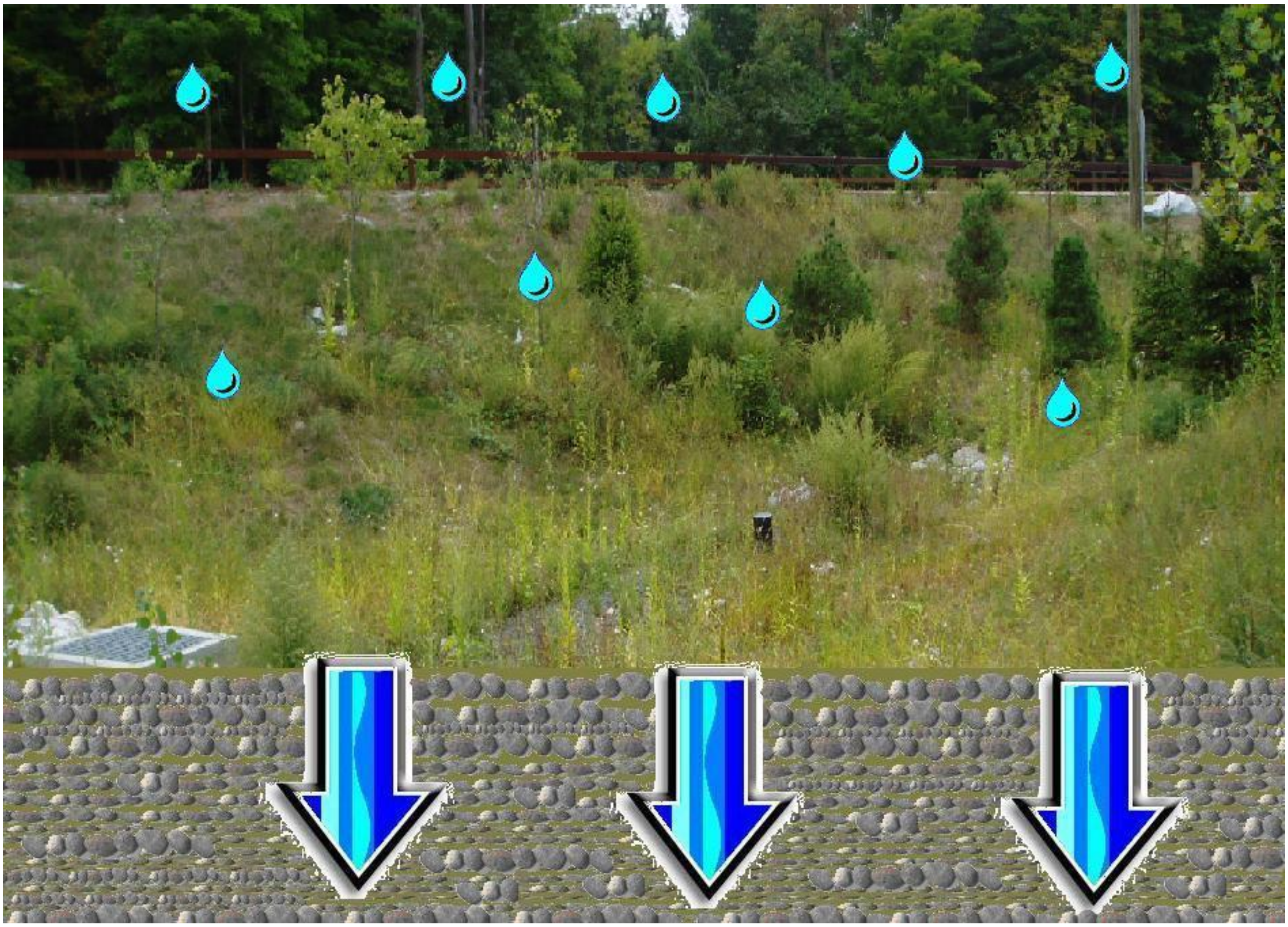
GDP-8

DESIGN, CONSTRUCTION, AND MAINTENANCE OF RECHARGE BASINS



GEOTECHNICAL DESIGN PROCEDURE

GDP-8

Revision #5

AUGUST 2015

NEW YORK STATE OF OPPORTUNITY. | Department of Transportation | Office of Technical Services | Geotechnical Engineering Bureau

GEOTECHNICAL DESIGN PROCEDURE:
DESIGN, CONSTRUCTION, AND MAINTENANCE OF RECHARGE BASINS

GDP-8
Revision #5

STATE OF NEW YORK
DEPARTMENT OF TRANSPORTATION

GEOTECHNICAL ENGINEERING BUREAU

AUGUST 2015

PREFACE

This manual is intended to serve as a guide for determining feasibility, design, construction, and maintenance requirements for recharge basins (more precisely basins). As a user's manual, discussions of theoretical or developmental aspects are avoided since these subject areas have been documented previously by the Department[1, 2]. The manual has been developed such that designer-users need not be soil experts, although appropriate input from this expertise is of prime importance. It is expected that this manual, with the included computer program RECHARGE, will enable the practicing engineer to design basins easily and quickly. A program RECHARGE diskette for use on an IBM PC-AT, XT, PS/2 or any IBM compatible is also available upon written request to:

Director
Geotechnical Engineering Bureau
New York State Department of Transportation
50 Wolf Road, Mail Pod 31
Albany, New York 12232

While replenishment of groundwater through recharge has been proven to be technically feasible and cost effective, this Bureau believes that the success of any recharge project depends upon adherence to the principles presented in this manual. Furthermore, periodic reviews of basin performance need to be an ongoing activity. Information obtained from these reviews can provide the Department with a greater experience base. It is therefore recommended that each Region establish an inventory of recharge basins which have been designed in accordance with this manual. This inventory should be reviewed on a scheduled basis to evaluate performance and gain further experience. Initial and updated inventory information should be transmitted to this Bureau where a master file will be maintained.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF NOTATIONS

SYMBOL	DESCRIPTION
A_f	Horizontal Plane Area of the Basin at Depth of H/2
A_s	Basin Top Surface Area
G	Specific Gravity of Soil Solids
H	Maximum Basin Operating Head
k_s	Coefficient of Saturated Permeability
k_t	Hydraulic Conductivity of Transmission Zone
η	Soil Porosity
Q	Cumulative Infiltration Flow
Q_i	Cumulative Inflow
s	Degree of Saturation
SS	Specific Surface of Soils
t	Time
w_n	Natural Drained Moisture Content
θ_n	Volumetric Water Content in Natural Drained State
θ_t	Volumetric Water Content in Transmission Zone
α	Hydraulic Diffusivity
ψ_n	Capillary Suction Potential at Natural Drained Moisture Content

1. INTRODUCTION

1.1 Recharge: Background and Perspectives

Infiltration or percolation of precipitation to replenish the groundwater supply is an important phase in the natural hydrologic cycle. The groundwater levels and hence, groundwater supplies, generally rise in relationship to the amount of precipitation and to infiltration rates of soils. The hydrologist or groundwater geologist refers to water entering the aquifer as “recharge”.

Soil properties and hydraulic factors are the chief controllers of the rate and amount of natural recharge. However, urbanization and development can create local conditions that may change the pre-existing natural process of groundwater recharge. In many areas, for example, the amount of water recharged into the groundwater is reduced by one or more of the following factors:

1. Public and commercial development which decreases the pervious surface area otherwise available for infiltration,
2. Lining of stream channels for erosion control,
3. Discharging of sewage and industrial wastes to ocean or inland lakes, or
4. Diverting and conveying surface runoff that might otherwise infiltrate naturally into the aquifer.

Recharge deficiencies coupled with heavy groundwater withdrawals can create an imbalance in the regional hydrologic cycle and cause serious groundwater supply problems. These, in turn, can lead to the following local problems:

1. Reduction of water well yields and drying up of shallower wells,
2. Deterioration of groundwater quality in inland areas due to reduced dilution by fresh water recharge,
3. Coastal area intrusions of salt water into fresh groundwater supplies, render much of the unpotable, and,
4. Ground subsidence caused by consolidation of underlying compressible sediments due to an attendant increase in overburden pressure.

These problems have prompted many public agencies to study possible methods to replenish the groundwater, and to establish regulations for groundwater recharge and reuse of waste water. The existing regulations in some urban jurisdictions in New York State, notably counties and towns on Long Island, require that all storm water be recharged. Elsewhere, designers conditioned by traditional practices to dispose of storm water by more conventional methods need to expand their choice of possible design alternatives to included planned infiltration and groundwater recharge.

Neglecting to evaluate the feasibility of a recharge system can also be a costly oversight, since disposal by this method may potentially be much less expensive than storm sewer networks. With the recharge concept, runoff from small local areas is simply collected and directed by a short trunk to an available or planned depression for quick and harmless infiltration.

1.2 Artificially Induced Infiltration of Storm Water - An Alternative

The deliberate engineering of facilities to dispose of storm water by infiltration into the ground is an attractive way of reversing declining levels of groundwater and restoring the natural balance between recharge and withdrawal. As a matter of retaining perspective, artificial depressions, commonly known as recharge basins, function identically to natural depressions that flood during a storm.

1.3 Hydraulics of Infiltration and Recharge

Groundwater replenishment by means of recharge basins, as shown in Figure 1, generally takes place through the unsaturated soil zone above the groundwater level. The process of water flow to and through an unsaturated soil is termed as infiltration. Infiltration is an unsteady-state process of flow, meaning that the flow rate varies with time under a given head.

Flow by means of infiltration is faster than saturated flow. Theoretically, the lower limit of the infiltration rate is the rate of saturated flow. However, this limit will not be attained where storms are the water source since an extraordinarily long time of sustained infiltration is required to achieve saturated flow. Fortunately, infiltration rates are much greater than saturated flow rates despite their continuous decrease with time. This factor enables recharge basins to be designed to operate with remarkable efficiency.

Although the unsaturated flow processes are more complex than the saturated ones, the same fundamental principles apply for both, i.e., Darcy's law and the equation of continuity. The driving gradient for saturated flow includes positive pressure heads, whereas the driving gradient for unsaturated flow includes not only the positive pressure heads but a negative pressure head as well. The negative pressure head is frequently referred to as capillary suction potential.

If the duration of a storm is short and the groundwater is deep, infiltration will cease once the surface water supply ends. Water which has thus infiltrated into the unsaturated zone will continue moving downward, but at a slower rate until the soil-water surface tension equals gravitational forces.

Recharge starts if the duration of a storm is long enough for the advancing infiltrating wetting front to reach the groundwater. The merging of the wetting front with the underlying saturated zone will develop a groundwater mound. If the unsaturated zone is not laterally confined, or if the infiltrating water can move and store horizontally, the groundwater mound will not result in any significant decrease in the infiltration rate.

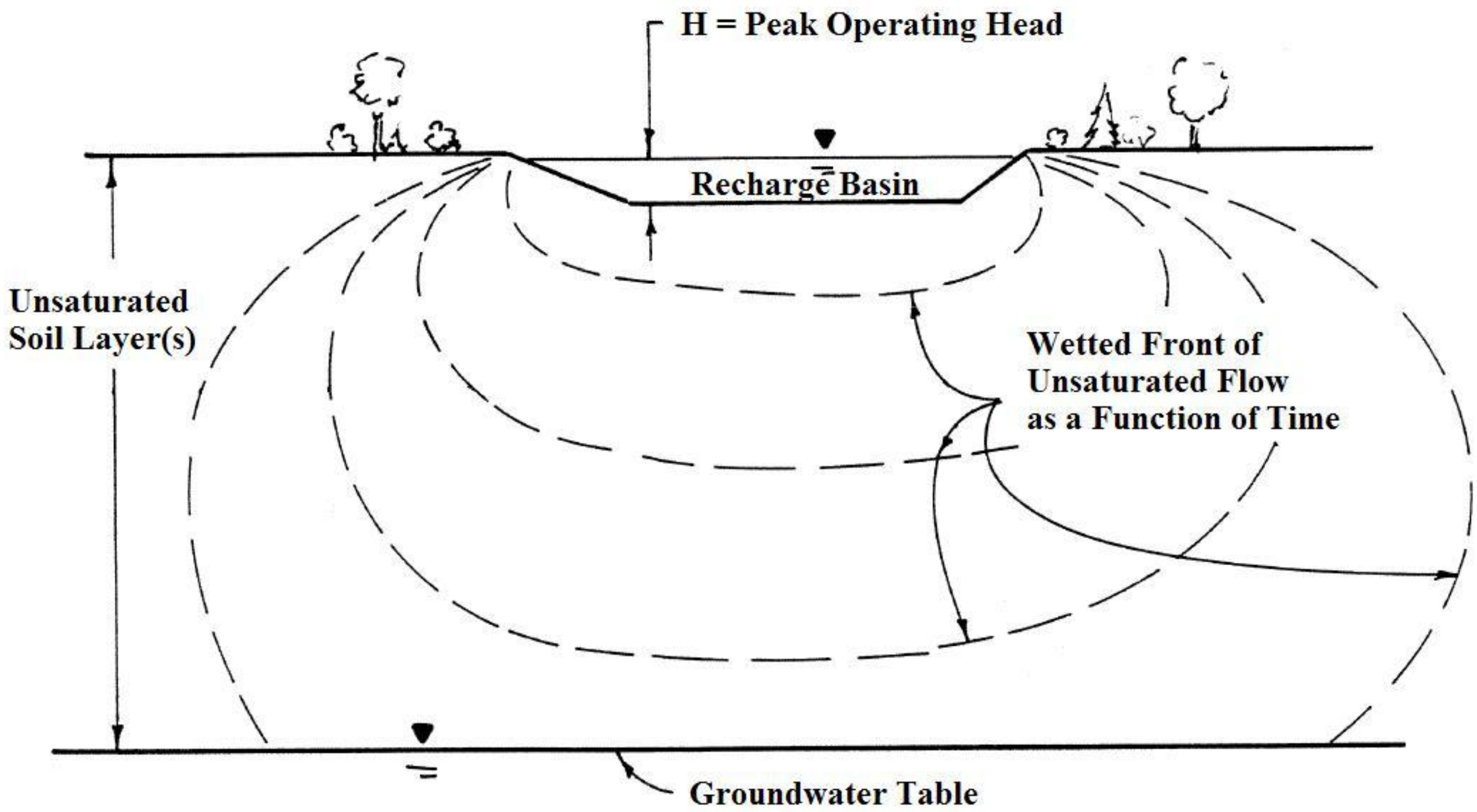


Figure 1 Groundwater Replenishment through a Recharge Basin

2. DESIGN PROCEDURE

2.1 General

The design objective is to safely dispose of storm runoff as unobtrusively and inexpensively as possible. This is best achieved, where possible, by a “distributed” approach, i.e. dispose of water at selected depressions along the entire project length. Conversely, the practice of collecting project runoff from many square miles and directing it to a single discharge point often provides a result that is more expensive, disruptive to construct, and possibly costly to maintain.

The design of a recharge basin consists of a number of discrete steps, as shown in Figure 2. Each step is referenced to a section of this chapter where it is discussed in detail.

Basin recharge is feasible wherever the following conditions exist:

1. The soils, excluding the top 5 ft. (1.5 m) of surface soil, are relatively permeable,
2. Unsaturated conditions exist to a considerable depth below the surface. Infiltration cannot occur if a soil is already saturated by permanent groundwater. For a design to be valid, a good rule-of-thumb is that the depth of unsaturated soil below the proposed basin floor is greater than 25 percent of the peak basin operating head. The peak basin operating head, H, is defined as the maximum depth of water permissible for the proposed basin,
3. Unsaturated soils are not laterally confined, i.e. they have the capacity for water to move and store horizontally, and
4. Sufficient space is available for sitting single or multiple basins in the project vicinity. Maximum use should be made of the surrounding natural terrain, interchange loop interiors and other depressions. Substantial runoff can be disposed of by infiltration in a very small space.

The remaining question of recharge efficiency as related to basin size can only be answered by applying the design procedure.

2.2 Area Reconnaissance

Subsurface conditions may be generally evaluated for recharge basin feasibility early in project planning and without borings through the use of terrain reconnaissance techniques. This includes comparison of alternate basin sites along the proposed alignments. References used in this phase may include old borings, aerial photographs, well records, groundwater bulletins, geologic reports, agricultural soil survey maps and bulletins, construction records of excavations in the area, and the Department’s soil survey reports, if available, for the project area. Information from these sources combined with field inspections will give good insight into the potential of recharge basins from the standpoint of favorable subsurface conditions. This research exercise may eliminate much work otherwise necessary to disclose the general feasibility of basin designs at given locations.

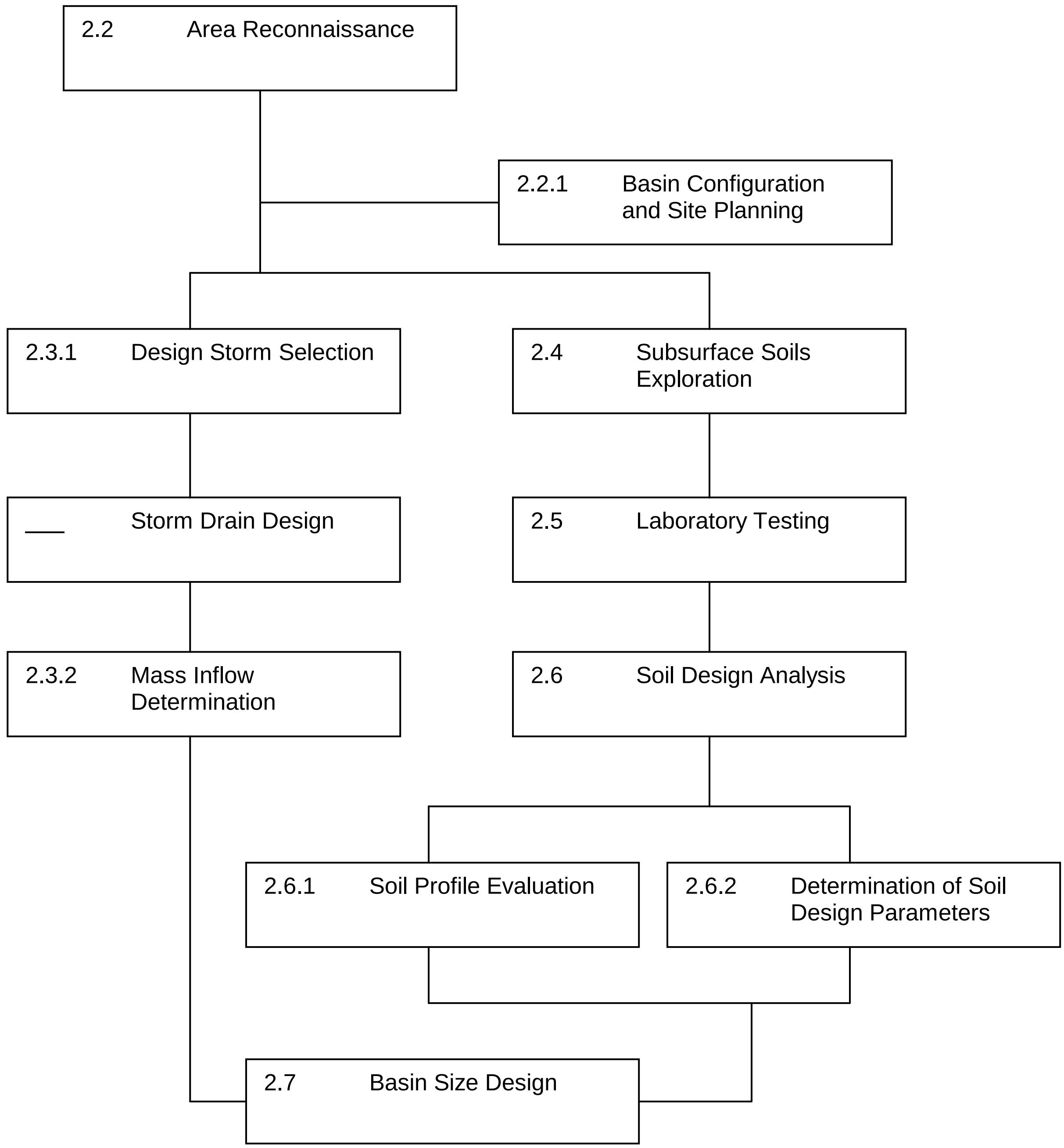


Figure 2 Sequence of Steps in Design Procedure

2.2.1 Basin Configuration and Site Planning

All locations favorable for basins in terms of soils, groundwater depth and topography should be delineated. At this time, the designer should strive for optimum results for hydraulic performance, construction feasibility, environmental esthetics, cost and minimum future maintenance requirements. These ideals can be best approached by subdividing the total project watershed area into smaller units if possible. Each would be served by its own small, less conspicuous recharge basin which would appear more or less like a depression rather than some kind of unsightly "works". In this sense, the designer is more closely simulating the natural recharge process.

The opposite approach of using a single or very small number of basin sites leads to larger runoff volumes. This requires greater basin depths, and usually steeper side slopes because of limits in the size of the area available, not to mention longer and larger pipe runs.

Where choices are available, the designer's approach should be influenced by the following characteristics of basin performance:

1. While large operating depths will infiltrate more water faster than shallow depths, the following disadvantages are incurred:
   a. Essential drying out of the floor after a storm is impeded by restricted exposure to winds and sunlight. That in turn causes microbial growths to rapidly populate the soil at the floor surface and clog the pores (see Sec. 4 .2). This adversely affects the ability of floor turf and grasses to assimilate norm silting (see Sec. 4.3). The effects are more pronounced as basins become deeper, making it more difficult for the basin to be self-maintained.
   b. Deep basins require protection for people and cars. They also require substantial fencing to keep out trash or refuse dumping.
   c. A recharge basin functions only temporarily and during infrequent rainfall periods. Consequently, it makes little sense for the area occupied by a designed depression to be unsuitable and categorically denied for other uses at other times. Conversely, the potential exists for a well designed basin to be integrated into a pleasing scenic part of the roadside landscape, a local playing field, etc.
2. The design method will provide a recharge basin that will not overflow for the incidence of storm equal to the design storm. Sooner or later, a storm will occur and cause overflow of any reasonably sized basin. Such a storm magnitude would probably cause wide-scale folding no matter what provisions were made for storm water disposal. Therefore, the designer should choose a conservative design storm such that basin overflow will not occur without general flooding of drainage system elsewhere in the locality.

   The designer must understand that most future basin maintenance, reconstruction or remedial treatments may be kept to a minimum if careful site planning is performed before detailed design. As detailed design advances for the distributed small basins, some compromises may be necessary because of restricted right-of-way or other conditions. This is expected since compromise is not consistent with rational engineering design.

2.3 Watershed Hydraulics

2.3.1 Design Storm Selection

The objective in conventional drainage design is to obtain peak flow quantities per unit time and velocities for proper sizing of various elements in the drainage system . For basin deign, the cumulative discharge into the basin with time is the object of interest. However, when drainage system design is completed, all formation necessary to calculate mass inflow to the basin is available for use with an appropriate design storm, as described in the following section .

Selection of rainfall intensity, frequency and duration for a design storm should be made using Weather Bureau data[3] pertaining to the locality. Selected curves for New York State are shown in Appendix E. The design rainfall frequency and duration to be used in constructing the mass inflow curve of rainfall should be chosen with due regard for possible consequences of basin overflow during the peak of a storm, especially where that particular storm would not be accompanied by flash flooding elsewhere in the area. Local topography, present or projected land use and the adequacy of other storm drainage systems in the area are important considerations when deciding on an adequate, yet reasonable, recurrence interval. In general, under the conditions that a basin overflow would pond water on the highway in depressed sections, a 10- or 25-year storm would be adequate and conservative. However, if excessive basin overflow may cause costly damage to adjacent property and disrupt essential activities, a 50-year storm should be chosen.

2.3.2 Determination of Mass Inflow Curve

The methods used most to develop the mass inflow curve of runoff at any given rainfall frequency are the rational method and the unit hydrograph method. The rational method is only reliable for estimating peak runoff from drainage areas less than 640 acres (2 .6 km^2). Detailed procedures used by this method in developing a mass inflow curve can be found in Ref. 1. Although this method is mathematically simple, the designer must use judgment in evaluating the limitations of its accuracy. In particular, care must be exercised in selecting the weighted average runoff coefficient, sine it can have a very significant effect on the mass inflow curve.

For drainage areas greater than 640 acres (2 .6 km^2), the unit hydrograph method is recommended for estimating runoff magnitudes of different frequencies. To use this approach, continuous records of runoff and precipitation for the particular drainage area are needed.

A number of other methods have been developed for representing a unit hydrograph in terms of runoff parameters such as lag time, coefficient of peak discharge, time concentration, storage coefficient, etc. If such parameters can be adequately related to measurable physical characteristics of water sheds, it becomes possible to synthesize unit hydrographs for ungaged watersheds. Three commonly used techniques for depicting unit hydrographs are the Clark, Snyder, and SCS methods. Details of each are generally presented in standard hydrology tests[4, 5]. Once a unit hydrograph has been derived for a particular drainage area and rainfall duration, the unit hydrograph and inflow hydrograph for any other duration can be obtained. Finally, the inflow hydrograph would be mathematically manipulated to yield the mass inflow curve.

If the watershed tributary to the recharge basin is divided into subareas of homogeneous characteristics, unit hydrographs for each subareas are superimposed to result in a composite inflow hydrograph for the entire watershed.

2.4 Subsurface Soils Explorations

Subsurface soils explorations should be scheduled with the Regional Geotechnical Engineer as soon as possible after the proposed basin sites are established. Subsurface information is then available at the appropriate time for design use. These explorations are used for the following purposes:

1. To establish the subsurface soil profile and location of each unsaturated permeable soil layer,
2. To establish the highest groundwater and the perched water elevations, and
3. To obtain soil samples for laboratory testing throughout the profile depth, particularly below side slopes and the basin floor elevation to be established later.

The number and extent of explorations for a site will be determined by the Regional Geotechnical Engineer, based on terrain reconnaissance data, if available, and existing knowledge of local geology and subsurface conditions. However, at least one boring or test pit is required for any site to provide samples for the special analyses necessary to calculated the characteristic infiltration curve.

2.5 Soil Properties and Laboratory Tests Required for Analysis

The particular strata of interest for determining infiltration properties are those that lie directly below the basin side slopes and basin floor. This shallow zone of soil extending from the ground surface to a depth not exceeding 0.25H ft. below the basin floor will control all infiltration out of the basin. It does not matter whether soils further down have greater or lesser permeability, so long as they are reasonably permeable (two orders of magnitude less is a reasonable limit), are not laterally confined and are unsaturated. Because the basin floor elevation is not definitely established until later, soil tests are run throughout the depth of the exploration to accommodate the range of possible floor elevations expected. Where soil deposits are deep and uniform, this is of little consequence and the testing program can be abbreviated.

The tests recommended for cohesionless, non-plastic soils differ from those required for soils exhibiting plasticity, as shown in Table 1. Tests are described in this manual only by name. They may be performed in the Regional Soils laboratory or by the Geotechnical Engineering Bureau, at the discretion of the Regional Geotechnical Engineer.

2.6 Soil Design Analysis

2.6.1 Soil Profile Evaluation

Plot and summarize all subsurface and laboratory test data. These data must be studied with respect to the soil properties controlling infiltration at the site. As a general rule, the control zone for the infiltration rate will be in the soil below the basin side slopes and the first 0.25H ft. of the soil layer underlying the basin floor. Soil properties outside this area may exert a secondary control only when the soil lis markedly less permeable and the profile is such that lateral spread of the wetting front is prevented if its vertical advance is impeded by this layer. In other words, the surface control zone, where the primary transmission zone is established, will control infiltration under any condition where the water transmitted through it has a place to go, vertically and/or laterally.

2.6.2 Determination of Soil Design Parameters

The following additional calculations of soil properties are required for the infiltration analysis.

a. Volumetric water content in natural drained state, θ_n

The natural drained moisture content of soil is defined as the water held in the soil after the excess gravitational water has drained away and after the rate of downward movement of water has practically ceased. The volumetric water content in natural drained state can be found from:

$$\theta_n = w_n G (1-\eta) \qquad (1)$$

where w_n = natural drained moisture content expressed as a decimal. Use 0.03 for gravels and sands, and 0.05 for silts.

G = specific gravity of soil solids, and

η = porosity.

Table 1 Test Schedule

Testing Required			
Test	**Property Symbol**	**Cohesionless Non-Plastic Soils**	**Soils Exhibiting Cohesion or Plasticity**
Specific Surface Analysis	SS	Yes[1]	No
Natural In-Situ Porosity	η	Yes[2]	Yes
Specific Gravity of Soil Solids	G	Yes	Yes
Saturated Permeability	k_s	No[3]	Yes[4]
Capillary Suction Potential	ψ_n	No[5]	Yes[4]

1 The purpose of this analysis is to estimate k_s based on k_s-SS-η relationship developed by Loudon[1]. However, the analysis is recommended only for sands and gravels having not more than 5 % passing the No. 200 (75 μm) sieve. For materials having more than 5% fines, skip this analysis and determine k_s by laboratory test.

2 May be estimated from grain size description as shown in Figure 3.

3 Estimated by Loudon Formula or may be determined by laboratory test on soil sample, using upward flow.

4 These tests should be performed only by the Geotechnical Engineering Bureau at Albany.

5 ψ_n can be estimated from Figure 4. D_{50} can be determined from the sieve analysis or hydrometer test.

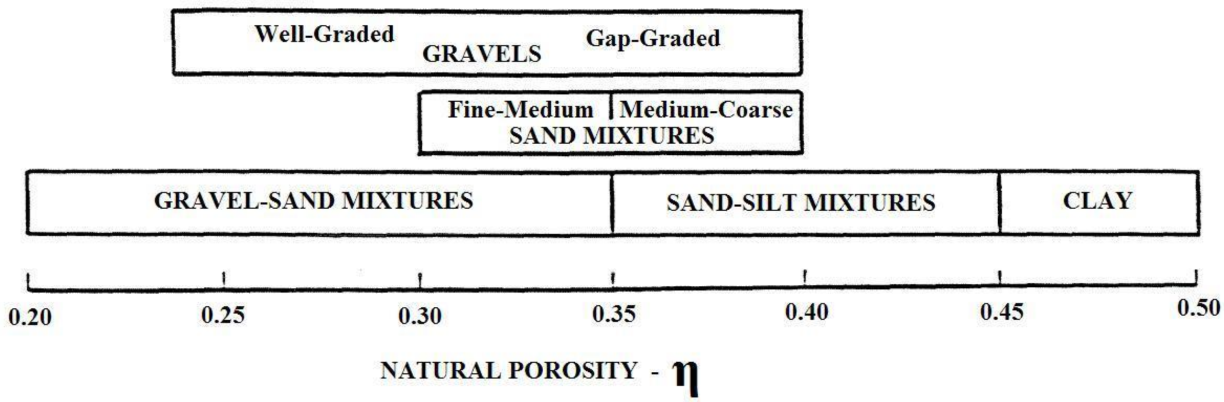


Figure 3 Soil Porosity in Relation to Grain Size Classification (from Ref. 1)

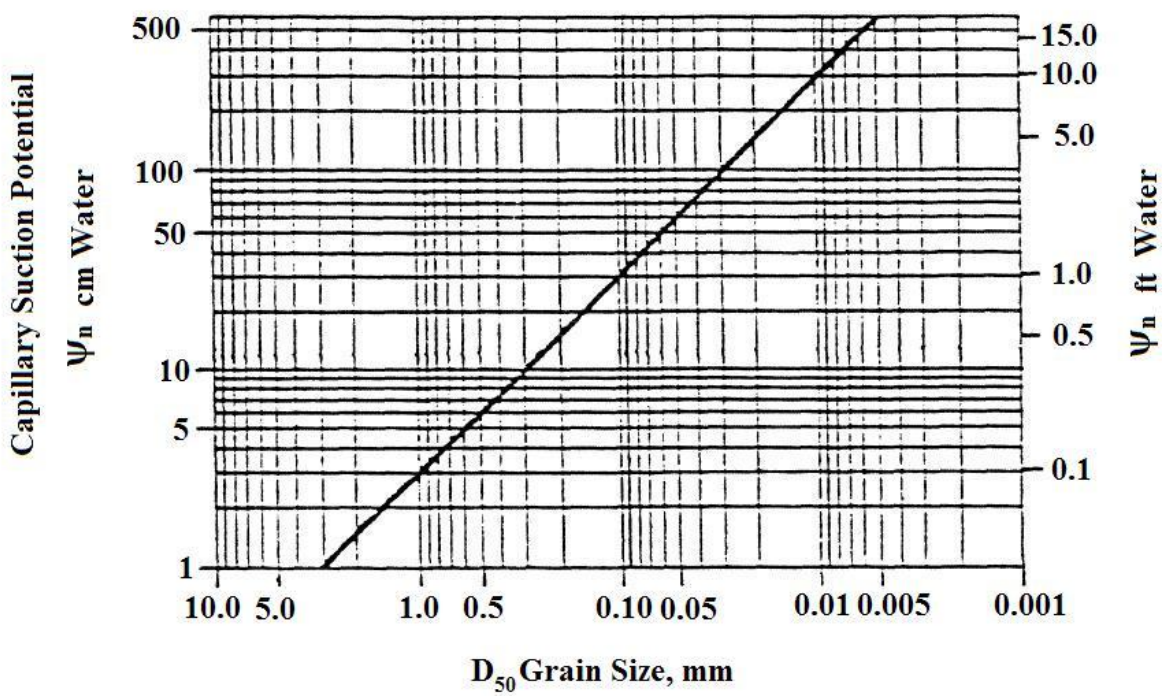


Figure 4 Capillary Suction Potential Term ψ_n vs. Grain Size of Cohesionless Soils (from Ref. 1)

b. Volumetric water content in transmission zone during ifiltration, θ_t

The moisture content in the transmission zone during infiltration is not known beforehand. However, moisture contents corresponding to 80% and 70% saturation can be assumed for silts and sands, respectively. Therefore, θ_t can be found from:

$$\theta_t = s\,(\eta) \qquad (2)$$

where s = degree of saturation expressed as a decimal, and
η = porosity.

c. Hydraulic conductivity of transmission zone, k_t

The hydraulic conductivity of the transmission zone is obtained from the saturated soil permeability, k_s, by means of the following equation:

$$k_t = \frac{k_s\,(\theta_t - \theta_n)}{(\eta - \theta_n)} \qquad (3)$$

d. Hydraulic diffusivity, α

This term is obtained by the following equation:

$$\alpha = k_t / (\theta_t - \theta_n) \qquad (4)$$

2.6.3 The Infiltration Equation

The cumulative infiltration quantity is give by:

$$Q = 2k_t\ A_f\ (H/2 + \psi_n) \sqrt{(t / \pi\,\alpha)} \qquad (5)$$

where Q = cumulative infiltration flow at any time t,
ψ_n = capillary suction potential at natural drained moisture content prior to infiltration
α = hydraulic diffusivity
H = maximum basin operating head, and
A_f = plane flow area which is defined as the horizontal plan area of the basin at depth of H/2.

Eq. (5) can also be expressed in the form,

$$Q = N\,(t)^{½} A_f \qquad (6)$$

$$\text{where } N = 2k_t\ (H/2 + \psi_n) / \sqrt{(\pi\,\alpha)} \qquad (7)$$

2.6.4 Basin Operating Head and Basin Top Surface Area

For a given unsaturated permeable soil subjected to infiltration, the cumulative infiltration flow, Q, through soil at any time t is a function of the soil parameters, the basin operating head and plane flow area as shown in Eq. 5. If the basin configuration and side slopes are given, the plane flow area can be expressed in terms of the basin operating head, H, and corresponding basin top surface area. For example, the plane flow area, A_f, for a square basin with 1 vertical on 2 horizontal side slopes is:

$$A_f = A_s - 4 H \sqrt{A_s} + 4 H^2$$

where A_s= basin top surface area

Eq. (5) indicates that the infiltration quantity per unit of flow area is directly proportional to the operating head selected. Similarly, if the maximum operating head is kept constant, the flow mass infiltration quantity is directly proportional to the flow area. The designer, therefore, can establish a whole spectrum of paired values for H and A_f or A_s, that will provide an equal hydraulic result for a proposed basin. This becomes a relatively simple task using the computer program.

These results can then be examined with varying shapes and side slopes to find a "best match" for a site. The objective, of course, is to find an optimum pair of values, H and A_s, for the site in terms of environmental impact, available right-of-way and a long, maintenance-free life.

2.7 Basin Size Design

Rational basin designs can be developed using two different approaches. Approach I deals with the case where available land is limited in area or a basin is to be sized with a given top surface area and a peak operating head to be determined. Approach II deals with the case where a basin is to be designed at a given peak operating head. The respective design procedures for Approaches I and II are illustrated by example problems in Appendix A.

2.7.1 Compute Program RECHARGE

The Fortran program RECHARGE, which consists of a main program and four subroutines (SIEVE, FLOW, HITA and TAHI), was developed especially for basin design. This program is designed to run on an IBM PC-AT, P-XT, PS/2 microcomputer or any IBM compatible.

The infiltration equation was incorporated into the program to represent unsaturated, unsteady-state flow through soils. The form of input is interactive. The program is written to enable the designer to make multiple runs of the basin analysis for given soil properties and inflow quantities. The sequence of program operation, input data and output sequences, and error messages are listed in

Appendix B. An example of computer input and output summary is shown in Appendix C. A listing of program RECHARGE is included in Appendix D.

The New York State Department of Transportation will not be responsible for any results obtained from the use of shared computer programs or stored data. including direct, indirect, or special or consequential damages. No technical support will be provided. No warranties are extended or granted, either expressed or implied, with respect to the accuracy and/or performance of any materials provided. The materials provided may be reproduced by the receiving agency, but may not be given to another agency without the permission of the NYSDOT.

3. CONSTRUCTION GUIDELINES

3.1 Construction

As basin excavation is a source of fill for embankments, excavation is usually desired early in project construction. However, transport of excessive quantities of tine sediments into the basin from storms occurring during the project construction period will reduce or impair the expected performance of the basin. If protection of the basin under construction is not provided and damage occurs, then corrective (restorative) maintenance will be the required recourse. A recommended way of avoiding this problem at no additional cost is to sequence the steps in constructing the basin with the work on the main project. This is described below as a two-stage operation.

The basin is initially excavated early in construction, leaving a 1 ft. (0.3 m) thickness of material over the final floor elevation. Drainage from the project watershed during construction may then be led to the basin if necessary. If heavy inflow occurs, bringing excessive sedimentation of fines, the surface will "mud-crack" after drying. At this time the surface should be skimmed off prior to subsequent storms.

When the project is nearly complete and permanent erosion controls are in place throughout the basin watershed, excavate the basin to final lines and grade, removing the excess natural soil and sediment. Care should be exercised during this step to avoid excessive compaction of the basin surfaces. Then seed or sod as described in Sec. 3.4, construct the permanent inlet(s) and connect to the storm drain system.

3.2 Watershed Erosion Control

Close attention to sound erosion control practices[6, 7, 8] in the watershed will result tolerable sediment deposition in the basin and keep maintenance costs to a minimum. The quantity of silt contained in water flowing into the basin by erosion will vary from storm to storm depending on many factors, but as an annual average, concentrations of solids up to about 1,000 ppm can probably be assimilated by a basin floor with a vigorous stand of turf (see Sec. 3 .4). This is equivalent to about 1 ton of solids for each 32,000 ft^3 of water (1 kg of solids per m^3 of water). If the earth slopes in the watershed are provided with thick vegetative cover, and ditches or channels are suitably protected from erosion, solid concentrations of one-half or less of this figure are reasonable expectations. Good erosion control in the watershed can produce practically maintenance-free recharge sites with turf floors. On the other hand, poor attention to erosion control in the watershed can result in excessive maintenance, cause poor public relations and environmental or health problems.

In urban areas, a portion of the watershed area often may lie outside of State right-of-way. If construction activities occur in these areas, those responsible for design should establish temporary and permanent erosion controls as required to protect the recharge area from excessive siltation.

3.3 Inlet Design

The fundamental consideration for basin inlet design is the prevention of scour at the culvert and at the basin floor. Thus the peak entrance velocity of inflow to the basin must be held within limits by suitable design of the upstream storm drain system and the inlet itself. Refer to Ref. 6 (specifically Section 3.5.2 and 3.5.3) for protective aprons, energy dissipators and stilling basins when steep gradients and high velocities cannot be avoided.

Runoff from surrounding land, flowing toward the basin, should be intercepted by top-of-slope gutters and collected for guided discharge into the main basin inlet[8].

3.4 Turf Establishment

Surfaces of the side slopes and floor should be seeded, as they represent the flow area of the basin. Dense turf not only prevents erosion and sloughing of the slopes, but also provides a natural means of maintaining relatively high infiltration rates.

Development of thick vigorous turf in the basin is a self-maintaining feature for a recharge site once erosion control is satisfactorily established in the watershed (See Section 3 .2).

3.4.1 Topsoil

Topsoil native to the site and stockpiled prior to excavation may be used to aid in turf establishment. Care should be taken to avoid excessive compaction of the seedbed so that the new roots have little difficulty in taking hold.

3.4.2 Fertilization

A complete starter fertilizer such as 10-6-4 is recommended to encourage deep root development. Apply at a rate of 1,000 lbs per acre, approximately 23 lbs per 1,000 ft^2 (1 kg per 10 m^2) when preparing the seedbed. These general criteria should be reviewed with the Regional Landscape Architect to verify their applicability to a specific site.

3.4.3 Seeding

The brief periods of inundation in a recharge area are no problem for most grass species. Drought-resistance, however, is an important consideration. The Regional Landscape Architect should be consulted regarding an appropriate seed for a given climate and soil condition.

The placement of sod may be advisable in the vicinity of the inlet and protective apron. The sod will not only better resist erosion around the inlet during a storm before the grass gets a foothold, but will also help slow down velocities as the inflow spreads over the floor. Mulch should always be employed over the newly seeded surfaces for protection, moisture retention and early germination of the seed.

4. MAINTENANCE GUIDELINES

4.1 General

The primary requirement for assuring that a recharge basin continues to perform as intended is periodic maintenance as dictated by the results of regularly scheduled inspections and evaluations. Noting warning symptoms early, instead of waiting for a major performance problem to occur, often creates a situation where a quick, simple and inexpensive cure is possible. Fortunately, there may be a lag of years between the first appearance of symptoms and a sudden trend to non-performance. This chapter explains how performance problems develop with recharge basins, then closes with a table summarizing the readily observable symptoms, effects and the corresponding corrective recommendations.

4.2 Basin Performance Decline

The major cause of diminishing basin performance is clogging of the infiltration surface. This occurs by a succession of events. First, fine sediments in the inflow settle out and accumulate over the infiltration surface over a period of time. Second, infiltration does not occur as rapidly as before and soon there is a sustained period of time where the basin does not dry out for several weeks because of the accumulated "silt" coupled with frequent rainfall. It is during this period, when favored by high temperatures, that the third event takes place -- strains of microbiological growths rapidly propagate, clogging the layer of fine sediment and interfacing soil pores still further with what is best described as "slime". If the basin does dry out, these colonies die and the surface unclogs. If it does not dry out, the colonies continue growing, reducing the probability of ever drying out. This situation leads to a transformation wherein the basin becomes a more or less permanent body of standing water, with only its upper side slopes still able to infiltrate storm water in any appreciable quantity.

The above scenario is not inevitable and can be avoided entirely. The key is to promote drying out following a storm. Very modest control of watershed erosion (Sec. 3.2) coupled with vigorous turf in the basin as next discussed, can neutralize the sedimentation problem which otherwise starts the performance decline cycle. Drying out, however, is still essential and the grass will help achieve this condition. Keeping the basin shallow for good air circulation assists the grass to complete the job resulting in a basin which can be practically maintenance-free.

4.3 Turf as a Preventive of Decline

Turf on the basin floor and side slopes has five beneficial functions as follows:

1. Increases soil porosity and maintains stable granulation and therefore, high infiltration capacity due to root growth.
2. Increases transpiration of water leading to subsequent drying out of soil.
3. Promotes desirable biotic activity leading to greater air and water permeability.
4. When inflow to the basin is rapid, resists the cutting action of water currents and protects against erosion in the basin itself.
5. Provides the ability to assimilate light sediment depositions and rapidly convert them

into the growth supporting layer.

In the absence of healthy vigorous vegetation, these five benefits are lost and their opposites apply.

4.4 <u>Inspection and Troubleshooting</u>

The principle function of periodic inspection is to detect and correct any source of heavy sediment deposition from the watershed and any adverse effects from it over the recharge area.

Table 2 provides a guide for conditions to look for, their effect upon performance if not attended to, and the corrective action to be taken.

Rules are often desired to set a fixed interval for making basin inspections. Unfortunately, a desirable inspection frequency varies with individual watershed conditions and recent storm activity. An adequate frequency for one basin in a give time period may be inadequate (or excessive) for other basins in the same time period. However, some rules are understandably desirable and the following are suggested:

<u>Inspect all basins</u> following any **<u>major</u>** storm causing local flooding or backed up storm sewers in the local area (Town, County).

<u>Inspect any basins</u> where major construction activity is taking place in their watershed areas following any storm. Also **<u>inspect</u>** erosion protection adequacy at the construction sites at the same times.

4.5 <u>Removal of Accumulated Sediment</u>

As outlined in the Environmental Procedures Manual, Chapter 5.1 Hazardous Waste and Contaminated Material, project managers, designers and Regional Environmental Units should screen all projects for hazardous wastes and contaminated materials if they involve excavation or other disturbance of the soil. This is intended to help assess the nature and extent of contamination and understand how to properly manage or cleanup various kinds of contaminants to comply with federal and State requirements.

Prior to removal of accumulated sediment, Department staff should perform a contaminated materials' screenings, or a "Phase I assessment" as described in Ch. 5.1, to determine whether additional study or testing is necessary.

If the results of an assessment indicate contamination, Section 205 of the Standard Specifications describes how to test and dispose of contaminated soil.

Table 2   Inspection and Troubleshooting Guide

Condition Noted	Effect Upon Performance	Corrective Actions to be Taken
Floor erosion and scour hole near inlet	Adverse to turf maintenance and satisfactory long term performance. May undermine apron or culvert. Unsightly.	1. Lower velocity of entering water by using energy dissipators, stilling pool, or both. 2. Refer to Ref. 9 for protection design.
Appearance of sediment overtopping turf	Adverse to turf maintenance and satisfactory long term performance.	1. Immediately locate and correct source of sediment in the watershed. 2. When floor is dry, remove patches of sediment where turf has been covered, and re-establish turf.
Constriction activity in watershed	May load basin with sediment if adequate precautions are not taken.	1. Require temporary diversion of storm runoff from reaching recharge area, or 2. See that proper temporary and permanent erosion controls are instituted.
Weeds	Assist to maintain infiltration rates, but may be unsightly, crowd out turf, and become a fire hazard.	1. Regular mowing of turf provides good weed control. Herbicides may be used according to instructions in similar fashion to the adjacent watershed.
Lack of normal drying out after a storm	Can quickly become extremely adverse to performance. Caused by neglect of regular preventative inspection and timely correction of minor problems. Provides environment favorable to soil-clogging microbial growths such as algae, slimes, and fungi.	1. Treat standing water to kill off the microbial growths, using chlorine or copper sulfate in recommended dosages*. 2. When dry, remove accumulated sediment and correct cause of excessive sedimentation in watershed. 3. Re-establish turf over the basin floor.

*Subsequent to approval from NYSDEC or other local water authorities (especially on Long Island), permissible dosage ranges are as follows:

	Minimum Effective	Maximum Permissible
Copper Sulfate	0.01 ppm (0.8 lb/10^6 gal, 0.1 kg/10^7 L)	2.0 ppm (16.2 lb/10^6 gal, 2.0 kg/10^6 L)
Cholrine	1.0 ppm (8.3 lb/10^6 gal, 1.0 kg/10^6 L)	2.0 ppm (16.6 lb/10^6 gal, 2.0 kg/10^6 L)

REFERENCES

1. Weaver, R. J. Recharge Basins for Disposal of Highway Storm Drainage, Research Report 69-2, Engineering Research and Development Bureau, New York State Department of Transportation, May 1971.

2. Weaver, R. J. and Kuthy, R. A. Field Evaluation of A Recharge Basin, Research Report 26, Engineering Research and Development Bureau, New York State Department of Transportation, February 1975.

3. Rainfall Intensity-Duration-Frequency Curves for Selected Stations in the United Sates, Alaska, Hawaiian Islands, and Puerto Rico, Technical Pater No. 25, Weather Bureau, US Department of Commerce, December 1955, P. 31.

4. Viessman, W. Jr., et. al. Introduction to Hydrology, New York: Harper and Row, 2nd Edition, 1977.

5. Hydrology, Engineering Handbook Section 4, Soil Conservation Service. US Department of Agriculture, 1972.

6. Bank and Channel Protective Lining Design Procedures, Soil Design Procedure SDP-2, Soil Mechanics Bureau, New York State Department of Transportation, August 1971.

7. Construction Guidelines for Temporary Erosion Controls, Construction Subdivision, New York State Department of Transportation, April 1974.

8. "Temporary Soil Erosion and Water Pollution Control, Section 209, Standard Specifications, New York State Department of Transportation, January 1985 PP. 2-25 through 2-27.

9. Peterka, A. J. Hydraulic Design of Stilling Basins and Energy Dissipators, Bureau of Reclamation, US Department of the Interior, July 1963.

APPENDICES

APPENDIX A

EXAMPLE PROBLEMS (MANUAL COMPUTATIONS)

Rational recharge basin design is arrived at through a combination of hydraulic and soils engineering functions. The most important elements affecting basin sizes are adequate assessment of local mass inflow and accurate prediction of water infiltration into the underlying soils. Specific information required for design consists of the design storm runoff data for the local watershed, depth to groundwater table and unsaturated properties of the cohesionless soil into which the water will infiltrate. The necessary soil properties are specific gravity, natural moisture content, specific surface area, grain size distribution, natural porosity, hydraulic conductivity of transmission zone, capillary suction potential and hydraulic diffusivity. These are covered in detail in Ref. 1.

The designer can choose one of two design approaches, each of which is illustrated by an example problem. Approach I deals with the case where a basin is to be designed for a given surface area, but with basin peak operating head unknown. Approach II permits the basin size and dimensions to be designed for a given peak basin operating head.

The procedures for calculating the time-dependent mass inflow quantities are not presented here. The reader may refer to Example Problem 1 of Ref. 1 for details of the method used in the following design example or use any other appropriate procedure for obtaining mass inflow.

APPROACH I *(US Customary Units)*

Given: A recharge basin is proposed to dispose of highway storm runoff. Coordinates of the mass inflow curve for the proposed basin site are listed below:

Time (hours)	Inflow Q_i (million ft^3)	Time (hours)	Inflow Q_i (million ft^3)
1	0.08	10	6.48
2	0.16	11	7.10
3	0.50	12	7.60
4	1.11	13	7.94
5	1.82	14	8.16
6	2.80	15	8.27
7	3.79	16	8.37
8	4.80	17	8.42
9	5.74	18	8.42

The available land for basin use is limited to 210,000 ft^2. The subsurface soil is sandy silt with the following properties:

Natural porosity,η = 0.40
Hdraulic conductivity of transmission zone, k_t = 2.16 ft/hr (from Equations (1), (2), and (3))

Capillary suction potential, ψ_n = 0.18 ft. (from Fig . 4)
Hydraulic diffusivity, α = 9.32 ft^2 /hr (from Equations (1), (2), (3) and (4))
Depth from ground surface to ground water table = 50 ft.

Find: Size and dimension of a square basin plan with 1 vertical on 2 horizontal side slopes.

Step 1: Actual mass inflow curves (such as determined from field instrumentation) usually will have a tail or inflection at early values of time. The tabulated data have this characteristic, which requires correction to time coordinates to remove this tail. The method of establishing this time correction, 3.3 hours, is shown in Figure 1A. The coordinates of the corrected mass inflow curve are tabulated below:

Time (hours)	**Corrected Inflow Q_i (million ft^3)**	**Time (hours)**	**Corrected Inflow Q_i (million ft^3)**
1	1.00	10	8.00
2	2.05	11	8.19
3	3.00	12	8.35
4	4.08	13	8.41
5	5.02	14	8.42
6	5.85	15	8.42
7	6.85	16	8.42
8	7.22	17	8.42
9	7.68	18	8.42

If the mass inflow curve is calculated from the procedures in Example Problem 1 of Ref. 1, no tail is obtained and not time correction is necessary.

Step 2: The equation for infiltration over the basin area is:

$$Q = 2k_t \; A_f \; (H/2 + \psi_n) \sqrt{(t / \pi \alpha)}$$

where: H/2 = the average basin operating head for the peak design storm or half of the maximum basin operating head.
A_f = the basin horizontal cross-sectional area or plan flow area at H/2.

Substituting values of soil parameters into the above equation, gives:

$$Q = (2)(2.16)(H/2+0.18) \sqrt{(t/29.3)} (A_f)$$

$$Q = 0.798 (H/2+0.18) \sqrt{t} (A_f)$$

Step 3: Estimate the range of the peak basin operating head, H, to be used in design in accordance with the following assumptions:

1. From experience, the final design value of Q will be bracketed within the range of 0.29 Q_{ip} and 0.76 Q_{ip}; where Q_{ip} is the cumulative flow at the time when the corrected mass-inflow curve starts peaking.
2. Also from experience, the area of the water surface, A_s, will lie within the range of 1.05 A_f and 1.25 A_f.

The corrected mass-inflow curve as shown in Fig. 1A indicates it starts peaking approximately at coordinates, t=8 hours and $Q_{ip} = 7.3 \times 10^6$ ft^3. Substituting these two numbers into the infiltration equation established in Step 2 and using the two above mentioned basin operating range criteria, yield the following equations:

$$0.76 \text{ x } 7.3\text{x}10^6 = 0.798\ (H_{max}/2+0.18)\ \sqrt{8}\ (A_s/\ 1.25)$$

$$0.29 \text{ x } 7.3\text{x}10^6 = 0.798\ (H_{min}/2+0.18)\ \sqrt{8}\ (A_s/\ 1.05)$$

with A_s = 210,000 ft^2, H_{max}= 28.90 ft. and H_{min}= 9.02 ft.

Step 4: Replot or trace the corrected mass inflow curve on a new sheet of graph paper (Fig. 1B to permit convenient superposition of mass infiltration curves for various assumed peak operating heads.

Step 5: For a square basin with 1 on 2 side slopes, A_f can be expressed in terms of H and A_s as follows:

$$A_f = A_s - 4\,H\,\sqrt{A_s} + 4\,H^2$$

The infiltration equation then becomes:

$$Q = 0.798\ (H/2+0.18)\ \sqrt{t}\ (A_s - 4\,H\,\sqrt{A_s} + 4\,H^2)$$

Assume four values of the peak basin operating head between H_{max} and H_{min} and compute the cumulative infiltration for convenient values of time from the infiltration equation for each value of assumed H throughout the time period of interest.

Plot these four accumulated infiltration vs. time curves on the graph prepared in Step 4. Figure 1B shows the final plot as it will appear at the end of this step.

APPENDIX A

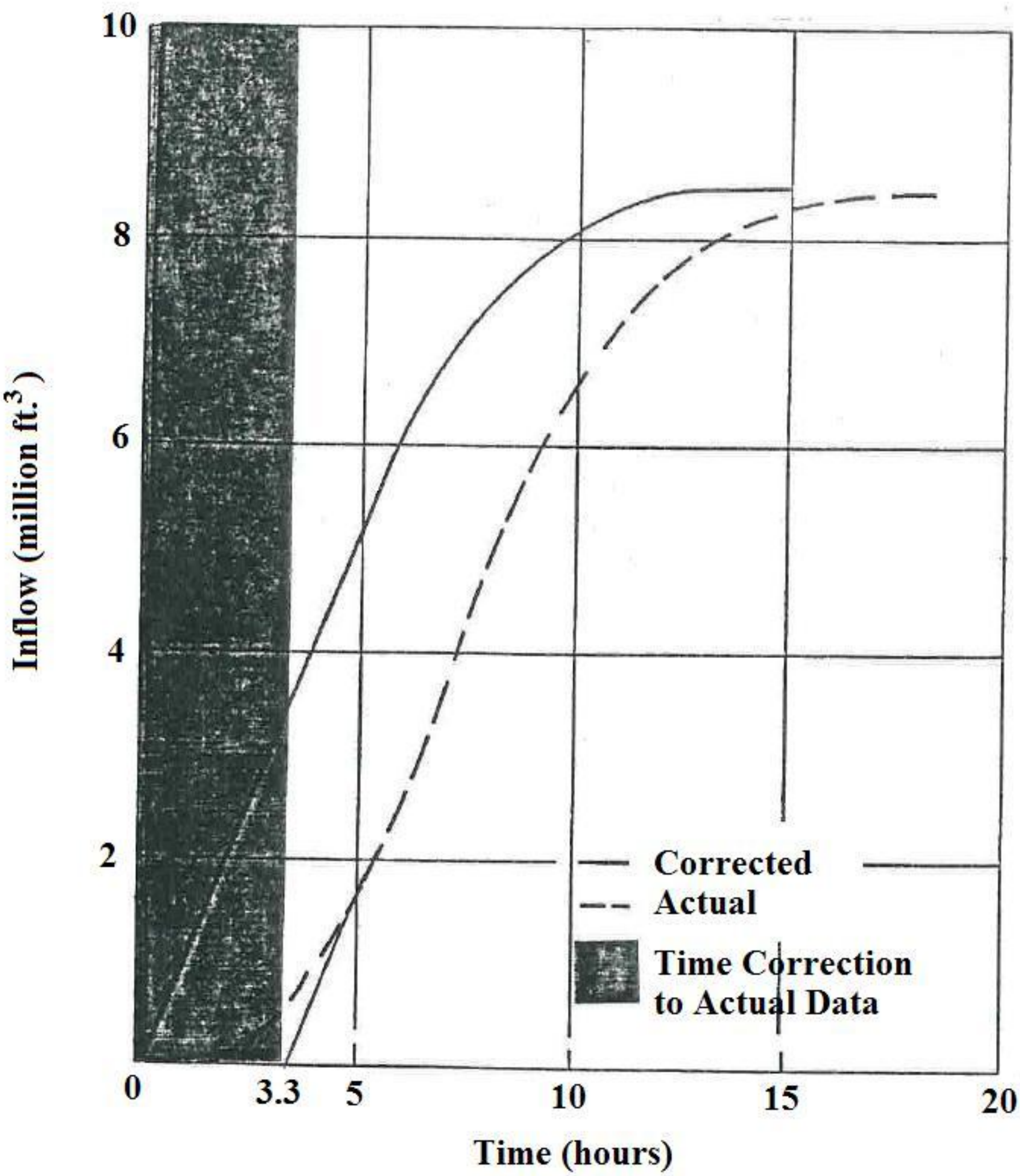


Figure 1A Time Correction for Mass Inflow Curve with Tail

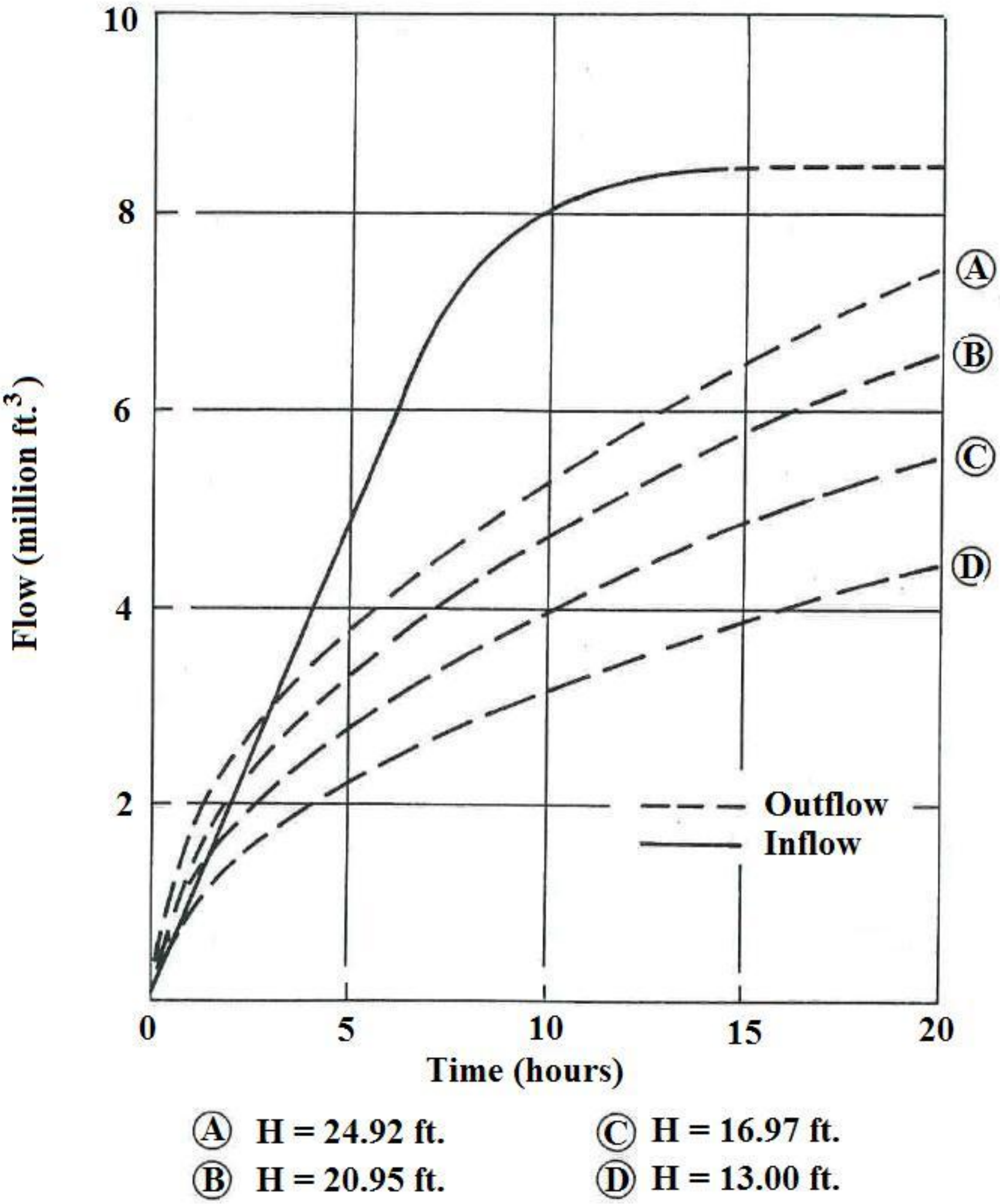


Figure 1B Comparison of Inflow-Outflow Rates

APPENDIX A

Step 6: In Figures 1B, scale off the peak differential, Q, between the mass inflow curve and each of the infiltration curves. This is most conveniently done with dividers. Calculated the basin volumes for the given value of A_s and for each value of assumed peak basin operating head. The following table provides simplified formulae for square, rectangular, and circular basin plans.

Basin Type	**P_b**	**A_s-A_b**	**Basin Volume**
Square and Rectangular	$P_s – 8SH$	$SH(P_b + 4SH)$	$(A_b + A_s + \sqrt{A_bA_s})\ H/3$
Circular	$P_s – 2HS\pi$	$SH(P_b + \pi SH)$	$(2A_b + A_s + SH\sqrt{\pi A_b})\ H/3$

where : P_b = perimeter of basin bottom,
P_s = perimeter of water surface when basin operating head equals H,
A_b = area of basin bottom,
A_s = area of basin top when basin operating head equal H,
S = side slope 1 vertical: S horizontal or cotangent of the angle between the basin side slope and a horizontal plane.
$\pi = 3.1416$

Next determine the difference between ΔQ and basin volume, and tabulate the information as follows:

H (ft.)	**ΔQ (10^6 ft^3)**	**Basin Volume (10^6 ft^3)**	**ΔQ – Basin Volume (10^6 ft^3)**
13.00	4.90	2.43	2.47
16.97	4.05	3.06	0.99
20.95	3.25	3.64	-0.39
24.92	2.65	4.18	-1.53

Step 7: Graphically plot ΔQ – Basin Volume values against H and draw the curve as in Figure 1C. The peak basin operating head H required for the basin is indicated by the point of intersection of the curve with the horizontal axis, in this case, 20 ft.

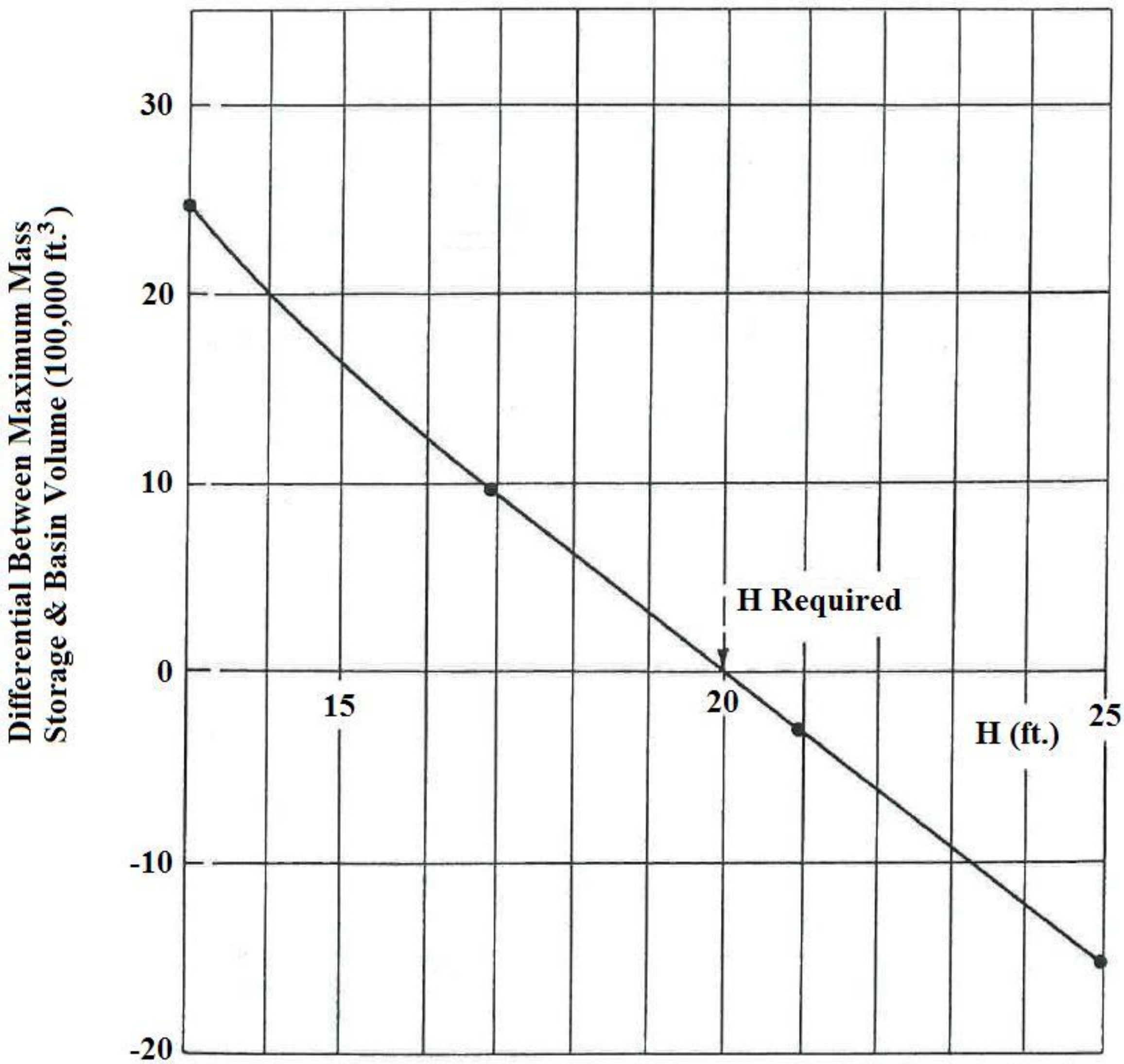


Figure 1C Determination of Required Peak Operating Head, H

Step 8: Check to verify that the distance from the basin floor to the groundwater talble is greater than 0.25H ft. (5 ft.) so that the developed infinite depth infiltration theory holds for the entire time span. In this case, the distance from the basin floor to the groundwater table is 30 ft.; therefore the theory holds.

If the distance from the basin floor to the groundwater was found to be less than 0.25H ft., the design volume would have to be obtained through a combination of steeper side slopes or larger basin surface area than originally proposed.

Step 9: Determine the required basin volume and area of basin bottom using the relationship presented in Step 6.

Design Summary:	**The basin size and dimensions are as follows:**
Top:	458.25 ft. x 458.25 ft., Area = 210,000 ft^2
Bottom:	378.26 ft. x 378.26 ft., Area = 143,000 ft^2
Volume:	3,509,000 ft^3
Depth:	20 ft

APPROACH II *(US Customary Units)*

For the same subsurface conditions and data give in the Approach I example problem, determine the size and dimensions of the basin if the proposed peak basin operating head is 20 ft.

Step 1: The same as Step 1 in the Approach I example problem.

Step 2: With the given values of H, α, k_t, and ψ_n, the infiltration equation is established as follows:

$$Q = 8.12 \sqrt{t} \; A_f$$

Step 3: Using the same approach as detailed in Step 3 of Approach I example problem, estimate the range of the basin surface area to be used in design. This leads to the following two limiting infiltration equations:

$$0.76 \times 7.3\text{x}10^6 = 8.12 \sqrt{8} \; (A_{s\,(max)} / 1.25)$$

$$0.29 \times 7.3\text{x}10^6 = 8.12 \sqrt{8} \; (A_{s\,(min)} / 1.05)$$

thus $A_{s(max)} = 301{,}957 \text{ ft}^2$ and $A_{s(min)} = 96{,}785 \text{ ft}^2$.

Step 4: The same as Step 4 in the Approach I example problem.

APPENDIX A

Step 5: For a square basin with H = 20 ft. and side slopes of 1 on 2, A_f in terms of A_s may be expressed as follows:

$$A_f = A_s - 80\sqrt{A_s} + 1600$$

Substituting this expression in the infiltration equation of Step 2 gives:

$$Q = 8.12\sqrt{t}\,(A_s - 80\sqrt{A_s} + 1600)$$

Assume four values of the basin surface area between A_s limits from Step 3. Next, compute the accumulated infiltration for convenient values for time from the infiltration equation for each assumed value of A_s throughout the time period of interest. Figure 2B show the comparison of inflow and outflow rates.

Step 6: Follow the same procedure as illustrated in Step 6 in the Approach I example problem and tabulate ΔQ, Basin Volume, and the difference between these values (ΔQ-Basin Volume) for each assumed basin surface area as follows:

A_s (10^5 ft^2)	**ΔQ (10^6 ft^3)**	**Basin Volume (10^6 ft^3)**	**ΔQ – Basin Volume (10^6 ft^3)**
1.37	5.15	2.21	2.94
1.79	4.25	2.94	1.31
2.20	3.30	3.69	-0.39
2.61	2.30	4.44	-2.14

Step 7: Graphically plot ΔQ – Basin Volume values against A_s and draw the curve as shown in Figure 2C. The intercept of the curve with the A_s axis gives the required A_s for the basin, in this case 210,000 ft^2.

Step 8: The same as Step 9 in the Approach example problem

Step 9: **Design Summary: The basin size and dimensions are as follows:**

Top: 458.25 ft. x 458.25 ft., Area = 210,000 ft^2
Bottom: 378.26 ft. x 378.26 ft., Area = 143,000 ft^2
Volume: 3,509,000 ft^3
Depth: 20 ft

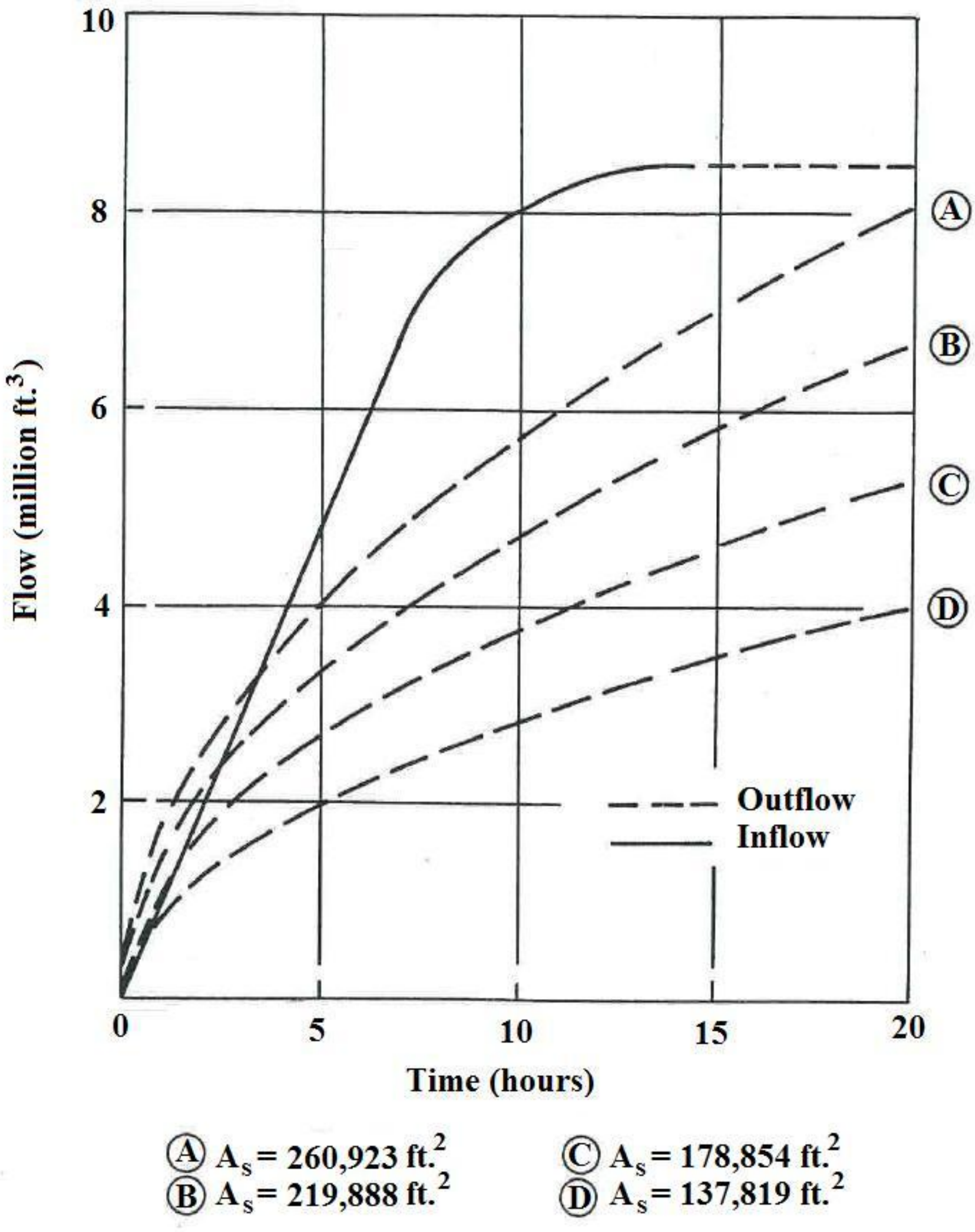


Figure 2B Comparison of Inflow-Outflow Rates

APPENDIX A

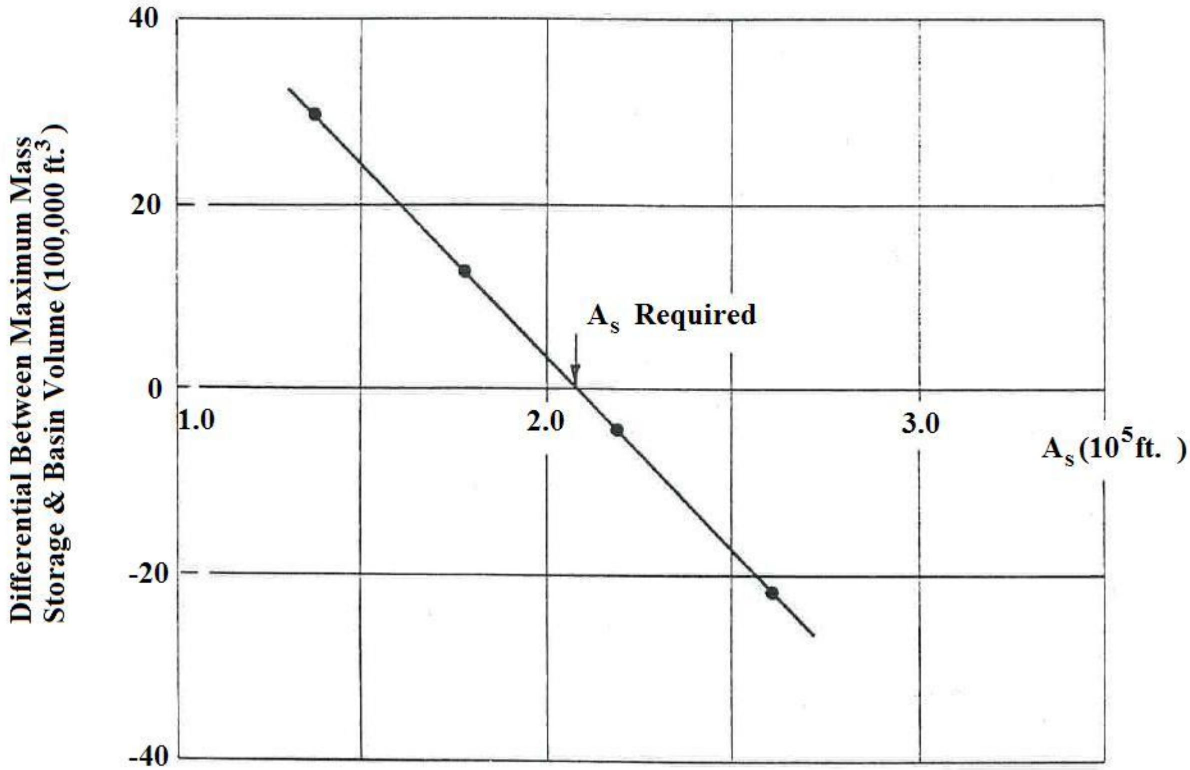


Figure 2C Determination of Required Basin Surface Area, A_s

APPENDIX A

APPROACH I *(International System of Units (SI))*

Given: A recharge basin is proposed to dispose of highway storm runoff. Coordinates of the mass inflow curve for the proposed basin site are listed below:

Time (hours)	**Inflow Q_i (thousand m^3)**	**Time (hours)**	**Inflow Q_i (thousand m^3)**
1	2	10	183
2	5	11	200
3	14	12	215
4	30	13	225
5	50	14	230
6	79	15	235
7	107	16	238
8	135	17	240
9	162	18	240

The available land for basin use is limited to 18,600 m^2. The subsurface soil is sandy silt with the following properties:

Natural porosity, $\eta = 0.40$
Hdraulic conductivity of transmission zone, $k_t = 0.66$ m/hr (from Equations (1), (2), and (3))
Capillary suction potential, $\psi_n = 0.054$ m (from Fig . 4)
Hydraulic diffusivity, $\alpha = 0.866$ m^2 /hr (from Equations (1), (2), (3) and (4))
Depth from ground surface to ground water table = 15 m.

Find: Size and dimension of a square basin plan with 1 vertical on 2 horizontal side slopes.

Step 1: Actual mass inflow curves (such as determined from field instrumentation) usually will have a tail or inflection at early values of time. The tabulated data have this characteristic, which requires correction to time coordinates to remove this tail. The method of establishing this time correction, 3.3 hours, is shown in Figure 1A. The coordinates of the corrected mass inflow curve are tabulated below:

APPENDIX A

Time (hours)	Corrected Inflow Q_i (thousand m^3)	Time (hours)	Corrected Inflow Q_i (thousand m^3)
1	29.0	10	226.0
2	58.0	11	231.0
3	86.7	12	236.0
4	115.0	13	239.0
5	142.0	14	240.0
6	168.0	15	240.0
7	188.0	16	240.0
8	204.0	17	240.0
9	218.0	18	240.0

If the mass inflow curve is calculated from the procedures in Example Problem 1 of Ref. 1, no tail is obtained and not time correction is necessary.

Step 2: The equation for infiltration over the basin area is:

$$Q = 2k_t\ A_f\ (H/2 + \psi_n) \sqrt{(t / \pi\ \alpha)}$$

where: $H/2$ = the average basin operating head for the peak design storm or half of the maximum basin operating head.

A_f = the basin horizontal cross-sectional area or plan flow area at H/2.

Substituting values of soil parameters into the above equation, gives:

$$Q = (2)\ (0.66)\ (H/2+0.054) \sqrt{(t/2.72)}\ (A_f)$$

$$Q = 0.8\ (H/2+0.054) \sqrt{t}\ (A_f)$$

Step 3: Estimate the range of the peak basin operating head, H, to be used in design in accordance with the following assumptions:

1. From experience, the final design value of Q will be bracketed within the range of 0.29 Q_{ip} and 0.76 Q_{ip}; where Q_{ip} is the cumulative flow at the time when the corrected mass-inflow curve starts peaking.
2. Also from experience, the area of the water surface, A_s, will lie within the range of 1.05 A_f and 1.25 A_f.

The corrected mass-inflow curve as shown in Fig. 1A indicates it starts peaking approximately at coordinates, t=8 hours and $Q_{ip} = 2.04 \times 10^5\ m^3$. Substituting these two numbers into the infiltration equation established in Step 2 and using the two above mentioned basin operating range criteria, yield the following equations:

$$0.76 \times 2.04\mathrm{x}10^5 = 0.8\,(H_{max}/2+0.054)\,\sqrt{8}\,(A_s/1.25)$$

$$0.29 \times 2.04\mathrm{x}10^5 = 0.8\,(H_{min}/2+0.054)\,\sqrt{8}\,(A_s/1.05)$$

with A_s = 18,600 m^2, H_{max}= 9.1 m and H_{min}= 2.84 m.

Step 4: Replot or trace the corrected mass inflow curve on a new sheet of graph paper (Fig. 1B to permit convenient superposition of mass infiltration curves for various assumed peak operating heads.

Step 5: For a square basin with 1 on 2 side slopes, A_f can be expressed in terms of H and A_s as follows:

$$A_f = A_s - 4\,H\,\sqrt{A_s} + 4\,H^2$$

The infiltration equation then becomes:

$$Q = 0.8\,(H/2+0.054)\,\sqrt{t}\,(A_s - 4\,H\,\sqrt{A_s} + 4\,H^2)$$

Assume four values of the peak basin operating head between H_{max} and H_{min} and compute the cumulative infiltration for convenient values of time from the infiltration equation for each value of assumed H throughout the time period of interest.

Plot these four accumulated infiltration vs. time curves on the graph prepared in Step 4. Figure 1B shows the final plot as it will appear at the end of this step.

APPENDIX A

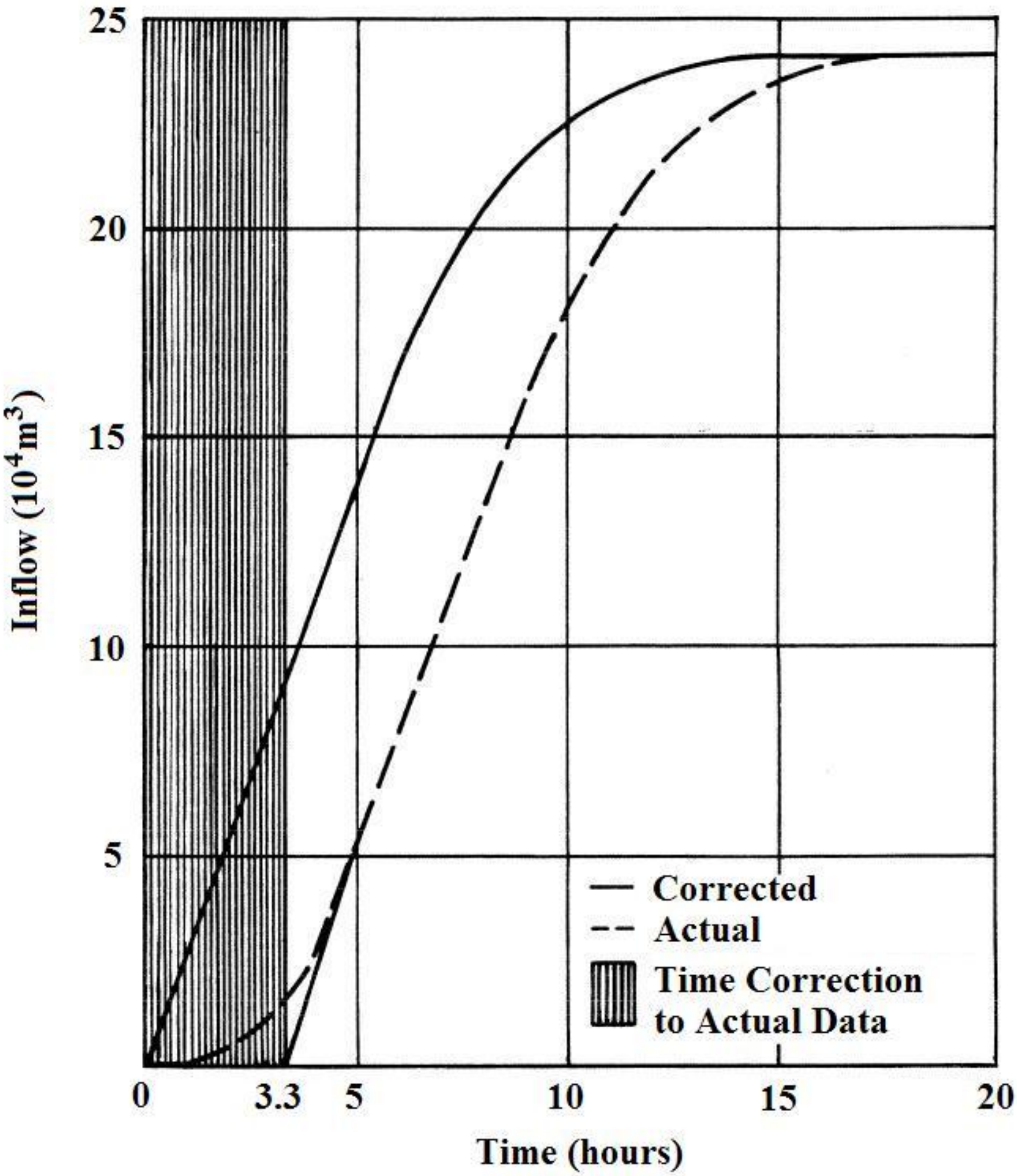
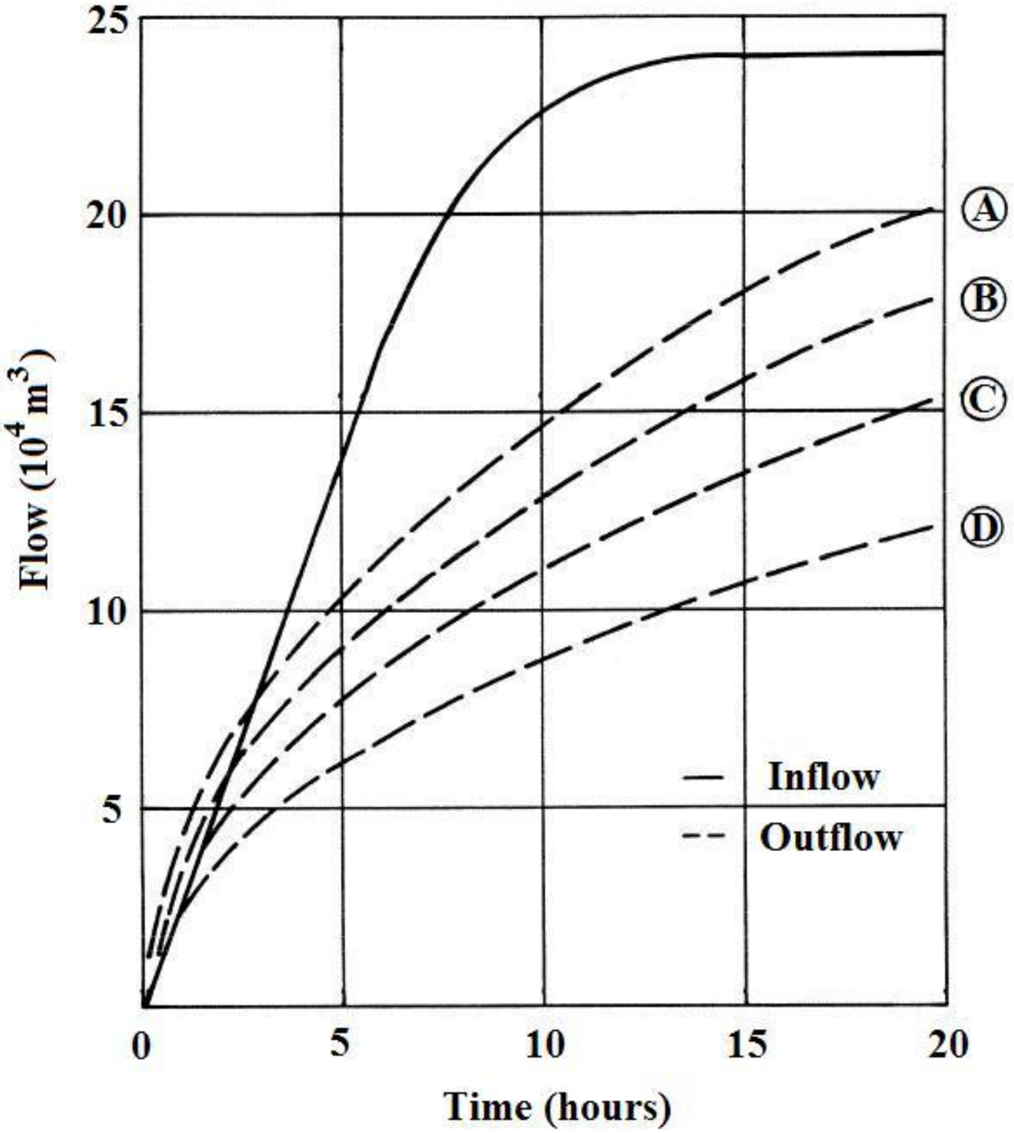


Figure 1A Time Correction for Mass Inflow Curve with Tail

APPENDIX A



A – H = 7.87 m   C – H = 5.36 m

B – H = 6.61 m   D – H = 4.11 m

Figure 1B Comparison of Inflow-Outflow Rates

Step 6: In Figures 1B, scale off the peak differential, Q, between the mass inflow curve and each of the infiltration curves. This is most conveniently done with dividers. Calculated the basin volumes for the given value of A_s and for each value of assumed peak basin operating head. The following table provides simplified formulae for square, rectangular, and circular basin plans.

Basin Type	**P_b**	**A_s-A_b**	**Basin Volume**
Square and Rectangular	$P_s - 8SH$	$SH(P_b + 4SH)$	$(A_b + A_s + \sqrt{A_bA_s})\ H/3$
Circular	$P_s - 2HS\pi$	$SH(P_b + \pi SH)$	$(2A_b + A_s + SH\sqrt{\pi A_b})\ H/3$

where : P_b = perimeter of basin bottom,
P_s = perimeter of water surface when basin operating head equals H,
A_b = area of basin bottom,
A_s = area of basin top when basin operating head equal H,
S = side slope 1 vertical: S horizontal or cotangent of the angle between the basin side slope and a horizontal plane.
$\pi = 3.1416$

Next determine the difference between ΔQ and basin volume, and tabulate the information as follows:

H (m)	**ΔQ (10^5 m^3)**	**Basin Volume (10^4 m^3)**	**ΔQ – Basin Volume (10^4 m^3)**
4.11	1.40	6.75	7.25
5.36	1.17	8.48	3.25
6.61	0.97	10.10	-0.31
7.87	0.79	11.50	-3.54

Step 7: Graphically plot ΔQ – Basin Volume values against H and draw the curve as in Figure 1C. The peak basin operating head H required for the basin is indicated by the point of intersection of the curve with the horizontal axis, in this case, 6.5 m.

APPENDIX A

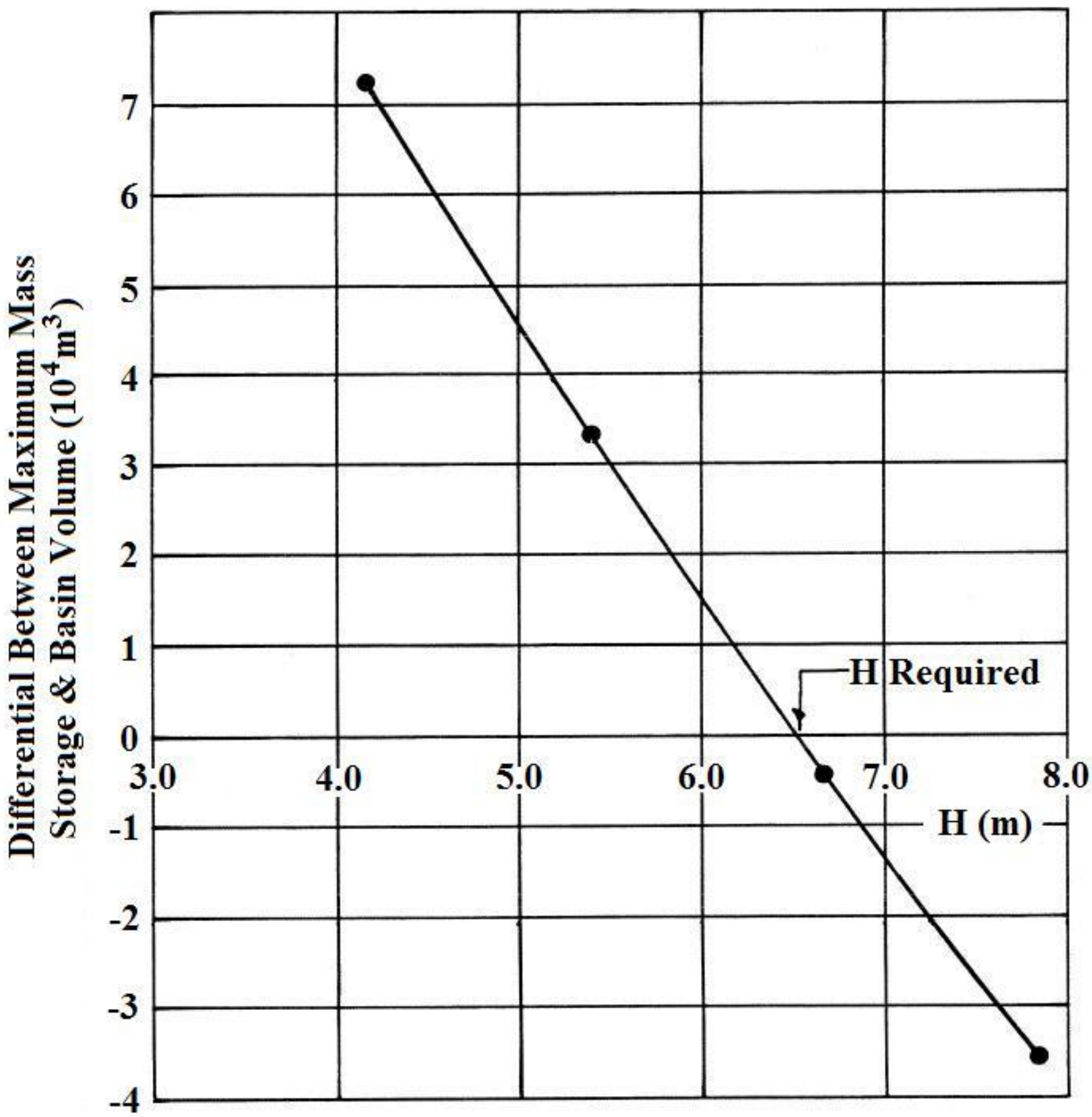


Figure 1C Determination of Required Peak Operating Head, H

Step 8: Check to verify that the distance from the basin floor to the groundwater talble is greater than 0.25H m (1.63 m) so that the developed infinite depth infiltration theory holds for the entire time span. In this case, the distance from the basin floor to the groundwater table is 8.5 m; therefore the theory holds.

If the distance from the basin floor to the groundwater was found to be less than 0.25H m, the design volume would have to be obtained through a combination of steeper side slopes or larger basin surface area than originally proposed.

Step 9: Determine the required basin volume and area of basin bottom using the relationship presented in Step 6.

Design Summary:	**The basin size and dimensions are as follows:**
Top:	136.38 m x 136.38 m, Area = 18,600 m^2
Bottom:	110.36 m x 110.36 m, Area = 12,180 m^2
Volume:	99,400 m^3
Depth:	6.5 m

APPROACH II *(International System of Units (SI))*

For the same subsurface conditions and data give in the Approach I example problem, determine the size and dimensions of the basin if the proposed peak basin operating head is 6.5 m.

Step 1: The same as Step 1 in the Approach I example problem.

Step 2: With the given values of H, α, k_t, and ψ_n, the infiltration equation is established as follows:

$$Q = 2.64 \sqrt{t}\ A_f$$

Step 3: Using the same approach as detailed in Step 3 of Approach I example problem, estimate the range of the basin surface area to be used in design. This leads to the following two limiting infiltration equations:

$$0.76 \times 2.04\text{x}10^5 = 2.64 \sqrt{8}\ (A_{s\,(max)} / 1.25)$$

$$0.29 \times 2.04\text{x}10^5 = 2.64 \sqrt{8}\ (A_{s\,(min)} / 1.05)$$

thus $A_{s(max)} = 25{,}954\ m^2$ and $A_{s(min)} = 8319\ m^2$.

Step 4: The same as Step 4 in the Approach I example problem.

<u>Step 5:</u> For a square basin with H = 6.5 m and side slopes of 1 on 2, A_f in terms of A_s may be expressed as follows:

$$A_f = A_s - 26\sqrt{A_s} + 169$$

Substituting this expression in the infiltration equation of Step 2 gives:

$$Q = 2.64\sqrt{t}\,(A_s - 26\sqrt{A_s} + 169)$$

Assume four values of the basin surface area between A_s limits from Step 3. Next, compute the accumulated infiltration for convenient values for time from the infiltration equation for each assumed value of A_s throughout the time period of interest. Figure 2B show the comparison of inflow and outflow rates.

<u>Step 6:</u> Follow the same procedure as illustrated in Step 6 in the Approach I example problem and tabulate ΔQ, Basin Volume, and the difference between these values (ΔQ-Basin Volume) for each assumed basin surface area as follows:

A_s (10^4 m^2)	**ΔQ (10^5 m^3)**	**Basin Volume (10^4 m^3)**	**ΔQ – Basin Volume (10^4 m^3)**
1.19	1.52	6.01	9.16
1.54	1.23	8.05	4.29
1.89	0.97	10.1	-0.43
2.25	0.70	12.2	-5.19

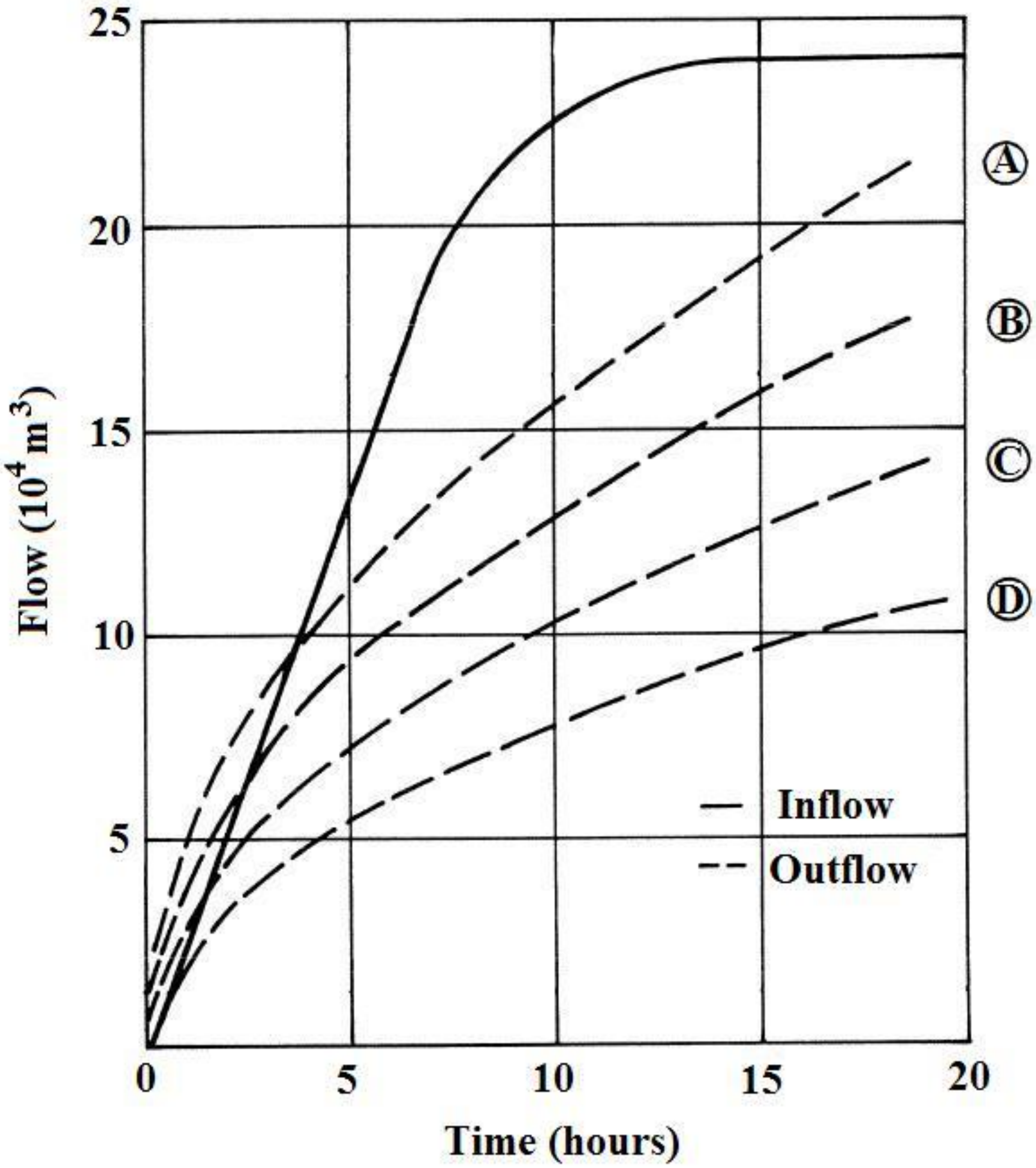
<u>Step 7:</u> Graphically plot ΔQ – Basin Volume values against A_s and draw the curve as shown in Figure 2C. The intercept of the curve with the A_s axis gives the required A_s for the basin, in this case 18,600 m^2.

<u>Step 8:</u> The same as Step 9 in the Approach example problem

<u>Step 9:</u> <u>**Design Summary: The basin size and dimensions are as follows:**</u>

Top:	136.38 m x 136.38 m, Area = 18,600 m^2
Bottom:	110.36 m x 110.36 m, Area = 12,180 m^2
Volume:	99,400 m^3
Depth:	6.5 m

APPENDIX A



A – A_s = 22450 m^2 C – A_s = 15400 m^2

B – A_s = 18920 m^2 D – A_s = 11860 m^2

Figure 2B Comparison of Inflow-Outflow Rates

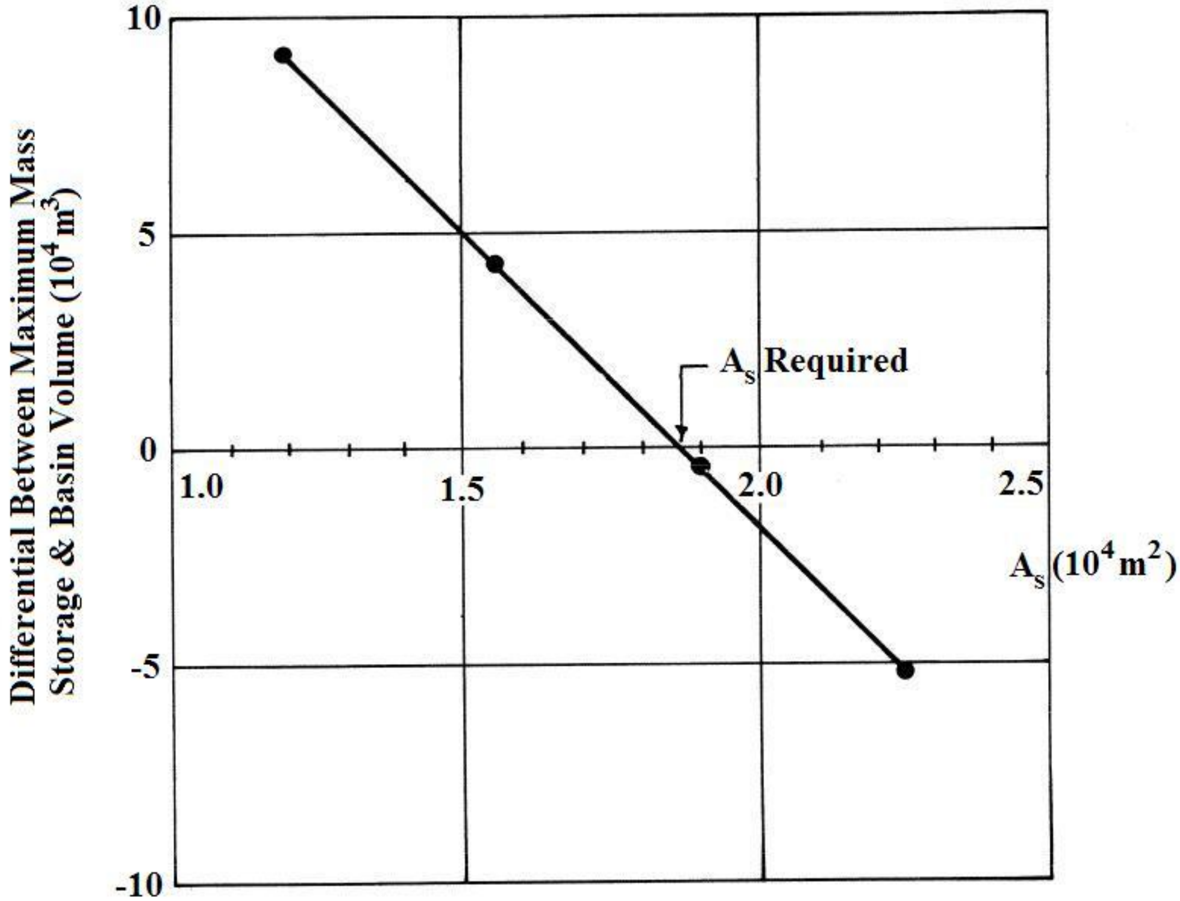


Figure 2C Determination of Required Basin Surface Area, A_s

APPENDIX B

PROGRAM "RECHARGE"– SEQUENCE OF OPERATION, INPUT DATA SEQUENCE, OUTPUT SEQUENCE AND ERROR MESSAGES

1. Sequence of Operation
   a. The main program handles the initial input on material properties and basin geometric information.
   b. Subroutine SIEVE handles the required input for the specific surface analysis fro cohesionless soils, calculates specific surface of solids, and plots a soil grain size distribution curve. For detailed information on specific surface analysis of cohesionless oils, see Test Procedure For Specific Surface Analysis, Soil Test Procedure STP-1, Geotechnical Engineering Bureau, New York State Department of Transportation, August 1973.
   c. Subroutine FLOW corrects the coordinates of the actual mass inflow curve to eliminate a tail or inflection, if existing, at early values of time and to plot the actual and the corrected mass inflow curves and infiltration-time curve.
   d. Subroutine HITA calculates the range of values of top basin surface aarea to be used in design for the problem where a peak basin operating head was given and established the infiltration equation for each assumed value of top basin surface area.
   e. Subroutine TAHI calculates the range of values of peak operating head to be used in design for the problem where a top basin surface area was given and established the infiltration equation for each assumed value of peak operating head.
   f. Subroutine DESIGN plots the differentials between maximum mass storage and basin volume versus basin operating head or basin top surface area. Maximum storage is defined as the maximum differential between mass inflow and infiltration over the entire time span.
   g. Subroutines OPENWS and CLOSWS prepare the screen for graphics output and return the computer to regular text mode, respectively.

2. Input Data Sequence
   Each line of input should contain the following properties listed in the given order and separated by spaces between data. The sequence of input is as follows:
   a. 1st line: maximum 40 alphanumeric characters to identify the project title and PIN.
   b. 2nd line: 1. type of problem, 2. peak operating head in feet or basin top surface area in ft^2.
      If type of problem = 1.0, peak operating head is given
      = 0.0, basin top surface area is given
   c. 3rd line: 1. basin shape, 2. side slopes and 3. ratio of length to width for the basin top surface area.
      If basin shape = 1.0, square or retangular basin plan
      = 0.0, circular basin plan
      For circular basin plan design, assign 0.0 to ratio of length to width for the basin top surface area.
   d. 4th line: depth to groundwater surface in feet (assume a value of 999 if no groundwater table is encountered), specific gravity of solids, moisture

content in the natural drained state expressed as a decimal (use 0.03 for gravels and sands, and 0.05 for silts), porosity of the soil, and degree of saturation in the transmission zone expressed as a decimal (can generally be assumed between 0.8 and 0.85 for silts and 0.7 for sand).

e. 5^{th} line: Enter either 1.0 or 0.0. If the entry is 1.0, the program will calculate the value of saturated permeability of soil using the specific surface analysis, which requires additional inputs as detailed in f. and g. below. Note that, however, this analysis should only be applied to gravels and sands having not more than 5% finer than the No. 200 sieve.

If the entry is 0.0, input values of DFIT and KS are required, where DFIT is defined as the soil particle size at 50% finer by weight and KS as the saturated permeability of soil in ft/hr.

For sands and gravels, enter either 1.0 or 0.0. For silts and soils exhibiting plasticity, enter 0.0.

f. 6^{th} line: number of sets of data for specific surface analysis. Each set consist of three pieces of information as discussed in g. below. The maximum permissible number of data sets is 12.

g. 7^{th} line: data sets of grain-size analysis and shape factor. Each set consists of the following three pieces of information separated by spaces:

1. The opening size, in millimeters, of the finer sieve in a sieve interval or d^2 (Column 2 on Form SM 389).
2. The percentage of the total specimen retained in that sieve interval (Column 5 on Form SM 389).
3. The shape factor

APPENDIX C
EXAMPLE PROBLEM (COMPUTER – *US Customary Units*)

The following pages show an example problem solved by RECHARGE. The pages that appear on the screen and the printer are indicated appropriately on the right-hand top corner of each page. Pages with the word –SCREEN—appear only on the screen and require user input or give directions concerning the output. Pages with the word –PRINTER—appear only on the printed output and re the only form of hardcopy you will acquire by running the program.

Sequence for running RECHARGE is as follows:

1. Start IBM-DOS or MS-DOS
2. Insert the RECHARGE Program diskette into floppy drive A:.
3. When “A:>” appears, type RECHARGE and then press ENTER to run the program. This enables the program to provide you with design results.
4. Press the “Caps Lock” key. Leave this function activated while running the program.
5. Follow the example problem starting on the next page.

NOTE: All input values require decimal points unless otherwise indicated.

APPENDIX C
EXAMPLE PROBLEM (COMPUTER – *US Customary Units*)

--SCREEN--

```
A:\>RECHARGE

****************************************************
*                                                  *
* THE NEW YORK STATE DEPARTMENT OF TRANSPORTATION *
* WILL NOT BE RESPONSIBLE FOR ANY RESULTS OBTAINED*
* FROM THE USE OF SHARED COMPUTER PROGRAMS OR     *
* STORED DATA, INCLUDING DIRECT, INDIRECT, SPECIAL*
* OR CONSEQUENTIAL DAMAGES. NO TECHNICAL SUPPORT  *
* WILL BE PROVIDED. NO WARRANTIES ARE EXTENDED OR *
* GRANTED, EITHER EXPRESSED OR IMPLIED, WITH RE-  *
* SPECT TO THE ACCURACY AND/OR PERFORMANCE OF ANY *
* MATERIALS PROVIDED.  THE MATERIALS PROVIDED MAY *
* BE REPRODUCED BY THE RECEIVING AGENCY, BUT MAY  *
* NOT BE GIVEN TO ANOTHER AGENCY WITHOUT THE PER- *
* MISSION OF THE NYSDOT.                          *
*                                                  *
****************************************************

**************************************************
********** NYSDOT RECHARGE BASIN DESIGN **********
**************************************************

THIS IS A PROGRAM TO CALCULATE RECHARGE BASIN SIZE.
THERE ARE TWO POSSIBLE DESIGN PROCEDURES ALLOWED BY THE
PROGRAM, EITHER THE BASIN OPERATING HEAD IS GIVEN AND
THE TOP SURFACE AREA IS CALCULATED (PROB=0), OR THE TOP
SURFACE AREA IS GIVEN AND THE OPERATING HEAD IS CALCULAT-
ED (PROB=1).

THE OUTPUT IS SENT DIRECTLY TO THE PRINTER AS THE
PROGRAM IS RUNNING, THEREFORE, MAKE SURE THE PRINTER
IS ON. FOR EACH RUN OF THE PROGRAM, THERE WILL BE
FOUR GRAPHS SHOWN ON THE SCREEN. A HARDCOPY OF
THESE GRAPHS MAY BE OBTAINED BY CHOOSING THE AP-
PROPRIATE OPTION. NOTE: THESE GRAPHS REQUIRE A FEW
MOMENTS TO CREATE THEMSELVES ON THE SCREEN SO
PLEASE BE PATIENT.

***********************************************
* WHEN INPUT INVOLVES ALPHABETICAL CHARACTERS,*
* ALWAYS USE CAPS.                            *
***********************************************

DO YOU NEED MORE INFORMATION? (YES=Y,NO=N) --> Y


THIS LIST OF ADDITIONAL INFORMATION DESCRIBES
SPECIFICS OF THE PROGRAM. INFORMATION PERTAINING TO
THEORY AND DESIGN OF RECHARGE BASINS MAY BE FOUND IN
THE MANUAL.
1. A GRAPHICS BOARD AND GRAPHICS DRIVER ARE NECES-
   SARY TO RUN THE PROGRAM. A LIST OF DRIVERS FOR
   DIFFERENT HARDWARE COMBINATIONS CAN BE FOUND IN
   THE USER MANUAL.
2. THIS PROGRAM IS WRITTEN IN IBM PROFESSIONAL FOR-
   TRAN AND THEREFORE REQUIRES A MATH COPROCESSOR.
3. MANY LOCATIONS IN THE PROGRAM REFER TO THE
   CARRIAGE RETURN (<CR>), THIS IS THE SAME AS
   THE ENTER KEY OR RETURN KEY.
4. RUNNING RECHARGE MAY CREATE PROBLEMS WITH OTHER
   PROGRAMS BECAUSE OF THE SCREEN MANIPULATIONS RELATED
   TO THE GRAPHICS. IF THIS OCCURS, WARM BOOT THE
   SYSTEM

**ENTER PROJECT TITLE & P.I.N. (LIMITED TO 40 ALPHANUMERIC CHARACTERS):
>>   EXAMPLE 1
```

APPENDIX C
EXAMPLE PROBLEM (COMPUTER – *US Customary Units*)

--SCREEN--

```
================================================
DESIGN TRIAL NO.   1

  **TYPE OF PROBLEM (PROB) ?

    THIS PROGRAM WILL COMPUTE THE PHYSICAL DIMENSIONS FOR THE
    REQUIRED BASIN TO OPERATE AT
    1. A GIVEN BASIN OPERATING HEAD (H)------PROB=Ø.Ø
    2. A GIVEN BASIN TOP SURFACE AREA (ATS)--PROB=1.Ø

    ENTER A Ø.Ø OR 1.Ø FOR PROB >>    .Ø

ENTER THE PROPOSED BASIN OPERATING HEAD (H) IN ft >>  2Ø.


**ENTER THE FOLLOWING BASIN GEOMETRIC INFORMATION IN SEQUENCE
  (DATA SEPARATED BY SPACES):

   1. BASIN SHAPE (SHAP): IF SHAP=Ø.Ø, CIRCULAR-SHAPED BASIN
                          IF SHAP=1.Ø, SQUARE OR RECTANGULAR SHAPED BASIN
   2. SIDE SLOPES (SSL) : 1(VERTICAL) ON  SSL(HORIZONTAL)
   3. RATIO OF LENGTH TO WIDTH FOR THE BASIN SURFACE AREA (RLW):
      ENTER RLW=Ø.Ø IF SHAP=Ø.Ø
ENTER SHAP,SSL & RLW >>  1. 2. 1.


**ENTER THE FOLLOWING SUBSURFACE INFORMATION AND SOIL PROPERTIES
  (DATA SEPARATED BY SPACES):

 1. Z   : DEPTH TO GROUND WATER TABLE IN ft. ENTER Z=999., IF NO G.W.T.
          IS ENCOUNTERED
 2. SG  : SPECIFIC GRAVITY OF SOIL SOLIDS
 3. W   : NATURAL DRAINED WATER CONTENT EXPRESSED AS A DECIMAL
          USE Ø.Ø3 FOR GRAVELS & SANDS, AND Ø.Ø5 FOR SILTS
 4. POR: POROSITY OF SOIL
 5. SAT: DEGREE OF SATURATION IN THE TRANSMISSION ZONE
          SAT GENERALLY RANGES FROM Ø.8Ø TO Ø.85 FOR SILTS
          AND IS APPROXIMATELY Ø.7Ø FOR SANDS
ENTER Z,SG,W,POR & SAT >>    999. 2.67 Ø.Ø3 Ø.4 Ø.7


**DETERMINATION OF THE COEFFICIENT OF SATURATED PER-
**MEABILITY OF SOIL, KS

  ENTER A 1.Ø IF YOU WISH THE PROGRAM TO ESTIMATE KS
  VALUE USING SPECIFIC SURFACE ANALYSIS ESTABLISHED
  BY LOUDON. NOTE THAT, HOWEVER, THIS METHOD SHOULD
  ONLY BE APPLIED TO GRAVELS AND SANDS HAVING NOT MORE
  THAN 5 PERCENT OF THE MATERIAL PASSING THE NO.2ØØ SIEVE.
  OTHERWISE ENTER A Ø.Ø -------1.Ø OR Ø.Ø ? >> 1.Ø
```

APPENDIX C
EXAMPLE PROBLEM (COMPUTER – *US Customary Units*)

--SCREEN--

```
******************************************
**INPUT DATA TO CALCULATE THE SPECIFIC SURFACE OF **
**A COHESIONLESS SOIL FROM GRAIN SIZE DISTRIBUTION**

UP TO TWELVE (12) LINES OF GRAIN-SIZE ANALYSIS AND
SHAPE FACTOR DATA. THE PROGRAM WILL ASK FOR THE FOLLOW-
ING THREE PIECES OF INFORMATION.

1. THE OPENING SIZE (in millimeters) OF THE FINER SIEVE
   IN A SIEVE INTERVAL (COLUMN 2 ON FORM SM 389)

2. THE PERCENT RETAINED OF THE TOTAL SPECIMEN IN THAT
   SIEVE INTERVAL (COLUMN 5 ON FORM SM 389)

3. THE SHAPE FACTOR (COLUMN 6 ON FORM SM 389)

FOR DETAILED INFORMATION ON SPECIFIC SURFACE ANALYSIS OF
COHESIONLESS SOILS, SEE SOIL TEST PROCEDURE STP-1, [TEST
PROCEDURE FOR SPECIFIC SURFACE ANALYSIS], SOIL MECHANICS
BUREAU, NEW YORK STATE DEPARTMENT OF TRANSPORTATION, AUG.
1973.

HOW MANY SETS OF DATA FOR SPEC. SURFACE ANALYSIS NS=(1-12) ? --->>  11

DATA NO.  1:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> 38.1 0. 0.

DATA NO.  2:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> 19.1 8.8 1.2

DATA NO.  3:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> 9.51 4.3 1.25

DATA NO.  4:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> 4.76 4.9 1.25

DATA NO.  5:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> 2.38 5.8 1.3

DATA NO.  6:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> 1.19 7.8 1.35
```

--SCREEN--

```
DATA NO.  7:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> .595 15.7 1.4

DATA NO.  8:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> .297 31. 1.5

DATA NO.  9:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> .149 13.8 1.55

DATA NO. 1Ø:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> .Ø74 2.9 1.6

DO YOU WISH THE COMPUTER TO CALCULATE SIZE(11)?
WHERE SIZE(11) IS DEFINED AS THE PARTICLE SIZE AT ZERO
PERCENT FINER BY WEIGHT.
Y OR N >>   Y

IF YES, ENTER D(11)=Ø.Ø, OTHERWISE D(11)=Ø.XXXX

DATA NO. 11:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> Ø. 5. 1.65

DATA NO.  1   SIZE( 1)=  38.1ØØØ mm   RET( 1)=   Ø.ØØ   SFAC( 1)= Ø.ØØ
DATA NO.  2   SIZE( 2)=  19.1ØØØ mm   RET( 2)=   8.8Ø   SFAC( 2)= 1.2Ø
DATA NO.  3   SIZE( 3)=   9.51ØØ mm   RET( 3)=   4.3Ø   SFAC( 3)= 1.25
DATA NO.  4   SIZE( 4)=   4.76ØØ mm   RET( 4)=   4.9Ø   SFAC( 4)= 1.25
DATA NO.  5   SIZE( 5)=   2.38ØØ mm   RET( 5)=   5.8Ø   SFAC( 5)= 1.3Ø
DATA NO.  6   SIZE( 6)=   1.19ØØ mm   RET( 6)=   7.8Ø   SFAC( 6)= 1.35
DATA NO.  7   SIZE( 7)=   Ø.595Ø mm   RET( 7)=  15.7Ø   SFAC( 7)= 1.4Ø
DATA NO.  8   SIZE( 8)=   Ø.297Ø mm   RET( 8)=  31.ØØ   SFAC( 8)= 1.5Ø
DATA NO.  9   SIZE( 9)=   Ø.149Ø mm   RET( 9)=  13.8Ø   SFAC( 9)= 1.55
DATA NO. 1Ø   SIZE(1Ø)=   Ø.Ø74Ø mm   RET(1Ø)=   2.9Ø   SFAC(1Ø)= 1.6Ø
DATA NO. 11   SIZE(11)=   Ø.ØØØØ mm   RET(11)=   5.ØØ   SFAC(11)= 1.65

ARE ALL 11 SETS OF DATA CORRECT? (Y OR N) >>  Y

          AFTER NEXT GRAPH APPEARS, PRESS <CR> TO CONTINUE

            ***PRESS <CR> NOW TO CONTINUE***
```

APPENDIX C
EXAMPLE PROBLEM (COMPUTER – *US Customary Units*)

--SCREEN--

```
************MASS INFLOW VS. TIME************

The following values are the inflow quantities
measured at every hour. The program makes any time
correction  necessary illustrating both the actual
and corrected inflow curve.

The first input value is at time=Ø.


        ENTER NUMBER OF TIME READINGS(INTEGER, max of 2Ø) -->>  19

 1> INFLOW(cu.ft.) AT  Ø HOURS-->  Ø.

 2> INFLOW(cu.ft.) AT  1 HOURS-->  8ØØØØ.

 3> INFLOW(cu.ft.) AT  2 HOURS-->  16ØØØØ.

 4> INFLOW(cu.ft.) AT  3 HOURS-->  5ØØØØØ.

 5> INFLOW(cu.ft.) AT  4 HOURS-->  111ØØØØ.

 6> INFLOW(cu.ft.) AT  5 HOURS-->  182ØØØØ.

 7> INFLOW(cu.ft.) AT  6 HOURS-->  28ØØØØØ.

 8> INFLOW(cu.ft.) AT  7 HOURS-->  379ØØØØ.

 9> INFLOW(cu.ft.) AT  8 HOURS-->  48ØØØØØ.

1Ø> INFLOW(cu.ft.) AT  9 HOURS-->  574ØØØØ.
```

--SCREEN--

```
11> INFLOW(cu.ft.) AT 10 HOURS-->  6480000.

12> INFLOW(cu.ft.) AT 11 HOURS-->  7100000.

13> INFLOW(cu.ft.) AT 12 HOURS-->  7600000.

14> INFLOW(cu.ft.) AT 13 HOURS-->  7940000.

15> INFLOW(cu.ft.) AT 14 HOURS-->  8160000.

16> INFLOW(cu.ft.) AT 15 HOURS-->  8270000.

17> INFLOW(cu.ft.) AT 16 HOURS-->  8370000.

18> INFLOW(cu.ft.) AT 17 HOURS-->  8420000.

19> INFLOW(cu.ft.) AT 18 HOURS-->  8420000.
 TIME(hours)= 0      INFLOW(cu.ft.)=        0.0
 TIME(hours)= 1      INFLOW(cu.ft.)=    80000.0
 TIME(hours)= 2      INFLOW(cu.ft.)=   160000.0
 TIME(hours)= 3      INFLOW(cu.ft.)=   500000.0
 TIME(hours)= 4      INFLOW(cu.ft.)=  1110000.0
 TIME(hours)= 5      INFLOW(cu.ft.)=  1820000.0
 TIME(hours)= 6      INFLOW(cu.ft.)=  2800000.0
 TIME(hours)= 7      INFLOW(cu.ft.)=  3790000.0
 TIME(hours)= 8      INFLOW(cu.ft.)=  4800000.0
 TIME(hours)= 9      INFLOW(cu.ft.)=  5740000.0
 TIME(hours)=10      INFLOW(cu.ft.)=  6480000.0
 TIME(hours)=11      INFLOW(cu.ft.)=  7100000.0
 TIME(hours)=12      INFLOW(cu.ft.)=  7600000.0
 TIME(hours)=13      INFLOW(cu.ft.)=  7940000.0
 TIME(hours)=14      INFLOW(cu.ft.)=  8160000.0
 TIME(hours)=15      INFLOW(cu.ft.)=  8270000.0
 TIME(hours)=16      INFLOW(cu.ft.)=  8370000.0
 TIME(hours)=17      INFLOW(cu.ft.)=  8420000.0
 TIME(hours)=18      INFLOW(cu.ft.)=  8420000.0

ARE ALL 19 SETS OF DATA CORRECT? (Y OR N) >>  Y
```

APPENDIX C
EXAMPLE PROBLEM (COMPUTER – *US Customary Units*)

--PRINTER--

SUMMARY OF SOIL PROPERTIES:

```
D5Ø GRAIN SIZE,mm------------------------=  Ø.56
SPECIFIC GRAVITY-------------------------=2.67Ø
DEGREE OF SATURATION---------------------=Ø.7ØØ
NATURAL DRAINED WATER CONTENT------------=Ø.Ø3Ø
POROSITY---------------------------------=Ø.4ØØ
HYDRAULIC CONDUCTIVITY,ft/hr-------------= 2.161
CAPILLARY SUCTION POTENTIAL,ft-----------=Ø.176
HYDRAULIC DIFFUSIVITY,sq ft/hr-----------=  9.317
DEPTH TO GROUNDWATER TABLE,ft------------= NO G.W.T.
TOTAL SPECIFIC SURFACE,sq cm/cu cm-------= 3Ø9.58
```

MASS INFLOW QUANTITY(cu ft) VS. TIME(hr)

TIME	ACTUAL	CORRECTED
Ø.	Ø.ØØØE+ØØ	Ø.ØØØE+ØØ
1.	Ø.8ØØE+Ø5	Ø.1Ø1E+Ø7
2.	Ø.16ØE+Ø6	Ø.2Ø2E+Ø7
3.	Ø.5ØØE+Ø6	Ø.3Ø3E+Ø7
4.	Ø.111E+Ø7	Ø.4Ø4E+Ø7
5.	Ø.182E+Ø7	Ø.5Ø3E+Ø7
6.	Ø.28ØE+Ø7	Ø.592E+Ø7
7.	Ø.379E+Ø7	Ø.663E+Ø7
8.	Ø.48ØE+Ø7	Ø.722E+Ø7
9.	Ø.574E+Ø7	Ø.768E+Ø7
1Ø.	Ø.[illegible]48E+Ø7	Ø.799E+Ø7
11.	Ø.71ØE+Ø7	Ø.819E+Ø7
12.	Ø.76ØE+Ø7	Ø.829E+Ø7
13.	Ø.794E+Ø7	Ø.838E+Ø7
14.	Ø.816E+Ø7	Ø.842E+Ø7
15.	Ø.827E+Ø7	Ø.842E+Ø7
16.	Ø.837E+Ø7	Ø.842E+Ø7
17.	Ø.842E+Ø7	Ø.842E+Ø7
18.	Ø.842E+Ø7	Ø.842E+Ø7

Note: E+XX stands for 1Ø to the XXth power.

--SCREEN-PRINTER--

```
    DESIGN SUMMARY FOR TRIAL NO.  1
    THE BASIN SIZE AND DIMENSIONS ARE AS FOLLOWS:

      SIDE SLOPES:   2.ØØ  (HORIZONTAL) TO 1 (VERTICAL)

    DESIGN SUMMARY FOR TRIAL NO.  1
    THE BASIN SIZE AND DIMENSIONS ARE AS FOLLOWS:

      SIDE SLOPES:   2.ØØ  (HORIZONTAL) TO 1 (VERTICAL)

 L/W AT BASIN TOP:   1.ØØ
             TOP:    457.96ft X   457.96ft, AREA =  2Ø973Ø.47 sq ft
           FLOOR:    377.96ft X   377.96ft, AREA =  142856.33 sq ft


          VOLUME:   Ø.35ØE+Ø7 cu ft
           DEPTH:   2Ø.ØØft

MORE TO DO ?? [Y OR N] >>   N
```

APPENDIX C
EXAMPLE PROBLEM (COMPUTER – *International System of Units*)

```
A:\>RECHARGE
                                                    -- SCREEN --
***************************************************
*                                                 *
* THE NEW YORK STATE DEPARTMENT OF TRANSPORTATION *
* WILL NOT BE RESPONSIBLE FOR ANY RESULTS OBTAINED*
* FROM THE USE OF SHARED COMPUTER PROGRAMS OR     *
* STORED DATA, INCLUDING DIRECT, INDIRECT, SPECIAL*
* OR CONSEQUENTIAL DAMAGES. NO TECHNICAL SUPPORT   *
* WILL BE PROVIDED. NO WARRANTIES ARE EXTENDED OR *
* GRANTED, EITHER EXPRESSED OR IMPLIED, WITH RE-  *
* SPECT TO THE ACCURACY AND/OR PERFORMANCE OF AN  *
* MATERIALS PROVIDED.  THE MATERIALS PROVIDED MAY *
* BE REPRODUCED BY THE RECEIVING AGENCY, BUT MAY  *
* NOT BE GIVEN TO ANOTHER AGENCY WITHOUT THE PER- *
* MISSION OF THE NYSDOT.                          *
*                                                 *
***************************************************

   PRESS <ENTER> TO CONTINUE

***************************************************
*********** NYSDOT RECHARGE BASIN DESIGN **********
***************************************************

THIS IS A PROGRAM TO CALCULATE RECHARGE BASIN SIZE.
THERE ARE TWO POSSIBLE DESIGN PROCEDURES ALLOWED BY THE
PROGRAM, EITHER THE BASIN OPERATING HEAD IS GIVEN AND
THE TOP SURFACE AREA IS CALCULATED (PROB=0), OR THE TOP
SURFACE AREA IS GIVEN AND THE OPERATING HEAD IS CALCULAT-
ED (PROB=1).

THE OUTPUT IS SENT DIRECTLY TO THE PRINTER AS THE
PROGRAM IS RUNNING, THEREFORE, MAKE SURE THE PRINTER
IS ON.
***********************************************
* WHEN INPUT INVOLVES ALPHABETICAL CHARACTERS,*
* ALWAYS USE CAPS.                            *
***********************************************

   PRESS <ENTER> TO CONTINUE

THIS PROGRAM IS WRITTEN IN IBM PROFESSIONAL FOR-
TRAN AND THEREFORE REQUIRES A MATH PROCESSOR.

MANY LOCATIONS IN THE PROGRAM REFER TO THE
CARRIAGE RETURN (<CR>),  THIS IS THE SAME AS
THE ENTER KEY OR RETURN KEY.

INFORMATION PERTAINING TO THEORY AND DESIGN OF
RECHARGE BASINS MAY BE FOUND IN THE USER MANUAL.

**ENTER PROJECT TITLE & P.I.N. (LIMITED TO 40 ALPHANUMERIC CHARACTERS)
-->>SAMPLE
```

```
                                                        -- SCREEN --
 ====================================================
 DESIGN TRIAL NO.  1

   **TYPE OF PROBLEM (PROB) ?

     THIS PROGRAM WILL COMPUTE THE PHYSICAL DIMENSIONS FOR THE
     REQUIRED BASIN TO OPERATE AT
     1. A GIVEN BASIN OPERATING HEAD (H)------PROB=0.0
     2. A GIVEN BASIN TOP SURFACE AREA (ATS)--PROB=1.0

     ENTER A 0.0 OR 1.0 FOR PROB >>  0.0


ENTER THE PROPOSED BASIN OPERATING HEAD (H) IN m  >>  6.5



**ENTER THE FOLLOWING BASIN GEOMETRIC INFORMATION IN SEQUENCE
  (DATA SEPARATED BY SPACES):

   1. BASIN SHAPE (SHAP): IF SHAP=0.0, CIRCULAR-SHAPED BASIN
                          IF SHAP=1.0, SQUARE OR RECTANGULAR SHAPED BASIN
   2. SIDE SLOPES (SSL) : 1(VERTICAL) ON  SSL(HORIZONTAL)
   3. RATIO OF LENGTH TO WIDTH FOR THE BASIN SURFACE AREA (RLW):
      ENTER RLW=0.0 IF SHAP=0.0


   ENTER SHAP,SSL & RLW >>1. 2. 1.

  (DATA SEPARATED BY SPACES):

 1. Z   : DEPTH TO GROUND WATER TABLE IN  m  ENTER Z=999., IF NO G.W.T.
          IS ENCOUNTERED
 2. SG  : SPECIFIC GRAVITY OF SOIL SOLIDS
 3. W   : NATURAL DRAINED WATER CONTENT EXPRESSED AS A DECIMAL
          USE 0.03 FOR GRAVELS & SANDS, AND 0.05 FOR SILTS
 4. POR: POROSITY OF SOIL
 5. SAT: DEGREE OF SATURATION IN THE TRANSMISSION ZONE
          SAT GENERALLY RANGES FROM 0.80 TO 0.85 FOR SILTS
          AND IS APPROXIMATELY 0.70 FOR SANDS

   ENTER Z,SG,W,POR & SAT >> 999. 2.67 0.03 0.4 0.7


**DETERMINATION OF THE COEFFICIENT OF SATURATED PER-
**MEABILITY OF SOIL, KS

  ENTER A 1.0 IF YOU WISH THE PROGRAM TO ESTIMATE KS
  VALUE USING SPECIFIC SURFACE ANALYSIS ESTABLISHED
  BY LOUDON. NOTE THAT, HOWEVER, THIS METHOD SHOULD
  ONLY BE APPLIED TO GRAVELS AND SANDS HAVING NOT MORE
  THAN 5 PERCENT OF THE MATERIAL PASSING THE NO.200 SIEVE.
  OTHERWISE ENTER A 0.0. **MAKE SURE THE PRINTER IS ON**
  -------1.0 OR 0.0 ? >>  1.0
```

APPENDIX C
EXAMPLE PROBLEM (COMPUTER – *International System of Units*)

```
**********************************************            -- SCREEN --
**INPUT DATA TO CALCULATE THE SPECIFIC SURFACE OF **
**A COHESIONLESS SOIL FROM GRAIN SIZE DISTRIBUTION**

UP TO TWELVE (12) LINES OF GRAIN-SIZE ANALYSIS AND
SHAPE FACTOR DATA. THE PROGRAM WILL ASK FOR THE FOLLOW-
ING THREE PIECES OF INFORMATION.

1. THE OPENING SIZE (in millimeters) OF THE FINER SIEVE
   IN A SIEVE INTERVAL (COLUMN 2 ON FORM SM 389)

2. THE PERCENT RETAINED OF THE TOTAL SPECIMEN IN THAT
   SIEVE INTERVAL (COLUMN 5 ON FORM SM 389)

3. THE SHAPE FACTOR (COLUMN 6 ON FORM SM 389)

FOR DETAILED INFORMATION ON SPECIFIC SURFACE ANALYSIS OF
COHESIONLESS SOILS, SEE SOIL TEST PROCEDURE STP-1, [TEST
PROCEDURE FOR SPECIFIC SURFACE ANALYSIS], SOIL MECHANICS
BUREAU, NEW YORK STATE DEPARTMENT OF TRANSPORTATION, AUG.
1973.

HOW MANY SETS OF DATA FOR SPECIFIC SURFACE ANALYSIS NS=(1-12) ? >>  11


DATA NO.  1:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> 38.1 0. 0.

DATA NO.  2:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> 19.1 8.8 1.2

DATA NO.  3:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> 9.51 4.3 1.25

DATA NO.  4:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> 4.76 4.9 1.25

DATA NO.  5:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> 2.38 5.8 1.3

DATA NO.  6:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> 1.19 7.8 1.35

DATA NO.  7:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> .595 15.7 1.4

DATA NO.  8:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> .297 31. 1.5
```

APPENDIX C
EXAMPLE PROBLEM (COMPUTER – *International System of Units*)

-- SCREEN --

```
DATA NO.  9:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> .149 13.8 1.55


DATA NO. 10:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> .074 2.9 1.6


DO YOU WISH THE COMPUTER TO CALCULATE SIZE(11)?
WHERE SIZE(11) IS DEFINED AS THE PARTICLE SIZE AT ZERO
PERCENT FINER BY WEIGHT.
Y OR N >>   Y


IF YES, ENTER D(11)=0.0, OTHERWISE D(11)=0.XXXX


DATA NO. 11:  OPENING SIZE, PERCENT RETAINED, SHAPE FACTOR
 >> 0. 5. 1.65


DATA NO.  1   SIZE( 1)=  38.1000 mm   RET( 1)=  0.00   SFAC( 1)= 0.00
DATA NO.  2   SIZE( 2)=  19.1000 mm   RET( 2)=  8.80   SFAC( 2)= 1.20
DATA NO.  3   SIZE( 3)=   9.5100 mm   RET( 3)=  4.30   SFAC( 3)= 1.25
DATA NO.  4   SIZE( 4)=   4.7600 mm   RET( 4)=  4.90   SFAC( 4)= 1.25
DATA NO.  5   SIZE( 5)=   2.3800 mm   RET( 5)=  5.80   SFAC( 5)= 1.30
DATA NO.  6   SIZE( 6)=   1.1900 mm   RET( 6)=  7.80   SFAC( 6)= 1.35
DATA NO.  7   SIZE( 7)=   0.5950 mm   RET( 7)= 15.70   SFAC( 7)= 1.40
DATA NO.  8   SIZE( 8)=   0.2970 mm   RET( 8)= 31.00   SFAC( 8)= 1.50
DATA NO.  9   SIZE( 9)=   0.1490 mm   RET( 9)= 13.80   SFAC( 9)= 1.55
DATA NO. 10   SIZE(10)=   0.0740 mm   RET(10)=  2.90   SFAC(10)= 1.60
DATA NO. 11   SIZE(11)=   0.0000 mm   RET(11)=  5.00   SFAC(11)= 1.65

ARE ALL 11 SETS OF DATA CORRECT? (Y OR N) >>  Y
```

APPENDIX C
EXAMPLE PROBLEM (COMPUTER – *International System of Units*)

```
                                                        -- SCREEN --

             ************MASS INFLOW VS. TIME************

The following values are the inflow quantities
measured at every hour. The program makes any time
correction neccessary illustrating both the actual
and corrected inflow curve.

The first input value is at time=0.


      ENTER NUMBER OF TIME READINGS (INTEGER, MAX OF 20) -->>  19

 1> INFLOW (cubic meter) AT  0 HOURS
    -->>  0.

 2> INFLOW (cubic meter) AT  1 HOURS
    -->>  2000.

 3> INFLOW (cubic meter) AT  2 HOURS
    -->>  5000.

 4> INFLOW (cubic meter) AT  3 HOURS
    -->>  14000.

 5> INFLOW (cubic meter) AT  4 HOURS
    -->>  30000.

 6> INFLOW (cubic meter) AT  5 HOURS
    -->>  50000.

 7> INFLOW (cubic meter) AT  6 HOURS
    -->>  79000.

 8> INFLOW (cubic meter) AT  7 HOURS
    -->>  107000.

 9> INFLOW (cubic meter) AT  8 HOURS
    -->>  135000.

10> INFLOW (cubic meter) AT  9 HOURS
    -->>  162000.

11> INFLOW (cubic meter) AT 10 HOURS
    -->>  183000.
```

-- SCREEN --

```
12> INFLOW (cubic meter) AT 11 HOURS
    -->>  200000.


13> INFLOW (cubic meter) AT 12 HOURS
    -->>  215000.


14> INFLOW (cubic meter) AT 13 HOURS
    -->>  225000.


15> INFLOW (cubic meter) AT 14 HOURS
    -->>  230000.


16> INFLOW (cubic meter) AT 15 HOURS
    -->>  235000.


17> INFLOW (cubic meter) AT 16 HOURS
    -->>  238000.


18> INFLOW (cubic meter) AT 17 HOURS
    -->>  240000.


19> INFLOW (cubic meter) AT 18 HOURS
    -->>  240000.



   TIME(hours)= 0     INFLOW (m^3) =         0.0
   TIME(hours)= 1     INFLOW (m^3) =      2000.0
   TIME(hours)= 2     INFLOW (m^3) =      5000.0
   TIME(hours)= 3     INFLOW (m^3) =     14000.0
   TIME(hours)= 4     INFLOW (m^3) =     30000.0
   TIME(hours)= 5     INFLOW (m^3) =     50000.0
   TIME(hours)= 6     INFLOW (m^3) =     79000.0
   TIME(hours)= 7     INFLOW (m^3) =    107000.0
   TIME(hours)= 8     INFLOW (m^3) =    135000.0
   TIME(hours)= 9     INFLOW (m^3) =    162000.0
   TIME(hours)=10     INFLOW (m^3) =    183000.0
   TIME(hours)=11     INFLOW (m^3) =    200000.0
   TIME(hours)=12     INFLOW (m^3) =    215000.0
   TIME(hours)=13     INFLOW (m^3) =    225000.0
   TIME(hours)=14     INFLOW (m^3) =    230000.0
   TIME(hours)=15     INFLOW (m^3) =    235000.0
   TIME(hours)=16     INFLOW (m^3) =    238000.0
   TIME(hours)=17     INFLOW (m^3) =    240000.0
   TIME(hours)=18     INFLOW (m^3) =    240000.0

ARE ALL 19 SETS OF DATA CORRECT? (Y OR N) >>  Y
```

APPENDIX C
EXAMPLE PROBLEM (COMPUTER – *International System of Units*)

-- PRINTER --

MASS INFLOW QUANTITY (m^3) VS. TIME (hr)

TIME	ACTUAL	CORRECTED
0.	0.000E+00	0.000E+00
1.	0.200E+04	0.290E+05
2.	0.500E+04	0.580E+05
3.	0.140E+05	0.867E+05
4.	0.300E+05	0.115E+06
5.	0.500E+05	0.142E+06
6.	0.790E+05	0.168E+06
7.	0.107E+06	0.188E+06
8.	0.135E+06	0.204E+06
9.	0.162E+06	0.218E+06
10.	0.183E+06	0.226E+06
11.	0.200E+06	0.231E+06
12.	0.215E+06	0.236E+06
13.	0.225E+06	0.239E+06
14.	0.230E+06	0.240E+06
15.	0.235E+06	0.240E+06
16.	0.238E+06	0.240E+06
17.	0.240E+06	0.240E+06
18.	0.240E+06	0.240E+06

Note: E+XX stands for 10 to the XXth power.

APPENDIX C
EXAMPLE PROBLEM (COMPUTER – *International System of Units*)

-- PRINTER --

NYSDOT RECHARGE BASIN DESIGN

PROJECT TITLE & P.I.N.: SAMPLE

GRAIN SIZE DISTRIBUTION FOR PROJECT SOIL

PERCENTAGE FINER BY WEIGHT(%)	GRAIN SIZE(mm)
100.00	38.100
91.20	19.100
86.90	9.510
82.00	4.760
76.20	2.380
68.40	1.190
52.70	0.595
21.70	0.297
7.90	0.149
5.00	0.074
0.00	0.022

SUMMARY OF SOIL PROPERTIES:

```
D50 GRAIN SIZE,mm-----------------------=  0.56
SPECIFIC GRAVITY-------------------------=2.670
DEGREE OF SATURATION---------------------=0.700
NATURAL DRAINED WATER CONTENT------------=0.030
POROSITY---------------------------------=0.400
HYDRAULIC CONDUCTIVITY, m/hr-------------= 0.659
CAPILLARY SUCTION POTENTIAL, m-----------=0.054
HYDRAULIC DIFFUSIVITY,  m^2 /hr-----------=  0.866
DEPTH TO GROUNDWATER TABLE, m------------= NO G.W.T.
TOTAL SPECIFIC SURFACE, cm^2/cm^3 -------= 309.58
```

APPENDIX C
EXAMPLE PROBLEM (COMPUTER – *International System of Units*)

-- PRINTER --

BASIN SURFACE AREA (m^2)	MAXIMUM MASS STORAGE (m^3)	BASIN VOLUME (m^3)	DIFF. BETWEEN MAXI. MASS STORAGE & BASIN VOL.(m^3)
0.833E+04	0.180E+06	0.402E+05	0.140E+06
0.119E+05	0.152E+06	0.601E+05	0.916E+05
0.154E+05	0.123E+06	0.805E+05	0.429E+05
0.189E+05	0.969E+05	0.101E+06	-0.427E+04
0.224E+05	0.701E+05	0.122E+06	-0.519E+05
0.260E+05	0.439E+05	0.143E+06	-0.992E+05

```
    DESIGN SUMMARY FOR TRIAL NO.  1
    THE BASIN SIZE AND DIMENSIONS ARE AS FOLLOWS:

      SIDE SLOPES:   2.00  (HORIZONTAL) TO 1 (VERTICAL)

 L/W AT BASIN TOP:   1.00
              TOP:   136.38 m X   136.38 m, AREA =   18599.75 m^2
            FLOOR:   110.38 m X   110.38 m, AREA =   12183.94 m^2

           VOLUME:  0.993E+05 m^3
            DEPTH:    6.50 m

 MORE TO DO ?? (Y/N) >> N
```

APPENDIX D
PROGRAM “RECHARGE” LISTING – *US Customary Units*)

```
          PROGRAM RECHARGE
C**********************************************************************
C  SOIL MECHANICS BUREAU. NEW YORK STATE DEPARTMENT OF TRANSPORTATION *
C**********************************************************************
C                                                                     *
C                                                                     *
C        FORTRAN PROGRAM [RECHARGE]:                                  *
C                DESIGN OF A RECHARGE BASIN FOR DISPOSAL              *
C                OF HIGHWAY STORM DRAINAGE                            *
C                                                                     *
C          PROGRAM [RECHARGE] WAS DEVELOPED BASED ON A THEORY OF WATER *
C          INFILTRATION IN A SEMI-INFINITE UNSATURATED POROUS MEDIUM.  *
C          INDIVIDUALS INTERESTED IN THE ORIGINAL STUDY MAY REFER TO   *
C          A RESEARCH REPORT BY ROBERT J. WEAVER, ENTITLED "RECHARGE   *
C          BASINS FOR DISPOSAL OF HIGHWAY STORM DRAINAGE", RESEARCH    *
C          REPORT 69-2, ENGINEERING RESEARCH AND DEVELOPMENT BUREAU,   *
C          NEW YORK STATE DEPARTMENT OF TRANSPORTATION, MAY 1971.      *
C                                                                     *
C                                                                     *
C          PROGRAM WAS WRITTEN BY J. T. SUNG AND J. S. RAMSEY.         *
C                                                                     *
C                                                                     *
C        THE NEW YORK STATE DEPARTMENT OF TRANSPORTATION WILL NOT BE   *
C        RESPONSIBLE FOR ANY RESULTS OBTAINED FROM THE USE OF SHARED   *
C        COMPUTER PROGRAMS OR STORED DATA, INCLUDING DIRECT, INDIRECT, *
C        SPECIAL OR CONSEQUENTIAL DAMAGES.  NO TECHNICAL SUPPORT WILL  *
C        BE PROVIDED. NO WARRANTIES ARE EXTENDED OR GRANTED, EITHER    *
C        EXPRESSED OR IMPLIED, WITH RESPECT TO THE ACCURACY AND/OR     *
C        PERFORMANCE OF ANY MATERIALS PROVIDED. THE MATERIALS PROVIDED *
C        MAY BE REPRODUCED BY THE RECEIVING AGENCY, BUT MAY NOT BE     *
C        GIVEN TO ANOTHER AGENCY WITHOUT THE PERMISSION OF THE NYSDOT. *
C                                                                     *
C                                                                     *
C                                                                     *
C**********************************************************************
        COMMON/NARAG/IB,QMI(20),QMIC(20),T(20),ZZ(20),K,HH(6),SHAP,
     + IWRITE,PROB,ATS,IBRK,RLW,ALFA,SM,H,SSL,TITL(10),NUM,IBREAK,
     + IERROR
      COMMON/SHAKE/SS,DFIT,DDQ(6),AS(6),PSIN,PT
      COMMON/LUSH/Y,IX,APX,APY,IJJ,CX,CY
      COMMON/ILUSH/QINF(6,20)
      COMMON/DOVER/IIII
      CHARACTER*1 YES, NO, ACODE
      INTEGER*2 CRTDEV,PRTDEV,WSSDEV
      DATA YES,NO/'Y','N'/
C      *****INPUT THE DATA POINTS*****
      WSSDEV=0
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
      CRTDEV=1
      PRTDEV=2
      III=1
      WRITE(*,298)
      READ(*,297)ACODE
      IF(ACODE.EQ.YES) THEN
  294 WRITE(*,296)
      ENDIF
  295 WRITE(*,300)
      READ(*,301)TITL
    1 IERROR=0
      WRITE(*,302)III
      READ(*,307) PROB
      IF(PROB) 3,2,3
    2 WRITE(*,304)
      READ(*,307)H
      GO TO 4
    3 WRITE(*,306)
      READ(*,307) ATS
    4 WRITE(*,308)
      READ*,SHAP,SSL,RLW
      IF(III.EQ.1)GO TO 5
      OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE,310)III
      CLOSE(IWRITE,ERR=39)
      GO TO 18
    5 WRITE(*,311)
      READ*,Z,SG,W,POR,SAT
      WRITE(*,333)
      READ(*,307)SSS
      IWRITE=6
      IF(SSS-1.0)334,335,334
  334 WRITE(*,336)
      READ*,DFIT,PSAT
  335 IF(PROB)7,6,7
    6 IF(Z-(1.25*H))38,7,7
C
C     DETERMINE SPECIFIC SURFACE AND PLOT GRAIN SIZE
C     DISTRIBUTION CURVE
C
    7 CALL SIEVE(III,SSS)
      IF(IERROR.EQ.1)GOTO 999
      OPEN(IWRITE,FILE='PRN')
      IF(III.GT.1)GOTO 18
      IF (SSS-1.0) 341,340,341
  340 PSAT=(2737.08/SS**2.)*(10.**(5.15*POR))
  341 DFIT=DFIT*10.
      PSIN=(0.098425)/DFIT
      THETAN=W*SG*(1-POR)
      THEDIF=SAT*POR-THETAN
      IF(POR-THETAN) 9,33,9
    9 PT=THEDIF/(POR-THETAN)*PSAT
      IF(THEDIF) 10,34,10
   10 ALFA=PT/THEDIF
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
      WRITE(IWRITE,318)DFIT,SG,SAT,W,POR,PT,PSIN,ALFA
      IF(Z.NE.999.)GOTO 11
      WRITE(IWRITE,501)
      GOTO 12
   11 WRITE(IWRITE,502)Z
   12 IF(SSS.EQ.1.0)THEN
       WRITE(IWRITE,338)SS
      ENDIF
   14 CLOSE(IWRITE,ERR=39)
      IIII=0
C     PLOT THE INFLOW VS. TIME CURVE
      CALL FLOW(III)
      IF(IERROR.EQ.1)GOTO 999
      DO 16 I=2,NUM
      XX=QMIC(I)-QMIC(I-1)
      IF(XX) 16,17,16
   16 CONTINUE
C
C     DETERMINE THE TIME AT WHICH THE INFLOW CURVE STARTS PEAKING
C
   17 SN=QMIC(I-1)-QMIC(I-2)
      XX=QMIC(I-1)-SN*(I-1)
      ZZZ=XX/(SM-SN)
      IBRK=INT(ZZZ+0.5)
C     ****************************************************************
C     SEPERATE THE PROBLEM. IS IT TYPE 0 OR 1?
   18 IF(PROB) 24,19,24
C
C     DETERMINE THE INFILTRATION QUANTITIES FOR PROBLEM WITH
C     BASIN OPERATING HEAD GIVEN
C     ****************************************************************
C     PROB=0
   19 CALL HITA(BW,BR)
      IF(IERROR.EQ.2)GOTO 37
C     PLOT THE DESIGN CURVES
      CALL FLOW(III)
      IF(IERROR.EQ.1)GOTO 999
      IF(Z-(1.25*H).LT.0.)GOTO 38
      OPEN(IWRITE,FILE='PRN')
      IF(DDQ(IBREAK).GE.0.) GOTO 40
      IF(DDQ(1).LE.0.)GO TO 45
      CLOSE(IWRITE,ERR=39)
C
C     DDQ IS DEFINED AS THE DIFFERENCE BETWEEN THE MAX. MASS
C     STORAGE AND THE BASIN WATER VOLUME
C
C     DETERMINE THE REQUIRED BASIN SURFACE AREA
      DO 22 JJ=1,IBREAK
      IF(DDQ(JJ))21,20,22
   20 ATS=AS(JJ)
      GOTO 23
   21 ATS=AS(JJ-1)+DDQ(JJ-1)*(AS(JJ)-AS(JJ-1))/
     +(DDQ(JJ-1)-DDQ(JJ))
      GOTO 23
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
   22 CONTINUE
C       PLOT DDQ AGAINST BASIN SURFACE AREA
   23 WRITE(IWRITE,122)
  122 FORMAT(1H1)
      CALL DESIGN
        GOTO 29
C
C       DETERMINE THE INFILTRATION QUANTITIES FOR PROBLEM WITH
C       BASIN SURFACE AREA GIVEN
C       ***************************************************************
C       PROB=1
   24 CALL TAHI(BW,BR)
      IF(IERROR.EQ.2)GOTO 37
C       PLOT THE DESIGN CURVES
      CALL FLOW(III)
      IF(IERROR.EQ.1)GOTO 999
      IF(DDQ(IBREAK).GE.Ø.)GOTO 35
      IF(DDQ(1).LE.Ø.)GOTO 46
C
C       DETERMINE THE REQUIRED OPERATING HEAD
      DO 27 JJ=1,IBREAK
      IF(DDQ(JJ))26,25,27
   25 H=HH(JJ)
      GOTO 28
   26 H=HH(JJ-1)+DDQ(JJ-1)*(HH(JJ)-HH(JJ-1))/(DDQ(JJ-1)-DDQ(JJ))
      GOTO 28
   27 CONTINUE
   28 IF(Z-(1.25*H).LT.Ø.)GOTO 38
C       PLOT DDQ AGAINST BASIN DEPTH
      WRITE(IWRITE,124)
  124 FORMAT(1H1)
      CALL DESIGN
      IF(IERROR.EQ.1)GOTO 999
   29 OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE,322)III,SSL
      CLOSE(IWRITE,ERR=39)
      WRITE(IWRITE,322)III,SSL
      OPEN(IWRITE,FILE='PRN')
      IF(SHAP)3Ø,31,3Ø
C       DETERMINE THE BASIN DIMENSIONS
   3Ø SWT=(ATS/RLW)**Ø.5
      SWB=SWT-2.*SSL*H
      SLT=RLW*SWT
      SLB=SLT-2.*SSL*H
      IF(SWB.LE.Ø.OR.SLB.LE.Ø.) GO TO 36
      ABF=ATS-2.*SSL*H*(SLB+SWB+2.*SSL*H)
      VOL=H/3*(ATS+ABF+(ATS*ABF)**Ø.5)
      WRITE(IWRITE,323) RLW,SWT,SLT,ATS,SWB,SLB,ABF
      CLOSE(IWRITE,ERR=39)
      WRITE(IWRITE,323) RLW,SWT,SLT,ATS,SWB,SLB,ABF OPEN(IWRITE,FILE='PRN'
      GO TO 32
   31 RAT=(ATS/3.1416)**Ø.5
      RAB=RAT-SSL*H
      IF(RAB.LE.Ø.)GO TO 36
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
      ABF=3.1416*RAB**2.
      VOL=H/3.*(2*ABF+ATS+((3.1416*ABF)**Ø.5*SSL*H))
      WRITE(IWRITE,324) RAT,ATS,RAB,ABF
      CLOSE(IWRITE,ERR=39)
      WRITE(IWRITE,324) RAT,ATS,RAB,ABF
      OPEN(IWRITE,FILE='PRN')
   32 WRITE(IWRITE,325) VOL,H
      CLOSE(IWRITE,ERR=39)
      WRITE(IWRITE,325) VOL,H
      OPEN(IWRITE,FILE='PRN')
      GO TO 37
   33 OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE,326)
      IERROR=1
      GO TO 39
   34 OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE,327)
      IERROR=1
      GO TO 39
   35 OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE,328)
      IERROR=2
      GO TO 37
   36 OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE,329)
      IERROR=2
      GO TO 37
   4Ø OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE,332)
      IERROR=2
      GOTO 37
   45 OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE,777)
      IERROR=2
      GOTO 37
   46 OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE,778)
      IERROR=2
      GOTO 37
   38 OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE,321)
      IERROR=1
   37 CLOSE(IWRITE,ERR=39)
      GOTO 993
  999 CLOSE(IWRITE,ERR=39)
  993 IF(IERROR.LT.1)GOTO 994
      WRITE(*,991)
  991 FORMAT(' !!!!!   CHECK OUTPUT FOR ERROR   !!!!!')
  994 IF(IERROR.EQ.1)GOTO 399
      WRITE(*,33Ø)
      READ(*,297)ACODE
      IF(ACODE.EQ.YES)THEN
      III=III+1
      WRITE(*,992)
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
  992 FORMAT(///,'*************************************************',/,
     +'  *********',/,
     +'*************************************************',//)
      ATS=Ø.
      H=Ø.
      GO TO 1
      ENDIF
   39 CALL CLOSWS(CRTDEV)
      CALL CLOSWS(WSSDEV)
      CALL GCLKS
      CLOSE(14)
  399 STOP
C
C      I/O FORMAT SPECIFICATIONS
C
  298 FORMAT(3X,'**************************************************',/,
     +3X,'********** NYSDOT RECHARGE BASIN DESIGN **********',/,
     +3X,'**************************************************',//, +3X,'THIS
     IS A PROGRAM TO CALCULATE RECHARGE BASIN SIZE.',/, +3X,'THERE ARE TWO
     POSSIBLE DESIGN PROCEDURES ALLOWED BY THE',/, +3X,'PROGRAM, EITHER THE
     BASIN OPERATING HEAD IS GIVEN AND',/, +3X,'THE TOP SURFACE AREA IS
     CALCULATED (PROB=Ø), OR THE TOP',/, +3X,'SURFACE AREA IS GIVEN AND THE
     OPERATING HEAD IS CALCULAT-',/, +3X,'ED (PROB=1).',//,
     +3X,'THE OUTPUT IS SENT DIRECTLY TO THE PRINTER AS THE',/,
     +3X,'PROGRAM IS RUNNING THEREFORE, MAKE SURE THE PRINTER',/,
     +3X,'IS ON. FOR EACH RUN OF THE PROGRAM, THERE WILL BE',/,
     +3X,'FOUR GRAPHS SHOWN ON THE SCREEN. A HARDCOPY OF',/,
     +3X,'THESE GRAPHS MAY BE OBTAINED BY CHOOSING THE AP-',/,
     +3X,'PROPRIATE OPTION. NOTE: THESE GRAPHS REQUIRE A FEW ',/,
     +3X,'MOMENTS TO CREATE THEMSELVES ON THE SCREEN SO ',/,
     +3X,'PLEASE BE PATIENT.                               ',//,
     +3X,'***********************************************',/,
     +3X,'* WHEN INPUT INVOLVES ALPHABETICAL CHARACTERS,*',/,
     +3X,'* ALWAYS USE CAPS.                            *',/,
     +3X,'***********************************************',//,
     +3X,'DO YOU NEED MORE INFORMATION? (YES=Y,NO=N) --> ')
  297 FORMAT(A1)
  296 FORMAT(///,3X,'THIS LIST OF ADDITIONAL INFORMATION DESCRIBES',/,
     +       3X,'SPECIFICS OF THE PROGRAM. INFORMATION PERTAINING TO',/,
     +       3X,'THEORY AND DESIGN OF RECHARGE BASINS MAY BE FOUND IN',/,
     3X,'THE MANUAL.                                           ',/,
     +       3X,'1. A GRAPHICS BOARD AND GRAPHICS DRIVER ARE NECES-',/,
     +       6X,'SARY TO RUN THE PROGRAM. A LIST OF DRIVERS FOR',/,
     +       6X,'DIFFERENT HARDWARE COMBINATIONS CAN BE FOUND IN',/,
     +       6X,'THE USER MANUAL.                                ',/,
     +       3X,'2. THIS PROGRAM IS WRITTEN IN IBM PROFESSIONAL FOR-',/,
     +       6X,'TRAN AND THEREFORE REQUIRES A MATH COPROCESSOR.',/,
     +       3X,'3. MANY LOCATIONS IN THE PROGRAM REFER TO THE',/,
     +       6X,'CARRIAGE RETURN (<CR>), THIS IS THE SAME AS',/,
     +       6X,'THE ENTER KEY OR RETURN KEY.                  ',/,
     +       3X,'4. RUNNING RECHARGE MAY CREATE PROBLEMS WITH OTHER',/,
     +       6X,'PROGRAMS BECAUSE OF THE SCREEN MANIPULATIONS RELATED',/, +
     6X,'TO THE GRAPHICS. IF THIS OCCURS, WARM BOOT THE',/,
     +       6X,'SYSTEM',/)
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
300 FORMAT(' **ENTER PROJECT TITLE & P.I.N. (LIMITED TO 40 ALPHANUMERI
   1C CHARACTERS):',/,' >>    ')
301 FORMAT(10A4)
302 FORMAT(/7,'===================================================',/,
   1' DESIGN TRIAL NO. ',I2,//,3X,'**TYPE OF PROBLEM (PROB) ?',//,5X,
   1'THIS PROGRAM WILL COMPUTE THE PHYSICAL DIMENSIONS FOR THE',/,5X,
   1'REQUIRED BASIN TO OPERATE AT',/,5X,
   1'1. A GIVEN BASIN OPERATING HEAD (H)------PROB=0.0 ',/,
   15X,'2. A GIVEN BASIN TOP SURFACE AREA (ATS)--PROB=1.0', 1//,5X,'ENTER
   A 0.0 OR 1.0 FOR PROB >>  ')
304 FORMAT(' ENTER THE PROPOSED BASIN OPERATING HEAD (H) IN ft >>  ')
306 FORMAT(' ENTER THE PROPOSED BASIN SURFACE AREA (ATS) IN sq ft
   1 >>    ')
307 FORMAT(F10.2)
308 FORMAT(///,'***',
   1'ENTER THE FOLLOWING BASIN GEOMETRIC INFORMATION IN SEQUENCE',/,
   1'    (DATA SEPARATED BY SPACES):',//,
   1'      1. BASIN SHAPE (SHAP): IF SHAP=0.0, CIRCULAR-SHAPED BASIN',/,
   127X,'IF SHAP=1.0, SQUARE OR RECTANGULAR SHAPED BASIN',/,
   1'      2. SIDE SLOPES (SSL) : 1(VERTICAL) ON  SSL(HORIZONTAL)',/,
   1'      3. RATIO OF LENGTH TO WIDTH FOR THE BASIN SURFACE AREA (RLW):
   1',/,7X,'ENTER RLW=0.0 IF SHAP=0.0',/,' ENTER SHAP,SSL & RLW >>  ')
310 FORMAT(/,'                  DESIGN TRIAL NUMBER ',I2)
311 FORMAT(//,'***',
   1'ENTER THE FOLLOWING SUBSURFACE INFORMATION AND SOIL PROPERTIES'
   1,/,'     (DATA SEPARATED BY SPACES):',//,
   1'  1. Z   : DEPTH TO GROUND WATER TABLE IN ft. ENTER Z=999., IF NO
   1G.W.T.',/,10X,'IS ENCOUNTERED',/,
   1'  2. SG : SPECIFIC GRAVITY OF SOIL SOLIDS ',/,
   1'  3. W   : NATURAL DRAINED WATER CONTENT EXPRESSED AS A DECIMAL'
   1,/,10X,'USE 0.03 FOR GRAVELS & SANDS, AND 0.05 FOR SILTS',/,
   1'  4. POR: POROSITY OF SOIL',/,
   1'  5. SAT: DEGREE OF SATURATION IN THE TRANSMISSION ZONE',/,10X,
   1'SAT GENERALLY RANGES FROM 0.80 TO 0.85 FOR SILTS',/,10X,
   1'AND IS APPROXIMATELY 0.70 FOR SANDS',/,
   1' ENTER Z,SG,W,POR & SAT >>    ')
501 FORMAT(12X,'DEPTH TO GROUNDWATER TABLE,ft------------= NO G.W.T.')
502 FORMAT(12X,'DEPTH TO GROUNDWATER TABLE,ft------------=',F6.2)
318 FORMAT(10X,'SUMMARY OF SOIL PROPERTIES:',//,12X,
   1'D50 GRAIN SIZE,mm------------------------=',F6.2,/,12X,
   1'SPECIFIC GRAVITY-------------------------=',F5.3,/,12X,
   1'DEGREE OF SATURATION---------------------=',F5.3,/,12X,
   1'NATURAL DRAINED WATER CONTENT------------=',F5.3,/,12X,
   1'POROSITY---------------------------------=',F5.3,/,12X,
   1'HYDRAULIC CONDUCTIVITY,ft/hr-------------=',F6.3,/,12X,
   1'CAPILLARY SUCTION POTENTIAL,ft-----------=',F5.3,/,12X,
   1'HYDRAULIC DIFFUSIVITY,sq ft/hr-----------=',F7.3)
338 FORMAT(12X,'TOTAL SPECIFIC SURFACE,sq cm/cu cm--------=',F7.2)
321 FORMAT(10X,'ERROR:DISTANCE BETWEEN BASIN FLOOR TO G.W.T. IS LESS',
   1//,' THAN [0.25*H] AND INFINITE  DEPTH THEORY LOSES VALIDITY')
322 FORMAT(10X,'DESIGN SUMMARY FOR TRIAL NO. ',I2,/,10X,
   1'THE BASIN SIZE AND DIMENSIONS ARE AS FOLLOWS:',//,12X,
   1'SIDE SLOPES:  ',F5.2,'  (HORIZONTAL) TO 1 (VERTICAL)')
323 FORMAT(7X,'L/W AT BASIN TOP:  ',F5.2,/,20X,'TOP: ',F8.2,
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
    1'ft X ',F8.2,'ft,',' AREA = ',F1Ø.2,' sq ft',/,18X,'FLOOR: ',F8.2,
    1'ft X ',F8.2,'ft,',' AREA = ',F1Ø.2,' sq ft',/)
324 FORMAT(13X,'TOP RADIUS: ',F8.2,'ft,',3X,'AREA= ',F1Ø.2,' sq ft',/,
    1 11X,'FLOOR RADIUS; ',F8.2,'ft,',3X,'AREA= ',F1Ø.2,' sq ft')
325 FORMAT(17X,'VOLUME: ',E1Ø.3,' cu ft',/,18X,'DEPTH: ',F6.2,'ft')
326 FORMAT(1ØX,'ERROR:DIVIDE BY ZERO (POR-THETAN)')
327 FORMAT(1ØX,'ERROR:ALFA=Ø/Ø')
328 FORMAT(1ØX,'ERROR:THE PROPOSED BASIN SURFACE AREA IS TOO BIG')
778 FORMAT(1ØX,'ERROR:THE PROPOSED BASIN SURFACE AREA IS TOO SMALL')
329 FORMAT(1ØX,'ERROR:ZERO OR NEGATIVE FLOOR AREA')
33Ø FORMAT(' MORE TO DO ?? [Y OR N] >>    ')
332 FORMAT(1ØX,'ERROR:THE PROPOSED PEAK OPERATING HEAD IS TOO BIG')
777 FORMAT(1ØX,'ERROR:THE PROPOSED PEAK OPERATING HEAD IS TOO SMALL') 330
FORMAT(/,'***DETERMINATION OF THE COEFFICIENT OF SATURATED PER-',
    1/,'***MEABILITY OF SOIL, KS',//,
    13X,'ENTER A 1.Ø IF YOU WISH THE PROGRAM TO ESTIMATE KS',/, 13X,'VALUE
    USING SPECIFIC SURFACE ANALYSIS ESTABLISHED',/,
    13X,'BY LOUDON. NOTE THAT, HOWEVER, THIS METHOD SHOULD',/,
    13X,'ONLY BE APPLIED TO GRAVELS AND SANDS HAVING NOT MORE',/,
    13X,'THAN 5 PERCENT OF THE MATERIAL PASSING THE NO.2ØØ SIEVE.',/,
    13X,'OTHERWISE ENTER A Ø.Ø -------1.Ø OR Ø.Ø ? >> ')
336 FORMAT(' DFIT IS DEFINED AS THE SOIL PARTICLE SIZE AT 5Ø% FINER BY
    1 WEIGHT IN cm.',/,' KS IS DEFINED AS THE SATURATED PERMEABILITY
    1OF SOIL IN ft./hr.',//,'    ENTER DFIT & KS >>   ')
337 FORMAT(1H1)
     END
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
       SUBROUTINE SIEVE(III,SSS)
C      This program is designed to develop a grain size distribution
C      curve. This subroutine is also where the Kernel System is opened
       IMPLICIT REAL*4 (a-z)
       COMMON/NARAG/IB,QMI(20),QMIC(20),T(20),ZZ(20),K,HH(6),SHAP,
     + IWRITE,PROB,ATS,IBRK,RLW,ALFA,SM,H,SSL,TITL(10),NUM,IBREAK,
     + IERROR
       COMMON/SHAKE/SS,DFIT,DDQ(6),AS(6),PSIN,PT
       INTEGER*2 SEGNAM,IX,IY,GRACOM
       COMMON /B1/ SEGNAM,ITX,IY,XNDC,YNDC,SCRHGT,SCRWID,SCALE,SIGN,
     +              CPX,CPY
       DIMENSION FINER(12),SIZE(12),SFAC(12),RET(12)
       DIMENSION FINER1(12),SIZE1(12),SSI(12)
       REAL*8 CHAR,GS1(6)
       INTEGER*4 SIZES,INTARY(12500)
       CHARACTER*2 NUMBER(9),YES,NO,ACODE
       CHARACTER*4 NUMBERS(5)
       DIMENSION GRIDXX(2),GRIDXY(2),GRIDYY(2),GRIDYX(2)
       DIMENSION XAXISX(2),XAXISY(2),YAXISX(2),YAXISY(2)
       DIMENSION W(2), V(2)
       INTEGER NUM, I, L, M, N, NUM1, JA, JB, NA, J, NNN, MM, MN
       INTEGER NUM2, JJ, K, KK, IA, IJ, IWRITE
C
       COMMON /GRACOM/ SIZES,INTARY
C
C      SET VARIABLES FOR GRAPHING PROCEDURES
       INTEGER*2 CRTDEV,WSSDEV,PRTDEV
       INTEGER*2 CHNUM,STATUS,WKTYPE(3)
       DATA YES,NO/'Y','N'/
       DATA WKTYPE/0,1,2/
       DATA NUMBER/'10','20','30','40','50','60','70','80','90'/
       DATA NUMBERS/'0.01','0.10','1.0','10.0','100.'/
C      *****INITIALIZE SCRATCH MEMORY AREA*****
       SIZES=12500
      IWRITE=6
      IF(III.GT.1)THEN
       GOTO 199
      ENDIF
      IF(SSS.EQ.0.0)THEN
       GOTO 199
      ENDIF
  123 WRITE(*,101)
      READ(*,102)NUM
      DO 3 IJ=1,NUM
      IF(IJ-NUM)2,1,2
    1 WRITE(*,103)IJ,IJ
      READ(*,104)ACODE
      WRITE(*,121)IJ,IJ
    2 WRITE(*,105)IJ
      READ*,SIZE(IJ),RET(IJ),SFAC(IJ)
    3 CONTINUE
  129 DO 817 IJ=1,NUM
      WRITE(*,107)IJ,IJ,SIZE(IJ),IJ,RET(IJ),IJ,SFAC(IJ)
  817 CONTINUE
      IJ=IJ-1
      WRITE(*,108)IJ
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
      READ(*,104)ACODE
      IF(ACODE.EQ.YES)GO TO 4
      WRITE(*,109)
      READ(*,171)I
  171 FORMAT(I3)
      WRITE(*,105)I
      READ*,SIZE(I),RET(I),SFAC(I)
      GOTO 129
    4 WRITE(*,791)
  791 FORMAT(10X,'AFTER NEXT GRAPH APPEARS, PRESS <CR> TO CONTINUE',///,
     +10X,'  ***PRESS <CR> NOW TO CONTINUE***')
      READ(*,792)NNN
  792 FORMAT(I2)
      TEMP=0.
      DO 861 I=1,NUM
       TOTAL=RET(I)+TEMP
       TEMP=TOTAL
  861 CONTINUE
      IF(TOTAL.LT.99.9)THEN
       IERROR=1
       OPEN(IWRITE,FILE='PRN')
       WRITE(IWRITE,113)
       GOTO 124
      ENDIF
      IF(TOTAL.GT.100.)THEN
       RET(NUM)=RET(NUM)-(TOTAL-100.)
      ENDIF
      IF(TOTAL.LT.100.)THEN
       RET(NUM)=RET(NUM)+(100.-TOTAL)
      ENDIF
      OPEN(IWRITE,FILE='PRN')
      IF(RET(1).EQ.0 .AND. SFAC(1).EQ.0) GO TO 5
      WRITE (IWRITE,110)
      IERROR=1
      GOTO 124
    5 DO 7 I=2,NUM
      IF(SFAC(I).GE.1.AND.SFAC(I).LE.1.99) GO TO 6
      WRITE(IWRITE,111)
      IERROR=1
      GOTO 124
    6 IF((SIZE(I)-SIZE(I-1)).LE.0)GO TO 7
      WRITE(IWRITE,112)
      IERROR=1
      GOTO 124
    7 CONTINUE
      TRET=0.
      II=0
      DO 599 I=1,NUM
       SIZE1(I)=SIZE(I)
  599 CONTINUE
      DO 8 I=1,NUM
      TRET=TRET+RET(I)
      FINER(I)=100.-TRET
      IF (FINER(I).GT.50.) GO TO 8
      IF(II.GT.0) GO TO 8
      S=(ALOG10(SIZE(I-1)/SIZE(I)))/(FINER(I-1)-FINER(I))
```

```
      DFIT=(SIZE(I)*(10.**(S*(50.-FINER(I)))))/10.
      II=I
    8 CONTINUE
C
C     OBTAIN THE PARTICLE SIZE @ ZERO PERCENT FINER
C
   10 IF(SIZE(NUM))13,13,11
   13 A=(ALOG10(SIZE(NUM-2)/SIZE(NUM-1))*FINER(NUM-1))/(FINER(NUM-2)-
     +  FINER(NUM-1))
      SIZE(NUM)=SIZE(NUM-1)/10.**A
      SIZE1(NUM)=SIZE(NUM)
   11 SS=0.
      DO 12 I=1,NUM-1
      DTIO=SIZE(I)/SIZE(I+1)
      SAV=-2.61*(1.-DTIO)/(ALOG10(DTIO)*SIZE(I)*0.1)
      SSI(I)=SAV*(RET(I+1)*0.01)*SFAC(I+1)
      SS=SS+SSI(I)
   12 CONTINUE
      CLOSE(IWRITE,ERR=124)
C
C     CALCULATE SPECIFIC SURFACE AREA
C
C      ****************************************************************
C      ****************************************************************
C      SET SCREEN DIMENSIONS
C      ****************************************************************
  199  X=5.75
       YNORM=125.
       Y=115.
       X1=0.75
       Y1=15.
       XAXISX(1)=X1
       XAXISX(2)=X
       XAXISY(1)=Y1
       XAXISY(2)=Y1
       YAXISX(1)=X1
       YAXISX(2)=X1
       YAXISY(1)=Y1
       YAXISY(2)=Y
C      **********************************
C      *INITIALIZE AND OPEN KERNEL SYSTEM*
C      **********************************
       OPEN(14,FILE='ERRORS')
       CALL GINKS(3,'WISS;DISPLAY;PRINTER;',WKTYPE,VERNUM)
       WSSDEV=0
       CRTDEV=1
       PRTDEV=2
        CALL GOPKS(14,10000)
C      SET WORLD WINDOW (USER UNITS)
       CALL GSWN(1,0.0,X,0.0,YNORM)
C      SELECT TRANSFORMATION 1
       CALL GSELNT(1)
C      ***OPEN AND ACTIVATE DISPLAY AND WISS***
       CALL GOPWK(WSSDEV,0,WSSDEV)
       CALL GACWK(WSSDEV)
       OPEN(IWRITE,FILE='PRN')
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
      WRITE(IWRITE,120)TITL
  120 FORMAT(//////,10X,'**NYSDOT RECHARGE BASIN DESIGN**',///,
     1 10X,'PROJECT TITLE & PIN NO: ',10A4,///)
      IF(III.GT.1)THEN
       GOTO 124
      ENDIF
      IF(SSS.EQ.0.0)THEN
       GOTO 124
      ENDIF
      CALL OPENWS(CRTDEV)
C     ***************************************************
C     FORM X AND Y AXIS
      CALL GCRSG(200)
      CALL GSLN(1)
      CALL GSPLCI(3)
      CALL GPL(2,XAXISX,XAXISY)
      CALL GPL(2,YAXISX,YAXISY)
C     LABEL AXES
      CALL GSTXCI(1)
      CALL GSCHH(2.57)
      XA=X*0.40
      YA=Y1*0.35
      XC=X1*0.55
      YC=Y1*0.70
      XAB=X*0.30
      YAB=Y*1.03
       CALL GTX(XAB,YAB,'GRAIN SIZE DISTRIBUTION CURVE')
       CALL GTX(XA,YA,'GRAIN SIZES (MM)')
      CALL GCLSG(200)
      XR=X1*0.30
      YR=Y*0.14
      CALL GSCHUP(-1.0,0.0)
      CALL GTX(XR,YR,'PERCENT FINER BY WGT.')
C     ***********************************************************
C     SET UP GRID
      CALL GCRSG(300)
      CALL GSLN(1)
      CALL GSPLCI(4)
       GRIDXY(1)=X1
       GRIDXY(2)=X
       GRIDYY(1)=Y
       GRIDYY(2)=Y
      DO 400 M=1,10
       CALL GPL(2,GRIDXY,GRIDYY)
       GRIDYY(1)=Y-(M*10.)
       GRIDYY(2)=Y-(M*10.)
  400 CONTINUE
      GRIDYX(1)=Y1
      GRIDYX(2)=Y
      GRIDXX(1)=X
      GRIDXX(2)=X
      GR=0.0
      DO 500 N=1,5
       DO 501 NA=1,5
       CALL GPL(2,GRIDXX,GRIDYX)
       GRIDXX(1)=5.75-(ALOG10(NA*2.))-GR
```

```
        GRIDXX(2)=5.75-(ALOG10(NA*2.))-GR
  501  CONTINUE
        GR=GR+1.0
  500  CONTINUE
       CALL GSLN(1)
       CALL GSPLCI(5)
        W(1)=4.75
        W(2)=4.75
        V(1)=14.
        V(2)=115.
       DO 502 NA=1,4
         CALL GPL(2,W,V)
         W(1)=W(1)-1.
         W(2)=W(2)-1.
  502  CONTINUE
       CALL GCLSG(300)
C      ***************************************************************
       CALL GCRSG(510)
       CALL GSTXCI(1)
       CALL GSCHH(2.57)
       CALL GSCHUP(0.0,1.0)
         TEMP3=114.
         CALL GTX(XC*0.90,TEMP3,'100')
       DO 515 MM=1,9
         TEMP3=114.-(MM*10.)
         CALL GTX(XC,TEMP3,NUMBER(9-MM+1))
  515  CONTINUE
         A=10.
       DO 518 MN=1,5
         TEMP4=5.60-(ALOG10(A))
         CALL GTX(TEMP4,YC,NUMBERS(MN))
         A=A*10.
  518  CONTINUE
       CALL GCLSG(510)
C      ***************************************************************
C      PLOT THE GRAIN SIZE CURVE
       CALL GCRSG(600)
       CALL GSLN(1)
       CALL GSPLCI(2)
       DO 521 IA=1,NUM
          SIZE(IA)=5.00-(ALOG10(1000*(SIZE(IA))))
  521  CONTINUE
       DO 520 IJ=1,NUM
          SIZE(IJ)=SIZE(IJ)+0.75
          FINER(IJ)=FINER(IJ)+15.
  520  CONTINUE
       CALL GPL(NUM,SIZE,FINER)
       CALL GCLSG(600)
       DO 522 IJ=1,NUM
          SIZE(IJ)=SIZE(IJ)-0.75
          FINER(IJ)=FINER(IJ)-15.
  522  CONTINUE
C      ***************************************************
      WRITE(IWRITE,125)
      WRITE (IWRITE,114)
      DO 499 I=1,NUM
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
      WRITE(IWRITE,115) FINER(I),SIZE1(I)
  499 CONTINUE
      WRITE(IWRITE,122)
  122 FORMAT(1H1)
       CLOSE(IWRITE,ERR=124)
C      **************************************************
C      PLOT WILL REMAIN ON THE SCREEN TILL YOU PRESS ENTER
       READ(*,700)NNN
  700  FORMAT(I3)
C      **************************************************
C      PRINT THE GRAPH
       CALL GCLRWK(CRTDEV,1)
       WRITE(*,809)
  809  FORMAT(' DO YOU WANT A HARDCOPY OF THE GRAPH? (Y OR N)-->')
       READ(*,104)ACODE
       IF(ACODE.EQ.YES)THEN
       WRITE(*,699)
  699  FORMAT(///,' DO NOT TOUCH A THING!!!!, WAIT FOR GRAPH TO REAPPEAR
     + ',///,' AFTER GRAPH REAPPEARS, <CR> TO CONTINUE')
C      TERMINATION
C      DEACTIVATE AND CLOSE:DISPLAY, OPEN AND ACTIVATE DISPLAY
       CALL CLOSWS(CRTDEV)
       CALL OPENWS(PRTDEV)
        CALL GCSGWK(PRTDEV,200)
        CALL GCSGWK(PRTDEV,300)
        CALL GCSGWK(PRTDEV,510)
        CALL GCSGWK(PRTDEV,600)
       CALL GCRSG(201)
       XB=X1*0.30
       YB=Y*0.20
       CALL GSCHUP(-1.0,0.0)
        CALL GTX(XB,YB,'PERCENT FINER THAN SIZE SHOWN')
       CALL GCLSG(201)
        CALL CLOSWS(PRTDEV)
C      REDRAW SEGMENTS ON SCREEN
       CALL OPENWS(CRTDEV)
        CALL GCSGWK(CRTDEV,200)
        CALL GCSGWK(CRTDEV,202)
        CALL GCSGWK(CRTDEV,300)
        CALL GCSGWK(CRTDEV,510)
        CALL GCSGWK(CRTDEV,600)
C      PLOT WILL REMAIN ON SCREEN UNTIL <CR> IS PRESSED
        READ(*,814)NNN
  814   FORMAT(I3)
       ENDIF
        CALL GCLRWK(WSSDEV,1)
        CALL GCLRWK(CRTDEV,1)
        CALL CLOSWS(CRTDEV)
  811  CONTINUE
  124  RETURN
C
C     I/O FORMAT SPECIFICATIONS
C
  101 FORMAT(///,'*************************************************'
     1,/,' **INPUT DATA TO CALCULATE THE SPECIFIC SURFACE OF **'
     1,/,' **A COHESIONLESS SOIL FROM GRAIN SIZE DISTRIBUTION**',//,
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
   1' UP TO TWELVE (12) LINES OF GRAIN-SIZE ANALYSIS AND',/,
   1' SHAPE FACTOR DATA. THE PROGRAM WILL ASK FOR THE FOLLOW-',/,
   1' ING THREE PIECES OF INFORMATION.',//,
   1'Ø1. THE OPENING SIZE (in millimeters) OF THE FINER SIEVE',/,
   1'     IN A SIEVE INTERVAL (COLUMN 2 ON FORM SM 389)',/,
   1'Ø2. THE PERCENT RETAINED OF THE TOTAL SPECIMEN IN THAT',/,
   1'     SIEVE INTERVAL (COLUMN 5 ON FORM SM 389)',/,
   1'Ø3. THE SHAPE FACTOR (COLUMN 6 ON FORM SM 389)',/,
   1'ØFOR DETAILED INFORMATION ON SPECIFIC SURFACE ANALYSIS OF',/,
   1' COHESIONLESS SOILS, SEE SOIL TEST PROCEDURE STP-1, [TEST',/,
   1' PROCEDURE FOR SPECIFIC SURFACE ANALYSIS], SOIL MECHANICS',/,
   1' BUREAU, NEW YORK STATE DEPARTMENT OF TRANSPORTATION, AUG.',/, ,
   1' 1973.',//,
   1' HOW MANY SETS OF DATA FOR SPEC. SURFACE ANALYSIS NS=(1-12) ? ---
   1>>   ')
102 FORMAT(I2)
103 FORMAT(' DO YOU WISH THE COMPUTER TO CALCULATE SIZE(',I2,')?',
   1/,' WHERE SIZE(',I2,') IS DEFINED AS THE PARTICLE SIZE AT ZERO',
   1/,' PERCENT FINER BY WEIGHT.',
   1/,' Y OR N >>    ')
104 FORMAT(A1)
105 FORMAT(/,' DATA NO. ',I2,':  OPENING SIZE, PERCENT RETAINED, SHAPE
   + FACTOR ',/,'  >> ')
107 FORMAT(' DATA NO. ',I2,3X,'SIZE(',I2,')= ',F8.4,1X,'mm',3X,
   1'RET(',I2,')=',F6.2,3X,'SFAC(',I2,')= ',F4.2)
108 FORMAT('ØARE ALL ',I2,' SETS OF DATA CORRECT? (Y OR N) >>   ')
109 FORMAT('ØWHICH VALUE WOULD YOU LIKE TO CHANGE? (NUMBER)-->>   ')
110 FORMAT(10X,'ERROR:RET(1) AND SFAC(1) NOT ZERO')
111 FORMAT(10X,'ERROR:SFAC NOT WITHIN LIMITS')
112 FORMAT(10X,'ERROR:THE VALUES FOR SIZE MUST BE DECREASING')
113 FORMAT(10X,'ERROR: % RETAINED DOES NOT TOTAL 100')
125 FORMAT(///,10X,'GRAIN SIZE DISTRIBUTION FOR PROJECT SOIL')
114 FORMAT(/,8X,'PERCENTAGE FINER BY WEIGHT(%)    GRAIN SIZE(MM)',/)
115 FORMAT(18X,F6.2,19X,F6.3)
121 FORMAT(' IF YES, ENTER D(',I2,')=Ø.Ø, OTHERWISE D(',I2,')=Ø.XXXX'
   1,/)
    END
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
      SUBROUTINE HITA(BW,BR)
C       PROB=Ø, The basin depth is given.
        COMMON/NARAG/IB,QMI(2Ø),QMIC(2Ø),T(2Ø),ZZ(2Ø),K,HH(6),SHAP,
     + IWRITE,PROB,ATS,IBRK,RLW,ALFA,SM,H,SSL,TITL(1Ø),NUM,IBREAK,
     + IERROR
      COMMON/SHAKE/SS,DFIT,DDQ(6),AS(6),PSIN,PT
      COMMON/ILUSH/QINF(6,2Ø)
       CHARACTER*14 FOUT
       COMMON/OUT/FOUT
      OPEN(IWRITE,FILE='PRN')
      FAC=(2.*PT*(H/2.+PSIN))/((3.1416*ALFA)**Ø.5)
      FAC1=QMIC(IBRK+1)/(FAC*(IBRK)**Ø.5)
      ASMX=Ø.955*FAC1
      ASMN=Ø.3Ø*FAC1
      DO 1 I=1,1Ø
      ASM=ASMX/1Ø.**I
      IF(ASM-99.)2,2,1
    1 CONTINUE
    2 ASMX=(INT(ASM)+1.)*1Ø.**I
      ASMN=(INT(ASMN/1Ø.**I))*1Ø.**I
      IBREAK=6
      WRITE(IWRITE,1ØØ)
      DO 13 IJ=1,IBREAK
      AS(IJ)=ASMN+(IJ-1)*(ASMX-ASMN)/5.
      IF(SHAP)3,6,3
    3 IF(IJ-1)4,4,5
    4 BW=(AS(IJ)/RLW)**Ø.5-2.*(H*SSL)
      IF(BW)14,14,5
    5 FAV=AS(IJ)-SSL*H*(2.*(1.+RLW)*(AS(IJ)/RLW)**Ø.5
     1-4.*SSL*H)
      QV=H/3.*(AS(IJ)+FAV+(AS(IJ)*FAV)**Ø.5)
      FAV=AS(IJ)-(SSL*H/2.)*(2.*(1+RLW)*(AS(IJ)/RLW)**Ø.5
     1-2.*SSL*H)
      GO TO 9
    6 IF(IJ-1)7,7,8
    7 BR=(AS(IJ)/3.1416)**Ø.5-2.*(H*SSL)
      IF(BR)14,14,8
    8 QV=H*(AS(IJ)-(AS(IJ)*3.1416)**Ø.5*SSL*H+
     1(3.1416/3.)*(SSL*H)**2.)
      FAV=AS(IJ)-SSL*H/2.*(2.*(AS(IJ)*3.1416)**Ø.5-
     13.1416*(SSL*H/2.))
    9 PQ=Ø.
      DO 1Ø J=1,NUM
      QINF(IJ,J)=FAV*FAC*T(J)**Ø.5
      DQ=QMIC(J)-QINF(IJ,J)
      IF(DQ.GE.PQ)PQ=DQ
   1Ø CONTINUE
  999 IF(PQ)11,11,12
   11 IBREAK=IJ-1
      GO TO 15
   12 DDQ(IJ)=PQ-QV
      WRITE(IWRITE,1Ø1)AS(IJ),PQ,QV,DDQ(IJ)
   13 CONTINUE
      GO TO 15
   14 WRITE(IWRITE,1Ø2)
      IERROR=2
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
 15 RETURN
100 FORMAT(///,10X,'BASIN SURFACE',8X,'MAXIMUM MASS',8X,'BASIN VOLUME'
   1,7X,'DIFF. BETWEEN MAXIMUM MASS ',/,10X,'AREA(sq.ft.)',7X,'STORAGE
   1(cu.ft.)',10X,'(cu.ft.)',6X,'STORAGE & BASIN VOLUME (cu.ft.)',/)
101 FORMAT(12X,4(E10.3,10X))
102 FORMAT(12X,'**********',10X,'**********',10X,'**********',10X,'**
   1********',/,10X,'ERROR:FLOOR SIZE LE ZERO, PROPOSED H TOO BIG OR S
   1IDE SLOPES TOO FLAT',/,10X,'TRY SMALLER H OR STEEP SIDE SLOPE')
    END
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
      SUBROUTINE TAHI(BW,BR)
C       PROB=1, The basin surface area is given.
       COMMON/NARAG/IB,QMI(20),QMIC(20),T(20),ZZ(20),K,HH(6),SHAP,
     + IWRITE,PROB,ATS,IBRK,RLW,ALFA,SM,H,SSL,TITL(10),NUM,IBREAK,
     + IERROR
      COMMON/SHAKE/SS,DFIT,DDQ(6),AS(6),PSIN,PT
      COMMON/ILUSH/QINF(6,20)
       CHARACTER*14 FOUT
       COMMON/OUT/FOUT
      OPEN(IWRITE,FILE='PRN')
      FAC=QMIC(IBRK+1)*(3.1416*ALFA)**0.5
      FAC=FAC/(2.*PT*(IBRK)**0.5)
      HMA=2.*((FAC*0.955)/ATS-PSIN)
      HMN=2.*((FAC*0.30)/ATS-PSIN)
      IF(HMN.LT.0..AND.HMA.LT.0.)GO TO 14
      IF(HMN.LT.0.)HMN=0.
      X=2.*(1.+RLW)*(ATS/RLW)**0.5
      IBREAK=6
      WRITE(IWRITE,100)
      DO 9 IJ=1,IBREAK
      HH(IJ)=HMN+(IJ-1.)*(HMA-HMN)/5.
      IF(SHAP)1,3,1
    1 BW=(ATS/RLW)**0.5-2.*(HH(IJ)*SSL)
      IF(BW)10,10,2
    2 DX=X-4.*SSL*HH(IJ)
      DX=SSL*HH(IJ)*DX
      QV=HH(IJ)/3.*(2.*ATS-DX+(ATS*(ATS-DX))**0.5)
      DA=(X-2.*SSL*HH(IJ))*SSL*HH(IJ)*0.5
      GO TO 5
    3 BR=(ATS/3.1416)**0.5-2.*(HH(IJ)*SSL)
      IF(BR)10,10,4
    4 QV=HH(IJ)*(ATS-(ATS*3.1416)**0.5*SSL*HH(IJ)+
     1(3.1416/3.)*(SSL*HH(IJ))**2.)
      DA=SSL*HH(IJ)*((3.1416*ATS)**0.5-3.1416*SSL*HH(IJ)/4.)
    5 PQ=0.
      DO 6 J=1,NUM
      QINF(IJ,J)=2.*(ATS-DA)*PT*(HH(IJ)/2.+PSIN)*
     1(T(J)/(3.1416*ALFA))**0.5
      DQ=QMIC(J)-QINF(IJ,J)
      IF(DQ.GE.PQ)PQ=DQ
    6 CONTINUE
  999 IF(PQ)7,7,8
    7 IBREAK=IJ-1
      GO TO 11
    8 DDQ(IJ)=PQ-QV
      IF(IJ.GT.1)GO TO 12
      GO TO 13
   12 IF((-DDQ(IJ)+DDQ(IJ-1)).GT.0.) GO TO 13
      IBREAK=IJ-1
      GO TO 11
   13 WRITE(IWRITE,101)HH(IJ),PQ,QV,DDQ(IJ)
    9 CONTINUE
      GO TO 11
   10 WRITE(IWRITE,102)
      IERROR=2
      GO TO 11
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
  14 BR=-1.
     BW=-1.
     WRITE(IWRITE,103)
     IERROR=2
  11 RETURN
 100 FORMAT(///,10X,'BASIN OPERATING',6X,'MAXIMUM MASS',8X,'BASIN VOLUM
    1E',7X,'DIFF. BETWEEN MAXIMUM MASS ',/,10X,'HEAD (sq.ft.)',7X,'STOR
    1AGE (cu.ft.)',5X,'(cu.ft.)',10X,'STORAGE & BASIN VOLUME (cu.ft.)',
    1/)
 101 FORMAT(12X,F6.2,14X,3(E10.3,10X))
 102 FORMAT(12X,'******',14X,'**********',14X,'**********',14X,'*****
    1*****',/,10X,'ERROR:FLOOR SIZE LE ZERO, THE PROPOSED BASIN SURFACE
    1 AREA IS TOO SMALL !',/,10X,'TRY A LARGER SURFACE AREA!')
 103 FORMAT(10X,'ERROR:THE PROPOSED BASIN SURFACE AREA IS TOO BIG')
     END
```

APPENDIX D
PROGRAM “RECHARGE” LISTING – *US Customary Units*)

```
      SUBROUTINE FLOW(III)
C     This program is designed to develop a graph of the
C     time vs. inflow function for recharge basins. It is run twice
C     once for the inflow and corrected curve and the other for
C     the corrected and design curves.
      COMMON/NARAG/IB,QMI(2Ø),QMIC(2Ø),T(2Ø),ZZ(2Ø),K,HH(6),SHAP,
     + IWRITE,PROB,ATS,IBRK,RLW,ALFA,SM,H,SSL,TITL(1Ø),NUM,IBREAK,
     + IERROR
     COMMON/SHAKE/SS,DFIT,DDQ(6),AS(6),PSIN,PT
      COMMON/LUSH/Y,IX,APX,APY,IJJ,CX,CY
      COMMON/ILUSH/QINF(6,2Ø)
      COMMON /B1/ SEGNAM,ITX,IY,XNDC,YNDC,SCRHGT,SCRWID,SCALE,SIGN,
     +            CPX,CPY
      COMMON/DOVER/IIII
C
C     SET VARIABLES FOR GRAPHING PROCEDURES
      INTEGER*2 WSSDEV,CRTDEV,PRTDEV,CHOICE
      CHARACTER*2 NUMBER(1Ø)
      CHARACTER*1 LANG1(11)
      DIMENSION LANG(1Ø),XAXISX(2),XAXISY(2),YAXISX(2),YAXISY(2) DIMENSION
      GRIDXY(2),GRIDYY(2),ACT(2),ACTY(2),A1(2),B1(2)
      DIMENSION COR(2),CORY(2),GRIDYX(2),GRIDXX(2)
      DIMENSION TXEXPX(4), TXEXPY(4)
      CHARACTER*2 ARNO(6), ACODE, YES, NO
      DIMENSION DYY(2Ø)
      DIMENSION QMI1(2Ø),QMI2(2Ø),T1(2Ø)
C
      DATA YES,NO/'Y','N'/
      DATA ARNO/'A','B','C','D','E','F'/
      DATA NUMBER / '2','4','6','8','1Ø','12','14','16','18','2Ø'/
      DATA LANG/1Ø.,1ØØ.,1ØØØ.,1ØØØØ.,1ØØØØØ.,1ØØØØØØ.,1ØØØØØØØ.,
     +          1ØØØØØØØØ.,1ØØØØØØØØØ.,1ØØØØØØØØØØ./
      DATA LANG1/'1','2','3','4','5','6','7','8','9','1Ø','11'/
C     FIND THE MAXIMUM INPUT VALUES
      IF(III.GT.1)GOTO 377
      IF(IIII)377,378,377
  378 WRITE(*,1Ø)
  1Ø  FORMAT(///2ØX,'************MASS INFLOW VS. TIME************',//)
      WRITE(*,915)
  915 FORMAT(5X,' The following values are the inflow quantities',/
     +        ,5X,' measured at every hour. The program makes any time',/
     +        ,5X,' correction necessary illustrating both the actual',/
     +        ,5X,' and corrected inflow curve.'//
     +        ,5X,' The first input value is at time=Ø.',///)
      WRITE(*,92Ø)
  92Ø  FORMAT(//,15X,'ENTER NUMBER OF TIME READINGS(INTEGER, max of 2Ø)
     + -->>  ')
      READ(*,3Ø)NUM
  3Ø  FORMAT(I3)
      DO 32 I=1,NUM
        T(I)=(I*1.)-1.Ø
        WRITE(*,37)I,I-1
  37    FORMAT(/,5X,I2,'> INFLOW(cu.ft.) AT ',I2,' HOURS-->  ')
        READ(*,38)QMI(I)
```

APPENDIX D
PROGRAM “RECHARGE” LISTING – *US Customary Units*)

```
 38       FORMAT(F14.2)
 32    CONTINUE
 129   DO 817 IJ=1,NUM
        WRITE(*,107)IJ-1,QMI(IJ)
 107    FORMAT('    TIME(hours)=',I2,'      INFLOW(cu.ft.)=',F12.1)
 817   CONTINUE
       IJ=IJ-1
       WRITE(*,108)IJ
 108   FORMAT('ØARE ALL ',I2,' SETS OF DATA CORRECT? (Y OR N) >>   ')
       READ(*,104)ACODE
 104   FORMAT(A1)
       IF(ACODE.EQ.YES) GOTO 379
        WRITE(*,631)
 631    FORMAT('ØWHICH TIME READING WOULD YOU LIKE TO CHANGE?  >>   ')
        READ(*,171)I
 171    FORMAT(I3)
        WRITE(*,105)I+1,I
 105     FORMAT(/,5X,I2,'> INFLOW(cu.ft.) AT ',I2,' HOURS-->   ')
        READ*,QMI(I+1)
       GOTO 129
 379 WRITE(*,791)
 791 FORMAT(1ØX,'AFTER NEXT GRAPH APPEARS, PRESS <CR> TO CONTINUE',///,
    +1ØX,'***PRESS <CR> NOW TO CONTINUE***')
     READ(*,792)NNN
 792 FORMAT(I2)
       DO 376 I=1,NUM
        QMI1(I)=QMI(I)
 376   CONTINUE
 377   OPEN(IWRITE,FILE='PRN')
       DO 375 I=1,NUM
        QMI(I)=QMI1(I)
 375   CONTINUE
C      ****************************************************************
C      THIS IS THE ROUTINE TO PICK THE SCALE FOR THE GRAPH.
C      FIRST FIND THE MAXIMUM VALUES FOR THE INFLOW AND THE
C      TIME THEN CHOOSE THE SCALE FOR THE X AND Y AXIS
C      RESPECTIVELY.
C      ****************************************************************
 9     NUM1=1
       DO 41 J=2,NUM
         IF(QMI(J-1).LT.QMI(J))THEN
           NUM1=J
         ENDIF
 41    CONTINUE
C
C      Y AXIS
       TEMP1=QMI(NUM1)
 5Ø    IF(TEMP1.GT.1Ø.)THEN
         TEMP1=TEMP1/1Ø.
         GO TO 5Ø
       ENDIF
       K=TEMP1+1
       A=K*1.
       IA=A*1
```

```
C       ****************************************************************
C       MAKE A GREATER THAN ALL INPUT VALUES
C       A ARE THE VALUES ON THE Y AXIS
  7Ø    IF(A.LT.QMI(NUM1))THEN
           A=A*1Ø.
           GO TO 7Ø
        ENDIF
C       ****************************************************************
C       SET SCREEN DIMENSIONS
C       ****************************************************************
        NUMM=NUM*1.Ø
        X=NUM*1.15
        Y=A*1.15
        YNORM=A*1.25
        X1=NUM*Ø.15
        Y1=A*Ø.15
        XAXISX(1)=X1
        XAXISX(2)=X
        XAXISY(1)=Y1
        XAXISY(2)=Y1
        YAXISX(1)=X1
        YAXISX(2)=X1
        YAXISY(1)=Y1
        YAXISY(2)=Y
C       ****************************************************************
        FLAG=Ø
        WSSDEV=Ø
        CRTDEV=1
        PRTDEV=2
C       ************************************************
C       ***SET WORLD WINDOW (USER UNITS)***
  117   CALL GSWN(1,Ø.Ø,X,Ø.Ø,YNORM)
C       ***SELECT TRANSFORMATION 1***
        CALL GSELNT(1)
C       ***OPEN AND ACTIVATE DISPLAY***
        CALL OPENWS(CRTDEV)
C       ***CLEAR SCREEN***
        CALL GCLRWK(CRTDEV,1)
C       ************************************************
C       FORM X AND Y AXIS
  118   CALL GCRSG(2ØØ)
        CALL GSLN(1)
        CALL GSPLCI(3)
        CALL GPL(2,XAXISX,XAXISY)
        CALL GPL(2,YAXISX,YAXISY)
C       LABEL AXES
        CALL GSTXCI(1)
        CALL GSCHUP(Ø.Ø,1.Ø)
        CALL GSCHH(A*Ø.Ø25)
        XA=X*Ø.45
        YA=Y1*Ø.35
        XB=X1*Ø.5Ø
        YB=Y*Ø.19
        XC=X1*Ø.65
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
      YC=Y1*Ø.7Ø
      XD=X1*Ø.38
      YD=Y*Ø.78
      TEMPX=1
      TEMPY=A/IA
      CALL GTX(XA,YA,'TIME (HOURS)')
      CALL GCLSG(2ØØ)
      CALL GCRSG(2Ø1)
      CALL GSCHUP(-1.Ø,Ø.Ø)
       CALL GTX(XB,YB,'INFLOW(CU.FT.*1Ø')
       CALL GQTXX(CRTDEV,XB,YB,'INFLOW(CU.FT.*1Ø',ERRIND,CPX,
     +           CPY,TXEXPX,TXEXPY)
       INN=1
 1Ø9   IF(LANG(INN).LT.A)THEN
        INN=INN+1
       GOTO 1Ø9
       ENDIF
       CALL GTX(CPX-Ø.16,CPY+Ø.1Ø,LANG1(INN-1))
       CALL GQTXX(CRTDEV,CPX-Ø.12,CPY,LANG1(INN-1),ERRIND,
     +           CPX,CPY,TXEXPX,TXEXPY)
       CALL GTX(CPX+Ø.16,CPY-1.,')')
       CALL GCLSG(2Ø1)
C     ****************************************************************
C     SET UP GRID
      CALL GCRSG(3ØØ)
      CALL GSLN(1)
      CALL GSPLCI(4)
       GRIDXY(1)=X1
       GRIDXY(2)=NUMM+X1
       GRIDYY(1)=A+Y1
       GRIDYY(2)=A+Y1
      DO 4ØØ M=1,IA
       CALL GPL(2,GRIDXY,GRIDYY)
       GRIDYY(1)=A-(M*(A/IA))+Y1
       GRIDYY(2)=A-(M*(A/IA))+Y1
 4ØØ  CONTINUE
      GRIDYX(1)=Y1
      GRIDYX(2)=A+Y1
      GRIDXX(1)=NUMM+X1
      GRIDXX(2)=NUMM+X1
      DO 5ØØ N=1,NUM
       CALL GPL(2,GRIDXX,GRIDYX)
       GRIDXX(1)=GRIDXX(1)-1.Ø
       GRIDXX(2)=GRIDXX(2)-1.Ø
 5ØØ  CONTINUE
      CALL GCLSG(3ØØ)
C     ****************************************************************
      CALL GCRSG(51Ø)
      CALL GSTXCI(1)
      CALL GSCHH(A*Ø.Ø25)
      CALL GSCHUP(Ø.Ø,1.Ø)
      MUMM=IA
        CALL GTX(XC,Y1-(Ø.Ø2*A),'Ø')
        TEMP3=A+Y1-(Ø.Ø2*A)
```

```
      DO 515 MM=1,MUMM
        CALL GTX(XC,TEMP3,LANG1(MUMM-MM+1))
        TEMP3=TEMP3-(A/IA)
  515 CONTINUE
      MUM=NUM/2
        TEMP4=(2*MUM)+X1-(Ø.Ø12*NUM)
      DO 518 MN=1,MUM
        CALL GTX(TEMP4,YC,NUMBER(MUM-MN+1))
        TEMP4=(2*MUM)+X1-((2*MN)+(Ø.Ø12*NUM))
  518 CONTINUE
      CALL GCLSG(51Ø)
      IF(IIII)333,334,333
C     ******************************************************************
C     PLOT THE LINE
  334 CALL GCRSG(6ØØ)
      IIII=1
C     ***************************************************
C     ROUTINE TO CHECK WHETHER A TIME CORRECTION IS NECESSARY
      FLAG1=Ø
     IB=Ø
     SM=Ø.
     WRITE(IWRITE,43Ø)
     DO 17 I=2,NUM
     SL=QMI(I)-QMI(I-1)
     IF(SL.GT.SM) GO TO 15
     IF(SL.EQ.SM) GO TO 16
     IF(IB)11,11,18
  11 DO 12 J=I+1,NUM
     SX=QMI(J)-QMI(J-1)
     IF(SX.GT.SL) GO TO 26
     SL=SX
  12 CONTINUE
      CALL GTX(Ø.23*X,1.Ø3*Y,'MASS INFLOW CURVE, NO TIME CORRECTION')
C    NO TIME CORRECTION IS NECESSARY
     DO 13 II=1,NUM
     QMIC(II)=QMI(II)
  13 CONTINUE
     WRITE(IWRITE,431)
     DO 14 IJ=1,NUM
      WRITE(IWRITE,435)T(IJ),QMI(IJ)
  14 CONTINUE
     GO TO 27
  15 IB=I-2
  16 SM=SL
  17 CONTINUE
     GO TO 26
  18 WRITE(IWRITE,432)
     DO 31 I=2,NUM
      IF(QMI(I).LT.QMI(I-1))GOTO 26
  31 CONTINUE
     FLAG1=1
C    REQUIRE A CORRECTION TO TIME COORDINATES
     IB=IB+1
     XX=QMI(IB)/SM
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
      IX=INT(XX)
      DX=1.-(XX-IX)
      DO 19 I=1,IX
      QMIC(I)=SM*I
   19 CONTINUE
      DO 22 I=IB,NUM
      IX=IX+1
      IF(I-NUM) 20,21,23
   20 QMIC(IX)=QMI(I)+DX*(QMI(I+1)-QMI(I))
      GO TO 22
   21 QMIC(IX)=QMI(NUM)
   22 CONTINUE
   23 IF(IX.GE.NUM) GO TO 25
      DO 24 I=IX+1,NUM
      QMIC(I)=QMI(NUM)
   24 CONTINUE
   25 DO 29 I=NUM,2,-1
       QMIC(I)=QMIC(I-1)
   29 CONTINUE
       QMIC(1)=Ø.
      WRITE(IWRITE,433)(T(I),QMI(I),QMIC(I),I=1,NUM)
       CALL GTX(Ø.2Ø*X,1.Ø3*Y,'TIME CORRECTION FOR MASS INFLOW WITH TAIL
     + ')
      GOTO 27
   26 WRITE(IWRITE,434)
      IERROR=1
      GOTO 811
  43Ø   FORMAT(//,14X,'**MASS INFLOW QUANTITY(cu ft) VS. TIME(hr)**')
  431   FORMAT(//,2ØX,'TIME',6X,'ACTUAL',//)
  432   FORMAT(//,2ØX,'TIME',6X,'ACTUAL',4X,'CORRECTED',//)
  433   FORMAT(2ØX,F3.Ø,4X,E1Ø.3,2X,E1Ø.3)
  434   FORMAT(14X,'ERROR:IRREGULAR MASS INFLOW CURVE !',/,
     +  2ØX,'MASS INFLOW CURVE SHOULD BE A CONTINUOUS SMOOTH CURVE'
     +  ,/,2ØX,'AND QMI(T+1) SHOULD NOT BE LESS THAN QMI(T).')
  435   FORMAT(2ØX,F3.Ø,4X,E1Ø.3)
   27  WRITE(IWRITE,436)
  436  FORMAT('  Note: E+XX stands for 1Ø to the XXth power.')
      WRITE(IWRITE,123)
  123 FORMAT(1H1)
       DO 521 I=1,NUM
          T(I)=T(I)+X1
          T1(I)=T(I)
          QMI(I)=QMI(I)+Y1
          QMIC(I)=QMIC(I)+Y1
          QMI2(I)=QMIC(I)
  521  CONTINUE
       CALL GSLN(6)
       CALL GSPLCI(2)
       CALL GPL(NUM,T,QMI)
       ACT(1)=X*Ø.7Ø
       ACT(2)=X*Ø.75
       ACTY(1)=Y*Ø.2Ø
       ACTY(2)=Y*Ø.2Ø
       COR(1)=Ø.7Ø*X
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
      COR(2)=Ø.75*X
      CORY(1)=Ø.17*Y
      CORY(2)=Ø.17*Y
      IF(FLAG1.EQ.Ø)GOTO 57Ø
      G=ACTY(1)-(.Ø1*Y1)
      CALL GPL(2,ACT,ACTY)
      CALL GTX(ACT(2),G,'ACTUAL')
C     DRAW THE CORRECTED CURVE
      CALL GSPLCI(7)
      CALL GSLN(1)
      CALL GPL(NUM,T,QMIC)
      G=CORY(1)-(.Ø1*Y)
      CALL GPL(2,COR,CORY)
      CALL GTX(COR(2),G,'CORRECTED')
      GOTO 57Ø
C     ****************************************************************
 57Ø  CALL GCLSG(6ØØ)
C     ****************************************************
C     PLOT WILL REMAIN ON THE SCREEN TILL YOU PRESS ENTER
 28Ø  CLOSE(IWRITE,ERR=811)
      READ(*,7Ø1)NNN
 7Ø1  FORMAT(I3)
C     *****************************************************
      CALL GCLRWK(CRTDEV,1)
      WRITE(*,8Ø9)
 8Ø9  FORMAT(' DO YOU WANT A HARDCOPY OF THE GRAPH? (Y OR N)-->')
      READ(*,1Ø4)ACODE
      IF(ACODE.EQ.YES)THEN
      WRITE(*,699)
 699  FORMAT(///,' DO NOT TOUCH A THING!!!!, WAIT FOR GRAPH TO REAPPEAR
     + ',///,' AFTER GRAPH REAPPEARS, <CR> TO CONTINUE')
C     TERMINATION
C     DEACTIVATE AND CLOSE DISPLAY, ACTIVATE AND OPEN PRINTER
      CALL CLOSWS(CRTDEV)
      CALL OPENWS(PRTDEV)
       CALL GCSGWK(PRTDEV,2ØØ)
       CALL GCSGWK(PRTDEV,3ØØ)
       CALL GCSGWK(PRTDEV,51Ø)
       CALL GCSGWK(PRTDEV,6ØØ)
      CALL GCRSG(2Ø2)
      CALL GSTXCI(1)
      CALL GSCHH(Ø.ØØ3)
      XB=X1*Ø.5Ø
      YB=Y*Ø.3Ø
      YC=Y*Ø.5Ø
      XC=X1*Ø.38
      CALL GSCHUP(-1.Ø,Ø.Ø)
       CALL GTX(XB,YB,'INFLOW (CUBIC FEET * 1Ø   )')
       INN=1
 111   IF(LANG(INN).LT.A)THEN
        INN=INN+1
       GOTO 111
       ENDIF
       CALL GTX(XC,YC,LANG1(INN-1))
```

```
       CALL GCLSG(202)
        CALL CLOSWS(PRTDEV)
C      REDRAW SEGMENTS ON SCREEN
       CALL OPENWS(CRTDEV)
        CALL GCSGWK(CRTDEV,200)
        CALL GCSGWK(CRTDEV,201)
        CALL GCSGWK(CRTDEV,300)
        CALL GCSGWK(CRTDEV,510)
        CALL GCSGWK(CRTDEV,600)
C      ***********************************************
C      PLOT WILL REMAIN ON SCREEN UNTIL <CR> IS PRESSED *
C      ***********************************************
        READ(*,814)NNN
  814   FORMAT(I3)
       ENDIF
        CALL GCLRWK(WSSDEV,1)
        CALL GCLRWK(CRTDEV,1)
        CALL CLOSWS(CRTDEV)
C
        DO 749 I=1,NUM
          T(I)=T(I)-X1
          QMI(I)=QMI(I)-Y1
          QMIC(I)=QMIC(I)-Y1
  749   CONTINUE
       GOTO 800
  333  QC=QMIC(NUM)
       DO 103 IJJ=1,7
        QC=QC/10.
        IF(QC.LT.5.)GOTO 101
        M=1
        GOTO 797
  101   IF(QC.GT.10.)GOTO 102
        M=2
        GOTO 797
  102   IF(QC.GT.20.)GOTO 103
        M=3
        GOTO 797
  103  CONTINUE
C      DRAW INFLOW CURVE
  797  CALL GCRSG(717)
       CALL GSLN(1)
       CALL GSPLCI(2)
        DO 520 II=1,NUM
         T(II)=T1(II)
         QMIC(II)=QMI2(II)
  520   CONTINUE
       CALL GPL(NUM,T,QMIC)
         BBB=0.36*X
         CCC=0.24*Y
         DDD=0.31*X
         EEE=0.20*Y
         FFF=0.18*X
         GGG=0.16*Y
        CALL GTX(X*0.22,Y*1.03,'COMPARISON OF INFLOW-OUTFLOW RATES')
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
        IF(PROB.EQ.Ø)THEN
         CALL GTX(BBB,CCC,'PROB=Ø')
         CALL GTX(DDD,EEE,'H is Given')
         GOTO 593
        ENDIF
         CALL GTX(BBB,CCC,'PROB=Ø')
         CALL GTX(DDD,EEE,'As is Given')
  593    CALL GTX(FFF,GGG,'A-F described in output')
        ACTY(1)=Y*Ø.2Ø
        ACTY(2)=Y*Ø.2Ø
        G=ACTY(1)-(Ø.Ø1*Y1)
       CALL GPL(2,ACT,ACTY)
       CALL GTX(ACT(2),G,'INFLOW')
       CALL GCLSG(717)
C      THE OUTFLOW CURVES ARE NOW DRAWN
       CALL GCRSG(718)
       CALL GSCHH(A*Ø.Ø25)
       CALL GSTXCI(5)
       CALL GSPLCI(7)
       CALL GSLN(3)
       ICHOICE=Ø
       IKK=Ø
       KKK=2
  666  DO 5 I=1,IBREAK
        JK=Ø
        DYY(1)=Ø.Ø+(A*Ø.15)
        T(1)=Ø.Ø+(NUM*Ø.15)
        DO 4 J=2,NUM
         IF((QINF(I,J)+(Ø.15*A)).LE.QMIC(NUM))GOTO 1
          JK=JK+1
         IF(JK.GT.1)GOTO 523
    1    DYY(J)=QINF(I,J)
         IF(CHOICE.EQ.Ø)THEN
          DYY(J)=DYY(J)+(A*Ø.15)
         ENDIF
    4   CONTINUE
  523    CALL GPL(J-1,T,DYY)
         AAA=DYY(J-1)-(Ø.Ø15*A)
         CALL GTX(T(J-1),AAA,ARNO(IBREAK-I+1))
    5  CONTINUE
       DO 7Ø4 I=1,NUM
        QMIC(I)=QMIC(I)-Y1
        T(I)=T(I)-X1
  7Ø4  CONTINUE
       G=CORY(1)-(.Ø1*Y)
       CALL GPL(2,COR,CORY)
       CALL GTX(COR(2),G,'OUTFLOW CURVE')
       CALL GCLSG(718)
       WRITE(IWRITE,2Ø6)
  2Ø6  FORMAT(//,8X,' VALUES FOR CURVES LABELED A-F',/)
       IF(PROB)7,6,7
    6  DO 2Ø7 I=1,IBREAK
        WRITE(IWRITE,2Ø8)ARNO(I),AS(IBREAK-I+1)
  2Ø8   FORMAT(1ØX,A3,' >>  As = ',E9.3,' (sq.ft.)')
```

APPENDIX D
PROGRAM “RECHARGE” LISTING – *US Customary Units*)

```
  207  CONTINUE
      WRITE(IWRITE,124)
  124 FORMAT(1H1)
       GOTO 799
    7  DO 209 I=1,IBREAK
        WRITE(IWRITE,210)ARNO(I),HH(IBREAK-I+1)
  210   FORMAT(10X,A4,'>>    H = ',F6.2,' (ft.)')
  209  CONTINUE
       WRITE(IWRITE,125)
  125  FORMAT(1H1)
  799  CLOSE(IWRITE,ERR=811)
C      **************************************************
C      PLOT WILL REMAIN ON THE SCREEN TILL YOU PRESS ENTER
       READ(*,700)NNN
  700  FORMAT(I3)
C      **************************************************
C      PRINT THE GRAPH
       CALL GCLRWK(CRTDEV,1)
       WRITE(*,879)
  879  FORMAT(' DO YOU WANT A HARDCOPY OF THE GRAPH? (Y OR N)-->')
       READ(*,104)ACODE
       IF(ACODE.EQ.YES)THEN
       WRITE(*,703)
  703  FORMAT(///,' DO NOT TOUCH A THING!!!!, WAIT FOR GRAPH TO REAPPEAR
     + ',///,' AFTER GRAPH REAPPEARS, <CR> TO CONTINUE')
C      TERMINATION
C      DEACTIVATE AND CLOSE DISPLAY, OPEN AND ACTIVATE PRINTER
       CALL CLOSWS(CRTDEV)
       CALL OPENWS(PRTDEV)
        CALL GCSGWK(PRTDEV,200)
        CALL GCSGWK(PRTDEV,300)
        CALL GCSGWK(PRTDEV,510)
        CALL GCSGWK(PRTDEV,717)
        CALL GCSGWK(PRTDEV,718)
       CALL GCRSG(203)
       CALL GSTXCI(1)
       CALL GSCHH(0.003)
       XB=X1*0.50
       YB=Y*0.30
       YC=Y*0.50
       XC=X1*0.38
       CALL GSCHUP(-1.0,0.0)
        CALL GTX(XB,YB,'INFLOW (CUBIC FEET * 10   )')
        INN=1
  112   IF(LANG(INN).LT.A)THEN
         INN=INN+1
        GOTO 112
        ENDIF
        CALL GTX(XC,YC,LANG1(INN-1))
       CALL GCLSG(203)
        CALL CLOSWS(PRTDEV)
C      REDRAW SEGMENTS ON SCREEN
       CALL OPENWS(CRTDEV)
        CALL GCSGWK(CRTDEV,200)
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
       CALL GCSGWK(CRTDEV,2Ø1)
       CALL GCSGWK(CRTDEV,3ØØ)
       CALL GCSGWK(CRTDEV,51Ø)
       CALL GCSGWK(CRTDEV,717)
       CALL GCSGWK(CRTDEV,718)
C     ************************************************
C     PLOT WILL REMAIN ON SCREEN UNTIL <CR> IS PRESSED *
C     ************************************************
       READ(*,881)NNN
  881  FORMAT(I3)
      ENDIF
       CALL GCLRWK(WSSDEV,1)
       CALL GCLRWK(CRTDEV,1)
       CALL CLOSWS(CRTDEV)
  8ØØ WRITE(*,769)
  769 FORMAT(1ØX,'AFTER NEXT GRAPH APPEARS, PRESS <CR> TO CONTINUE ',
     + ///,1ØX,'***PRESS <CR> NOW TO CONTINUE***')
      READ(*,877)CHOICE
  877 FORMAT(I3)
  811 RETURN
      END
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
      SUBROUTINE DESIGN
      COMMON/NARAG/IB,QMI(2Ø),QMIC(2Ø),T(2Ø),ZZ(2Ø),K,HH(6),SHAP,
     + IWRITE,PROB,ATS,IBRK,RLW,ALFA,SM,H,SSL,TITL(1Ø),NUM,IBREAK,
     + IERROR
      COMMON/SHAKE/SS,DFIT,DDQ(6),AS(6),PSIN,PT
      COMMON /B1/ SEGNAM,ITX,IY,XNDC,YNDC,SCRHGT,SCRWID,SCALE,SIGN,
     +              CPX,CPY
      INTEGER*2 WSSDEV,CRTDEV,PRTDEV
      CHARACTER*2 PLUS(11),YES,NO,ACODE
      CHARACTER*3 MINUS(1Ø),PLUSS(11)
      DIMENSION AAA(2),BBB(2),XXX(2),YYY1(2)
      DIMENSION XAXISX(2),XAXISY(2),YAXISX(2),YAXISY(2)
      DIMENSION YYY2(2),ASS(6),HHH(6),DDDQ(6)
      DIMENSION ASX(1Ø), HX(1Ø), DVY(1Ø)
      DATA YES,NO/'Y','N'/
      DATA PLUS/'Ø','1','2','3','4','5','6','7','8','9','1Ø'/
      DATA MINUS/'-1','-2','-3','-4','-5','-6','-7','-8','-9','-1Ø'/
      DATA PLUSS/'Ø.Ø','1.Ø','2.Ø','3.Ø','4.Ø','5.Ø','6.Ø','7.Ø',
     +           '8.Ø','9.Ø','1Ø.'/
C*********************************************************************
      X=1ØØ.
      Y=1ØØ.
      WSSDEV=Ø
      CRTDEV=1
      PRTDEV=2
C     SET WORLD WINDOW (USER UNITS)
      CALL GSWN(1,Ø.Ø,X,Ø.Ø,Y*1.Ø8)
C     SELECT TRANSFORMATION 1
      CALL GSELNT(1)
C     ***OPEN AND ACTIVATE DISPLAY AND WISS***
      CALL OPENWS(CRTDEV)
C     ****************************************************************
C     SET SCREEN DIMENSIONS
C     ****************************************************************
      XAXISX(1)=Ø.2*X
      XAXISX(2)=1.*X
      XAXISY(1)=Ø.6*Y
      XAXISY(2)=Ø.6*Y
      YAXISX(1)=Ø.2*X
      YAXISX(2)=Ø.2*X
      YAXISY(1)=Ø.2*Y
      YAXISY(2)=1.Ø*Y
C     PLOT THE X AND Y AXIS
      CALL GCRSG(1Ø7)
      CALL GSLN(1)
      CALL GSPLCI(3)
      CALL GPL(2,XAXISX,XAXISY)
      CALL GPL(2,YAXISX,YAXISY)
C     LABEL THE AXES
      CALL GSTXCI(1)
      CALL GSCHH(2.57)
      XA=Ø.21*X
      YA=1.Ø15*Y
      XG=Ø.44*X
      YG=Ø.12*Y
      XV=Ø.23*X
```

```
      XT=Ø.1Ø*X
      YV=Ø.Ø7*Y
      YT=Ø.Ø2*Y
      CALL GSCHUP(Ø.Ø,1.Ø)
      IF(PROB.GT.Ø)GOTO 111
      CALL GTX(XA,YA,'DETERMINATION OF REQUIRED BASIN TOP, As')
      GOTO 112
  111 CALL GTX(XA,YA,'DETERMINATION OF REQ'D OPERATING HEAD, H')
C*******************************************************************
  112 DQ=ABS(DDQ(IBREAK))
      IF(DQ-DDQ(1))1,2,2
    1 DQ=DDQ(1)
    2 KK=Ø
    3 IF(DQ.GE.1Ø)THEN
       DQ=DQ/1Ø.
       KK=KK+1
       GOTO 3
      ENDIF
      IYY=INT(DQ)
      IYY=IYY+1
      STEP=(Ø.4*Y)/IYY
       XXX(1)=Ø.2*X
       XXX(2)=1.*X
       YYY1(1)=(Ø.6*Y)+STEP
       YYY1(2)=(Ø.6*Y)+STEP
       YYY2(1)=(Ø.6*Y)-STEP
       YYY2(2)=(Ø.6*Y)-STEP
       TXTX=Ø.16*X
       TXTX2=Ø.14*X
       TXY1=(Ø.585*Y)+STEP
       TXY2=(Ø.595*Y)-STEP
       CALL GSLN(1)
       CALL GSPLCI(4)
       CALL GSCHUP(Ø.Ø,1.Ø)
       CALL GTX(Ø.16*X,Ø.585*Y,'Ø')
      DO 2Ø I=1,IYY
       CALL GPL(2,XXX,YYY1)
       CALL GPL(2,XXX,YYY2)
       CALL GTX(TXTX,TXY1,PLUS(I+1))
       CALL GTX(TXTX2,TXY2,MINUS(I))
       YYY1(1)=YYY1(1)+STEP
       YYY1(2)=YYY1(2)+STEP
       YYY2(1)=YYY2(1)-STEP
       YYY2(2)=YYY2(2)-STEP
       TXY1=TXY1+STEP
       TXY2=TXY2-STEP
   2Ø CONTINUE
      CALL GSCHUP(Ø.Ø,1.Ø)
C     WHICH KIND OF PROBLEM
      IF(PROB)91,9Ø,91
   9Ø  BOT=AS(1)
       TOP=AS(IBREAK)
       GOTO 92
   91  BOT=HH(1)
       TOP=HH(IBREAK)
   92  J=Ø
```

```
       JJ=1
 93     IF(BOT.GE.1Ø.)THEN
         BOT=BOT/1Ø.
         J=J+1
         GOTO 93
        ENDIF
 94     IF(TOP.GE.1Ø.)THEN
         TOP=TOP/1Ø.
         JJ=JJ+1
         GOTO 94
        ENDIF
 95    IF(TOP.LE.BOT)THEN
        BOT=BOT/1Ø.
        J=J+1
        GOTO 95
       ENDIF
       IF(BOT.LE.1.)THEN
        VERT1=Ø.
       ELSEIF(BOT.GT.1)THEN
        VERT1=BOT-1.
       ENDIF
       VERT2=TOP+1.
       IVERT=INT(VERT2)-INT(VERT1)
       STEP=(Ø.8*X)/IVERT
       IPOINT=INT(VERT1)
        AAA(1)=(Ø.2*X)+STEP
        AAA(2)=(Ø.2*X)+STEP
        BBB(1)=Ø.2*Y
        BBB(2)=1.Ø*Y
        AA=(Ø.188*X)+STEP
        BB=(Ø.56*Y)
       DO 3Ø I=1,IVERT
        CALL GPL(2,AAA,BBB)
        CALL GTX(AA,BB,PLUSS(IPOINT+2))
         AAA(1)=AAA(1)+STEP
         AAA(2)=AAA(2)+STEP
         AA=AA+STEP
         IPOINT=IPOINT+1
 3Ø    CONTINUE
       DO 36 I=1,IBREAK
       DDDQ(I)=DDQ(I)
        IF(PROB)33,34,33
 33      ASS(I)=AS(I)
         GOTO 36
 34      HHH(I)=HH(I)
 36    CONTINUE
C*******************************************************************
       KKK=INT(VERT1)
        DO 99 I=1,J
         XMIN=KKK*1Ø.
         KKK=INT(XMIN)
 99     CONTINUE
       IF(J.EQ.Ø.)XMIN=KKK*1.
       LLL=INT(VERT2)
        DO 1ØØ I=1,JJ-1
         XMAX=LLL*1Ø.
```

APPENDIX D
PROGRAM “RECHARGE” LISTING – *US Customary Units*)

```
       LLL=INT(XMAX)
100    CONTINUE
      IF(JJ.EQ.1.)XMAX=LLL*1.
      DX=(Ø.8*X)/(XMAX-XMIN)
      IF(PROB)1Ø3,1Ø1,1Ø3
1Ø1   DO 1Ø2 M=1,IBREAK
       ASS(M)=((AS(M)-XMIN)*DX)+(Ø.2*X)
1Ø2   CONTINUE
      GOTO 1Ø5
1Ø3   DO 1Ø4 M=1,IBREAK
       HHH(M)=((HH(M)-XMIN)*DX)+(Ø.2*X)
1Ø4   CONTINUE
1Ø5   DO 1Ø6 I=1,KK
       YMAX=IYY*1Ø.
       IYY=INT(YMAX)
1Ø6   CONTINUE
      DY=(Ø.4*Y)/YMAX
      DO 1Ø7 N=1,IBREAK
       IF(DDQ(N).LE.Ø.)THEN
        DDDQ(N)=(Ø.6*Y)-(ABS(DDQ(N))*DY)
       ELSEIF(DDQ(N).GE.Ø.)THEN
        DDDQ(N)=(Ø.6*Y)+(DDQ(N)*DY)
       ENDIF
1Ø7   CONTINUE
      CALL GSPLCI(2)
      IF(PROB)11Ø,1Ø8,11Ø
1Ø8   CALL GPL(IBREAK,ASS,DDDQ)
      CALL GPM(IBREAK,ASS,DDDQ)
      GOTO 1Ø9
11Ø   CALL GPL(IBREAK,HHH,DDDQ)
      CALL GPM(IBREAK,HHH,DDDQ)
1Ø9   CALL GCLSG(1Ø7)
      CALL GCRSG(1Ø8)
      CALL GSCHUP(-1.Ø,Ø.Ø)
      XB=Ø.Ø4*X
      YB=Ø.24*Y
      CALL GTX(XB,YB,'MASS STOR.-VOLUME')
       XC=Ø.1Ø*X
       YC=Ø.4Ø*Y
        CALL GTX(XC,YC,'(CU.FT.*1Ø   )')
       XD=Ø.Ø9*X
       YD=Ø.84*Y
        CALL GTX(XD,YD,PLUS(KK+1))
      CALL GSCHUP(Ø.Ø,1.Ø)
      IF(PROB)2Ø3,2Ø2,2Ø3
2Ø2    CALL GTX(XG,YG,'As(sq.ft.*1Ø   )')
       GOTO 2Ø4
2Ø3    CALL GTX(XG,YG,'H (Feet * 1Ø   )')
2Ø4    XF=Ø.653*X
       YF=Ø.13*Y
       CALL GTX(XF,YF,PLUS(JJ))
      CALL GCLSG(1Ø8)
      CALL GCRSG(1Ø9)
      CALL GTX(XV,YV,'The horiz. interception of the curve at')
      IF(PROB)757,747,757
747    CALL GTX(XT,YT,'(Max. Mass Stor.-Basin Vol.)=Ø, is the Basin Top
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
     +,As')
        GOTO 767
 757    CALL GTX(XT,YT,'(Max. Mass Stor.-Basin Vol.)=Ø, is the Oper. Hea
     +d,H')
 767  CALL GCLSG(1Ø9)
C     **************************************************
C     PLOT WILL REMAIN ON SCREEN TILL <CR> IS PRESSED
      READ(*,199)NNN
 199  FORMAT(I3)
C     **************************************************
      CALL GCLRWK(CRTDEV,1)
      WRITE(*,8Ø9)
 8Ø9  FORMAT(' DO YOU WANT A HARDCOPY OF THE GRAPH? (Y OR N)-->')
      READ(*,81Ø)ACODE
 81Ø  FORMAT(A1)
      IF(ACODE.EQ.YES)THEN
      WRITE(*,7Ø3)
 7Ø3  FORMAT(///,' DO NOT TOUCH A THING!!!!, WAIT FOR GRAPH TO REAPPEAR
     + ',///,' AFTER GRAPH REAPPEARS,<CR> TO CONTINUE')
C     TERMINATION
C     DEACTIVATE AND CLOSE DISPLAY, ACTIVATE AND OPEN PRINTER
      CALL CLOSWS(CRTDEV)
      CALL OPENWS(PRTDEV)
       CALL GCSGWK(PRTDEV,1Ø7)
       CALL GCSGWK(PRTDEV,1Ø9)
      CALL GCRSG(119)
      CALL GSCHH(Ø.ØØ3)
      CALL GSCHUP(-1.Ø,Ø.Ø)
      XB=Ø.Ø4*X
      YB=Ø.32*Y
      CALL GTX(XB,YB,'MAX. MASS STORAGE-BASIN VOLUME')
       XC=Ø.1Ø*X
       YC=Ø.34*Y
        CALL GTX(XC,YC,'(CUBIC FEET * 1Ø   )')
       XD=Ø.Ø85*X
       YD=Ø.479*Y
        CALL GTX(XD,YD,PLUS(KK+1))
       CALL GSCHUP(Ø.Ø,1.Ø)
      IF(PROB)2Ø9,2Ø8,2Ø9
 2Ø8   CALL GTX(XG,YG,'As(sq.ft.*1Ø   )')
       GOTO 211
 2Ø9   CALL GTX(XG,YG,'H (Feet * 1Ø   )')
 211   XF=Ø.645*X
       YF=Ø.127*Y
       CALL GTX(XF,YF,PLUS(JJ))
      CALL GCLSG(119)
       CALL CLOSWS(PRTDEV)
C     REDRAW SEGMENTS ON SCREEN
      CALL OPENWS(CRTDEV)
       CALL GCSGWK(CRTDEV,1Ø7)
       CALL GCSGWK(CRTDEV,1Ø8)
       CALL GCSGWK(CRTDEV,1Ø9)
C     **************************************************
C     PLOT WILL REMAIN ON SCREEN UNTIL <CR> IS PRESSED *
C     **************************************************
       READ(*,814)NNN
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *US Customary Units*)

```
814    FORMAT(I3)
      ENDIF
       CALL GCLRWK(WSSDEV,1)
       CALL GCLRWK(CRTDEV,1)
      RETURN
      END


      SUBROUTINE OPENWS(DEVICE)
      INTEGER*2 DEVICE,ERRIND,DCUNIT,ISCRWD,ISCRHT,WKTY1
      REAL AXMAX
      INTEGER*2 SEGNAM,IX,IY
      REAL XNDC,YNDC,SCRHGT,SCRWID,SCALE,SIGN,CPX,CPY
      COMMON /B1/ SEGNAM,ITX,IY,XNDC,YNDC,SCRHGT,SCRWID,SCALE,SIGN,
     +            CPX,CPY
      CALL GOPWK(DEVICE,Ø,DEVICE)
      CALL GACWK(DEVICE)
      CALL GQMDS(DEVICE,ERRIND,DCUNIT,SCRWID,SCRHGT,ISCRWD,ISCRHT)
      AXMAX=AMAX1(SCRWID,SCRHGT)
      XNDC=SCRWID/(11./8.*AXMAX)
      YNDC=SCRHGT/AXMAX
      CALL GSVP(1,Ø.,XNDC,Ø.,YNDC)
      CALL GSWKWN(DEVICE,Ø.,1.35*XNDC,Ø.,YNDC)
      CALL GSWKVP(DEVICE,Ø.,SCRWID,Ø.,SCRHGT)
      RETURN
      END


C
C       DEACTIVATE AND CLOSE A WORKSTATION
C
        SUBROUTINE CLOSWS(DEVICE)
        INTEGER*2 DEVICE
        CALL GDAWK(DEVICE)
        CALL GCLWK(DEVICE)
        RETURN
        END
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *International System of Units*)

```
         PROGRAM RECHARGE
C*****************************************************************
C  GEOTECHNICAL  ENGINEERING BUREAU, NYS DEPARTMENT OF TRANSPORTATION *
C*****************************************************************
C                                                                 *
C                                                                 *
C        FORTRAN PROGRAM [RECHARGE]:                              *
C                DESIGN OF A RECHARGE BASIN FOR DISPOSAL          *
C                OF HIGHWAY STORM DRAINAGE                        *
C                                                                 *
C          PROGRAM [RECHARGE] WAS DEVELOPED BASED ON A THEORY OF WATER *
C          INFILTRATION IN A SEMI-INFINITE UNSATURATED POROUS MEDIUM.  *
C          INDIVIDUALS INTERESTED IN THE ORIGINAL STUDY MAY REFER TO   *
C          A RESEARCH REPORT BY ROBERT J. WEAVER, ENTITLED "RECHARGE   *
C          BASINS FOR DISPOSAL OF HIGHWAY STORM DRAINAGE", RESEARCH    *
C          REPORT 69-2, ENGINEERING RESEARCH AND DEVELOPMENT BUREAU,   *
C          NEW YORK STATE DEPARTMENT OF TRANSPORTATION, MAY 1971.      *
C                                                                 *
C                                                                 *
C                                                                 *
C       THE NEW YORK STATE DEPARTMENT OF TRANSPORTATION WILL NOT BE   *
C       RESPONSIBLE FOR ANY RESULTS OBTAINED FROM THE USE OF SHARED   *
C       COMPUTER PROGRAMS OR STORED DATA, INCLUDING DIRECT, INDIRECT, *
C       SPECIAL OR CONSEQUENTIAL DAMAGES.  NO TECHNICAL SUPPORT WILL  *
C       BE PROVIDED. NO WARRANTIES ARE EXTENDED OR GRANTED, EITHER    *
C       EXPRESSED OR IMPLIED, WITH RESPECT TO THE ACCURACY AND/OR     *
C       PERFORMANCE OF ANY MATERIALS PROVIDED. THE MATERIALS PROVIDED *
C       MAY BE REPRODUCED BY THE RECEIVING AGENCY, BUT MAY NOT BE     *
C       GIVEN TO ANOTHER AGENCY WITHOUT THE PERMISSION OF THE NYSDOT. *
C                                                                 *
C                                                                 *
C                                                                 *
C*****************************************************************
       COMMON/NARAG/IB,QMI(20),QMIC(20),T(20),ZZ(20),K,HH(6),SHAP,
     + IWRITE,PROB,ATS,IBRK,RLW,ALFA,SM,H,SSL,TITL(10),NUM,IBREAK,
     + IERROR
      COMMON/SHAKE/SS,DFIT,DDQ(6),AS(6),PSIN,PT
      COMMON/LUSH/Y,IX,APX,APY,IJJ,CX,CY
      COMMON/ILUSH/QINF(6,20)
      COMMON/DOVER/IIII
      CHARACTER*1 YES, NO, ACODE
      INTEGER*2 CRTDEV,PRTDEV,WSSDEV
      DATA YES,NO/'Y','N'/
C      *****INPUT THE DATA POINTS*****
      WSSDEV=0
      CRTDEV=1
      PRTDEV=2
      OPEN (UNIT=9,FILE='LPT1')
      III=1
      WRITE(*,299)
      WRITE(*,*)'      PRESS <ENTER> TO CONTINUE'
      READ(*,309)NNN
  309 FORMAT(I3)
      WRITE(*,298)
      WRITE(*,*)'      PRESS <ENTER> TO CONTINUE'
      READ(*,411)NNNN
  411 FORMAT(I3)
      WRITE(*,296)
```

```
  295 WRITE(*,300)
      WRITE(*,*)'-->>'
      READ(*,301)TITL
    1 IERROR=0
      WRITE(*,302)III
      WRITE(*,*)'     ENTER A 0.0 OR 1.0 FOR PROB >>   '
      READ(*,307) PROB
      WRITE(*,666)
  666 FORMAT(/)
      IF(PROB) 3,2,3
    2 WRITE(*,*)'ENTER THE PROPOSED BASIN OPERATING HEAD (H) IN m  >>  '
      READ(*,307)H
      OPEN(IWRITE,FILE='PRN')
      GO TO 4
    3 WRITE(*,*)'ENTER THE PROPOSED BASIN TOP AREA (ATS) IN m^2  >>'
      READ(*,307) ATS
    4 WRITE(*,308)
      WRITE(*,*) '    ENTER SHAP,SSL & RLW >>'
      READ*,SHAP,SSL,RLW
      IF(III.EQ.1)GO TO 5
      GO TO 18
    5 WRITE(*,311)
      WRITE(*,*) '    ENTER Z,SG,W,POR & SAT >> '
      READ*,Z,SG,W,POR,SAT
      IF(PROB)7,6,7
    6 IF(Z-(1.25*H))38,7,7
    7 WRITE(*,333)
      READ(*,307)SSS
      IWRITE=6
      IF(SSS-1.0)334,335,334
  334 WRITE(*,336)
      WRITE(*,*)' ENTER DFIT & KS >> '
      READ*,DFIT,PSAT
      GO TO 345
C
C     DETERMINE SPECIFIC SURFACE
C
  335 CALL SIEVE
  345 IF(IERROR.EQ.1)GOTO 999
      OPEN(IWRITE,FILE='PRN')
      IF (SSS-1.0) 341,340,341
  340 PSAT=(2737.08/SS**2.)*(10.**(5.15*POR))
      PSAT=PSAT/3.28
  341 DFIT=DFIT*10.
      PSIN=(0.098425)/DFIT
      PSIN=PSIN/3.28
      THETAN=W*SG*(1-POR)
      THEDIF=SAT*POR-THETAN
      IF(POR-THETAN) 9,33,9
    9 PT=THEDIF/(POR-THETAN)*PSAT
      IF(THEDIF) 10,34,10
   10 ALFA=PT/THEDIF
      ALFA=ALFA/3.28
      IF (SSS-1.0) 600,601,601
  600 WRITE(IWRITE,602)TITL
  602 FORMAT(///,10X,'**NYSDOT RECHARGE BASIN DESIGN**',//,
     110X,'PROJECT TITLE & P.I.N.: ',10A4,//)
  601 WRITE(IWRITE,318) DFIT,SG,SAT,W,POR,PT,PSIN,ALFA
      IF(Z.NE.999.)GOTO 11
      WRITE(IWRITE, 501)
```

```
      GOTO 12
   11 WRITE(IWRITE, 502)Z
   12 IF(SSS.EQ.1.0)THEN
      WRITE(IWRITE,338)SS
      ENDIF
   14 CLOSE(IWRITE,ERR=399)
      IIII=0
C     PLOT THE INFLOW VS. TIME CURVE
      CALL FLOW(III)
      IF(IERROR.EQ.1)GOTO 999
      DO 16 I=2,NUM
      XX=QMIC(I)-QMIC(I-1)
      IF(XX) 16,17,16
   16 CONTINUE
C
C     DETERMINE THE TIME AT WHICH THE INFLOW CURVE STARTS PEAKING
C
   17 SN=QMIC(I-1)-QMIC(I-2)
      XX=QMIC(I-1)-SN*(I-1)
      ZZZ=XX/(SM-SN)
      IBRK=INT(ZZZ+0.5)
      IB=IBRK+1
C     ****************************************************************
C     SEPERATE THE PROBLEM. IS IT TYPE 0 OR 1?
   18 IF(PROB) 24,19,24
C
C     DETERMINE THE INFILTRATION QUANTITIES FOR PROBLEM WITH
C     BASIN OPERATING HEAD GIVEN
C     ****************************************************************
   19 CALL HITA(BW,BR)
      IF(IERROR.EQ.2)GOTO 37
C     PLOT THE DESIGN CURVES
      CALL FLOW(III)
      IF(IERROR.EQ.1)GOTO 999
      IF(Z-(1.25*H).LT.0.)GOTO 41
      OPEN(IWRITE,FILE='PRN')
      IF(DDQ(IBREAK).GE.0.) GOTO 40
      IF(DDQ(1).LE.0.)GO TO 45
      CLOSE(IWRITE,ERR=399)
C
C     DDQ IS DEFINED AS THE DIFFERENCE BETWEEN THE MAX. MASS
C     STORAGE AND THE BASIN WATER VOLUME
C
C     DETERMINE THE REQUIRED BASIN SURFACE AREA
      DO 22 JJ=1,IBREAK
      IF(DDQ(JJ))21,20,22
   20 ATS=AS(JJ)
      GOTO 23
   21 ATS=AS(JJ-1)+DDQ(JJ-1)*(AS(JJ)-AS(JJ-1))/
     +(DDQ(JJ-1)-DDQ(JJ))
      GOTO 23
   22 CONTINUE
C     PLOT DDQ AGAINST BASIN SURFACE AREA
   23 WRITE(IWRITE,122)
  122 FORMAT(1H1)
        GOTO 29
C
C     DETERMINE THE INFILTRATION QUANTITIES FOR PROBLEM WITH
C     BASIN SURFACE AREA GIVEN
C     ****************************************************************
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *International System of Units*)

```
C       PROB=1
   24 CALL TAHI(BW,BR)
      IF(IERROR.EQ.2)GOTO 993
      CALL FLOW(III)
      IF(IERROR.EQ.1)GOTO 993
      IF(DDQ(IBREAK).GE.0.)GOTO 35
      IF(DDQ(1).LE.0.)GOTO 46
C
C     DETERMINE THE REQUIRED OPERATING HEAD
      DO 27 JJ=1,IBREAK
      IF(DDQ(JJ))26,25,27
   25 H=HH(JJ)
      GOTO 28
   26 H=HH(JJ-1)+DDQ(JJ-1)*(HH(JJ)-HH(JJ-1))/(DDQ(JJ-1)-DDQ(JJ))
      GOTO 28
   27 CONTINUE
   28 IF(Z-(1.25*H).LT.0.)GOTO 41
C     PLOT DDQ AGAINST BASIN DEPTH
      WRITE(IWRITE,124)
  124 FORMAT(1H1)
      IF(IERROR.EQ.1)GOTO 999
   29 OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE, 322)III,SSL
      CLOSE(IWRITE,ERR=399)
      WRITE(IWRITE,322)III,SSL
      OPEN(IWRITE,FILE='PRN')
      IF(SHAP)30,31,30
C     DETERMINE THE BASIN DIMENSIONS
   30 SWT=(ATS/RLW)**0.5
      SWB=SWT-2.*SSL*H
      SLT=RLW*SWT
      SLB=SLT-2.*SSL*H
      IF(SWB.LE.0.OR.SLB.LE.0.) GO TO 36
      ABF=ATS-2.*SSL*H*(SLB+SWB+2.*SSL*H)
      VOL=H/3*(ATS+ABF+(ATS*ABF)**0.5)
      WRITE(IWRITE, 323) RLW,SWT,SLT,ATS,SWB,SLB,ABF
      CLOSE(IWRITE,ERR=399)
      WRITE(IWRITE,323)RLW,SWT,SLT,ATS,SWB,SLB,ABF
      OPEN(IWRITE,FILE='PRN')
      GO TO 32
   31 RAT=(ATS/3.1416)**0.5
      RAB=RAT-SSL*H
      IF(RAB.LE.0.)GO TO 36
      ABF=3.1416*RAB**2.
      VOL=H/3.*(2*ABF+ATS+((3.1416*ABF)**0.5*SSL*H))
      WRITE(IWRITE, 324)RAT,ATS,RAB,ABF
      CLOSE(IWRITE,ERR=399)
      WRITE(IWRITE,324)RAT,ATS,RAB,ABF
      OPEN(IWRITE,FILE='PRN')
   32 WRITE(IWRITE, 325) VOL,H
      CLOSE(IWRITE,ERR=399)
      WRITE(IWRITE,325)VOL,H
      OPEN(IWRITE,FILE='PRN')
      GO TO 37
   33 OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE, 326)
      IERROR=1
      GO TO 399
   34 OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE,327)
```

```
      IERROR=1
      GO TO 399
   35 OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE,328)
      IERROR=2
      GO TO  37
   36 OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE,329)
      IERROR=2
      GO TO 37
   40 OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE, 332)
      IERROR=2
      GO TO 37
   45 OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE,777)
      IERROR=2
      GO TO 37
   41 OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE,321)
      IERROR=2
      GO TO 37
   46 OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE, 778)
      IERROR=2
      GOTO 37
   38 OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE,321)
      IERROR=1
   37 CLOSE(IWRITE,ERR=399)
      GO TO 993
  999 CLOSE(IWRITE,ERR=399)
  993 IF(IERROR.LT.1)GOTO 994
      WRITE(IWRITE, 991)
  991 FORMAT(' !!!!!   CHECK OUTPUT FOR ERROR   !!!!!')
  994 IF(IERROR.EQ.1)GOTO 399
  996 WRITE(*,470)
  470 FORMAT(/)
      WRITE(IWRITE,*) '      MORE TO DO ?? (Y/N) >> '
      READ(*,297)ACODE
      IF(ACODE.EQ.NO) GO TO 399
      IF(ACODE.EQ.YES)GO TO 995
  995 III=III+1
      WRITE(*,992)
  992 FORMAT(///)
      ATS=0.
      H=0.
      SHAP=0.
      SSL=0.
      RLW=0.
      GO TO 1
  399 STOP
C
C     I/O FORMAT SPECIFICATIONS
C
  299 FORMAT(3X,'****************************************************',/,
     +3X,'*                                                  *',/,
     +3X,'* THE NEW YORK STATE DEPARTMENT OF TRANSPORTATION *',/,
     +3X,'* WILL NOT BE RESPONSIBLE FOR ANY RESULTS OBTAINED*',/,
     +3X,'* FROM THE USE OF SHARED COMPUTER PROGRAMS OR      *',/,
```

```
    +3X,'* STORED DATA, INCLUDING DIRECT, INDIRECT, SPECIAL*',/,
    +3X,'* OR CONSEQUENTIAL DAMAGES. NO TECHNICAL SUPPORT  *',/,
    +3X,'* WILL BE PROVIDED. NO WARRANTIES ARE EXTENDED OR *',/,
    +3X,'* GRANTED, EITHER EXPRESSED OR IMPLIED, WITH RE-  *',/,
    +3X,'* SPECT TO THE ACCURACY AND/OR PERFORMANCE OF AN  *',/,
    +3X,'* MATERIALS PROVIDED.  THE MATERIALS PROVIDED MAY *',/,
    +3X,'* BE REPRODUCED BY THE RECEIVING AGENCY, BUT MAY  *',/,
    +3X,'* NOT BE GIVEN TO ANOTHER AGENCY WITHOUT THE PER- *',/,
    +3X,'* MISSION OF THE NYSDOT.                          *',/,
    +3X,'*                                                 *',/,
    +3X,'***************************************************',//)
298 FORMAT(3X,'***************************************************',/,
    +3X,'*********** NYSDOT RECHARGE BASIN DESIGN **********',/,
    +3X,'***************************************************',//,
    +3X,'THIS IS A PROGRAM TO CALCULATE RECHARGE BASIN SIZE.',/,
    +3X,'THERE ARE TWO POSSIBLE DESIGN PROCEDURES ALLOWED BY THE',/,
    +3X,'PROGRAM, EITHER THE BASIN OPERATING HEAD IS GIVEN AND',/,
    +3X,'THE TOP SURFACE AREA IS CALCULATED (PROB=0), OR THE TOP',/,
    +3X,'SURFACE AREA IS GIVEN AND THE OPERATING HEAD IS CALCULAT-',/,
    +3X,'ED (PROB=1).',//,
    +3X,'THE OUTPUT IS SENT DIRECTLY TO THE PRINTER AS THE',/,
    +3X,'PROGRAM IS RUNNING, THEREFORE, MAKE SURE THE PRINTER',/,
    +3X,'IS ON.',/,
    +3X,'**********************************************',/,
    +3X,'* WHEN INPUT INVOLVES ALPHABETICAL CHARACTERS,*',/,
    +3X,'* ALWAYS USE CAPS.                            *',/,
    +3X,'**********************************************',//)
297 FORMAT(A1)
296 FORMAT(///,3X,'THIS PROGRAM IS WRITTEN IN IBM PROFESSIONAL FOR-',/,
    +3X,'TRAN AND THEREFORE REQUIRES A MATH PROCESSOR.',//,
    +3X,'MANY LOCATIONS IN THE PROGRAM REFER TO THE',/,
    +3X,'CARRIAGE RETURN (<CR>),  THIS IS THE SAME AS',/,
    +3X,'THE ENTER KEY OR RETURN KEY.',//,
    +3X,'INFORMATION PERTAINING TO THEORY AND DESIGN OF',/,
    +3X,'RECHARGE BASINS MAY BE FOUND IN THE USER MANUAL.',//)
300 FORMAT(' **ENTER PROJECT TITLE & P.I.N. (LIMITED TO 40 ALPHANUMERI
    1C CHARACTERS):')
301 FORMAT(10A4)
302 FORMAT(//,'====================================================',/,
    1' DESIGN TRIAL NO. ',I2,//,3X,'**TYPE OF PROBLEM (PROB) ?',//,5X,
    1'THIS PROGRAM WILL COMPUTE THE PHYSICAL DIMENSIONS FOR THE',/,5X,
    1'REQUIRED BASIN TO OPERATE AT',/,5X,
    1'1. A GIVEN BASIN OPERATING HEAD (H)------PROB=0.0 ',/,
    15X,'2. A GIVEN BASIN TOP SURFACE AREA (ATS)--PROB=1.0',/)
307 FORMAT(F10.2)
308 FORMAT(///,'***',
    1'ENTER THE FOLLOWING BASIN GEOMETRIC INFORMATION IN SEQUENCE',/,
    1'    (DATA SEPARATED BY SPACES):',//,
    1'      1. BASIN SHAPE (SHAP): IF SHAP=0.0, CIRCULAR-SHAPED BASIN',/,
    127X,'IF SHAP=1.0, SQUARE OR RECTANGULAR SHAPED BASIN',/,
    1'      2. SIDE SLOPES (SSL) : 1(VERTICAL) ON  SSL(HORIZONTAL)',/,
    1'      3. RATIO OF LENGTH TO WIDTH FOR THE BASIN SURFACE AREA (RLW):
    1',/,7X,'ENTER RLW=0.0 IF SHAP=0.0',/)
311 FORMAT(//,'***',
    1'ENTER THE FOLLOWING SUBSURFACE INFORMATION AND SOIL PROPERTIES'
    1,/,'    (DATA SEPARATED BY SPACES):',//,
    1'  1. Z  : DEPTH TO GROUND WATER TABLE IN  m  ENTER Z=999., IF NO
    1G.W.T.',/,10X,'IS ENCOUNTERED',/,
    1'  2. SG : SPECIFIC GRAVITY OF SOIL SOLIDS ',/,
    1'  3. W  : NATURAL DRAINED WATER CONTENT EXPRESSED AS A DECIMAL'
```

```
   1,/,10X,'USE 0.03 FOR GRAVELS & SANDS, AND 0.05 FOR SILTS',/,
   1'  4. POR: POROSITY OF SOIL',/,
   1'  5. SAT: DEGREE OF SATURATION IN THE TRANSMISSION ZONE',/,10X,
   1'SAT GENERALLY RANGES FROM 0.80 TO 0.85 FOR SILTS',/,10X,
   1'AND IS APPROXIMATELY 0.70 FOR SANDS',/)
501 FORMAT(12X,'DEPTH TO GROUNDWATER TABLE, m------------= NO G.W.T.')
502 FORMAT(12X,'DEPTH TO GROUNDWATER TABLE, m------------=',F6.2)
318 FORMAT(10X,'SUMMARY OF SOIL PROPERTIES:',//,12X,
   1'D50 GRAIN SIZE,mm-----------------------=',F6.2,/,12X,
   1'SPECIFIC GRAVITY------------------------=',F5.3,/,12X,
   1'DEGREE OF SATURATION--------------------=',F5.3,/,12X,
   1'NATURAL DRAINED WATER CONTENT-----------=',F5.3,/,12X,
   1'POROSITY--------------------------------=',F5.3,/,12X,
   1'HYDRAULIC CONDUCTIVITY, m/hr------------=',F6.3,/,12X,
   1'CAPILLARY SUCTION POTENTIAL, m----------=',F5.3,/,12X,
   1'HYDRAULIC DIFFUSIVITY, m^2/hr-----------=',F7.3)
338 FORMAT(12X,'TOTAL SPECIFIC SURFACE, cm^2/cm^3 -------=',F7.2)
321 FORMAT(10X,'ERROR:DISTANCE BETWEEN BASIN FLOOR TO G.W.T. IS LESS',
   1//,' THAN [0.25*H] AND INFINITE  DEPTH THEORY LOSES VALIDITY')
322 FORMAT(////,10X,'DESIGN SUMMARY FOR TRIAL NO. ',I2,/,10X,
   1'THE BASIN SIZE AND DIMENSIONS ARE AS FOLLOWS:',//,12X,
   1'SIDE SLOPES:  ',F5.2,'  (HORIZONTAL) TO 1 (VERTICAL)')
323 FORMAT(7X,'L/W AT BASIN TOP:  ',F5.2,/,20X,'TOP: ',F8.2,
   1' m X ',F8.2,' m,',' AREA = ',F10.2,' m^2  ',/,18X,'FLOOR: ',F8.2,
   1' m X ',F8.2,' m,',' AREA = ',F10.2,' m^2  ',/)
324 FORMAT(13X,'TOP RADIUS: ',F8.2,' m,',3X,'AREA= ',F10.2,' m^2  ',/,
   1 11X,'FLOOR RADIUS; ',F8.2,' m,',3X,'AREA= ',F10.2,' m^2  ')
325 FORMAT(17X,'VOLUME: ',E10.3,' m^3  ',/,18X,'DEPTH:  ',F6.2,' m')
326 FORMAT(10X,'ERROR:DIVIDE BY ZERO (POR-THETAN)')
327 FORMAT(10X,'ERROR:ALFA=0/0')
328 FORMAT(10X,'ERROR:THE PROPOSED BASIN SURFACE AREA IS TOO BIG')
778 FORMAT(10X,'ERROR:THE PROPOSED BASIN SURFACE AREA IS TOO SMALL')
329 FORMAT(10X,'ERROR:ZERO OR NEGATIVE FLOOR AREA')
332 FORMAT(10X,'ERROR:THE PROPOSED PEAK OPERATING HEAD IS TOO BIG')
777 FORMAT(10X,'ERROR:THE PROPOSED PEAK OPERATING HEAD IS TOO SMALL')
333 FORMAT(/,'***DETERMINATION OF THE COEFFICIENT OF SATURATED PER-',
   1/,'***MEABILITY OF SOIL, KS',//,
   13X,'ENTER A 1.0 IF YOU WISH THE PROGRAM TO ESTIMATE KS',/,
   13X,'VALUE USING SPECIFIC SURFACE ANALYSIS ESTABLISHED',/,
   13X,'BY LOUDON. NOTE THAT, HOWEVER, THIS METHOD SHOULD',/,
   13X,'ONLY BE APPLIED TO GRAVELS AND SANDS HAVING NOT MORE',/,
   13X,'THAN 5 PERCENT OF THE MATERIAL PASSING THE NO.200 SIEVE.',/,
   13X,'OTHERWISE ENTER A 0.0. **MAKE SURE THE PRINTER IS ON**',/,
   13X,'-------1.0 OR 0.0 ? >>  ')
336 FORMAT(/,' DFIT IS DEFINED AS THE SOIL PARTICLE SIZE AT 50% FINER BY
   1 WEIGHT IN cm.',/,' KS IS DEFINED AS THE SATURATED PERMEABILITY
   1OF SOIL IN  m/hr  ')
337 FORMAT(1H1)
    END
      SUBROUTINE SIEVE
     IMPLICIT REAL*4 (a-z)
     COMMON/NARAG/IB,QMI(20),QMIC(20),T(20),ZZ(20),K,HH(6),SHAP,
   + IWRITE,PROB,ATS,IBRK,RLW,ALFA,SM,H,SSL,TITL(10),NUM,IBREAK,
   + IERROR
     COMMON/SHAKE/SS,DFIT,DDQ(6),AS(6),PSIN,PT
     INTEGER*2 SEGNAM,IX,IY,GRACOM
     DIMENSION FINER(12),SIZE(12),SFAC(12),RET(12)
     DIMENSION FINER1(12),SIZE1(12),SSI(12)
     REAL*8 CHAR,GS1(6)
     INTEGER*4 SIZES,INTARY(12500)
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *International System of Units*)

```
       CHARACTER*1 YES,NO,ACODE
       DIMENSION GRIDXX(2),GRIDXY(2),GRIDYY(2),GRIDYX(2)
       DIMENSION XAXISX(2),XAXISY(2),YAXISX(2),YAXISY(2)
       DIMENSION W(2), V(2)
       INTEGER NUM, I, L, M, N, NUM1, JA, JB, NA, J, NNN, MM, MN
       INTEGER NUM2, JJ, K, KK, IA, IJ, IWRITE
C
       COMMON /GRACOM/ SIZES,INTARY
C
       INTEGER*2 CRTDEV,WSSDEV,PRTDEV
       INTEGER*2 CHNUM,STATUS,WKTYPE(3)
       DATA YES,NO/'Y','N'/
       DATA WKTYPE/0,1,2/
C      *****INITIALIZE SCRATCH MEMORY AREA*****
      IWRITE=6
  123 WRITE(*,101)
      READ(*,102)NUM
      DO 3 IJ=1,NUM
      IF(IJ-NUM)2,1,2
    1 WRITE(*,103)IJ,IJ
      READ(*,104)ACODE
      WRITE(*,121)IJ,IJ
    2 WRITE(*,105)IJ
      READ*,SIZE(IJ),RET(IJ),SFAC(IJ)
    3 CONTINUE
      WRITE(*,666)
  666 FORMAT(/)
  129 DO 817 IJ=1,NUM
      WRITE(*,107)IJ,IJ,SIZE(IJ),IJ,RET(IJ),IJ,SFAC(IJ)
  817 CONTINUE
      IJ=IJ-1
      WRITE(*,108)IJ
      READ(*,104)ACODE
      IF(ACODE.EQ.YES)GO TO 4
      WRITE(*,109)
      READ(*,171)I
  171 FORMAT(I3)
      WRITE(*,105)I
      READ*,SIZE(I),RET(I),SFAC(I)
      WRITE(*,100)
  100 FORMAT(/)
      GOTO 129
    4 TEMP=0.
      DO 861 I=1,NUM
       TOTAL=RET(I)+TEMP
       TEMP=TOTAL
  861 CONTINUE
      IF(TOTAL.LT.99.9)THEN
       IERROR=1
      OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE,113)
       GOTO 124
      ENDIF
      IF(TOTAL.GT.100.)THEN
       RET(NUM)=RET(NUM)-(TOTAL-100.)
      ENDIF
      IF(TOTAL.LT.100.)THEN
       RET(NUM)=RET(NUM)+(100.-TOTAL)
      ENDIF
      OPEN(IWRITE,FILE='PRN')
```

```
      IF(RET(1).EQ.0 .AND. SFAC(1).EQ.0) GO TO 5
      WRITE(IWRITE, 110)
      IERROR=1
      GOTO 124
    5 DO 7 I=2,NUM
      IF(SFAC(I).GE.1.AND.SFAC(I).LE.1.99) GO TO 6
      WRITE(IWRITE, 111)
      IERROR=1
      GOTO 124
    6 IF((SIZE(I)-SIZE(I-1)).LE.0)GO TO 7
      WRITE(IWRITE,112)
      IERROR=1
      GOTO 124
    7 CONTINUE
      TRET=0.
      II=0
      DO 8 I=1,NUM
      TRET=TRET+RET(I)
      FINER(I)=100.-TRET
      IF (FINER(I).GT.50.) GO TO 8
      IF(II.GT.0) GO TO 8
      S=(ALOG10(SIZE(I-1)/SIZE(I)))/(FINER(I-1)-FINER(I))
      DFIT=(SIZE(I)*(10.**(S*(50.-FINER(I)))))/10.
      II=I
    8 CONTINUE
C
C     OBTAIN THE PARTICLE SIZE @ ZERO PERCENT FINER
C
   10 IF(SIZE(NUM))13,13,11
   13 A=(ALOG10(SIZE(NUM-2)/SIZE(NUM-1))*FINER(NUM-1))/(FINER(NUM-2)-
     +  FINER(NUM-1))
      SIZE(NUM)=SIZE(NUM-1)/10.**A
      SIZE1(NUM)=SIZE(NUM)
   11 SS=0.
      DO 12 I=1,NUM-1
      DTIO=SIZE(I)/SIZE(I+1)
      SAV=-2.61*(1.-DTIO)/(ALOG10(DTIO)*SIZE(I)*0.1)
      SSI(I)=SAV*(RET(I+1)*0.01)*SFAC(I+1)
      SS=SS+SSI(I)
   12 CONTINUE
C
C     CALCULATE SPECIFIC SURFACE AREA
C
C      ****************************************************************
       OPEN(IWRITE,FILE='PRN')
       WRITE(IWRITE, 120)TITL
  120  FORMAT(//////,10X,'**NYSDOT RECHARGE BASIN DESIGN**',///,
     1 10X,'PROJECT TITLE & P.I.N.: ',10A4,///)
C
C      ***************************************************
      WRITE(IWRITE,125)
      WRITE(IWRITE,114)
      DO 499 I=1,NUM
      WRITE(IWRITE,115)FINER(I),SIZE(I)
  499 CONTINUE
      WRITE(IWRITE,122)
  122 FORMAT(//)
C      ***************************************************
  124 CLOSE(IWRITE,ERR=126)
  126 RETURN
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *International System of Units*)

```
C
C      I/O FORMAT SPECIFICATIONS
C
  101 FORMAT(///,'**********************************************'
     1,/,' **INPUT DATA TO CALCULATE THE SPECIFIC SURFACE OF **'
     1,/,' **A COHESIONLESS SOIL FROM GRAIN SIZE DISTRIBUTION**',//,
     1' UP TO TWELVE (12) LINES OF GRAIN-SIZE ANALYSIS AND',/,
     1' SHAPE FACTOR DATA. THE PROGRAM WILL ASK FOR THE FOLLOW-',/,
     1' ING THREE PIECES OF INFORMATION.',//,
     1'01. THE OPENING SIZE (in millimeters) OF THE FINER SIEVE',/,
     1'     IN A SIEVE INTERVAL (COLUMN 2 ON FORM SM 389)',/,
     1'02. THE PERCENT RETAINED OF THE TOTAL SPECIMEN IN THAT',/,
     1'     SIEVE INTERVAL (COLUMN 5 ON FORM SM 389)',/,
     1'03. THE SHAPE FACTOR (COLUMN 6 ON FORM SM 389)',/,
     1'0FOR DETAILED INFORMATION ON SPECIFIC SURFACE ANALYSIS OF',/,
     1' COHESIONLESS SOILS, SEE SOIL TEST PROCEDURE STP-1, [TEST',/,
     1' PROCEDURE FOR SPECIFIC SURFACE ANALYSIS], SOIL MECHANICS',/,
     1' BUREAU, NEW YORK STATE DEPARTMENT OF TRANSPORTATION, AUG.',/,
     1' 1973.',//,
     1' HOW MANY SETS OF DATA FOR SPECIFIC SURFACE ANALYSIS NS=(1-12) ? ---
     1>>  ')
  102 FORMAT(I2)
  103 FORMAT(/,' DO YOU WISH THE COMPUTER TO CALCULATE SIZE(',I2,')?',
     1/,' WHERE SIZE(',I2,') IS DEFINED AS THE PARTICLE SIZE AT ZERO',
     1/,' PERCENT FINER BY WEIGHT.',
     1/,' Y OR N >>    ')
  104 FORMAT(A1)
  105 FORMAT(/,' DATA NO. ',I2,':  OPENING SIZE, PERCENT RETAINED, SHAPE
     + FACTOR ',/,'   >> ')
  107 FORMAT(' DATA NO. ',I2,3X,'SIZE(',I2,')= ',F8.4,1X,'mm',3X,
     1'RET(',I2,')=',F6.2,3X,'SFAC(',I2,')= ',F4.2)
  108 FORMAT('0ARE ALL ',I2,' SETS OF DATA CORRECT? (Y OR N) >>  ')
  109 FORMAT('0WHICH VALUE WOULD YOU LIKE TO CHANGE? (NUMBER)-->>  ')
  110 FORMAT(10X,'ERROR:RET(1) AND SFAC(1) NOT ZERO')
  111 FORMAT(10X,'ERROR:SFAC NOT WITHIN LIMITS')
  112 FORMAT(10X,'ERROR:THE VALUES FOR SIZE MUST BE DECREASING')
  113 FORMAT(10X,'ERROR: % RETAINED DOES NOT TOTAL 100')
  125 FORMAT(///,10X,'GRAIN SIZE DISTRIBUTION FOR PROJECT SOIL')
  114 FORMAT(/,8X,'PERCENTAGE FINER BY WEIGHT(%)   GRAIN SIZE(mm)',/)
  115 FORMAT(18X,F6.2,19X,F6.3)
  121 FORMAT(' IF YES, ENTER D(',I2,')=0.0, OTHERWISE D(',I2,')=0.XXXX'
     1,/)
      END
      SUBROUTINE HITA(BW,BR)
C       PROB=0, The basin depth is given.
        COMMON/NARAG/IB,QMI(20),QMIC(20),T(20),ZZ(20),K,HH(6),SHAP,
     + IWRITE,PROB,ATS,IBRK,RLW,ALFA,SM,H,SSL,TITL(10),NUM,IBREAK,
     + IERROR
      COMMON/SHAKE/SS,DFIT,DDQ(6),AS(6),PSIN,PT
      COMMON/ILUSH/QINF(6,20)
        CHARACTER*14 FOUT
        COMMON/OUT/FOUT
      OPEN(IWRITE,FILE='PRN')
      FAC=(2.*PT*(H/2.+PSIN))/((3.1416*ALFA)**0.5)
      FAC1=QMIC(IBRK+1)/(FAC*(IBRK)**0.5)
      ASMX=0.950*FAC1
      ASMN=0.3045*FAC1
      IBREAK=6
      OPEN(IWRITE,FILE='PRN')
      WRITE(IWRITE,100)
```

```
      DO 13 IJ=1,IBREAK
      AS(IJ)=ASMN+(IJ-1)*(ASMX-ASMN)/5.
      IF(SHAP)3,6,3
    3 IF(IJ-1)4,4,5
    4 BW=(AS(IJ)/RLW)**0.5-2.*(H*SSL)
      IF(BW)14,14,5
    5 FAV=AS(IJ)-SSL*H*(2.*(1.+RLW)*(AS(IJ)/RLW)**0.5
     1-4.*SSL*H)
      QV=H/3.*(AS(IJ)+FAV+(AS(IJ)*FAV)**0.5)
      FAV=AS(IJ)-(SSL*H/2.)*(2.*(1+RLW)*(AS(IJ)/RLW)**0.5
     1-2.*SSL*H)
      GO TO 9
    6 IF(IJ-1)7,7,8
    7 BR=(AS(IJ)/3.1416)**0.5-2.*(H*SSL)
      IF(BR)14,14,8
    8 QV=H*(AS(IJ)-(AS(IJ)*3.1416)**0.5*SSL*H+
     1(3.1416/3.)*(SSL*H)**2.)
      FAV=AS(IJ)-SSL*H/2.*(2.*(AS(IJ)*3.1416)**0.5-
     13.1416*(SSL*H/2.))
    9 PQ=0.
      DO 10 J=1,NUM
      QINF(IJ,J)=FAV*FAC*T(J)**0.5
      DQ=QMIC(J)-QINF(IJ,J)
      IF(DQ.GE.PQ)PQ=DQ
   10 CONTINUE
  999 IF(PQ)11,11,12
   11 IBREAK=IJ-1
      GO TO 15
   12 DDQ(IJ)=PQ-QV
      WRITE(IWRITE,101)AS(IJ),PQ,QV,DDQ(IJ)
   13 CONTINUE
      GO TO 15
   14 WRITE(IWRITE,102)
      IERROR=2
   15 RETURN
  100 FORMAT(///,4X,'BASIN SURFACE',4X,'MAXIMUM MASS',4X,'BASIN VOLUME',
     14X,'DIFF. BETWEEN MAXI. MASS ',/,4X,'AREA (m^2)',6X,'STORAGE',
     11X,'(m^3)',7X,'(m^3)',7X,'STORAGE & BASIN VOL.(m^3)',/)
  101 FORMAT(5X,4(E10.3,7X))
  102 FORMAT(12X,'**********',10X,'**********',10X,'**********',10X,'**
     1********',/,10X,'ERROR:FLOOR SIZE LE ZERO, PROPOSED H TOO BIG OR S
     1IDE SLOPES TOO FLAT',/,10X,'TRY SMALLER H OR STEEP SIDE SLOPE')
      END
      SUBROUTINE TAHI(BW,BR)
C       PROB=1, The basin surface area is given.
        COMMON/NARAG/IB,QMI(20),QMIC(20),T(20),ZZ(20),K,HH(6),SHAP,
     + IWRITE,PROB,ATS,IBRK,RLW,ALFA,SM,H,SSL,TITL(10),NUM,IBREAK,
     + IERROR
      COMMON/SHAKE/SS,DFIT,DDQ(6),AS(6),PSIN,PT
      COMMON/ILUSH/QINF(6,20)
        CHARACTER*14 FOUT
        COMMON/OUT/FOUT
      OPEN(IWRITE,FILE='PRN')
      FAC=QMIC(IBRK+1)*(3.1416*ALFA)**0.5
      FAC=FAC/(2.*PT*(IBRK)**0.5)
      HMA=2.*((FAC*0.950)/ATS-PSIN)
      HMN=2.*((FAC*0.3045)/ATS-PSIN)
      IF(HMN.LT.0..AND.HMA.LT.0.)GO TO 14
      IF(HMN.LT.0.)HMN=0.
      X=2.*(1.+RLW)*(ATS/RLW)**0.5
```

APPENDIX D
PROGRAM "RECHARGE" LISTING – *International System of Units*)

```
      IBREAK=6
      PRINT 100
      DO 9 IJ=1,IBREAK
      HH(IJ)=HMN+(IJ-1.)*(HMA-HMN)/5.
      IF(SHAP)1,3,1
    1 BW=(ATS/RLW)**0.5-2.*(HH(IJ)*SSL)
      IF(BW)10,10,2
    2 DX=X-4.*SSL*HH(IJ)
      DX=SSL*HH(IJ)*DX
      QV=HH(IJ)/3.*(2.*ATS-DX+(ATS*(ATS-DX))**0.5)
      DA=(X-2.*SSL*HH(IJ))*SSL*HH(IJ)*0.5
      GO TO 5
    3 BR=(ATS/3.1416)**0.5-2.*(HH(IJ)*SSL)
      IF(BR)10,10,4
    4 QV=HH(IJ)*(ATS-(ATS*3.1416)**0.5*SSL*HH(IJ)+
     1(3.1416/3.)*(SSL*HH(IJ))**2.)
      DA=SSL*HH(IJ)*((3.1416*ATS)**0.5-3.1416*SSL*HH(IJ)/4.)
    5 PQ=0.
      DO 6 J=1,NUM
      QINF(IJ,J)=2.*(ATS-DA)*PT*(HH(IJ)/2.+PSIN)*
     1(T(J)/(3.1416*ALFA))**0.5
      DQ=QMIC(J)-QINF(IJ,J)
      IF(DQ.GE.PQ)PQ=DQ
    6 CONTINUE
  999 IF(PQ)7,7,8
    7 IBREAK=IJ-1
      GO TO 11
    8 DDQ(IJ)=PQ-QV
      IF(IJ.GT.1)GO TO 12
      GO TO 13
   12 IF((-DDQ(IJ)+DDQ(IJ-1)).GT.0.) GO TO 13
      IBREAK=IJ-1
      GO TO 11
   13 WRITE(IWRITE,101)HH(IJ),PQ,QV,DDQ(IJ)
    9 CONTINUE
      GO TO 11
   10 WRITE(IWRITE, 102)
      IERROR=2
      GO TO 11
   14 BR=-1.
      BW=-1.
      WRITE(IWRITE,103)
      IERROR=2
   11 RETURN
  100 FORMAT(///,4X,'BASIN OPERATING',2X,'MAXIMUM MASS',4X,'BASIN VOLUM
     1E',4X,'DIFF. BETWEEN MAX. MASS',/,6X,'HEAD (m)',6X,'STORAGE',
     11X,'(m^3)',7X,'(m^3)',7X,'STORAGE & BASIN VOL.(m^3)',/)
  101 FORMAT(5X,F10.2,3(7X,E10.3))
  102 FORMAT(12X,'******',14X,'**********',14X,'**********',14X,'*****
     1*****',/,10X,'ERROR:FLOOR SIZE LE ZERO, THE PROPOSED BASIN SURFACE
     1 AREA IS TOO SMALL !',/,10X,'TRY A LARGER SURFACE AREA!')
  103 FORMAT(10X,'ERROR:THE PROPOSED BASIN SURFACE AREA IS TOO BIG')
      END
       SUBROUTINE FLOW(III)
       COMMON/NARAG/IB,QMI(20),QMIC(20),T(20),ZZ(20),K,HH(6),SHAP,
     + IWRITE,PROB,ATS,IBRK,RLW,ALFA,SM,H,SSL,TITL(10),NUM,IBREAK,
     + IERROR
       COMMON/SHAKE/SS,DFIT,DDQ(6),AS(6),PSIN,PT
       COMMON/LUSH/Y,IX,APX,APY,IJJ,CX,CY
       COMMON/ILUSH/QINF(6,20)
```

APPENDIX D
PROGRAM “RECHARGE” LISTING – *International System of Units*)

```
      COMMON/DOVER/IIII
C
      INTEGER*2 WSSDEV,CRTDEV,PRTDEV,CHOICE
      CHARACTER*1 ACODE,YES,NO
      DIMENSION XAXISX(2),XAXISY(2),YAXISX(2),YAXISY(2)
      DIMENSION GRIDXY(2),GRIDYY(2),ACT(2),ACTY(2),A1(2),B1(2)
      DIMENSION COR(2),CORY(2),GRIDYX(2),GRIDXX(2)
      DIMENSION TXEXPX(4), TXEXPY(4)
      DIMENSION DYY(20)
      DIMENSION QMI1(20),QMI2(20),T1(20)
C
      DATA YES,NO/'Y','N'/
C     FIND THE MAXIMUM INPUT VALUES
      IF(III.GT.1)GOTO 377
      IF(IIII)377,378,377
  378 WRITE(*,10)
  10  FORMAT(///20X,'************MASS INFLOW VS. TIME************',//)
      WRITE(*,915)
  915 FORMAT(5X,' The following values are the inflow quantities',/
     +       ,5X,' measured at every hour. The program makes any time',/
     +       ,5X,' correction neccessary illustrating both the actual',/
     +       ,5X,' and corrected inflow curve.'//
     +       ,5X,' The first input value is at time=0.',///)
      WRITE(*,920)
  920 FORMAT(//,15X,'ENTER NUMBER OF TIME READINGS (INTEGER, MAX OF 20)
     + -->>  ')
      READ(*,30)NUM
  30  FORMAT(I3)
      DO 32 I=1,NUM
        T(I)=(I*1.)-1.0
        WRITE(*,37)I,I-1
  37    FORMAT(/,5X,I2,'> INFLOW (cubic meter) AT ',I2,' HOURS ')
        WRITE(*,*) '             -->>  '
        READ(*,38)QMI(I)
  38    FORMAT(F14.2)
  32  CONTINUE
      WRITE(*,916)
  916 FORMAT(///)
  129 DO 817 IJ=1,NUM
       WRITE(*,107)IJ-1,QMI(IJ)
  107  FORMAT('     TIME(hours)=',I2,'     INFLOW (m^3) =',F12.1)
  817 CONTINUE
      IJ=IJ-1
      WRITE(*,108)IJ
  108 FORMAT('0ARE ALL ',I2,' SETS OF DATA CORRECT? (Y OR N) >>   ')
      READ(*,104)ACODE
  104 FORMAT(A1)
      IF(ACODE.EQ.YES) GOTO 379
      WRITE(*,631)
  631 FORMAT('0WHICH TIME READING WOULD YOU LIKE TO CHANGE?  >>   ')
      READ(*,171)I
  171 FORMAT(I3)
      WRITE(*,105)I+1,I
  105 FORMAT(/,5X,I2,'> INFLOW (m^3) AT ',I2,' HOURS-->  ')
      READ*,QMI(I+1)
      WRITE(*,530)
  530 FORMAT(/)
      GOTO 129
  379 DO 376 I=1,NUM
      QMI1(I)=QMI(I)
```

```
  376   CONTINUE
  377   DO 375 I=1,NUM
         QMI(I)=QMI1(I)
  375   CONTINUE
C       ****************************************************************
C       ****************************************************************
  9     NUM1=1
        DO 41 J=2,NUM
          IF(QMI(J-1).LT.QMI(J))THEN
            NUM1=J
          ENDIF
  41    CONTINUE
C
C       Y AXIS
        TEMP1=QMI(NUM1)
  50    IF(TEMP1.GT.10.)THEN
          TEMP1=TEMP1/10.
          GO TO 50
        ENDIF
        K=TEMP1+1
        A=K*1.
        IA=A*1
C       ****************************************************************
C       MAKE A GREATER THAN ALL INPUT VALUES
C       A ARE THE VALUES ON THE Y AXIS
  70    IF(A.LT.QMI(NUM1))THEN
           A=A*10.
           GO TO 70
        ENDIF
C       ****************************************************************
C       SET SCREEN DIMENSIONS
C       ****************************************************************
        NUMM=NUM*1.0
        X=NUM*1.15
        Y=A*1.15
        YNORM=A*1.25
        X1=NUM*0.15
        Y1=A*0.15
        XAXISX(1)=X1
        XAXISX(2)=X
        XAXISY(1)=Y1
        XAXISY(2)=Y1
        YAXISX(1)=X1
        YAXISX(2)=X1
        YAXISY(1)=Y1
        YAXISY(2)=Y
C       ****************************************************************
        FLAG=0
        WSSDEV=0
        CRTDEV=1
        PRTDEV=2
C       **************************************************
        XA=X*0.45
        YA=Y1*0.35
        XB=X1*0.50
        YB=Y*0.19
        XC=X1*0.65
        YC=Y1*0.70
        XD=X1*0.38
        YD=Y*0.78
```

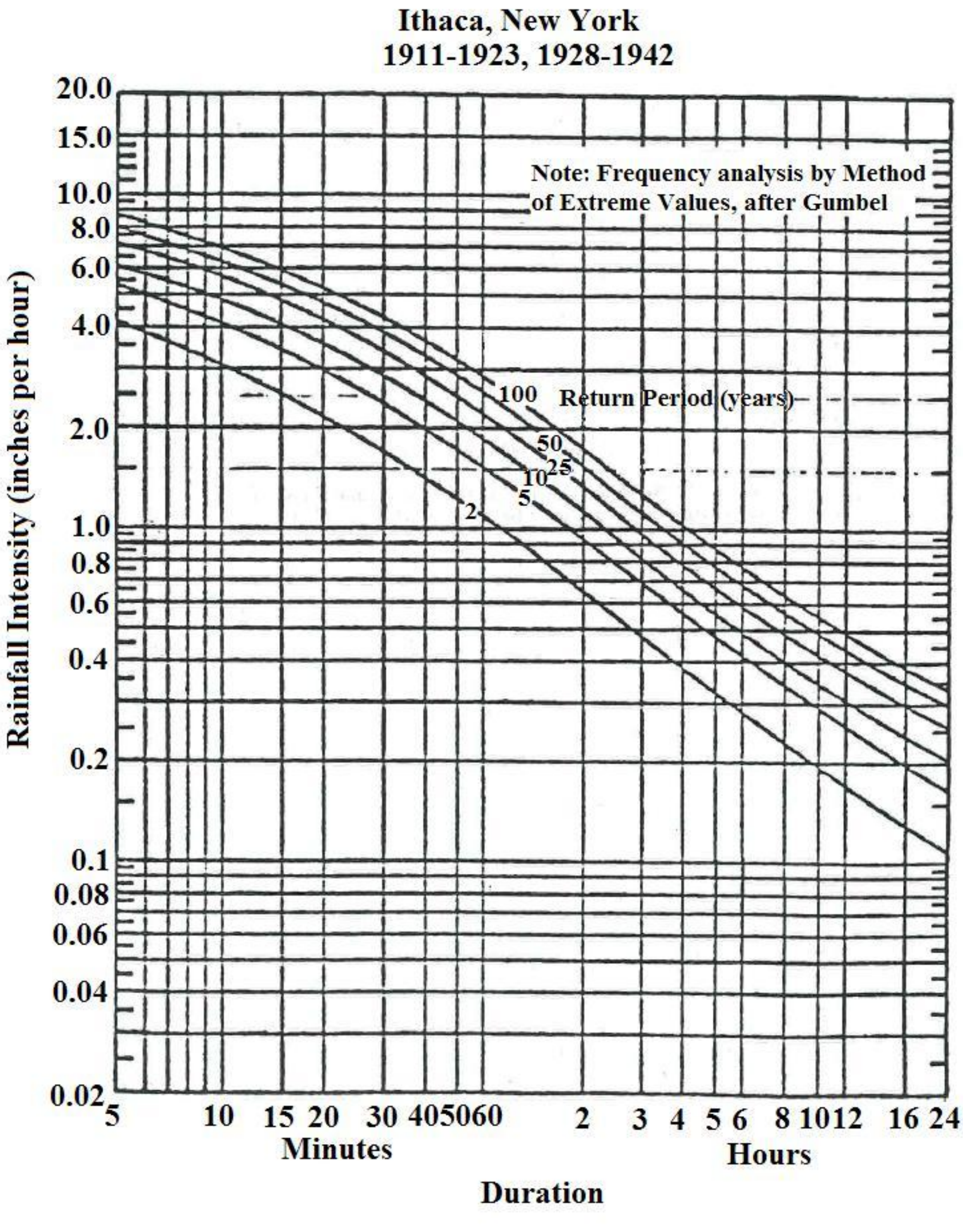
```
      TEMPX=1
      TEMPY=A/IA
       INN=1
C     ****************************************************************
C     SET UP GRID
       GRIDXX(1)=X1
       GRIDXY(2)=NUMM+X1
       GRIDYY(1)=A+Y1
       GRIDYY(2)=A+Y1
      DO 400 M=1,IA
       GRIDYY(1)=A-(M*(A/IA))+Y1
       GRIDYY(2)=A-(M*(A/IA))+Y1
  400 CONTINUE
      GRIDYX(1)=Y1
      GRIDYX(2)=A+Y1
      GRIDXX(1)=NUMM+X1
      GRIDXX(2)=NUMM+X1
      DO 500 N=1,NUM
       GRIDXX(1)=GRIDXX(1)-1.0
       GRIDXX(2)=GRIDXX(2)-1.0
  500 CONTINUE
      MUMM=IA
        TEMP3=A+Y1-(0.02*A)
      DO 515 MM=1,MUMM
        TEMP3=TEMP3-(A/IA)
  515 CONTINUE
      MUM=NUM/2
        TEMP4=(2*MUM)+X1-(0.012*NUM)
      DO 518 MN=1,MUM
        TEMP4=(2*MUM)+X1-((2*MN)+(0.012*NUM))
  518 CONTINUE
      IF(IIII)333,334,333
C     ****************************************************************
C     PLOT THE LINE
  334 IIII=1
C     ***************************************************
C     ROUTINE TO CHECK WHETHER A TIME CORRECTION IS NECESSARY
      FLAG1=0
     IB=0
     SM=0.
     OPEN(IWRITE,FILE='PRN')
     WRITE(IWRITE, 430)
     DO 17 I=2,NUM
     SL=QMI(I)-QMI(I-1)
     IF(SL.GT.SM) GO TO 15
     IF(SL.EQ.SM) GO TO 16
     IF(IB)11,11,18
   11 DO 12 J=I+1,NUM
     SX=QMI(J)-QMI(J-1)
     IF(SX.GT.SL) GO TO 26
     SL=SX
   12 CONTINUE
C    NO TIME CORRECTION IS NECESSARY
     DO 13 II=1,NUM
     QMIC(II)=QMI(II)
   13 CONTINUE
     WRITE(IWRITE, 431)
     DO 14 IJ=1,NUM
     WRITE(IWRITE,435)T(IJ),QMI(IJ)
   14 CONTINUE
```

```
      GO TO 27
   15 IB=I-2
   16 SM=SL
   17 CONTINUE
      GO TO 26
   18 WRITE(IWRITE, 432)
      DO 31 I=2,NUM
       IF(QMI(I).LT.QMI(I-1))GOTO 26
   31 CONTINUE
      FLAG1=1
C     REQUIRE A CORRECTION TO TIME COORDINATES
      IB=IB+1
      XX=QMI(IB)/SM
      IX=INT(XX)
      DX=1.-(XX-IX)
      DO 19 I=1,IX
      QMIC(I)=SM*I
   19 CONTINUE
      DO 22 I=IB,NUM
      IX=IX+1
      IF(I-NUM) 20,21,23
   20 QMIC(IX)=QMI(I)+DX*(QMI(I+1)-QMI(I))
      GO TO 22
   21 QMIC(IX)=QMI(NUM)
   22 CONTINUE
   23 IF(IX.GE.NUM) GO TO 25
      DO 24 I=IX+1,NUM
      QMIC(I)=QMI(NUM)
   24 CONTINUE
   25 DO 29 I=NUM,2,-1
       QMIC(I)=QMIC(I-1)
   29 CONTINUE
       QMIC(1)=0.
      WRITE(IWRITE,433)(T(I),QMI(I),QMIC(I),I=1,NUM)
      GOTO 27
   26 WRITE(IWRITE,434)
      IERROR=1
      GOTO 811
  430   FORMAT(//,14X,'**MASS INFLOW QUANTITY (m^3) VS. TIME (hr)**')
  431   FORMAT(//,20X,'TIME',6X,'ACTUAL',//)
  432   FORMAT(//,20X,'TIME',6X,'ACTUAL',4X,'CORRECTED',//)
  433   FORMAT(20X,F3.0,4X,E10.3,2X,E10.3)
  434   FORMAT(14X,'ERROR:IRREGULAR MASS INFLOW CURVE !',/,
     +  20X,'MASS INFLOW CURVE SHOULD BE A CONTINUOUS SMOOTH CURVE'
     +  ,/,20X,'AND QMI(T+1) SHOULD NOT BE LESS THAN QMI(T).')
  435   FORMAT(20X,F3.0,4X,E10.3)
   27  WRITE(IWRITE,436)
  436  FORMAT(/,'     Note: E+XX stands for 10 to the XXth power.')
       DO 521 I=1,NUM
          T(I)=T(I)+X1
          T1(I)=T(I)
          QMI(I)=QMI(I)+Y1
          QMIC(I)=QMIC(I)+Y1
          QMI2(I)=QMIC(I)
  521  CONTINUE
       ACT(1)=X*0.70
       ACT(2)=X*0.75
       ACTY(1)=Y*0.20
       ACTY(2)=Y*0.20
       COR(1)=0.70*X
```

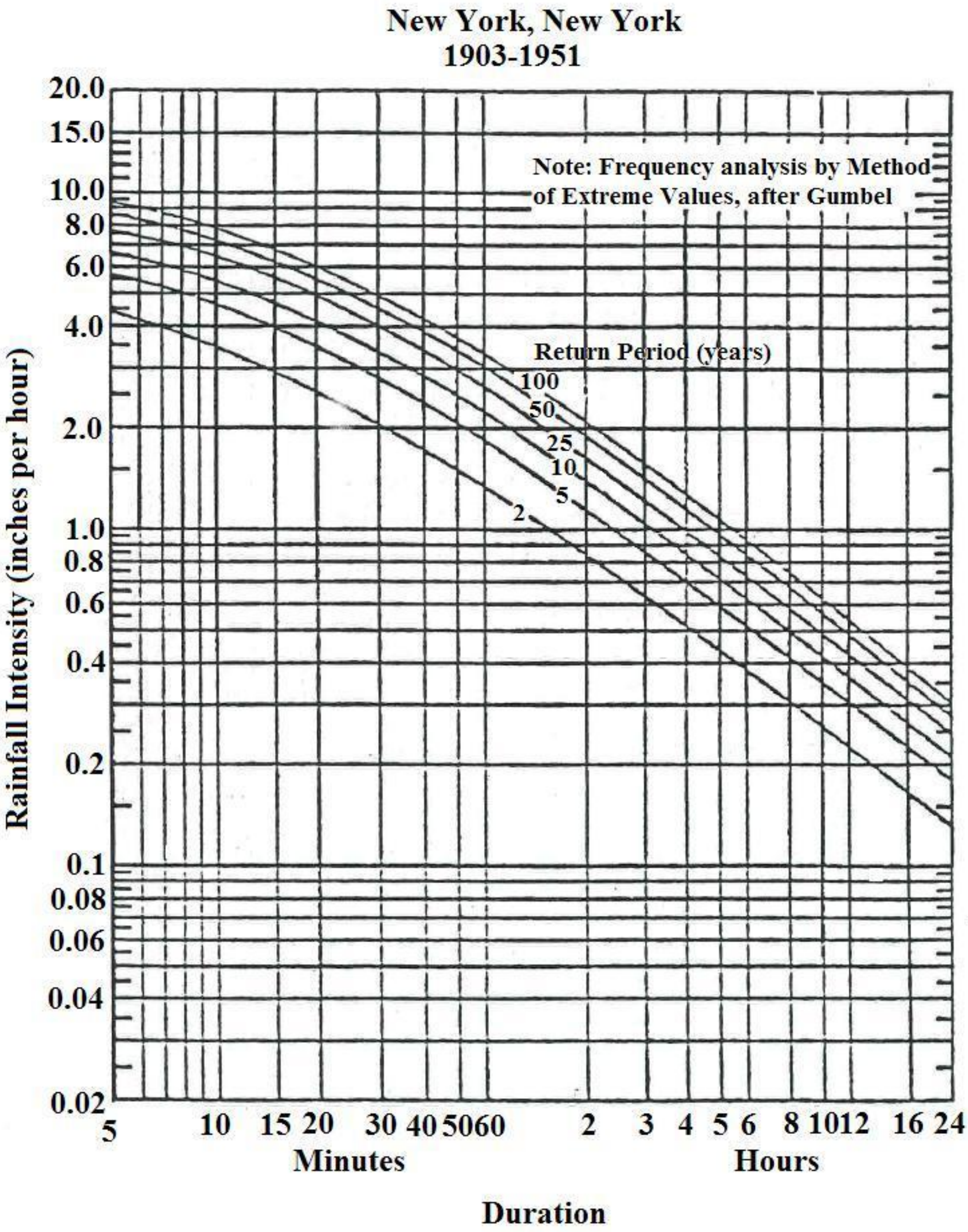
```
      COR(2)=0.75*X
      CORY(1)=0.17*Y
      CORY(2)=0.17*Y
      IF(FLAG1.EQ.0)GOTO 570
      G=ACTY(1)-(.01*Y1)
C     DRAW THE CORRECTED CURVE
      G=CORY(1)-(.01*Y)
  570 XB=X1*0.50
      YB=Y*0.30
      YC=Y*0.50
      XC=X1*0.38
      INN=1
       DO 749 I=1,NUM
         T(I)=T(I)-X1
         QMI(I)=QMI(I)-Y1
         QMIC(I)=QMIC(I)-Y1
  749  CONTINUE
      GOTO 811
  333 QC=QMIC(NUM)
      DO 103 IJJ=1,7
       QC=QC/10.
       IF(QC.LT.5.)GOTO 101
       M=1
       GOTO 797
  101  IF(QC.GT.10.)GOTO 102
       M=2
       GOTO 797
  102  IF(QC.GT.20.)GOTO 103
       M=3
       GOTO 797
  103 CONTINUE
C     DRAW INFLOW CURVE
  797  DO 520 II=1,NUM
        T(II)=T1(II)
        QMIC(II)=QMI2(II)
  520  CONTINUE
        BBB=0.36*X
        CCC=0.24*Y
        DDD=0.31*X
        EEE=0.20*Y
        FFF=0.18*X
        GGG=0.16*Y
        GOTO 593
  593  ACTY(1)=Y*0.20
       ACTY(2)=Y*0.20
       G=ACTY(1)-(0.01*Y1)
C     THE OUTFLOW CURVES ARE NOW DRAWN
      ICHOICE=0
      IKK=0
      KKK=2
  666 DO 5 I=1,IBREAK
       JK=0
       DYY(1)=0.0+(A*0.15)
       T(1)=0.0+(NUM*0.15)
       DO 4 J=2,NUM
        IF((QINF(I,J)+(0.15*A)).LE.QMIC(NUM))GOTO 1
         JK=JK+1
        IF(JK.GT.1)GOTO 523
    1   DYY(J)=QINF(I,J)
        IF(CHOICE.EQ.0)THEN
```

```
        DYY(J)=DYY(J)+(A*0.15)
       ENDIF
  4    CONTINUE
523     AAA=DYY(J-1)-(0.015*A)
  5   CONTINUE
      DO 704 I=1,NUM
       QMIC(I)=QMIC(I)-Y1
       T(I)=T(I)-X1
704   CONTINUE
      G=CORY(1)-(.01*Y)
      XB=X1*0.50
      YB=Y*0.30
      YC=Y*0.50
      XC=X1*0.38
       INN=1
811   CLOSE(IWRITE,ERR=812)
812   RETURN
      END
```

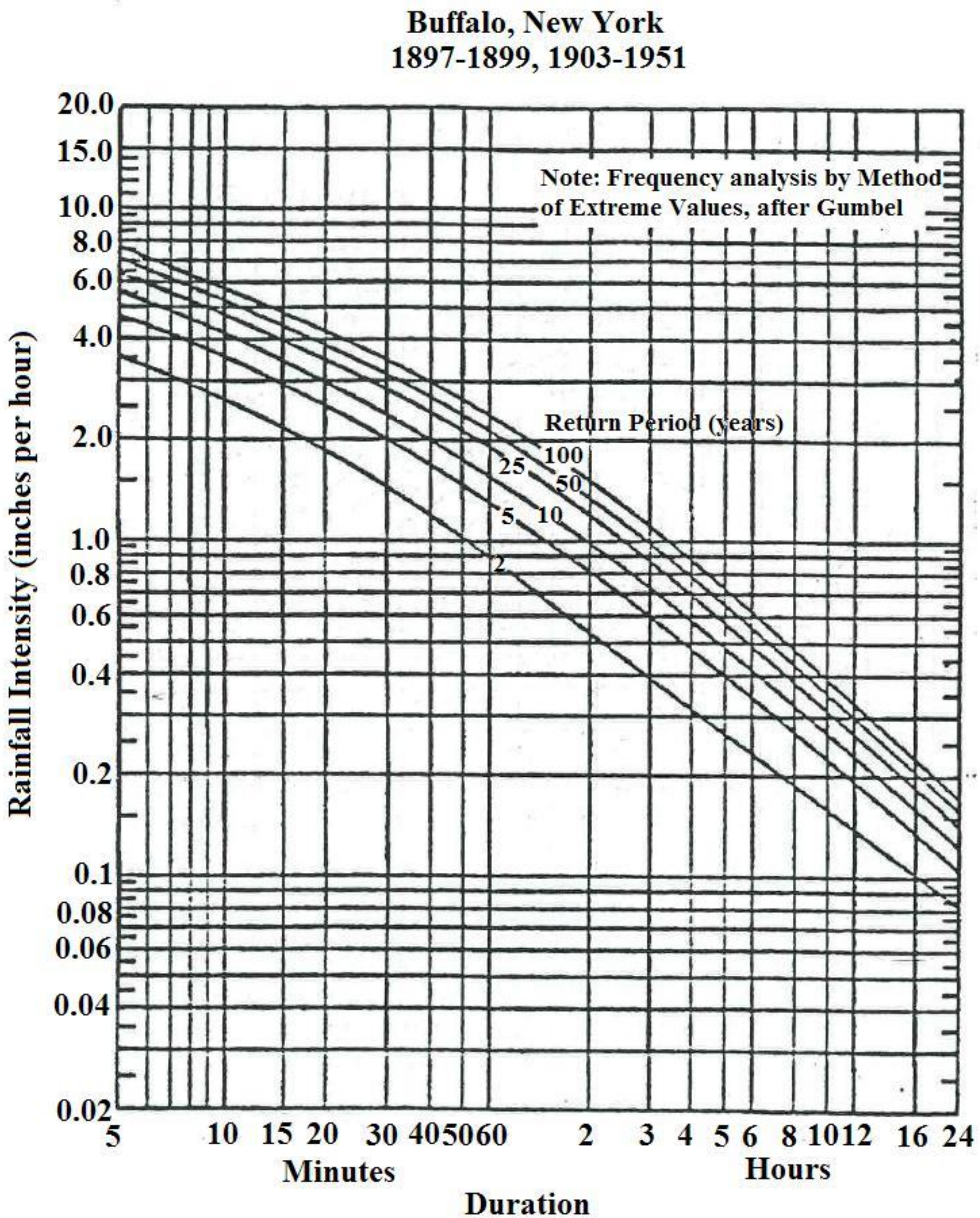
APPENDIX E
SELECTED RAINFALL INTENSITY, FREQUENCY AND DURATION CURVES FOR THE STATE OF NEW YORK



APPENDIX E
SELECTED RAINFALL INTENSITY, FREQUENCY AND DURATION CURVES FOR THE STATE OF NEW YORK



APPENDIX E
SELECTED RAINFALL INTENSITY, FREQUENCY AND DURATION CURVES FOR THE STATE OF NEW YORK



APPENDIX E
SELECTED RAINFALL INTENSITY, FREQUENCY AND DURATION CURVES FOR THE STATE OF NEW YORK