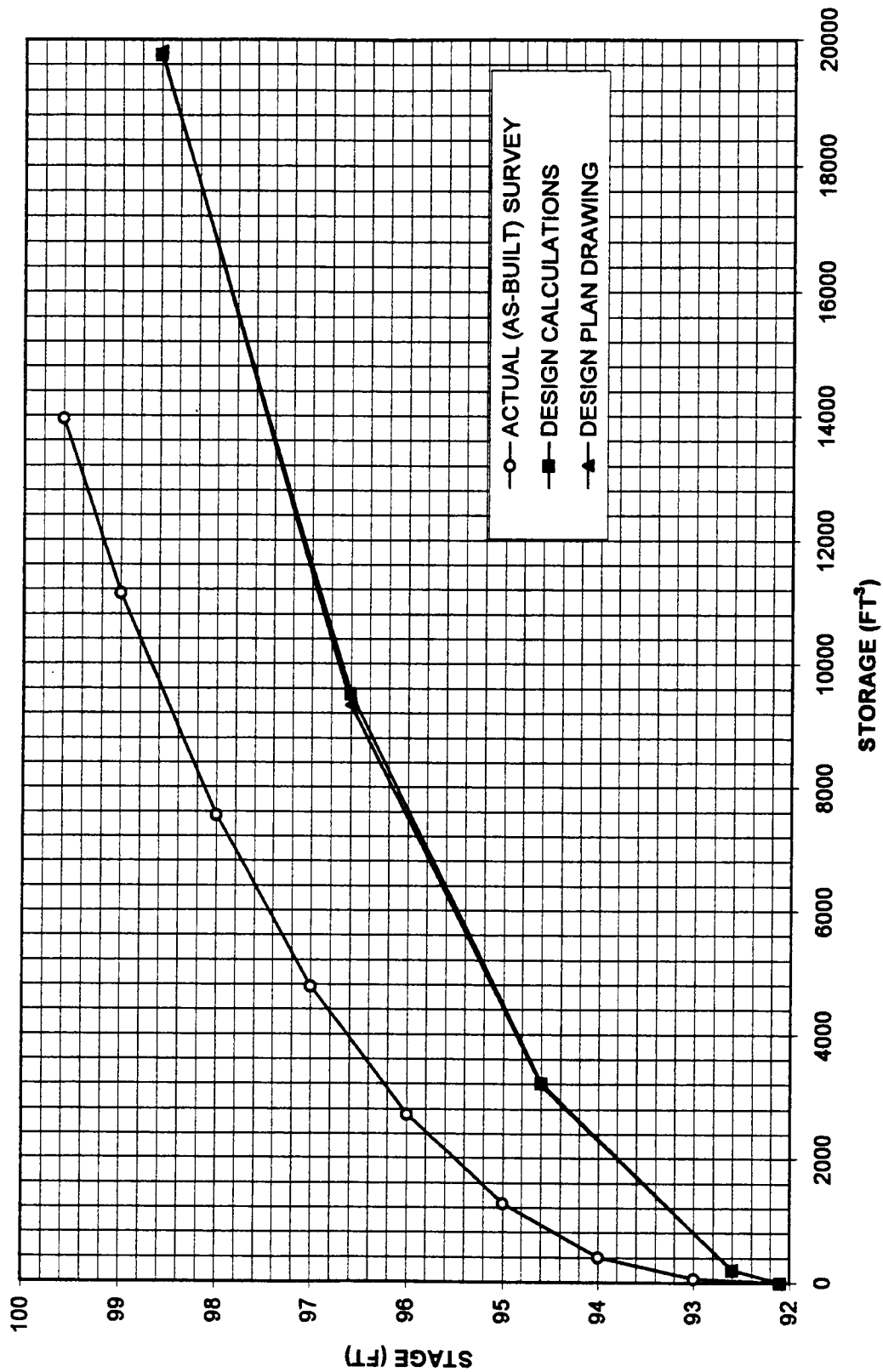
SCALE : 1" = 40'



A5.2 - POND 5 - DESIGN PLAN DRAWING

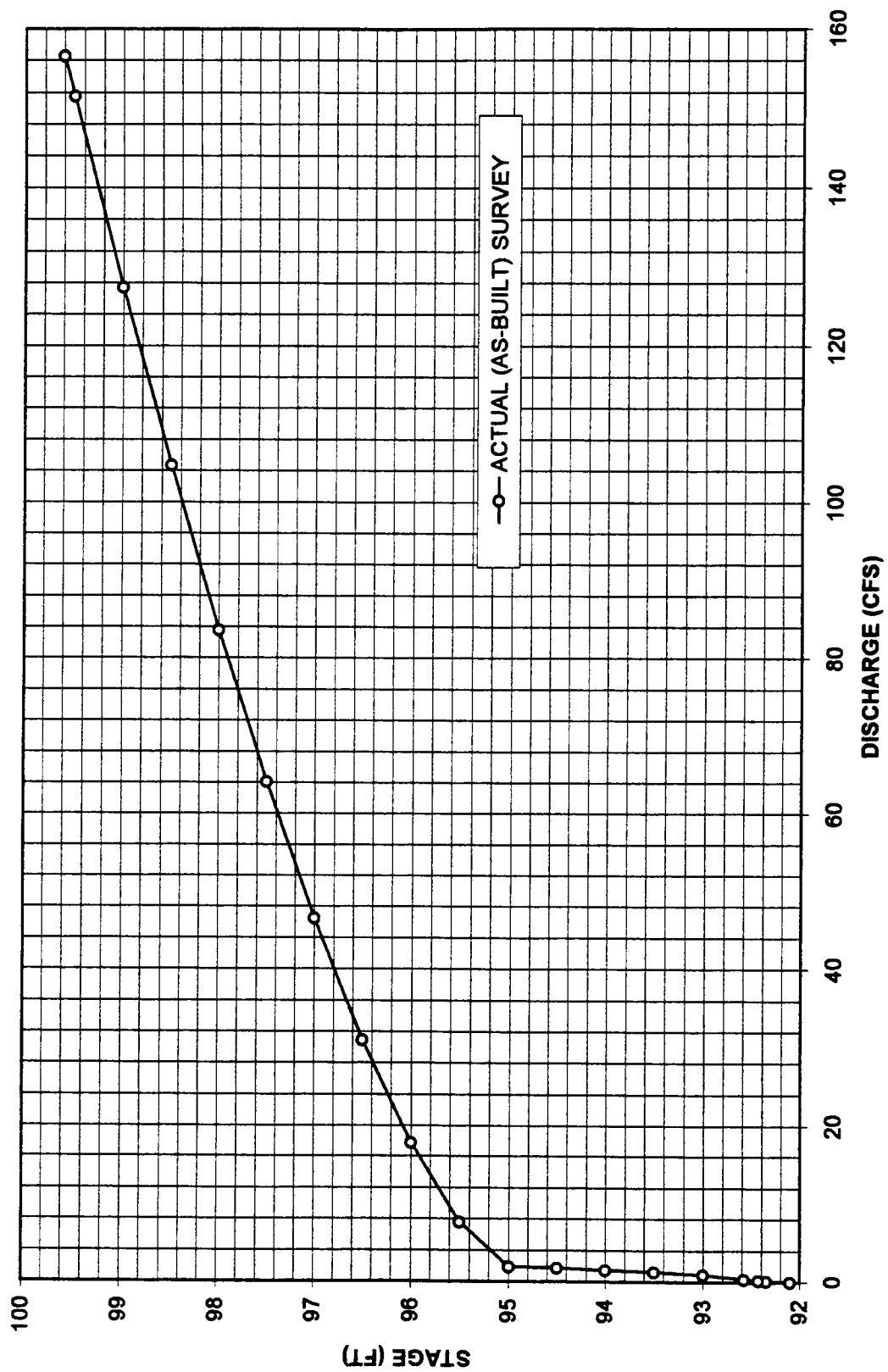


# A5.4 - POND 5 - STAGE vs. STORAGE





# A5.5 - POND 5 - STAGE vs. DISCHARGE



# A5.6 - POND 5 - INFLOW HYDROGRAPH

## TABULAR HYDROGRAPH METHOD

Version 2.00

Project : DETENTION POND ANALYSIS

User: TIR

Date: 04-09-97

County :

State: TN

Checked: \_\_\_\_\_

Date: \_\_\_\_\_

Subtitle: POND 5

Total watershed area: 0.002 sq mi Rainfall type: II Frequency: years

----- Subareas -----  
1  
Area(sq mi) 0.00  
Rainfall(in) 6.1  
Curve number 81  
Runoff(in) 3.97  
Tc (hrs) 0.10  
TimeToOutlet 0.00  
Ia/P 0.08  
(Used) 0.10

| Time (hr) | Total Flow | Subarea Contribution to Total Flow (cfs) |
|-----------|------------|------------------------------------------|
| 11.0      | 0          | 0                                        |
| 11.3      | 0          | 0                                        |
| 11.6      | 0          | 0                                        |
| 11.9      | 2          | 2                                        |
| 12.0      | 3          | 3                                        |
| 12.1      | 7P         | 7P                                       |
| 12.2      | 4          | 4                                        |
| 12.3      | 2          | 2                                        |
| 12.4      | 1          | 1                                        |
| 12.5      | 1          | 1                                        |
| 12.6      | 1          | 1                                        |
| 12.7      | 1          | 1                                        |
| 12.8      | 1          | 1                                        |
| 13.0      | 0          | 0                                        |
| 13.2      | 0          | 0                                        |
| 13.4      | 0          | 0                                        |
| 13.6      | 0          | 0                                        |
| 13.8      | 0          | 0                                        |
| 14.0      | 0          | 0                                        |
| 14.3      | 0          | 0                                        |
| 14.6      | 0          | 0                                        |
| 15.0      | 0          | 0                                        |
| 15.5      | 0          | 0                                        |
| 16.0      | 0          | 0                                        |
| 16.5      | 0          | 0                                        |
| 17.0      | 0          | 0                                        |
| 17.5      | 0          | 0                                        |
| 18.0      | 0          | 0                                        |
| 19.0      | 0          | 0                                        |
| 20.0      | 0          | 0                                        |
| 22.0      | 0          | 0                                        |
| 26.0      | 0          | 0                                        |

P - Peak Flow

A5.7 - POND 5 - HEC-1 INPUT FILE

ID  
ID POND5  
ID  
\*FREE  
IT 6 0 0 300  
IN 6 0 0  
IO 2 0 0  
KK INFLOW HYDROGRAPH  
KM 50 YEAR HYDROGRAPH  
QI 0 0 1 1.5 2 5 7 4 2 1  
QI 1 1 1 1 0.5 0 0  
KK POND 5  
KM ROUTE 50 YR POST DEV HYD  
RS 1 ELEV 92.1  
SV 0 0.0002 0.0004 0.001 0.006 0.009 0.018 0.029 0.046 0.062  
SV 0.086 0.11 0.142 0.173 0.216 0.256 0.312 0.32  
SQ 0 0.2 0.3 0.9 1.3 1.5 1.7 1.9 7.69 17.8  
SQ 30.9 46.5 64.1 83.6 104.7 127.4 151.6 156.6  
SE 92.1 92.4 92.6 93.0 93.5 94.0 94.5 95.0 95.5 96.0  
SE 96.5 97.0 97.5 98.0 98.5 99.0 99.5 99.6  
ST 99.6 50 3.33 1.5  
ZZ

## A5.8 - Pond 5 - HEC-1 SUMMARY OF RESULTS

| RUNOFF SUMMARY<br>FLOW IN CUBIC FEET PER SECOND<br>TIME IN HOURS, AREA IN SQUARE MILES                                               |                    |                                  |                              |                             |                                 |                               |                                 |                             |                  |
|--------------------------------------------------------------------------------------------------------------------------------------|--------------------|----------------------------------|------------------------------|-----------------------------|---------------------------------|-------------------------------|---------------------------------|-----------------------------|------------------|
|                                                                                                                                      | OPERATION          | STATION                          | PEAK<br>FLOW                 | TIME OF<br>PEAK             | AVERAGE FLOW FOR MAXIMUM PERIOD |                               |                                 | BASIN<br>AREA               | MAXIMUM<br>STAGE |
|                                                                                                                                      |                    |                                  |                              |                             | 6-HOUR                          | 24-HOUR                       | 72-HOUR                         |                             |                  |
| +                                                                                                                                    | HYDROGRAPH AT      |                                  |                              |                             |                                 |                               |                                 |                             |                  |
| +                                                                                                                                    | INFLOW             |                                  | 7.                           | .60                         | 1.                              | 1.                            | 1.                              | .00                         |                  |
| +                                                                                                                                    | ROUTED TO          |                                  |                              |                             |                                 |                               |                                 |                             |                  |
| +                                                                                                                                    | POND               |                                  | 6.                           | .60                         | 1.                              | 1                             | 1.                              | .00                         |                  |
| 1                                                                                                                                    |                    |                                  |                              |                             |                                 |                               |                                 |                             | 95.35 .60        |
| SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION POND<br>(PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION) |                    |                                  |                              |                             |                                 |                               |                                 |                             |                  |
| PLAN 1 .....                                                                                                                         |                    |                                  |                              |                             |                                 |                               |                                 |                             |                  |
|                                                                                                                                      | ELEVATION          | INITIAL VALUE                    |                              | SPILLWAY CREST              |                                 | TOP OF DAM                    |                                 |                             |                  |
|                                                                                                                                      | STORAGE            | 92.10                            |                              | 99.60                       |                                 | 99.60                         |                                 |                             |                  |
|                                                                                                                                      | OUTFLOW            | 0.                               |                              | 0.                          |                                 | 0.                            |                                 |                             |                  |
|                                                                                                                                      |                    | 0.                               |                              | 157.                        |                                 | 157                           |                                 |                             |                  |
|                                                                                                                                      | RATIO<br>OF<br>PMF | MAXIMUM<br>RESERVOIR<br>W.S.ELEV | MAXIMUM<br>DEPTH<br>OVER DAM | MAXIMUM<br>STORAGE<br>AC-FT | MAXIMUM<br>OUTFLOW<br>CFS       | DURATION<br>OVER TOP<br>HOURS | TIME OF<br>MAX OUTFLOW<br>HOURS | TIME OF<br>FAILURE<br>HOURS |                  |
|                                                                                                                                      | 1.00               | 95.35                            | .00                          | 0.                          | 6.                              | .00                           | .60                             | .00                         |                  |

\*\*\* NORMAL END OF HEC-1 \*\*\*



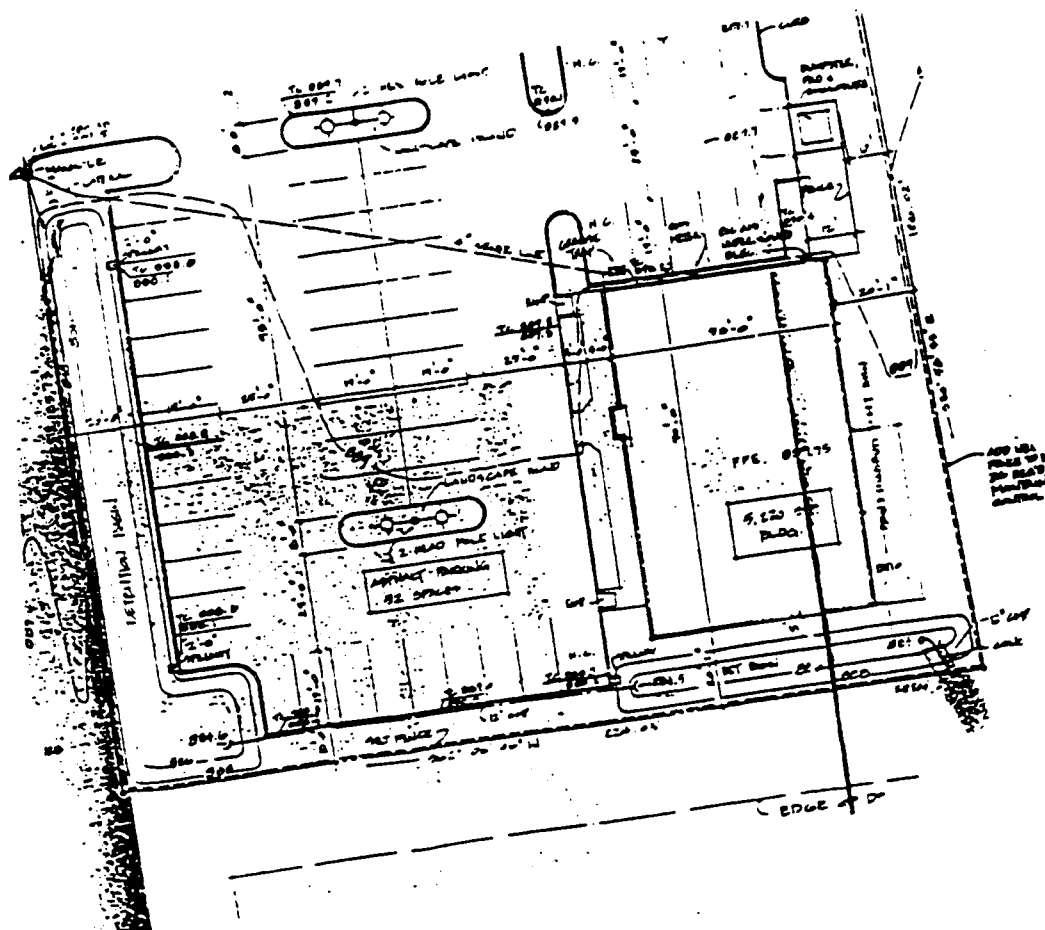
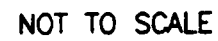
A6.1a - The outlet structure and emergency spillway for Pond 6 was constructed as a 9-in. x 9-in. square orifice but it was intended to be a 9-in. diameter orifice.



A6.1b - The storage volume for Pond 6 is divided into two ponds. This a view looking downstream of the second pond at the outlet structure. Both ponds are landscaped and very well maintained.



A6.1c - A view looking upstream at the second pond of Pond 6. The dam of this first pond is 2.2 ft. lower than the dam of the second pond and 1.3 ft. lower than the emergency spillway. This pond will overtop before the emergency spillway is utilized. The routed design storm overtops the dam.



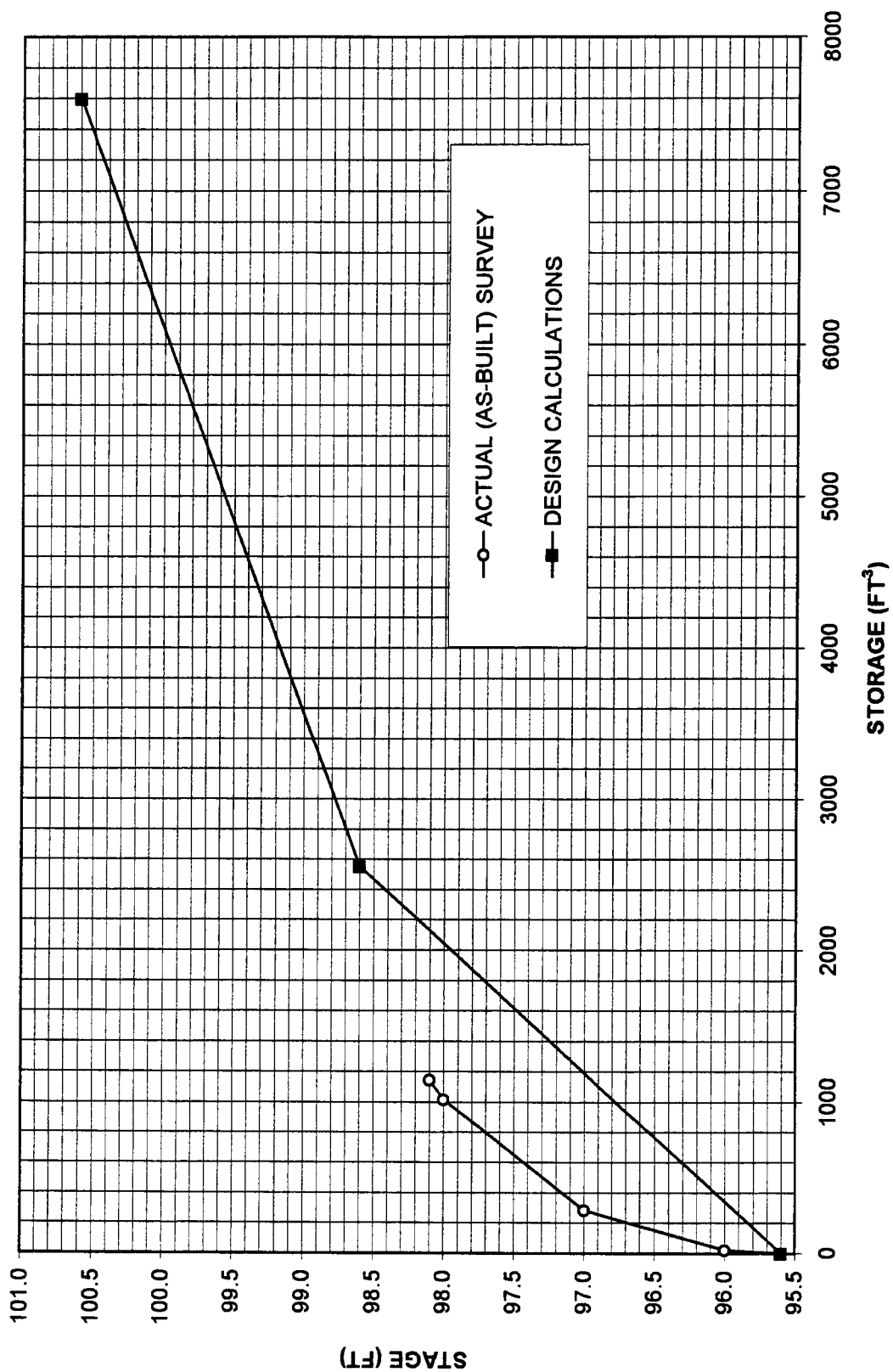
## A6.2 - POND 6 - DESIGN PLAN DRAWING



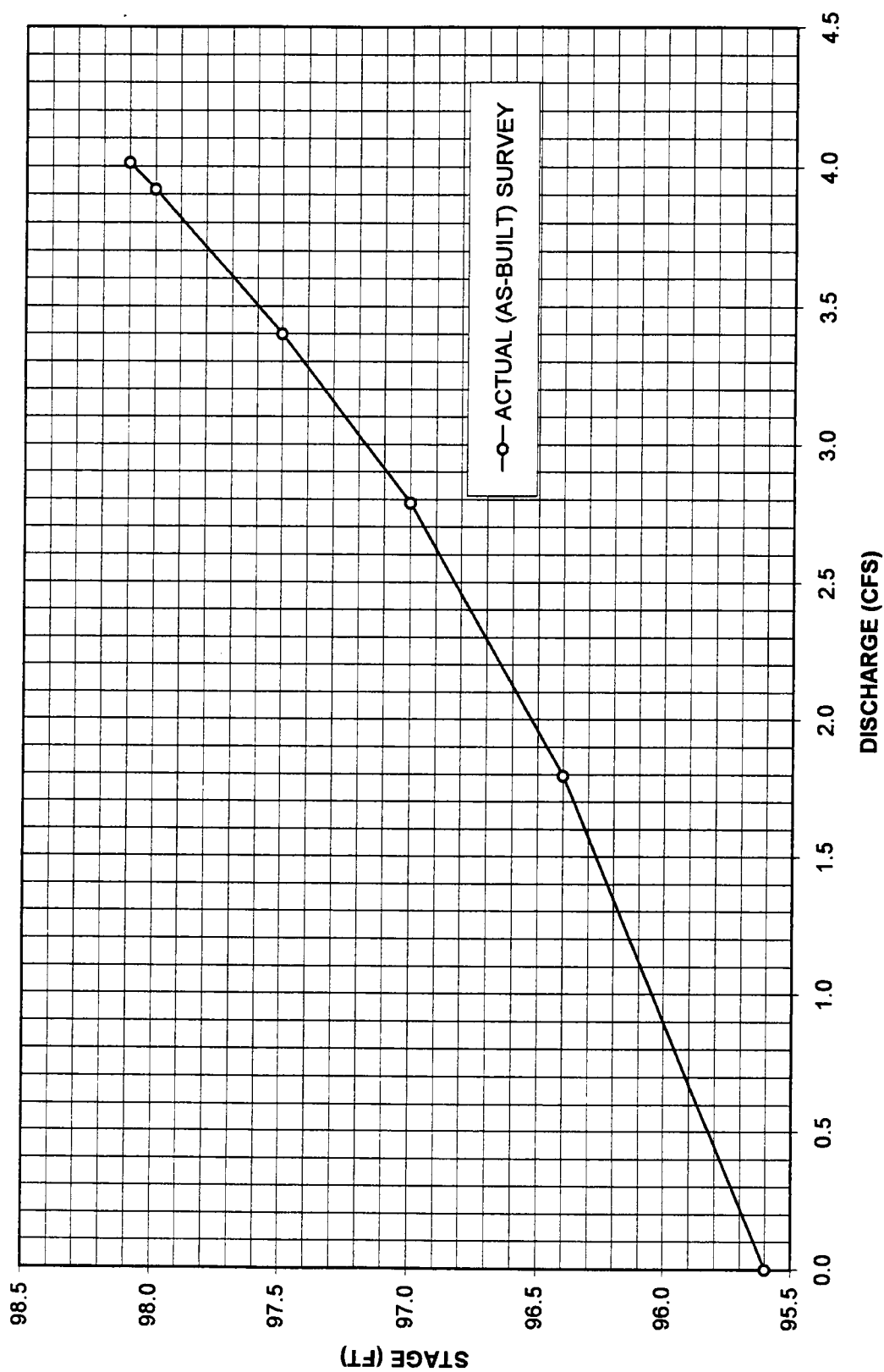




# A6.4 - POND 6 - STAGE vs. STORAGE



# A6.5 - POND 6 - STAGE vs. DISCHARGE



# A6.6 - POND 6 - INFLOW HYDROGRAPH

## TABULAR HYDROGRAPH METHOD

Version 2.0c

Project : DETENTION POND ANALYSIS User: TER Date: 04-09-97  
 County : KNOX State: TN Checked: Date:   
 Subtitle: POND 6

Total watershed area: 0.002 sq mi Rainfall type: II Frequency: 50 years  
 ----- Subareas -----

1  
 Area(sq mi) 0.00  
 Rainfall(in) 6.1 -  
 Curve number 92 -  
 Runoff(in) 1.17  
 Tc (hrs) 0.12  
 (Used) 0.10  
 TimeToOutlet 0.00  
 Ia/? 0.03 -  
 (Used) 0.10 -

Time Total ----- Subarea Contribution to Total Flow (cfs) -----  
 (hr) Flow 1

|      |    |    |
|------|----|----|
| 11.0 | 0  | 0  |
| 11.3 | 0  | 0  |
| 11.6 | 0  | 0  |
| 11.9 | 3  | 3  |
| 12.0 | 5  | 5  |
| 12.1 | 8P | 8P |
| 12.2 | 5  | 5  |
| 12.3 | 2  | 2  |

|      |   |   |
|------|---|---|
| 12.4 | 1 | 1 |
| 12.5 | 1 | 1 |
| 12.6 | 1 | 1 |
| 12.7 | 1 | 1 |
| 12.8 | 1 | 1 |
| 13.0 | 1 | 1 |
| 13.2 | 0 | 0 |
| 13.4 | 0 | 0 |

|      |   |   |
|------|---|---|
| 13.6 | 0 | 0 |
| 13.8 | 0 | 0 |
| 14.0 | 0 | 0 |
| 14.3 | 0 | 0 |
| 14.6 | 0 | 0 |
| 15.0 | 0 | 0 |
| 15.5 | 0 | 0 |
| 16.0 | 0 | 0 |

|      |   |   |
|------|---|---|
| 16.5 | 0 | 0 |
| 17.0 | 0 | 0 |
| 17.5 | 0 | 0 |
| 18.0 | 0 | 0 |
| 19.0 | 0 | 0 |
| 20.0 | 0 | 0 |
| 22.0 | 0 | 0 |
| 26.0 | 0 | 0 |

P - Peak Flow

A6.7 - POND 6 - HEC-1 INPUT FILE

ID  
ID POND 6  
ID  
\*FREE  
IT 6 0 0 300  
IN 6 0 0  
IO 2 0 0  
KK INFLOW HYDROGRAPH  
KM 50 YEAR HYDROGRAPH  
QI 0 0 1 2 3 5 8 5 2 2  
QI 1 1 1 1 1 1 1 1 0.5 0 0  
KK POND 6  
KM ROUTE 50 YR POST DEV HYD  
RS 1 ELEV 95.6  
SV 0 0.002 0.007 0.014 0.023 0.03  
SQ 0 1.8 2.8 3.4 3.9 4.0  
SE 95.6 96.4 97.0 97.5 98.0 98.1  
ST 98.1 10 3.33 1.5  
ZZ

## A6.8 - POND 6 - HEC-1 SUMMARY OF RESULTS

RUNOFF SUMMARY  
FLOW IN CUBIC FEET PER SECOND  
TIME IN HOURS, AREA IN SQUARE MILES

| + | OPERATION                                                             | STATION | PEAK<br>FLOW | TIME OF<br>PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD |         |         | BASIN<br>AREA | MAXIMUM<br>STAGE | TIME OF<br>MAX STAGE |
|---|-----------------------------------------------------------------------|---------|--------------|-----------------|---------------------------------|---------|---------|---------------|------------------|----------------------|
|   |                                                                       |         |              |                 | 6-HOUR                          | 24-HOUR | 72-HOUR |               |                  |                      |
| + | HYDROGRAPH AT<br>INFLOW                                               |         | 8.           | .60             | 1.                              | 1.      | 0.      | .00           |                  |                      |
| + | ROUTED TO<br>POND                                                     |         | 6.           | .70             | 1.                              | 1       | 0.      | .00           |                  |                      |
| + |                                                                       |         |              |                 |                                 |         |         |               | 98.27            | .70                  |
| 1 | SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION POND           |         |              |                 |                                 |         |         |               |                  |                      |
|   | (PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION) |         |              |                 |                                 |         |         |               |                  |                      |

| PLAN 1 ..... | INITIAL VALUE | SPILLWAY CREST | TOP OF DAM |
|--------------|---------------|----------------|------------|
| ELEVATION    | 95.60         | 98.10          | 98.10      |
| STORAGE      | 0.            | 0.             | 0.         |
| OUTFLOW      | 0.            | 4.             | 4.         |

| RATIO<br>OF<br>PMF | MAXIMUM<br>RESERVOIR<br>W.S.ELEV | MAXIMUM<br>DEPTH<br>OVER DAM | MAXIMUM<br>STORAGE<br>AC-FT | MAXIMUM<br>OUTFLOW<br>CFS | DURATION<br>OVER TOP<br>HOURS | TIME OF<br>MAX OUTFLOW<br>HOURS | TIME OF<br>FAILURE<br>HOURS |
|--------------------|----------------------------------|------------------------------|-----------------------------|---------------------------|-------------------------------|---------------------------------|-----------------------------|
| 1.00               | 98.27                            | .17                          | 0.                          | 6.                        | .20                           | .70                             | .00                         |

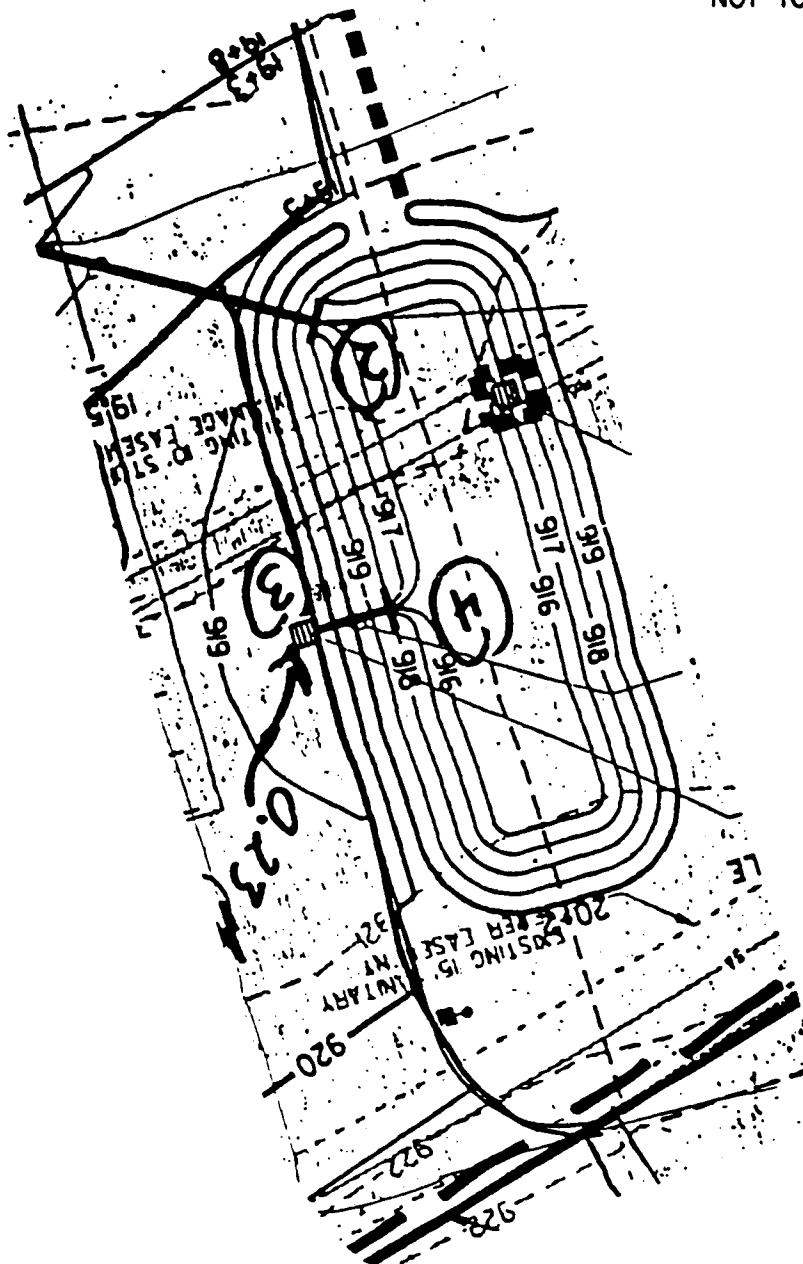
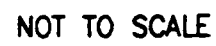
\*\*\* NORMAL END OF HEC-1 \*\*\*



A7.1a - The slot in the outlet structure was designed as a broad crested weir. The slot width was designed to be 0.15 ft. but, it was constructed 0.21 ft. wide.



A7.1b - Looking upstream of Pond 7. The sideslopes have a new stand of grass and the bottom of the pond has a 3-ft. wide concrete swale along the length of the pond.

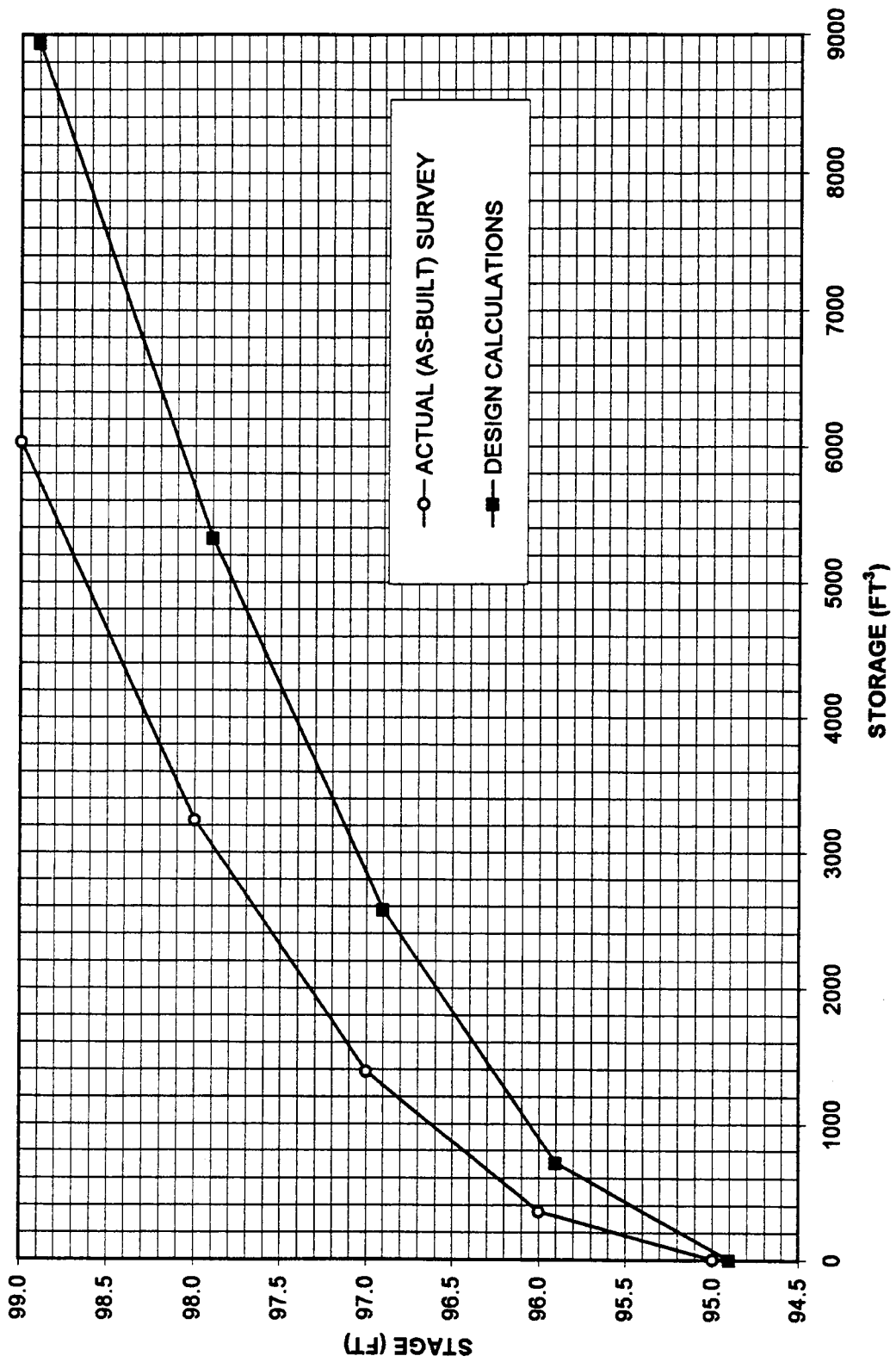


## A7.2 - POND 7 - DESIGN PLAN DRAWING

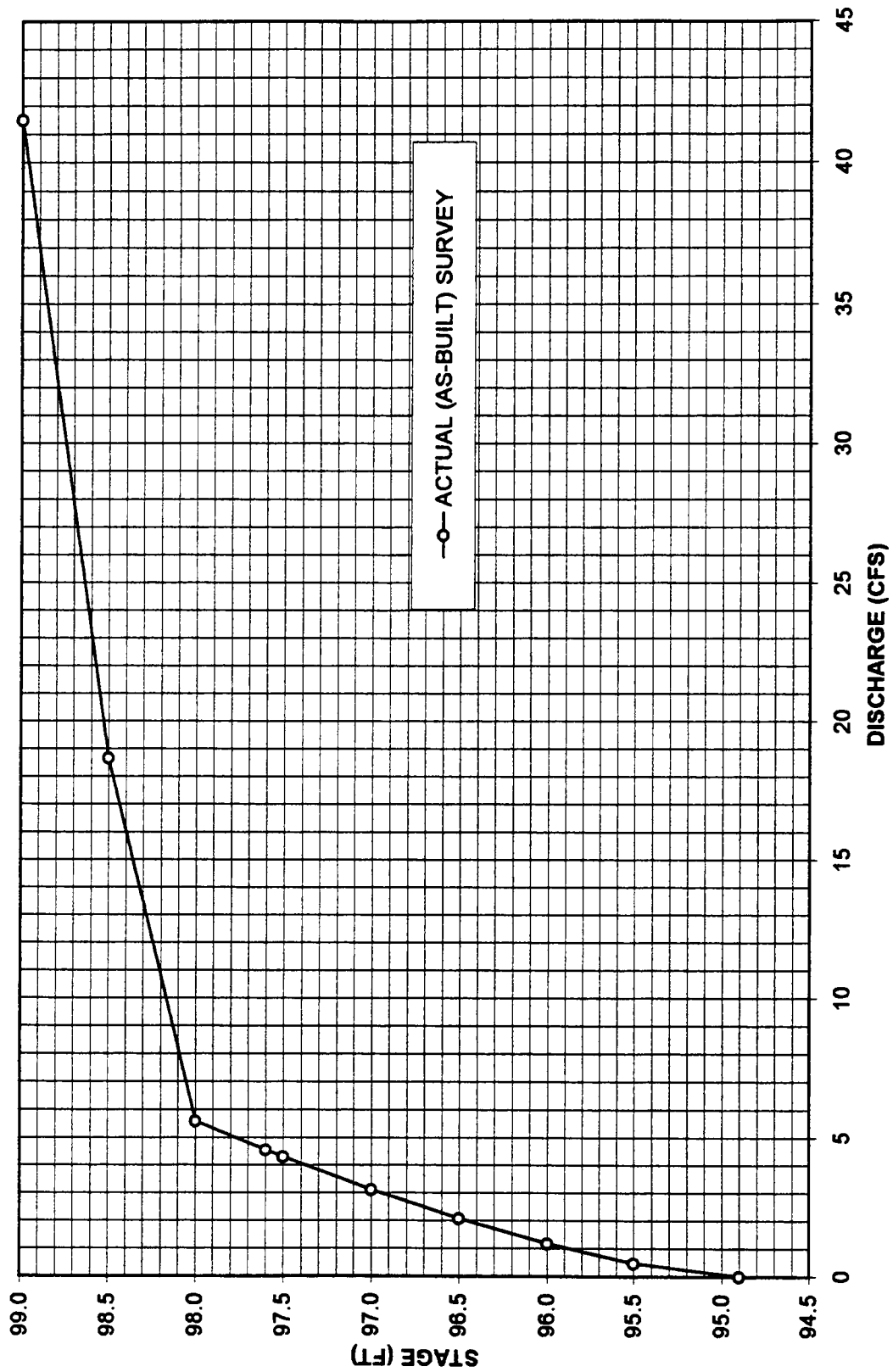




# A7.4 - POND 7 - STAGE vs. STORAGE



# A7.5 - POND 7 - STAGE vs. DISCHARGE



## **A7.6 - POND 7 - INFLOW HYDROGRAPH**

Inadequate Information

## A7.7 - POND 7 - HEC-1 INPUT FILE

Inadequate Information

## A7.8 - POND 7 - HEC-1 SUMMARY OF RESULTS

Inadequate Information



A8.1a - The dam (Right side of photograph) is 2.9 ft. lower than the intended design specified. The routed design storm overtops the dam.



A8.1b - This is a view of the emergency spillway looking upstream. The spillway is 9 ft. long and 11 inches deep and the design specified a length of 9.6 ft. and a depth of 11 inches.

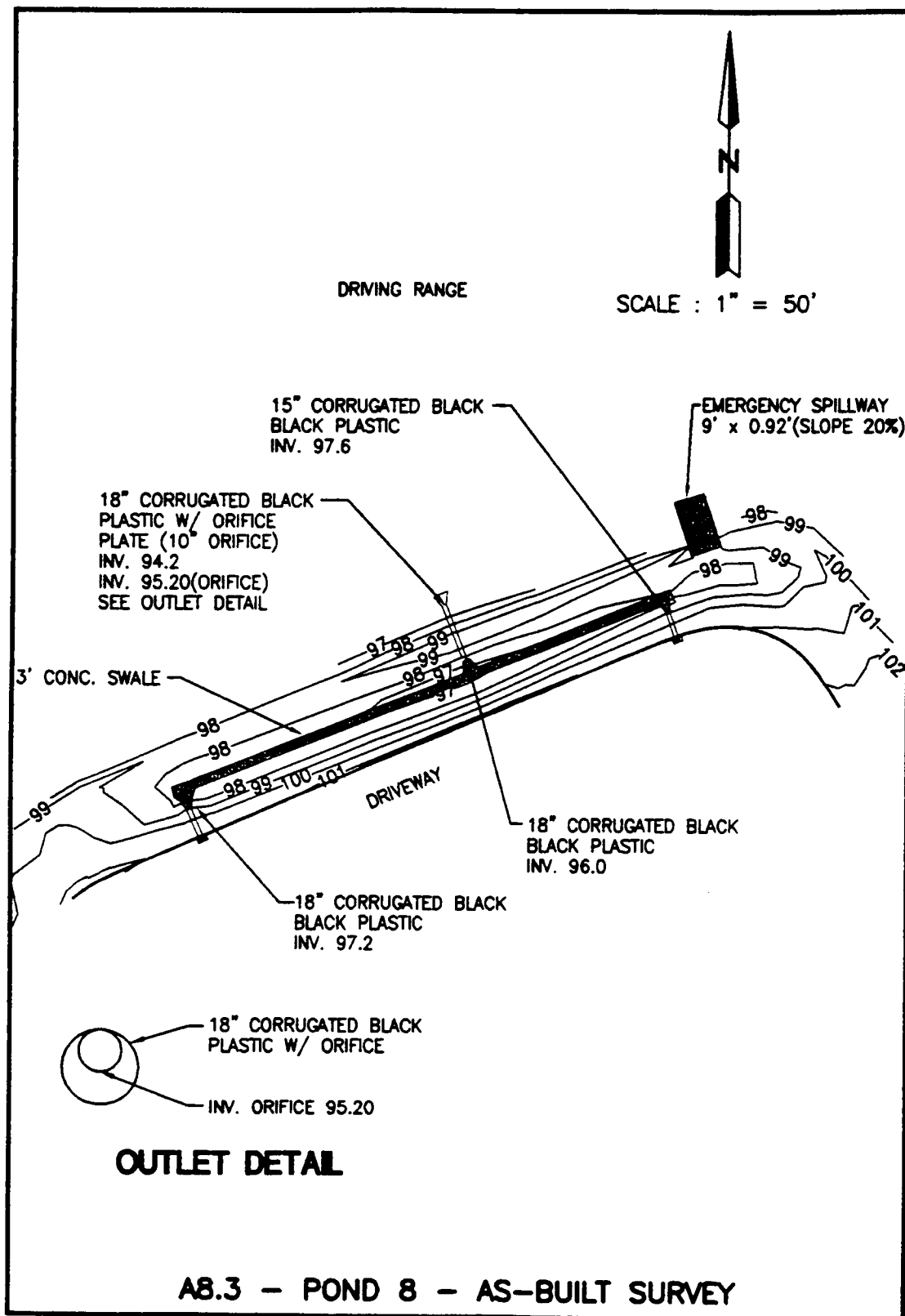


A8.1c - This is a view looking downstream at the dam (left side of the photograph). The downstream resident complains of excess water being discharged onto his property.

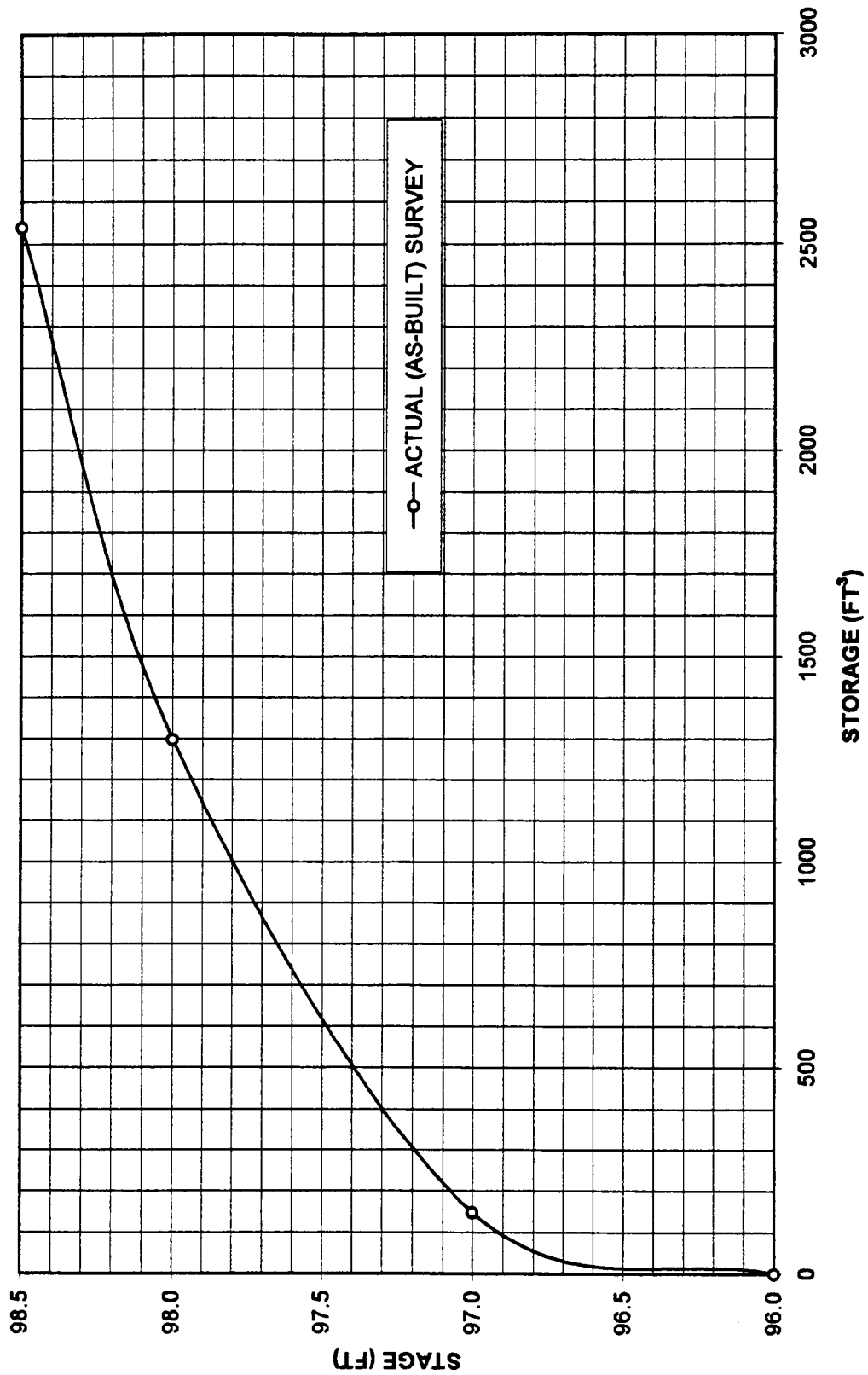
**INFORMATION NOT AVAILABLE**

**A8.2 – POND 8 – DESIGN PLAN DRAWING**

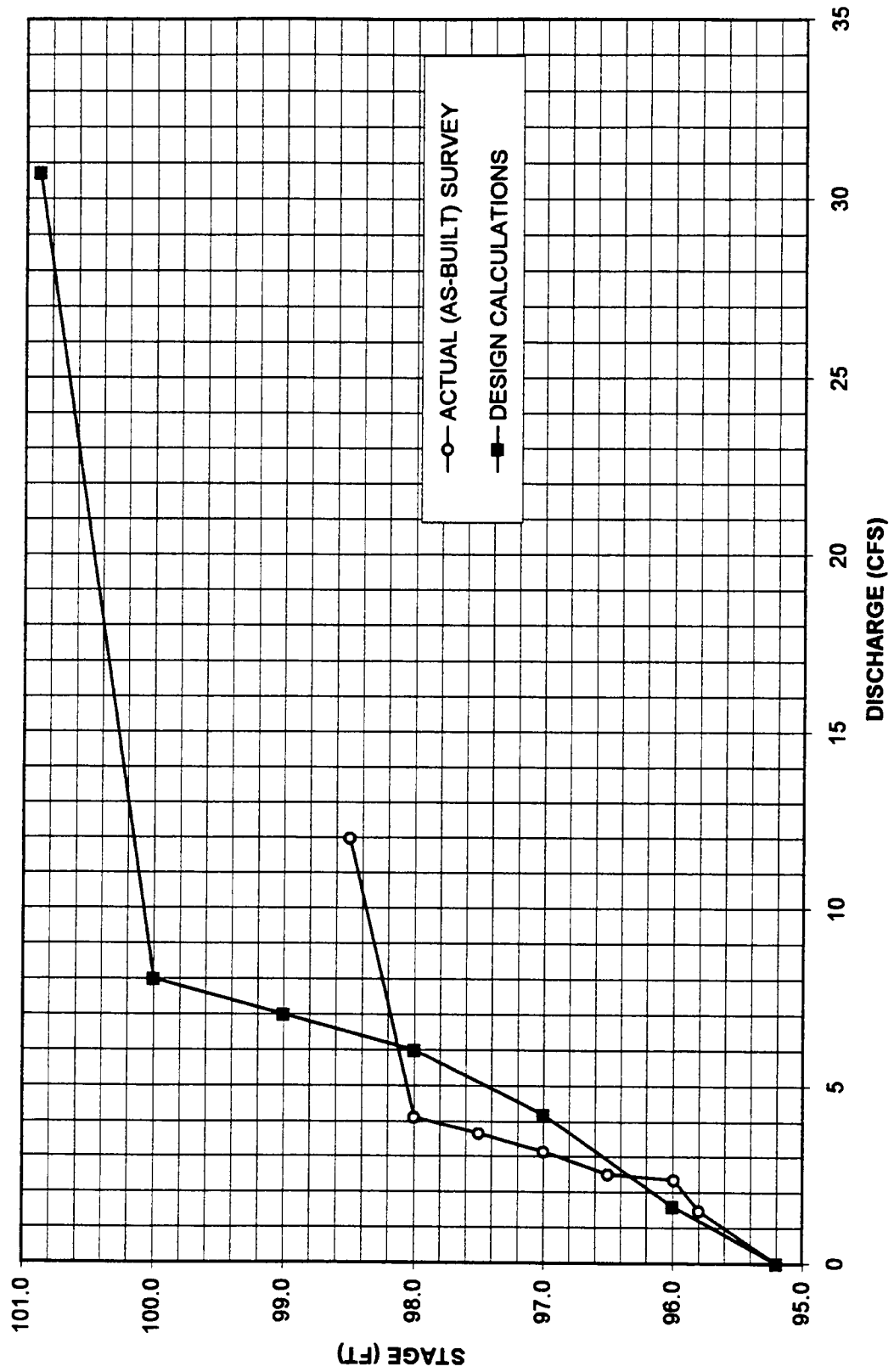




# A8.4 - POND 8 - STAGE vs. STORAGE



# A8.5 - POND 8 - STAGE vs. DISCHARGE



# A8.6 - POND 8 - INFLOW HYDROGRAPH

## TABULAR HYDROGRAPH METHOD

Version 2.00

Project : DETENTION POND ANALYSIS      User: TER      Date: 04-09-97  
 County :      State: TN      Checked:      Date:        
 Subtitle: POND 8

Total watershed area: 0.003 sq mi    Rainfall type: II    Frequency:    years  
 ----- Subareas -----

1  
 Area(sq mi)    0.00  
 Rainfall(in)    6.1  
 Curve number    94  
 Runoff(in)      3.48  
 Tc (hrs)        0.10  
 TimeToOutlet    0.00  
 Ia/P            0.02  
 (Used)          0.10

Time    Total    ----- Subarea Contribution to Total Flow (cfs) -----  
 (hr)    Flow        1

|      |     |     |
|------|-----|-----|
| 11.0 | 0   | 0   |
| 11.3 | 1   | 1   |
| 11.6 | 1   | 1   |
| 11.9 | 6   | 6   |
| 12.0 | 11  | 11  |
| 12.1 | 17P | 17P |
| 12.2 | 11  | 11  |
| 12.3 | 4   | 4   |
| 12.4 | 2   | 2   |
| 12.5 | 2   | 2   |
| 12.6 | 2   | 2   |
| 12.7 | 1   | 1   |
| 12.8 | 1   | 1   |
| 13.0 | 1   | 1   |
| 13.2 | 1   | 1   |
| 13.4 | 1   | 1   |
| 13.6 | 1   | 1   |
| 13.8 | 1   | 1   |
| 14.0 | 1   | 1   |
| 14.3 | 1   | 1   |
| 14.5 | 1   | 1   |
| 15.0 | 0   | 0   |
| 15.3 | 0   | 0   |
| 16.0 | 0   | 0   |
| 16.3 | 0   | 0   |
| 17.0 | 0   | 0   |
| 17.3 | 0   | 0   |
| 18.0 | 0   | 0   |
| 19.0 | 0   | 0   |
| 20.0 | 0   | 0   |
| 22.0 | 0   | 0   |
| 26.0 | 0   | 0   |

P - Peak Flow

A8.7 - POND 8 - HEC-1 INUT FILE

ID  
ID POND 8  
ID  
\*FREE  
IT 6 0 0 300  
IN 6 0 0  
IO 2 0 0  
KK INFLOW HYDROGRAPH  
KM 50 YEAR HYDROGRAPH  
QI 0 0 0.33 0.67 1 1 1 1 2.67 4.33  
QI 6 11 17 11 4 2 2 2 1 1  
QI 1 1 1 1 1 1 1 1 1 1  
QI 1 1 1 1 1 1 1 1 0.75 0.5  
QI 0.25 0 0  
KK POND 8  
KM ROUTE 50 YR POST DEV HYD  
RS 1 ELEV 95.2  
SV 0 0.0002 0.0003 0.0005 0.003 0.014 0.03 0.058  
SQ 0 1.5 2.4 2.5 3.1 3.7 4.1 12  
SE 95.2 95.8 96.0 96.5 97.0 97.5 98.0 98.5  
ST 98.5 30 3.33 1.5  
ZZ

## A8.8 - POND 8 - HEC-1 SUMMARY OF RESULTS

### RUNOFF SUMMARY FLOW IN CUBIC FEET PER SECOND TIME IN HOURS, AREA IN SQUARE MILES

| + | OPERATION                                                                                                                            | STATION | PEAK<br>FLOW | TIME OF<br>PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD |         |         | BASIN<br>AREA | MAXIMUM<br>STAGE | TIME OF<br>MAX STAGE |
|---|--------------------------------------------------------------------------------------------------------------------------------------|---------|--------------|-----------------|---------------------------------|---------|---------|---------------|------------------|----------------------|
|   |                                                                                                                                      |         |              |                 | 6-HOUR                          | 24-HOUR | 72-HOUR |               |                  |                      |
| + | HYDROGRAPH AT<br>INFLOW                                                                                                              |         | 17.          | 1.20            | 2.                              | 1.      | 1.      | .00           |                  |                      |
| + | ROUTED TO<br>POND                                                                                                                    |         | 15.          | 1.20            | 2.                              | 1       | 1.      | .00           |                  |                      |
| + |                                                                                                                                      |         |              |                 |                                 |         |         |               | 98.58            | 1.20                 |
| 1 | SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION POND<br>(PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION) |         |              |                 |                                 |         |         |               |                  |                      |

|              |                    |                                    |                              |                             |                           |                               |                                 |                             |  |
|--------------|--------------------|------------------------------------|------------------------------|-----------------------------|---------------------------|-------------------------------|---------------------------------|-----------------------------|--|
| PLAN 1 ..... |                    | INITIAL VALUE                      | SPILLWAY CREST               |                             | TOP OF DAM                |                               |                                 |                             |  |
|              | ELEVATION          | 95.20                              |                              | 98.50                       |                           | 98.50                         |                                 |                             |  |
|              | STORAGE            | 0.                                 |                              | 0.                          |                           | 0.                            |                                 |                             |  |
|              | OUTFLOW            | 0.                                 |                              | 12.                         |                           | 12.                           |                                 |                             |  |
|              | RATIO<br>OF<br>PMF | MAXIMUM<br>RESERVOIR<br>W. S. ELEV | MAXIMUM<br>DEPTH<br>OVER DAM | MAXIMUM<br>STORAGE<br>AC-FT | MAXIMUM<br>OUTFLOW<br>CFS | DURATION<br>OVER TOP<br>HOURS | TIME OF<br>MAX OUTFLOW<br>HOURS | TIME OF<br>FAILURE<br>HOURS |  |
|              | 1.00               | 98.58                              | .08                          | 0.                          | 15.                       | .20                           | 1.20                            | .00                         |  |

\*\*\* NORMAL END OF HEC-1 \*\*\*



A9.1a - The outlet structure for Pond 9 is an 18-in. diameter CMP having a 5-in. diameter orifice restrictor plate. The orifice was designed as a 12-in. diameter orifice. The orifice is in the center of the photograph in the shaded area.



A9.1b - This is the outlet end of the 18-in. diameter CMP. The discharge from the pipe is eroding the side of the ditch.



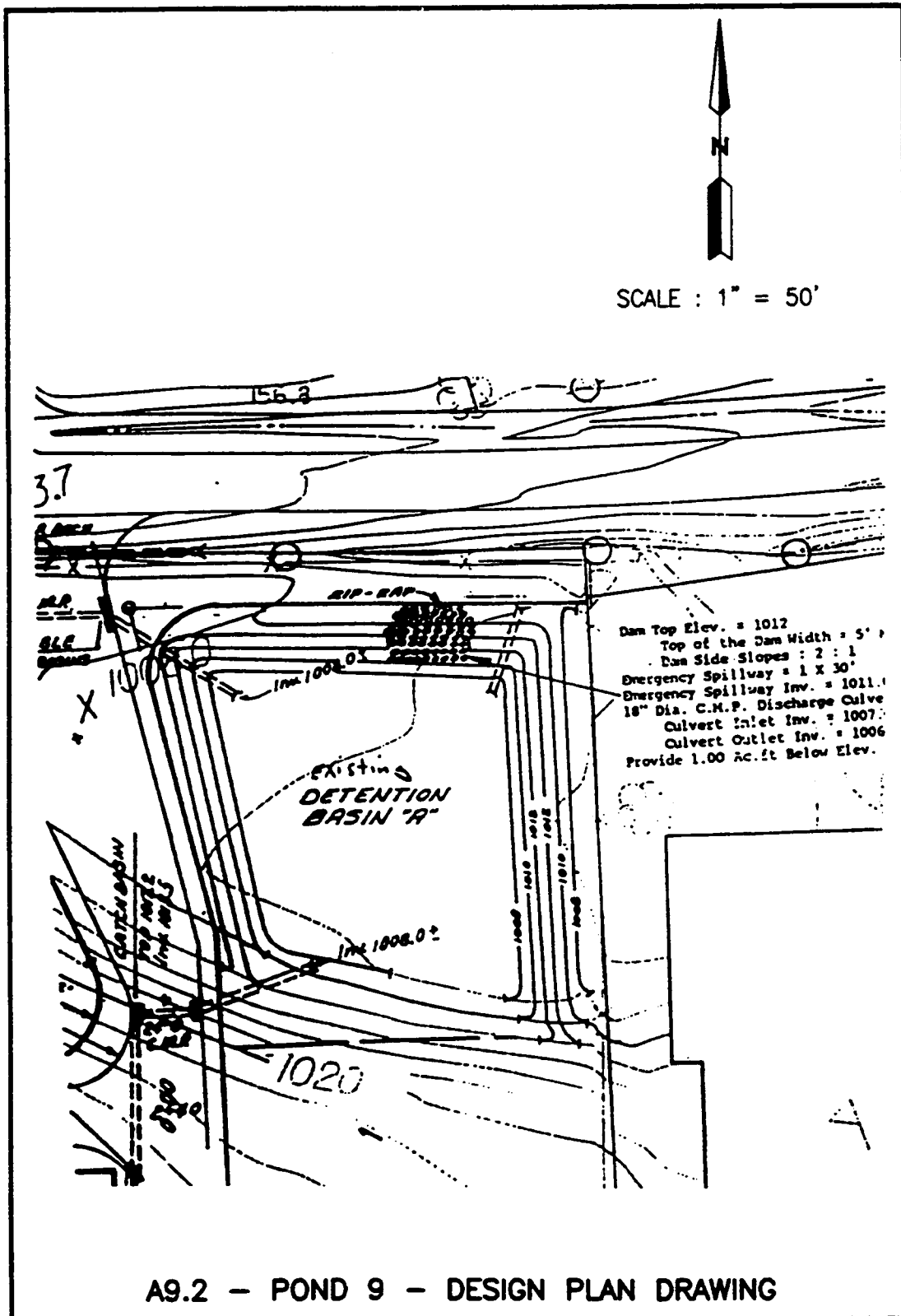


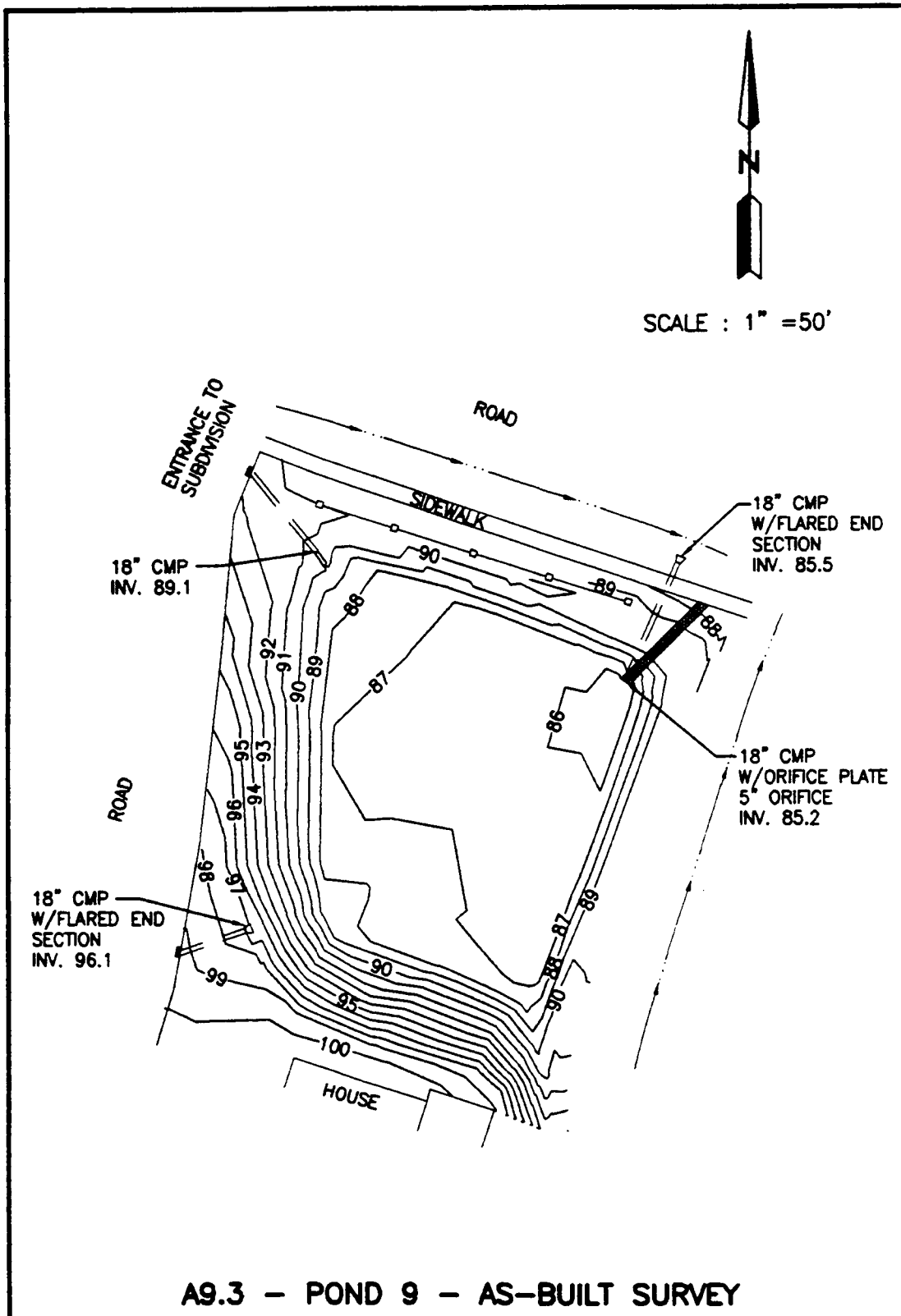
A9.1c - This is a view of the dam and the rip rap emergency spillway. The spillway was designed to be 30 ft. long x 1 ft. deep and 12 ft. to the left of the outlet pipe, but it is actually 3 ft. long x 0.2 ft. deep and directly over the outlet pipe.



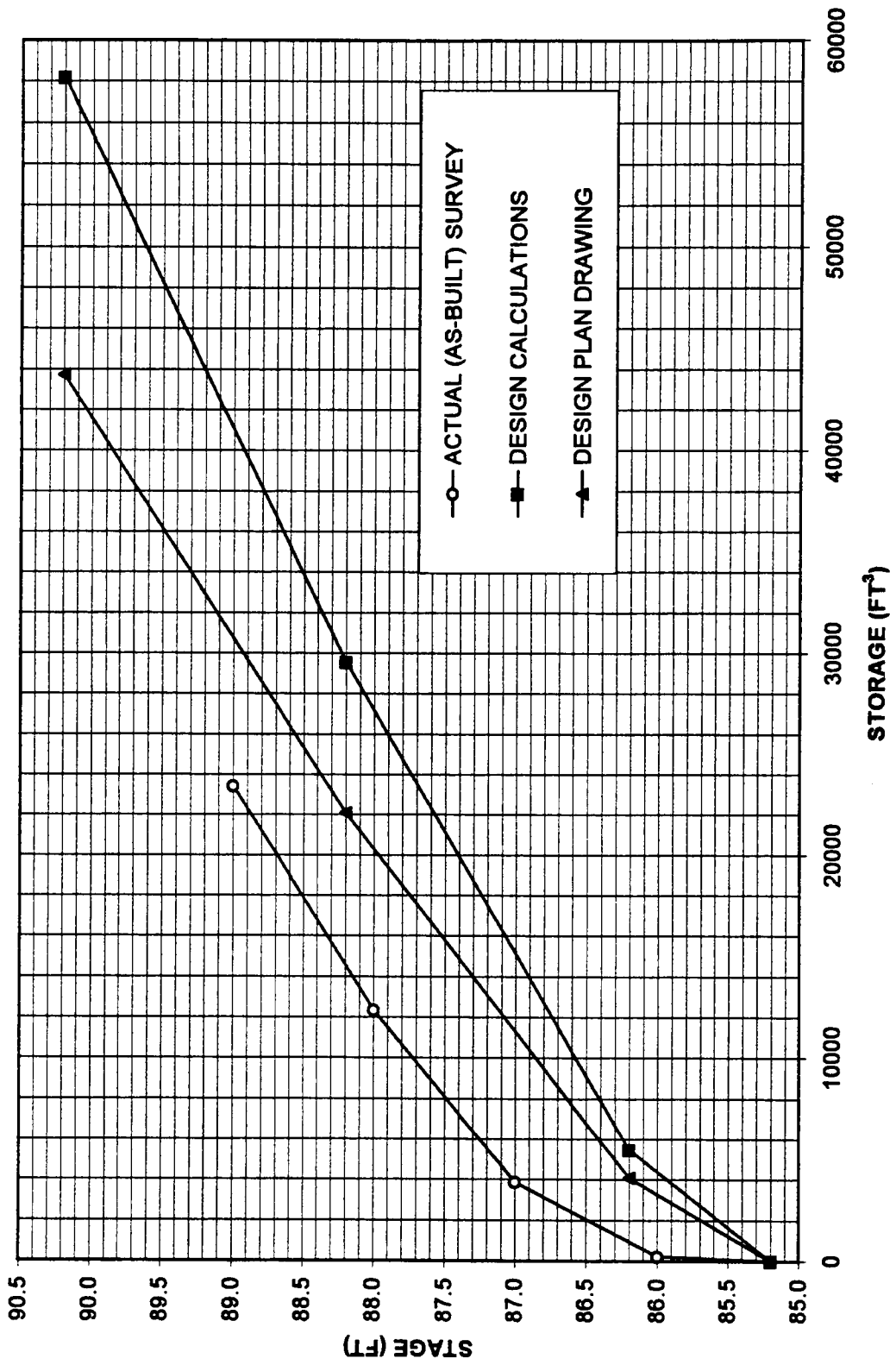
A9.1d - This is an overall view looking downstream at Pond 9. The dam and emergency spillway are in the center of the photograph.



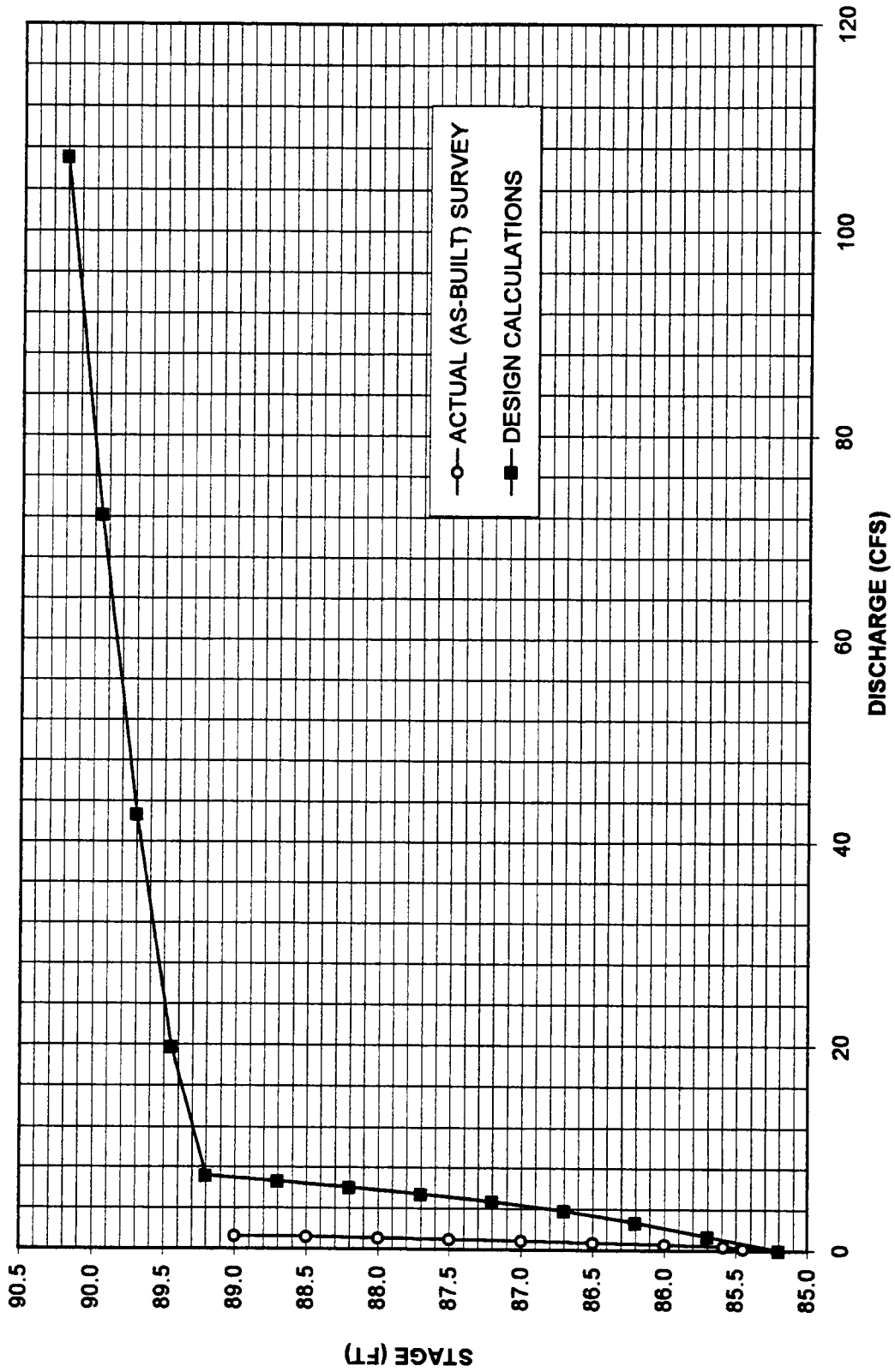




# A9.4 - POND 9 - STAGE vs. STORAGE



# A9.5 - POND 9 - STAGE vs. DISCHARGE



# A9.6 - POND 9 - INFLOW HYDROGRAPH

## TABULAR HYDROGRAPH METHOD

Version 2.00

Project : DETENTION POND ANALYSIS User: TZR Date: 04-09-97  
 County : State: TX Checked: Date:   
 Subtitle: POND 9

Total watershed area: 0.025 sq mi Rainfall type: II Frequency: years  
 ----- Subareas -----

1  
 Area(sq mi) 0.03  
 Rainfall(in) 4.8  
 Curve number 70  
 Runoff(in) 1.89  
 Tc (hrs) 0.26  
 (Used) 0.30  
 TimeToOutlet 0.00  
 Ia/P 0.18

| Time (hr) | Total Flow | Subarea Contribution to Total Flow (cfs) |
|-----------|------------|------------------------------------------|
|           | 1          |                                          |
| 11.0      | 1          | 1                                        |
| 11.3      | 1          | 1                                        |
| 11.6      | 1          | 1                                        |
| 11.9      | 4          | 4                                        |
| 12.0      | 8          | 8                                        |
| 12.1      | 18         | 18                                       |
| 12.2      | 30         | 30                                       |
| 12.3      | 31P        | 31P                                      |
| 12.4      | 22         | 22                                       |
| 12.5      | 14         | 14                                       |
| 12.6      | 10         | 10                                       |
| 12.7      | 8          | 8                                        |
| 12.8      | 6          | 6                                        |
| 13.0      | 4          | 4                                        |
| 13.2      | 4          | 4                                        |
| 13.4      | 3          | 3                                        |
| 13.6      | 3          | 3                                        |
| 13.8      | 3          | 3                                        |
| 14.0      | 2          | 2                                        |
| 14.3      | 2          | 2                                        |
| 14.6      | 2          | 2                                        |
| 15.0      | 2          | 2                                        |
| 15.5      | 2          | 2                                        |
| 16.0      | 1          | 1                                        |
| 16.5      | 1          | 1                                        |
| 17.0      | 1          | 1                                        |
| 17.5      | 1          | 1                                        |
| 18.0      | 1          | 1                                        |
| 19.0      | 1          | 1                                        |
| 20.0      | 1          | 1                                        |
| 22.0      | 1          | 1                                        |
| 26.0      | 0          | 0                                        |

P - Peak Flow

# A9.7 - POND 9 - HEC-1 INPUT FILE

```

ID
ID POND 9
ID
*FREE
IT 6 0 0 300
IN 6 0 0
IO 2 0 0
KK INFLOW HYDROGRAPH
KM 10 YEAR HYDROGRAPH
QI 0 0 1 1 1 1 1 1 1 2
QI 3 4 8 18 30 31 22 14 10 8
QI 6 5 4 4 4 3.5 3 3 3 3
QI 3 2.5 2 2 2 2 2 2 2 2
QI 2 2 2 2 2 2 2 2 1.8 1.6
QI 1.4 1.2 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 0.975 0.95 0.925 0.9 0.875 0.85 0.825
QI 0.8 0.775 0.75 0.725 0.7 0.675 0.65 0.625 0.6 0.575
QI 0.55 0.525 0.5 0.475 0.45 0.425 0.4 0.375 0.35 0.325
QI 0.3 0.275 0.25 0.225 0.2 0.175 0.15 0.125 0.1 .075
QI 0.05 0.025 0 0
KK POND 9
KM ROUTE 10 YR POST DEV HYD
RS 1 ELEV 85.2
SV 0 0.007 0.008 0.013 0.034 0.089 0.172 0.284 0.402 0.54
SQ 0 0.2 0.4 0.5 0.7 0.8 1 1.1 1.2 1.3
SE 85.2 85.5 85.6 86.0 86.5 87.0 87.5 88.0 88.5 89.0
ST 89.0 10 3.33 1.5
ZZ

```

## A9.8 - POND 9 - HEC-1 SUMMARY OF RESULTS

RUNOFF SUMMARY  
FLOW IN CUBIC FEET PER SECOND  
TIME IN HOURS, AREA IN SQUARE MILES

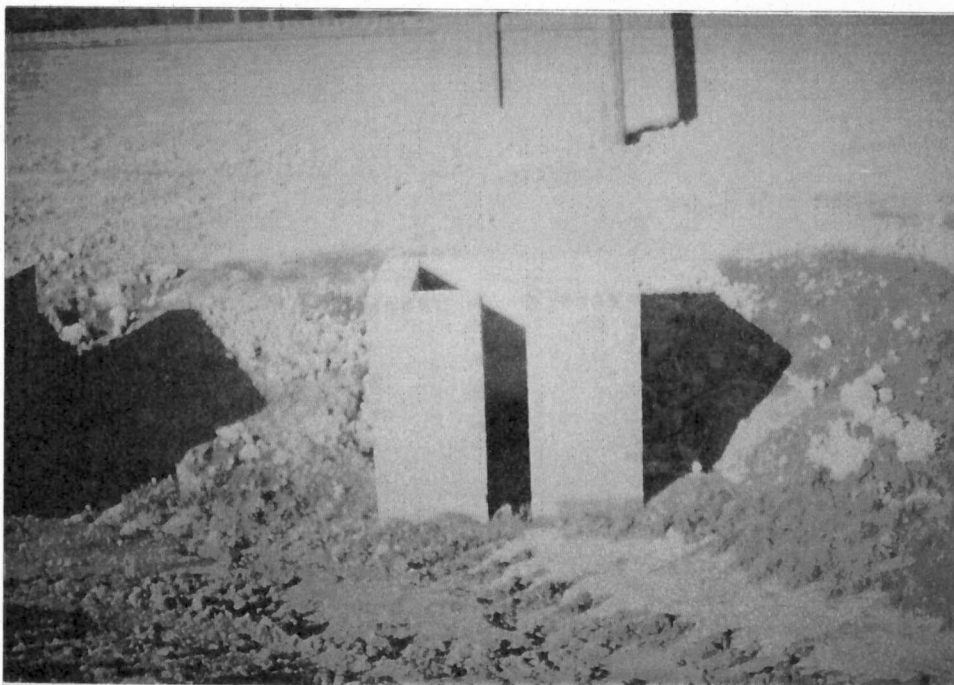
| OPERATION | STATION              | PEAK FLOW | TIME OF PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD |         |         | BASIN AREA | MAXIMUM STAGE | TIME OF MAX STAGE |
|-----------|----------------------|-----------|--------------|---------------------------------|---------|---------|------------|---------------|-------------------|
|           |                      |           |              | 6-HOUR                          | 24-HOUR | 72-HOUR |            |               |                   |
| +         |                      |           |              |                                 |         |         |            |               |                   |
| +         | HYDROGRAPH AT INFLOW | 31.       | 1.50         | 4.                              | 1.      | 1.      | .00        |               |                   |
| +         | ROUTED TO POND       | 15.       | 1.20         | 3.                              | 1       | 1.      | .00        |               |                   |
| +         |                      |           |              |                                 |         |         |            | 89.67         | 1.60              |

SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION POND  
(PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION)

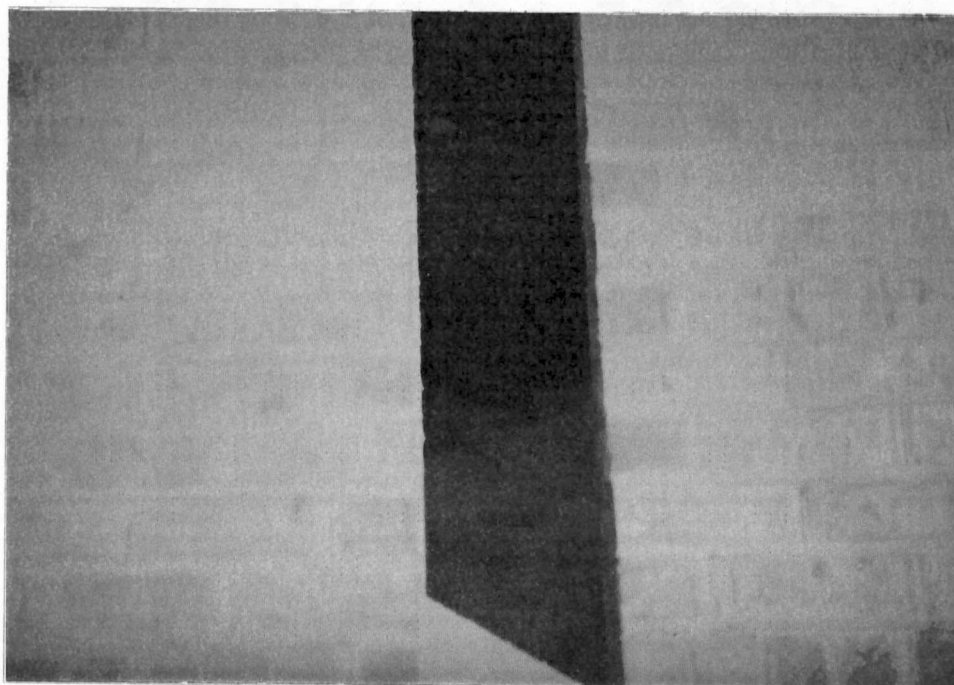
| PLAN 1 ..... | INITIAL VALUE | SPILLWAY CREST | TOP OF DAM |
|--------------|---------------|----------------|------------|
| ELEVATION    | 85.20         | 89.00          | 89.00      |
| STORAGE      | 0.            | 1.             | 1.         |
| OUTFLOW      | 0.            | 1.             | 1.         |

| RATIO OF PMF | MAXIMUM RESERVOIR W.S.ELEV | MAXIMUM DEPTH OVER DAM | MAXIMUM STORAGE AC-FT | MAXIMUM OUTFLOW CFS | DURATION OVER TOP HOURS | TIME OF MAX OUTFLOW HOURS | TIME OF FAILURE HOURS |
|--------------|----------------------------|------------------------|-----------------------|---------------------|-------------------------|---------------------------|-----------------------|
| 1.00         | 89.67                      | .67                    | 1.                    | 20.                 | 4.20                    | 1.60                      | .00                   |

\*\*\* NORMAL END OF HEC-1 \*\*\*

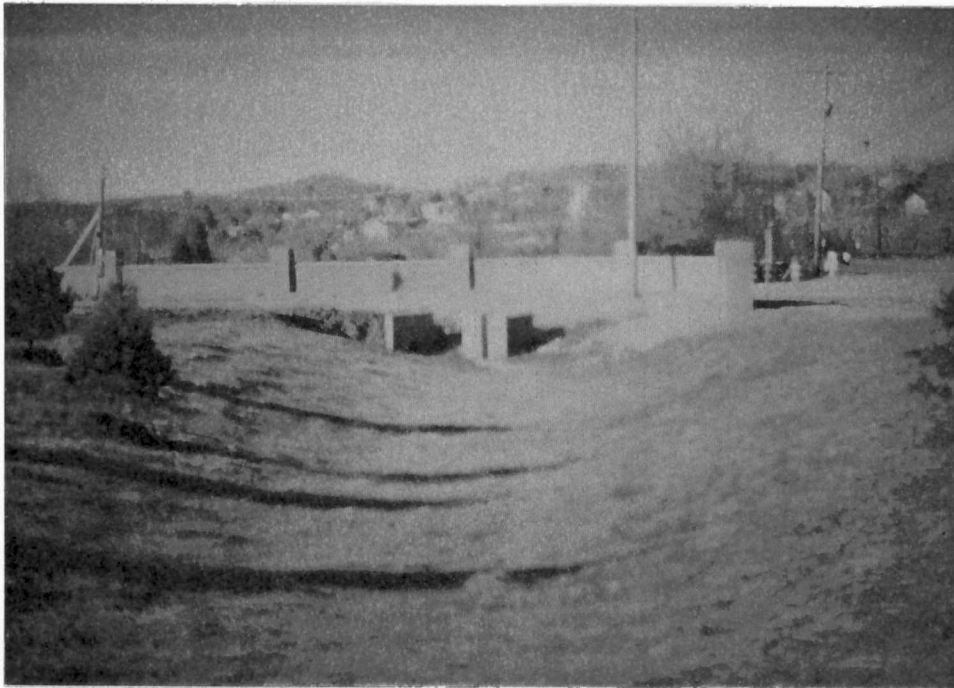


A10.1a - This is a view of the outlet structure. The intended design is a 2.5-in. diameter orifice plate and a 6-in. diameter CMP riser. The constructed outlet structure is a Brick box with a 9-in. wide slot up the side with and an 18-in. diameter CMP outlet pipe.



A10.1b - A close-up of the slot and 18 inch diameter CMP outlet pipe. The pond is discharging 5 times the pre-development flow because the outlet was not constructed according to the design plans.

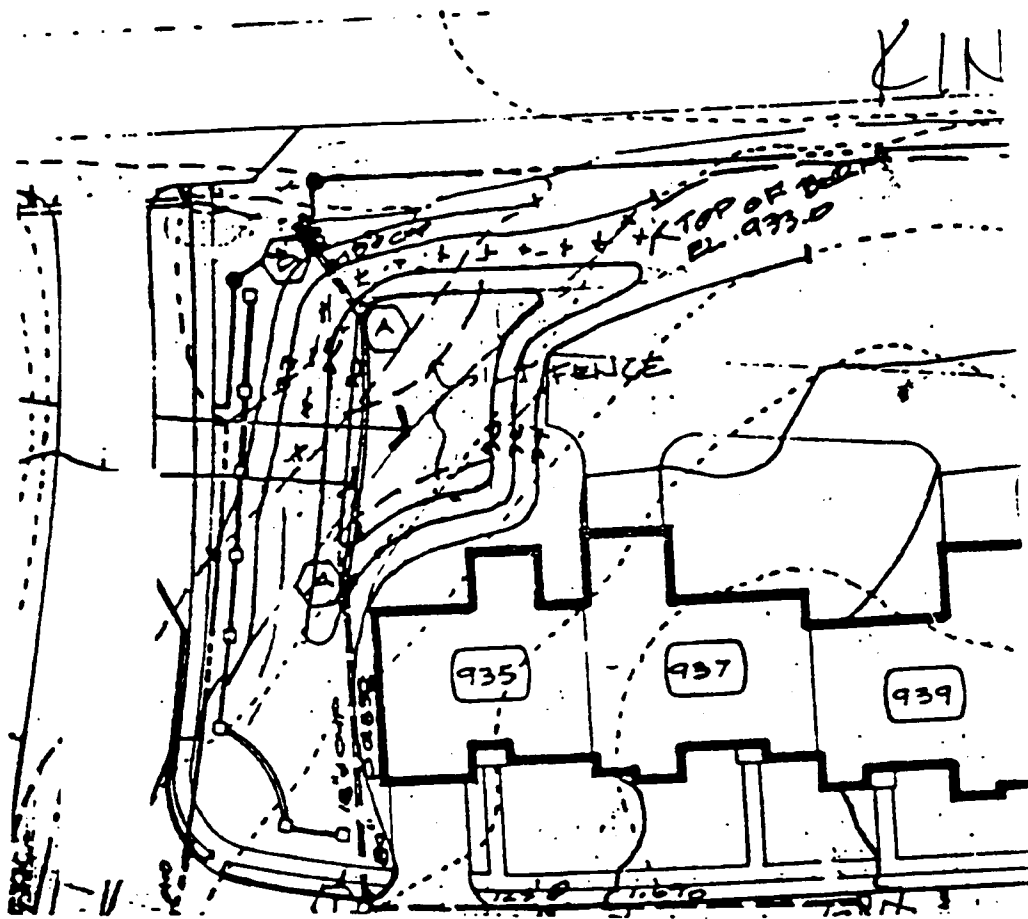




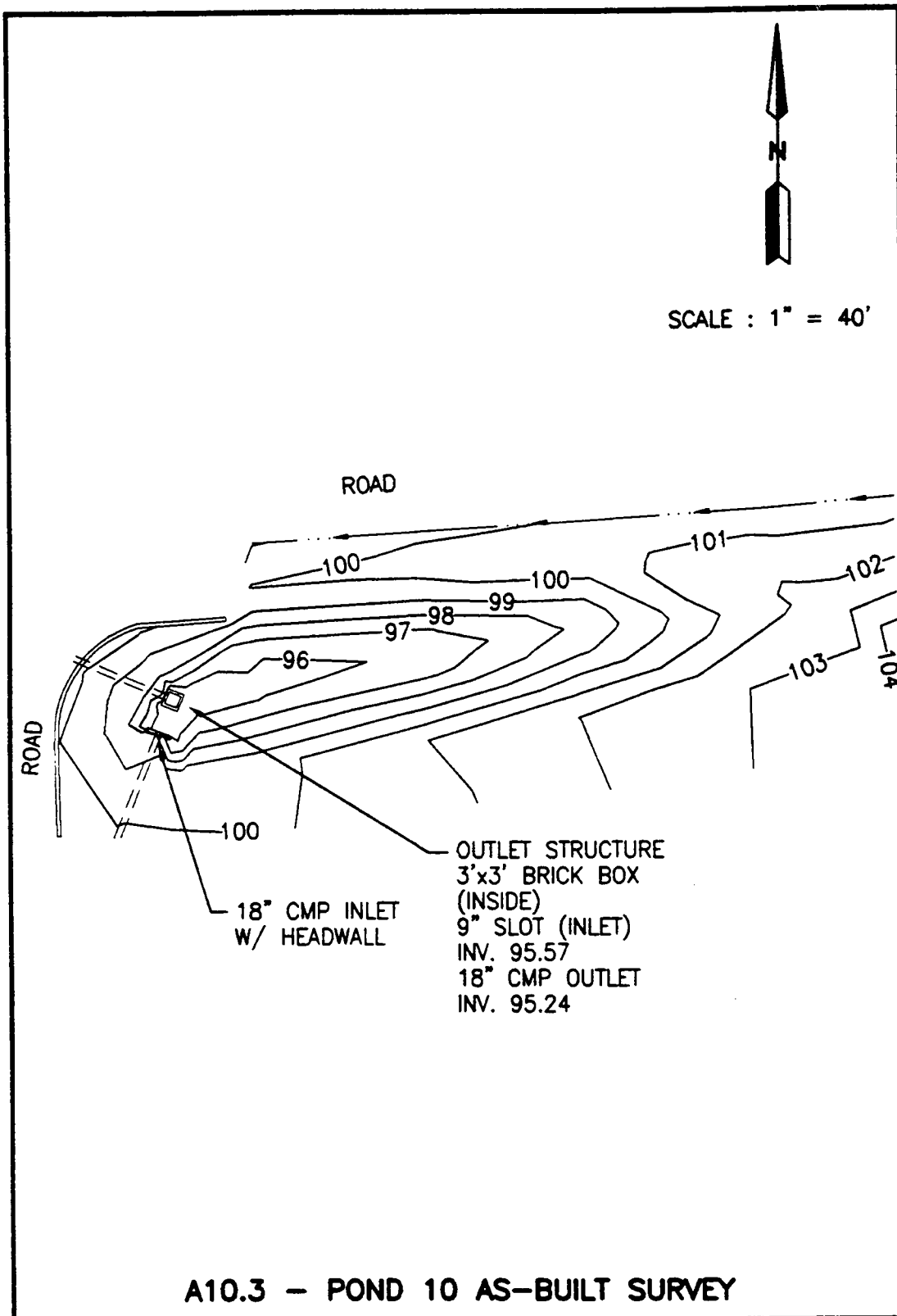
A10.1c - This photograph shows the overall view of Pond 10. The outlet structure is not protected from the bare soil of the surrounding construction site. The storage volume is inadequate, but with the oversized outlet the pond does not overtop during the design storm. The maximum depth during the design storm is 0.8 ft. and the intended design depth is 2.0 ft. Thus, the intended storage is not attained for the design storm inflow.



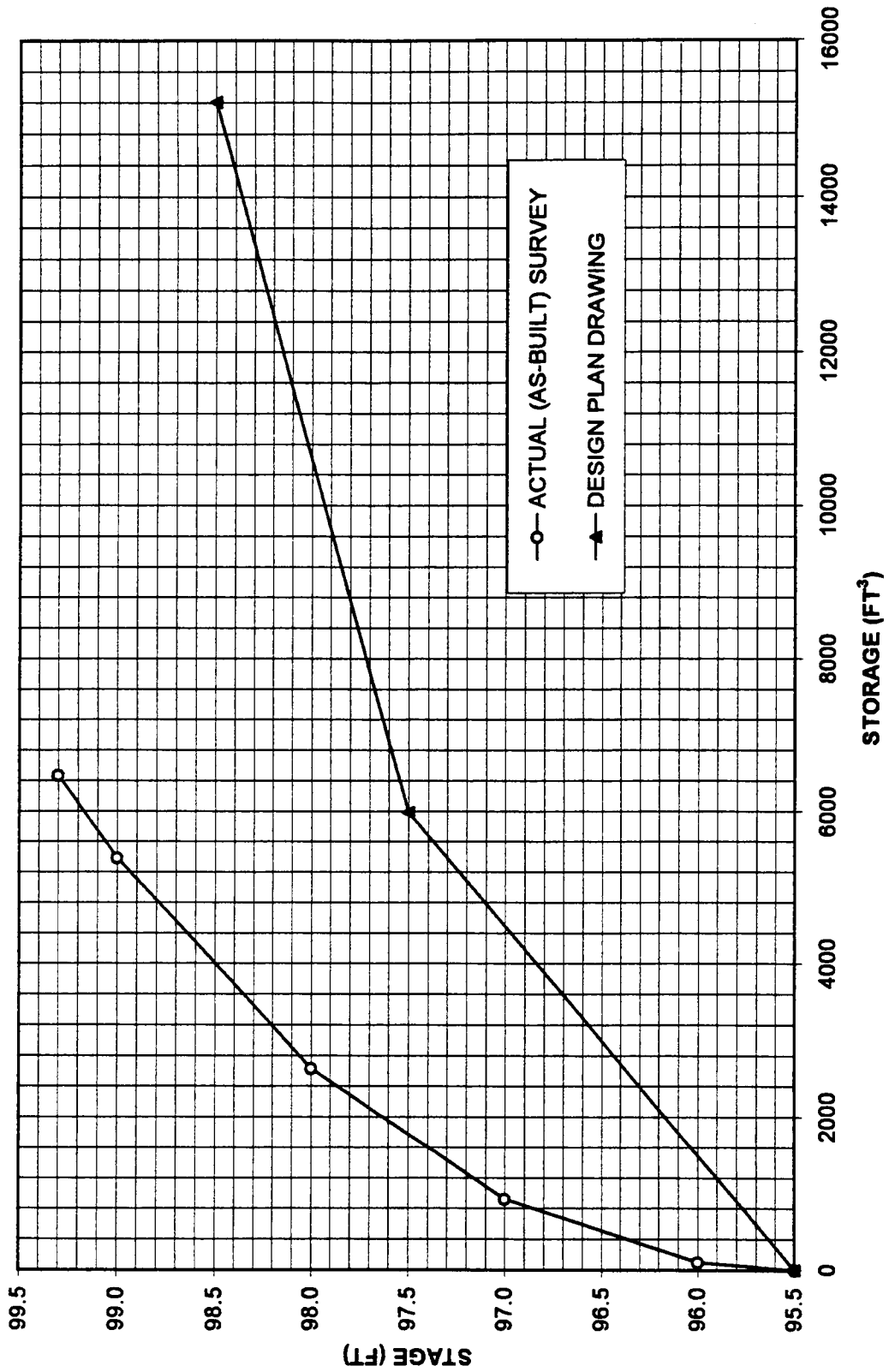
SCALE : 1" = 50'



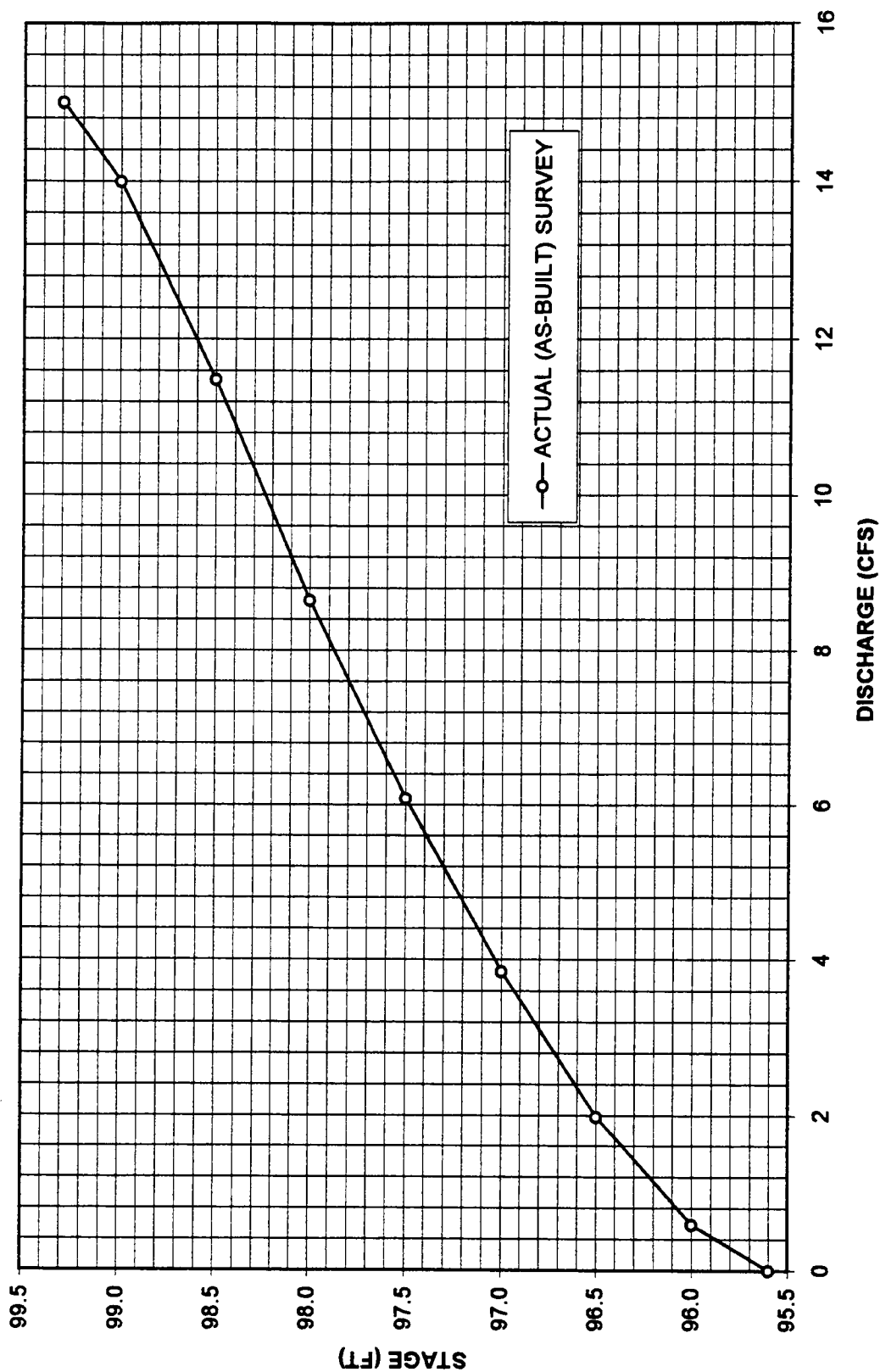
A10.2 - POND 10 - DESIGN PLAN DRAWING



# A10.4 - POND 10 - STAGE vs. STORAGE



# A10.5 - POND 10 - STAGE vs. DISCHARGE



# A10.6 - POND 10 - INFLOW HYDROGRAPH

## TABULAR HYDROGRAPH METHOD

Version 2.00

Project : DETENTION POND ANALYSIS

User: TIR

Date: 04-09-97

County :

State: TN

Checked: \_\_\_\_\_

Date: \_\_\_\_\_

Subtitle: POND 10

Total watershed area: 0.004 sq mi Rainfall type: II Frequency: years

----- Subareas -----

Area(sq mi) 0.00  
Rainfall(in) 4.8  
Curve number 93  
Runoff(in) 0.77  
Tc (hrs) 0.17  
(Used) 0.20  
TimeToOutlet 0.00  
Ia/P 0.37

Time Total ----- Subarea Contribution to Total Flow (cfs) -----  
(hr) Flow 1

|      |    |    |
|------|----|----|
| 11.0 | 0  | 0  |
| 11.3 | 0  | 0  |
| 11.6 | 0  | 0  |
| 11.9 | 0  | 0  |
| 12.0 | 0  | 0  |
| 12.1 | 1  | 1  |
| 12.2 | 2P | 2P |
| 12.3 | 1  | 1  |

|      |   |   |
|------|---|---|
| 12.4 | 1 | 1 |
| 12.5 | 1 | 1 |
| 12.6 | 1 | 1 |
| 12.7 | 0 | 0 |
| 12.8 | 0 | 0 |
| 13.0 | 0 | 0 |
| 13.2 | 0 | 0 |
| 13.4 | 0 | 0 |

|      |   |   |
|------|---|---|
| 13.6 | 0 | 0 |
| 13.8 | 0 | 0 |
| 14.0 | 0 | 0 |
| 14.3 | 0 | 0 |
| 14.6 | 0 | 0 |
| 15.0 | 0 | 0 |
| 15.5 | 0 | 0 |
| 16.0 | 0 | 0 |

|      |   |   |
|------|---|---|
| 16.5 | 0 | 0 |
| 17.0 | 0 | 0 |
| 17.5 | 0 | 0 |
| 18.0 | 0 | 0 |
| 19.0 | 0 | 0 |
| 20.0 | 0 | 0 |
| 22.0 | 0 | 0 |
| 26.0 | 0 | 0 |

P - Peak Flow

A10.7 - POND 10 - HEC-1 INPUT FILE

ID  
ID POND 10  
ID  
\*FREE  
IT 6 0 0 300  
IN 6 0 0  
IO 2 0 0  
KK INFLOW HYDROGRAPH  
KM 10 YEAR HYDROGRAPH  
QI 0 0 1 2 1 1 1 1 0 0  
QI 0 0  
KK POND 10  
KM ROUTE 10 YR POST DEV HYD  
RS 1 ELEV 95.6  
SV 0 0.002 0.01 0.021 0.038 0.06 0.09 0.124 0.15  
SQ 0 0.6 2.0 3.9 6.1 8.6 11.5 14 15  
SE 95.6 96.0 96.5 97.0 97.5 98.0 98.5 99.0 99.3  
ST 99.3 10 3.33 1.5  
ZZ

## A10.8 - Pond 10 - HEC-1 SUMMARY OF RESULTS

RUNOFF SUMMARY  
FLOW IN CUBIC FEET PER SECOND  
TIME IN HOURS, AREA IN SQUARE MILES

| OPERATION            | STATION | PEAK FLOW | TIME OF PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD |         |         | BASIN AREA | MAXIMUM STAGE | TIME OF MAX STAGE |
|----------------------|---------|-----------|--------------|---------------------------------|---------|---------|------------|---------------|-------------------|
|                      |         |           |              | 6-HOUR                          | 24-HOUR | 72-HOUR |            |               |                   |
| HYDROGRAPH AT INFLOW |         | 2.        | .30          | 0.                              | 0.      | 0.      | .00        |               |                   |
| ROUTED TO POND       |         | 1.        | .40          | 0.                              | 0       | 0.      | .00        |               |                   |
|                      |         |           |              |                                 |         |         |            | 96.30         | .40               |

SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION POND  
(PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION)

| PLAN 1 ..... | INITIAL VALUE | SPILLWAY CREST | TOP OF 99.30.00 |
|--------------|---------------|----------------|-----------------|
| STORAGE      | 0.            | 1.             | 1.              |
| OUTFLOW      | 0.            | 15.            | 15.             |

| RATIO OF PMF | MAXIMUM RESERVOIR W.S.ELEV | MAXIMUM DEPTH OVER DAM | MAXIMUM STORAGE AC-FT | MAXIMUM OUTFLOW CFS | DURATION OVER TOP HOURS | TIME OF MAX OUTFLOW HOURS | TIME OF FAILURE HOURS |
|--------------|----------------------------|------------------------|-----------------------|---------------------|-------------------------|---------------------------|-----------------------|
| 1.00         | 96.30                      | .00                    | 0.                    | 1.                  | .00                     | .40                       | .00                   |

\*\*\* NORMAL END OF HEC-1 \*\*\*





A11.1a - The Pond 11 is divided by an entrance driveway. Therefore, the storage volume is divided between two ponds. This photograph shows the inlet to the first pond. The pond receives runoff from a parking lot.



A11.1b - The water is conveyed through an 18-in. diameter RCP from the first pond to the second pond. This photograph shows the inlet end of the 18-in. diameter RCP.



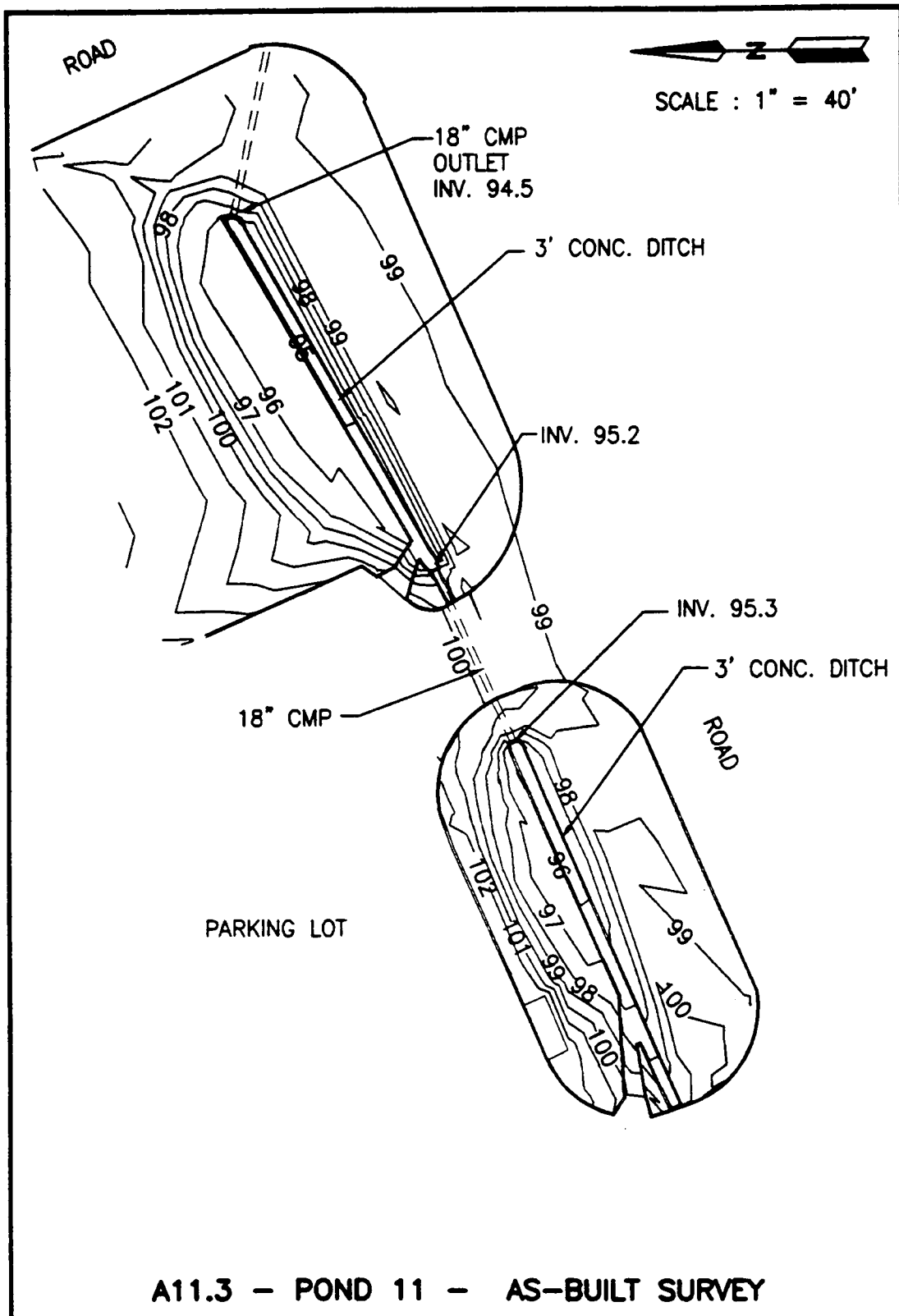


A11.1c - The second pond receives runoff from a parking lot, the first pond, and a pasture. The photograph shows the inlet from the parking lot and the first pond.

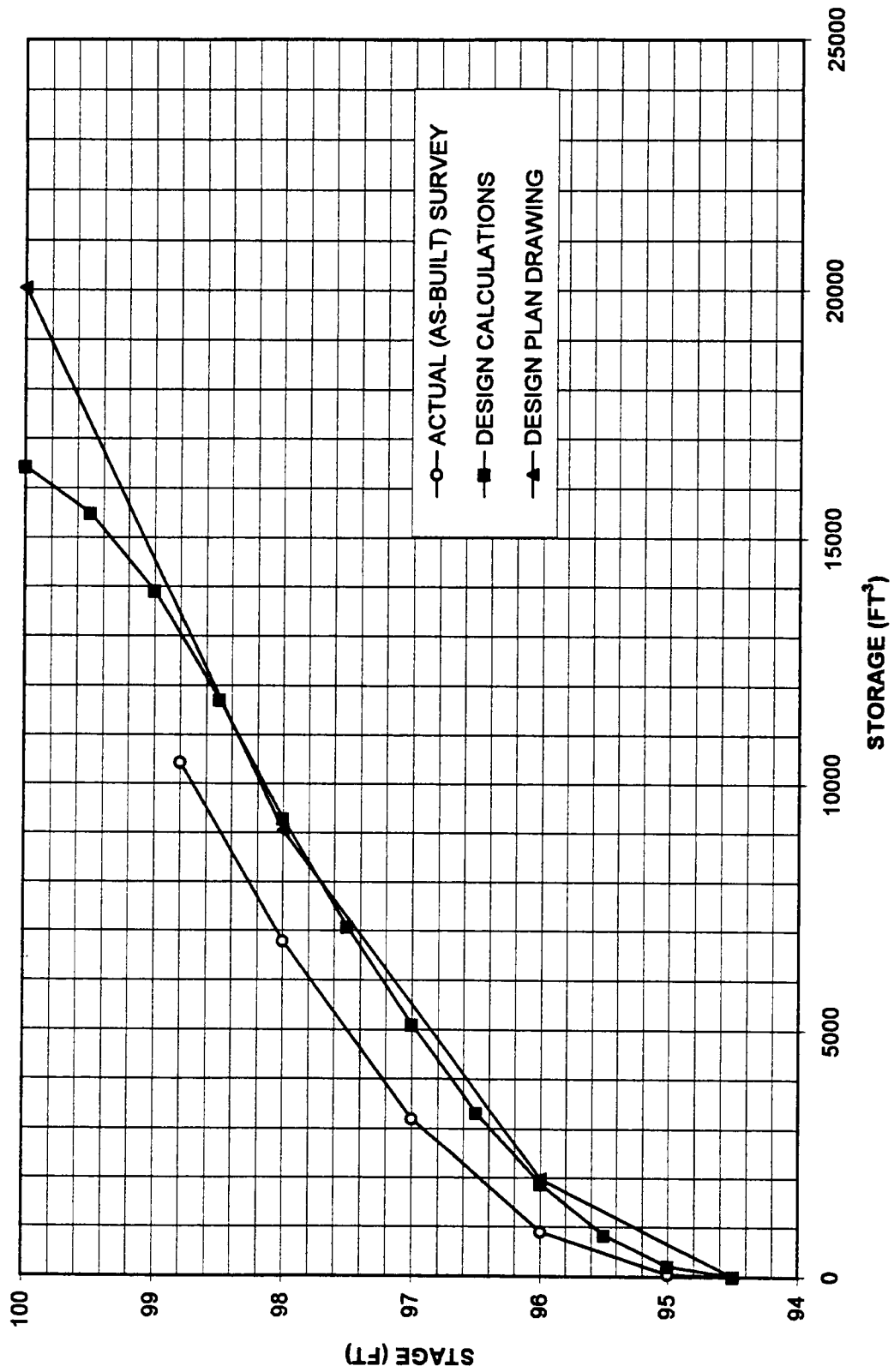


A11.1d - The outlet from the second was designed as an 18-in. diameter RCP having a 13-in. diameter orifice restrictor face plate. The photograph shows that the orifice plate was not constructed. The intended design called for a 5 ft. long x 2 ft. deep grass emergency spillway. The emergency spillway was not constructed.

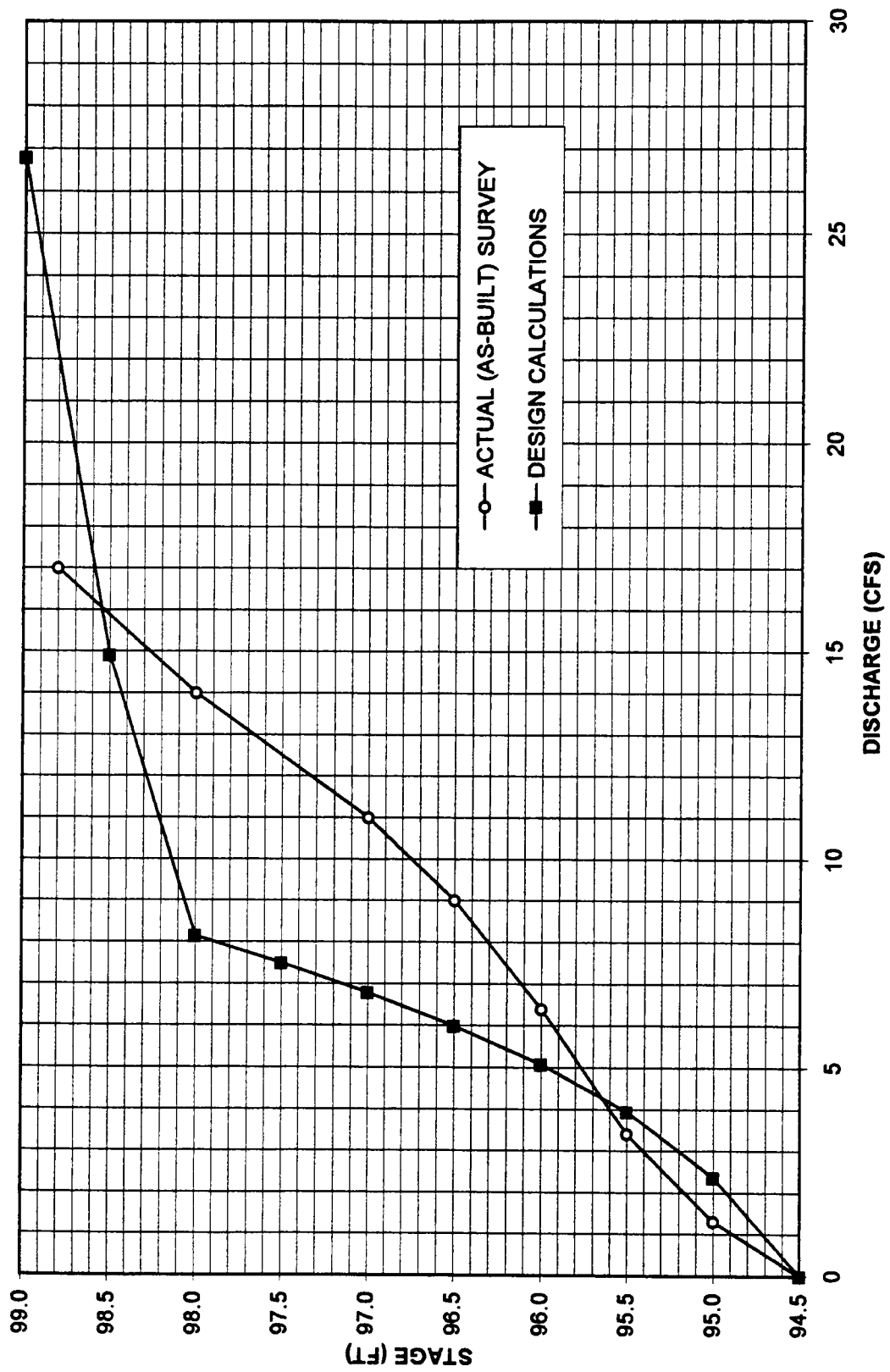




# A11.4 - POND 11 - STAGE vs. STORAGE



# A11.5 - POND 11 - STAGE vs. DISCHARGE



# A11.6 - POND 11 - INFLOW HYDROGRAPH

## TABULAR HYDROGRAPH METHOD

Version 2.00

Project : DETENTION POND ANALYSIS      User: TEL      Date: 04-09-97  
 County : \_\_\_\_\_      State: TX      Checked: \_\_\_\_\_      Date: \_\_\_\_\_  
 Subtitle: POND 11

Total watershed area: 0.004 sq mi    Rainfall type: II    Frequency:    years  
 ----- Subarea -----

1  
 Area(sq mi)    0.00  
 Rainfall(in)    6.1  
 Curve number    91  
 Runoff(in)    3.06  
 Tc (hrs)    0.26  
     (Used)    0.30  
 TimeToOutlet    0.00  
 Ia/P    0.03  
     (Used)    0.10

| Time (hr) | Total Flow | Subarea Contribution to Total Flow (cfs) |
|-----------|------------|------------------------------------------|
| 11.0      | 0          | 0                                        |
| 11.3      | 1          | 1                                        |
| 11.6      | 1          | 1                                        |
| 11.9      | 2          | 2                                        |
| 12.0      | 5          | 5                                        |
| 12.1      | 9          | 9                                        |
| 12.2      | 13P        | 13P                                      |
| 12.3      | 13         | 13                                       |
| 12.4      | 9          | 9                                        |
| 12.5      | 5          | 5                                        |
| 12.6      | 4          | 4                                        |
| 12.7      | 3          | 3                                        |
| 12.8      | 2          | 2                                        |
| 13.0      | 2          | 2                                        |
| 13.2      | 1          | 1                                        |
| 13.4      | 1          | 1                                        |
| 13.6      | 1          | 1                                        |
| 13.8      | 1          | 1                                        |
| 14.0      | 1          | 1                                        |
| 14.3      | 1          | 1                                        |
| 14.6      | 1          | 1                                        |
| 15.0      | 1          | 1                                        |
| 15.5      | 1          | 1                                        |
| 16.0      | 0          | 0                                        |
| 16.5      | 0          | 0                                        |
| 17.0      | 0          | 0                                        |
| 17.5      | 0          | 0                                        |
| 18.0      | 0          | 0                                        |
| 19.0      | 0          | 0                                        |
| 20.0      | 0          | 0                                        |
| 22.0      | 0          | 0                                        |
| 26.0      | 0          | 0                                        |

P - Peak Flow

A11.7 - POND 11 - HEC-1 INPUT FILE

ID  
ID POND 11  
ID  
\*FREE  
IT 6 0 0 300  
IN 6 0 0  
IO 2 0 0  
KK INFLOW HYDROGRAPH  
KM 50 YEAR HYDROGRAPH  
QI 0 0 1 1 1 1 1.33 1.67 2 5  
QI 9 13 13 9 5 4 3 2 2 2  
QI 1.5 1 1 1 1 1 1 1 1 1  
QI 1 1 1 1 1 1 1 1 1 1  
QI 1 1 1 1 1 0.8 0.6 0.4 0.2 0  
QI 0  
KK POND 11  
KM ROUTE 50 YR POST DEV HYD  
RS 1 ELEV 94.5  
SV 0 0.0009 0.007 0.021 0.042 0.074 0.156 0.240  
SQ 0 1.3 3.4 6.4 9 11 14 17  
SE 94.5 95 95.5 96 96.5 97 98 98.8  
ST 98.8 10 3.33 1.5  
ZZ



## A11.8 - Pond 11 - HEC-1 SUMMARY OF RESULTS

### RUNOFF SUMMARY FLOW IN CUBIC FEET PER SECOND TIME IN HOURS, AREA IN SQUARE MILES

|   | OPERATION               | STATION | PEAK<br>FLOW | TIME OF<br>PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD |         |         | BASIN<br>AREA | MAXIMUM<br>STAGE | TIME OF<br>MAX STAGE |
|---|-------------------------|---------|--------------|-----------------|---------------------------------|---------|---------|---------------|------------------|----------------------|
|   |                         |         |              |                 | 6-HOUR                          | 24-HOUR | 72-HOUR |               |                  |                      |
| + | HYDROGRAPH AT<br>INFLOW |         | 13.          | 1.10            | 2.                              | 0.      | 0.      | .00           |                  |                      |
| + | ROUTED TO<br>POND       |         | 11.          | 1.30            | 2.                              | 0.      | 0.      | .00           |                  |                      |
| + |                         |         |              |                 |                                 |         |         |               | 96.97            | 1.30                 |

SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION POND  
(PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION)

|              |                    |                                  |                              |                             |                           |                               |                                 |                             |  |
|--------------|--------------------|----------------------------------|------------------------------|-----------------------------|---------------------------|-------------------------------|---------------------------------|-----------------------------|--|
| PLAN 1 ..... | INITIAL VALUE      |                                  | SPILLWAY CREST               |                             | TOP OF DAM                |                               |                                 |                             |  |
|              | ELEVATION          | 94.50                            |                              | 98.80                       |                           | 98.80                         |                                 |                             |  |
|              | STORAGE            | 0.                               |                              | 0.                          |                           | 0.                            |                                 |                             |  |
|              | OUTFLOW            | 0.                               |                              | 17.                         |                           | 17.                           |                                 |                             |  |
|              | RATIO<br>OF<br>PMF | MAXIMUM<br>RESERVOIR<br>W.S.ELEV | MAXIMUM<br>DEPTH<br>OVER DAM | MAXIMUM<br>STORAGE<br>AC-FT | MAXIMUM<br>OUTFLOW<br>CFS | DURATION<br>OVER TOP<br>HOURS | TIME OF<br>MAX OUTFLOW<br>HOURS | TIME OF<br>FAILURE<br>HOURS |  |
|              | 1.00               | 96.97                            | .00                          | 0.                          | 11.                       | .00                           | 1.30                            | .00                         |  |

\*\*\* NORMAL END OF HEC-1 \*\*\*



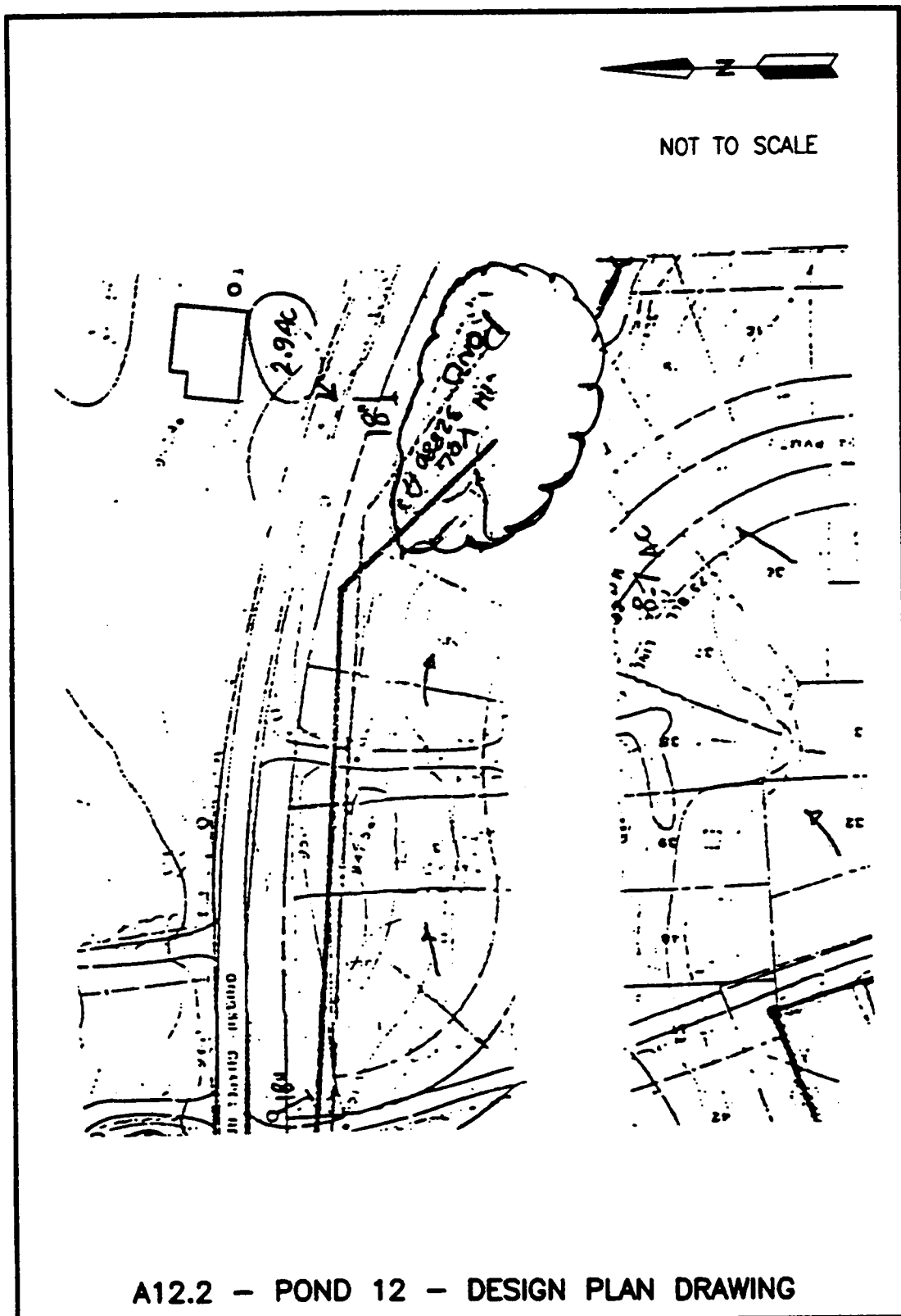
A12.1a - This photograph shows the dam, the outlet pipe, and the concrete emergency spillway. The storage volume in the pond is larger than designed, and is discharging less than the pre-development peak flow. The pond is over constructed.

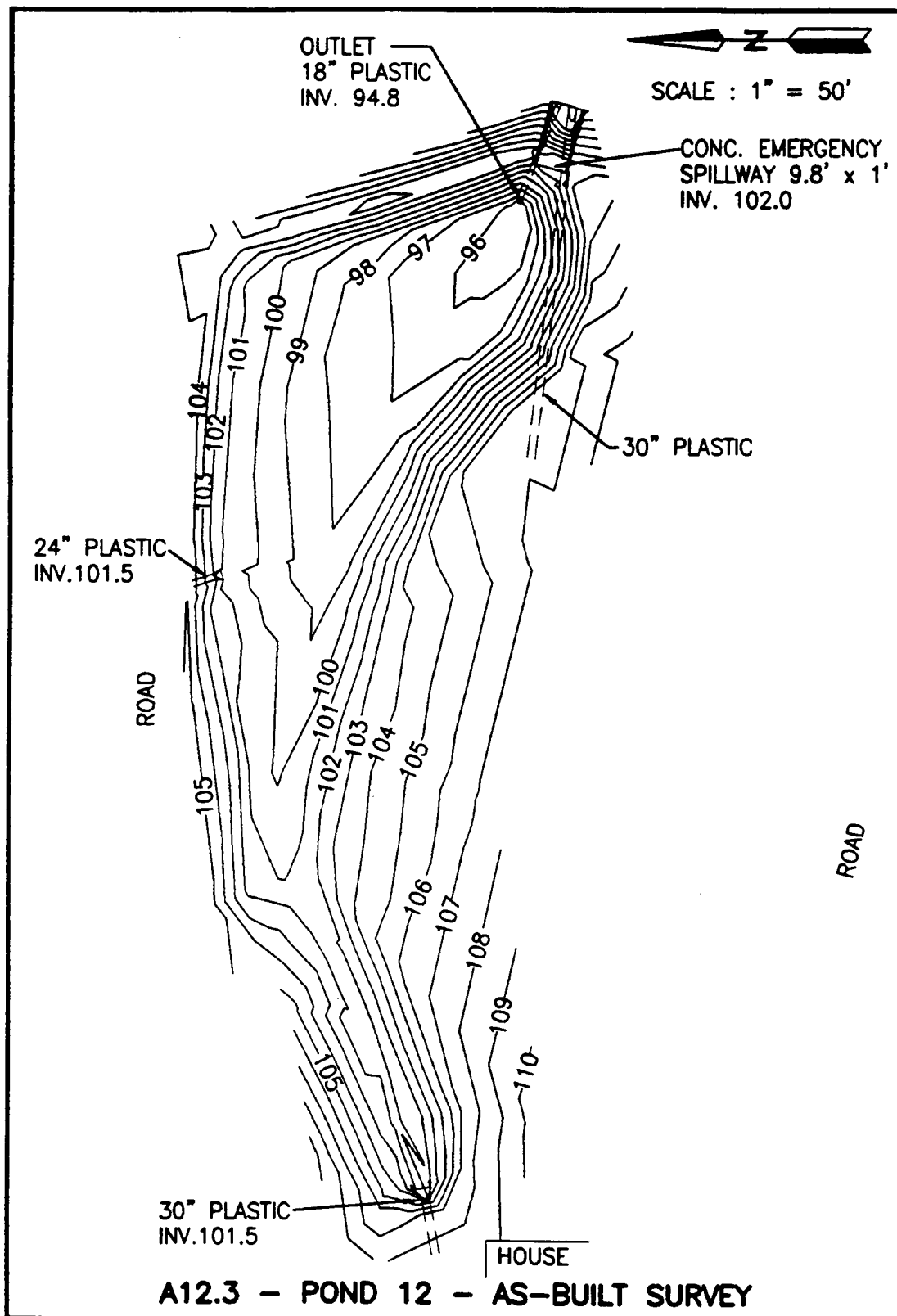


A12.1b - The downstream side of the emergency spillway. The 18-in. diameter pipe on the right is the discharge from Pond 12 and the 30-in. diameter pipe on the left is discharging from the upstream development.



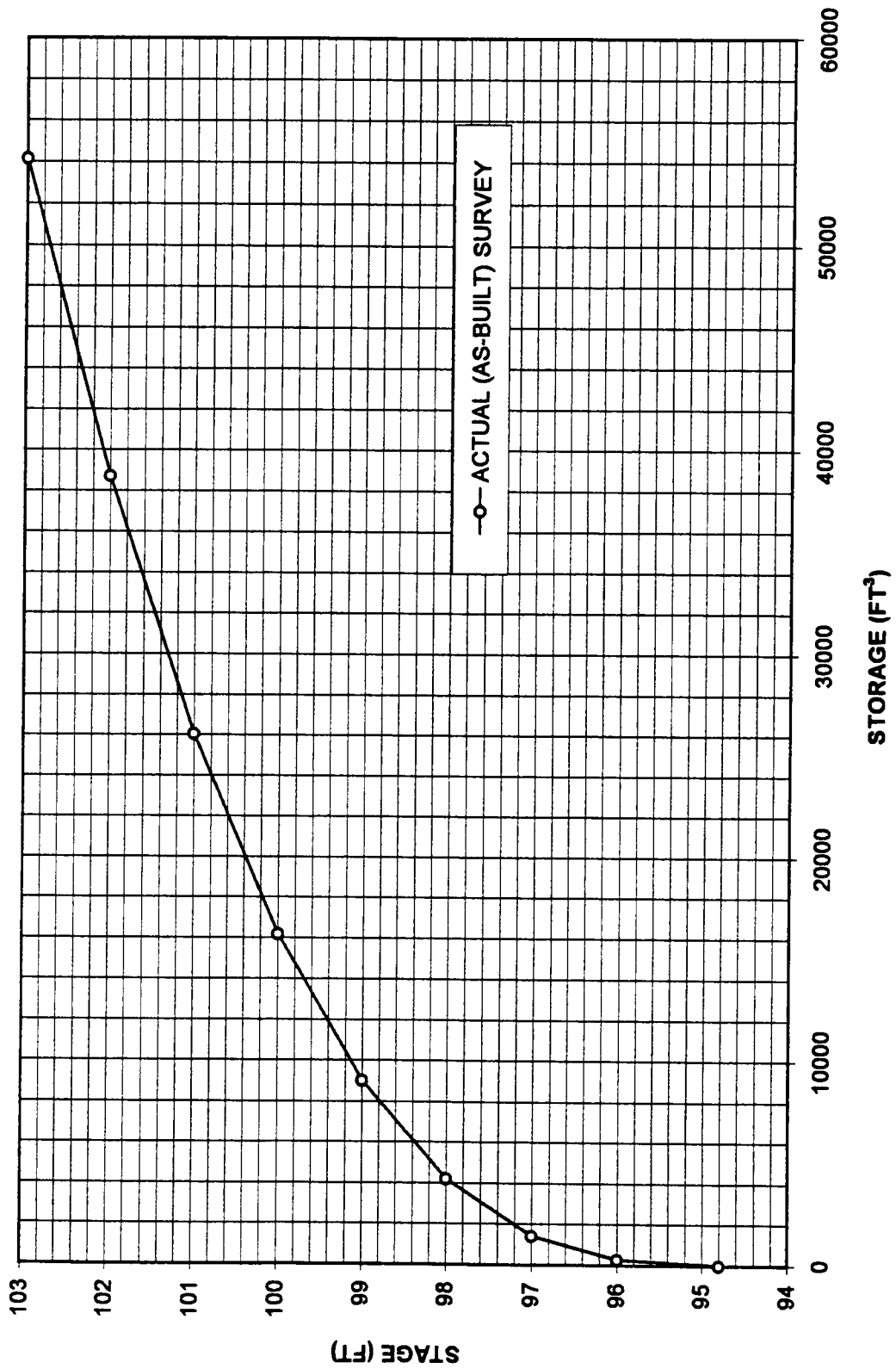
A12.1c - This photograph shows one of the 30 inch diameter plastic inlet pipe to Pond 12. The pipe is half full of mud from the upstream construction. This could have an impact on upstream flow and cause other problems.



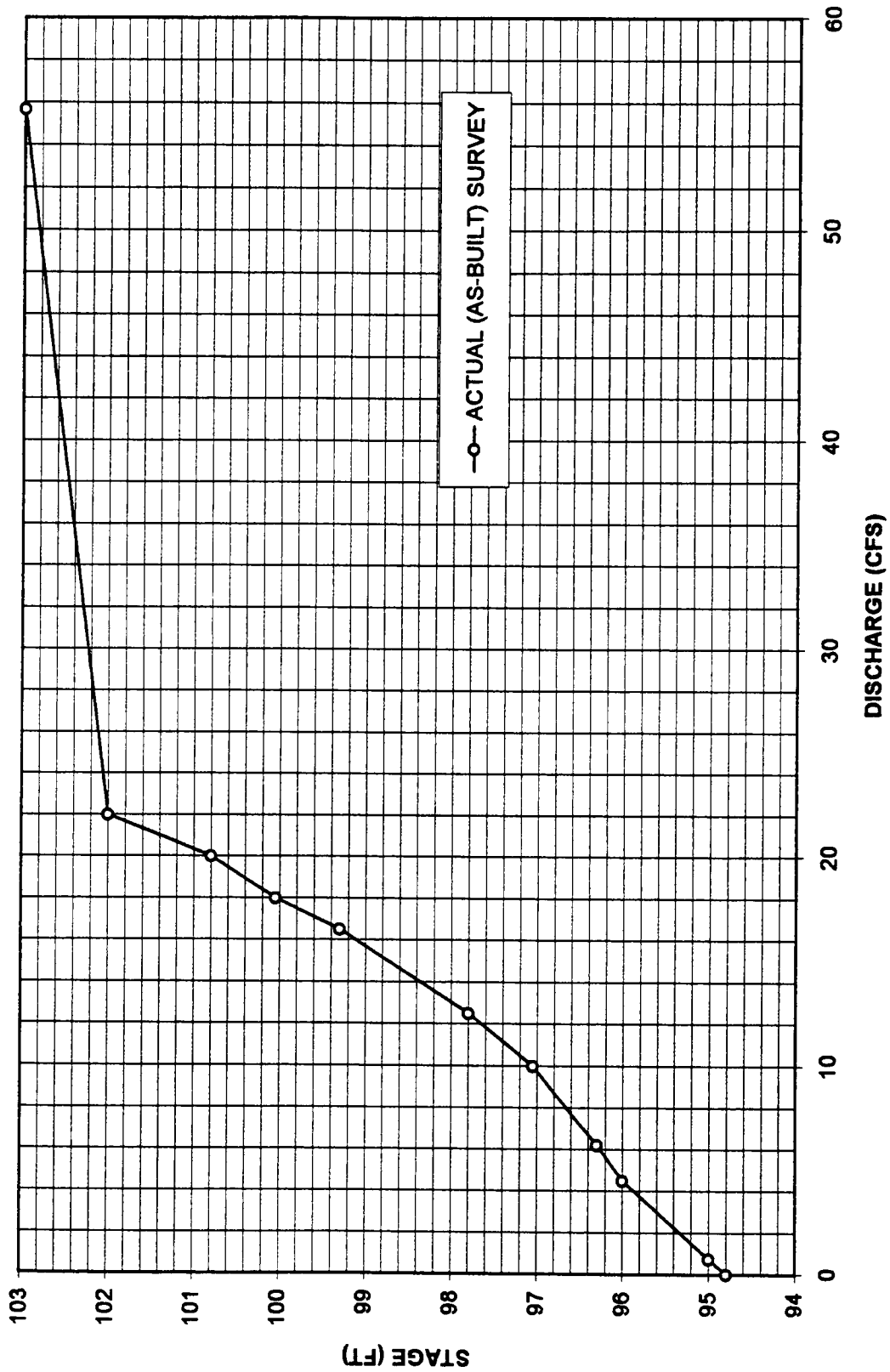




# A12.4 - POND 12 - STAGE vs. STORAGE



# A12.5 - POND 12 - STAGE vs. DISCHARGE



# A12.6 - POND 12 - INFLOW HYDROGRAPH

## TABULAR HYDROGRAPH METHOD

Version 2.00

Project : DETENTION POND ANALYSIS User: TIR Date: 04-09-97  
County : State: TN Checked: Date:   
Subtitle: POND 12

Total watershed area: 0.021 sq mi Rainfall type: II Frequency: years  
----- Subareas -----

1  
Area(sq mi) 0.02  
Rainfall(in) 6.1  
Curve number 67  
Runoff(in) 2.61  
Tc (hrs) 0.10  
TimeToOutlet 0.00  
Ia/7 0.16

Time Total ----- Subarea Contribution to Total Flow (cfs) -----  
(hrs) Flow 1

|      |     |     |
|------|-----|-----|
| 11.0 | 1   | 1   |
| 11.3 | 1   | 1   |
| 11.6 | 2   | 2   |
| 11.9 | 15  | 15  |
| 12.0 | 34  | 34  |
| 12.1 | 54P | 54P |
| 12.2 | 32  | 32  |
| 12.3 | 12  | 12  |
| 12.4 | 8   | 8   |
| 12.5 | 7   | 7   |
| 12.6 | 6   | 6   |
| 12.7 | 5   | 5   |
| 12.8 | 4   | 4   |
| 13.0 | 4   | 4   |
| 13.2 | 3   | 3   |
| 13.4 | 3   | 3   |
| 13.6 | 3   | 3   |
| 13.8 | 3   | 3   |
| 14.0 | 2   | 2   |
| 14.3 | 2   | 2   |
| 14.6 | 2   | 2   |
| 15.0 | 2   | 2   |
| 15.5 | 2   | 2   |
| 16.0 | 1   | 1   |
| 16.5 | 1   | 1   |
| 17.0 | 1   | 1   |
| 17.5 | 1   | 1   |
| 18.0 | 1   | 1   |
| 19.0 | 1   | 1   |
| 20.0 | 1   | 1   |
| 22.0 | 1   | 1   |
| 26.0 | 0   | 0   |

P - Peak Flow



# A12.7 - POND 12 - HEC-1 INPUT FILE

```

ID
ID POND 12
ID
*FREE
IT 6 0 0 300
IN 6 0 0
IO 2 0 0
KK INFLOW HYDROGRAPH
KM 50 YEAR POST DEV
QI 0 0 1 1 1 1 1.33 1.67 2 6.33
QI 10.67 15 34 54 32 12 8 7 6 5
QI 4 4 4 3.5 3 3 3 3 3
QI 3 2.5 2 2 2 2 2 2 2
QI 2 2 2 2 2 2 2 1.8 1.6
QI 1.4 1.2 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1
QI 1 1 1 .975 .950 .925 .9 .875 .85 .825
QI .8 .775 .75 .725 .7 .675 .65 .625 .6 .575
QI .55 .525 .5 .475 .45 .425 .4 .375 .35 .325
QI .3 .275 .25 .225 .2 .175 .15 .125 .1 .075
QI .05 .025 0 0
KK POND 12
KM POND DATA
RS 1 ELEV 94.8
SV 0 .001 .006 .014 .039 .084 .257 .395 .831 .889
SV 1.24
SQ 0 .7 4.5 6.2 10 12.5 16.5 18 20 22
SQ 55.7
SE 94.8 95 96 96.3 97.1 97.8 99.3 100.1 100.8 102
SE 103
ST 103 80 3.3 1.5
ZZ

```

## A12.8 - Pond 12 - HEC-1 SUMMARY OF RESULTS

RUNOFF SUMMARY  
FLOW IN CUBIC FEET PER SECOND  
TIME IN HOURS, AREA IN SQUARE MILES

|   | OPERATION               | STATION | PEAK<br>FLOW | TIME OF<br>PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD |         |         | BASIN<br>AREA | MAXIMUM<br>STAGE | TIME OF<br>MAX STAGE |
|---|-------------------------|---------|--------------|-----------------|---------------------------------|---------|---------|---------------|------------------|----------------------|
|   |                         |         |              |                 | 6-HOUR                          | 24-HOUR | 72-HOUR |               |                  |                      |
| + | HYDROGRAPH AT<br>INFLOW |         | 54.          | 1.30            | 5.                              | 1.      | 1.      | .00           |                  |                      |
| + | ROUTED TO<br>POND       |         | 19.          | 1.50            | 5.                              | 1.      | 1.      | .00           | 100.45           | 1.50                 |

SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION POND  
(PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION)

|              |                    |                                  |                              |                             |                           |                               |                                 |                             |  |
|--------------|--------------------|----------------------------------|------------------------------|-----------------------------|---------------------------|-------------------------------|---------------------------------|-----------------------------|--|
| PLAN 1 ..... | INITIAL VALUE      |                                  | SPILLWAY CREST               |                             | TOP OF DAM                |                               |                                 |                             |  |
|              | ELEVATION          | 94.80                            |                              | 103.00                      |                           | 103.00                        |                                 |                             |  |
|              | STORAGE            | 0.                               |                              | 1.                          |                           | 1.                            |                                 |                             |  |
|              | OUTFLOW            | 0.                               |                              | 56.                         |                           | 56.                           |                                 |                             |  |
|              | RATIO<br>OF<br>PMF | MAXIMUM<br>RESERVOIR<br>W.S.ELEV | MAXIMUM<br>DEPTH<br>OVER DAM | MAXIMUM<br>STORAGE<br>AC-FT | MAXIMUM<br>OUTFLOW<br>CFS | DURATION<br>OVER TOP<br>HOURS | TIME OF<br>MAX OUTFLOW<br>HOURS | TIME OF<br>FAILURE<br>HOURS |  |
|              | 1.00               | 100.45                           | .00                          | 10.                         | 19.                       | .00                           | 1.50                            | .00                         |  |

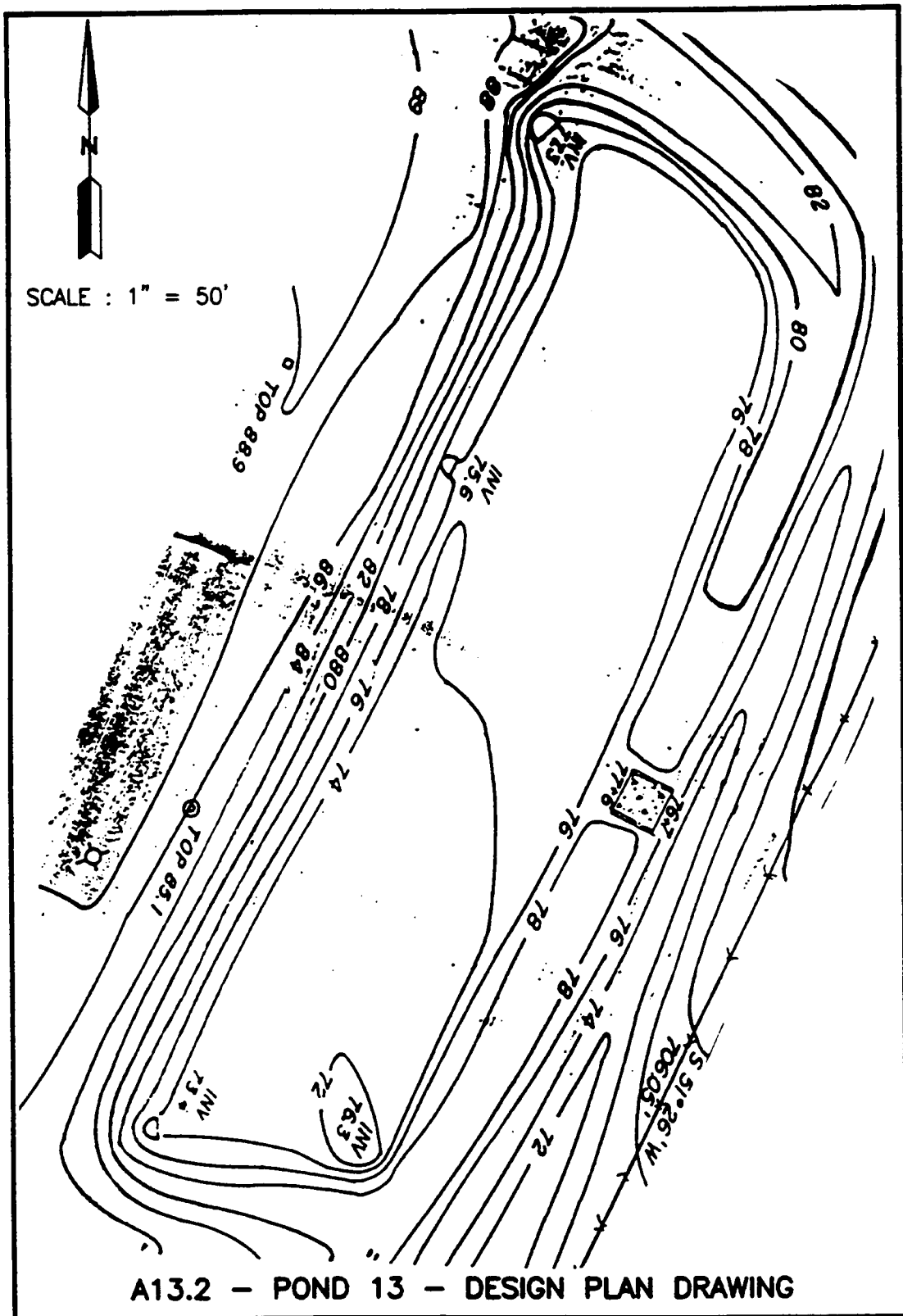
\*\*\* NORMAL END OF HEC-1 \*\*\*

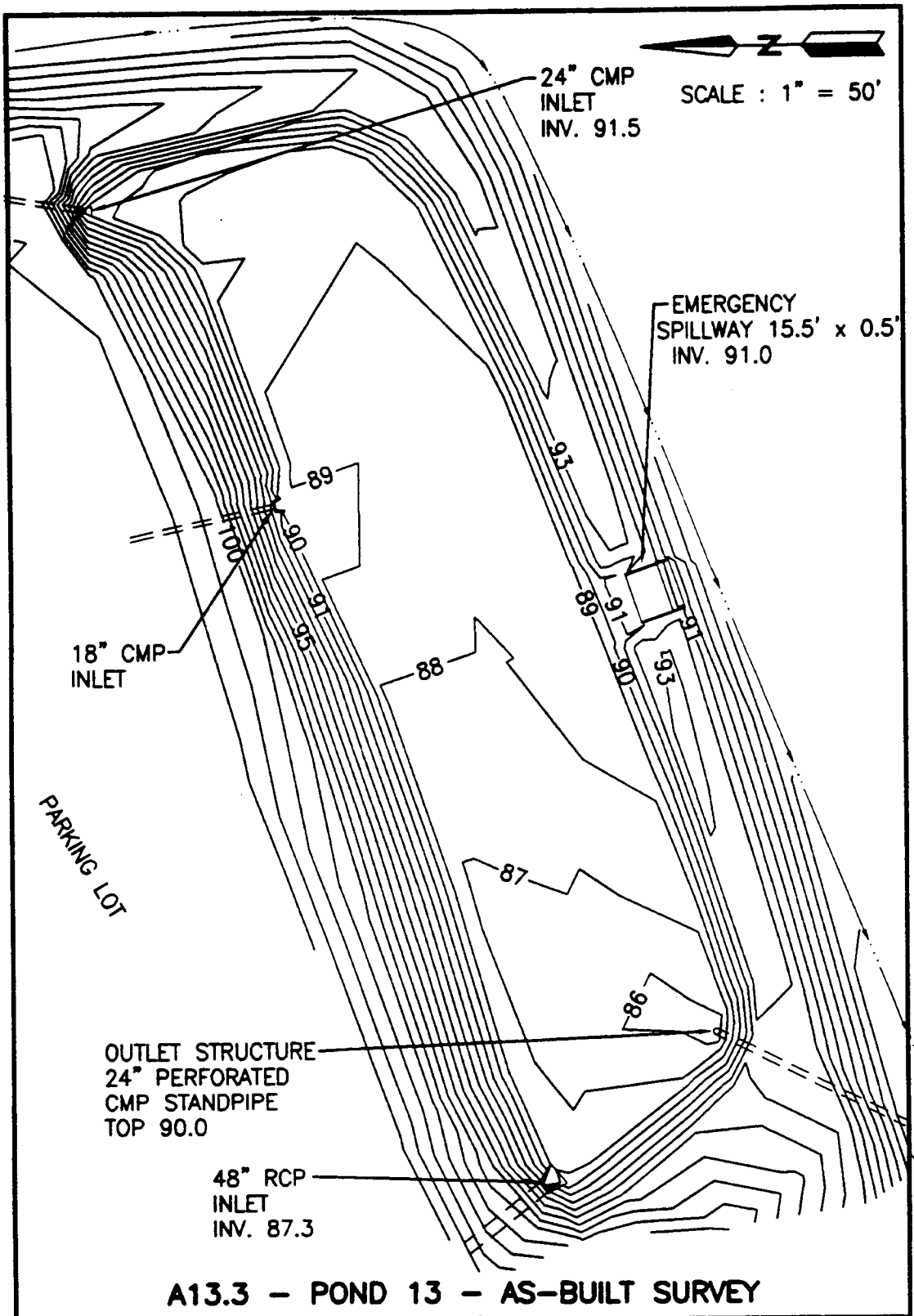


A13.1a - The 18-in. CMP perforated riser pipe is the outlet structure for Pond 13. The perforations are clogged with trash and because, there is no protection on top of the pipe it also has debris and trash in it.

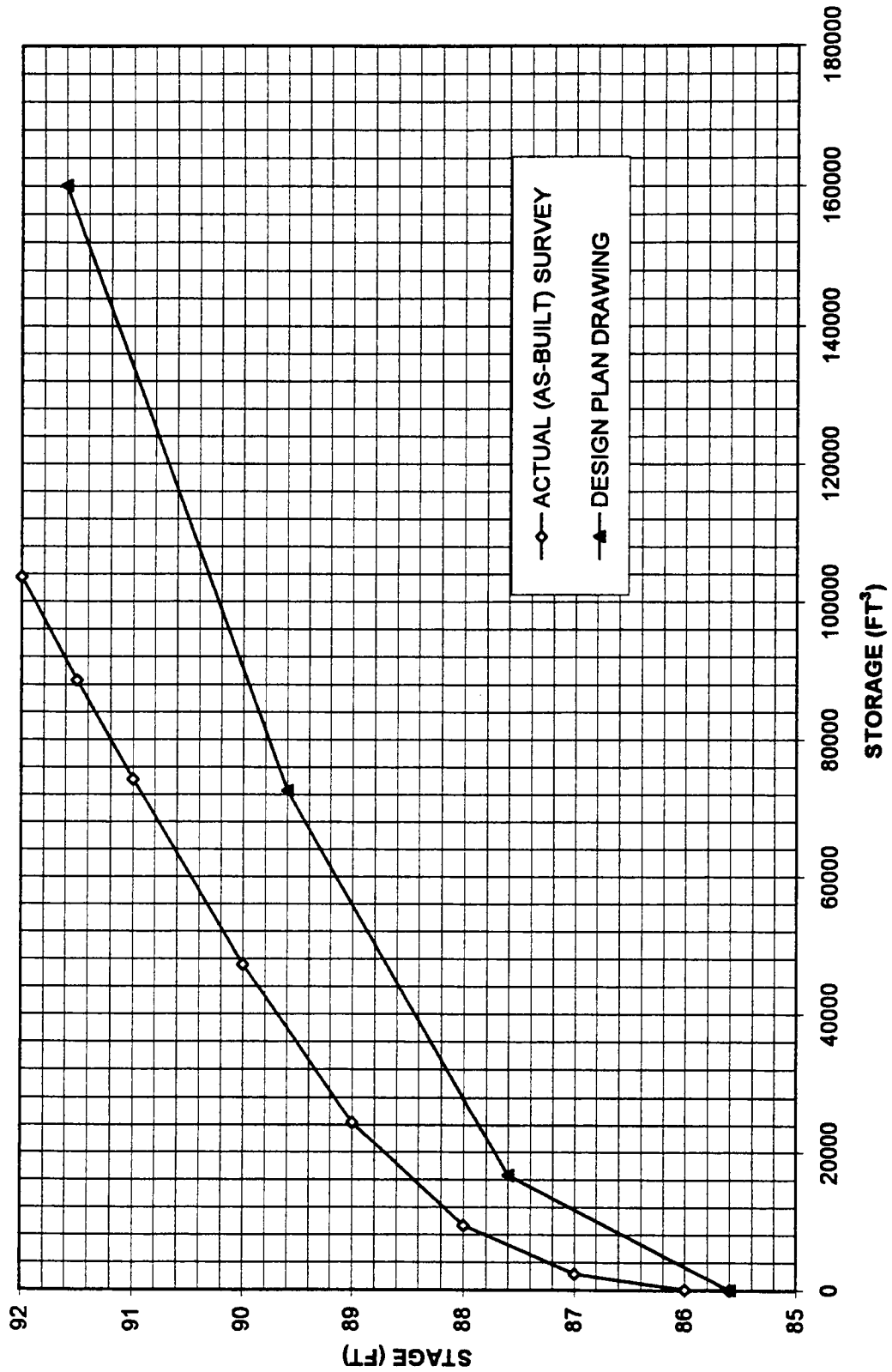


A13.1b - This is a view of the overall pond. The outlet structure is in the center of the photograph in the shaded area. The pond is grown up with weeds and brush and it appears that it is not maintained on a regular basis. The storage volume at the design depth is only 27% of the intended storage volume.

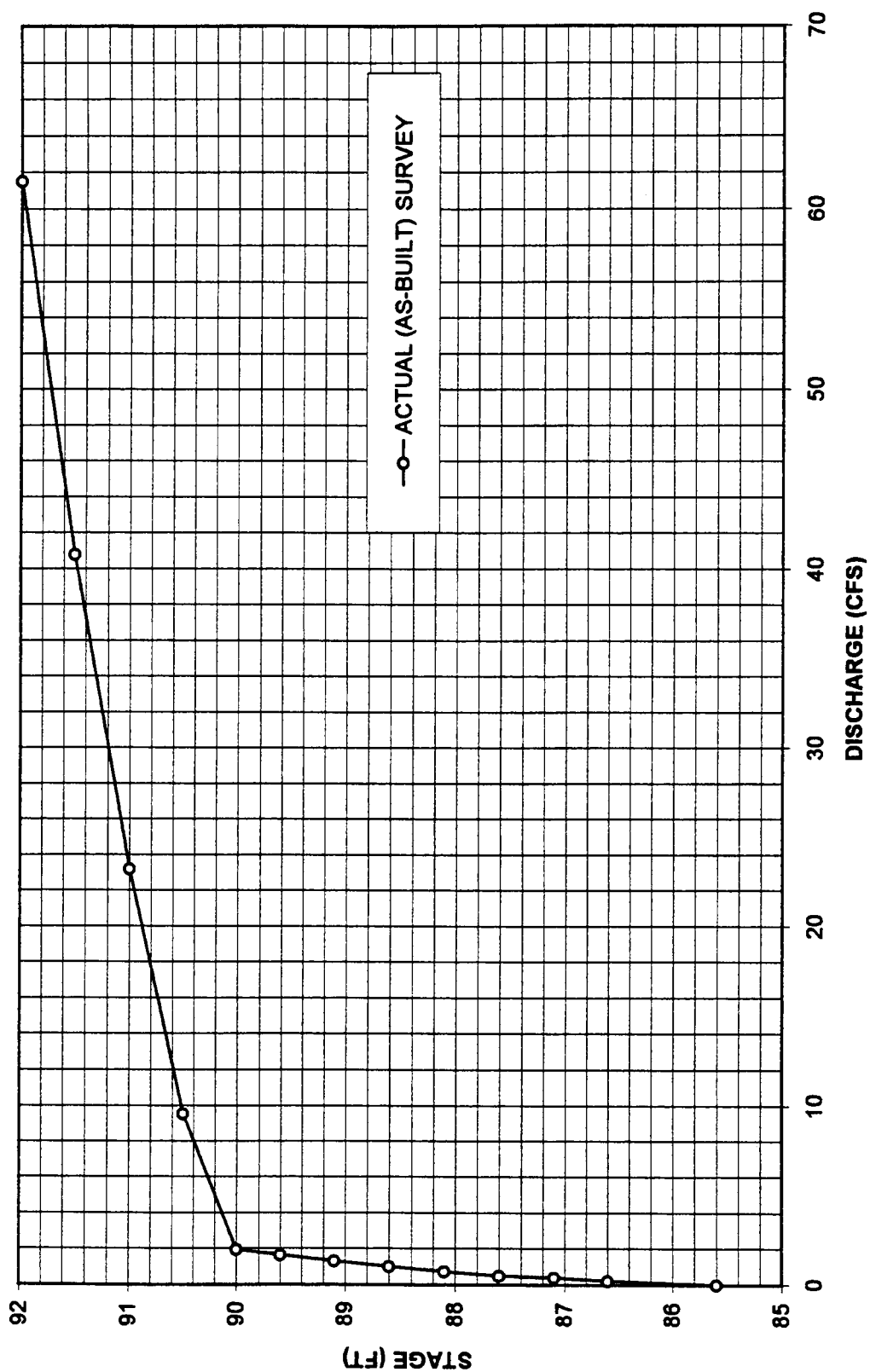




# A13.4 - POND 13 - STAGE vs. STORAGE



# A13.5 - POND 13 - STAGE vs. DISCHARGE



# A13.6 - POND 13 - INFLOW HYDROGRAPH

## TABULAR HYDROGRAPH METHOD

Version 2.00

Project : DETENTION POND ANALYSIS

User: TEJ

Date: 04-09-97

County :

State: TX

Checked: \_\_\_\_\_

Date: \_\_\_\_\_

Subsite: POND 13

Total watershed area: 0.111 sq mi Rainfall type: II Frequency: years

|                        | 1    | 2    | 3    |
|------------------------|------|------|------|
| Area(sq mi)            | 0.03 | 0.03 | 0.05 |
| Rainfall(in)           | 6.1  | 6.1  | 6.1  |
| Curve number           | 70   | 68   | 67   |
| Runoff(in)             | 2.88 | 2.70 | 2.61 |
| Tc (hrs)               | 0.30 | 0.30 | 0.75 |
| TimeToOutlet<br>(Used) | 0.00 | 0.00 | 0.01 |
| Ia/P                   | 0.14 | 0.15 | 0.16 |

| Time<br>(hr) | Total<br>Flow | 1   | 2   | 3   |
|--------------|---------------|-----|-----|-----|
| 11.0         | 3             | 1   | 1   | 1   |
| 11.3         | 5             | 2   | 1   | 2   |
| 11.6         | 7             | 3   | 2   | 2   |
| 11.9         | 18            | 9   | 6   | 3   |
| 12.0         | 36            | 18  | 14  | 4   |
| 12.1         | 72            | 37  | 28  | 7   |
| 12.2         | 116           | 58  | 46  | 12  |
| 12.3         | 128P          | 59P | 47P | 22  |
| 12.4         | 110           | 41  | 33  | 36  |
| 12.5         | 95            | 26  | 21  | 48  |
| 12.6         | 88            | 18  | 15  | 55P |
| 12.7         | 79            | 14  | 11  | 54  |
| 12.8         | 69            | 11  | 9   | 49  |
| 13.0         | 49            | 8   | 6   | 35  |
| 13.2         | 35            | 6   | 5   | 24  |
| 13.4         | 28            | 6   | 4   | 13  |
| 13.6         | 23            | 5   | 4   | 14  |
| 13.8         | 20            | 5   | 4   | 11  |
| 14.0         | 16            | 4   | 3   | 9   |
| 14.3         | 14            | 4   | 3   | 7   |
| 14.5         | 12            | 3   | 3   | 6   |
| 15.0         | 11            | 3   | 3   | 5   |
| 15.5         | 10            | 3   | 2   | 5   |
| 16.0         | 8             | 2   | 2   | 4   |
| 16.5         | 8             | 2   | 2   | 4   |
| 17.0         | 7             | 2   | 2   | 3   |
| 17.5         | 7             | 2   | 2   | 3   |
| 18.0         | 7             | 2   | 2   | 3   |
| 19.0         | 6             | 2   | 1   | 3   |
| 20.0         | 4             | 1   | 1   | 2   |
| 22.0         | 4             | 1   | 1   | 2   |
| 26.0         | 0             | 0   | 0   | 0   |

144.2

CHECK CALC POSSIBLE  
MISTAKE

P - Peak Flow



# A13.7 - POND 13 - HEC-1 INPUT FILE

```

ID
ID POND 13
ID
*FREE
IT 6 0 0 300
IN 6 0 0
IO 2 0 0
KK INFLOW HYDROGRAPH
KM 50 YEAR POST DEV
QI 0 0 3 3.67 4.33 5 5.67 6.33 7 10.67
QI 14.33 18 36 72 116 128 110 95 88 79
QI 69 59 49 42 35 31.5 28 25.5 23 21.5
QI 20 18 16 15.33 14.67 14 13.67 12.33 12 11.75
QI 11.5 11.25 11 10.8 10.6 10.4 10.2 10 9.6 9.2
QI 8.8 8.4 8 8 8 8 8 7.8 7.6
QI 7.4 7.2 7 7 7 7 7 7 7
QI 7 7 7 6.9 6.8 6.7 6.6 6.5 6.4 6.3
QI 6.2 6.1 6 5.8 5.6 5.4 5.2 5 4.8 4.6
QI 4.4 4.2 4 4 4 4 4 4 4 4
QI 4 4 4 4 4 4 4 4 4 4
QI 4 4 4 3.9 3.8 3.7 3.6 3.5 3.4 3.3
QI 3.2 3.1 3 2.9 2.8 2.7 2.6 2.5 2.4 2.3
QI 2.2 2.1 2 1.9 1.8 1.7 1.6 1.5 1.4 1.3
QI 1.2 1.1 1 0.9 0.8 0.7 0.6 0.5 0.4 0.3
QI 0.2 0.1 0 0
KK POND 13
KM POND DATA
RS 1 ELEV 85.6
SV 0 .032 .069 .15 .249 .421 .612 .874 1.08 1.39
SV 1.7 2.03 2.38
SQ 0 0.2 0.4 0.5 0.7 1 1.3 1.7 2 9.6
SQ 23.2 40.8 61.5
SE 85.6 86.6 87.1 87.6 88.1 88.6 89.1 89.6 90 90.5
SE 91 91.5 92
ST 92 20 3.3 1.5
ZZ

```

## A13.8 - POND 13 - HEC-1 SUMMARY OF RESULTS

RUNOFF SUMMARY  
FLOW IN CUBIC FEET PER SECOND  
TIME IN HOURS, AREA IN SQUARE MILES

|   | OPERATION                                                                                                                            | STATION | PEAK<br>FLOW | TIME OF<br>PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD |         |         | BASIN<br>AREA | MAXIMUM<br>STAGE | TIME OF<br>MAX STAGE |
|---|--------------------------------------------------------------------------------------------------------------------------------------|---------|--------------|-----------------|---------------------------------|---------|---------|---------------|------------------|----------------------|
|   |                                                                                                                                      |         |              |                 | 6-HOUR                          | 24-HOUR | 72-HOUR |               |                  |                      |
| + | HYDROGRAPH AT                                                                                                                        |         |              |                 |                                 |         |         |               |                  |                      |
| + | INFLOW                                                                                                                               |         | 128.         | 1.50            | 28.                             | 8.      | 6.      | .00           |                  |                      |
| + | ROUTED TO                                                                                                                            |         |              |                 |                                 |         |         |               |                  |                      |
| + | POND                                                                                                                                 |         | 102.         | 1.70            | 24.                             | 8.      | 6.      | .00           |                  |                      |
| 1 |                                                                                                                                      |         |              |                 |                                 |         |         |               | 92.47            | 1.70                 |
|   | SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION POND<br>(PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION) |         |              |                 |                                 |         |         |               |                  |                      |

|              |               |                |            |
|--------------|---------------|----------------|------------|
| PLAN 1 ..... | INITIAL VALUE | SPILLWAY CREST | TOP OF DAM |
| ELEVATION    | 85.60         | 92.00          | 92.00      |
| STORAGE      | 0.            | 2.             | 2.         |
| OUTFLOW      | 0.            | 62.            | 62.        |

| RATIO<br>OF<br>PMF | MAXIMUM<br>RESERVOIR<br>W.S.ELEV | MAXIMUM<br>DEPTH<br>OVER DAM | MAXIMUM<br>STORAGE<br>AC-FT | MAXIMUM<br>OUTFLOW<br>CFS | DURATION<br>OVER TOP<br>HOURS | TIME OF<br>MAX OUTFLOW<br>HOURS | TIME OF<br>FAILURE<br>HOURS |
|--------------------|----------------------------------|------------------------------|-----------------------------|---------------------------|-------------------------------|---------------------------------|-----------------------------|
| 1.00               | 92.47                            | .47                          | 3.                          | 102.                      | .70                           | 1.70                            | .00                         |

\*\*\* NORMAL END OF HEC-1 \*\*\*



A14.1a - The outlet structure for Pond 14 is a 5 ft. x 5 ft. concrete box having a triangular weir (2.5° notch) outlet control. The invert of the weir is higher than the bottom of the pond so, water always remains in the pond, thus reducing storage space.



A14.1b - The weir is currently clogged with a plastic bag which is decreasing the discharge capacity.



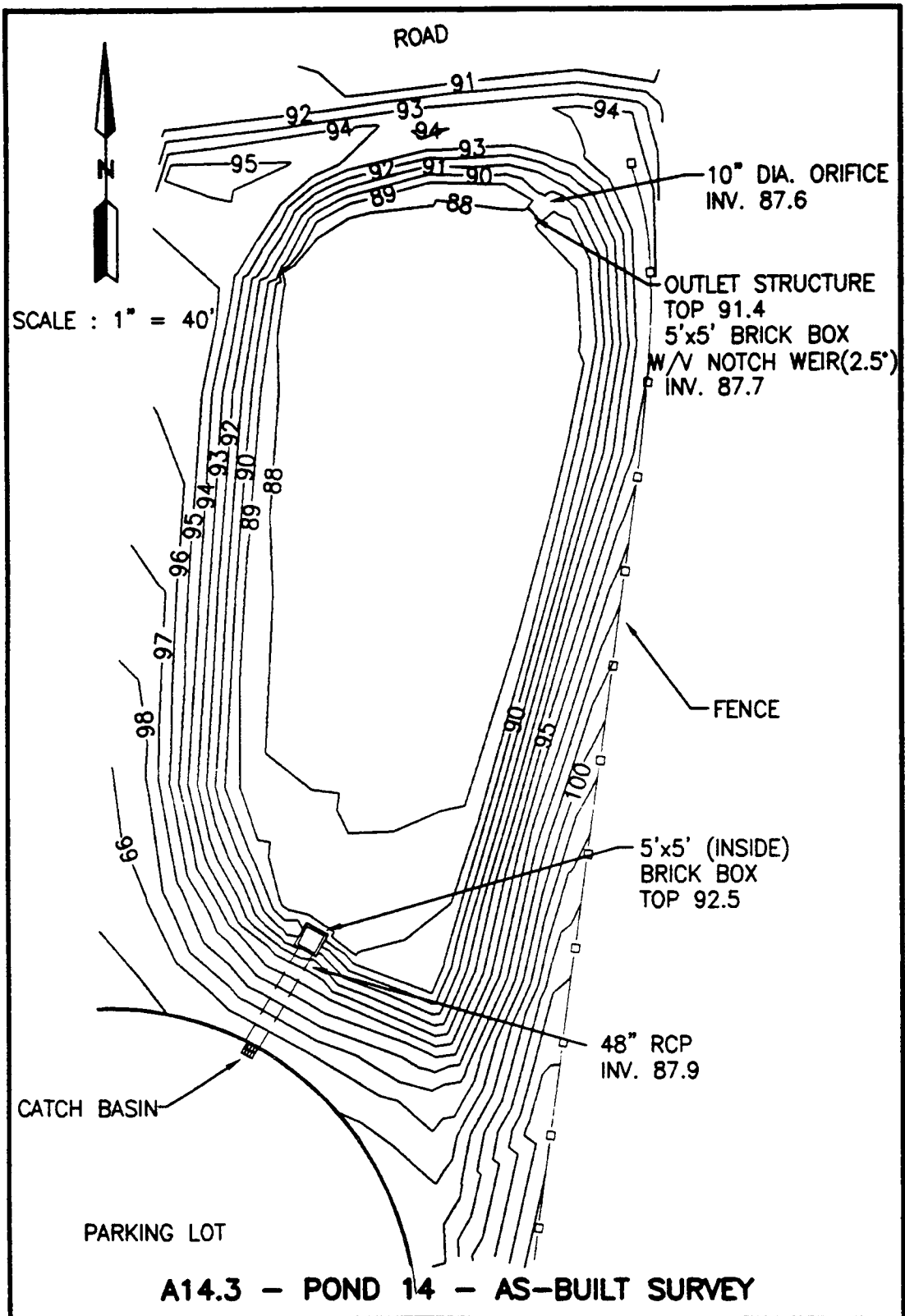


A14.1c - The outlet side of the outlet structure is a 10-in. diameter orifice.

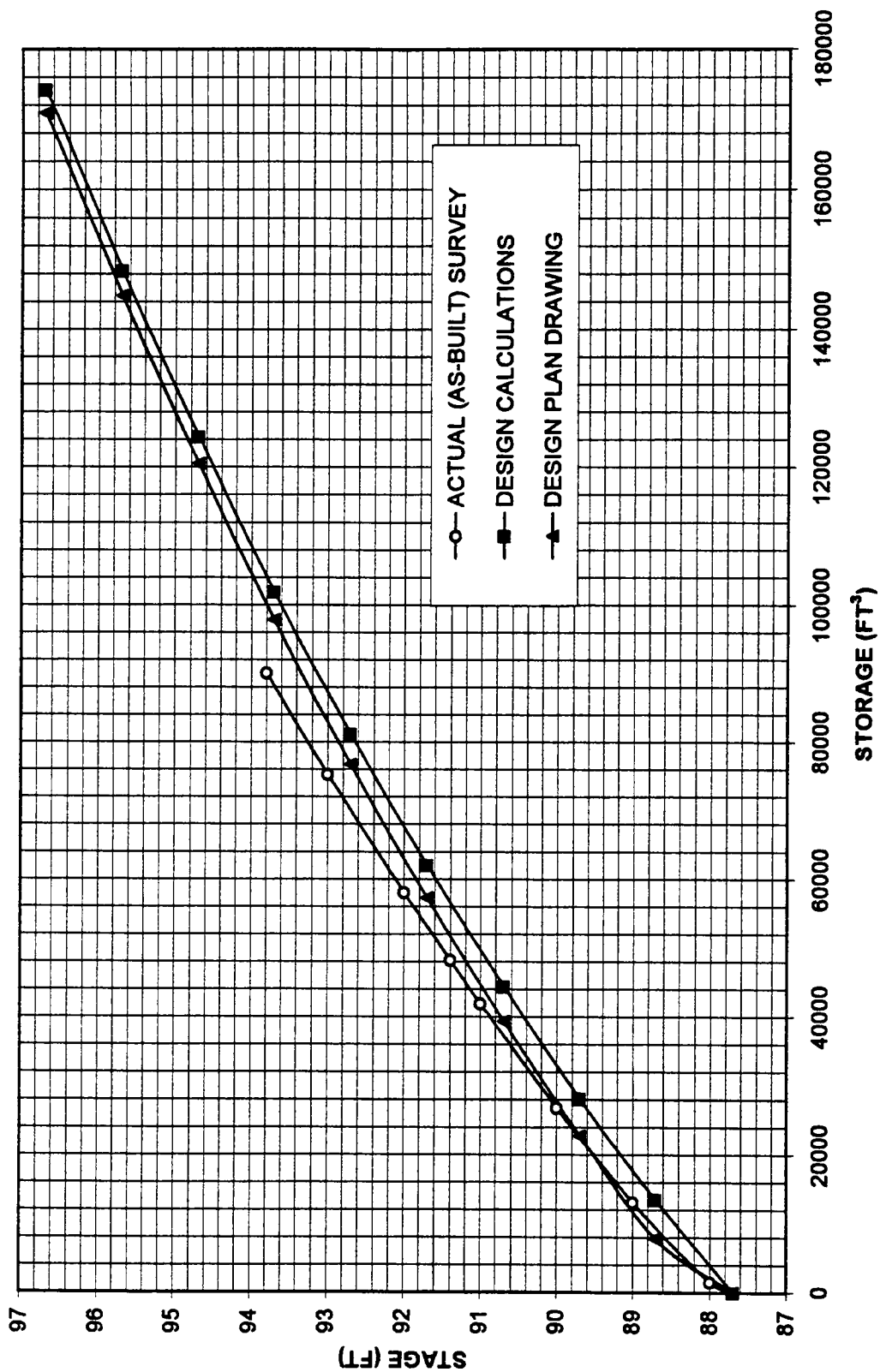


A14.1d - The inlet to the pond is a 5 ft. x 5 ft. concrete block box with a 48-in. diameter inlet pipe. The box does not have an outlet at the bottom therefore, the box stays full of water until it evaporates. The actual storage at the top of the dam is 52% of the intended storage volume. The actual measured dam height is 2.9 ft. lower than designed. The dam overtops during the design storm.

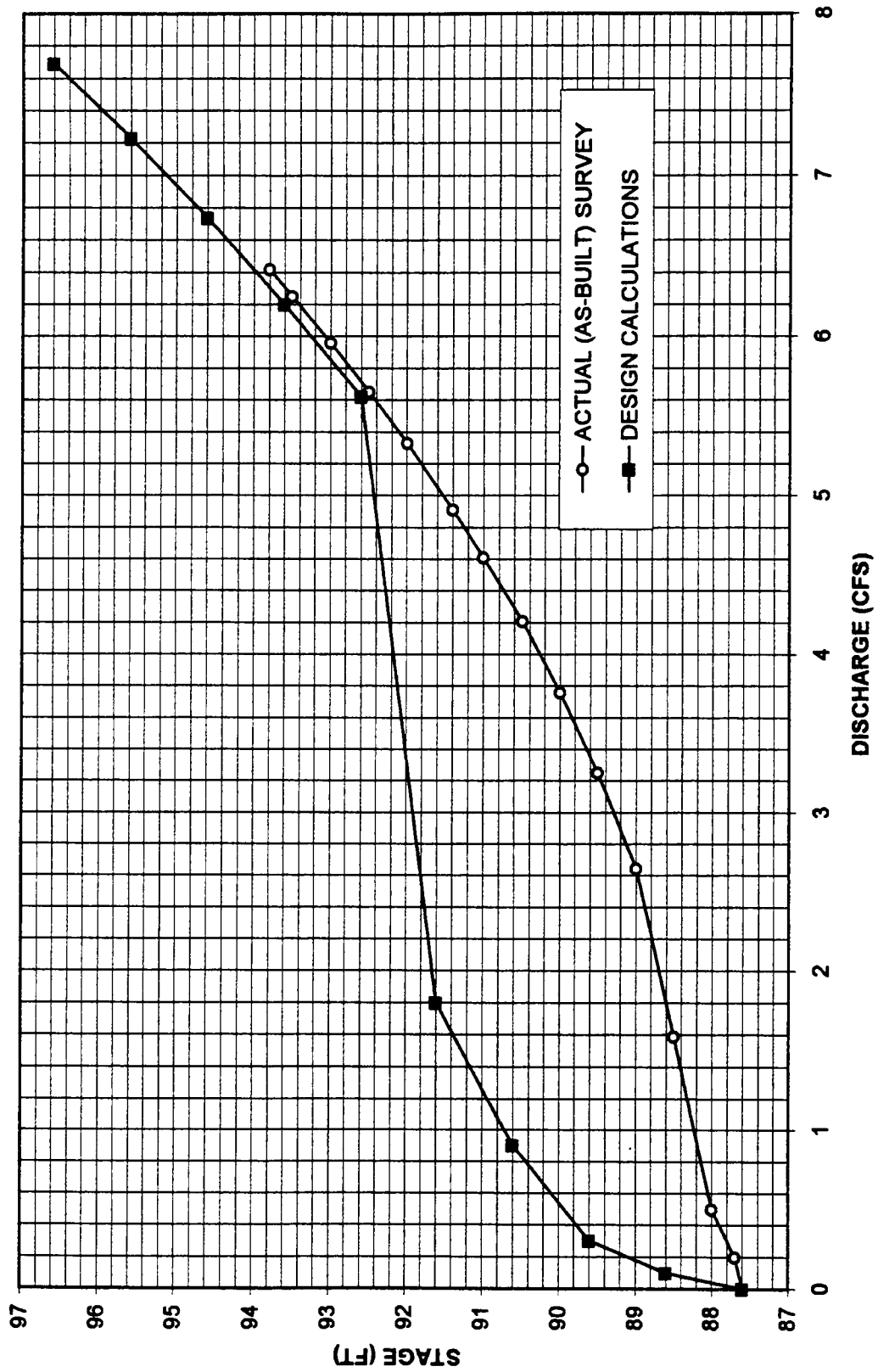




# A14.4 - POND 14 - STAGE vs. STORAGE



# A14.5 - POND 14 - STAGE vs. DISCHARGE





# A14.6 - POND 14 - INFLOW HYDROGRAPH

## TABULAR HYDROGRAPH METHOD

Version 2.00

Project : DETENTION POND ANALYSIS

User: TER

Date: 84-09-97

County :

State: TN

Checked: \_\_\_\_\_

Date: \_\_\_\_\_

Subtitle: POND 14

Total watershed area: 0.041 sq mi Rainfall type: XI Frequency: years

----- Subarea -----  
 1  
 Area(sq mi) 0.04  
 Rainfall(in) 6.6  
 Curve number 71  
 Runoff(in) 3.39  
 Tc (hrs) 0.44  
 (Used) 0.40  
 TimeToOutlet 0.00  
 Ia/P 0.12

| Time (hr) | Total Flow | Subarea Contribution to Total Flow (cfs) |
|-----------|------------|------------------------------------------|
| 11.0      | 2          | 2                                        |
| 11.3      | 3          | 3                                        |
| 11.6      | 4          | 4                                        |
| 11.9      | 9          | 9                                        |
| 12.0      | 17         | 17                                       |
| 12.1      | 35         | 35                                       |
| 12.2      | 62         | 62                                       |
| 12.3      | 80P        | 80P                                      |
| 12.4      | 78         | 78                                       |
| 12.5      | 59         | 59                                       |
| 12.6      | 41         | 41                                       |
| 12.7      | 30         | 30                                       |
| 12.8      | 23         | 23                                       |
| 13.0      | 15         | 15                                       |
| 13.2      | 11         | 11                                       |
| 13.4      | 9          | 9                                        |
| 13.6      | 8          | 8                                        |
| 13.8      | 7          | 7                                        |
| 14.0      | 6          | 6                                        |
| 14.3      | 6          | 6                                        |
| 14.6      | 5          | 5                                        |
| 15.0      | 5          | 5                                        |
| 15.5      | 4          | 4                                        |
| 16.0      | 4          | 4                                        |
| 16.5      | 3          | 3                                        |
| 17.0      | 3          | 3                                        |
| 17.5      | 3          | 3                                        |
| 18.0      | 3          | 3                                        |
| 19.0      | 2          | 2                                        |
| 20.0      | 2          | 2                                        |
| 22.0      | 2          | 2                                        |
| 26.0      | 0          | 0                                        |

P - Peak Flow

# A14.7 - POND 14 - HEC-1 INPUT FILE

```

ID
ID POND 14
ID
*FREE
IT 6 0 0 300
IN 6 0 0
IO 2 0 0
KK INFLOW HYDROGRAPH
KM 100 YEAR POST DEV
QI 0 0 2 2.33 2.67 3 3.33 3.67 4 5.67
QI 7.33 9 17 35 62 80 78 59 41 30
QI 23 19 15 13 11 10 9 8.5 8 7.5
QI 7 6.5 6 6 6 6 5.67 5.33 5 5
QI 5 5 5 4.8 4.6 4.4 4.2 4 4 4
QI 4 4 4 3.8 3.6 3.4 3.2 3 3 3
QI 3 3 3 3 3 3 3 3 3 3
QI 3 3 3 2.9 2.8 2.7 2.6 2.5 2.4 2.3
QI 2.2 2.1 2 2 2 2 2 2 2 2
QI 2 2 2 2 2 2 2 2 2 2
QI 2 2 2 2 2 2 2 2 2 2
QI 2 2 2 1.95 1.9 1.85 1.8 1.75 1.7 1.65
QI 1.6 1.55 1.5 1.45 1.4 1.35 1.3 1.2 1.15
QI 1.1 1.05 1 .95 .9 .85 .8 .75 .7 .65
QI .6 .55 .5 .45 .4 .35 .3 .25 .2 .15
QI .1 .05 0 0
KK POND 14
KM POND DATA
RS 1 ELEV 87.7
SV 0 .035 .168 .301 .459 .617 .79 .962 1.107 1.332
SV 1.531 1.729 1.9 2.07
SQ 0 0 1.6 2.6 3.3 3.8 4.2 4.6 4.9 5.3
SQ 5.7 6 6.3 6.4
SE 87.7 88 88.5 89 89.5 90 90.5 91 91.4 92
SE 92.5 93 93.5 93.8
ST 93.8 50 3.3 1.5
ZZ

```

## A14.8 - Pond 14 - HEC-1 SUMMARY OF RESULTS

RUNOFF SUMMARY  
FLOW IN CUBIC FEET PER SECOND  
TIME IN HOURS, AREA IN SQUARE MILES

|   | OPERATION                                                                                                                            | STATION | PEAK<br>FLOW | TIME OF<br>PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD |         |         | BASIN<br>AREA | MAXIMUM<br>STAGE | TIME OF<br>MAX STAGE |
|---|--------------------------------------------------------------------------------------------------------------------------------------|---------|--------------|-----------------|---------------------------------|---------|---------|---------------|------------------|----------------------|
|   |                                                                                                                                      |         |              |                 | 6-HOUR                          | 24-HOUR | 72-HOUR |               |                  |                      |
| + | HYDROGRAPH AT<br>INFLOW                                                                                                              |         | 80.          | 1.50            | 12.                             | 4.      | 3.      | .00           |                  |                      |
| + | ROUTED TO<br>POND                                                                                                                    |         | 59.          | 1.70            | 10.                             | 4.      | 3.      | .00           |                  |                      |
| + |                                                                                                                                      |         |              |                 |                                 |         |         |               | 94.27            | 1.70                 |
| 1 | SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION POND<br>(PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION) |         |              |                 |                                 |         |         |               |                  |                      |

|              |               |                |            |
|--------------|---------------|----------------|------------|
| PLAN 1 ..... | INITIAL VALUE | SPILLWAY CREST | TOP OF DAM |
| ELEVATION    | 87.7          | 93.8           | 93.8       |
| STORAGE      | 0.            | 2.             | 2.         |
| OUTFLOW      | 0.            | 6.             | 6.         |

| RATIO<br>OF<br>PMF | MAXIMUM<br>RESERVOIR<br>W.S.ELEV | MAXIMUM<br>DEPTH<br>OVER DAM | MAXIMUM<br>STORAGE<br>AC-FT | MAXIMUM<br>OUTFLOW<br>CFS | DURATION<br>OVER TOP<br>HOURS | TIME OF<br>MAX OUTFLOW<br>HOURS | TIME OF<br>FAILURE<br>HOURS |
|--------------------|----------------------------------|------------------------------|-----------------------------|---------------------------|-------------------------------|---------------------------------|-----------------------------|
| 1.00               | 94.27                            | .47                          | 2.                          | 59.                       | 2.00                          | 1.70                            | .00                         |

\*\*\* NORMAL END OF HEC-1 \*\*\*

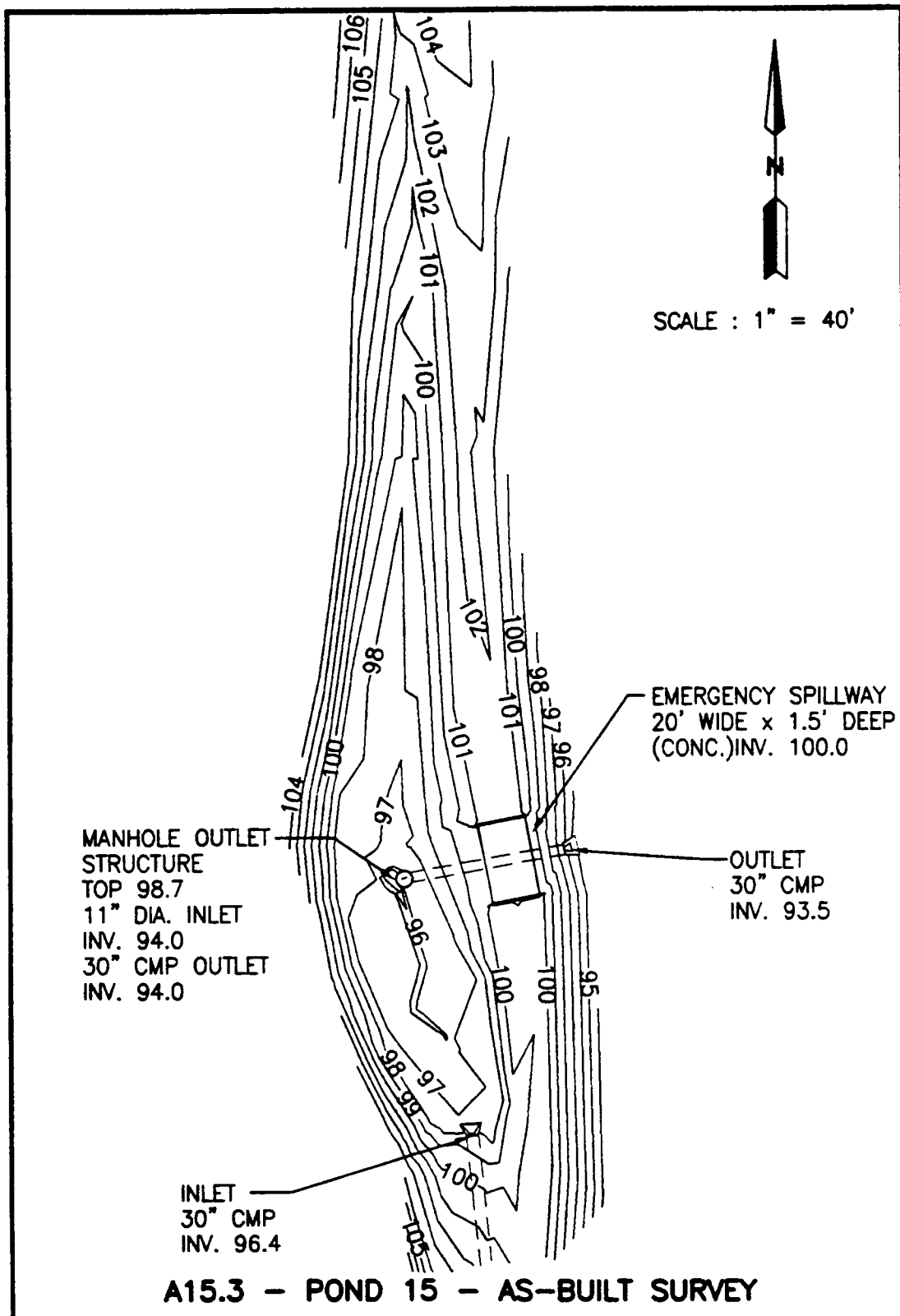


A15.1a - The outlet structure for Pond 15 is a 5-ft. diameter manhole 4.7 ft. high and having a 11-in. diameter orifice at the bottom of the structure.

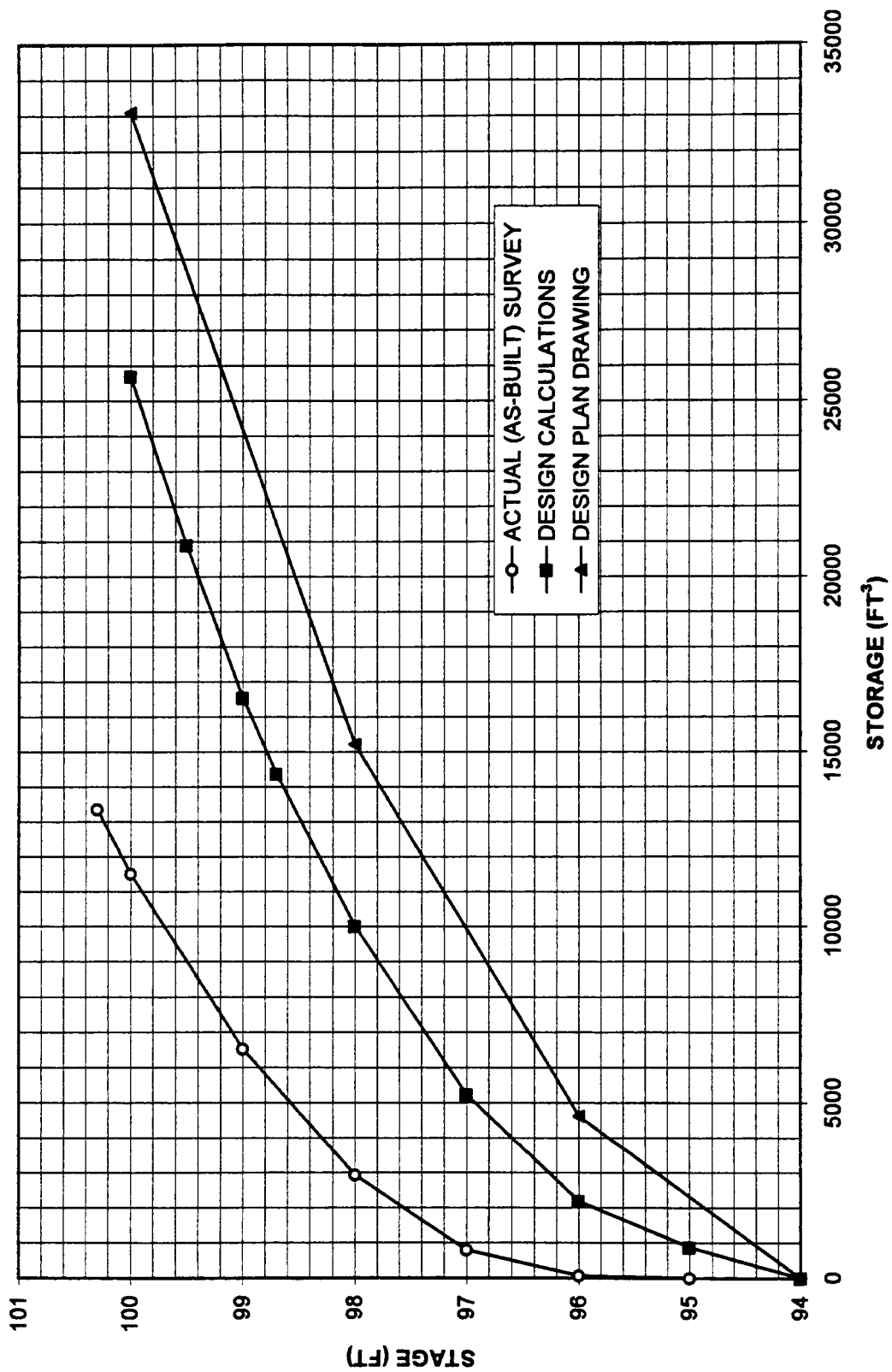


A15.1b - The actual storage volume in the pond is 52% of the intended design storage volume. The net result is that the routed design storm is discharging 3.3 times the pre-development peak flow because the actual water depth is 0.4 ft. higher than the maximum design depth and the water is discharging through the overflow.

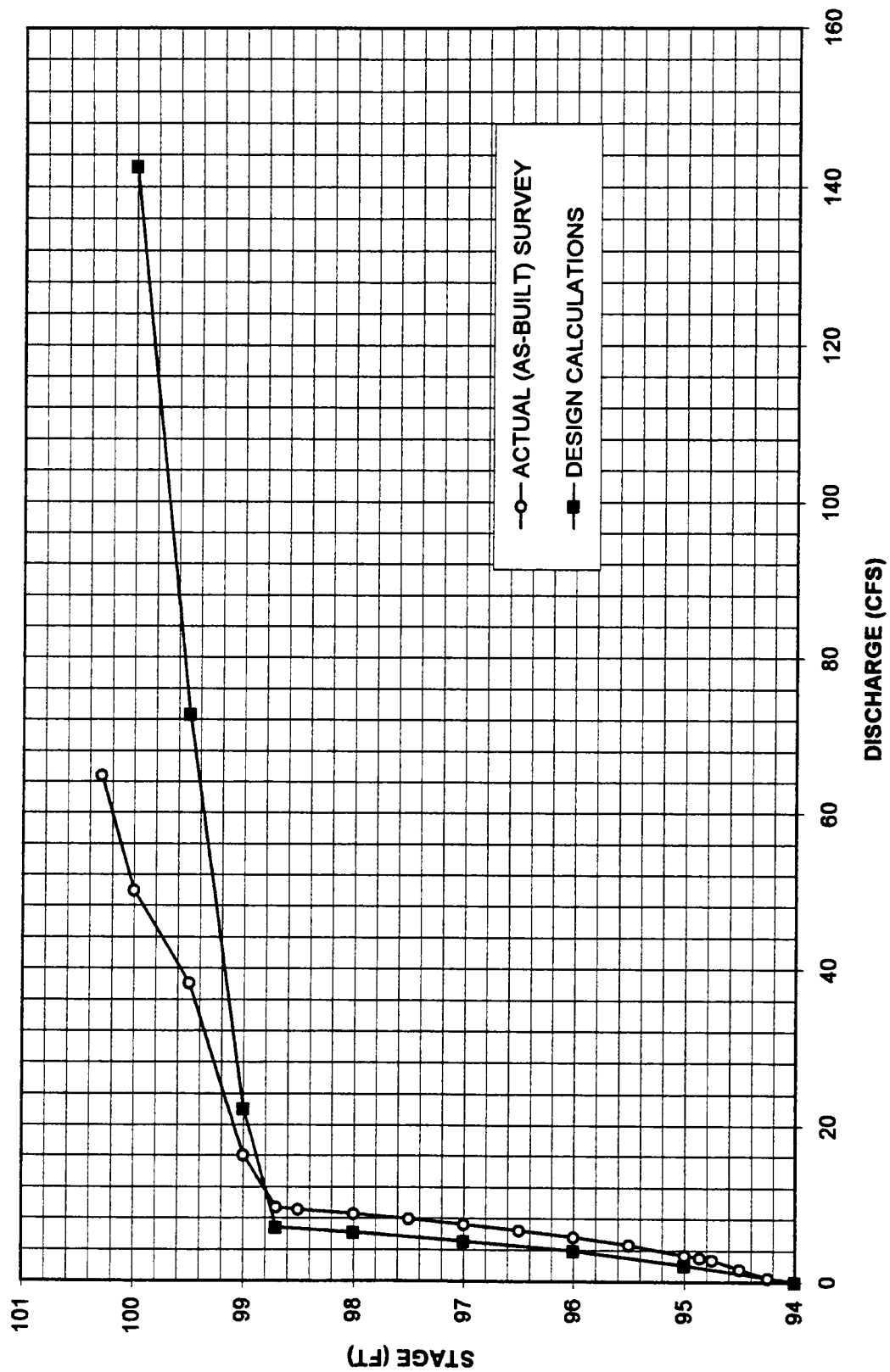




# A15.4 - POND 15 - STAGE vs. STORAGE



# A15.5 - POND 15 - STAGE vs. DISCHARGE





# A15.6 - POND 15 - INFLOW HYDROGRAPH

## TABULAR HYDROGRAPH METHOD

Version 2.00

Project : DETENTION POND ANALYSIS

User: TIR

Date: 04-09-97

County :

State: TN

Checked: \_\_\_\_\_

Date: \_\_\_\_\_

Subsite: POND 15

Total watershed area: 0.025 sq mi Rainfall type: II Frequency: Years  
----- Subareas -----

1  
Area(sq mi) 0.03  
Rainfall(in) 4.8  
Curve number 58  
Runoff(in) 1.06  
Tc (hrs) 0.10  
TimeToOutlet 0.00  
Ia/P 0.10

Time Total ----- Subarea Contribution to Total Flow (cfs) -----  
(hr) Flow 1

|      |     |     |
|------|-----|-----|
| 11.0 | 0   | 0   |
| 11.1 | 0   | 0   |
| 11.2 | 0   | 0   |
| 11.3 | 4   | 4   |
| 11.4 | 15  | 15  |
| 11.5 | 25P | 25P |
| 11.6 | 14  | 14  |
| 11.7 | 6   | 6   |
| 11.8 | 5   | 5   |
| 11.9 | 4   | 4   |
| 12.0 | 3   | 3   |
| 12.1 | 3   | 3   |
| 12.2 | 3   | 3   |
| 12.3 | 2   | 2   |
| 12.4 | 2   | 2   |
| 12.5 | 2   | 2   |
| 12.6 | 2   | 2   |
| 12.7 | 2   | 2   |
| 12.8 | 2   | 2   |
| 12.9 | 2   | 2   |
| 13.0 | 2   | 2   |
| 13.1 | 2   | 2   |
| 13.2 | 2   | 2   |
| 13.3 | 2   | 2   |
| 13.4 | 2   | 2   |
| 13.5 | 2   | 2   |
| 13.6 | 2   | 2   |
| 13.7 | 2   | 2   |
| 13.8 | 1   | 1   |
| 13.9 | 1   | 1   |
| 14.0 | 1   | 1   |
| 14.1 | 1   | 1   |
| 14.2 | 1   | 1   |
| 14.3 | 1   | 1   |
| 14.4 | 1   | 1   |
| 14.5 | 1   | 1   |
| 14.6 | 1   | 1   |
| 14.7 | 1   | 1   |
| 14.8 | 1   | 1   |
| 14.9 | 1   | 1   |
| 15.0 | 1   | 1   |
| 15.1 | 1   | 1   |
| 15.2 | 1   | 1   |
| 15.3 | 1   | 1   |
| 15.4 | 1   | 1   |
| 15.5 | 1   | 1   |
| 15.6 | 1   | 1   |
| 15.7 | 1   | 1   |
| 15.8 | 1   | 1   |
| 15.9 | 1   | 1   |
| 16.0 | 1   | 1   |
| 16.1 | 1   | 1   |
| 16.2 | 1   | 1   |
| 16.3 | 1   | 1   |
| 16.4 | 1   | 1   |
| 16.5 | 1   | 1   |
| 16.6 | 1   | 1   |
| 16.7 | 1   | 1   |
| 16.8 | 1   | 1   |
| 16.9 | 1   | 1   |
| 17.0 | 1   | 1   |
| 17.1 | 1   | 1   |
| 17.2 | 1   | 1   |
| 17.3 | 1   | 1   |
| 17.4 | 1   | 1   |
| 17.5 | 1   | 1   |
| 17.6 | 1   | 1   |
| 17.7 | 1   | 1   |
| 17.8 | 1   | 1   |
| 17.9 | 1   | 1   |
| 18.0 | 1   | 1   |
| 18.1 | 1   | 1   |
| 18.2 | 1   | 1   |
| 18.3 | 1   | 1   |
| 18.4 | 1   | 1   |
| 18.5 | 1   | 1   |
| 18.6 | 1   | 1   |
| 18.7 | 1   | 1   |
| 18.8 | 1   | 1   |
| 18.9 | 1   | 1   |
| 19.0 | 1   | 1   |
| 19.1 | 1   | 1   |
| 19.2 | 1   | 1   |
| 19.3 | 1   | 1   |
| 19.4 | 1   | 1   |
| 19.5 | 1   | 1   |
| 19.6 | 1   | 1   |
| 19.7 | 1   | 1   |
| 19.8 | 1   | 1   |
| 19.9 | 1   | 1   |
| 20.0 | 1   | 1   |
| 20.1 | 1   | 1   |
| 20.2 | 1   | 1   |
| 20.3 | 1   | 1   |
| 20.4 | 1   | 1   |
| 20.5 | 1   | 1   |
| 20.6 | 1   | 1   |
| 20.7 | 1   | 1   |
| 20.8 | 1   | 1   |
| 20.9 | 1   | 1   |
| 21.0 | 1   | 1   |
| 21.1 | 1   | 1   |
| 21.2 | 1   | 1   |
| 21.3 | 1   | 1   |
| 21.4 | 1   | 1   |
| 21.5 | 1   | 1   |
| 21.6 | 1   | 1   |
| 21.7 | 1   | 1   |
| 21.8 | 1   | 1   |
| 21.9 | 1   | 1   |
| 22.0 | 1   | 1   |
| 22.1 | 1   | 1   |
| 22.2 | 1   | 1   |
| 22.3 | 1   | 1   |
| 22.4 | 1   | 1   |
| 22.5 | 1   | 1   |
| 22.6 | 1   | 1   |
| 22.7 | 1   | 1   |
| 22.8 | 1   | 1   |
| 22.9 | 1   | 1   |
| 23.0 | 1   | 1   |
| 23.1 | 1   | 1   |
| 23.2 | 1   | 1   |
| 23.3 | 1   | 1   |
| 23.4 | 1   | 1   |
| 23.5 | 1   | 1   |
| 23.6 | 1   | 1   |
| 23.7 | 1   | 1   |
| 23.8 | 1   | 1   |
| 23.9 | 1   | 1   |
| 24.0 | 1   | 1   |
| 24.1 | 1   | 1   |
| 24.2 | 1   | 1   |
| 24.3 | 1   | 1   |
| 24.4 | 1   | 1   |
| 24.5 | 1   | 1   |
| 24.6 | 1   | 1   |
| 24.7 | 1   | 1   |
| 24.8 | 1   | 1   |
| 24.9 | 1   | 1   |
| 25.0 | 1   | 1   |
| 25.1 | 1   | 1   |
| 25.2 | 1   | 1   |
| 25.3 | 1   | 1   |
| 25.4 | 1   | 1   |
| 25.5 | 1   | 1   |
| 25.6 | 1   | 1   |
| 25.7 | 1   | 1   |
| 25.8 | 1   | 1   |
| 25.9 | 1   | 1   |
| 26.0 | 0   | 0   |

P - Peak Flow

```
ID
ID POND 15
ID
*FREE
IT 6 0 0 300
IN 6 0 0
IO 2 0 0
KK INFLOW HYDROGRAPH
KM 10 YEAR POST DEV
QI 0 0 1.33 2.67 4 15 25 14 6 5
QI 4 3 3 3 2.5 2 2 2 2 2
QI 2 2 2 2 1.5 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI 1 1 1 1 1 1 1 1 1 1
QI .875 .85 .825 .8 .775 .75 .725 .7 .675 .65
QI .625 .6 .575 .55 .525 .5 .475 .45 .425 .4
QI .375 .35 .325 .3 .275 .25 .225 .2 .175 .15
QI .125 .1 .075 .05 .025 0 0
KK POND 15
KM POND DATA
RS 1 ELEV 94
SV 0 .00005 .00009 .00014 .00016 .0002 .0009 .0016 .0098 .018
SV .043 .067 .109 .125 .15 .207 .264 .31
SQ 0 .5 1.6 2.8 3 3.4 4.6 5.7 6.5 7.3
SQ 7.9 8.6 9.2 9.4 16.1 38.1 50 64.8
SE 94 94.3 94.5 94.8 94.9 95 95.5 96 96.5 97
SE 97.5 98 98.5 98.7 99 99.5 100 100.3
ST 100.3 60 3.3 1.5
ZZ
```

## A15.8 - Pond 15 - HEC-1 SUMMARY OF RESULTS

### RUNOFF SUMMARY FLOW IN CUBIC FEET PER SECOND TIME IN HOURS, AREA IN SQUARE MILES

|   | OPERATION                                                                                                                            | STATION | PEAK<br>FLOW | TIME OF<br>PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD |         |         | BASIN<br>AREA | MAXIMUM<br>STAGE | TIME OF<br>MAX STAGE |
|---|--------------------------------------------------------------------------------------------------------------------------------------|---------|--------------|-----------------|---------------------------------|---------|---------|---------------|------------------|----------------------|
|   |                                                                                                                                      |         |              |                 | 6-HOUR                          | 24-HOUR | 72-HOUR |               |                  |                      |
| + | HYDROGRAPH AT<br>INFLOW                                                                                                              |         | 25.          | .60             | 2.                              | 1.      | 1.      | .00           |                  |                      |
| + | ROUTED TO<br>POND                                                                                                                    |         | 20.          | .70             | 2.                              | 1.      | 1.      | .00           |                  |                      |
| + |                                                                                                                                      |         |              |                 |                                 |         |         |               | 99.09            | .70                  |
| 1 | SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION POND<br>(PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION) |         |              |                 |                                 |         |         |               |                  |                      |

| PLAN 1 ..... | INITIAL VALUE | SPILLWAY CREST | TOP OF DAM |
|--------------|---------------|----------------|------------|
| ELEVATION    | 94.00         | 100.30         | 100.30     |
| STORAGE      | 0.            | 0.             | 0.         |
| OUTFLOW      | 0.            | 65.            | 65.        |

| RATIO<br>OF<br>PMF | MAXIMUM<br>RESERVOIR<br>W.S.ELEV | MAXIMUM<br>DEPTH<br>OVER DAM | MAXIMUM<br>STORAGE<br>AC-FT | MAXIMUM<br>OUTFLOW<br>CFS | DURATION<br>OVER TOP<br>HOURS | TIME OF<br>MAX OUTFLOW<br>HOURS | TIME OF<br>FAILURE<br>HOURS |
|--------------------|----------------------------------|------------------------------|-----------------------------|---------------------------|-------------------------------|---------------------------------|-----------------------------|
| 1.00               | 99.09                            | .00                          | 0.                          | 20.                       | .00                           | .70                             | .00                         |

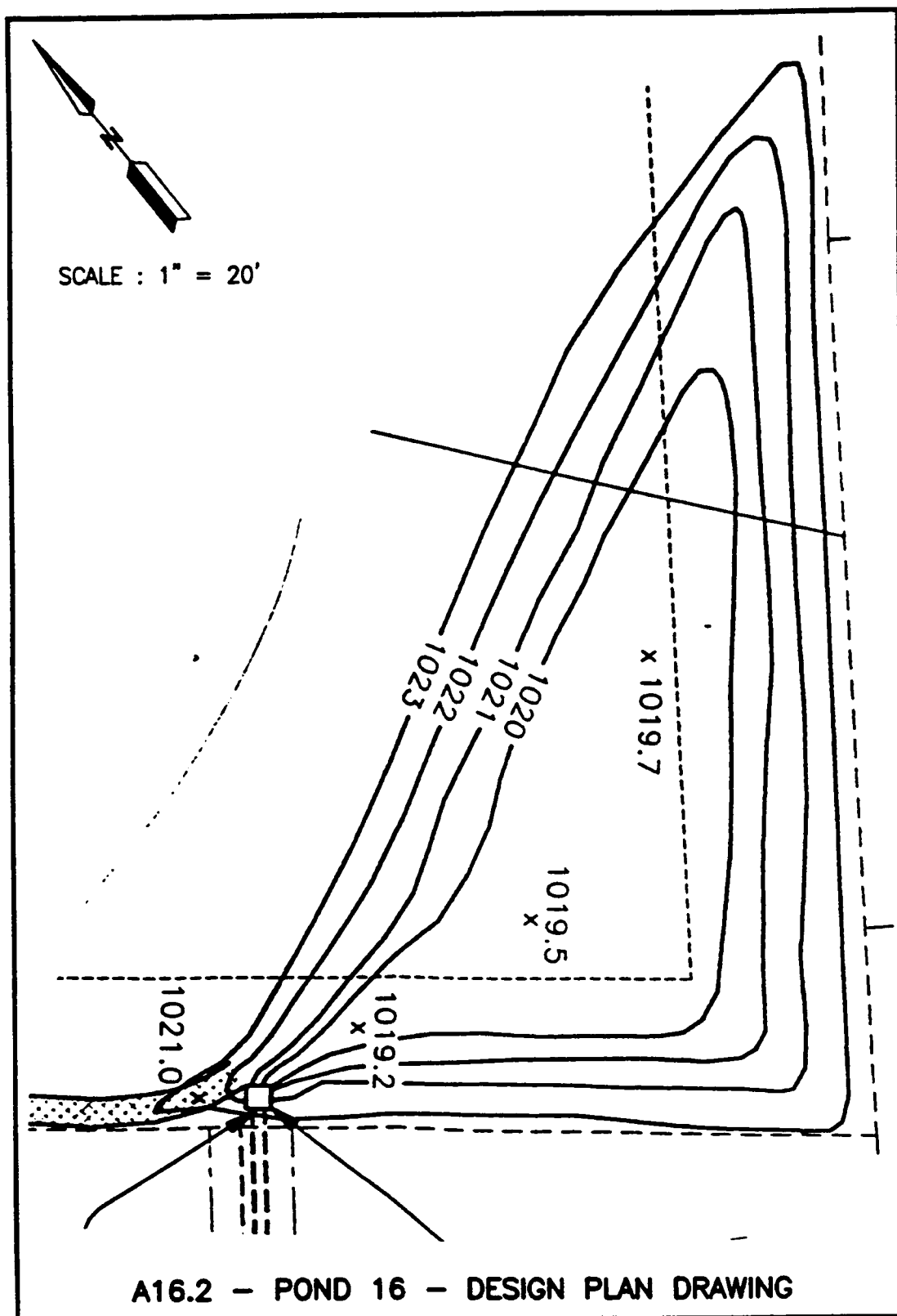
\*\*\* NORMAL END OF HEC-1 \*\*\*

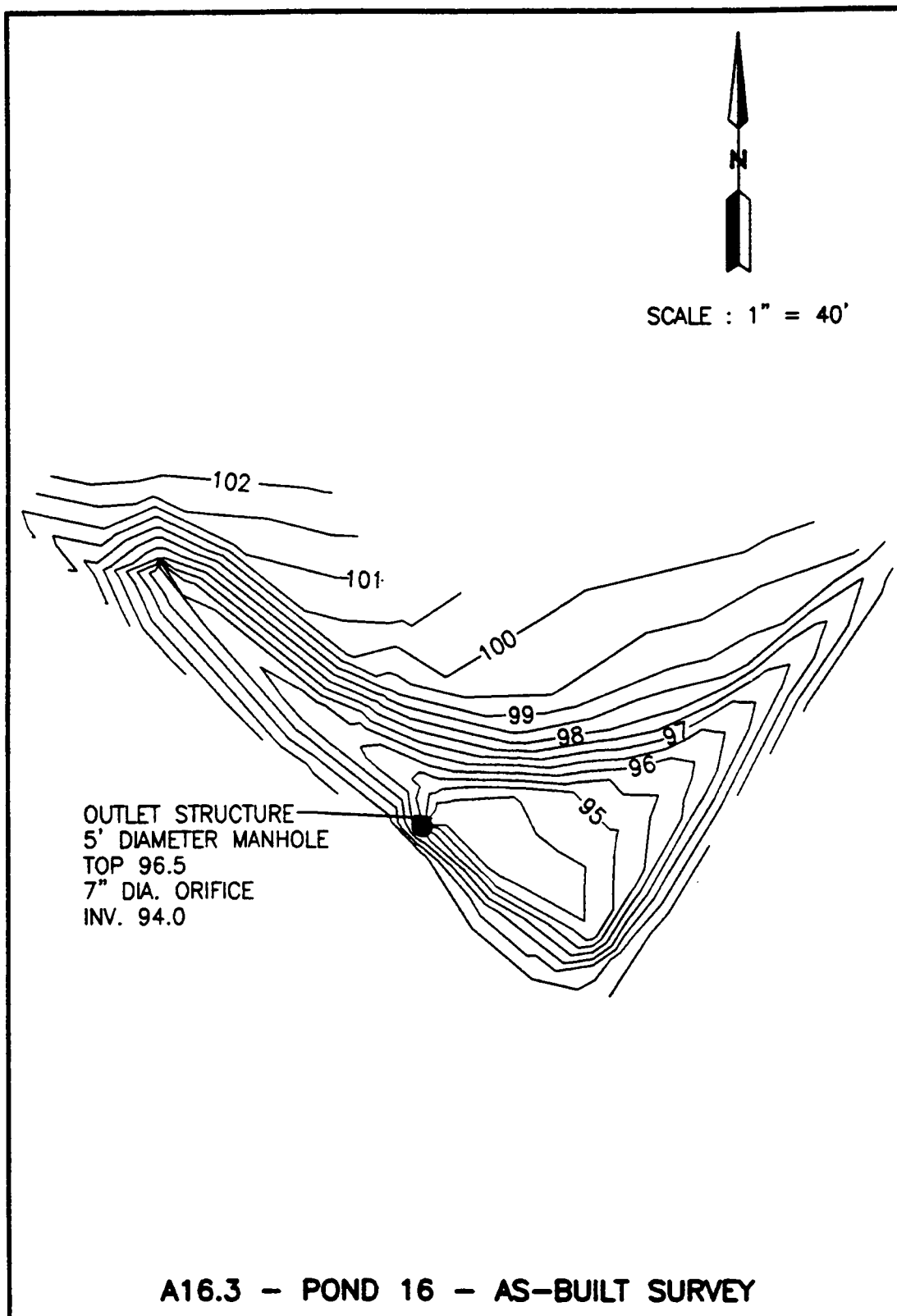


A16.1a - The outlet structure is a 60-in. diameter manhole with a grate on top. The manhole is 2.5 ft. high and has a 7-in. diameter orifice at the bottom. The outlet structure is 1 ft. lower than designed.

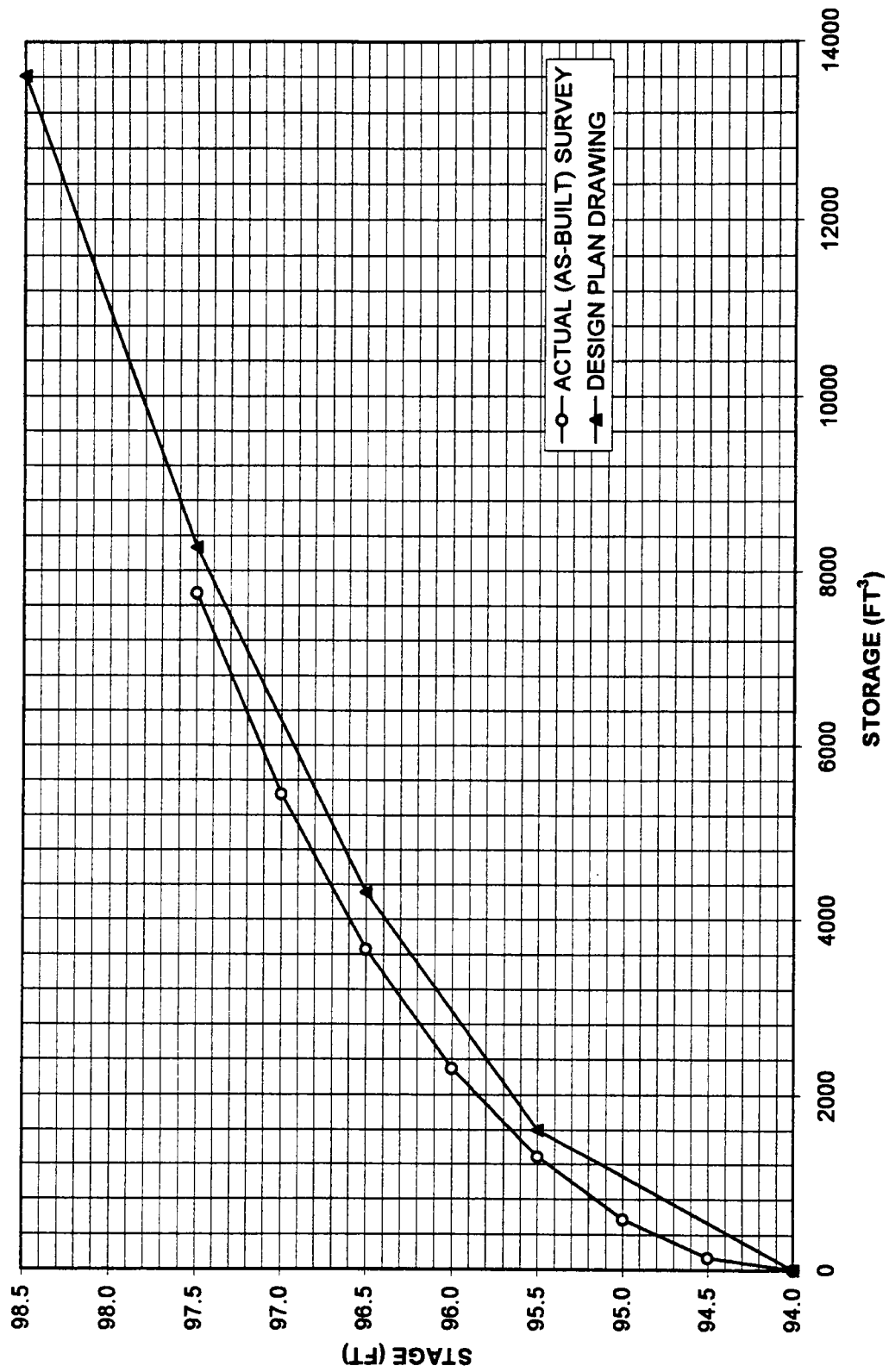


A16.1b - The pond is built to the design drawing plan, but the storage volume at the design depth of 1.3 ft. is only 0.03 ac.-ft., and the design calculations require 0.12 ac.-ft. at the design depth. The design drawing plan does not support the design calculations. The net result is the pond is discharging 1.7 times more than intended during the design storm.

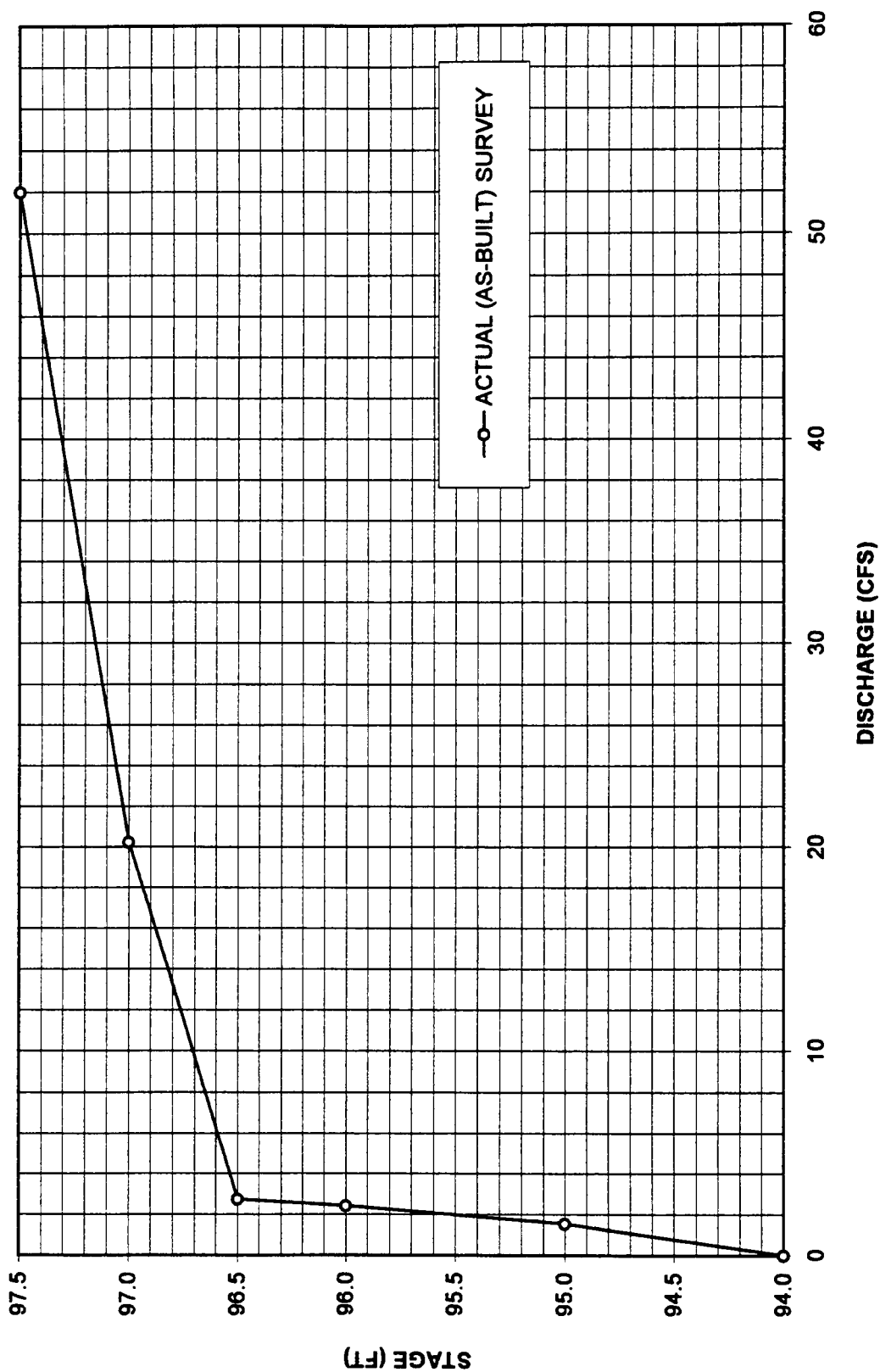




# A16.4 - POND 16 - STAGE vs. STORAGE



# A16.5 - POND 16 - STAGE vs. DISCHARGE





# A16.6 - POND 16 - INFLOW HYDROGRAPH

Table Two: Detention Pond Design Analysis - Drainage Area One  
Subdivision

March 1996

Detention Pond Size (acres) 6  
Detention Pond Length (feet) 2  
Pipe drop over length (feet) 0.1  
Manning's "n" for pipe material 0.015  
Minimum Tailwater Depth 0  
Current Inflow Duration (MFL) 104.20

| Time   | INFLOW DATA                      |                           | INFLOW DATA             |                                 | RECEPTION SURFACE DATA          |                                 | RECEPTION SURFACE DATA                            |                           | RECEPTION SURFACE DATA                            |                           | RECEPTION SURFACE DATA                            |                           |
|--------|----------------------------------|---------------------------|-------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------------------------|---------------------------|---------------------------------------------------|---------------------------|---------------------------------------------------|---------------------------|
|        | Peak<br>Intensity<br>(inches/hr) | Peak<br>Duration<br>(min) | Inflow<br>Rate<br>(cfs) | Peak<br>Inflow<br>Rate<br>(cfs) | Volume<br>to<br>Pond<br>(cu ft) | Volume<br>to<br>Pond<br>(cu ft) | Duration of<br>Flow Above<br>Pipe Bottom<br>(sec) | Flow<br>Volume<br>(cu ft) | Duration of<br>Flow Above<br>Pipe Bottom<br>(sec) | Flow<br>Volume<br>(cu ft) | Duration of<br>Flow Above<br>Pipe Bottom<br>(sec) | Flow<br>Volume<br>(cu ft) |
| 0 Min  | 0.00                             | 1.0                       | 0.00                    | 0.00                            | 0.00                            | 0.00                            | 0                                                 | 0.00                      | 0.00                                              | 0.00                      | 0.00                                              | 0.00                      |
| 1 Min  | 0.02                             | 1.0                       | 0.02                    | 0.02                            | 2                               | 2                               | 0.01                                              | 44                        | 104.20                                            | 0.02                      | 0.02                                              | 7                         |
| 2 Min  | 0.04                             | 1.0                       | 0.04                    | 0.04                            | 14                              | 14                              | 0.02                                              | 146                       | 104.20                                            | 0.04                      | 0.04                                              | 21                        |
| 3 Min  | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 22                              | 22                              | 0.03                                              | 236                       | 104.20                                            | 0.05                      | 0.05                                              | 33                        |
| 4 Min  | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 27                              | 27                              | 0.03                                              | 285                       | 104.20                                            | 0.05                      | 0.05                                              | 45                        |
| 5 Min  | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 31                              | 31                              | 0.03                                              | 334                       | 104.20                                            | 0.05                      | 0.05                                              | 57                        |
| 6 Min  | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 34                              | 34                              | 0.03                                              | 378                       | 104.20                                            | 0.05                      | 0.05                                              | 69                        |
| 7 Min  | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 36                              | 36                              | 0.03                                              | 417                       | 104.20                                            | 0.05                      | 0.05                                              | 81                        |
| 8 Min  | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 38                              | 38                              | 0.03                                              | 451                       | 104.20                                            | 0.05                      | 0.05                                              | 93                        |
| 9 Min  | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 39                              | 39                              | 0.03                                              | 479                       | 104.20                                            | 0.05                      | 0.05                                              | 105                       |
| 10 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 40                              | 40                              | 0.03                                              | 502                       | 104.20                                            | 0.05                      | 0.05                                              | 117                       |
| 11 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 519                       | 104.20                                            | 0.05                      | 0.05                                              | 129                       |
| 12 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 531                       | 104.20                                            | 0.05                      | 0.05                                              | 141                       |
| 13 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 538                       | 104.20                                            | 0.05                      | 0.05                                              | 153                       |
| 14 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 541                       | 104.20                                            | 0.05                      | 0.05                                              | 165                       |
| 15 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 541                       | 104.20                                            | 0.05                      | 0.05                                              | 177                       |
| 16 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 538                       | 104.20                                            | 0.05                      | 0.05                                              | 189                       |
| 17 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 531                       | 104.20                                            | 0.05                      | 0.05                                              | 201                       |
| 18 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 519                       | 104.20                                            | 0.05                      | 0.05                                              | 213                       |
| 19 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 502                       | 104.20                                            | 0.05                      | 0.05                                              | 225                       |
| 20 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 479                       | 104.20                                            | 0.05                      | 0.05                                              | 237                       |
| 21 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 451                       | 104.20                                            | 0.05                      | 0.05                                              | 249                       |
| 22 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 417                       | 104.20                                            | 0.05                      | 0.05                                              | 261                       |
| 23 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 378                       | 104.20                                            | 0.05                      | 0.05                                              | 273                       |
| 24 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 334                       | 104.20                                            | 0.05                      | 0.05                                              | 285                       |
| 25 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 285                       | 104.20                                            | 0.05                      | 0.05                                              | 297                       |
| 26 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 236                       | 104.20                                            | 0.05                      | 0.05                                              | 309                       |
| 27 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 185                       | 104.20                                            | 0.05                      | 0.05                                              | 321                       |
| 28 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 146                       | 104.20                                            | 0.05                      | 0.05                                              | 333                       |
| 29 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 117                       | 104.20                                            | 0.05                      | 0.05                                              | 345                       |
| 30 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 88                        | 104.20                                            | 0.05                      | 0.05                                              | 357                       |
| 31 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 59                        | 104.20                                            | 0.05                      | 0.05                                              | 369                       |
| 32 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 30                        | 104.20                                            | 0.05                      | 0.05                                              | 381                       |
| 33 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 1                         | 104.20                                            | 0.05                      | 0.05                                              | 393                       |
| 34 Min | 0.05                             | 1.0                       | 0.05                    | 0.05                            | 41                              | 41                              | 0.03                                              | 0                         | 104.20                                            | 0.05                      | 0.05                                              | 405                       |

Note: • Time of concentration for the basin is approx. 7 minutes  
• Basin area = 2.88 acres, runoff coeff. = 0.31  
• Rainfall intensity data per IDF Curve Knoxville, Tennessee (1903-1991)  
• Assume a 0' tailwater depth (under control)

A16.7 - POND 16 - HEC-1 INPUT FILE

ID  
ID POND 16  
ID  
\*FREE  
IT 6 0 0 300  
IN 6 0 0  
IO 2 0 0  
KK INFLOW HYDROGRAPH  
KM 25 YEAR POST DEV  
QI 0 .3 .328 .356 .384 .412 .44 .552 .664 .776  
QI .888 1 1.31 1.63 1.94 2.26 2.57 6.24 9.72 7.44  
QI 3.43 3.00 2.58 2.16 1.74 1.32 .89 .80 .71 .614  
QI .522 .43 .39 .35 .31 .27 .23 .223 .216 .209  
QI .202 .195 .188 .181 .174 .167 .16 .128 .096 .064  
QI .032 0  
KK POND 16  
KM POND DATA  
RS 1 ELEV 94  
SV 0 .013 .0536 .084 .125 .18  
SQ 0 1.6 2.4 2.7 20.3 52  
SE 94 95 96 96.5 97 97.5  
ST 97.5 20 3.33 1.5  
ZZ

## A16.8 - Pond 16 - HEC-1 SUMMARY OF RESULTS

### RUNOFF SUMMARY FLOW IN CUBIC FEET PER SECOND TIME IN HOURS, AREA IN SQUARE MILES

|   | OPERATION     | STATION | PEAK<br>FLOW | TIME OF<br>PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD |         |         | BASIN<br>AREA | MAXIMUM<br>STAGE | TIME OF<br>MAX STAGE |
|---|---------------|---------|--------------|-----------------|---------------------------------|---------|---------|---------------|------------------|----------------------|
|   |               |         |              |                 | 6-HOUR                          | 24-HOUR | 72-HOUR |               |                  |                      |
| + | HYDROGRAPH AT |         |              |                 |                                 |         |         |               |                  |                      |
| + | INFLOW        |         | 10.          | 1.80            | 1.                              | 0.      | 0.      | .00           |                  |                      |
| + | ROUTED TO     |         |              |                 |                                 |         |         |               |                  |                      |
| + | POND          |         | 10.          | 1.90            | 1.                              | 0.      | 0.      | .00           |                  |                      |
| 1 |               |         |              |                 |                                 |         |         |               | 96.71            | 1.90                 |

SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION POND  
(PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION)

|              |                    |                                  |                              |                             |                           |                               |                                 |                             |
|--------------|--------------------|----------------------------------|------------------------------|-----------------------------|---------------------------|-------------------------------|---------------------------------|-----------------------------|
| PLAN 1 ..... | INITIAL VALUE      |                                  | SPILLWAY CREST               |                             | TOP OF DAM                |                               |                                 |                             |
|              | ELEVATION          | 94.00                            |                              | 97.50                       |                           | 97.50                         |                                 |                             |
|              | STORAGE            | 0.                               |                              | 0.                          |                           | 0.                            |                                 |                             |
|              | OUTFLOW            | 0.                               |                              | 52.                         |                           | 52.0                          |                                 |                             |
|              | RATIO<br>OF<br>PMF | MAXIMUM<br>RESERVOIR<br>W.S.ELEV | MAXIMUM<br>DEPTH<br>OVER DAM | MAXIMUM<br>STORAGE<br>AC-FT | MAXIMUM<br>OUTFLOW<br>CFS | DURATION<br>OVER TOP<br>HOURS | TIME OF<br>MAX OUTFLOW<br>HOURS | TIME OF<br>FAILURE<br>HOURS |
|              | 1.00               | 96.71                            | .00                          | 0.                          | 10.                       | .00                           | 1.90                            | .00                         |

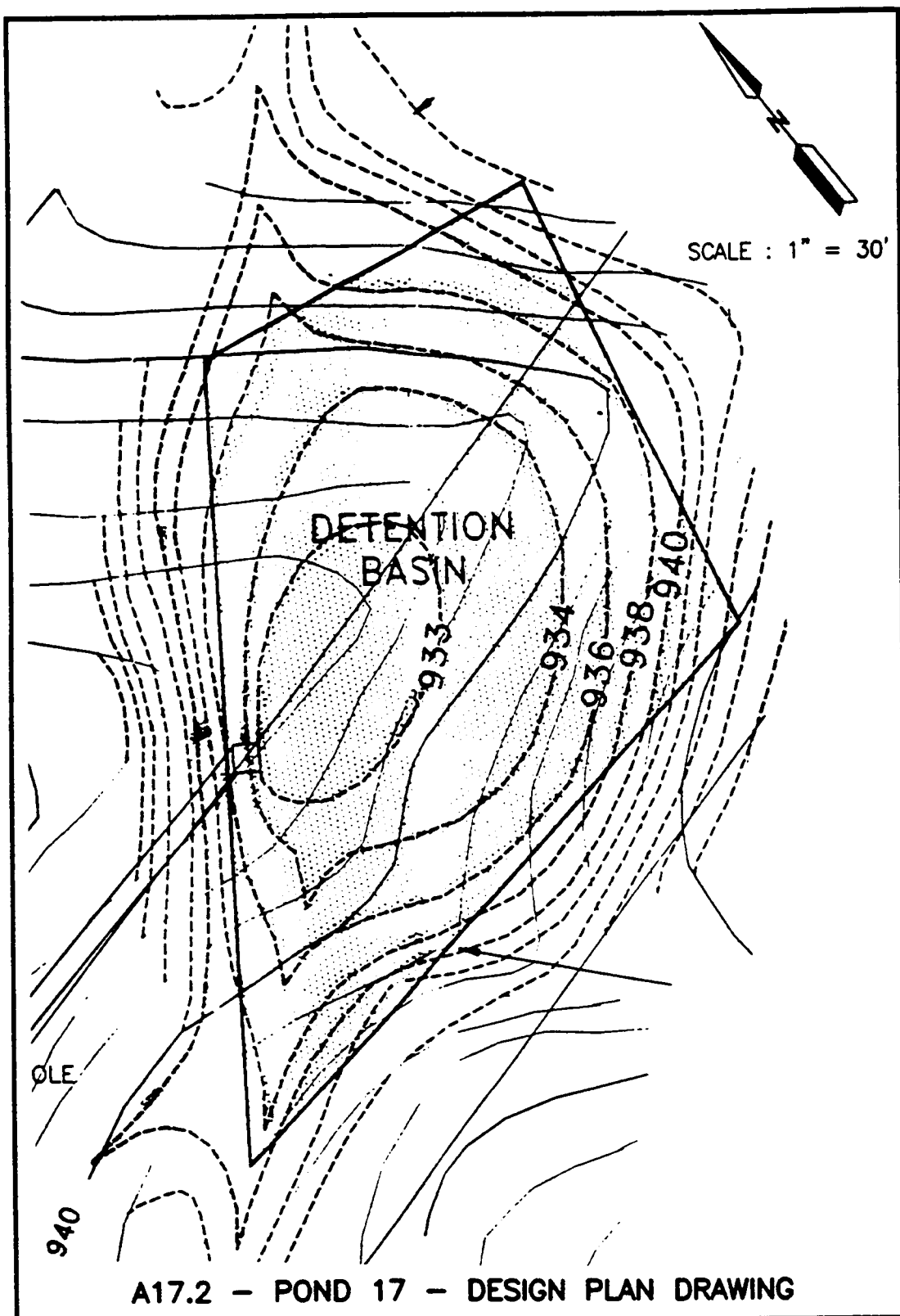
\*\*\* NORMAL END OF HEC-1 \*\*\*

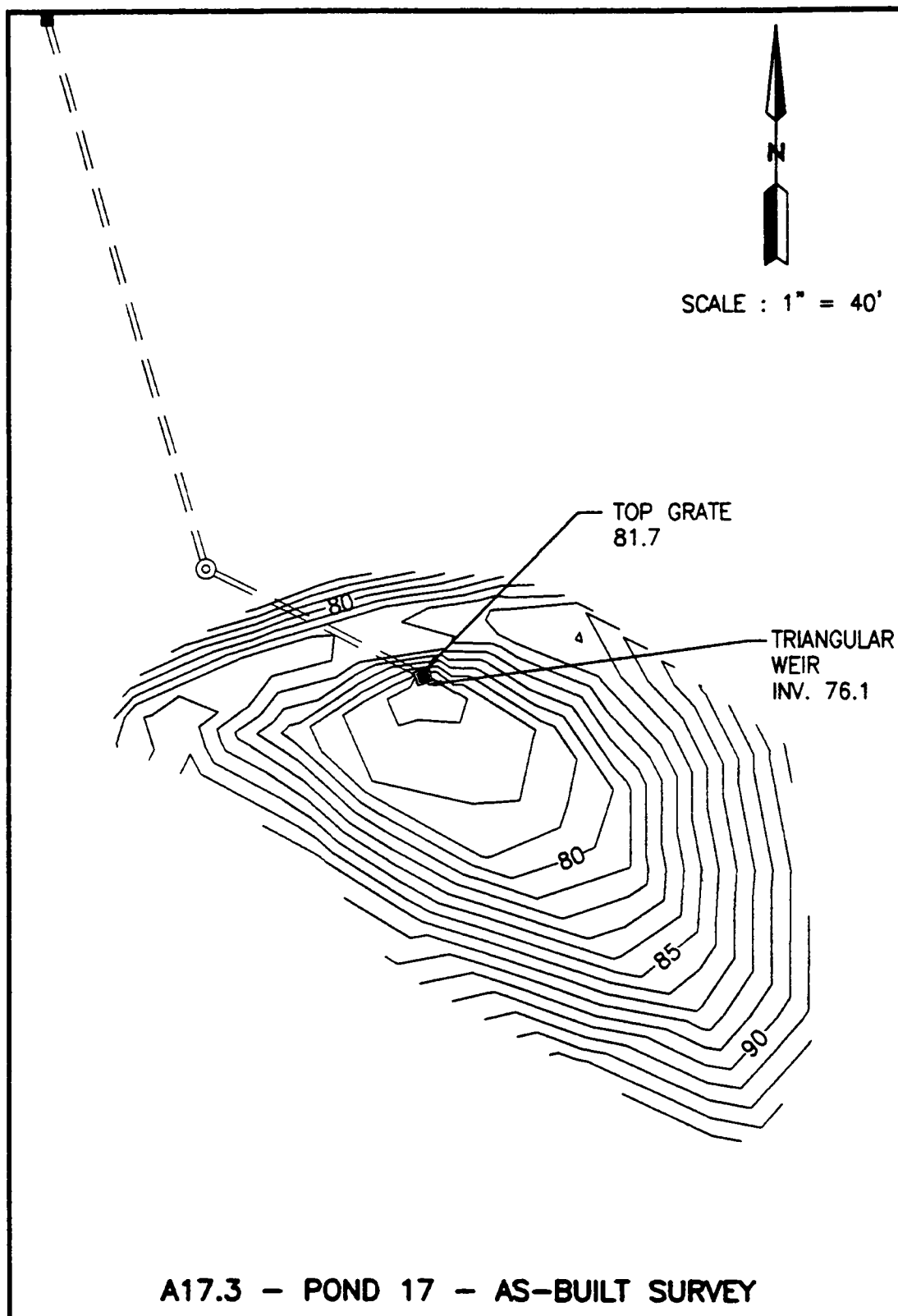


A17.1a - This photograph shows the overall outlet structure and dam. The outlet structure is 0.9 ft. lower than designed. The dam is 0.6 ft. lower than the design plan drawing indicates and is 0.4 ft. higher than the design calculations indicate.

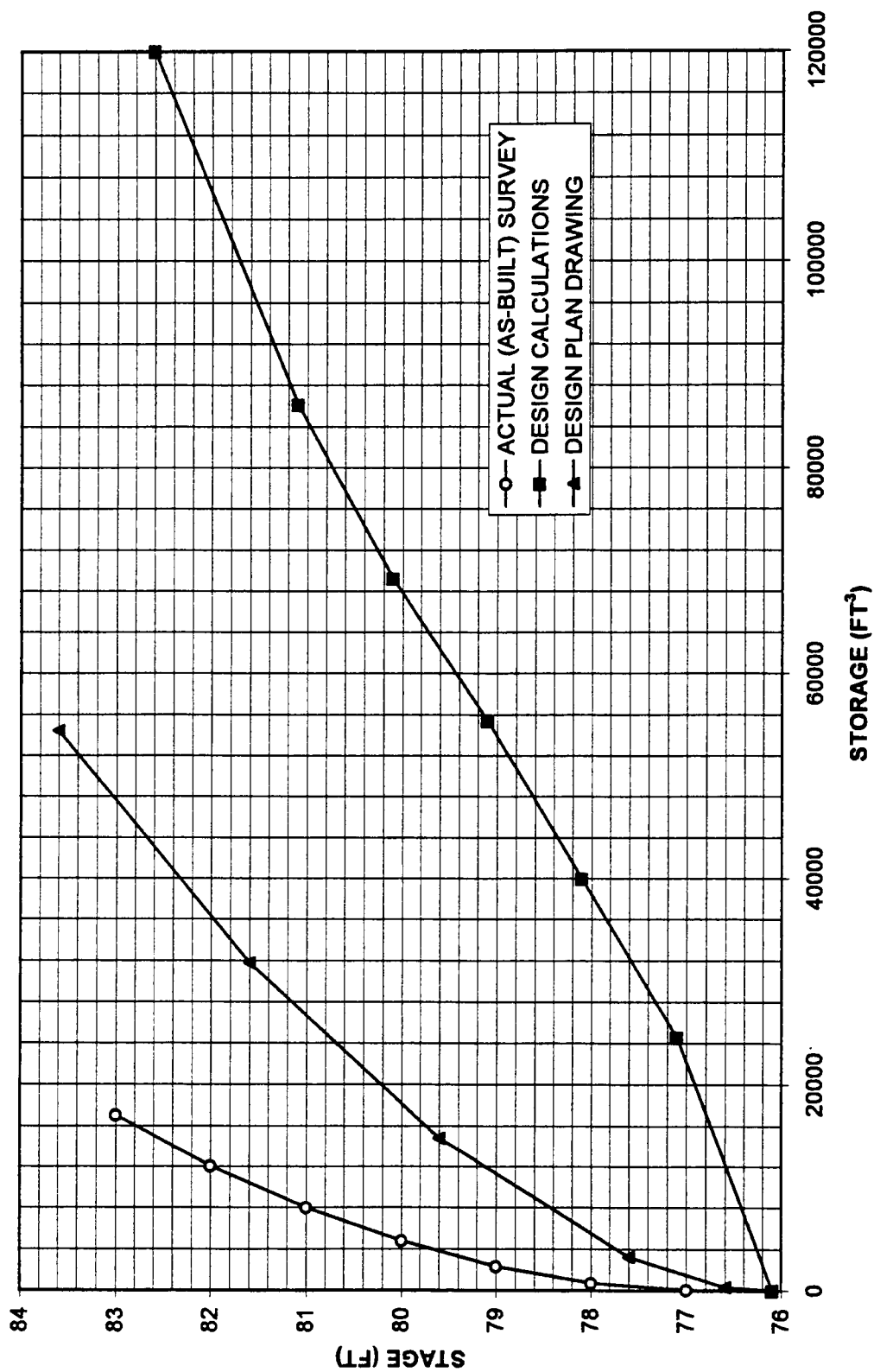


A17.1b - The actual storage volume at any given depth is less than the storage volume as represented by the design plan drawing and shown in the the design calculations. The design plan drawing storage volume at any given depth is less than the storage volume shown in the design calculations. The net result of inadequate storage is that the pre-development peak flow is being exceeded for the design storm.

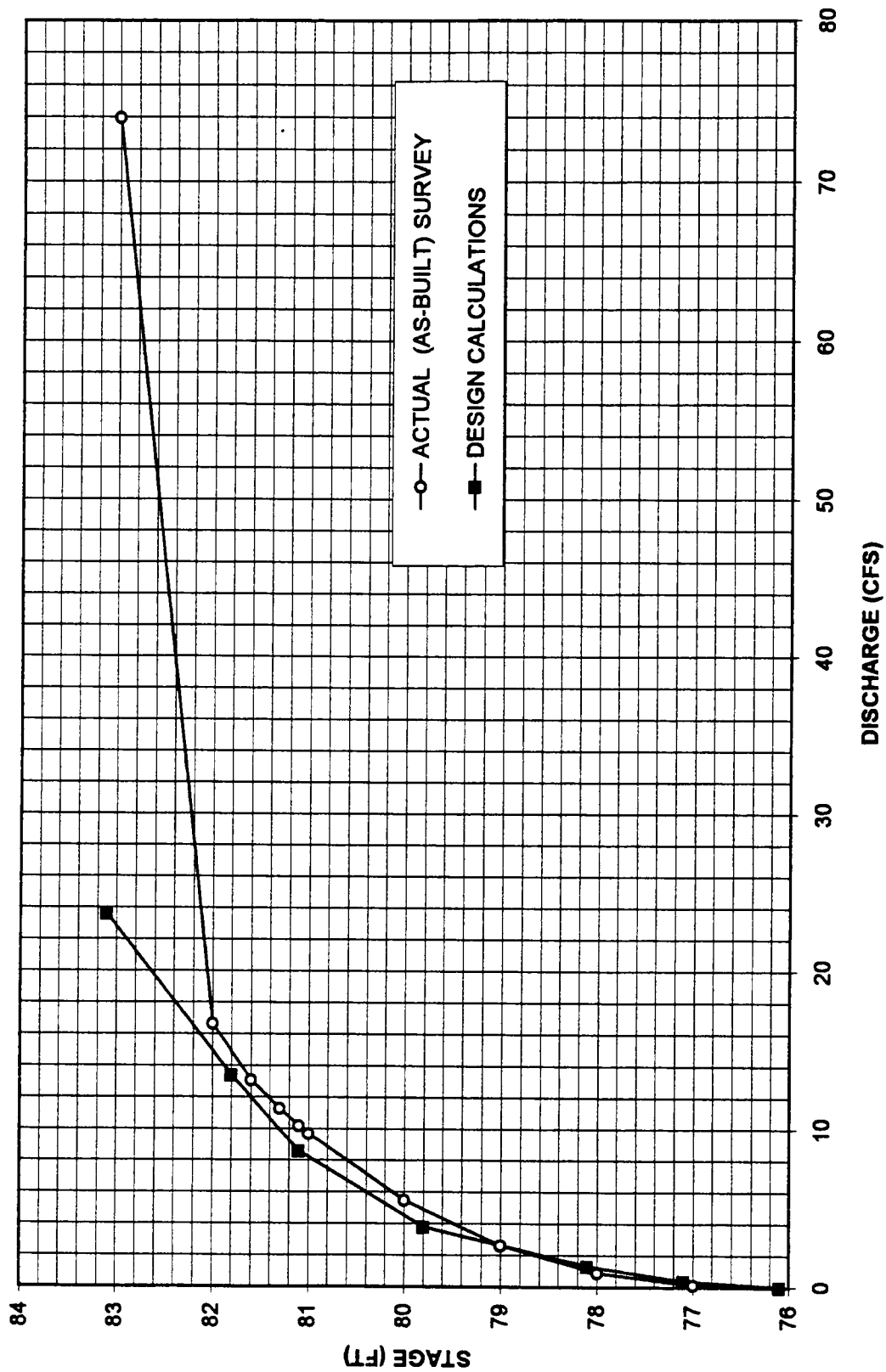




# A17.4 - POND 17 - STAGE vs. STORAGE



# A17.5 - POND 17 - STAGE vs. DISCHARGE





### A17.6 - POND 17 - INFLOW HYDROGRAPH

Table 7: Damaged Road Damage Analysis -  
November 1976

Damage = (Length x Width) x Depth  
Then = Damage x C<sub>d</sub> = C<sub>d</sub>

Routing of the -year / 24-hour Storm Run through the  
Proposed -year Pre- vs. -year Post-Development Drainage System

Damage Pre = 17 CDF  
Damage Post = see column  
Percent Damage Ratio

0.00  
0

| UNPAVED Road |               | PAVED Road   |                |              |                | ESTIMATED DAMAGE |                |              |                | UNPAVED Road  |              |                |
|--------------|---------------|--------------|----------------|--------------|----------------|------------------|----------------|--------------|----------------|---------------|--------------|----------------|
| Run          | Length (feet) | Width (feet) | Depth (inches) | Area (sq ft) | Volume (cu ft) | Area (sq ft)     | Volume (cu ft) | Area (sq ft) | Volume (cu ft) | Length (feet) | Width (feet) | Depth (inches) |
| 0.00         | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 1.00         | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 2.00         | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 3.00         | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 4.00         | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 5.00         | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 6.00         | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 7.00         | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 8.00         | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 9.00         | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 10.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 11.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 12.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 13.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 14.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 15.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 16.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 17.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 18.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 19.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 20.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 21.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 22.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 23.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 24.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 25.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 26.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 27.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 28.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 29.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 30.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 31.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 32.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 33.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 34.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 35.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 36.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 37.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 38.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 39.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 40.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 41.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 42.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 43.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 44.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 45.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 46.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 47.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 48.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 49.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 50.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 51.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 52.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 53.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 54.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 55.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 56.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 57.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 58.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 59.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 60.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 61.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 62.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 63.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 64.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 65.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 66.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 67.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 68.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 69.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 70.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 71.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 72.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 73.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 74.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 75.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 76.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 77.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 78.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 79.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 80.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 81.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 82.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 83.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 84.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 85.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 86.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 87.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 88.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 89.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 90.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 91.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 92.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 93.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 94.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
| 95.00        | 0.00          | 0.00         | 0.00           | 0.00         | 0.00           | 0.00             | 0.00           | 0.00         | 0.00           | 0.00          | 0.00         | 0.00           |
|              |               |              |                |              |                |                  |                |              |                |               |              |                |

**RESULT:** YR Pre-Development Flow = 11.6 CFS vs. 11.89 CFS . YR Post-Development OKAY

A17.7 - POND 17 - HEC-1 INPUT FILE

ID  
ID POND 17  
ID  
\*FREE  
IT 6 0 0 300  
IN 6 0 0  
IO 2 0 0  
KK INFLOW HYDROGRAPH  
KM 100 YEAR POST DEV  
QI 0 0 .87 .91 .94 .98 1.02 1.06 1.09 1.13  
QI 1.17 1.20 1.24 1.36 1.49 1.61 1.74 1.86 1.92 1.98  
QI 2.04 2.11 2.17 2.36 2.54 2.7 2.9 3.1 3.5 3.8  
QI 4.2 4.6 5 12.4 17.3 22.3 31 52.6 31.6 24.8  
QI 14.9 9.97 5.1 4.8 4.5 4.2 4.0 3.7 3.3 2.9  
QI 2.5 2.1 1.7 1.7 1.6 1.5 1.5 1.4 1.35 1.3  
QI 1.2 1.2 1.1 1.1 1.1 1.0 1.0 1 1 .9  
QI .9 .9 .9 .8 .8 .8 .8 .8 .8 .7  
QI .7 .7 .7 .7 .7 .6 .6 .6 .6 .6  
QI .6 .6 .6 .6 .5 .5 .5 .5 .5 .5  
QI .5 .5 .5 0 0  
KK POND 17  
KM POND DATA  
RS 1 ELEV 76.1  
SV 0 0.0017 0.0165 0.0533 0.109 0.184 0.193 0.212 0.24 0.28  
SV 0.39  
SQ 0 0.1 0.9 2.5 5.2 9.2 9.7 10.8 12.4 15.9  
SQ 73  
SE 76.1 77 78 79 80 81 81.1 81.3 81.6 82  
SE 83  
ST 83 30 3.33 1.5  
ZZ

## A17.8 - Pond 17 - HEC-1 SUMMARY OF RESULTS

### RUNOFF SUMMARY FLOW IN CUBIC FEET PER SECOND TIME IN HOURS, AREA IN SQUARE MILES

|   | OPERATION               | STATION | PEAK<br>FLOW | TIME OF<br>PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD |         |         | BASIN<br>AREA | MAXIMUM<br>STAGE | TIME OF<br>MAX STAGE |
|---|-------------------------|---------|--------------|-----------------|---------------------------------|---------|---------|---------------|------------------|----------------------|
|   |                         |         |              |                 | 6-HOUR                          | 24-HOUR | 72-HOUR |               |                  |                      |
| + | HYDROGRAPH AT<br>INFLOW |         | 53.          | 3.70            | 6.                              | 2.      | 2.      | .00           |                  |                      |
| + | ROUTED TO<br>POND       |         | 47.          | 3.7             | 6.                              | 2.      | 2.      | .00           |                  |                      |
| + |                         |         |              |                 |                                 |         |         |               | 82.54            | 3.70                 |

SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION POND  
(PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION)

|              |               |                |            |
|--------------|---------------|----------------|------------|
| PLAN 1 ..... | INITIAL VALUE | SPILLWAY CREST | TOP OF DAM |
| ELEVATION    | 78.10         | 83.00          | 83.00      |
| STORAGE      | 0.            | 0.             | 0.         |
| OUTFLOW      | 0.            | 73.            | 73.0       |

| RATIO<br>OF<br>PMF | MAXIMUM<br>RESERVOIR<br>W.S.ELEV | MAXIMUM<br>DEPTH<br>OVER DAM | MAXIMUM<br>STORAGE<br>AC-FT | MAXIMUM<br>OUTFLOW<br>CFS | DURATION<br>OVER TOP<br>HOURS | TIME OF<br>MAX OUTFLOW<br>HOURS | TIME OF<br>FAILURE<br>HOURS |
|--------------------|----------------------------------|------------------------------|-----------------------------|---------------------------|-------------------------------|---------------------------------|-----------------------------|
| 1.00               | 82.54                            | .00                          | 0.                          | 47.                       | .00                           | 3.70                            | .00                         |

\*\*\* NORMAL END OF HEC-1 \*\*\*



A18.1a - The outlet structure is an 18-in. riser having a 6-in. diameter orifice face plate on the upstream end, an anti-vortex device, and a trash rack.

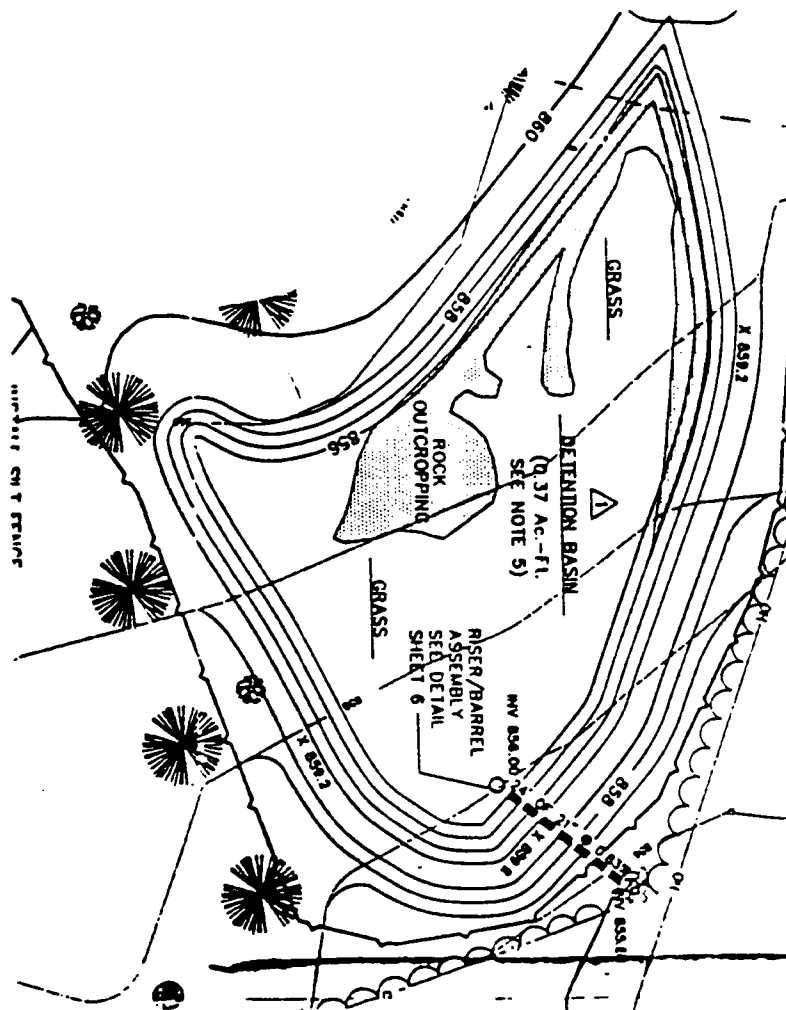
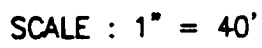


A18.1b - The side view of the outlet structure.

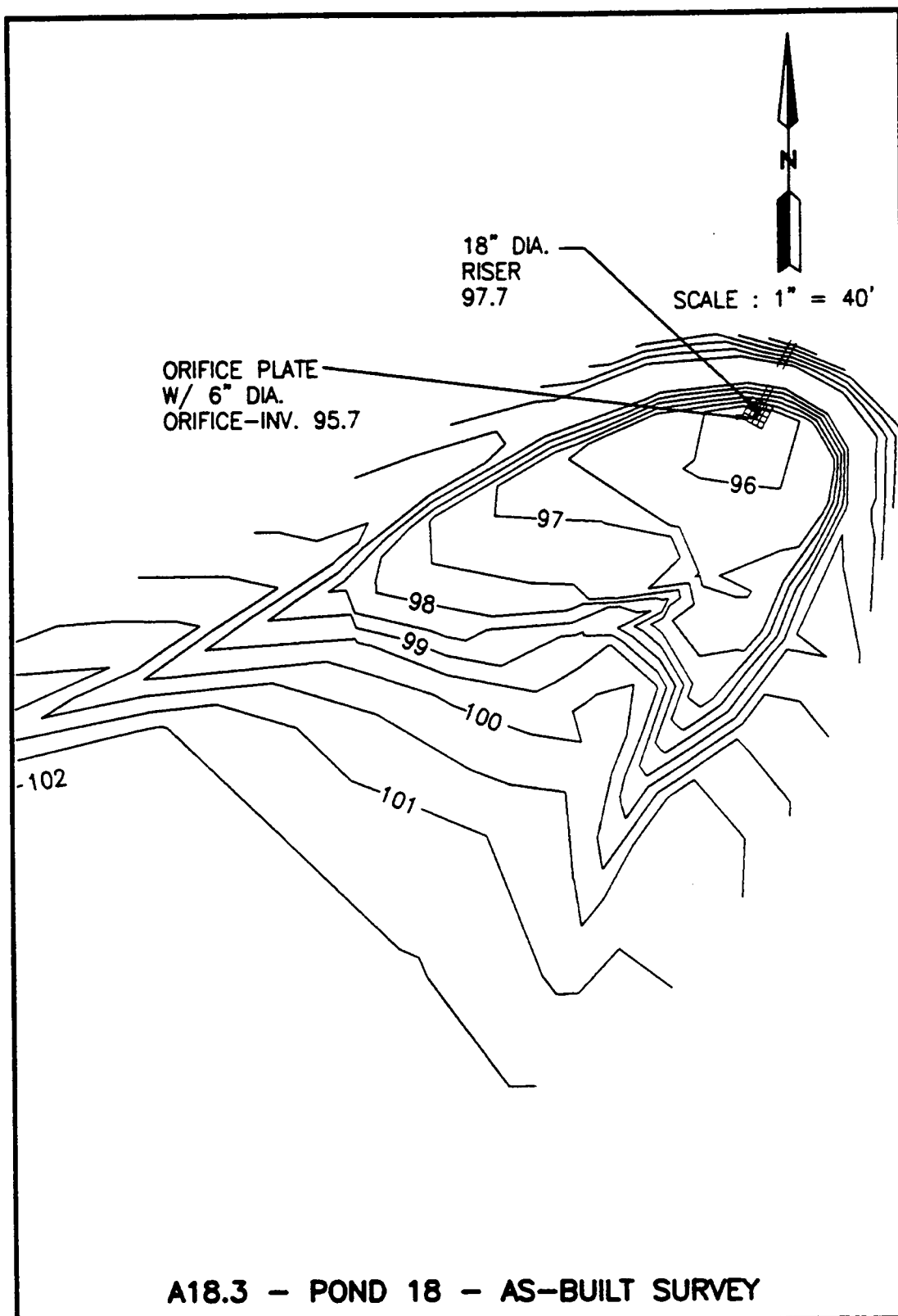


A18.1c - The pond is designed to have 0.43 ac.-ft. of storage volume, but because of bedrock in the bottom of the pond the actual volume is 0.11 ac.-ft. The inadequate storage volume causes a higher water depth during the design storm and the water spills over into the riser, thus exceeding the pre-development flow by a factor of two.

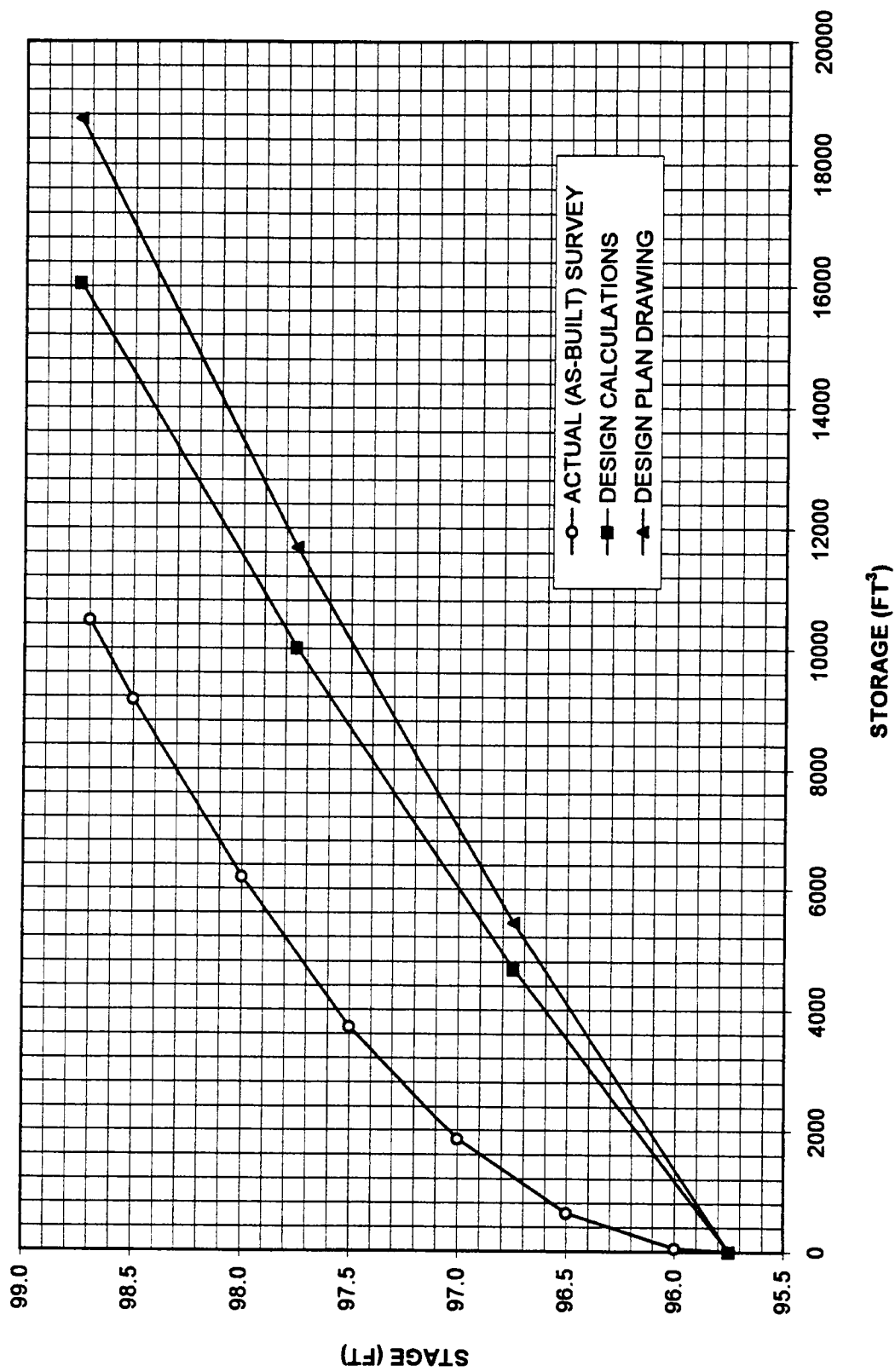




## A18.2 - POND 18 - DESIGN PLAN DRAWING

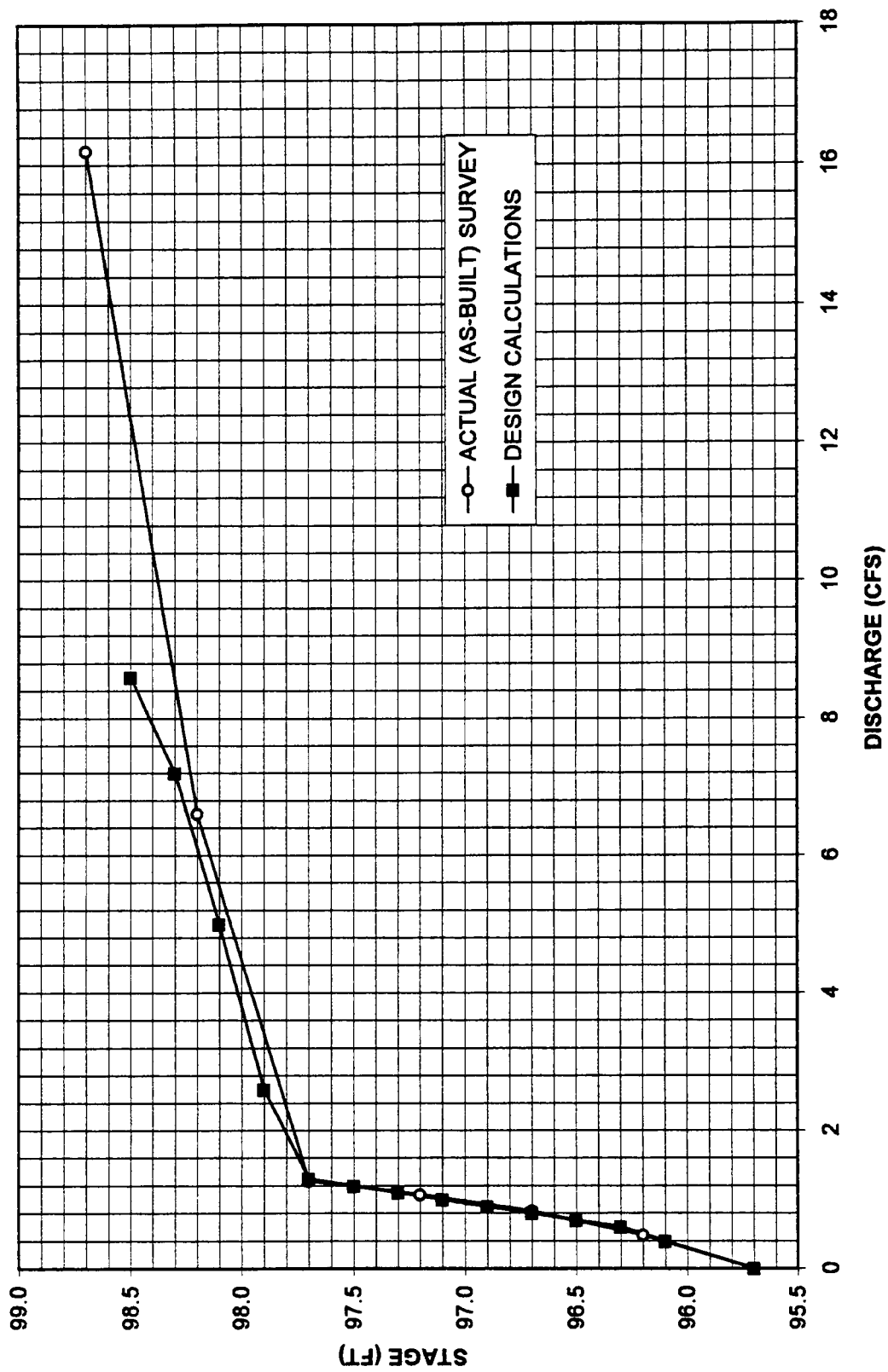


# A18.4 - POND 18 - STAGE vs. STORAGE





# A18.5 - POND 18 - STAGE vs. DISCHARGE



# A18.6 - POND 18 - INFLOW HYDROGRAPH

## TABULAR HYDROGRAPH METHOD

Version 2.00

Project : DETENTION POND ANALYSIS      User: TER      Date: 84-09-97  
 County :      State: TX      Checked:      Date:        
 Subtitle: POND 18

Total watershed area: 0.002 sq mi    Rainfall type: II    Frequency:    years  
 ----- Subareas -----

1  
 Area(sq mi)    0.00  
 Rainfall(in)    5.5  
 Curve number    87  
 Runoff(in)      4.04  
 Tc (hrs)        0.10  
 TimeToOutlet    0.00  
 Ia/P            0.05  
 (Used)          0.10

Time    Total    ----- Subarea Contribution to Total Flow (cfs) -----  
 (hr)    Flow      1

|      |    |    |
|------|----|----|
| 11.0 | 0  | 0  |
| 11.3 | 0  | 0  |
| 11.6 | 0  | 0  |
| 11.9 | 2  | 2  |
| 12.0 | 4  | 4  |
| 12.1 | 7P | 7P |
| 12.2 | 4  | 4  |
| 12.3 | 1  | 1  |
| 12.4 | 1  | 1  |
| 12.5 | 1  | 1  |
| 12.6 | 1  | 1  |
| 12.7 | 1  | 1  |
| 12.8 | 1  | 1  |
| 13.0 | 0  | 0  |
| 13.2 | 0  | 0  |
| 13.4 | 0  | 0  |
| 13.6 | 0  | 0  |
| 13.8 | 0  | 0  |
| 14.0 | 0  | 0  |
| 14.3 | 0  | 0  |
| 14.6 | 0  | 0  |
| 15.0 | 0  | 0  |
| 15.5 | 0  | 0  |
| 16.0 | 0  | 0  |
| 16.5 | 0  | 0  |
| 17.0 | 0  | 0  |
| 17.5 | 0  | 0  |
| 18.0 | 0  | 0  |
| 19.0 | 0  | 0  |
| 20.0 | 0  | 0  |
| 22.0 | 0  | 0  |
| 26.0 | 0  | 0  |

P - Peak Flow

A18.7 - POND 18 - HEC-1 INPUT FILE

ID  
ID POND 8  
ID  
\*FREE  
IT 6 0 0 300  
IN 6 0 0  
IO 2 0 0  
KK INFLOW HYDROGRAPH  
KM 50 YEAR HYDROGRAPH  
QI 0 0 0.33 0.67 1 1 1 1 2.67 4.33  
QI 6 11 17 11 4 2 2 2 1 1  
QI 1 1 1 1 1 1 1 1 1 1  
QI 1 1 1 1 1 1 1 1 0.75 0.5  
QI 0.25 0 0  
KK POND 8  
KM ROUTE 50 YR POST DEV HYD  
RS 1 ELEV 95.2  
SV 0 0.0002 0.0003 0.0005 0.003 0.014 0.03 0.058  
SQ 0 1.5 2.4 2.5 3.1 3.7 4.1 12  
SE 95.2 95.8 96.0 96.5 97.0 97.5 98.0 98.5  
ST 98.5 30 3.33 1.5  
ZZ

## A18.8 - Pond 18 - HEC-1 SUMMARY OF RESULTS

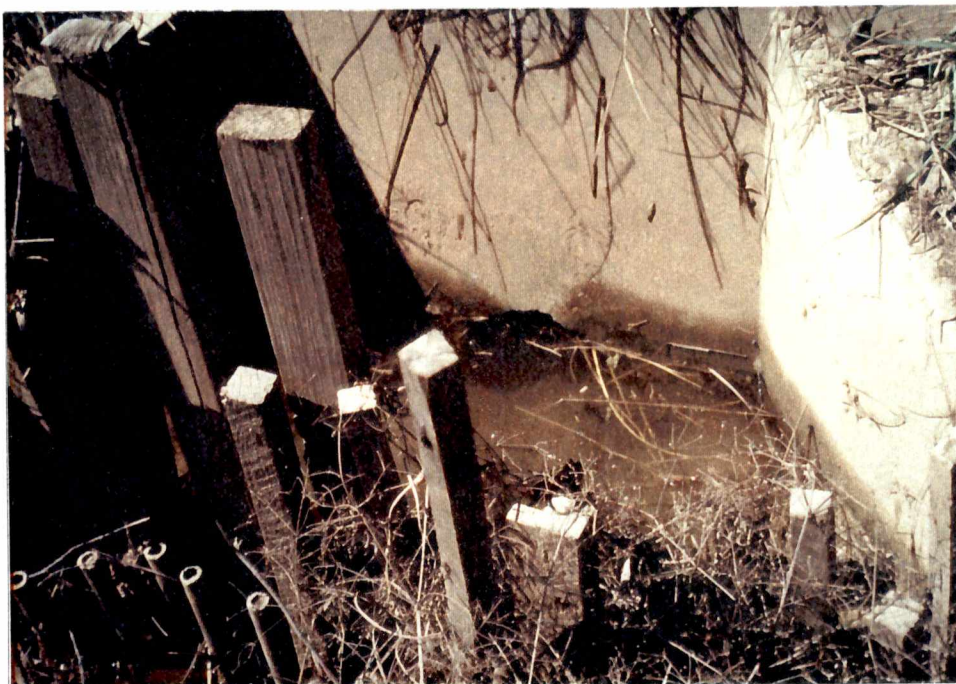
RUNOFF SUMMARY  
FLOW IN CUBIC FEET PER SECOND  
TIME IN HOURS, AREA IN SQUARE MILES

|   | OPERATION                                                             | STATION | PEAK<br>FLOW | TIME OF<br>PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD |         |         | BASIN<br>AREA | MAXIMUM<br>STAGE | TIME OF<br>MAX STAGE |
|---|-----------------------------------------------------------------------|---------|--------------|-----------------|---------------------------------|---------|---------|---------------|------------------|----------------------|
|   |                                                                       |         |              |                 | 6-HOUR                          | 24-HOUR | 72-HOUR |               |                  |                      |
| + | HYDROGRAPH AT<br>INFLOW                                               |         | 7.           | .80             | 1.                              | 1.      | 1.      | .00           |                  |                      |
| + | ROUTED TO<br>POND                                                     |         | 2.           | .80             | 1.                              | 1.      | 1.      | .00           |                  |                      |
| + |                                                                       |         |              |                 |                                 |         |         |               | 97.72            | .80                  |
| + | SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION POND           |         |              |                 |                                 |         |         |               |                  |                      |
| 1 | (PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION) |         |              |                 |                                 |         |         |               |                  |                      |

| PLAN 1 ..... | INITIAL VALUE | SPILLWAY CREST | TOP OF DAM |
|--------------|---------------|----------------|------------|
| ELEVATION    | 95.70         | 98.70          | 98.70      |
| STORAGE      | 0.            | 0.             | 0.         |
| OUTFLOW      | 0.            | 16.            | 16.        |

| RATIO<br>OF<br>PMF | MAXIMUM<br>RESERVOIR<br>W.S.ELEV | MAXIMUM<br>DEPTH<br>OVER DAM | MAXIMUM<br>STORAGE<br>AC-FT | MAXIMUM<br>OUTFLOW<br>CFS | DURATION<br>OVER TOP<br>HOURS | TIME OF<br>MAX OUTFLOW<br>HOURS | TIME OF<br>FAILURE<br>HOURS |
|--------------------|----------------------------------|------------------------------|-----------------------------|---------------------------|-------------------------------|---------------------------------|-----------------------------|
| 1.00               | 97.72                            | .00                          | 0.                          | 2.                        | .00                           | .80                             | .00                         |

\*\*\* NORMAL END OF HEC-1 \*\*\*



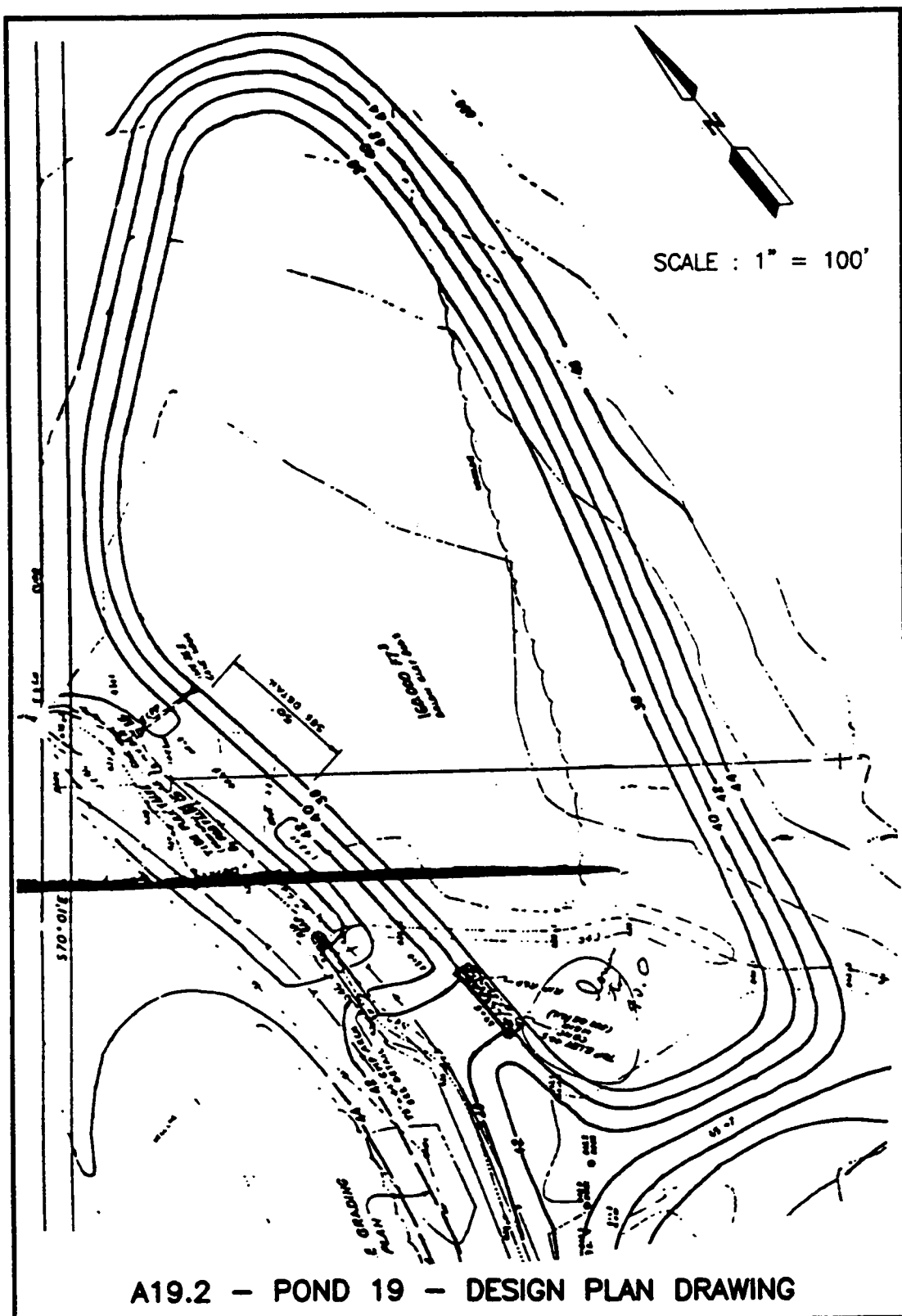
A19.1a - The outlet for Pond 19 is an 8-in. diameter plastic pipe with a square headwall. The pipe appears to be clogged.



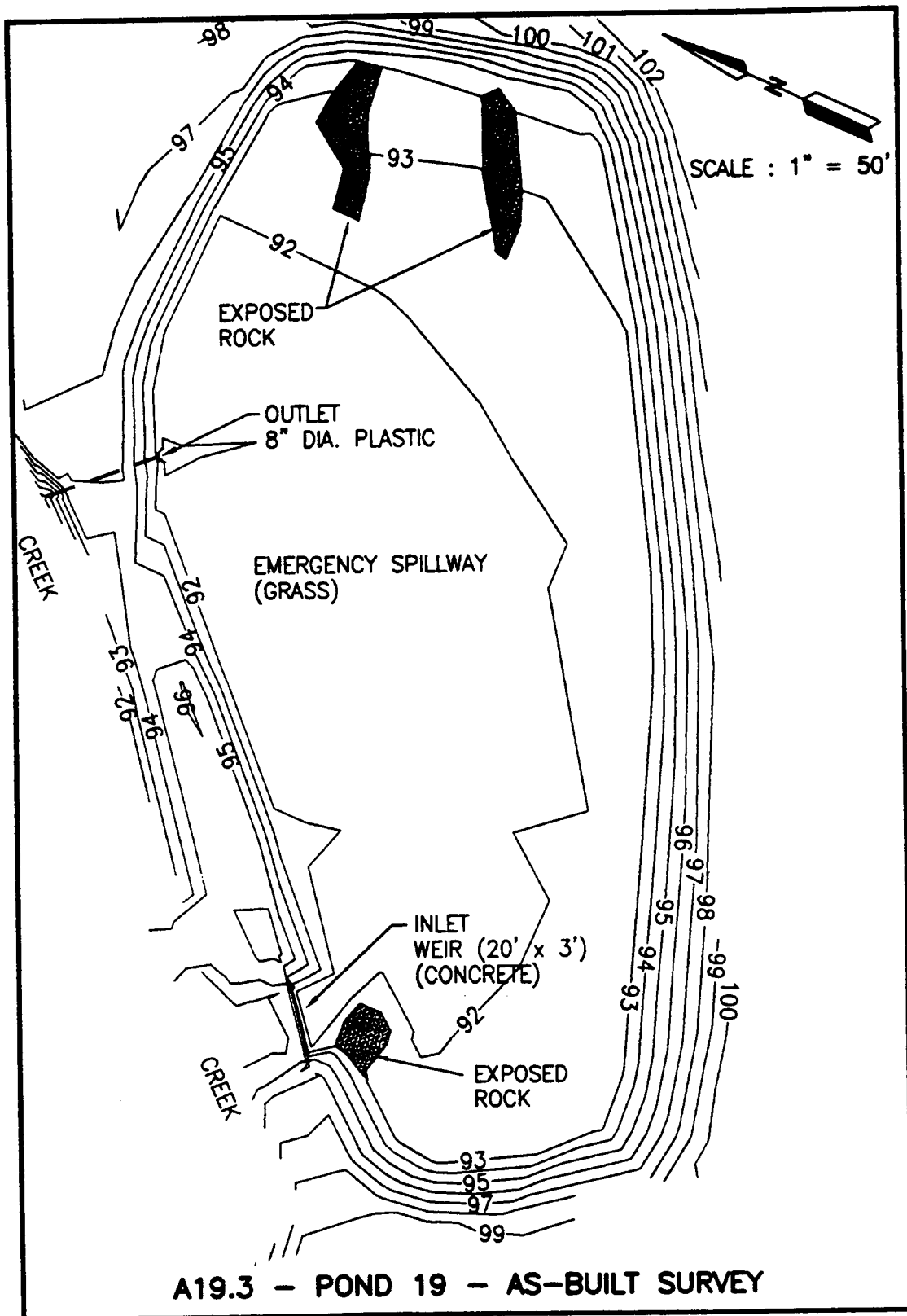
A19.1b -This photograph shows the overall view of the pond. The actual storage volume is only 53% of the intended design volume. The intended storage could not be attained probably due to underlying bedrock.



A19.1c - The pond is designed to detain the excess flow from the adjacent creek during the design storm. The inlet to the pond is a weir 20 ft. long and 3 ft. deep.

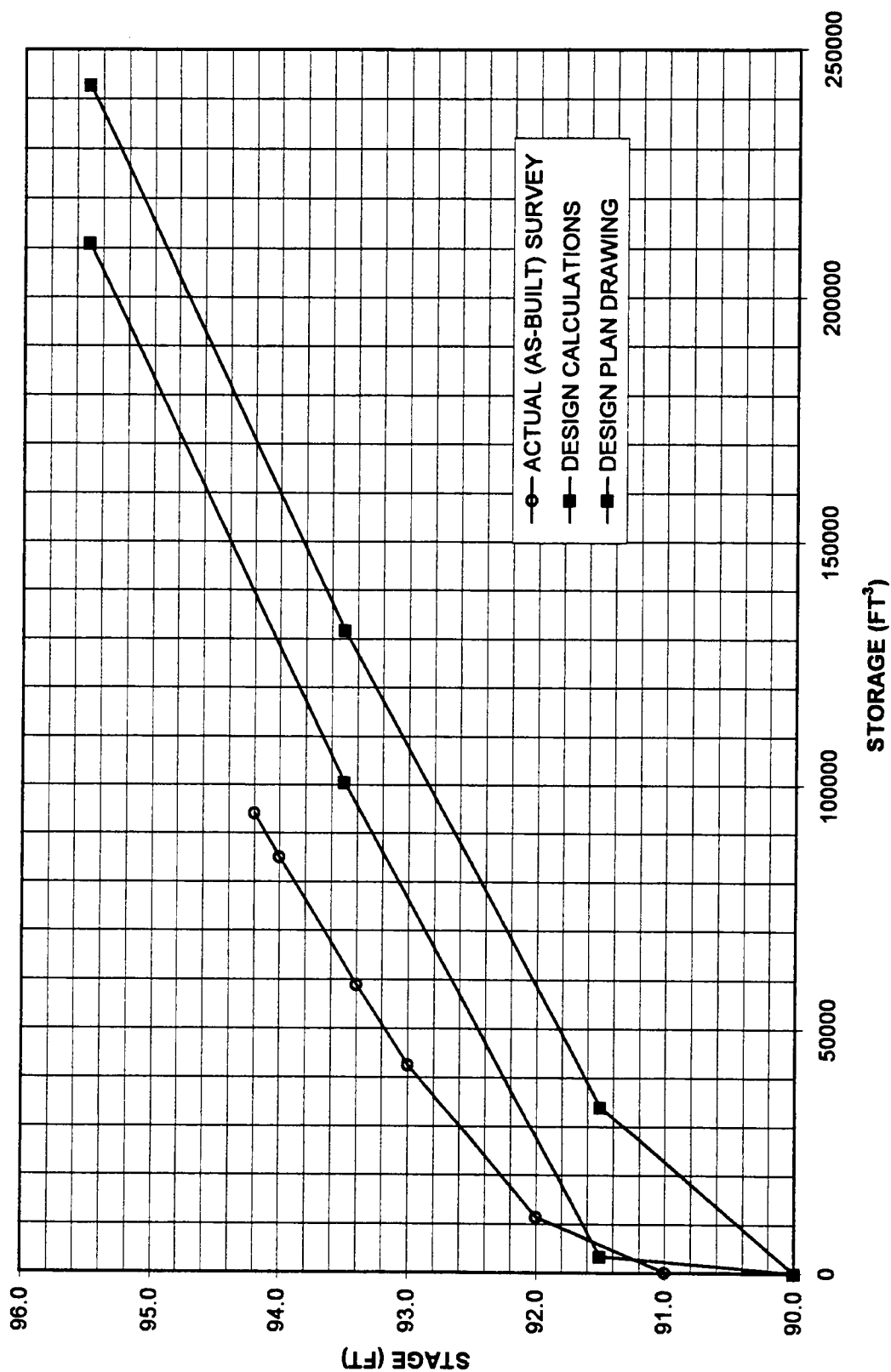




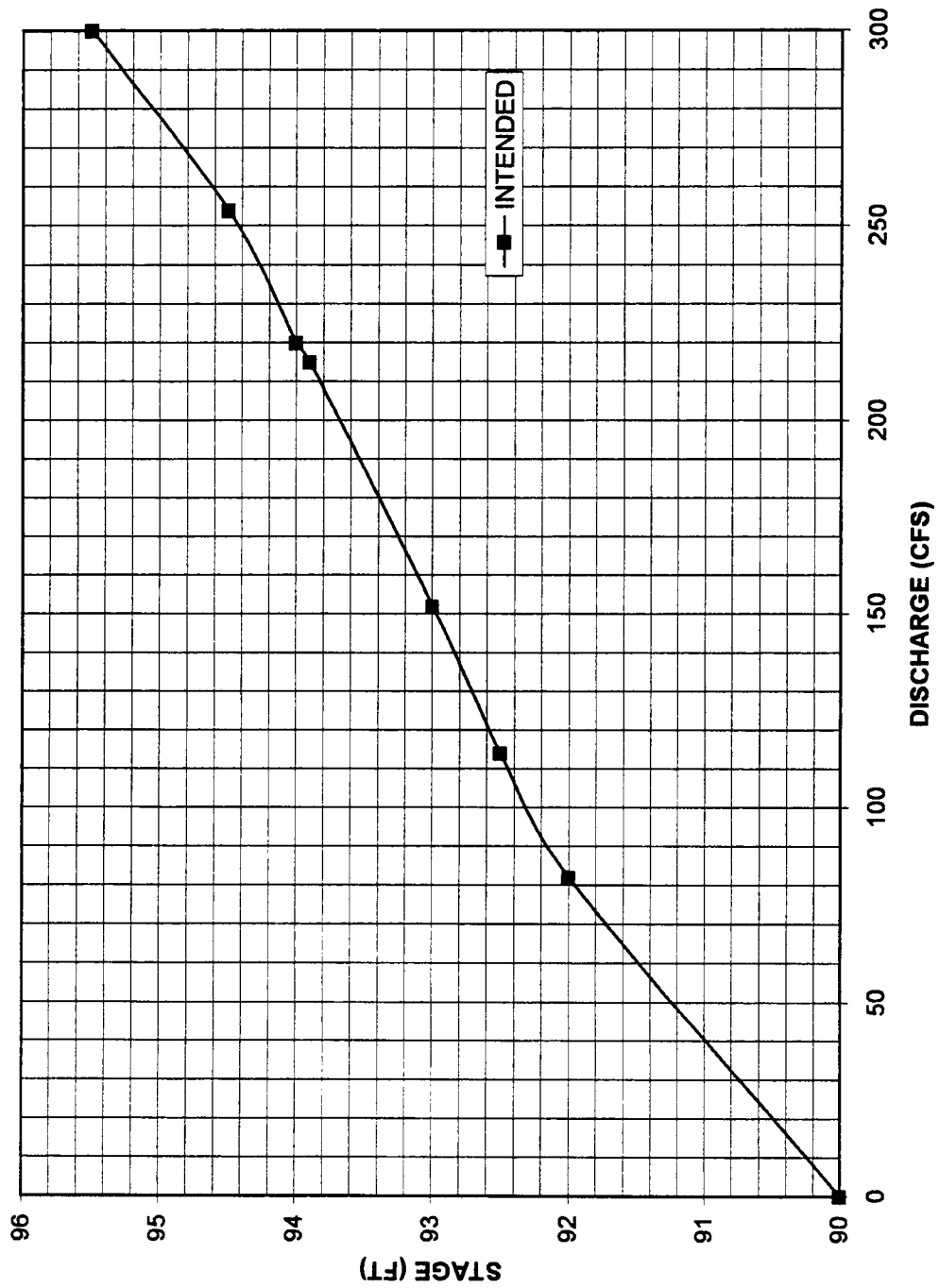




# A19.4 - POND 19 - STAGE vs. STORAGE



# A19.5 - POND 19 - STAGE vs. DISCHARGE



# **A19.6 - POND 19 - INFLOW HYDROGRAPH**

| <b>Time<br/>(hrs)</b> | <b>Flow<br/>(cfs)</b> | <b>Time<br/>(hrs)</b> | <b>Flow<br/>(cfs)</b> |
|-----------------------|-----------------------|-----------------------|-----------------------|
| 11.0                  | 0                     | 14.8                  | 24                    |
| 11.1                  | 0                     | 14.9                  | 23                    |
| 11.2                  | 0                     | 15.0                  | 23                    |
| 11.3                  | 0                     | 15.1                  | 23                    |
| 11.4                  | 0                     | 15.2                  | 22                    |
| 11.5                  | 0                     | 15.3                  | 22                    |
| 11.6                  | 0                     | 15.4                  | 21                    |
| 11.7                  | 0                     | 15.5                  | 21                    |
| 11.8                  | 1                     | 15.6                  | 20                    |
| 11.9                  | 1                     | 15.7                  | 20                    |
| 12.0                  | 5                     | 15.8                  | 19                    |
| 12.1                  | 27                    | 15.9                  | 19                    |
| 12.2                  | 86                    | 16.0                  | 18                    |
| 12.3                  | 169                   | 16.1                  | 18                    |
| 12.4                  | 215                   | 16.2                  | 18                    |
| 12.5                  | 214                   | 16.3                  | 17                    |
| 12.6                  | 182                   | 16.4                  | 17                    |
| 12.7                  | 147                   | 16.5                  | 17                    |
| 12.8                  | 117                   | 16.6                  | 17                    |
| 12.9                  | 96                    | 16.7                  | 16                    |
| 13.0                  | 76                    | 16.8                  | 16                    |
| 13.1                  | 66                    | 16.9                  | 15                    |
| 13.2                  | 56                    | 17.0                  | 15                    |
| 13.3                  | 50                    | 17.1                  | 15                    |
| 13.4                  | 45                    | 17.2                  | 15                    |
| 13.5                  | 42                    | 17.3                  | 14                    |
| 13.6                  | 39                    | 17.4                  | 14                    |
| 13.7                  | 37                    | 17.5                  | 14                    |
| 13.8                  | 35                    | 17.6                  | 14                    |
| 13.9                  | 33                    | 17.7                  | 14                    |
| 14.0                  | 31                    | 17.8                  | 14                    |
| 14.1                  | 30                    | 17.9                  | 14                    |
| 14.2                  | 29                    | 18.0                  | 14                    |
| 14.3                  | 28                    | 18.1                  | 14                    |
| 14.4                  | 27                    | 18.2                  | 14                    |
| 14.5                  | 25                    | 18.3                  | 14                    |
| 14.6                  | 24                    | 18.4                  | 14                    |
| 14.7                  | 24                    | 18.5                  | 14                    |

A19.7 - POND 19 - HEC-1 INPUT FILE

ID  
ID POND 19  
ID  
\*FREE  
IT 6 0 0 300  
IN 6 0 0  
IO 2 0 0  
KK INFLOW HYDROGRAPH  
KM 50 YEAR POST DEV  
QI 0 0 1 1 5 27 86 169 215 214  
QI 182 147 117 96 76 66 56 50 45 42  
QI 39 37 35 33 31 30 29 28 27 25  
QI 24 24 24 23 23 23 22 22 21 21  
QI 20 20 19 19 18 18 18 17 17 17  
QI 17 16 16 15 15 15 15 14 14 14  
QI 14 14 14 14 14 14 14 14 14 14  
QI 13.6 13.2 12.8 12.4 12 11.6 11.2 10.8 10.4 10  
QI 9.6 9.2 8.8 8.4 8 7.6 7.2 6.8 6.4 6  
QI 5.6 5.2 4.8 4.4 4 3.6 3.2 2.8 2.4 2  
QI 1.6 1.2 .8 .4 0 0  
KK POND 19  
KM POND DATA  
RS 1 ELEV 90  
SV 0 0.0014 0.26 0.98 1.35 1.95 2.16 3.03  
SQ 0 4.5 7.6 9.8 10.5 11.5 11.9 83.9  
SE 90 91 92 93 94 94.2 95  
ST 95 50 3.33 1.5  
ZZ

## A19.8 - Pond 19 - HEC-1 SUMMARY OF RESULTS

### RUNOFF SUMMARY FLOW IN CUBIC FEET PER SECOND TIME IN HOURS, AREA IN SQUARE MILES

| OPERATION | STATION                                                                                                                              | PEAK<br>FLOW | TIME OF<br>PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD |         |         | BASIN<br>AREA | MAXIMUM<br>STAGE | TIME OF<br>MAX STAGE |
|-----------|--------------------------------------------------------------------------------------------------------------------------------------|--------------|-----------------|---------------------------------|---------|---------|---------------|------------------|----------------------|
|           |                                                                                                                                      |              |                 | 6-HOUR                          | 24-HOUR | 72-HOUR |               |                  |                      |
| +         |                                                                                                                                      |              |                 |                                 |         |         |               |                  |                      |
| +         | HYDROGRAPH AT<br>INFLOW                                                                                                              | 215.         | .80             | 42.                             | 12.     | 10.     |               | .00              |                      |
| +         | ROUTED TO<br>POND                                                                                                                    | 218          | .90             | 38.                             | 15.     | 13.     |               | .00              |                      |
| +         |                                                                                                                                      |              |                 |                                 |         |         |               | 98.15            | .90                  |
| 1         | SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION POND<br>(PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION) |              |                 |                                 |         |         |               |                  |                      |

|              |               |                |            |
|--------------|---------------|----------------|------------|
| PLAN 1 ..... | INITIAL VALUE | SPILLWAY CREST | TOP OF DAM |
| ELEVATION    | 90.00         | 95.00          | 98.70      |
| STORAGE      | 0.            | 2.             | 2.         |
| OUTFLOW      | 0.            | 12.            | 12.        |

| RATIO<br>OF<br>PMF | MAXIMUM<br>RESERVOIR<br>W.S.ELEV | MAXIMUM<br>DEPTH<br>OVER DAM | MAXIMUM<br>STORAGE<br>AC-FT | MAXIMUM<br>OUTFLOW<br>CFS | DURATION<br>OVER TOP<br>HOURS | TIME OF<br>MAX OUTFLOW<br>HOURS | TIME OF<br>FAILURE<br>HOURS |
|--------------------|----------------------------------|------------------------------|-----------------------------|---------------------------|-------------------------------|---------------------------------|-----------------------------|
| 1.00               | 98.15                            | 1.15                         | 2.                          | 218.                      | 6.80                          | .90                             | .00                         |

\*\*\* NORMAL END OF HEC-1 \*\*\*



A20.1a - The as-built outlet for Pond 20 is a 15-in. diameter CMP, but a 36-in. diameter riser having an 8-in. diameter riser was the intended design.

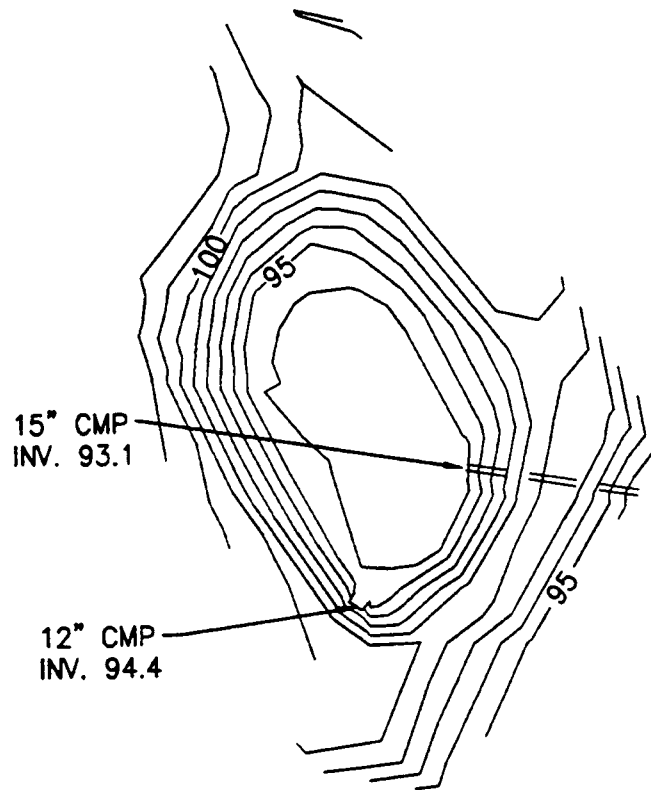


A20.1b - The pond is receiving oil and debris from an upstream parking lot.





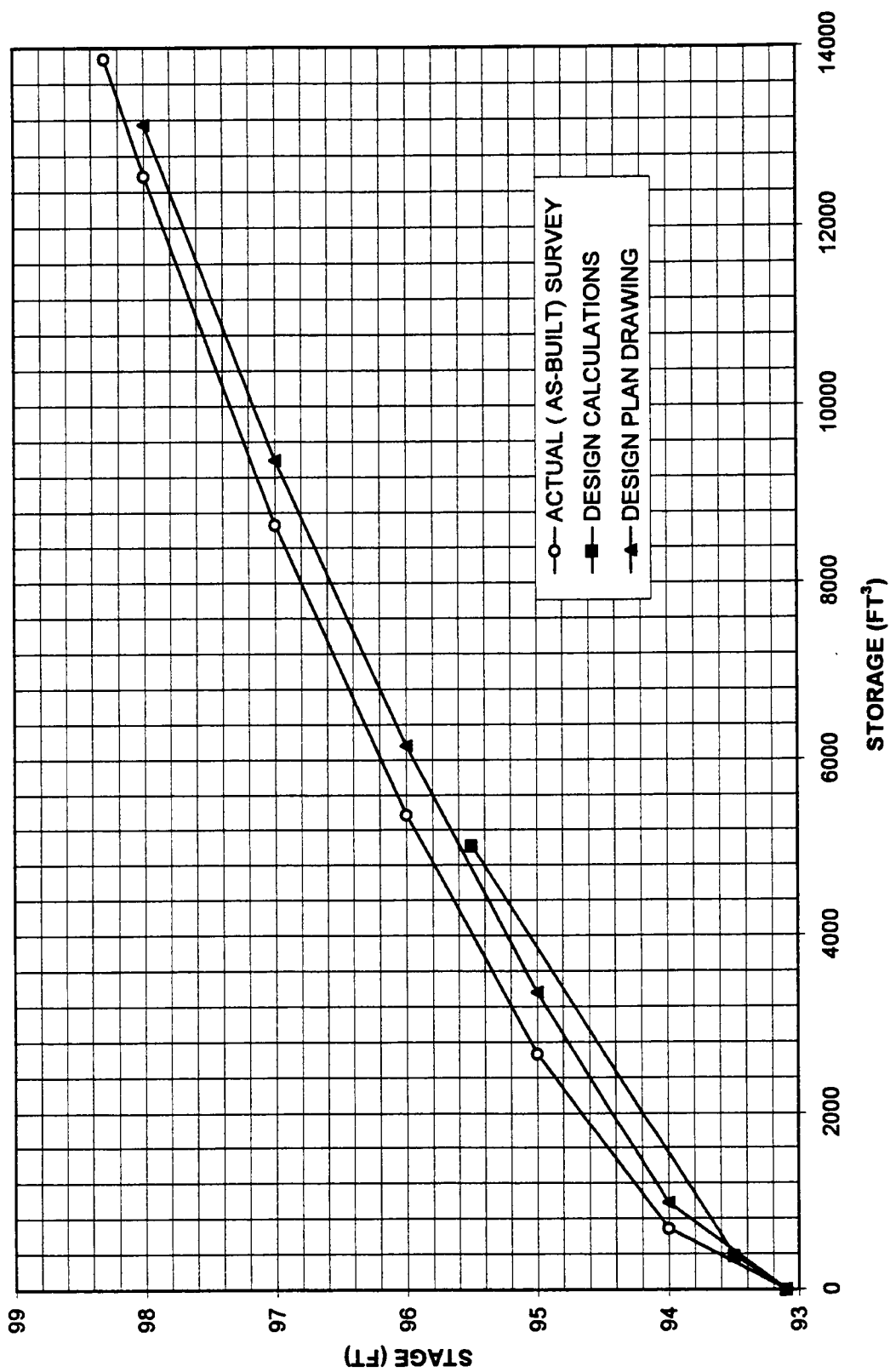
SCALE : 1" = 40'



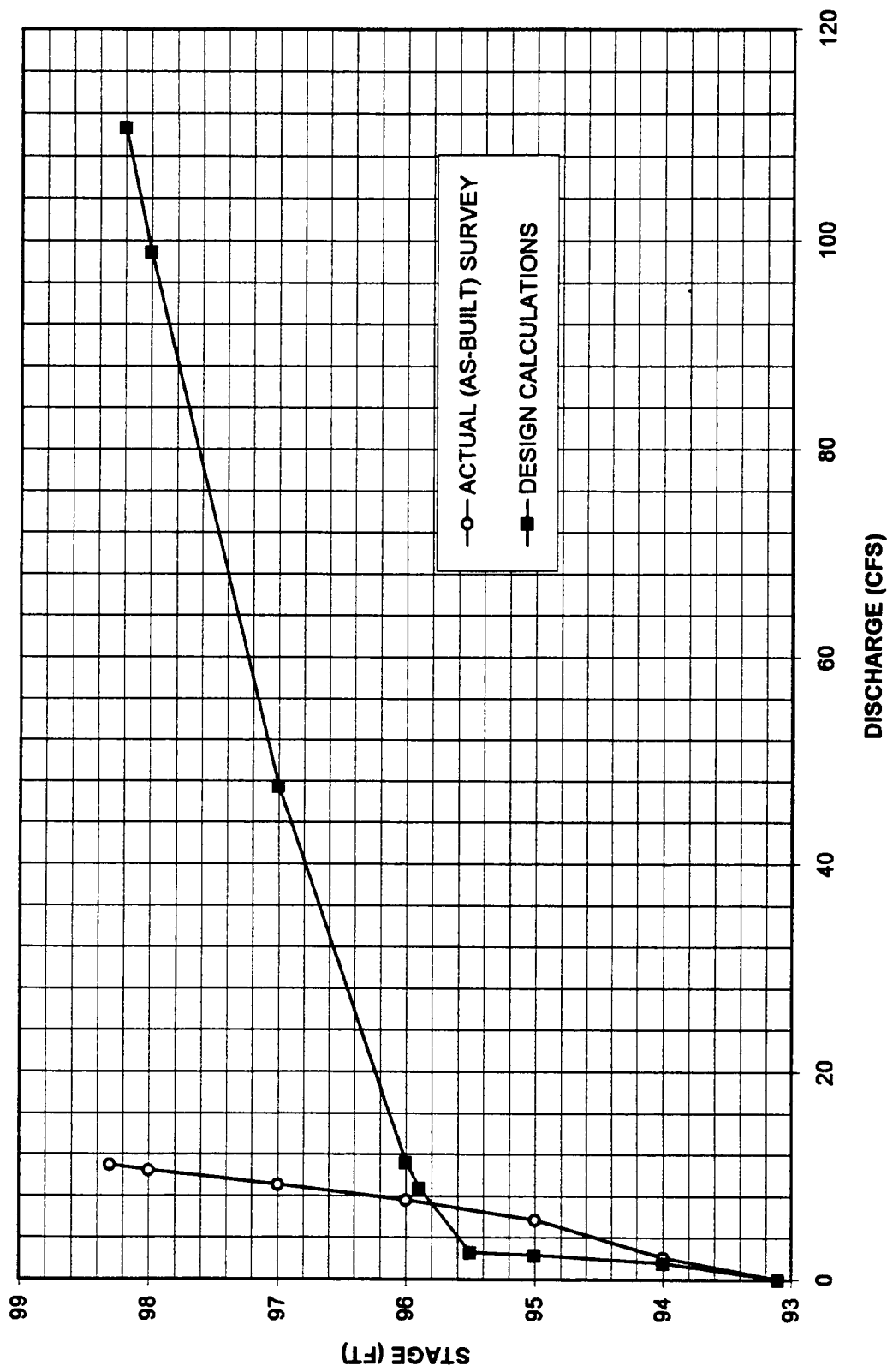
A20.3 - POND 20 - AS-BUILT SURVEY



# A20.4 - POND 20 - STAGE vs. STORAGE



# A20.5 - POND 20 - STAGE vs. DISCHARGE



# A20.6 - POND 20 - INFLOW HYDROGRAPH

## TABULAR HYDROGRAPH METHOD

Version 2.00

Project : DETENTION POND ANALYSIS

User: TER

Date: 04-09-97

County :

State: TN

Checked: \_\_\_\_\_

Date: \_\_\_\_\_

Subtitle: POND 20

Total watershed area: 0.002 sq mi Rainfall type: II Frequency: years  
----- Subarea -----

1  
Area(sq mi) 0.00  
Rainfall(in) 4.8  
Curve number 88  
Runoff(in) 3.48  
Tc (hrs) 0.10  
TimeToOutlet 0.00  
Is/P 0.06  
(Used) 0.10

Time Total ----- Subarea Contribution to Total Flow (cfs) -----  
(hr) Flow 1

|      |    |    |
|------|----|----|
| 11.0 | 0  | 0  |
| 11.1 | 0  | 0  |
| 11.6 | 0  | 0  |
| 11.9 | 2  | 2  |
| 12.0 | 4  | 4  |
| 12.1 | 67 | 67 |
| 12.2 | 4  | 4  |
| 12.3 | 1  | 1  |
| 12.4 | 1  | 1  |
| 12.5 | 1  | 1  |
| 12.6 | 1  | 1  |
| 12.7 | 1  | 1  |
| 12.8 | 0  | 0  |
| 13.0 | 0  | 0  |
| 13.2 | 0  | 0  |
| 13.4 | 0  | 0  |
| 13.6 | 0  | 0  |
| 13.8 | 0  | 0  |
| 14.0 | 0  | 0  |
| 14.3 | 0  | 0  |
| 14.6 | 0  | 0  |
| 15.0 | 0  | 0  |
| 15.5 | 0  | 0  |
| 16.0 | 0  | 0  |
| 16.5 | 0  | 0  |
| 17.0 | 0  | 0  |
| 17.5 | 0  | 0  |
| 18.0 | 0  | 0  |
| 19.0 | 0  | 0  |
| 20.0 | 0  | 0  |
| 22.0 | 0  | 0  |
| 26.0 | 0  | 0  |

P - Peak Flow

A20.7 - POND 20 - HEC-1 INPUT FILE

ID  
ID POND 20  
ID  
\*FREE  
IT 6 0 0 300  
IN 6 0 0  
IO 2 0 0  
KK INFLOW HYDROGRAPH  
KM 10 YEAR HYDROGRAPH  
QI 0 0 .67 1.33 2 4 6 4 1 1  
QI 1 1 1 1 0 0  
KK POND 20  
KM ROUTE 10 YR POST DEV HYD  
RS 1 ELEV 93.1  
SV 0 0.016 .061 .123 .199 .289 .319  
SQ 0 2.1 5.7 7.6 9.1 10.5 11  
SE 93.1 94 95 96 97 98 98.3  
ST 98.3 70 3.33 1.5  
ZZ

## A20.8 - Pond 20 - HEC-1 SUMMARY OF RESULTS

### RUNOFF SUMMARY FLOW IN CUBIC FEET PER SECOND TIME IN HOURS, AREA IN SQUARE MILES

|   | OPERATION     | STATION | PEAK<br>FLOW | TIME OF<br>PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD |         |         | BASIN<br>AREA | MAXIMUM<br>STAGE | TIME OF<br>MAX STAGE |
|---|---------------|---------|--------------|-----------------|---------------------------------|---------|---------|---------------|------------------|----------------------|
|   |               |         |              |                 | 6-HOUR                          | 24-HOUR | 72-HOUR |               |                  |                      |
| + | HYDROGRAPH AT |         |              |                 |                                 |         |         |               |                  |                      |
| + | INFLOW        |         | 6.           | .60             | 1.                              | 1.      | 1.      | .00           |                  |                      |
| + | ROUTED TO     |         |              |                 |                                 |         |         |               |                  |                      |
| + | POND          |         | 4            | .70             | 1.                              | 1.      | 1.      | .00           |                  |                      |
| 1 |               |         |              |                 |                                 |         |         |               | 94.61            | .70                  |

SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION POND  
(PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION)

| PLAN 1 ..... | INITIAL VALUE | SPILLWAY CREST | TOP OF DAM |
|--------------|---------------|----------------|------------|
| ELEVATION    | 93.10         | 96.30          | 96.30      |
| STORAGE      | 0.            | 0.             | 0.         |
| OUTFLOW      | 0.            | 11.            | 11.        |

| RATIO<br>OF<br>PMF | MAXIMUM<br>RESERVOIR<br>W.S.ELEV | MAXIMUM<br>DEPTH<br>OVER DAM | MAXIMUM<br>STORAGE<br>AC-FT | MAXIMUM<br>OUTFLOW<br>CFS | DURATION<br>OVER TOP<br>HOURS | TIME OF<br>MAX OUTFLOW<br>HOURS | TIME OF<br>FAILURE<br>HOURS |
|--------------------|----------------------------------|------------------------------|-----------------------------|---------------------------|-------------------------------|---------------------------------|-----------------------------|
| 1.00               | 94.61                            | .00                          | 0.                          | 4.                        | .00                           | .70                             | .00                         |

\*\*\* NORMAL END OF HEC-1 \*\*\*

## VITA

Terry Eldridge Romans was born September 9, 1965 in Nashville, Tennessee. He attended school in Cheatham County, Tennessee where he graduated from Cheatham County Central High School in June 1983. In January 1989 he entered the University of Tennessee, Knoxville where he graduated with a BS in Civil Engineering in December 1993. While at the University he was a member of Chi Epsilon, the American Society of Civil Engineers (ASCE), and Tau Beta Pi. He received the John L. Callaway Academic Achievement Award in and the Tennessee Road Builders Scholarship. Mr. Romans co-oped with Allen and Hoshall Architects and Engineer.

Mr. Romans enrolled in graduate school at the University of Tennessee, Knoxville in June 1993 with a student teaching assistantship. The assistantship encompassed teaching the a three-hour hydraulics lab, keeping office hours to help students, grading the lab reports, and reporting the grades to the professor (Dr. Tschantz).

Mr. Romans started working full time with Allen and Hoshall Architects and Engineers in December 1994. While at Allen and Hoshall his main tasks are site design and development. He designs the grading plans, storm drainage plans, and utility plans for industrial sites. He has designed roadway extensions, sewer and water line extensions, greenway trails for Knox County, and performed HEC-2 studies.

Mr. Romans graduated with a Master of Science Degree in Environmental Engineering in December 1997.