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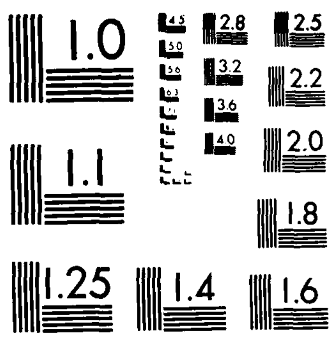

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UNDERDRAIN SYSTEMS FOR LARGE STRUCTURES PLACED BELOW THE GROUNDWATER TABLE

A Special Research Problem

Presented to

The Faculty of the School of Civil Engineering
Georgia Institute of Technology

CONTRACT # N-00228-G-3247

by

Gary N. Pirtle

August, 1986

GEORGIA INSTITUTE OF TECHNOLOGY
A UNIT OF THE UNIVERSITY SYSTEM OF GEORGIA
SCHOOL OF CIVIL ENGINEERING
ATLANTA, GEORGIA 30332

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In Partial Fulfillment

of the Requirements for the Degree of

Master of Science in Civil Engineering

Approved:

8/19/86

Dr. Richard D. Barksdale/Date

8/21/86

Dr. Robert C. Bachus/Date

Dr. Mustafa M. Aral/Date 8/25/86

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ABSTRACT

This research is a study in seepage analysis for engineered structures built below the groundwater table; in particular an analysis of underdrain systems for such structures. General seepage theories and design considerations are discussed as part of the literature review. Also design concepts and methods of analysis are covered which gives a brief overview of design considerations and techniques which are currently used for this type of seepage problem.

Key variables to the design of an underdrain system are studied in detail by using a two dimensional, steady state finite element model. Such variables studied are drain spacing, drain width, anisotropic hydraulic conductivity, thickness of the aquifer, head differential and sloping aquifers.

Results are presented in the form of dimesionless plots and nomographs for drain discharge and free surface plots for the different variables studied.

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CHAPTER ONE

INTRODUCTION

For civil engineered structures which interact with soil, a major consideration for design is the presence of groundwater. Dams, buildings, dry dock facilities, underground structures, pavements and earth retaining walls must be designed considering the quantity of seepage, the position of the free surface, seepage forces and seepage control. Good drainage incorporated in the design of these and other structures can often benefit through substantial cost reductions as well as increasing the safety and usefulness of the structure.

Many embarassing and sometimes disastrous problems often result from man's endeavors to control seepage. Saturated soil backfills have caused many retaining wall failures due to increased hydrostatic pressures following extensive rainfall. Highways and roadways prematurely deteriorate and fail due to trapped water in the pavement section. Basement slabs, pond liners and drydock facilities have been severely damaged by hydrostatic uplift pressures and seepage. Most dam and slope failures can be attributed to excessive seepage or uplift pressures. These examples and untold others indicate that good seepage and drainage control together with an adequate understanding of groundwater is a key element in the design of most civil engineering structures.

Many civil engineering structures are located in areas where groundwater causes problems of uplift and seepage. The design therfore must consider all problems associated with high groundwater and what measures must be taken to assure the integrity of the overall design. Casagrande(1965), in talking about engineering risks, concludes that, "The margin of safety that we incorporate into our structures should bear a direct relationship to the magnitude of potential losses, and it must also take into account the range of uncertainty involved." This important concept hopefully will be considered throughout the presentation of facts and data obtained in this paper.

Prior to the 20th century, analysis of seepage and the control of drainage for enginerring structures was done by experienced engineers who based their designs on trial and error methods which sometimes were successful and sometimes not. Though experience has proven to be very neccesary and helpful in the design of drainage systems, very useful tools employed today are numerical methods such as finite element and finite difference techniques which require the use of the digital computer. Their problem solving capabilities have made possible solving very complicated and complex groundwater problems.

The purpose of this research is to study the design of underdrain systems for large structures placed below the groundwater table. In chapter two, basic seepage theories and design requirements, designs concepts and useful methods of analysis are presented as a brief literature review. This chapter covers critical aspects of designs that should be considered and contains a brief review of methods used by geotechnical engineers.

In chapter three, the finite element program developed by Dr. M. Aral, of the School of Civil Engineering at Georgia Institute of Technology, is discussed describing how the design of building underdrain systems can be modeled using this technique. This finite element program made possible studying effects of key variables such as permeability, hydraulic head, drain geometry, depth of groundwater, and anisotropic soils. Program verification is performed using another program, SEEP84, modified by the Civil Engineering Department at Virginia Polytechnic Institute and State University, for the microcomputer. Dupuit's solution is also used to compare selected cases with the finite element programs.

Chapter four presents data generated from the finite element study such as position of the free surface and flow quantity for selected systems of underdrains suitable for use beneath a foundation. The data is presented in the form of charts and nomographs to be used as a guide for underdrain system design.

Chapter five summarizes the results of the study and presents appropriate conclussions.

Appendix A contains program documentation for the finite element program used in this study which details to the user, documentation to the use of the program. Appendix B presents example input and output data generated by this study.

CHAPTER 2

LITERATURE REVIEW

2.1 Seepage Theories and Design Requirements

Groundwater

Soils, sometimes described as a porous media, is a mass made up of solid matter having interconnected voids, passages, fissures or pore spaces. These pore spaces can be filled by a liquid and or a gaseous phase. Figure 2.1 shows several typical soil and rock indices which depicts how pore spaces can act as conduits for water or subcapillary openings in which water may be held by adhesive capillary forces (Meinzer,1942).

The soil mass forms a complex network of irregular passages through which the fluid may flow. A key parameter of groundwater movement is the porosity of the soil. As gravity acts on the fluid, it moves through the pore spaces at varying rates through each open pore space. From a macro scale, this flow has been mathematically described by several authors (Bear, 1981; Terzaghi, 1943; Cedergren, 1977; Harr, 1962; Bouwer, 1978;Freeze, 1971).

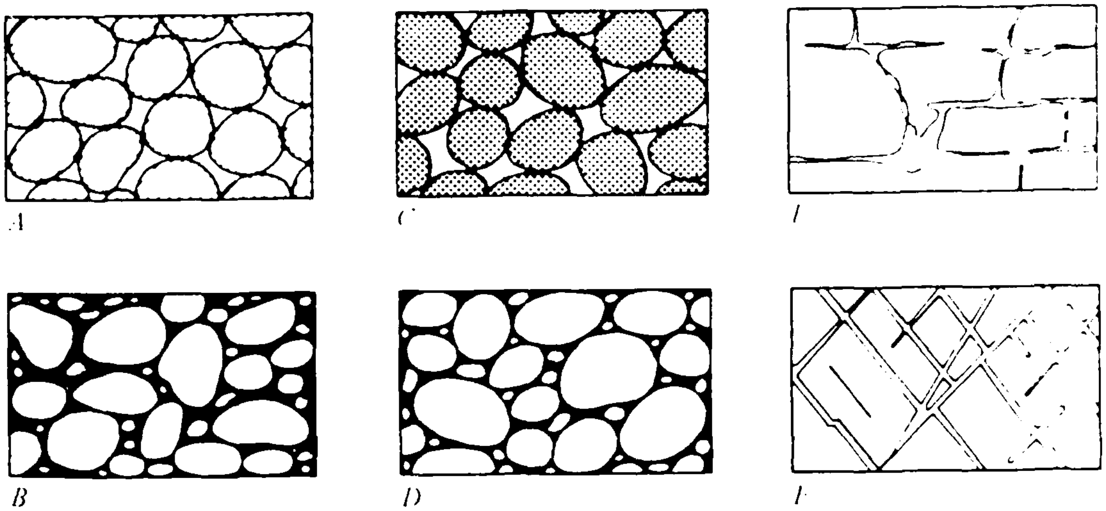

Figure 2.1 Diagram showing soil and rock interstices. A. Well sorted sand deposit having high porosity; B. Poorly sorted deposit having low porosity; C. Particles that may be porous themselves; D. Deposit whose porosity may be diminished by deposition of mineral matter in the interstices; E. Rock that is porous by solution; F. Rock that is porous by fracturing (after Meinzer, 1942)

Moisture content in soils can vary with depth from the surface, as shown by Figure 2.2. Most seepage problems considers the zone of saturation which is the zone where the soil mass is completely saturated. The terms groundwater level, phreatic water level, water table, free surface or groundwater surface are all synonymous to denote the level of water where atmospheric pressure exists.

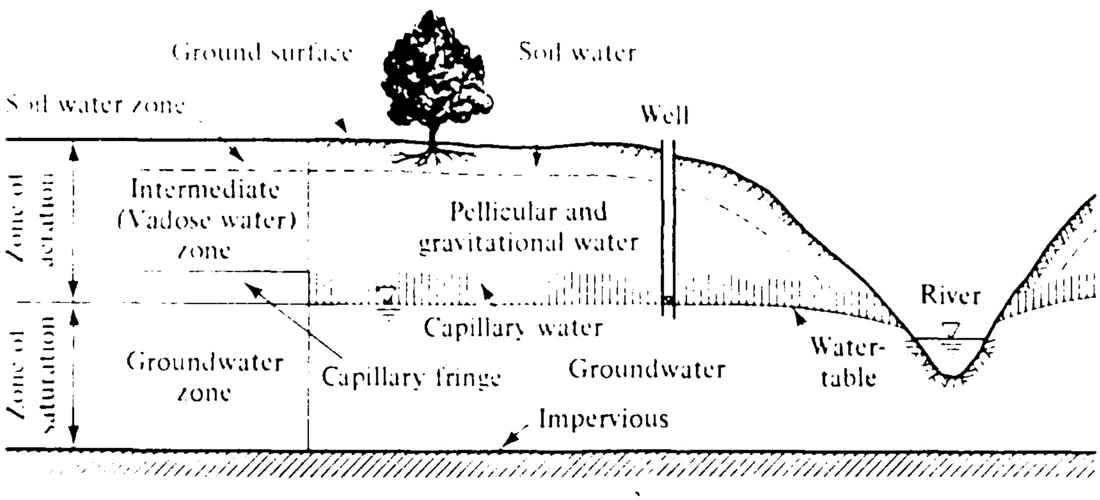

Figure 2.2 Subsurface groundwater distribution.
(after Bear, 1979)

In dealing with capillary fringe in fine grained soils the height of water can very significant. As the pore diameter decreases, the capillary rise increases. Although the soil is considered unsaturated, the soils moisture content will be higher with depth.

The zone of capillary rise and fringe zone may contain large quantities of water for fine grained soils. Water removal by drainage, due to capillary forces, may be difficult for such fine grained soils. Figure 2.3 shows how the actual moisture distribution is approximated by a step distribution. This approximation of the capillary fringe level above the free surface, h_c, is often neglected in some seepage problems. Several emperical methods, based on grain size diameter and porosity of soil, are available to estimate h_c (Mavis and Tsui, 1939; Polubarinova, 1952, 1962; Silin Bekchurin, 1958).

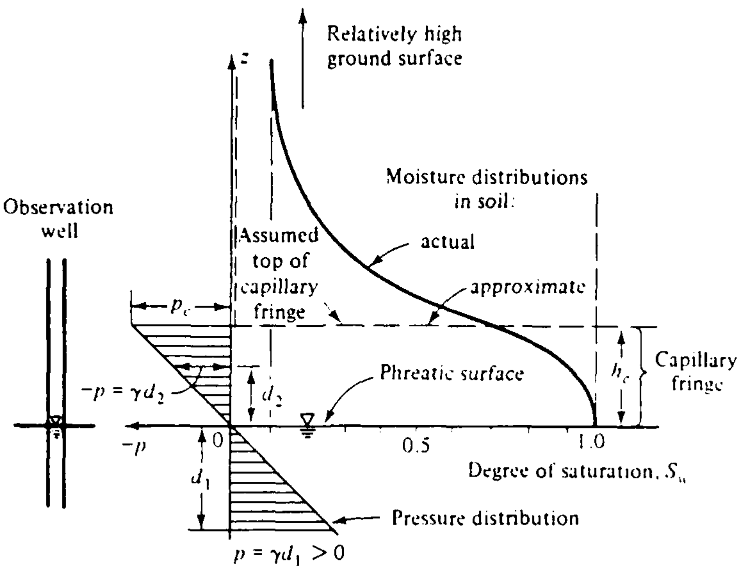

Figure 2.3 Approximation of phreatic surface and capillary fringe zone. (after Bear, 1979)

Many textbooks on seepage and groundwater discuss water bearing and retention capibilities of the capillary fringe and movement of moisture through this zone (Terzaghi, 1943; Kovacs, 1981; Sowers, 1979). However, when this height of water is very small relative to the total thickness of the aquifer, the capillary fringe is sometimes neglected. The geotechnical engineer should be concerned with the unsaturated-saturated flow condition when the stability of the engineered structure is to be analyzed, such as a dam.

Groundwater analysis for seepage problems must consider the quantity of water to be drained, the soils resistance to drainage, and what effects the drainage may have on the soil and the structure. Movement of groundwater can be categorized either as seepage; capillary rise or flow; percolation; or turbulent flow. For this study, only movement of groundwater by seepage is considered.

Design Requirements

Structures built below the watertable must be designed considering the following:

(1) structural ability to withstand the applied hydrostatic water pressures,

(2) drainage control which short-cuts the flow or movement of groundwater from getting to the structure,

(3) drainage control which is incorporated with the overall design to remove the groundwater,

(4) assure water velocities be small enough to prevent excess particle migration and erosion.

Savings of dollars, time and natural resources can be recognized when structures can be considered on dry, stable material;in addition to thinner basement slab thicknesses may be used.

Darcy's Law

In 1856, Henry Darcy investigated the flow of water in vertical homogeneous sand. This work has developed the most fundamental relationship which is still used in seepage analysis today. Darcy's Law states:

$$Q = k\ i\ A \qquad (2.1)$$

where Q (L^3/T) is a volume discharge or flow of a given cross-sectional area, A (L^2) in a given time. The discharge is also a function of the hydraulic gradient, i (L/L) and a resistance coefficient, k (L/T), the permeability of the soil. Investigators, Muskat (1937), Taylor (1949) and Leonards (1962), have concluded that Darcy's Law is valid where velocities are low or when flow is laminar, i.e. Reynolds number less than 10.

Hydraulic Conductivity

The soils resistance to flow or the coefficient of porportionality, k, for Darcy's Law, is also called the hydraulic conductivity. Hydraulic conductivity is a coefficient which expresses the ease or resistance the water has flowing through the soil. It depends on the soils matrix and fluid properties of the permeant.

Many researchers have performed tests to attempt to develope empirical relationships of the soils properties to hydraulic conductivity. Some of these properties considered are grain or pore size distribution, shape of the grains or pores, tortuosity, specific surface and porosity (Mitchell, 1976; Kozeny, 1927; Carman, 1956; Cedergren, 1977; Kovacs, 1981). All report that careful field investiagation and careful conductivity studies are necessary for each design. Figure 2.4 is presented to show some characteristics of various soil types and most important, methods for determination of selected properties (Terzaghi and Peck, 1948).

In the unsaturated zone, the hydraulic conductivity, moisture content and pressure head is extremely complex and not well understood. Again, field measurement is the best method for obtaining the best parameters, such as the use of theistor psychrometer (Kay and Low, 1970) or gamma ray absorption techniques (Ferguson, 1970; Aral, 1983). However, many empirical formulas have been developed to relate the soil parameters to a relative hydraulic conductivity of the un-saturated zone (Kovacs, 1981; Irmay, 1954; Childs and Collis-George, 1950; Gardner, 1958; Brooks and Corey, 1966; Maslia, 1980; Reeves and Duriguid, 1975).

Coefficient of Permeability k in cm per sec (log scale)

10^2 | 10^1 | 1.0 | 10^{-1} | 10^{-2} | 10^{-3} | 10^{-4} | 10^{-5} | 10^{-6} | 10^{-7} | 10^{-8} | 10^{-9}

Drainage	Good (10^2 to 10^{-4})	Poor (10^{-4} to 10^{-6})	Practically Impervious (10^{-6} to 10^{-9})	
Soil types	Clean gravel (10^2 to 1.0)	Clean sands, clean sand and gravel mixtures (1.0 to 10^{-3})	Very fine sands, organic and inorganic silts, mixtures of sand silt and clay, glacial till, stratified clay deposits, *etc.* (10^{-3} to 10^{-7})	"Impervious" soils, e.g., homogeneous clays below zone of weathering (10^{-7} to 10^{-9})
			"Impervious" soils modified by effects of vegetation and weathering (10^{-2} to 10^{-7})	
Direct determination of k	Direct testing of soil in its original position—pumping tests. Reliable if properly conducted. Considerable experience required (10^2 to 10^{-4})			
	Constant-head permeameter. Little experience required (10^2 to 10^{-3})			
Indirect determination of k	Falling-head permeameter. Reliable. Little experience required (1.0 to 10^{-3})	Falling-head permeameter. Unreliable. Much experience required (10^{-3} to 10^{-6})	Falling-head permeameter. Fairly reliable. Considerable experience necessary (10^{-6} to 10^{-9})	
	Computation from grain-size distribution. Applicable only to clean cohesionless sands and gravels (10^2 to 10^{-3})		Computation based on results of consolidation tests. Reliable. Considerable experience required (10^{-7} to 10^{-9})	

After A. Casagrande and R. E. Fadum

Figure 2.4 Permeability and Drainage Characteristics for Various Soil Types

2.2 Design Concepts

Seepage Forces

The effects of water on the soil and the structure is controlled by the pressures in the water. In soil mechanics, the water pressure is defined as neutral stress. For water not moving, or steady state, the pressure can be computed from the basic equation of hydrostatics

$$h = \frac{P}{\gamma_w} + z \qquad (2.2)$$

where h, energy head, is equal to the positic , z, plus the pressure head or piezometric head, P/γ_w . Typically in seepage designs, the velocity head is very small and may be neglected. Then the pressure head plus elevation is equal to head, h (Cedergren, 1977).

For the condition that water pressure is greater than the total load, say of the soil and structure, the pressures are termed uplift pressures and liquifaction can occur. Therfore the control of uplift pressures must be a primary design consideration.

Critical Velocity

According to Darcy's Law, the discharge velocity of seepage through soil is

$$v_d = k \times i \quad . \qquad (2.3)$$

Seepage is only occuring through the pores and voids. Therefore the true seepage velocity should be a function of the porosity of the soil mass. Re-writing equation (2.3) the seepage velocity can be expressed as

$$v_{sn} = \frac{k \times i}{\eta_e} \qquad (2.4)$$

where η_e is the effective porosity.

In flow conditions, the saturation of soil is moving into or away from the unsaturated soil. The capillary head, h_c, is working with gravity to increase the hydraulic gradient. For this condition the hydraulic gradient can be expressed

$$i = \frac{h + h_c}{L} \qquad (2.5)$$

Figure 2.5 depicts this condition for flow through a sand.

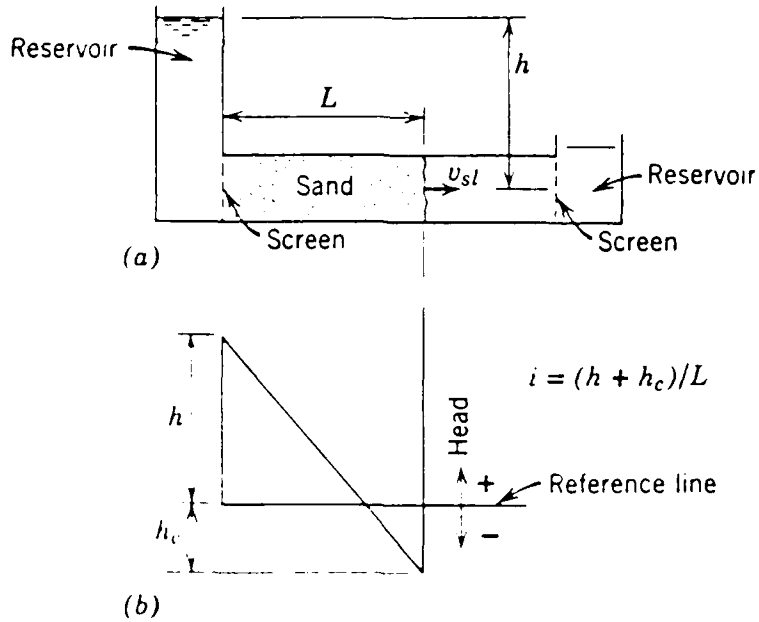

Figure 2.5 Force of saturation.

Boiling occurs when seepage pressures in an upward direction exceeds the downward force of the soil. This must be analysed for all seepage designs. Critical hydraulic gradient, i_c, can be expressed

$$i_c = \frac{\gamma_T - \gamma_W}{\gamma_W} = \frac{\gamma_b}{\gamma_W} \quad (2.6)$$

where γ_T = total unit weight of soil

γ_W = unit weight of water

γ_b = buoyant unit weight of soil (NAVFAC, DM-7.1).

Filters

A very important design consideration is the possibility of seepage forces moving erodible soils and rock, termed piping. Betram (1940), under Terzaghi and Casagrande, established the following criteria for filter design, based on grain size.

$$\frac{D_{15}\text{ (of filter)}}{D_{85}\text{ (of soil)}} < 4 \text{ to } 5 < \frac{D_{15}\text{ (of filter)}}{D_{15}\text{ (of soil)}} \qquad (2.7)$$

This relationship is represented by Figure 2.6 to illustrate the prevention of piping by filters (Cedergren, 1977).

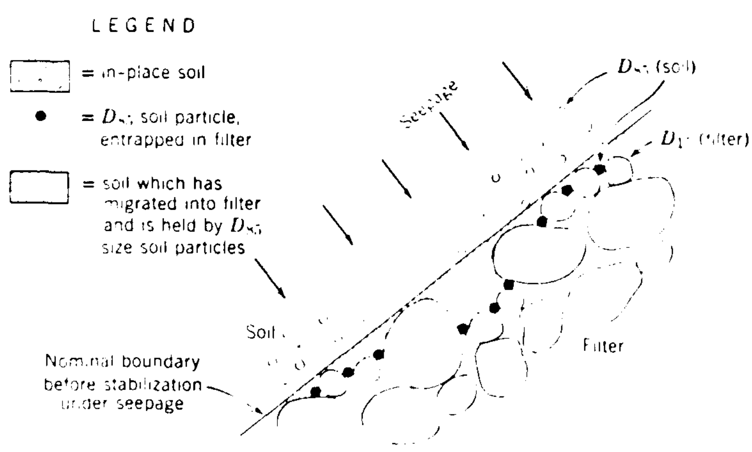

Figure 2.6 Illustration of prevention of piping by filters. (after Rankilor, 1981)

The ratio of D_{15} of a filter to the D_{85} of a soil is considered the piping ratio. Many authors and organizations have established other criteria for filters, similar to that of equation (2.7) (U.S. Army Corps of Engineers, 1941, 1955; U.S Bureau of Reclamation, 1955; Sherard,etal, 1963; Cedergren, 1977; Thanikachalam and Sakthivadivel, 1974).

Filters must be designed to meet two major requirements; (1) they must be safe with respect to erosion and piping, and (2) must have sufficient discharge capibillities to remove the seepage quickly and efficiently. This must be done without inducing high seepage forces or hydrostatic pressures. The right side of equation (2.7) states that the D_{15} size of a filter should be at least 4 to 5 times the D_{15} of the soil. This insures that the hydraulic conductivity of the filter and drains is sufficient to prevent the build-up of large seepage forces and hydrostatic pressures.

There is a wide range of engineering properties of materials to be considered for filter drainage systems designs. Properties which may influence hydraulic conductivity are grain size, density, mineralogical composition, the nature of the permeant or the degree of saturation. Much work has gone toward methods for determination and factors which influence hydraulic conductivity (Milligan, 1975; Lambe and Whitman, 1969; Yemington, 1963; Bouwer, 1978). There is still much research necessary to understand better this property of soil.

Trench Drains

For the application of drainage for structures built below the water table, the use of trench drains, which acts as collectors of the seepage or may contain collector pipes, is a very efficient method. Figure 2.7 shows the typical cross-section which may be considered for the application of this type of drainage system. Trench drains will be discussed further in the report and their utilization for this application will be studied in more detail.

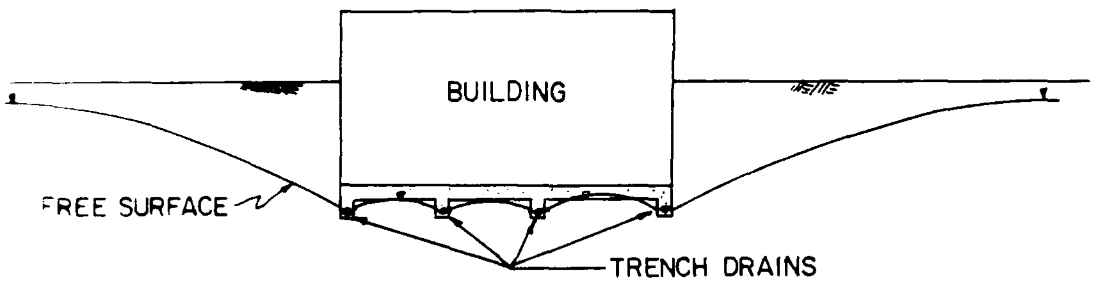

Figure 2.7 Typical application of a trench drain system.

Geosynthetics

Today, new synthetic membranes are used to serve the purpose of either filtration or seperation. This two factors are very important parameters for most seepage problems. Figure 2.8 shows comparisons of some of the features of membrane-wrapped drains to conventional granular pipe drains. Also Figure 2.9 shows the bridging effect caused by good seperation of the larger materials and smaller particles.

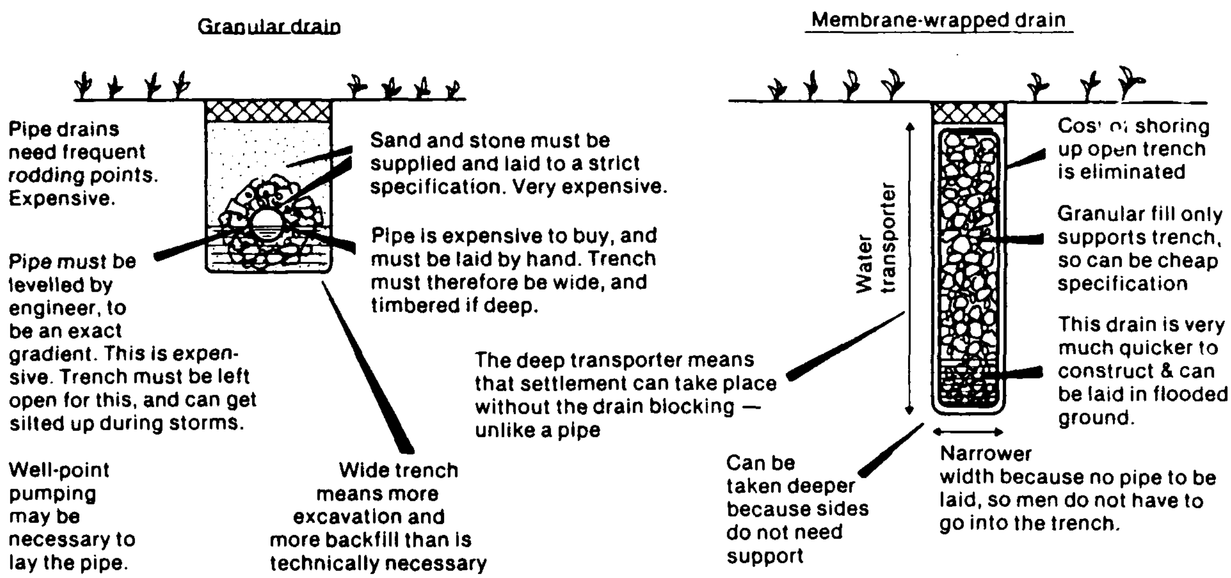

Figure 2.8 Conventional granular pipe trench drain and membrane-wrapped trench drain. (after Rankilor, 1981)

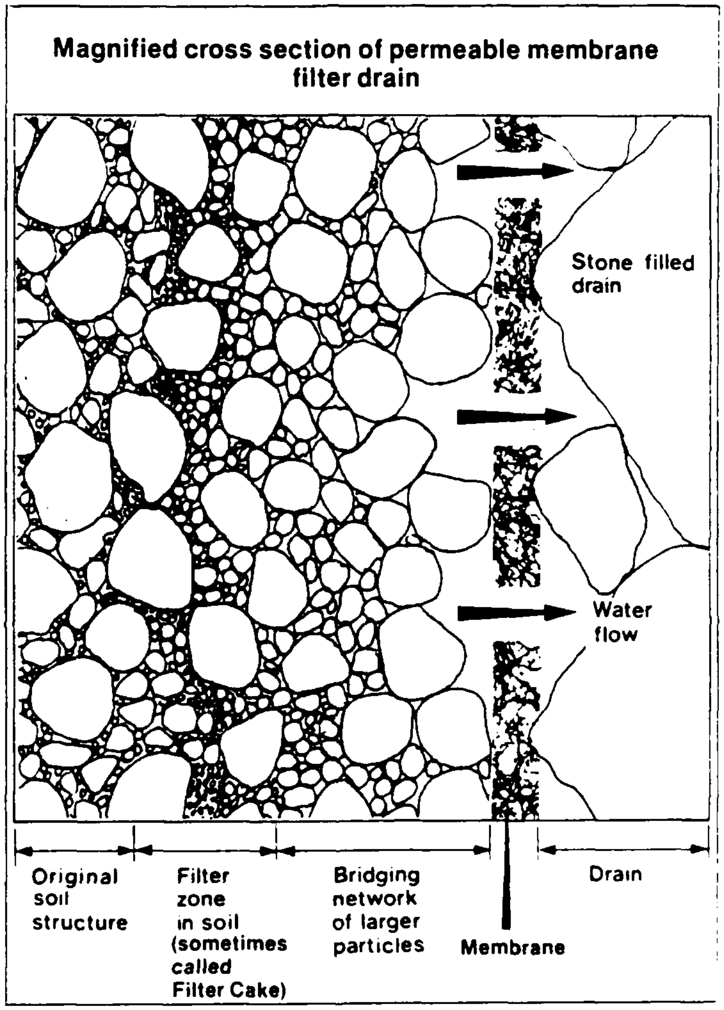

Figure 2.9 Bridging effects caused by use of membrane filter material. (after Rankilor, 1981)

A good representation of how geosynthetics combine action of seperation and filtration, is shown by Figure 2.10. As water has more area of flow with the membrane, the seepage can be considered to be at a faster rate or drain quicker (Rankilor, 1981)

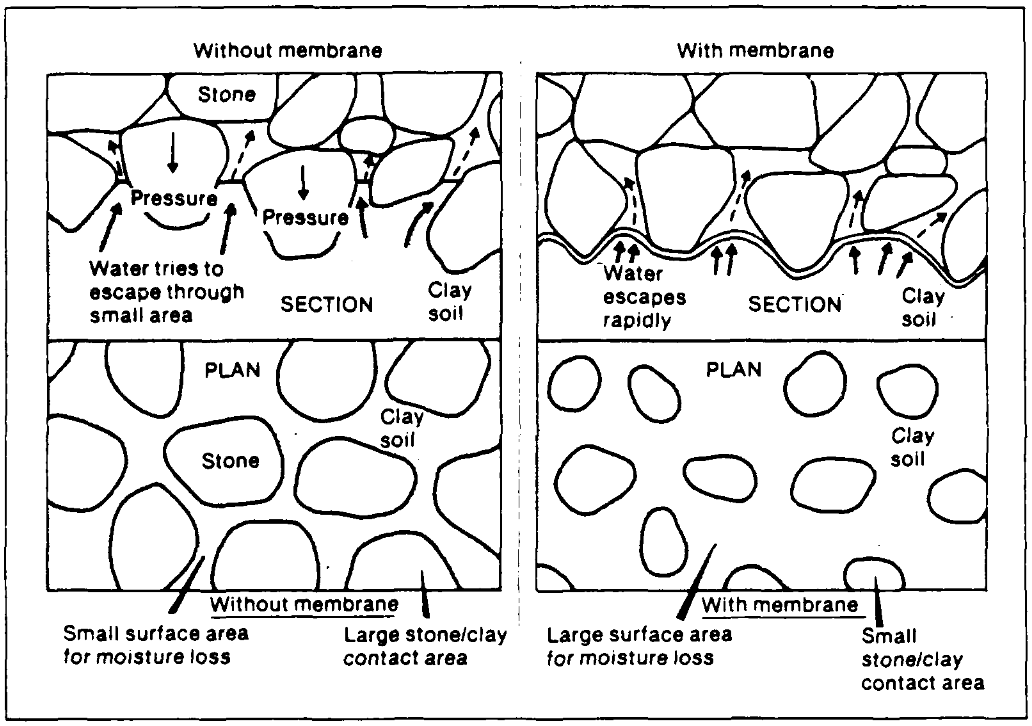

Figure 2.10 Seperation effects by using a membrane. (after Rankilor, 1981)

2.3 Methods of Analysis

In analyzing seepage problems; geometry, boundary conditions, soil parameters, flow quantities and location of the free surface must be quantified by some means. Though this involves many considerations, the engineer must gain reasonable safe results for the design.

Through the history of seepage analysis many techniques and methods have been developed, such as graphical, analytical and numerical solutions. Still used today is the graphical method of flow net construction. However with the complex geometries envolved and via the speed of computers, numerical models have been developed as very useful tools for the engineer.

Flow Nets

Many researchers have developed methods for analyzing flow through porous media. The oldest, developed by Casagrande and Terzaghi (1937), is the use of flow nets, a graphical approach to seepage analysis.

The continuity equation in the form

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \qquad (2.7)$$

shows for a Cartesian coordinate system, the quantity of water entering an element must equal that leaving. The terms u, v and w are discharge velocity components of directions x, y and z, respectfully.

According to Darcy's Law, expressed by equation (2.3), the component of discharge velocity can be expressed

$$u = -k \frac{\partial h}{\partial x}, \quad v = -k \frac{\partial h}{\partial y}, \quad w = -k \frac{\partial h}{\partial z} \qquad (2.8)$$

Substituting into equation (2.7)

$$\partial \frac{-k(\partial h/\partial x)}{\partial x} + \partial \frac{-k(\partial h/\partial y)}{\partial y} + \partial \frac{-k(\partial h/\partial z)}{\partial z} = 0 \qquad (2.9)$$

If k is constant for the element and then expressed in a typical two-dimensional form, equation (2.9) becomes the common Laplace equation.

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} = 0 \qquad (2.10)$$

The general conditon of flow analysis using flow nets is represented by Figure 2.11. Rules and good examples are presented in many textbooks (Cedergren, 1977; Harr, 1967).

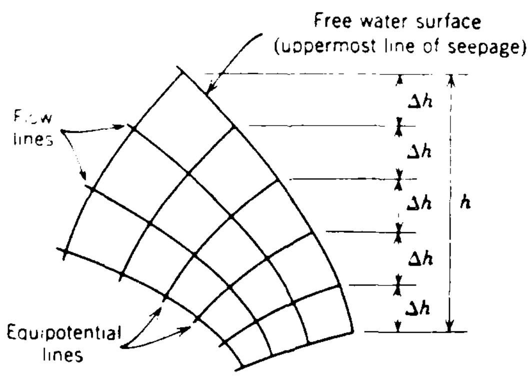

Figure 2.11 General condition for flow lines and equipotential lines in flow net construction.

Dupuit Assumptions

For unconfined seepage problems the engineer must calculate the location of the free surface. Many problems of flow have been approximated based on the Dupuit theory of unconfined flow. Dupuit (1893) assumed; (1) for small inclinations of the line of seepage, the streamlines can be taken as horizontal and equal potential lines vertical, and (2) the hydraulic gradient was equal to the slope of the free surface and invarient with depth (Harr, 1962).

Harr (1962) gives many example problems and has derived the condition of free surface elevations as shown by Figure 2.12.

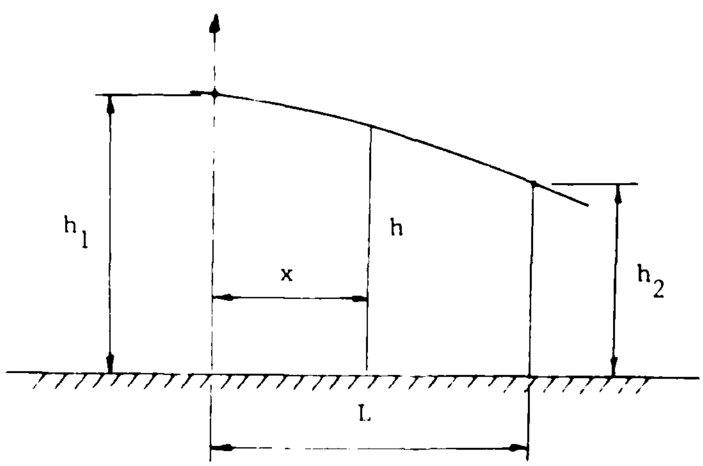

Figure 2.12 Simple free surface notation.

In the case of Figure 2.12 the Dupuit formula is expressed as

$$q = k \frac{h_1^2 - h_2^2}{2L} \qquad (2.11)$$

Many other reports and textbooks have presented charts and nomagraphs based on these assumptions. Later in this study a nomograph for a simple trench drain with blanket drain solution developed by the Federal Highway Administration (1980) will be presented.

Numerical Analysis

Flow through porous media has been approximated by many authors using ordinary non-linear differential equations and partial differential equations. Coupled with the speed of the computor, numerical solutions to many seepage problems have been developed. It should be pointed out that complex mathematical problems solved by numerical methods, are only as accurate as the math model can represent the conceptions and phenomina of seepage flow. In most cases, simplification is the rule, and numerical models can only be treated as approximations to the actual occurances. Nevertheless, the number crunching capibilities and time savings involved gives the engineer much needed time for the true analysis of the seepage problem.

The analytical and graphical methods mentioned previously are sometimes difficult and limited to flow systems which are relativly simple. In actual field conditions, the soils may be heterogeneous and anisotropic and boundary conditions very complex. These conditions make closed form methods very difficult and many simplifications would have to be made. However, with the numerical models, these complexities can be easily handled and many more check cases can be made in much less time.

Finite Difference Methods

Many numerical computer models have been developed using finite difference methodology. Since the classic work of Peaceman and Rachford (1955), the oil industry has sponsored many studies on model development. A good historical background of the finite difference methods developed in seepage analysis is giving by Huyakorn (1983). Worth mentioning are the works of Cooley (1971) and Freeze (1971) in the development of other finite difference models. These models solve for the free surface and treat the saturated-unsaturated flow as an immobile air phase.

Finite Element

The finite element method for solving subsurface flow has been widely used and researched be soils engineers and groundwater hydrologists. The program used in this research and discussed in more detail in Chapter 3 is a finite element model.

Most finite element models are built on the Galerkin method. Some earlier finite element models for steady state and saturated flow were developed by Desai and Abel (1972), Conner and Brebbia (1977) and Zienkiewicz (1977). Finder and Frind (1972) used isoparametric quadrilateral elements with the Galerkin's technique. Neuman (1973, 1974) used a four node quadrilateral element. A good reference for other works in the finite element models that have been developed is reported in Huyakorn and Pinder (1983) and Heijde (1985).

Some significant works were those of Taylor and Brown (1967) where a finite element model was developed for seepage through a dam solving for the free surface. The flow was only considerd for the saturated zone in this model. Freeze (1971) demonstrated that the conditions of the unsaturated zone may strongly influence the position of the free surface and results obtained not considering the capillary action for this case could be in error. Fredlund and Morgenstern (1976) developed improved constitutive equations for an unsaturated soil. Lam and Fredlund, etal (1984) presented additional theories and numerical development for further modeling techniques to consider the unsaturated zone in seepage analysis.

CHAPTER 3

FINITE ELEMENT STUDY

3.1 Finite Element Program Theory

<u>Introduction</u>

Finite element analysis of seepage problems can be described as follows (Huyakon and Pinder, 1983):

(1) A discrete number of interconnected nodes to define a series of sub-regions or elements. These can take the form of triangles, quadrilateral or rectangular shapes which are so spaced to define the geometric boundaries and soil types.

(2) A matrix expression is developed to relate flow variables to each node of the elements. The mathematical expression may be of the form of either a variational or weighted function. A weighted residual function is used in the Galerkin method (Conner and Brebbia, 1977).

(3) A set of algebraic equations that describe the entire global system is applied to assemble the element matrices. These equations are derived to consider compatible conditions at each node shared be each adjoining element.

(4) Boundary conditions of flow are incorporated to reflect appropriate limits to the global matrix equations.

(5) The resulting set of simultaneous algebraic equations are solved by some alogrithm method. Many algorithyms have

been used to efficiently take advantage of the banded and symmetric features of the coefficient matrix (Bathe and Wilson, 1976).

The finite element method has great potential in seepage analysis problems, in that the complex geometries of flow regions can be easily constructed via nodes and elements. This chapter will present the general theories and formulation of equations for the model used in this study.

Program Theory

A finite element program developed by Dr. Mustusfa Aral of the School of Civil Engineering, Georgia Institute of Technology, was used to study the flow and variables involved for subsurface drains as earlier described. This program was used to see effects of different parameters in the analysis performed. The program was operated on the Georgia Institute of Technology main-frame CDC CYBER computer. A complete user's guide for the program is included as Appendix A-1. Also example input and output used in this study is included by Appendix B-1. The formulation for the program presented here was summarized from a previous study (Aral, Sturm and Fulford, 1981).

This model only considers the flow condition of the free surface being the point where the water level is at atmospheric pressure. In other words, this model does not treat the unsaturated zone of the soil. For this study the flow continum is modeled to determine the quantity of flow at each drain and to determine the free surface location between each of the drains. This model also computed the velocities at each element for a good check.

Equations of Flow

Darcy's Law is used as the basic relationship governing groundwater flow. Flow is assumed to be laminar and the inertial forces are negligible compared to viscous forces. Rewriting Darcy's Law in the cartesian coordinate system:

$$\vec{v} = - K \vec{\nabla} h \qquad (3.1)$$

where $\vec{V}$ is seepage velocity, h is piezometric head and K the hydraulic conductivity. In the two dimensional case, equation (3.1) can be written as

$$v = - K_{ii} \frac{\partial h}{\partial x} , \quad i = 1,2 \qquad (3.2)$$

where K_{ii} is a conductivity tensor.

The continuity equation for the flow in an element of soil can be expressed

$$\frac{\partial}{\partial x} (\rho v_i) = - \frac{\partial}{\partial t}(\eta \rho) , \quad i = 1,2 \qquad (3.3)$$

where η is porosity of the soil and ρ is the density of the fluid. Assuming the fluid and soil particles are incompressible, equation (3.2) and (3.3) can be used for the following expression in the two-dimensional form:

$$\frac{\partial}{\partial x_i} K_{ii} \frac{\partial h}{\partial x_i} = 0 , \quad i = 1,2 \qquad (3.5)$$

Figure 3.1 can be refered to for notation of the key variables used is this study.

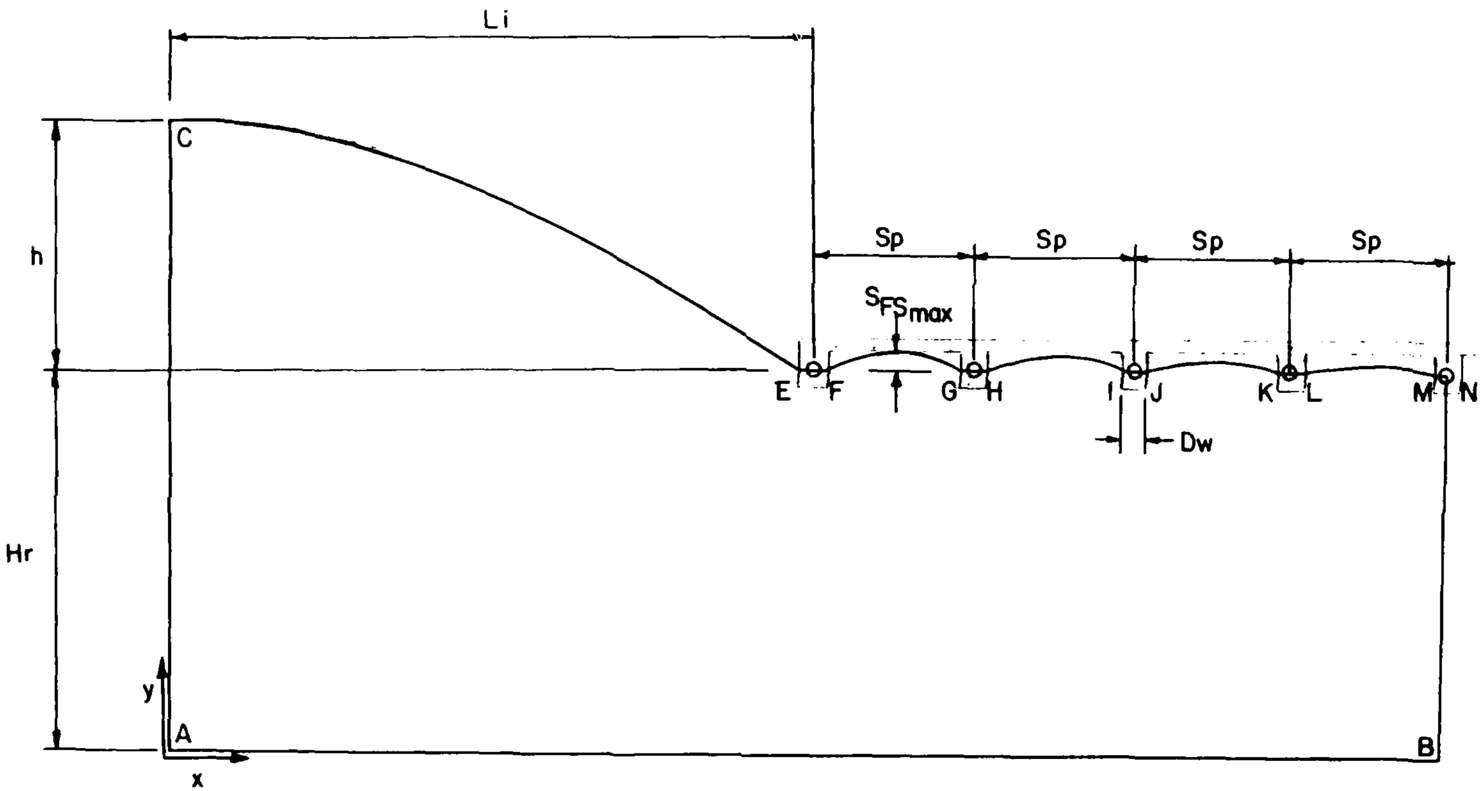

Figure 3.1 Typical Underdrain System with Variable Notation

Boundary Conditions

For free surface problems, which is the case for this study, the exact location of the phreatic surface is not known at the beginning of the solution. Location of the free surface is an iterative process using two independent boundary conditions available at the free surface. The line of seepage at the free surface is the upper streamline of the flow domain. At every point along this streamline the pore pressure is at atmospheric pressure and therefore the piezometric head equals the elevation head. Also the flow across this boundary is zero because of it being a streamline.

Considering the seepage domain as depicted by Figure 3.1, the steady state boundary conditions can be described as follows:

(a) Impervious Boundary (AB): The program considers this boundary as a streamline where velocity to this boundary equals zero.

(b) Constant Head Boundaries (AC) and (EF): Constant hydrostatic pressure is exerted on these boundaries where total piezometric head is constant, i.e. equal to the water level in a piezometric tube.

(c) Phreatic Surface (CE), (FG), (HI), (JK) and (LM): This boundary is a combination of both cases (a) and (b) above. By iteration, described later, both conditions must be satisfied independently.

(d) Seepage Faces (EF), (GH), (IJ), (KL) and (MN): Seepage forces occur at these boundary faces where water exits through the soil continum, i.e. trench drains. Therfore streamlines of flow must be normal to these boundaries.

3.2 Finite Element Formulation

General Equations

The first step in solving the seepage problem by the finite element method is to discretize the flow region into a finite number of subregions called elements. Using finite elements, equilibrium equations must be made to handle the geometries involved. This results in a set of simultaneous algebraic equations rather than differential equations. Figure 3.2 depicts the quadrilateral elements used for this program and shows how four six nodal triangles are formed internal to the program. A more detailed description is of finite element equations and formulations can be found in Zienkiewicz (1971), Desai (1972) and Aral (1974, 1976).

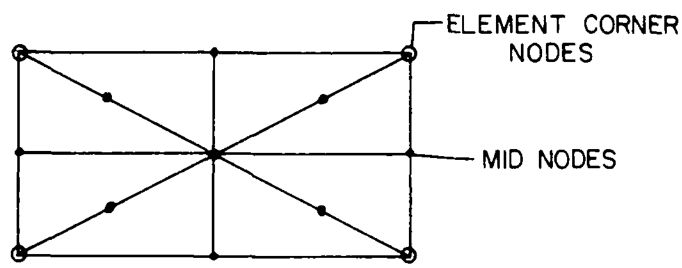

Figure 3.2 Typical element and nodes

A finite element approximation to equation (3.5) can be written through a variational approach. Assuming Dirichlet and Neuman boundary conditions, and considering the two dimensional case of steady flow, the following equations can be expressed:

$$h = \bar{h} \qquad \text{on} \quad S \ , \qquad (3.7)$$

$$\text{and} \quad V_n = -\left(K_{11}\frac{\partial h}{\partial x}\alpha_{n1} + K_{22}\frac{\partial h}{\partial x}\alpha_{n2}\right) = \bar{V}_n \quad \text{on } S_2 \quad (3.7)$$

where $\bar{h}$ is the specified Direchlet boundary condition in terms of piezometric head; $\bar{V}_n$ is the velocity in the direction normal to the boundary; α_{n1} and α_{n2} are the direction cosines of the normal with respect to x_1 and x_2 ; and S_1 and S_2 indicate respective boundaries of the domain. From equations (3.5) and (3.7), the following variational statement can be written:

$$\iint_A \left\{ \frac{\partial}{\partial x_1}\left(K_{11}\frac{\partial h}{\partial x_1}\right) + \frac{\partial}{\partial x_2}\left(K_{22}\frac{\partial h}{\partial x_2}\right)\right\} \delta h dx_1 dx_2$$

$$= \int_{S_2}\left\{V_n - \bar{V}_n\right\} \delta h dS \qquad (3.8)$$

Integrating by parts one obtains

$$\iint_A \left\{ K_{11} \frac{\partial h}{\partial x_1} \frac{\partial \delta h}{\partial x_1} + K_{22} \frac{\partial h}{\partial x_2} \frac{\partial \delta h}{\partial x_2} \right\} dx_1 dx_2$$

$$- \int_{S_2} \overline{V}_n \, \delta h dS = 0 \qquad (3.9)$$

Since from earlier discussed boundary conditions as for this problem studied, $\overline{V}_n = 0$. Thus, equation (3.9) can be further simplified by eliminating the boundary intregrals.

Assuming equation (3.9) is written for a single element, matrix equations can be generated using an interpolation function for approximating h over an element. The interpolation function used in this model is given as

$$h = N_k \; h_k \qquad k = 1,2,3,\ldots 6 \qquad (3.10)$$

where h_k's are the unknown nodal values of the dependent variable and N_k is the interpolating polynomial used to approximate h in an element.

For a typical six-nodal triangle element these polynomials are given as

$$N_i = \xi_i(2\xi_i - 1) \qquad i = 1,2,3 \qquad (3.11)$$

and

$$N_{i+3} = 4\,\xi_i\xi_j \qquad j = 2,3,1 \qquad (3.12)$$

where ξ_1, ξ_2 , and ξ_3 are area cordinates defined by the following relations

$$\xi_1 = \frac{A_1}{A} \quad \xi_2 = \frac{A_2}{A} \quad \xi_3 = \frac{A_3}{A} \qquad (3.13)$$

where A_1, A_2 and A_3 are the areas of the three subtriangles subtended by the point (P) and the corners, the index on (A) designating the opposite corner numbers, and A is the area of the triangle (123) shown in Figure 3.3.

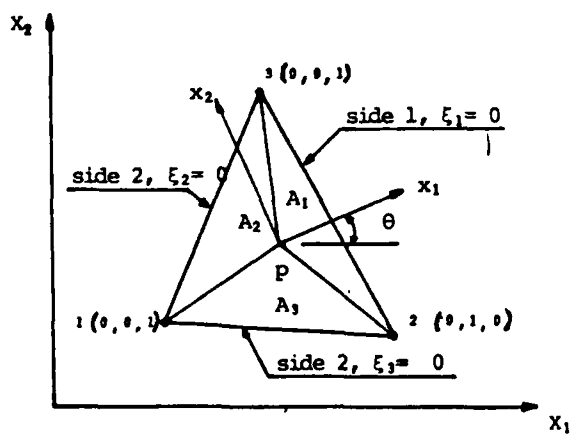

Figure 3.3 Area coordinates.

To simplify the resultant equations, the origin of the local axis which defines the local coordinates of the element, nodes are placed at the centroid of the element and the principle axis are inclined angle θ in the direction of local anisotropy.

Substituting equation (3.10) into equation (3.9) the final form of the approximating equations in an element can be expressed. The stationary condition of equation (3.9) is obtained by equating the first partial derivatives of the function, with respect to the undetermined parameters, h_j , to zero:

$$I^e(h),h_j = \iint_{A^e} \left\{ K_{11} \frac{\partial N_i}{\partial x_1} \frac{\partial N_j}{\partial x_1} + K_{22} \frac{\partial N_i}{\partial x_2} \frac{\partial N_j}{\partial x_2} \right\} h_i \, dx_1 dx_2 \quad ,$$

$$i,j = 1,2,3,\ldots 6 \qquad (3.14)$$

This results in a six by six element stiffness matrix, S^e, and a six by one element load vector F^e.

The six by six element matrix equations of equation (3.14) is written

$$[S^e] \quad \{h^e\} \quad = \quad \{F^e\} \qquad (3.15)$$

where

$$[S^e] = \iint_{A^e} \left\{ K_{11} \frac{\partial N_i}{\partial x_1} \frac{\partial N_j}{\partial x_1} + K_{22} \frac{\partial N_i}{\partial x_2} \frac{\partial N_j}{\partial x_2} \right\} dx_1 dx_2,$$

$$i, j = 1,2,3,\ldots 6 \qquad (3.16)$$

The same procedure is taken for all elements. Then the total stiffness matrix is arrived at by combining the element stiffness matrices using structural assembly techniques (Zienkwicz, 1971)

For a grid of elements, a system of banded simultaneous equations results:

$$[S] \quad \{h\} \quad = \quad \{F\} \qquad (3.17)$$

where [S] is the global matrix of cofficients which incorporates the properties of the materials and the geometry of the elements; {h} is the vector of the unknown h's at the nodes; and {F} is the load vector. After the introduction of appropriate boundary conditions, this system of equations can now be solved by computations for the unknowns, h, yielding the piezometric head distribution in the solution domain.

Free Surface Computation

The flow domain must initially be established assuming an arbitrary free surface, i.e. the user initially estimates the free surface loacation. All boundary conditions are solved for the preset conditions of the problem. The nodes which are not fixed are allowed to move, where during the adjustment the interior nodes are also moved in order not to have distortion of the elements. Then additional iterations are made until all boundary conditions and user prescribed error correlations have been met for the configuration.

3.3 Variables and Dimensional Analysis

The variables investigated in this study are shown in Figure 3.1. For the analysis of seepage using the finite element program, variables were changed for each computer run. From each run data was generated to compare the changes occuring for each variable change.

Only the two-dimensional flow condition was considered in this study. For this flow condition, the building drainage system is in one cross-section of the building where each drain collects the seepage and collector pipes or drains take the drainage by gravity to a sump or some exit drain. This is depicted by Figure 3.4.

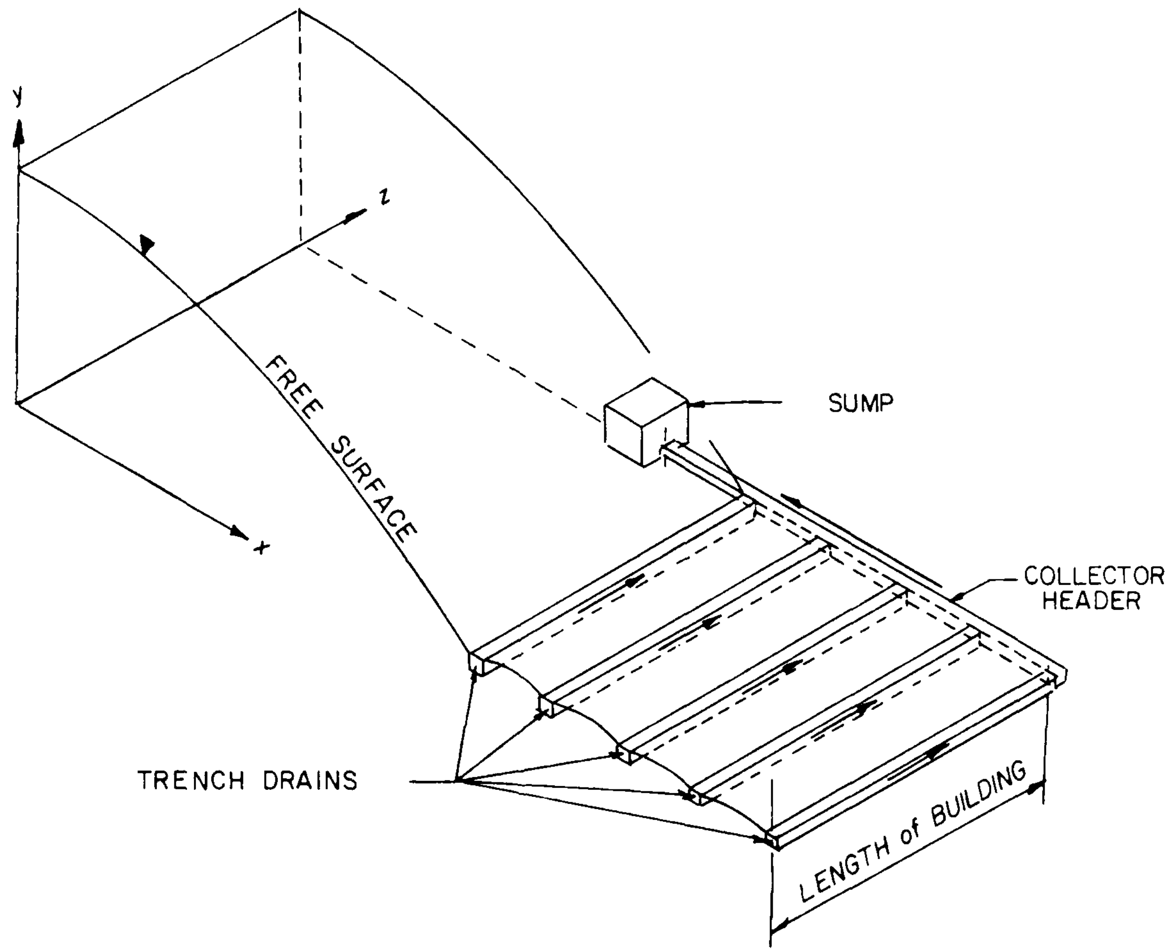

Figure 3.4 Underdrain System For Seepage Removal.

The total discharge of the system, q_T, can be express as the following function:

$$q_T = f(Hr, h, d_w, S_p, K, S_{FS}, \theta) \qquad (3.18)$$

where q_T = total discharge of all drains, i.e. the sum of discharges through each seepage face for the model, ft^3/day/ft

H_r = depth of saturated so_l from the drain discharge elevation to the impervious boundary, ft

h = fixed head of above the drains , ft

d_w = drain width, ft

S_p = drain spacing, ft

K = hydraulic conductivity of the soil, ft/day

S_{FS} = difference in elevation of the free surface to the water level of each drain, ft

θ = slope of the impervious boundary with horizontal, ft/ft

Dimensional analysis of equation (3.18) yields:

$$\frac{q_T}{K\,h} = f\left(\frac{H_r}{h}, \frac{d_w}{h}, \frac{S_p}{h}, \theta\right) \qquad (3.19)$$

Since permeability is moved to the left side of equation (3.19) these variable is made proportional to the discharge. The elevation of the free surface, S_{FS}, is an output variable, so it is not given in equation (3.19. Also since the slope of the impervious boundary, θ , is already dimensionless it can be given as a single term in FT/FT.

The effects of these functional variables and other results are given in the form of dimensionless plots in Chapter 4. A discussion of the results is given in that chapter. Since considerable interest is in quantities of discharge and the location of the free surface, this analysis can be used to see trends and effects that each variable has on the seepage domain.

3.4 Program Verification

To verify that the computer program used in this study is giving valid results, two other methods of solutions were used for a selected check case. Another micro computer finite element program, SEEP, and an appropriate analytical method based on Dupuit's assumption, was used for the simple configuration of a drainage blanket with a single pipe type drain (Duncan and Wong, 1985). This is shown in Figure 3.5.

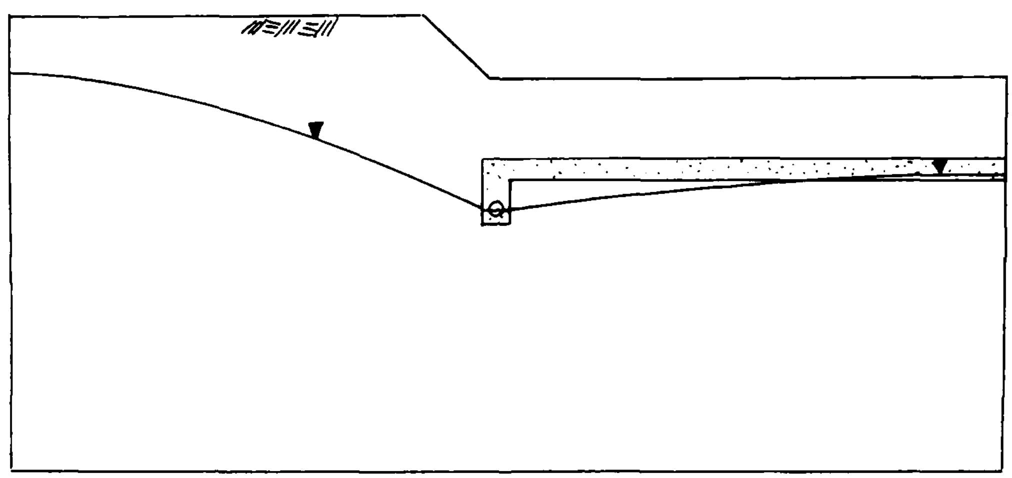

Figure 3.5 Check case example of a blanket drain with single pipe trench drain.

A grid was generated for the SEEP program to match the configuration and boundary conditions as by Figure 3.4. The total flow for this check case is calculated by the SEEP program as based on the Dupuit assumption of a fixed domain and fixed amount of head. Seep also tabulated the flow quantities for all nodal points with fixed heads. For this model, the free surface converged on the free surface location with an error criteria of 0.16 feet.

The location of the free surface as computed by the Georgia Tech model converged to the free surface having an error factor of only 0.001 feet, a much more accurate and sensitive convergence. However, the two models compared very close as far as the location of the free surface. Table 3.1 lists the elevations of the free surface nodes for the two models.

TABLE 3.1 Elevations of the Free Surface Nodes

x coordinate	SEEP:VPI Model y coordinate	Ga Tech Model y coordinate	
0	78.00	78.00	
40	72.55	72.73	
70	67.07	67.57	
80	64.27	65.17	
85	62.03	63.84	
87.5	60.39	58.73	
90	58.00	58.00	← drain location
92	58.00	58.00	← drain location
95	60.08	58.32	
97.5	61.16	62.15	
100	61.92	62.52	
106	63.00	63.28	
115	63.76	63.93	
130	64.26	64.42	
150	64.42	64.62	

To verify that flow quantities were accurate for the Ga Tech model, results were also compared with the results obtained from a Dupuit assumption solution, developed by the Federal Highway Administration's, Highway Subdrainage Design Manual, (1980). Figure 3.6 was used to calculate the quantity of flow to the drain. The following calculations based on Figure 3.6 are presented:

$$\frac{b}{H_o} = \frac{1}{58'} = 0.017 \quad , \quad \frac{L_i}{H_o} = \frac{91'}{58'} = 1.57$$

$$\frac{K(H - H_o)}{q_2} = \frac{0.2(78'-58')}{q_2} = 2.17 \quad \text{(from Figure 3.5)}$$

$$\text{therefore} \quad q_2 = \frac{0.2(20)}{2.17} = 1.84 \quad \text{CFD}$$

$$\frac{q_2}{K} = \frac{1.84}{0.2} = 9.22 \quad , \quad \frac{q_1}{K} = \frac{(H - H_o)^2}{2(L - b)} = \frac{(20)}{2(91-1)} = 2.22$$

$$\frac{q_d}{K} = 9.22 + 2.22 = 11.44$$

$$\text{therfore} \quad q_d = 0.2(11.44) = 2.29 \quad \text{CFD}$$

The results of this computation is compared with the results of the two finite elements in Table 3.2

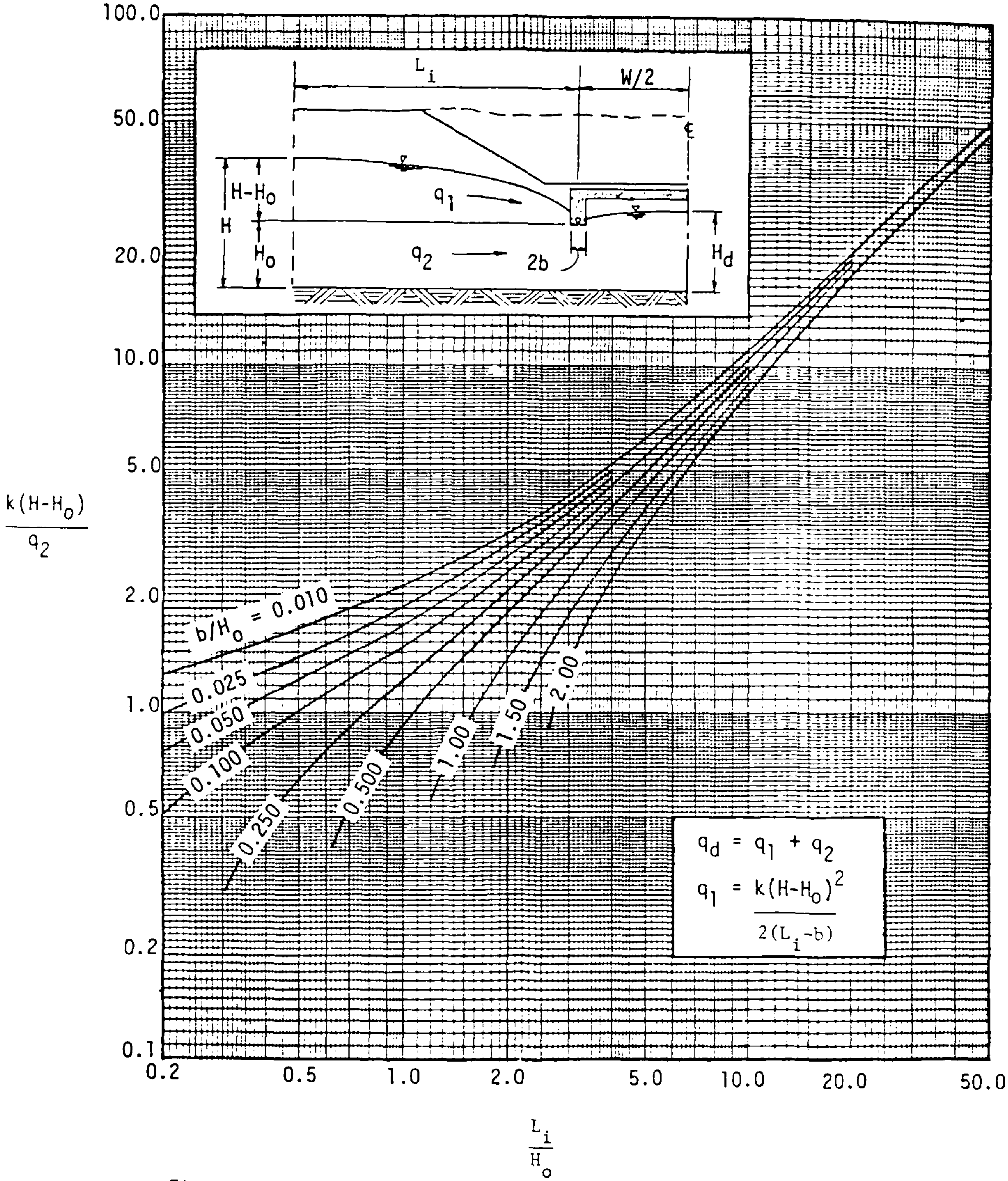

Figure 3.6 Chart for Determining Flow Rate in Symmetrical Underdrains (after FHA, 1980)

Table 3.2 Discharge to the drain check cases, CFD

	Discharge, CFD
SEEP:VPI Model	2.15
Ga Tech Model	2.34
FHA Nomograph	2.29

In summary, the Ga Tech model compares very well with other model and with the FHA nomograph for flow quantities. The Ga Tech model was found to more error criteria sensitive. The free surface location check also proved to compare very well with the SEEP model.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter discusses the analysis and results of the two dimensional, steady state, free surface finite element study of seepage to building underdrain systems. Details presented include model set-up such as boudary conditions, grid development and basic first assumptions. Output variables considered are total discharge and discharge at each drain, plus the free surface elevation between the drains.

In studying sensitivity of the model for the input variables, it was found that the distance from the Dirichlet boundary face, or constant head boundary, Li, to the first drain was critical. Li was found to be critical in terms of output charcteristics, i.e. discharge and location of the free surface between drains. Therfore, two sets of results are presented for two Li distances of 400 feet and 80 feet.

4.2 Model Set-up

Figure 4.1 shows the basic grid that was developed for this seepage problem. Using 150 elements and 521 nodes, the geometry of the mesh was based on a five drain system. The

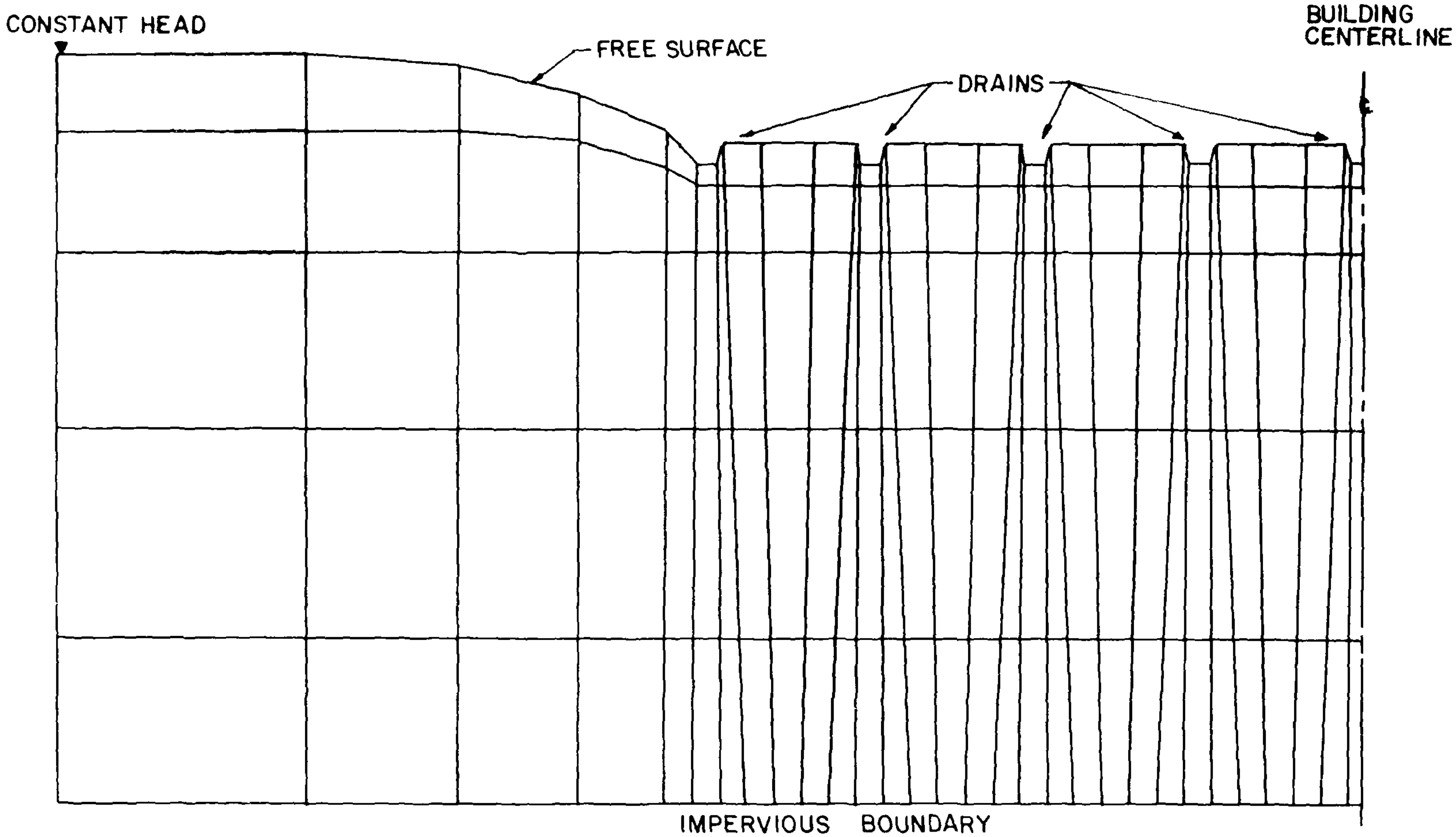

Figure 4.1 Example Mesh Used

sides and bottoms of the drains were modeled as seepage faces. Using the two-dimensional model, the fifth drain is considered to be at the building centerline. Assuming symmetry, only one-half of the building was analysed. The left most boundary, as shown in Figure 4.1, is a Dirichlet boundary condition which has the constant head required to allow for the seepage to enter the drains.

Listed below are some basic assumptions for the study made for this seepage problem:

(1) Steady state flow conditions

(2) Two-dimensional analysis where the right most boundary is the building centerline and by symmetry the flows are only one-half of the total for the total width of the building.

(3) Free surface nodes move to the computed phreatic level, i.e. piezometric head equals atmospheric pressure at the upper most nodes

(4) Partial saturated flow is not considered

(5) Evaporation is not considered

(6) Retardation is not considered

(7) Infiltration is not considered

(8) The soil is homogeous being either isotropic or anisotropic.

4.3 Variables Used

For this study, key variables were used in the finite element model to look at their effects on the flow of seepage for the building underdrain system. Two major design parameters necessary to model any seepage problem is the total discharge of the drain system and the location of the free surface. For this study, the following output variables are used:

q_d = discharge or seepage quantity to each drain (cubic feet per day per linear foot)

q_T = total discharge of all drains (same units)

S_{FS} = height of free surface above drain elevation.

Discharge quantities are in units of flow quantity in time per unit length of the total flow continum. Therfore, flow for a total system should be multiplied be the length of the structure, i.e. in the third dimension.

Input variables used in this problem to study their effects on seepage are listed below:

Li = distance from the left most constant head boundary to the first drain (feet)

K = hydraulic conductivity (feet/day)

Kv = hydraulic conductivity in the vertical direction (feet/day)

Kh	=	hydraulic conductivity in the horizontal direction (feet/day)
h	=	hydraulic head of flow continuum above the drain elevation (feet)
Hr	=	depth of aquifer between the elevation of the drain and the impervious boundary (feet)
Sp	=	spacing between drains (feet)
Dw	=	drain width (feet)
θ	=	slope of the impervious boundary (%)

For better reference to the notation of the variables refer to Figure 3.1 in Chapter 3.

For this finite element problem the units of feet and days were used to give results for the output variables in cubic feet per day and feet per day for velocity.

Hydraulic conductivity or permeability values used for this study were 0.0002, 0.02, 0.2, and 4 feet per day. A soil's hydraulic conductivity having a value of 0.0002 feet per day is equivalent to a fine grained soil such as a clay. Hydraulic conductivities are tabulated in Table 4.1 to show cross reference to soil types and permeabilities in units of centimeters per second.

Table 4.1 Hydraulic Conductivity Values For Various Soil Types

Fine grained soil	0.0002 feet/day	7×10^{-7} cm/sec
Fine grained soil	0.002 feet/day	7×10^{-7} cm/sec
silt	0.02 feet/day	7×10^{-7} cm/sec
sand, silt	0.2 feet/day	7×10^{-7} cm/sec
clean sand	4 feet/day	1.4×10^{-7} cm/sec

The other input variables used were typically realistic values to meet typical field conditions. Listed below are some of this values, where for each computor run specific variables were changed and the others held constant. The intent was to see what effects that each variable change made on the model.

Li = 80', 400' and 1000'

h = 10', 20' and 40'

Hr = 20', 58' and 100'

Sp = 15', 25' and 35'

Dw = 1', 2' and 4'

θ = 0%, 5%, 10% and 20%

Kv = .0002, 0.2, 4 and 15

Kh = 0.2

K = 0.0002, 0.02, 4

4.4 Model Sensitivity

The model was developed assuming a homogeneous isotropic media, except for a few cases where anisotropic conditions were studied. The nodes of the top three rows of elements were allowed to move for iteration of the free surface. In all runs, the maximum number of iterations was six and on an average three to four were found to be adequate. The model was made to iterate to an accuracy of 0.001 feet during the free surface moves.

In calibration of free surface models careful attention must be made to the moving nodes. Problems exist when the elements become less than zero in area or when the elements actual may become so distorted that they may become inverted. This was not the case for the mesh used in this study.

In studying the flow quantities and velocities for the basic geometries and variable changes, all results seemed reasonable and observed trends appeared physically possible. However large variation of output was noticed by the change in distance from the constant head boundary to the first drain, Li. The first set of results is presented based on the influence length, Li, being 10 times the maximum head difference, i.e. 10 x 40' = 400'. Depth of aquifer for this case was held constant at 100 feet. Use of 10 times the head differential is based on Bear's (1979) recommendation.

Figure 4.2 depicts the moved free surface corner nodes for an influence length of 400 feet. For comparison, Figure 4.3 shows the moved free surface corner nodes for Li equal to 80 feet and a thickness of aquifer, Hr, equal to 58 feet.

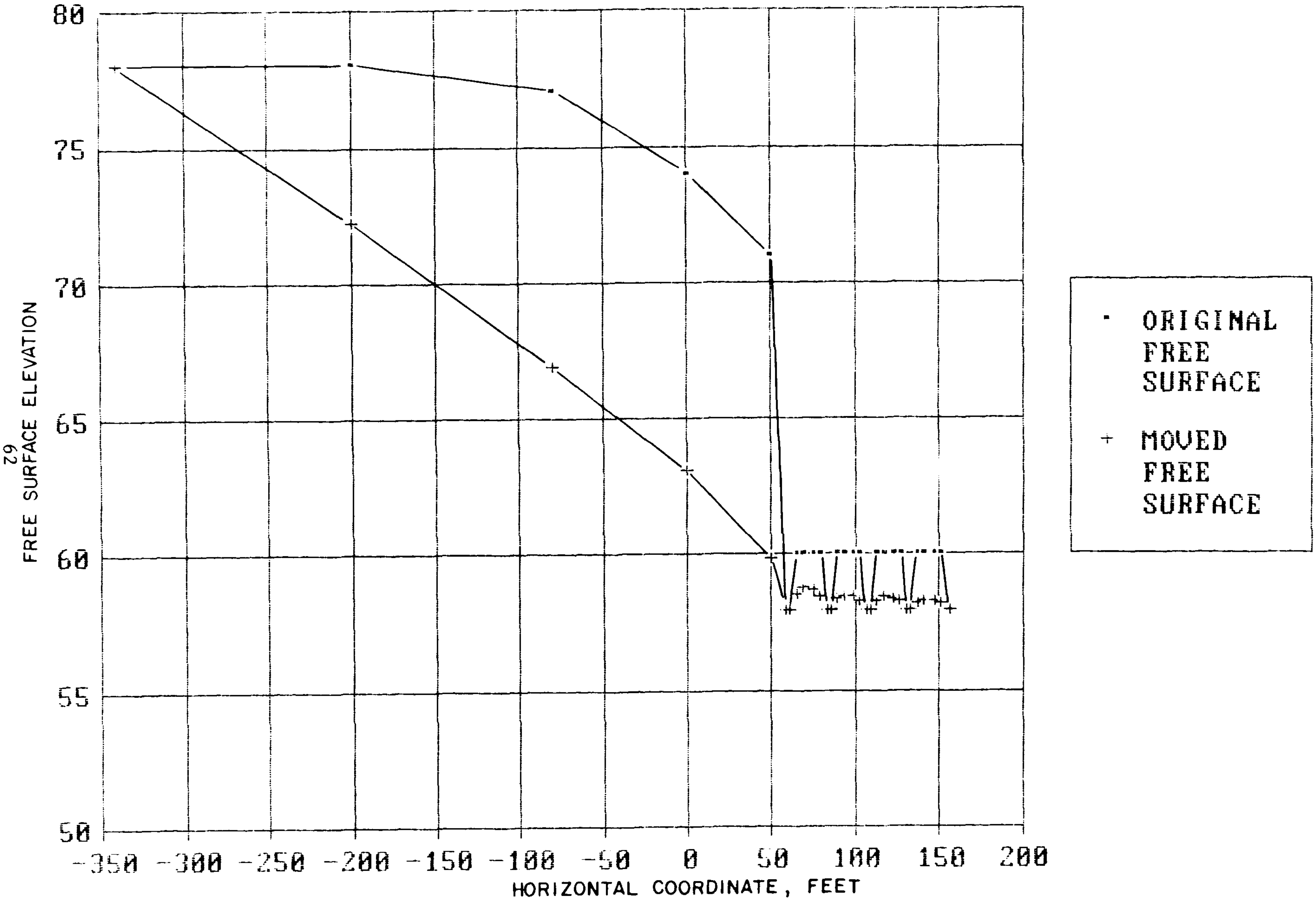

Figure 4.2 Moved Free Surface Corner Nodes vs. Original

Li = 400', Hr = 100', Sp = 25', Dw = 2', K = 0.2 ft/day

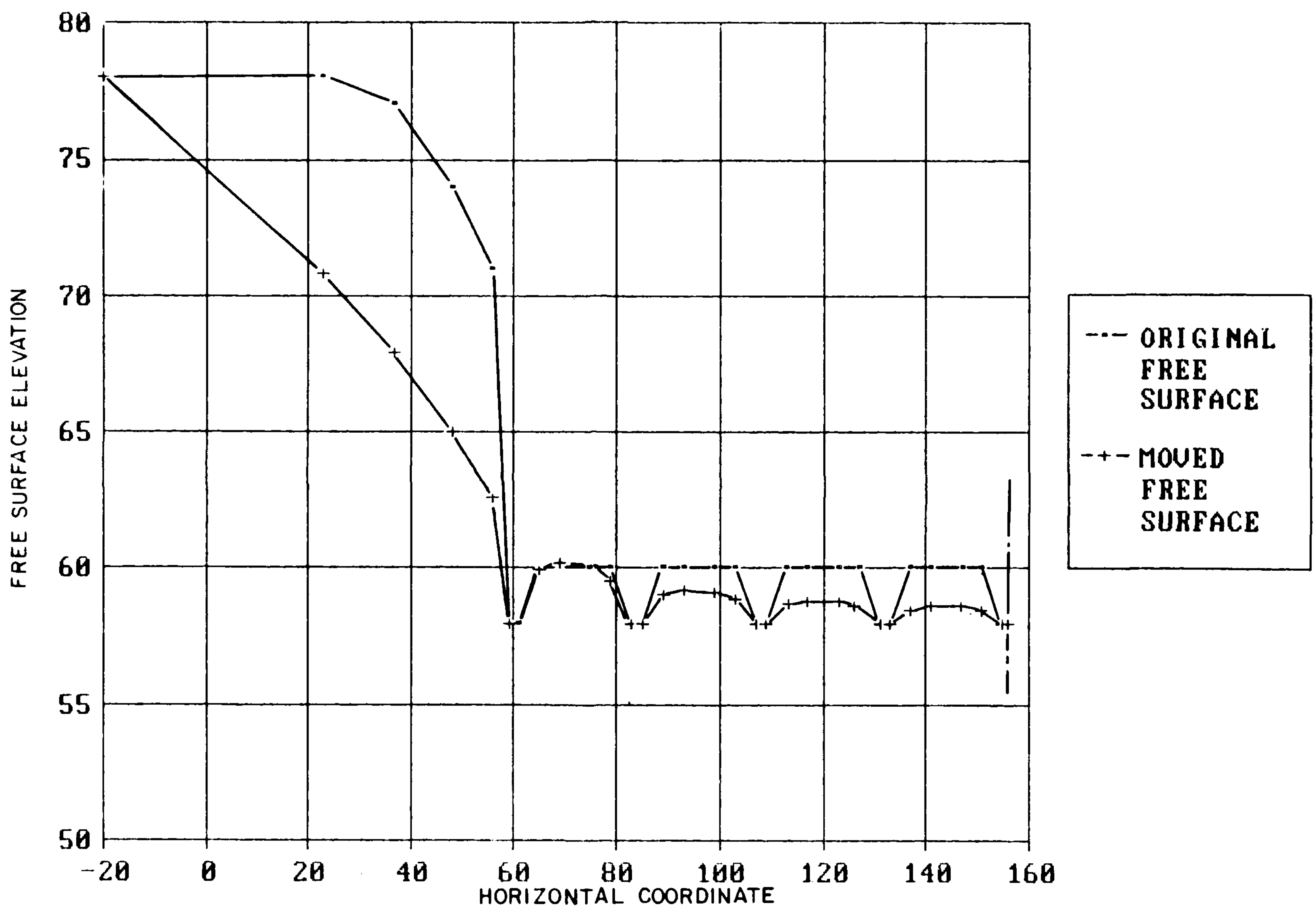

Figure 4.3 Moved Free Surface vs. Original
Li = 80', Hr = 58', Sp = 25', Dw = 2', K = 0.2 ft/day

Figure 4.4 and 4.5 are presented to show the dramatic influence that the distance from the constant head boundary from the first drain, Li, has on total discharge and the maximum free surface elevation, respectively. For further reference, the total discharge, q , is the sum of the drain discharges and the maximum free surface is the highest elevation of water above the drain elevation. Lengths between 300' and 400' appear to result in less change in flow quantity and free surface changes. This equates to the distance where the constant head boundary away from the drains begins to cause the least effect on discharge and free surface changes is approximately 15 to 20 times the head differential. This perhaps is good evidence that the actual field conditons for each particular application of groundwater movement should carefully be looked at in terms of this distance.

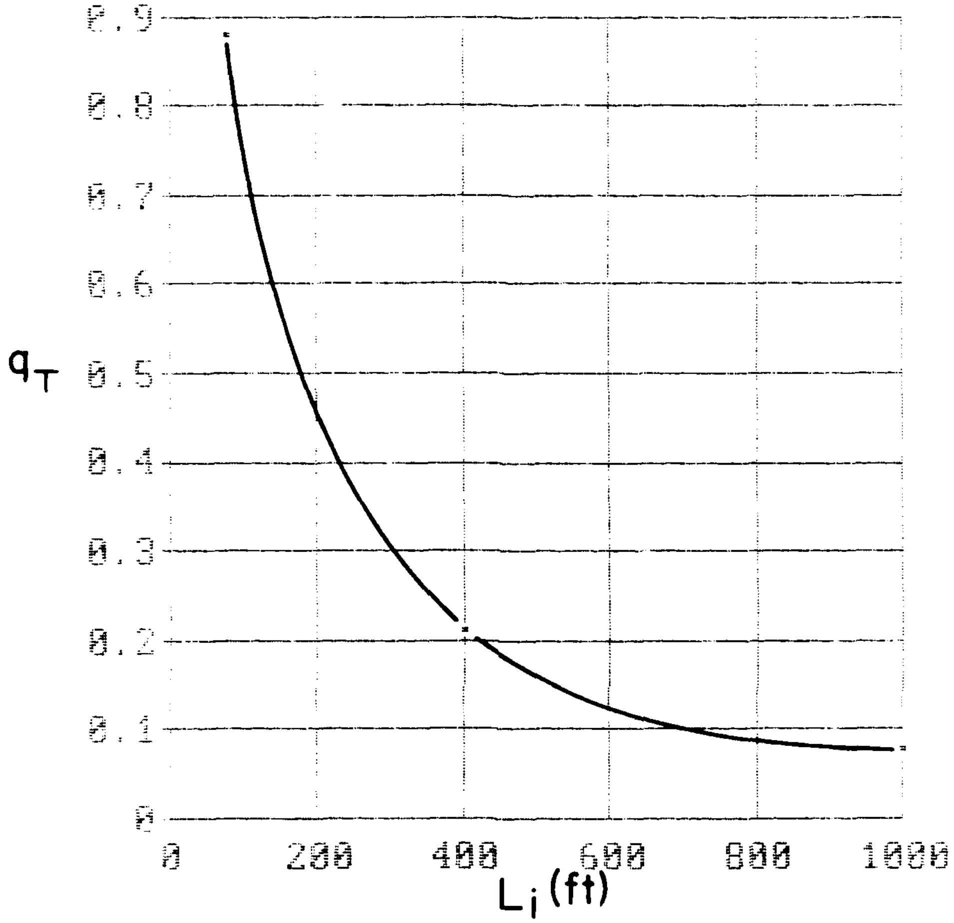

Figure 4.4 Distance from the constant head boundary to the first drain vs. total discharge of drains.
h = 20', Sp = 15', K = 0.2 ft/day

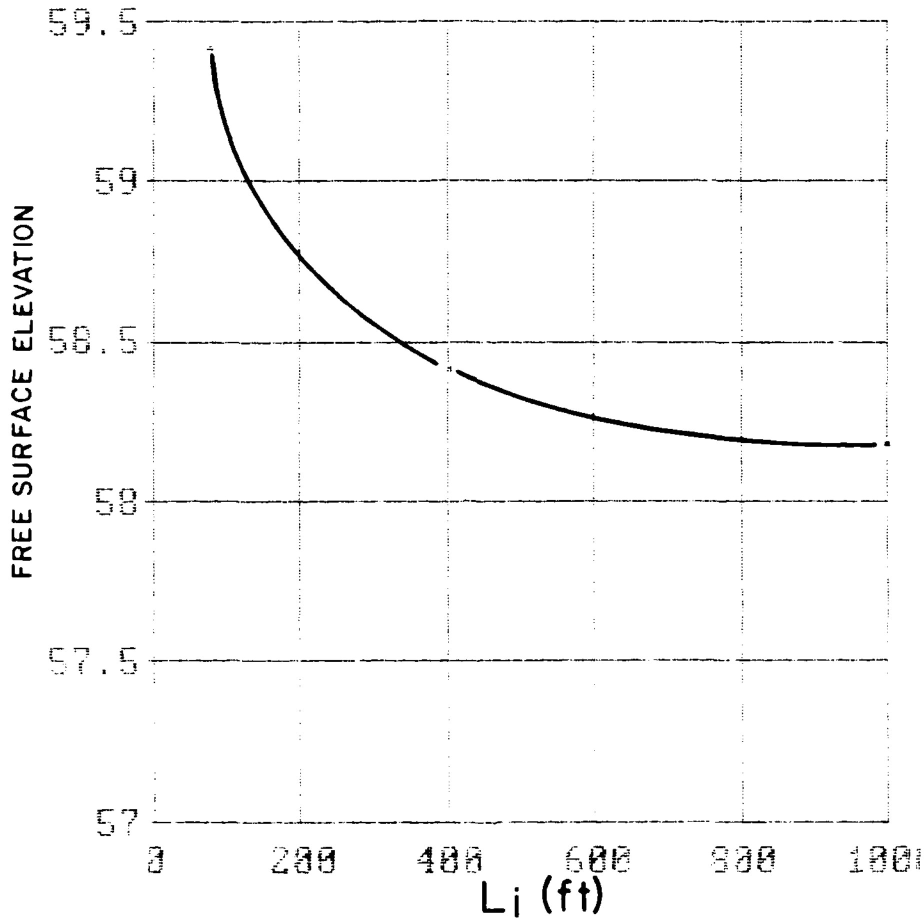

Figure 4.5 Distance from the constant head boundary to the first drain vs. maximum free surface elevation.
h = 20', Sp = 15', K = 0.2 ft/day

4.5 Results

This section will present the computer results in the form of dimensionless plots and other nomographs to show the effects that each variable change has on the seepage problem. Two sets of plots are given where the first set is for the constant head boundary distance, Li, equals 400 feet and the depth of rock, Hr, equals 100 feet. The second set of plots are essentially the same as the first except Li equals 80 feet and the Hr equals 58 feet. For variable notation refer to Figure 3.1.

<u>Drain Discharge (Li = 400' and Hr = 100')</u>

Figure 4.6 shows the influence of drain width, Dw, for head differentials, h, of 10, 20 and 40 feet on total discharge of the drains. This shows that drain width is not particularly critical for low head differences. It is reasonable to assume that total discharge could approach a constant for drain widths greater that four feet and head less than 20 feet. Although total discharge increases with drain width, this plot does not show what drain width is the most effective or most efficient. However, the influence of head can be easily observed

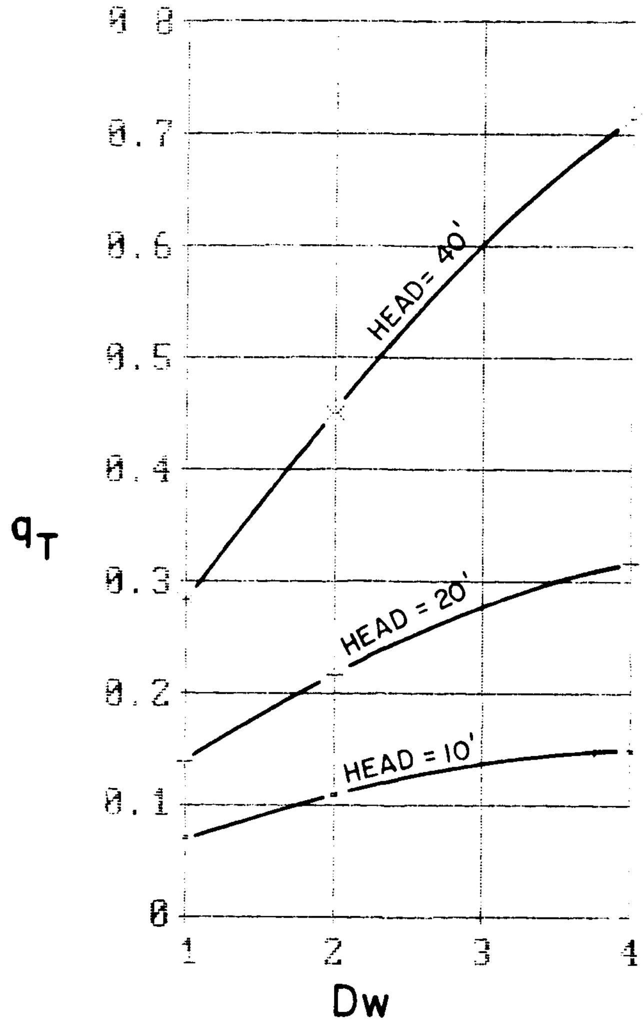

Figure 4.6 Total drain discharge vs. drain width with head differentials.
Li = 400', Hr = 100', Sp = 25', K = 0.2 ft/day

Figure 4.7 depicts the results of varying anisotropic soils with varying heads. In this analysis, vertical hydraulic conductivity varies while horizontal conductivity was held constant. Figure 4.7 shows that with increase in vertical hydraulic conductivity discharge increases. This appears to satisfy theory , that with less resistance flow increases.

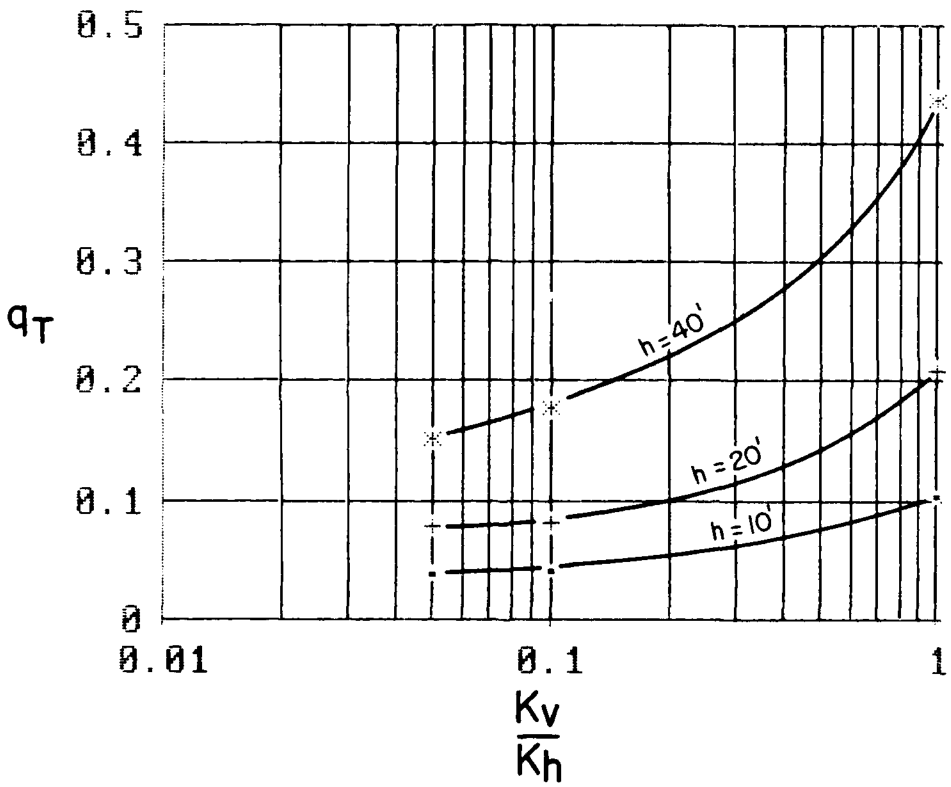

Figure 4.7 Total drain discharge vs. anisotropy with varying head differential.
Li = 400', Hr = 100', Sp = 15', Dw = 2', Kh = 0.2 ft/day

Figures 4.8 through 4.12 are graphs which show the discharge quantities for each of the five drains. Figure 4.8 depicts the effects of depth of impervious layer, Hr, on the drain discharge for each of the drains. This data shows that with increased depth discharge increases. It is interesting to note that practically no flow is recorded for drain 5 when a shallow depth of impervious layer exists, i.e. Hr = 20 feet.

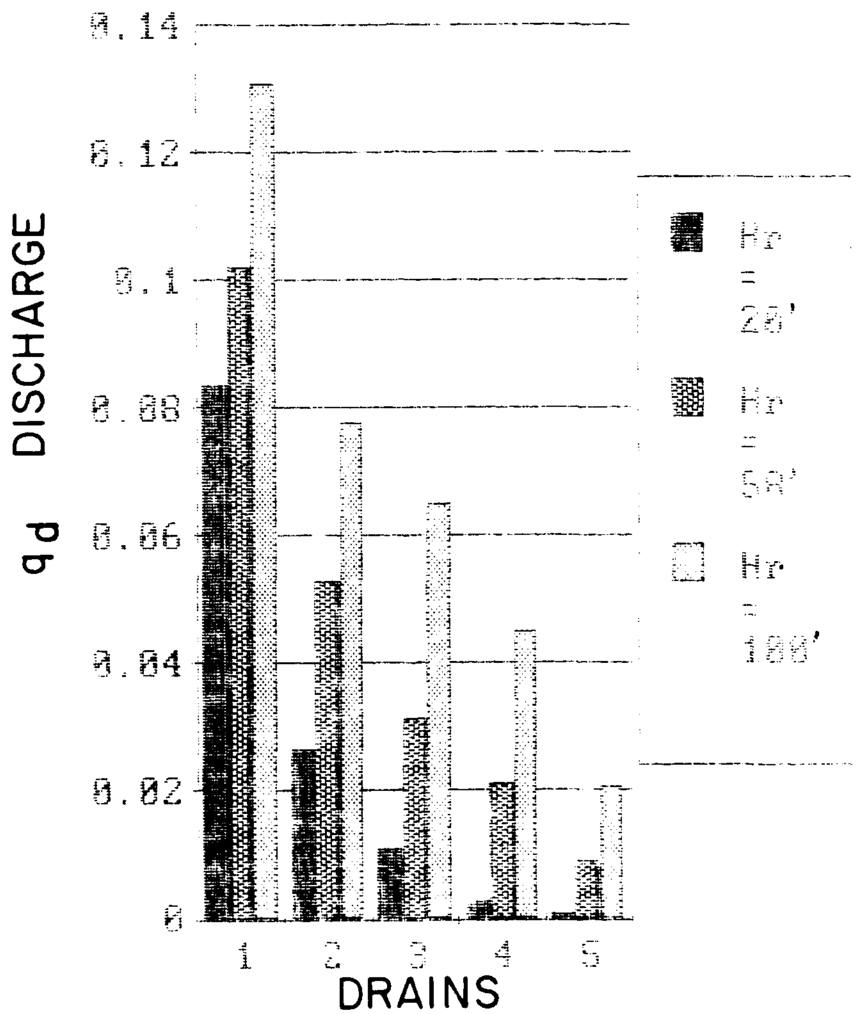

Figure 4.8 Drain discharge vs. thickness of aquifer.
Li = 400', h = 20', Sp = 25', Dw = 2', K = 0.2 ft/day

Figure 4.9 shows the effects of head differential on the discharge of each of the drains. It is interesting to see that though the first drain is the most critical drain, i. e. a large amount of the total flow is collected in this drain, the remaining drains collect discharge decreasing linearly from the left. This is possiblly due to the influence of the constant head boundary distance, Li, being 400 feet away. This shows that for the drains, flow quantity increases linearly with increase in head.

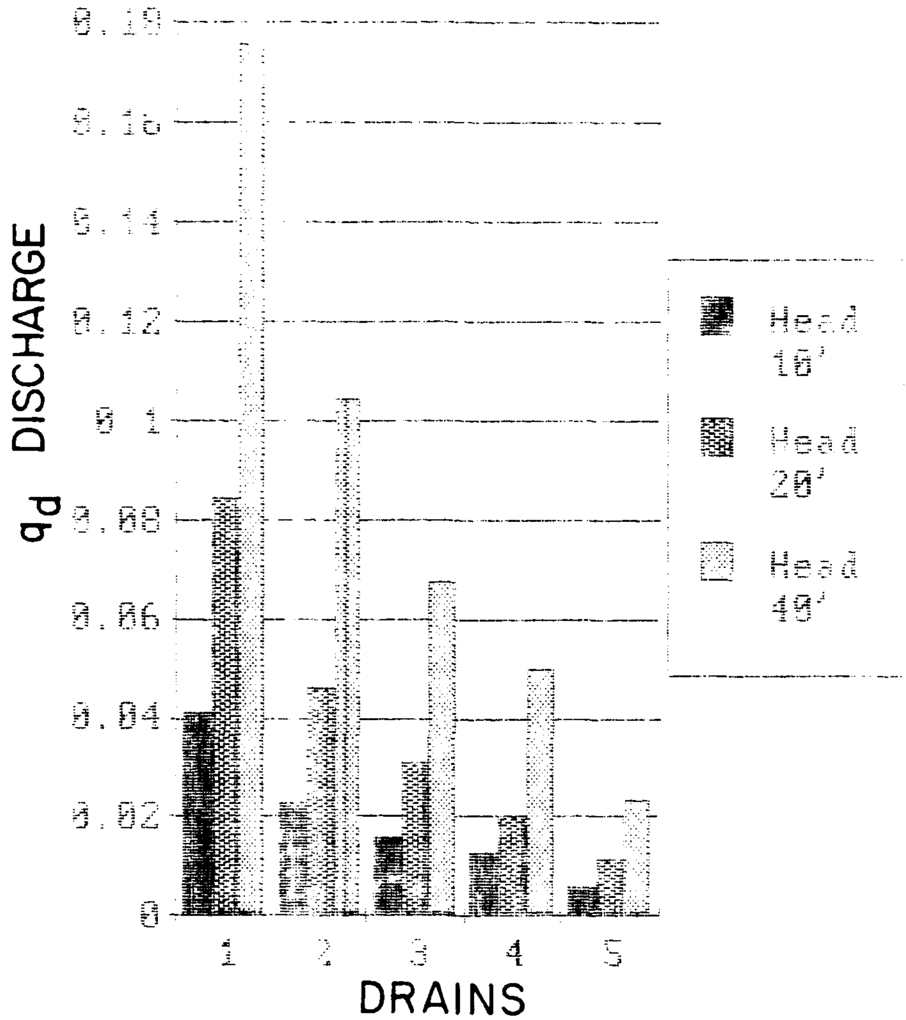

Figure 4.9 Drain discharge vs. head differential.
Li = 400', Hr = 100', Sp = 25', Dw = 2', K = 0.2 ft/day

Figure 4.10 depicts the results of comparing the drain discharge versus the spacing between drains. It is of interest to see that drain number one for spacing equal to 25 feet, collects more seepage than the other discharges for the other spacings. However, at drains 3 through 5 this changes and the discharge for 15 feet spacing is greatest. This will be analyzed later in the dimensional analysis.

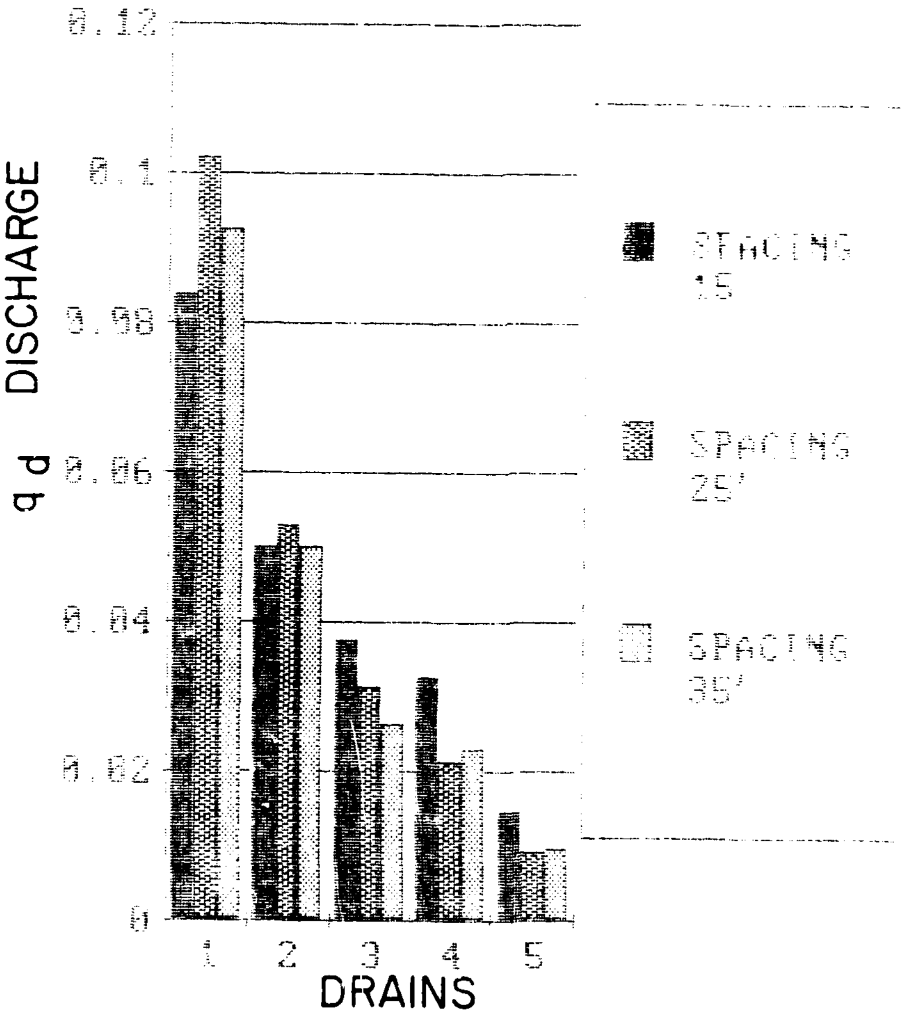

Figure 4.10 Drain discharge vs. drain spacing.
Li = 400', Hr = 100', h = 20', Dw = 2', K = 0.2 ft/day

Figure 4.11 shows the effects of anisotropy of the soil matrix on drain discharge. It is of interest to see that the discharge for Kv/Kh equal one is much greater than the other drain discharges for Kv/Kh less than one.

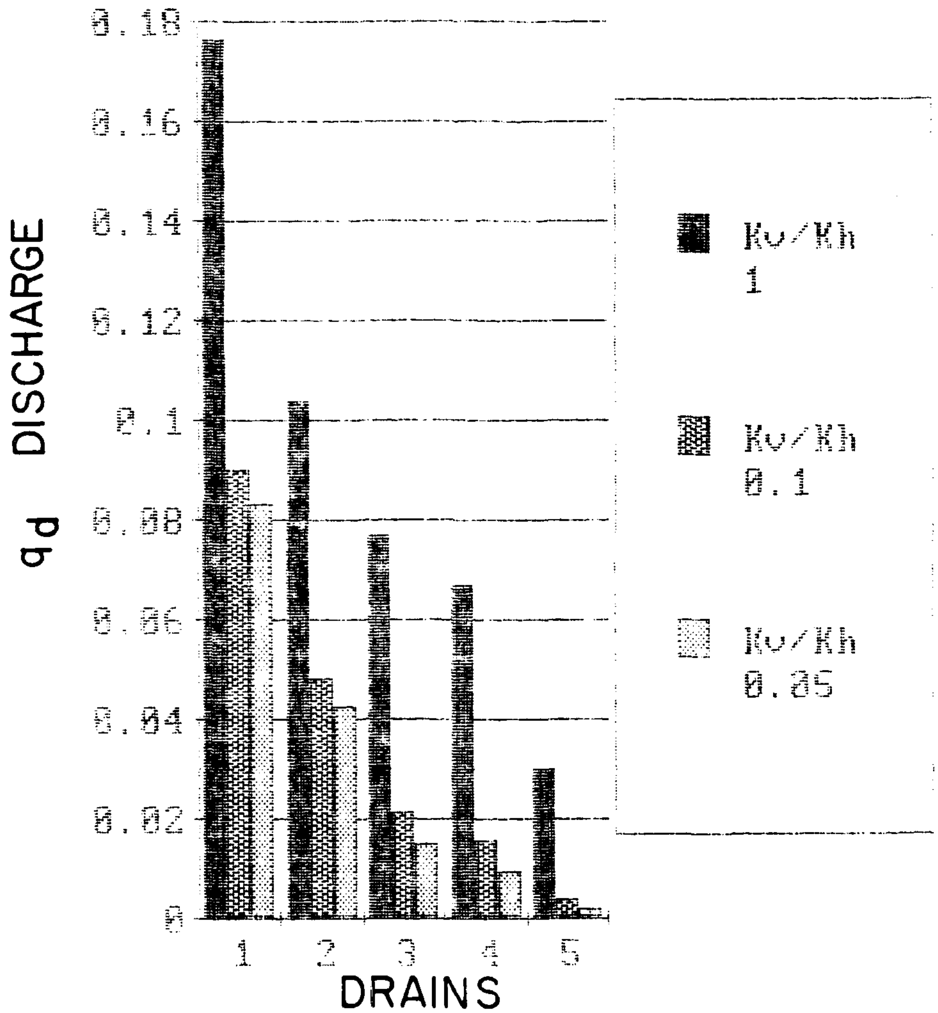

Figure 4.11 Drain discharge vs. anisotropy.
Li = 400', Hr = 100', Sp = 15', Dw = 2, h = 20'

Figure 4.12 depicts data generated for the condition of a sloping impervious layer. The slope of the boundary is given as a percentage of $\Delta x/\Delta y$. The depth of the layer is held constant at drain one and the layer slopes clockwise from the positive x horizontal axis.

Though actual quantities of discharge are only changing in very small ammounts, the trend is seen that for slopes greater than 5% the discharge increases in drains 3 through 5. However at some slope between 5% and 10% the discharge decreases. It is also seen that the discharge of drain five is the least effected by any slope change, in terms of discharge quantity.

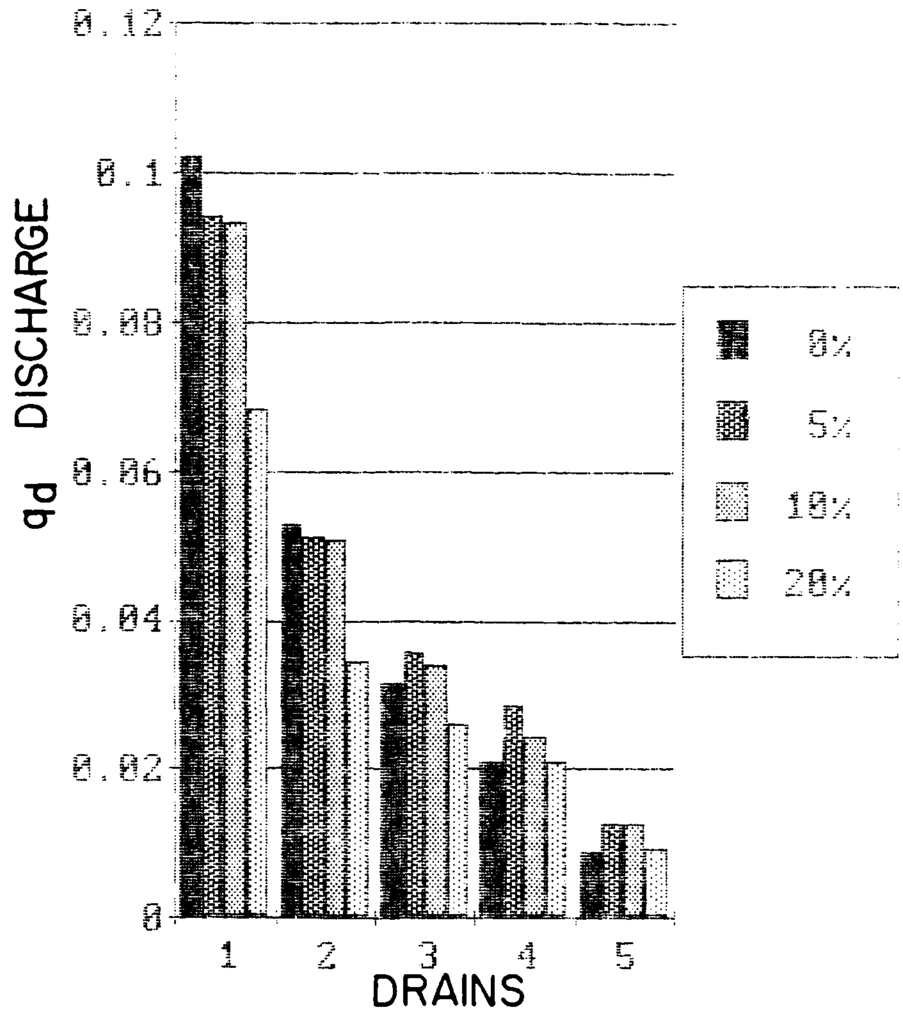

Figure 4.12 Drain discharge vs. slope of the impervious layer.
Li = 400', Hr = 100'(first drain), h = 20', Sp = 25', Dw = 2', K = 0.2 ft/day

Free Surface Location (Li = 400' and Hr = 100')

Figure 4.13 shows the influence of the drain width on the maximum free surface height, $S_{FS_{max}}$. In all cases this occured between drains one and two. This plot shows how the relationship is linear and that the height of the free surface is not greatly affected by the drain width.

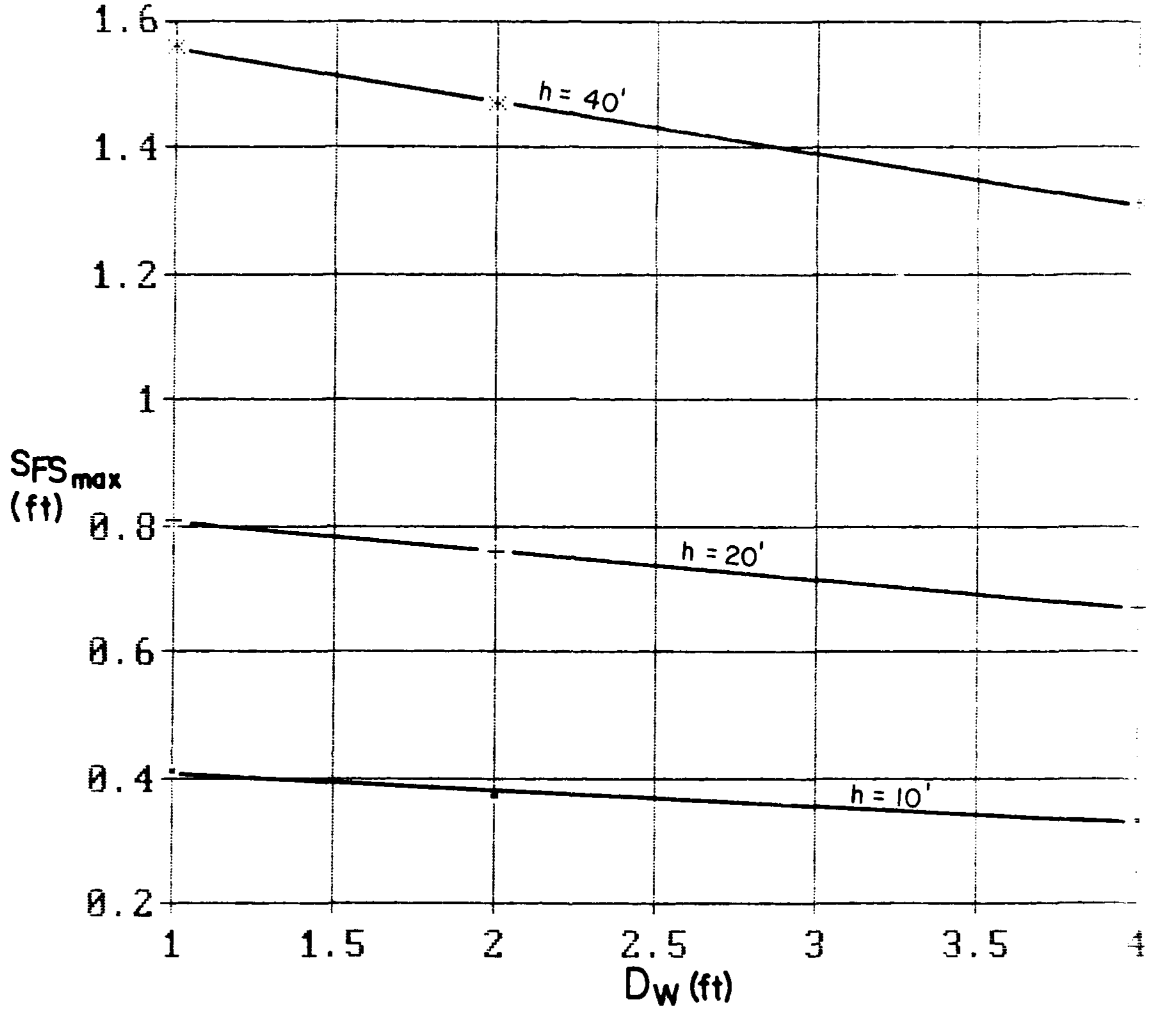

Figure 4.13 Maximum free surface height vs. drain width with varying heads.
Li = 400', Hr = 100', Sp = 25', K = 0.2 ft/day

Figure 4.14 depicts the influence of drain spacing and head on the maximum free surface height. These results show that increased drain spacing causes an increase in the free surface. Therefore one should consider the smaller spacing or possibly deeper drains.

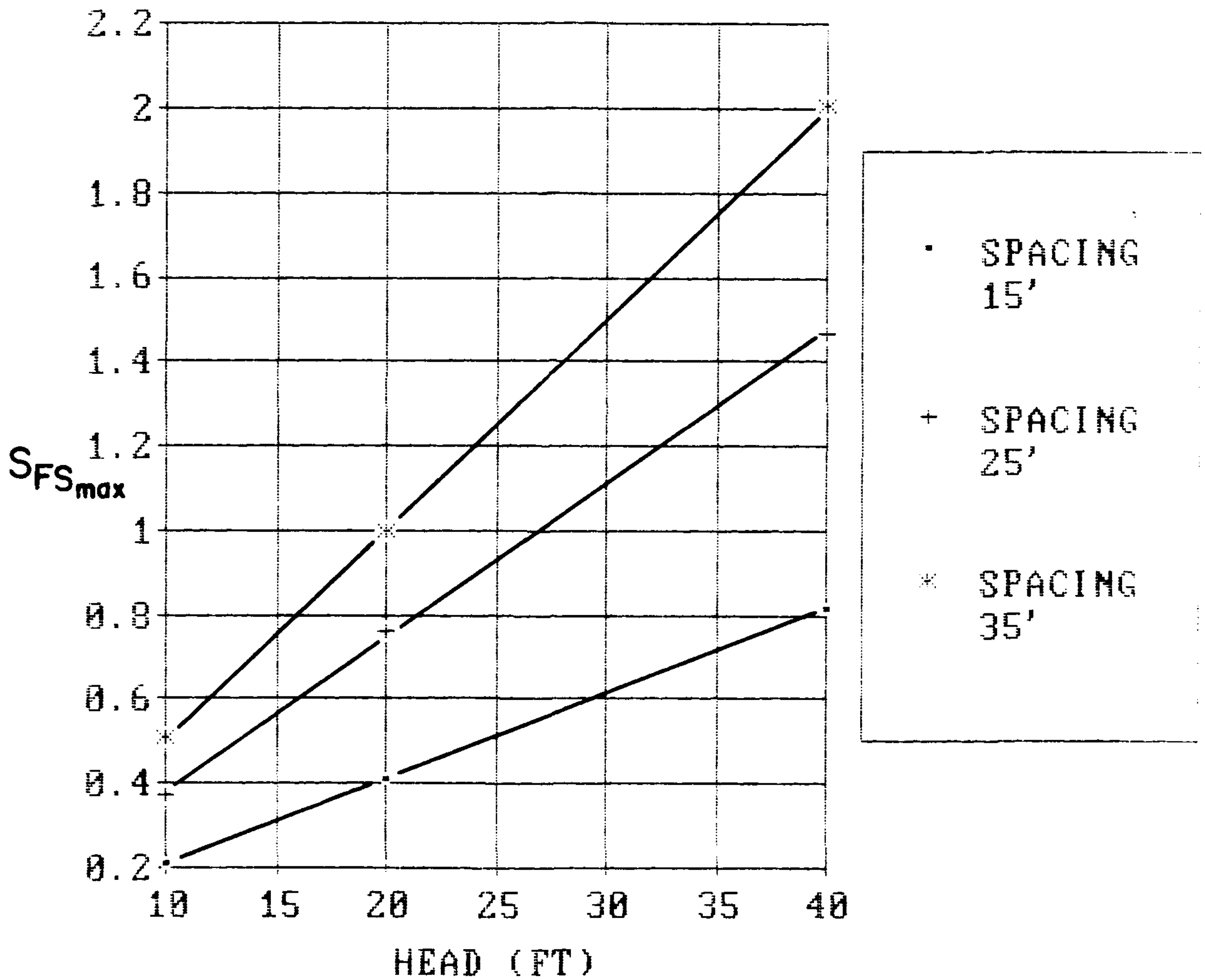

Figure 4.14 Maximum free surface height vs. spacing of drains with varying head.
Li = 400', Hr = 100', Dw = 2', K = 0.2 ft/day

Figure 4.15 shows the relationship of maximum free surface height, $S_{FS_{max}}$, as a fuction of head, h, and anisotropy, Kv/Kh. The same trend is seen here as noticed with discharge for anisotropy, that with increased vertical hydraulic conductivity the height of the free surface increases.

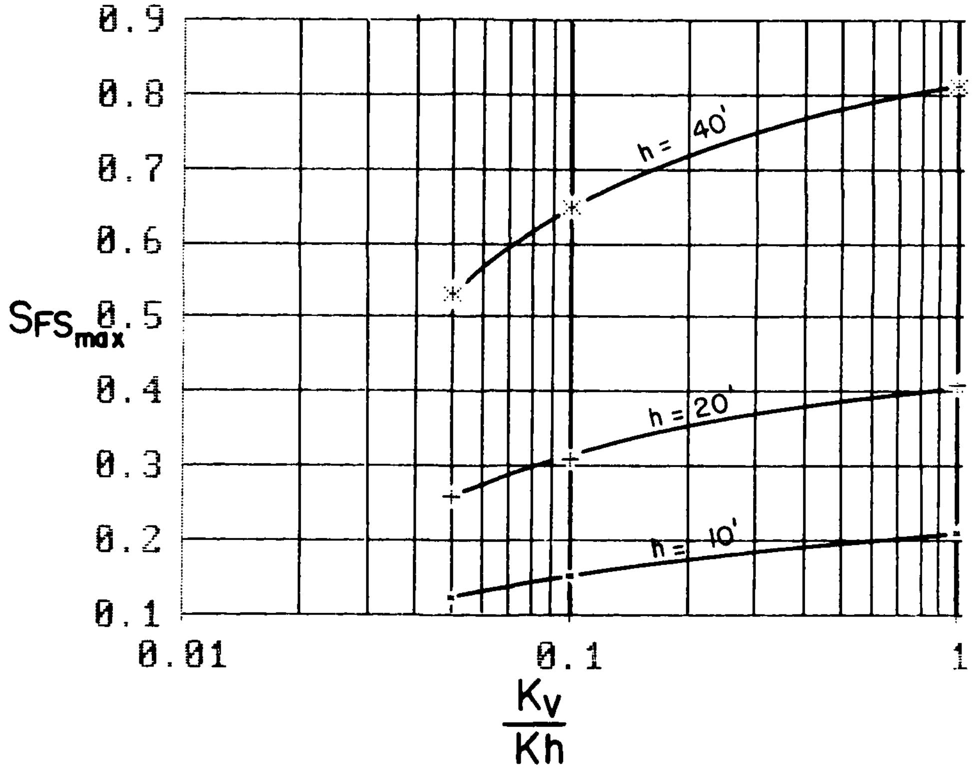

Figure 4.15 Maximum free surface height vs. anisotropy with varying head.
L1 = 400, Hr = 100', Sp = 25', Dw = 2'

In Figures 4.16 through 4.20, the free surface corner nodes are plotted for the different cases of analysis. To see the effects of the free surface changes versus the variable changes only nodes between the drains are plotted. In the sence of design, the maximum height of the free surface would be of the most concern, which is in between the first two drains. However, it is of interest to see the total free surface from a standpoint of total cross section of the building.

In Figure 4.16 the effect of thickness of aquifer on location of the free surface is shown. It is of interest to see, as in the case for discharge shown by Figure 4.8, that for shallow depths of impervious layer, Hr = 20', that very little rise in the free surface occurs in between drains four and five.

Figure 4.17 shows the effects of head differential on the location of the free surface nodes. It is of interest to see for cases of head equal to 20 and 10 feet the free surface nodes are approaching gentle mounds of water in between drains. However for the head equal to 40 feet the free surface peaks rather abruptly between the first two drains but resumes the gentle fall in free surface between the other drains.

Figure 4.18 shows the effects of drain spacing on the location of the free surface nodes. This shows as spacing is increased the free surface increases.

For Figure 4.19, the effects of the sloping aquifer on location of the free surface nodes is shown. The same trend is seen here as in discharge, shown by Figure 4.12, that for slopes greater than 10% the free surface location drops. The change in free surface nodes is very small for the cases of slope equal to 5% and 10%.

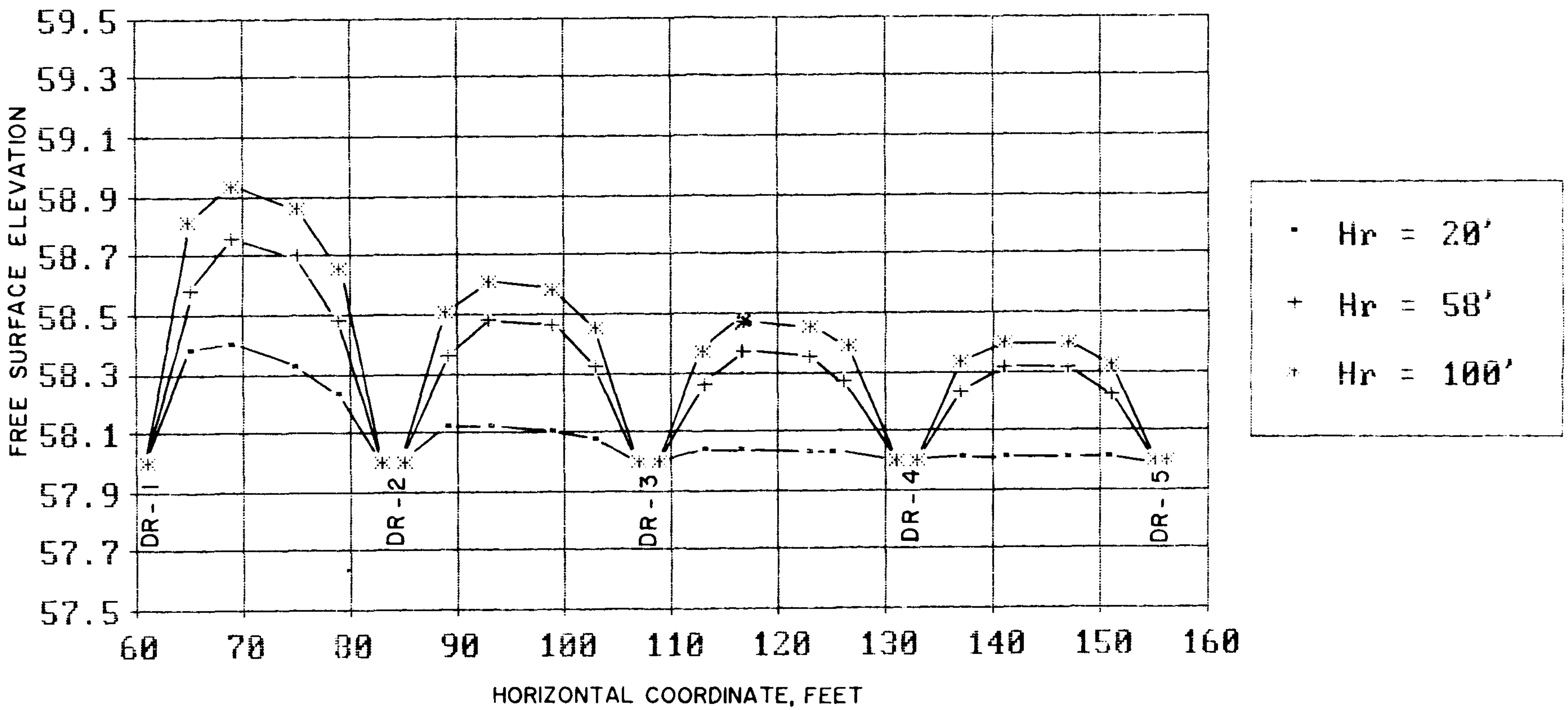

Figure 4.16 Free Surface corner nodes at drains with effects impervious boundary layer.

Li = 400', h = 20', Dw = 2', K = 0.2 ft/day

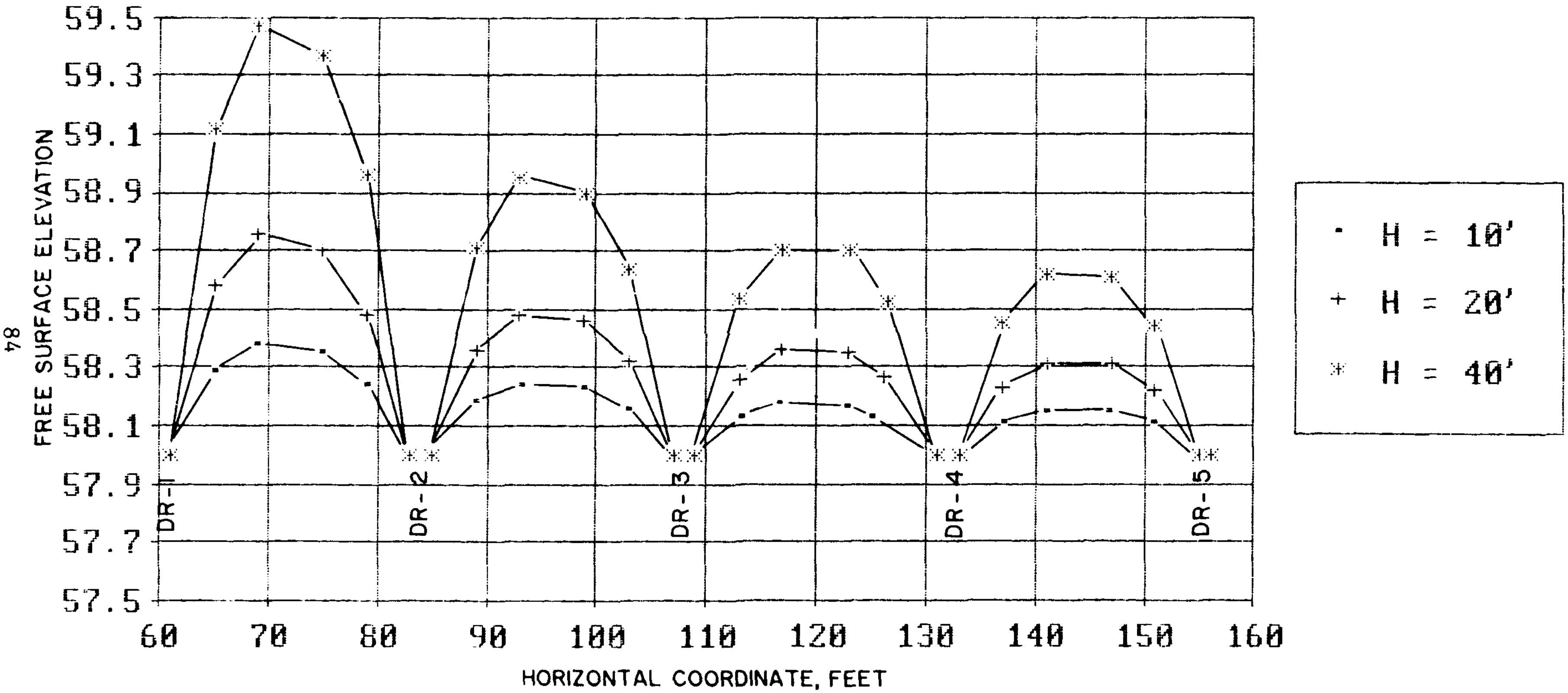

Figure 4.17 Free Surface corner nodes with drains with effects of head differential.
Li = 400', Hr = 100', Sp = 25', Dw = 2', K = 0.2 ft/day

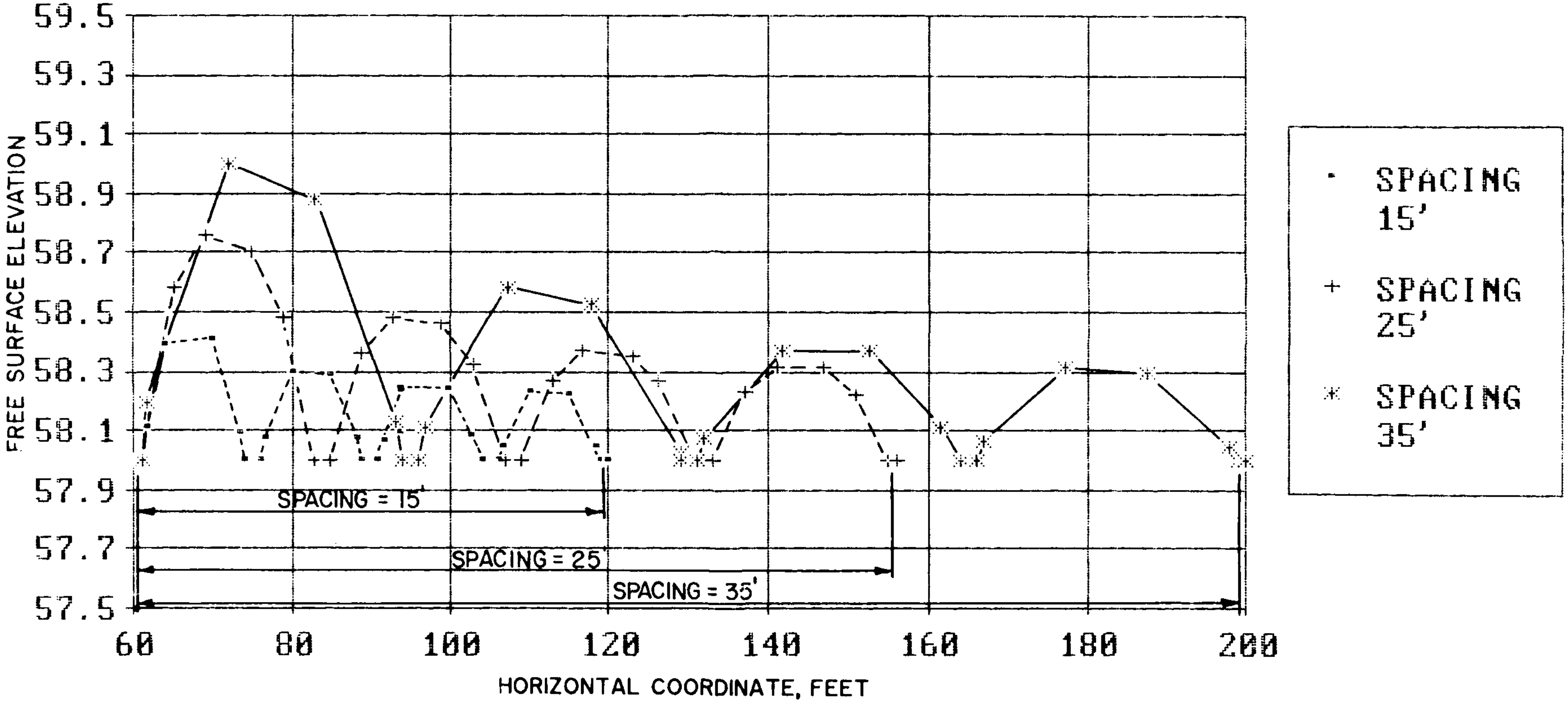

Figure 4.18 Free Surface corner nodes with drains with effects of drain spacing.

Li = 400', Hr = 100', h = 20', Dw = 2', K = 0.2 ft/day

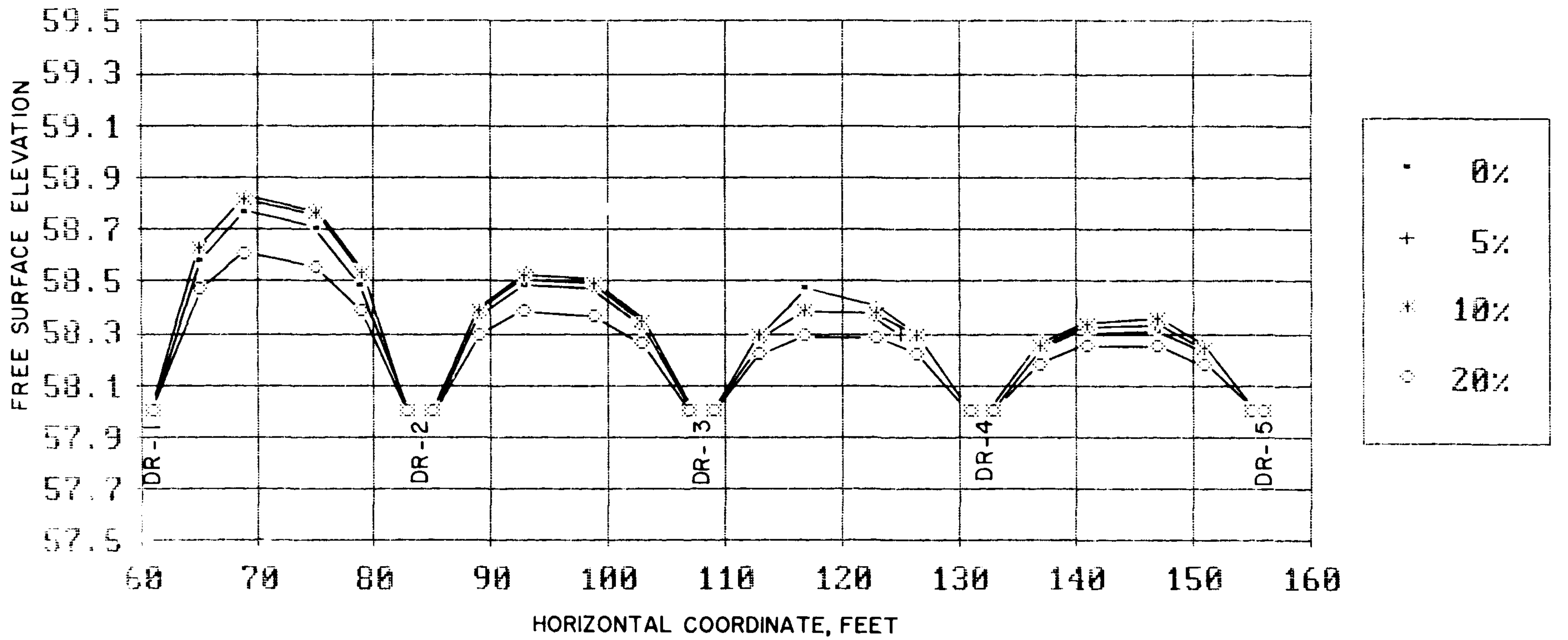

Figure 4.19 Free Surface corner nodes with drains with effects of slope of impervious boundary.

Li = 400', Hr = 100'(first drain), Sp = 25', h = 20', K = 0.2 ft/day

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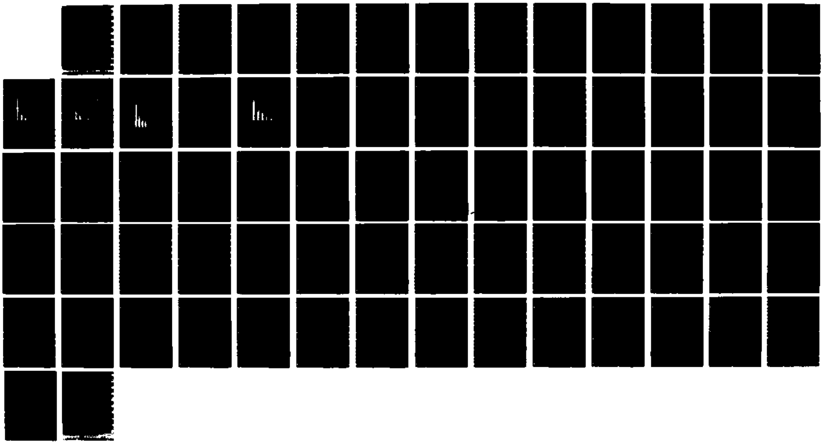

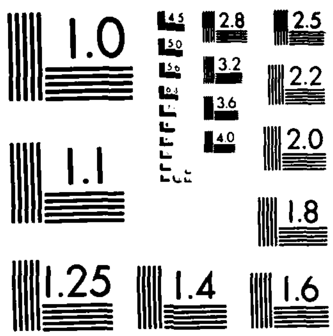

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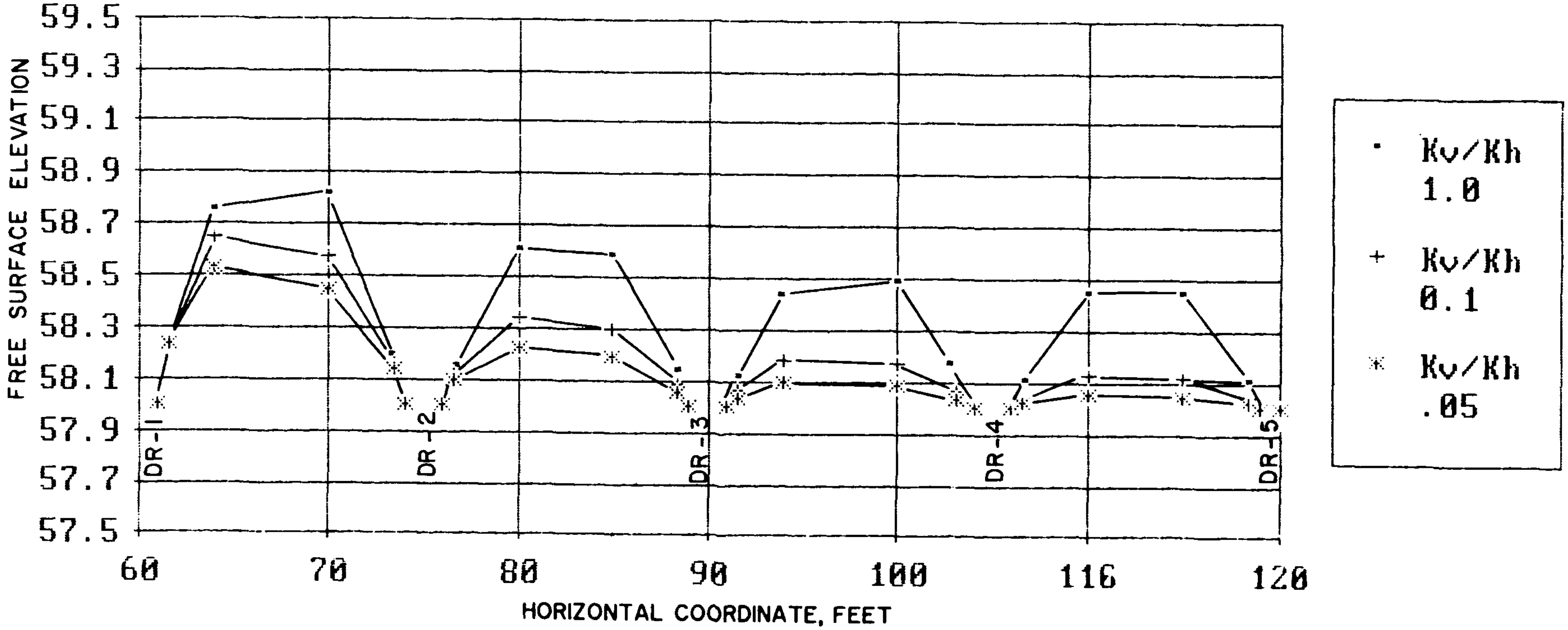

Figure 4.20 Free Surface corner nodes with effects of anisotropy.

Li = 400', Hr = 100', Sp = 25', h = 20', Dw = 2'

Dimensionsal Analysis (Li = 400' and Hr = 100')

Figures 4.21 through 4.24 are plots of the data generated by a dimensional analysis as discussed in Chapter 3. The discharge values given are unit discharge quantities and each case is for the particular variables noted in each figure. Unit discharge is defined as the sum of the total drain discharges for each of the drains per unit width in the z axis or the third dimension.

In Figure 4.21 the effect of drain width is analyzed. This plot shows that with increased drain width discharge increases, but with increased head the discharge may increase at a much faster rate. From this analysis it would appear that the greatest increases of flow rate would be for the drain widths between one and two feet wide. The following analysis is performed:

Drain Widths

head	1		2		3		4
10	0.034		0.053		0.065		0.073
increase →		0.019		0.012		0.009	
20	0.035		0.055		0.070		0.086
increase →		0.02		0.015		0.016	
40	0.036		0.057		0.075		0.09
increase →		0.021		0.018		0.015	

This analysis shows the increases of the flow function for the different head increases as shown. The maximum increase is seen for the values between drain widths of one and two. Therfore the most effective increase in flow occurs for drain widths between 1 and 2 feet. Another relationship could be stated, that for Dw/h ratios less than 0.2 the flow quantity increases at a rapid rate.

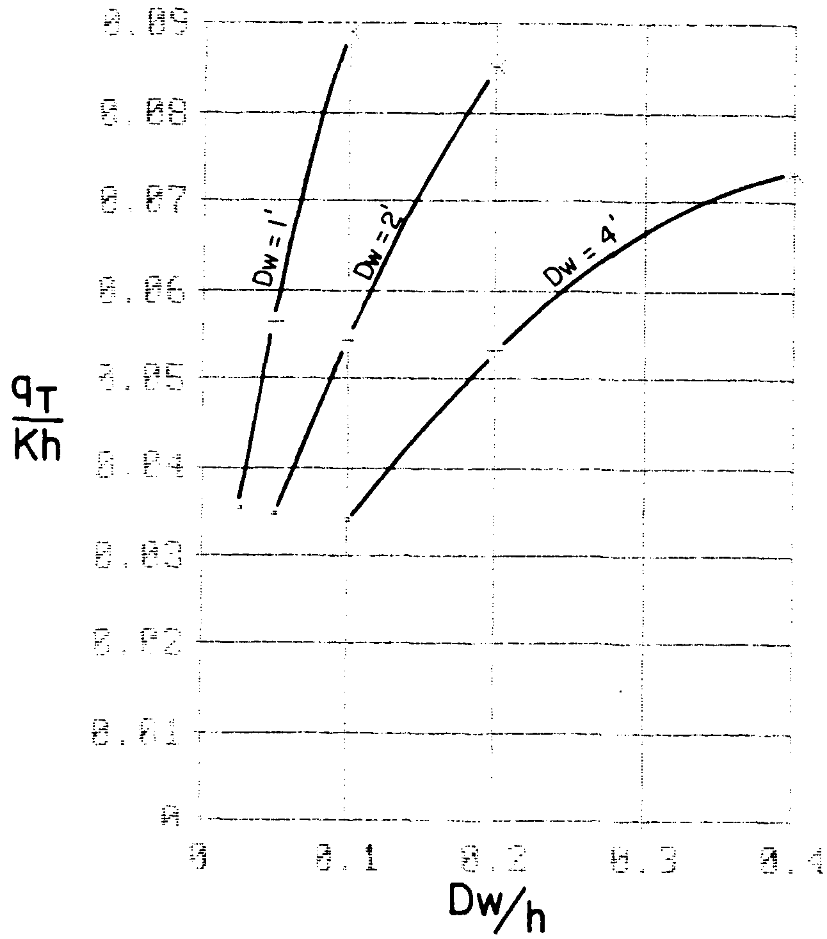

Figure 4.21 Dimensional analysis, Drain width.
Li = 400', Hr = 100', Sp = 25', K = 0.2 ft/day

In Figure 4.22 the effects of thickness of aquifer is shown for the dimensional analysis. This plot concludes that for Hr/h ratios greater than 2 or 3 the net increase in flow is approaching a linear relationship. This states that with increasing thickness of the aquifer the dicharge is expected to increase very near a linear increase and for very shallow thicknesses the flow becomes very small.

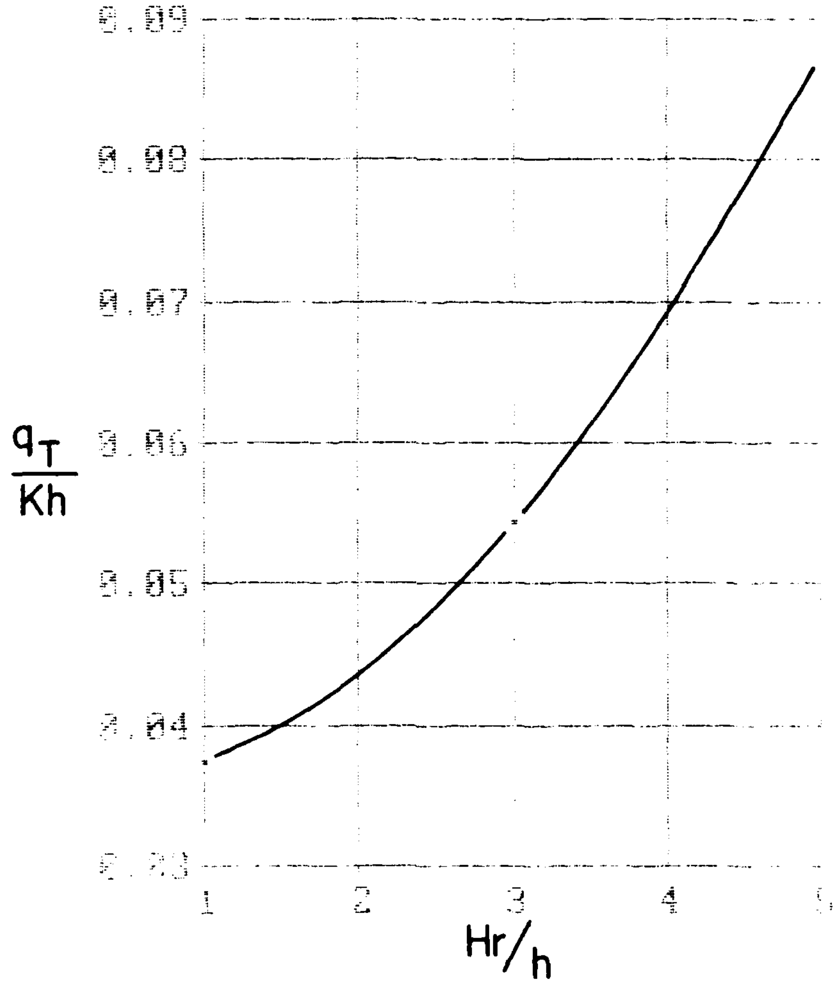

Figure 4.22 Dimensional Analysis, Depths of impervious layer. Li = 400', Sp = 25', Dw = 2', K = 0.2 ft/day

The effects of drain spacing is presented in Figure 4.23. The flow function for this analysis is treated differently for the spacing changes. As the spacing was increased for each of the computer runs the flow domain increased accordingly to accommodate the five drains at the appropriate spacing. Therfore to gain understanding of the effects of flow relationships with respect to drain spacing, each term was normalized by the corresponding spacing between the drains for each head increase. This analysis shows for decreased spacing discharge increases and as head increases so the discharge.

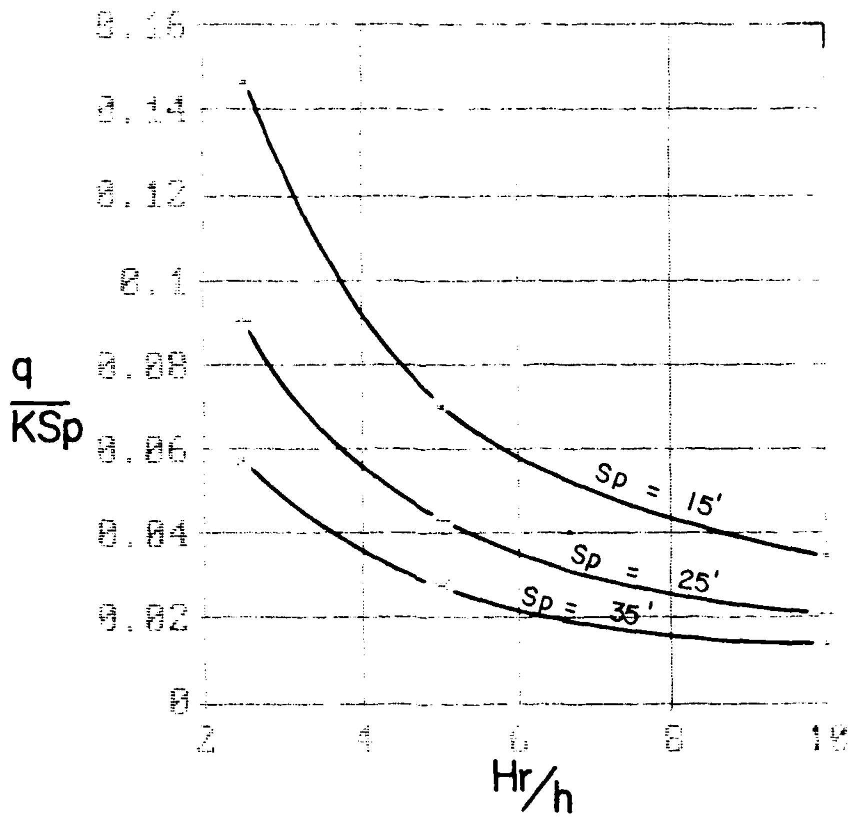

Figure 4.23 Dimensional Analysis, Drain spacing.
Li = 400, Hr = 100', Dw = 2', K = 0.2 ft/day

Figure 4.24 shows the dimensional analysis for effects of the sloping aquifer. For this particular flow matrix as modeled, a definate break in flow increase is noticed. The peak discharge function is at slope, Θ equal 0.05.

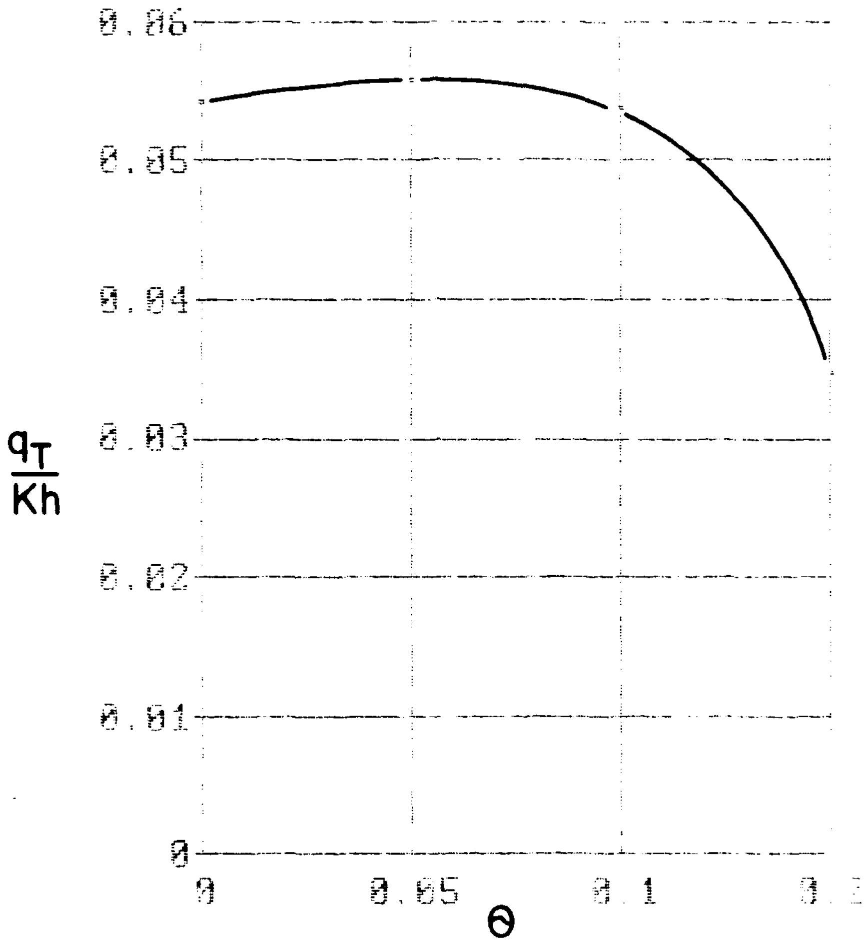

Figure 4.24 Dimensional Analysis, Slope of aquifer. Li = 400', Hr = 100'(first drain), Sp = 25', Dw = 2', K = 0.2 ft/day

Results For Li = 80' and Hr = 58'

The following plots and nomographs are the results for the computor runs where distance from the constant head boundary to the first drain, Li, equals 80 feet and the thickness of the aquifer equals 58 feet. The plots are essentially the same as for the previous case except these variables are held constant.

Drain Discharge (Li = 80' and Hr = 58')

Figure 4.25 shows the effects of drain width on total drain discharge. The results are generally the same as shown in Figure 4.6 except discharge quantities range from 3 to 4 times greater.

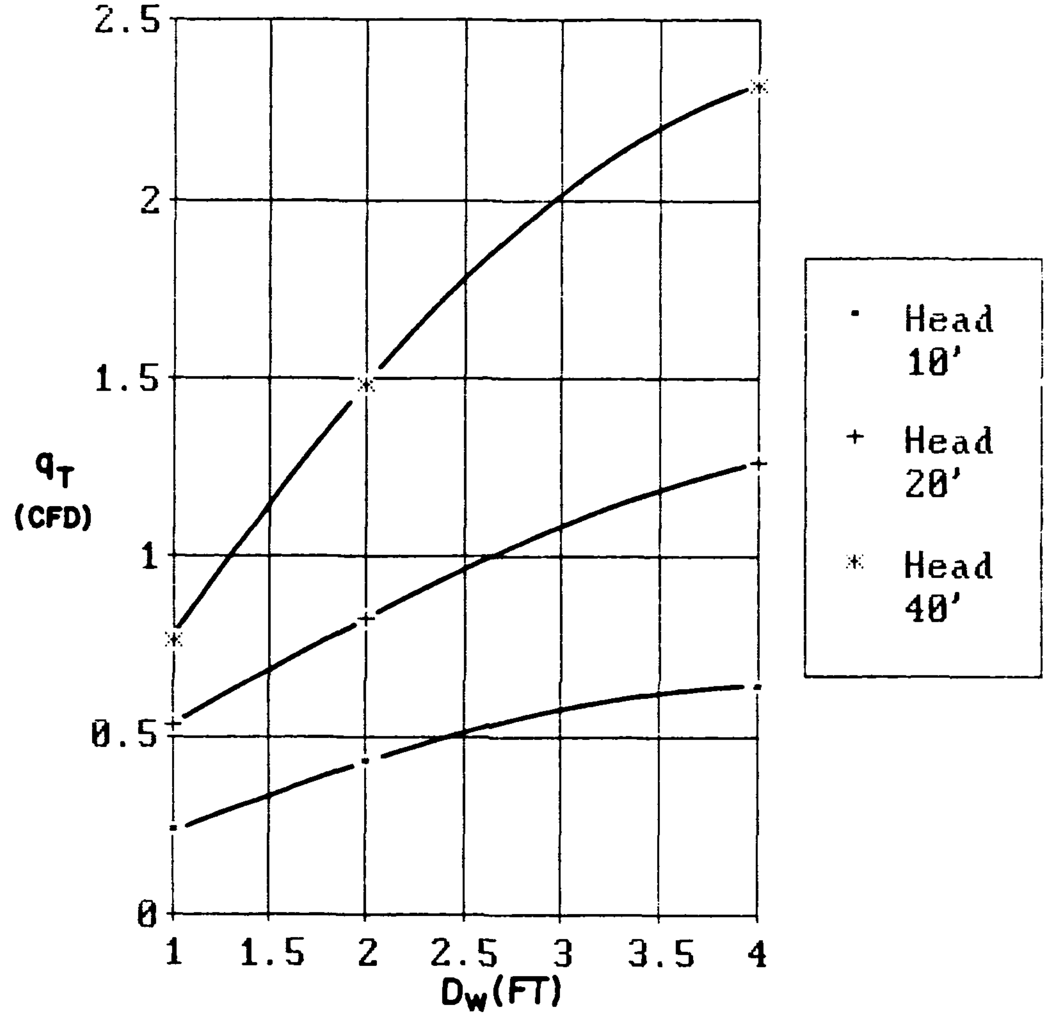

Figure 4.25 Total drain discharge vs. drain width with varying head.
Li = 80', Hr = 58', Sp = 25', K = 0.2 ft/day

The results of anisotropy of the soil continum is shown by Figure 4.26 for the short Li distance of 80 feet. The trend is slightly different than for the case for Li equal 400 feet as shown by Figure 4.7. For the largest head value of 40 feet the discharge decreases just slightly with decrease in vertical hydraulic conductivity, but for a Kv/Kh ratio less than 0.1 the discharge decrease is very dramatic. However for the low head value of 10 feet the general decreasing trend is prevelant as the case for Figure 4.7.

For this case the flow quantities have increased approximately 4 to 5 times. This shows the large effects that the distance of the constant head boundary has on the seepage quantities.

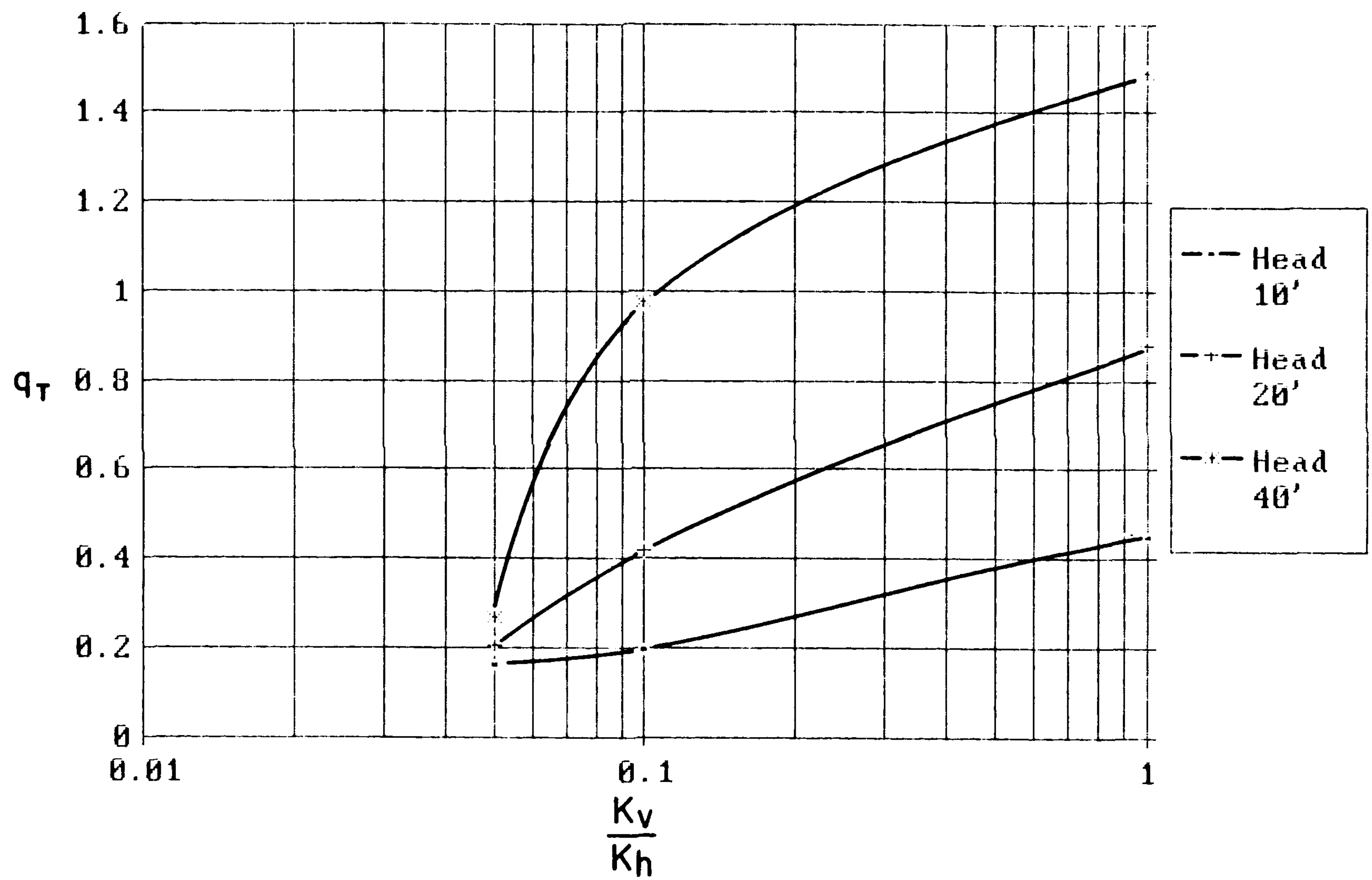

Figure 4.26 Total Drain Discharge vs. Anisotropy with varying heads
Li = 80', Hr = 58', Sp = 15', Dw = 2', Kh = 0.2 ft/day

Figures 4.27 and 4.28 depict the same general trend of maximum flow at drain one and a general decrease in flow for each consectutive drain is noticed for effects of thickness of aquifier and head respectively. Flow quantities are again 3 to 4 times greater for this case than for the earlier case as shown by Figures 4.8 and 4.9. For this case of shorter distance to the constant head boundary equal 80 feet, the mid-peak discharges at the third drain is not noticed as in Figure 4.9. In Figure 4.28 it is of interest to see that the largest head value equal 40 feet has such a large effect on the first drain collecting a large portion of the total discharge of the system.

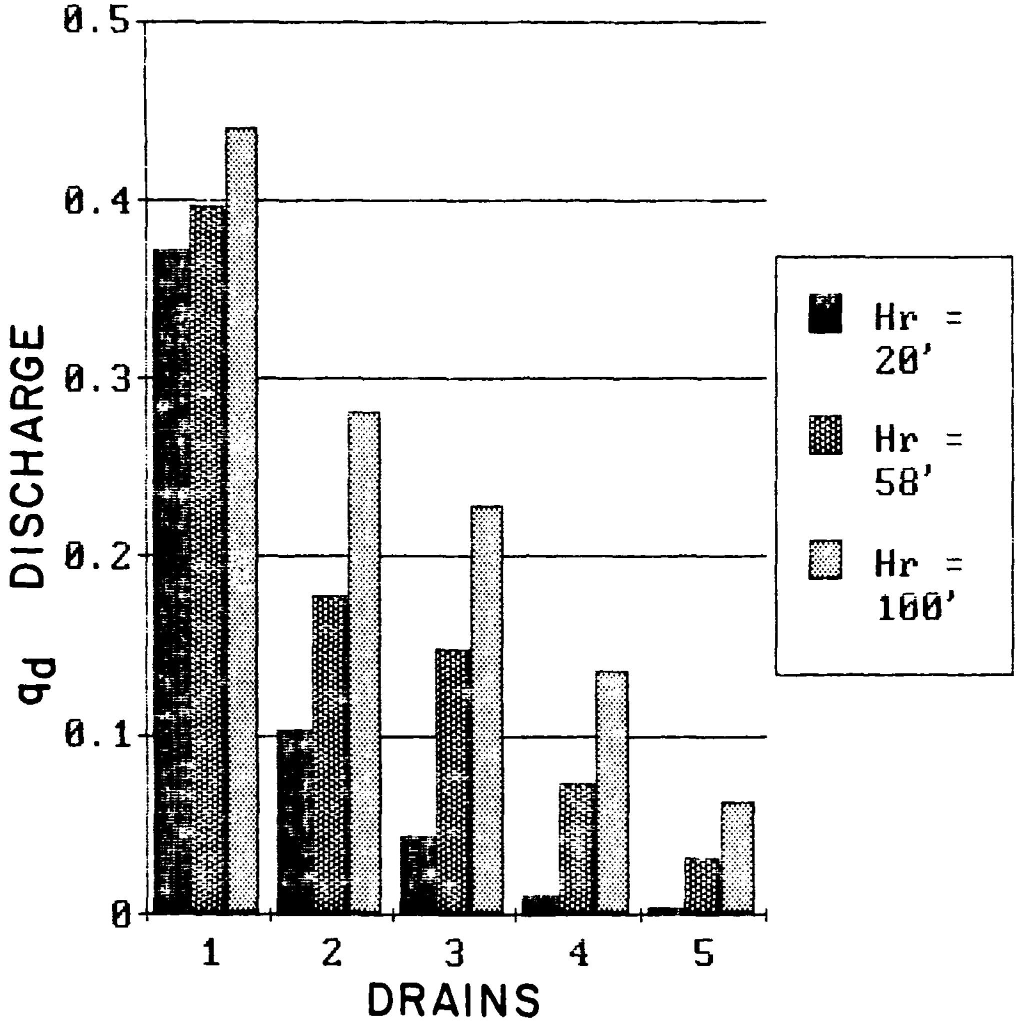

Figure 4.27 Drain discharge vs. depth of aquifer.
Li = 80', h = 20', Sp = 25', K = 0.2 ft/day, Dw = 2'

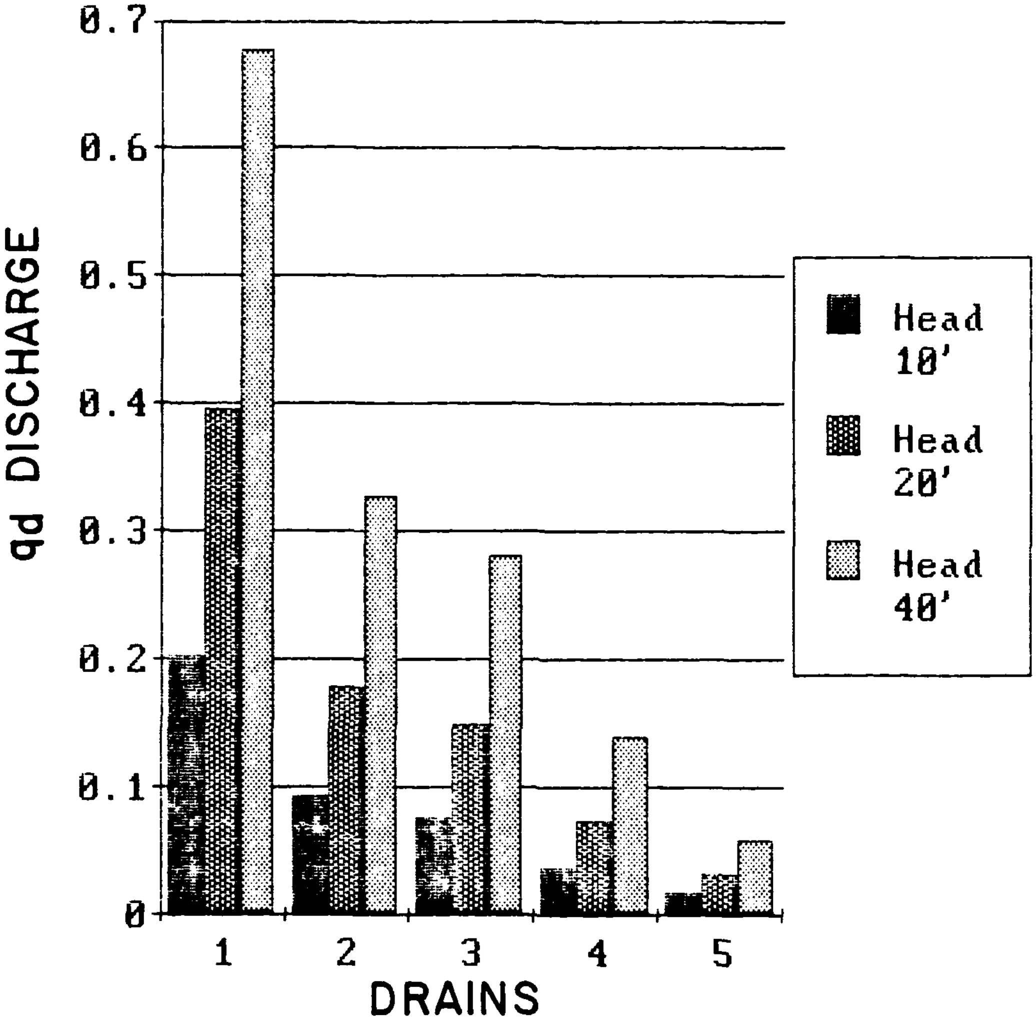

Figure 4.28 Drain discharge vs. head differential.
Li = 80', Hr = 58', Sp = 25', Dw = 2', K = 0.2 ft/day

The effects of drain spacing for distance of the constant head boundary to the first drain, Li, equal 80 feet, is shown by Figure 4.29. The same trends are seen for this case as that shown by Figure 4.10. Flow increase is somewhat less in this case compared to the earlier case of Li equal 400 feet. Flow quantities appear to range from 2 to 3 times as great.

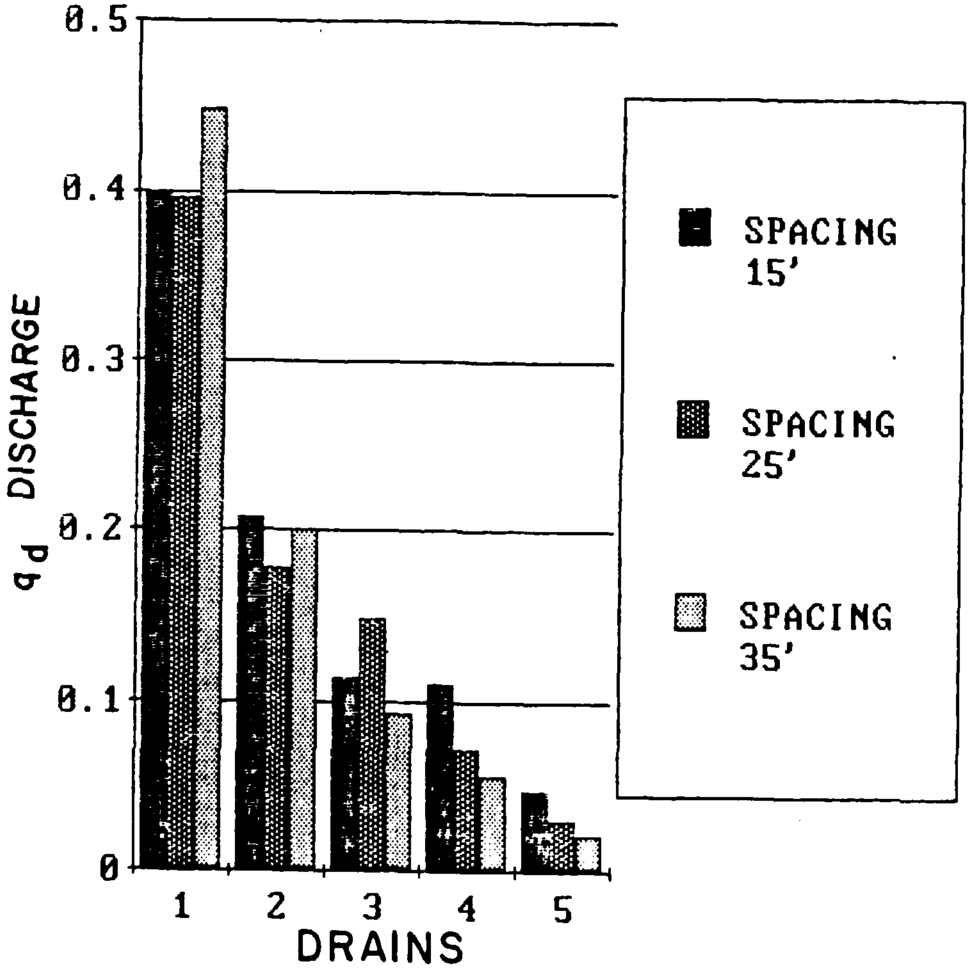

Figure 4.29 Drain discharge vs. drain spacing.
Li = 80', Hr = 58', h = 20', Dw = 2', K = 0.2 ft/day

In Figure 4.30 the effects of slope of the impervious boundary, θ , is shown for drain discharge. A significant change is noticed for this plot when compared to the earlier plot in Figure 4.12 for sloping aquifer. For Li equal to 400 feet, the peak discharge occured for a slope between 5 and 10 percent. In this case, where Li equals 80 feet, the peak flow is for the case of the steepest slope equal to 20 percent. For drain one, the flow is 8 times greater than the flow for drain one as shown by Figure 4.12, Li = 400 feet. The flow is 5 times greater in drain five in this case than the flow in drain five for the case of Li = 400 feet.

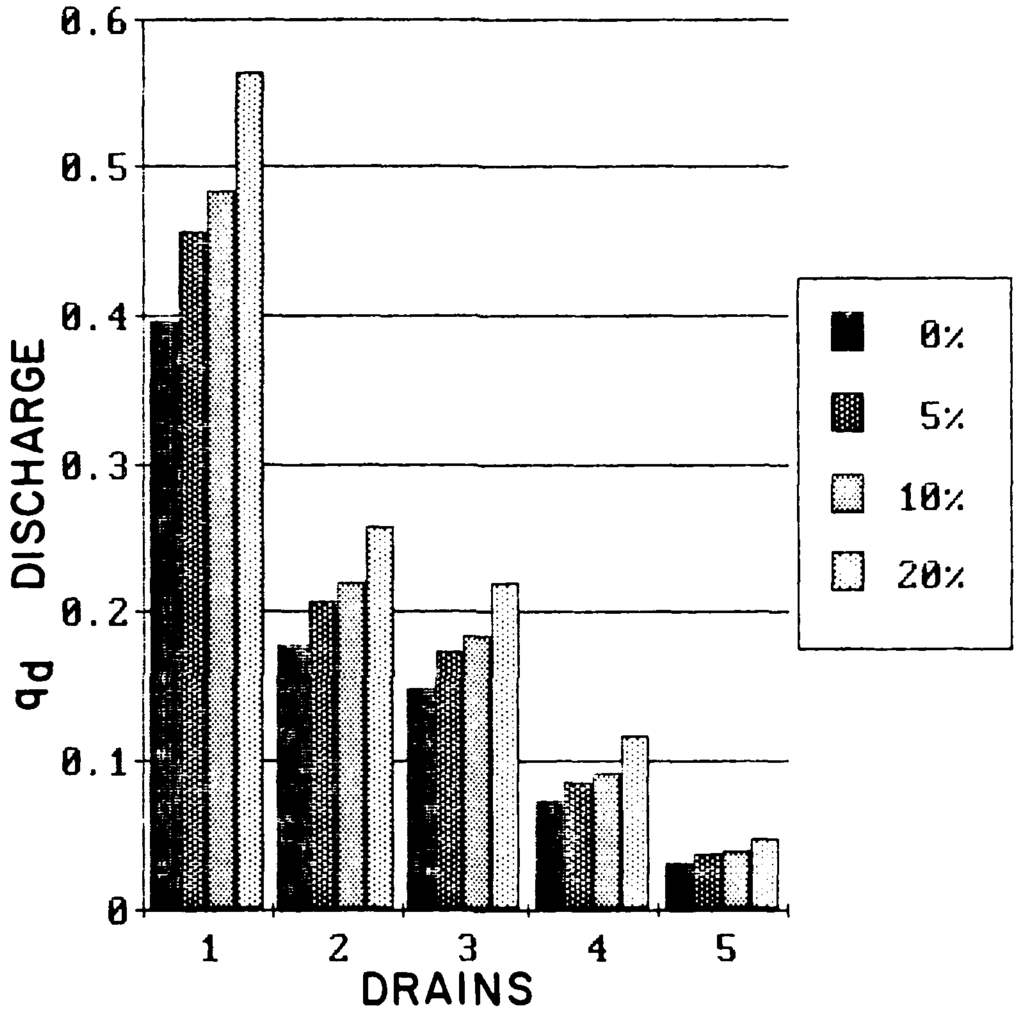

Figure 4.30 Drain discharge vs. slope of the impervious boundary.
Li = 80', Hr = 58'(first drain), h = 20', Sp = 25', Dw = 2', K = 0.2 ft/day

Free Surface Location (Li = 80' and Hr = 58')

Figures 4.31 through 4.36 show the results of the free surface location plots for the case of Li equal 80 feet and Hr equal 58 feet. The same general trends are shown for this plots as shown by the earlier case of Li equal 400 feet and Hr equal 100 feet. In general, the free surface has moved up approximately three times in height. An exception to the earlier case of is shown in Figure 4.36. This figure shows the location of the free surface nodes with the effects of slope of the impervious boundary. It is somewhat different in this case than in the earlier case as shown in Figure 4.19 for Li equal 400 feet. In this case the free surface continues to increase in height as the slope of the impervious boundary increases.

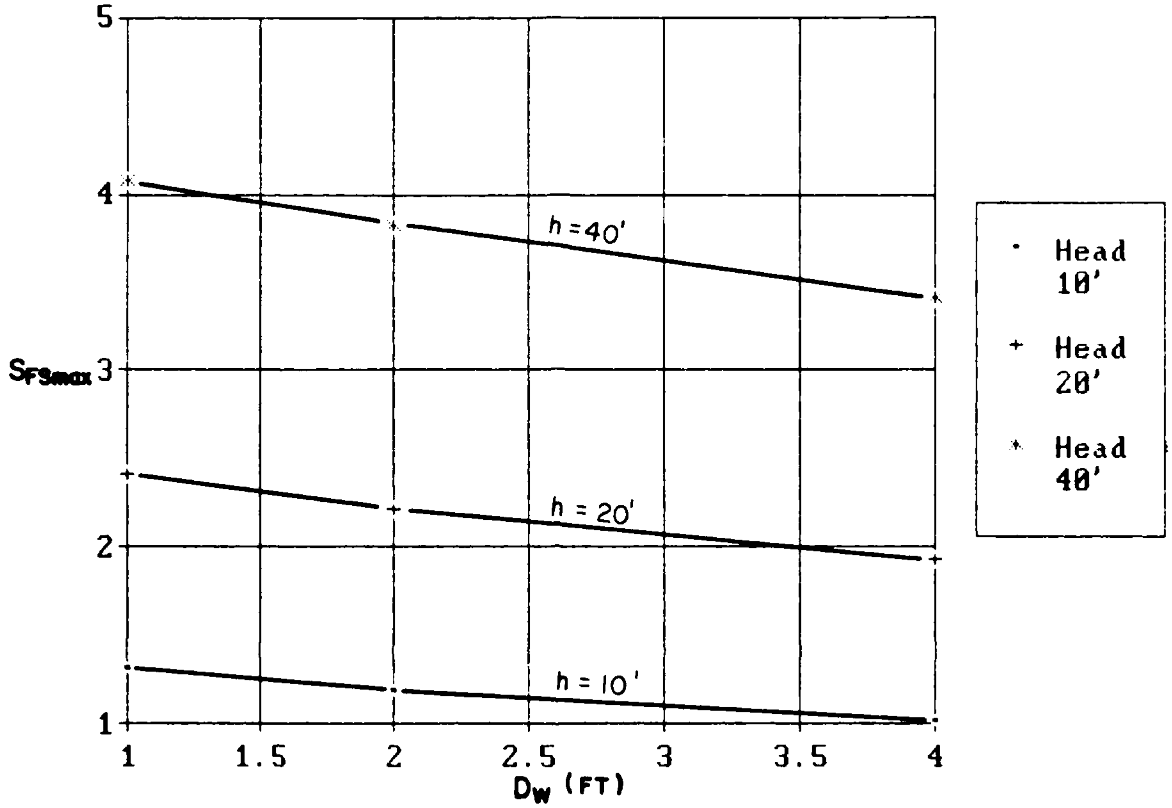

Figure 4.31 Maximum free surface height vs. drain width.
Li = 80', Hr = 58', Sp = 25', K = 0.2 ft/day

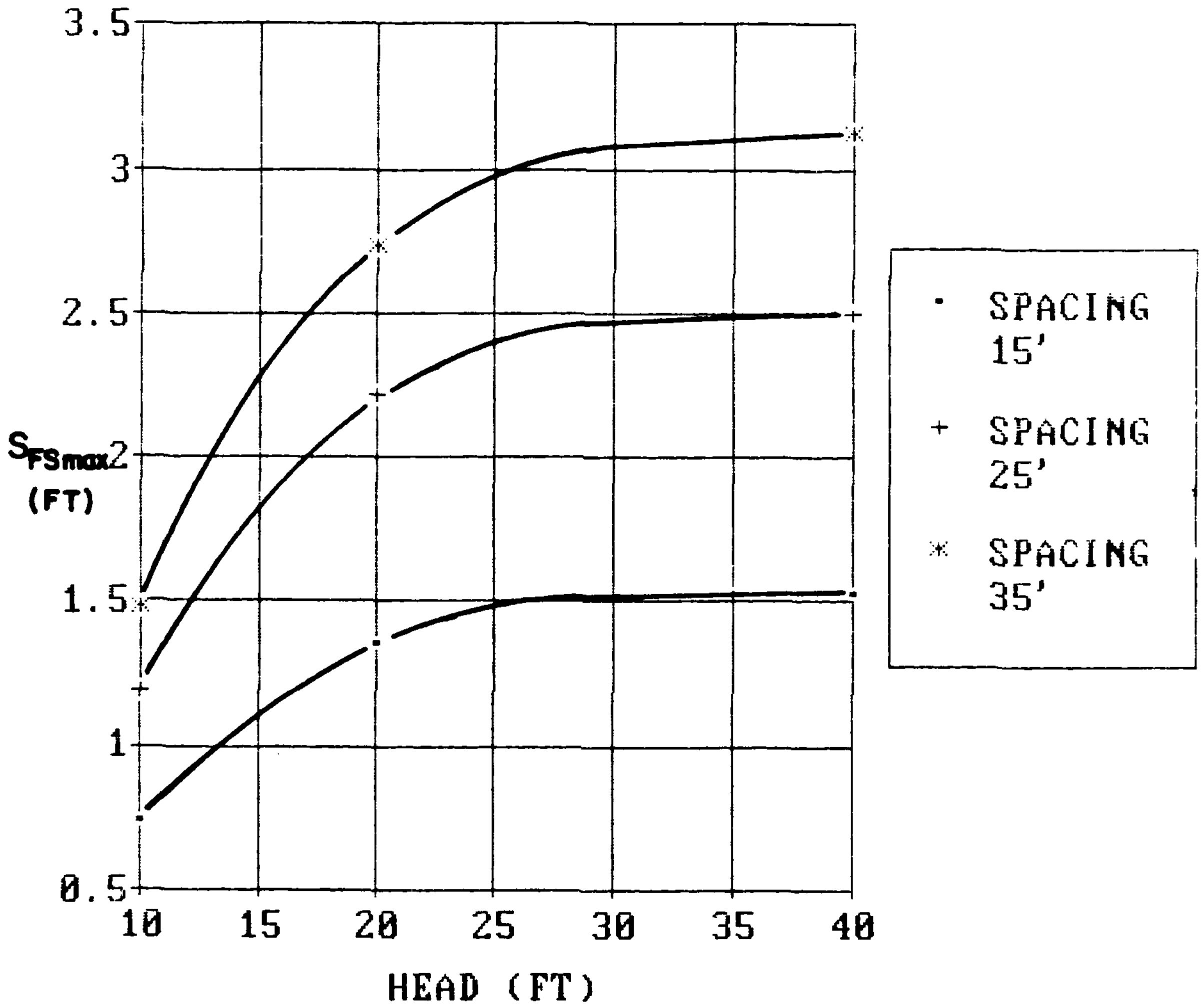

Figure 4.32 Maximum free surface height vs. frain spacing with head varying.
Li = 80', Hr = 58', Dw = 2', K = 0.2 ft/day

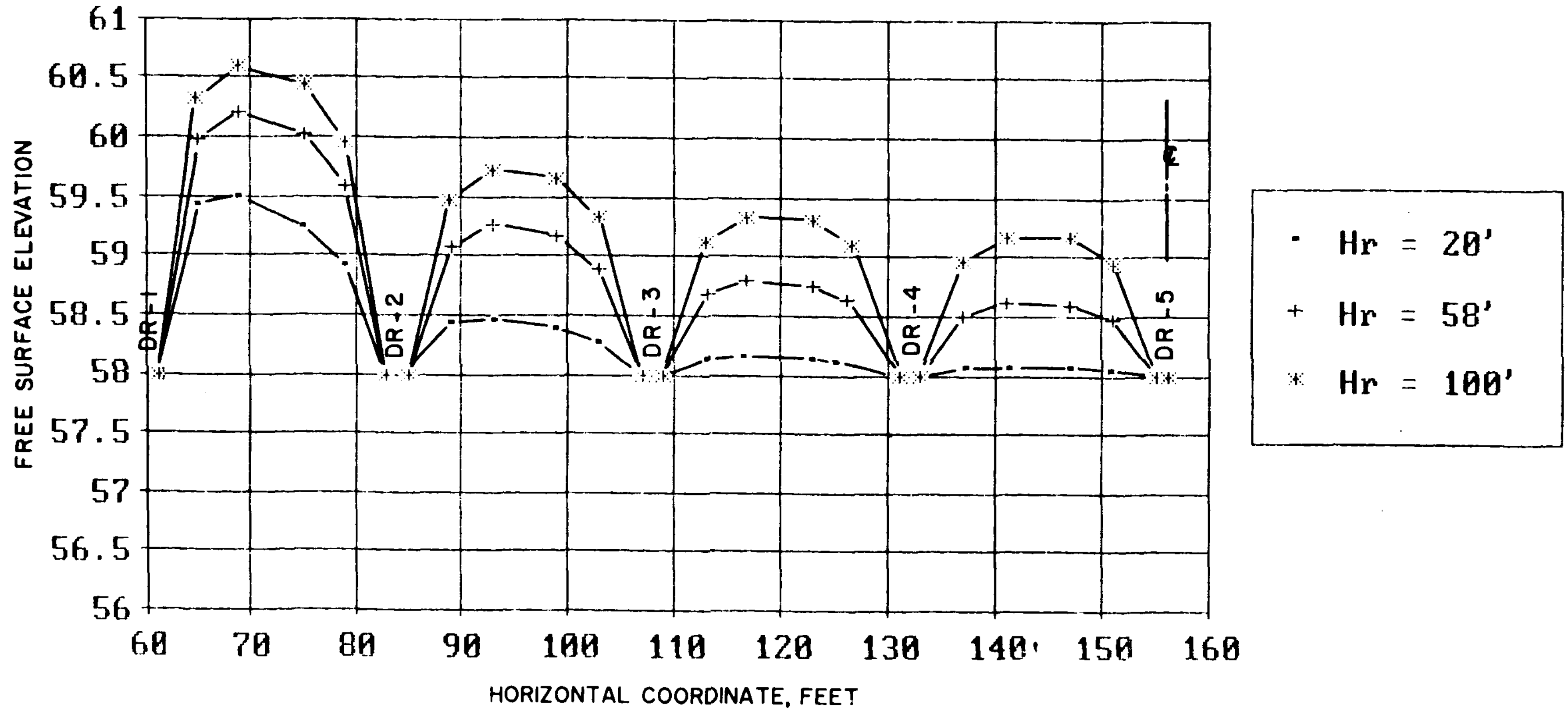

Figure 4.33 Free surface corner nodes with effects of Depth of impervious boundary.
Li = 80', h = 20', Dw = 2', K = 0.2 ft/day

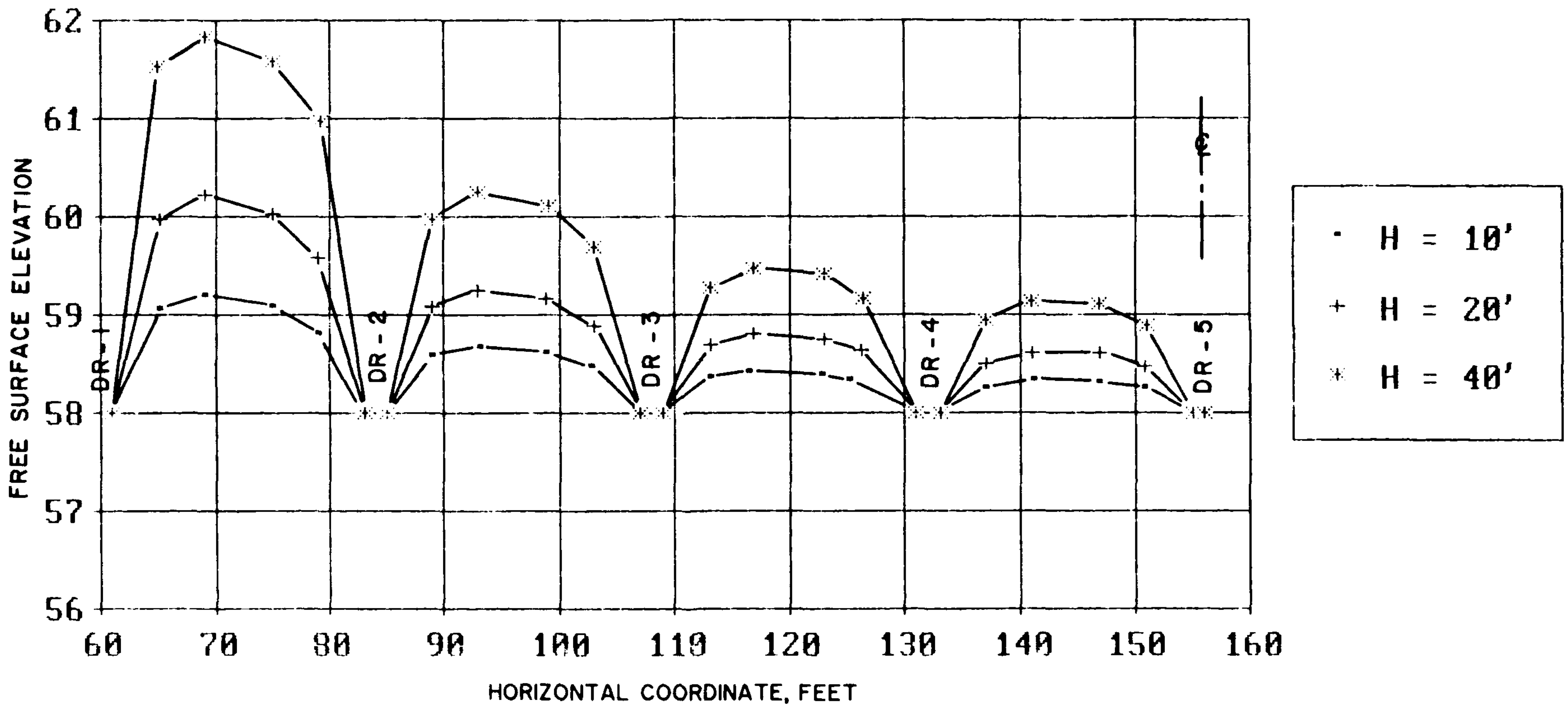

Figure 4.34 Free surface corner nodes with effects of head differential.
Li = 80', Hr = 58', Sp = 25', K = 0.2 ft/day

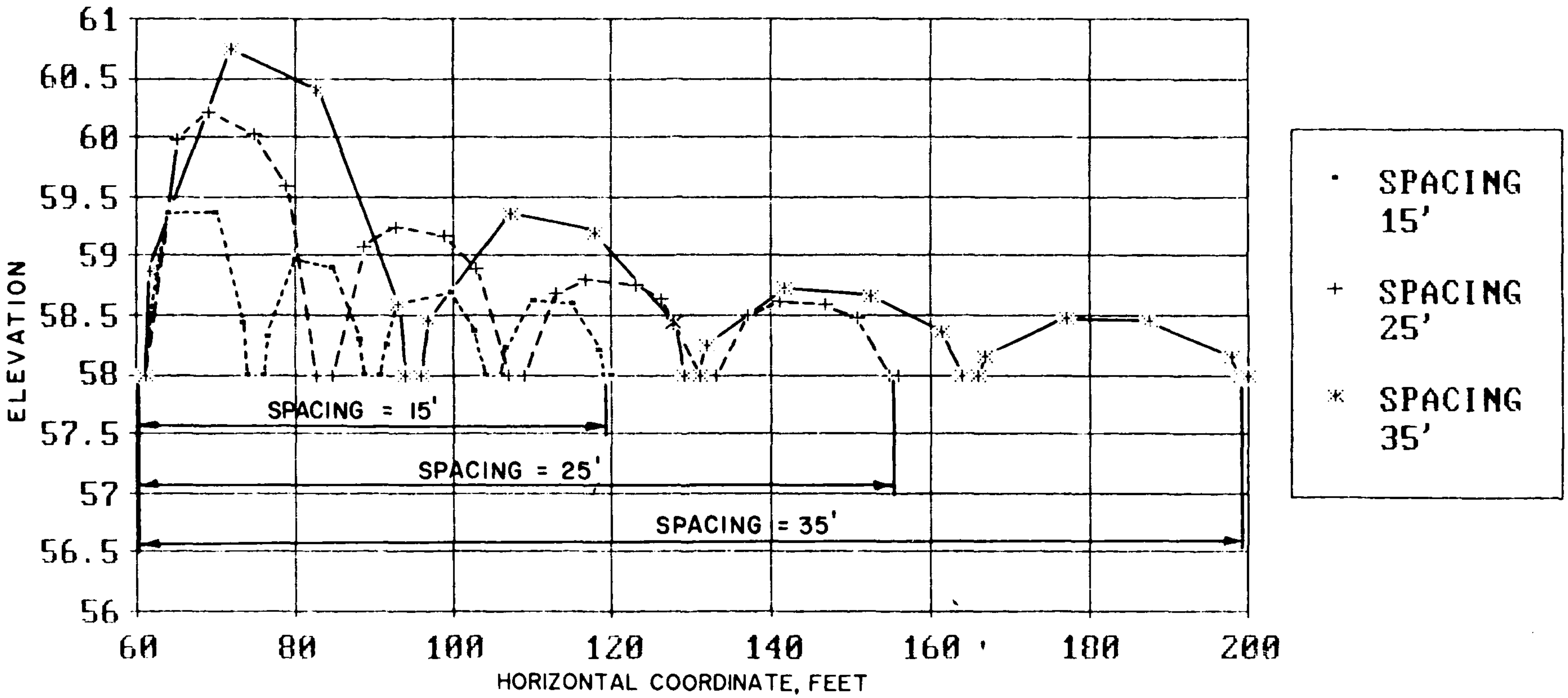

Figure 4.35 Free surface corner nodes with effects of Drain spacing
Li = 80', Hr = 58', h = 20, Dw = 2', K = 0.2 ft/day

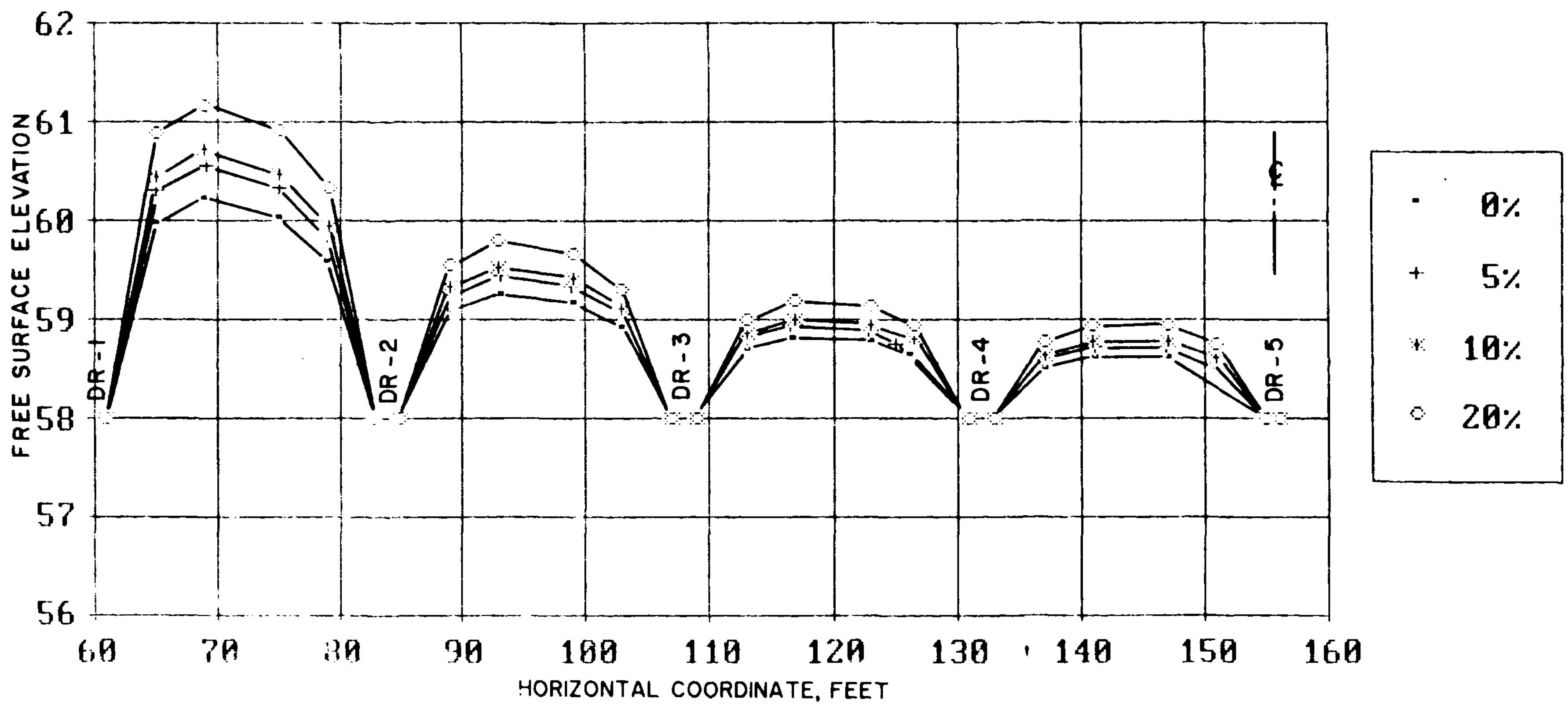

Figure 4.36 Free surface corner nodes with effects of slope of impervious boundary.
Li = 80', Hr =58'(first drain), Dw = 2', h = 20', K = 0.2 ft/day

Dimensional Analysis (Li = 80' and Hr = 58')

The effects of drain width as shown by the dimensional analysis is shown by Figure 4.37. The general trend of the discharge increasing with drain width is seen in the data. When compared to the earlier case for Li equal to 400 feet, it is seen that total discharge is greatly effected, by a factor of three times.

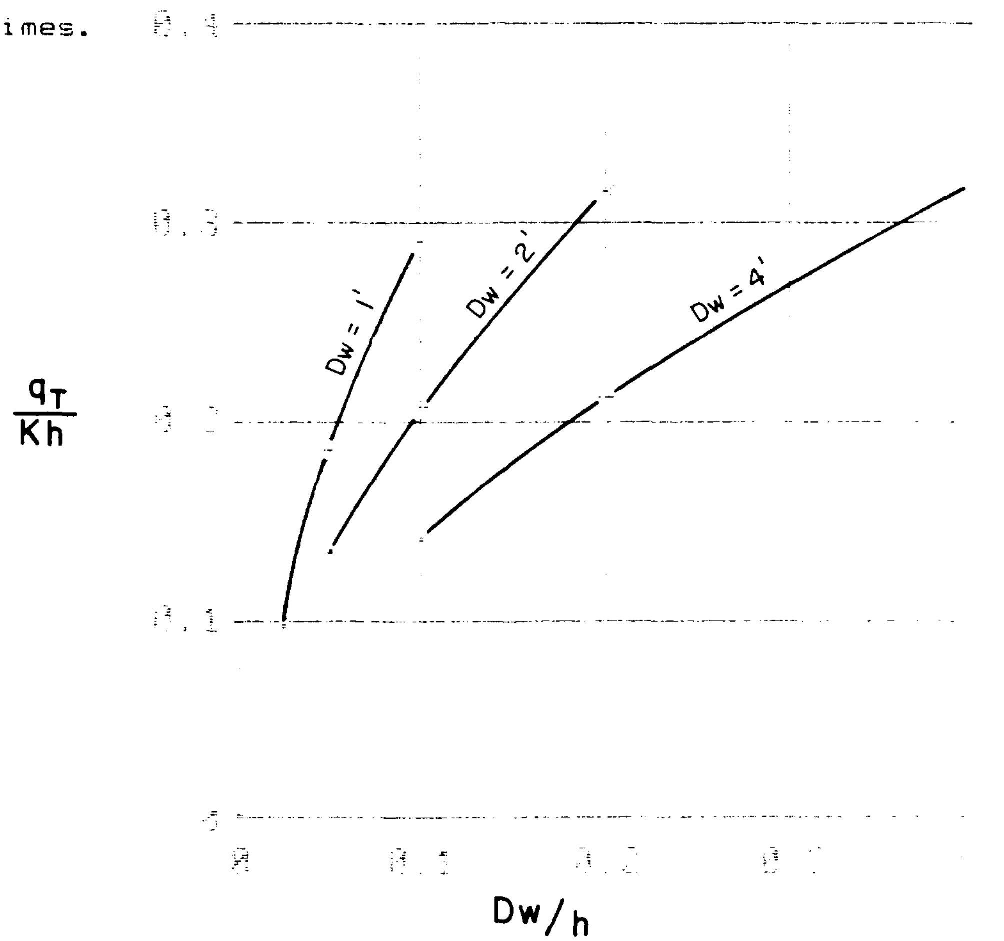

Figure 4.37 Dimensional Analysis, drain width.
Li = 80', Hr = 58', Sp = 25', K = 0.2 ft/day

Figure 4.38 shows the dimensional analysis results for thichness of the aquifer. In this case, Li equal 80 feet, the relationship is more linear than in the case of Li equal 400 feet as shown in Figure 4.22. This results in the conclusion that the effects of Hr has a pronounce influence on the flow quantities when coupled with the distance Li. For a shorter distance of Li, the effects of depths of Hr is more crictical and more of a linear relationship. However when the distance from the constant head boundary is larger, as in the earlier case, the effects of Hr are not as effective when Hr is very small.

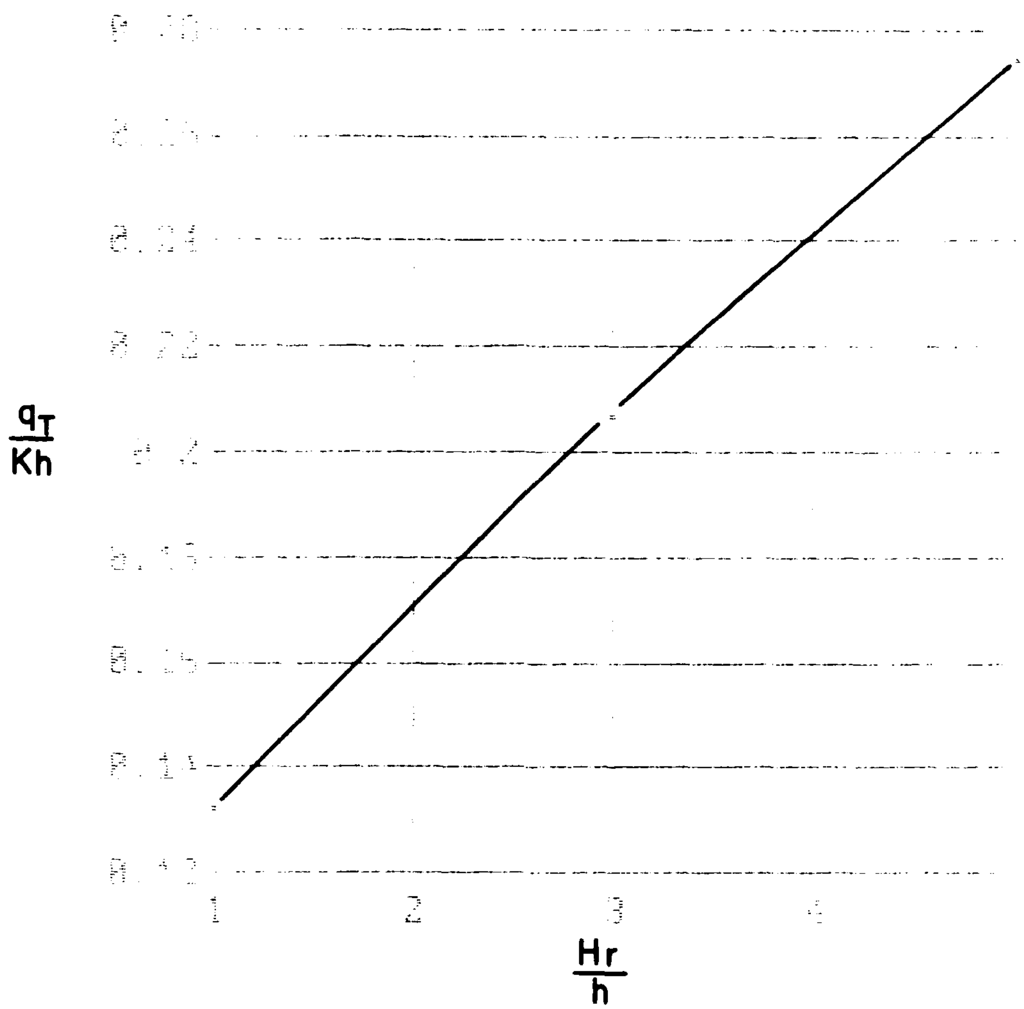

Figure 4.38 Dimensional Analysis, depth of aquifer.
Li = 80', Sp = 25', Dw = 2', K = 0.2 ft/day

Figure 4.39 shows the results of the dimensional analysis for drain spacing. Again the ordinate is normalized with respect to the area subtended by each flow continum for each case of spacing. Flow quantity would equate to an increase of approximately 5 to 6 times from this case of Li equal 80 feet versus Li equal 400 as shown in Figure 4.23.

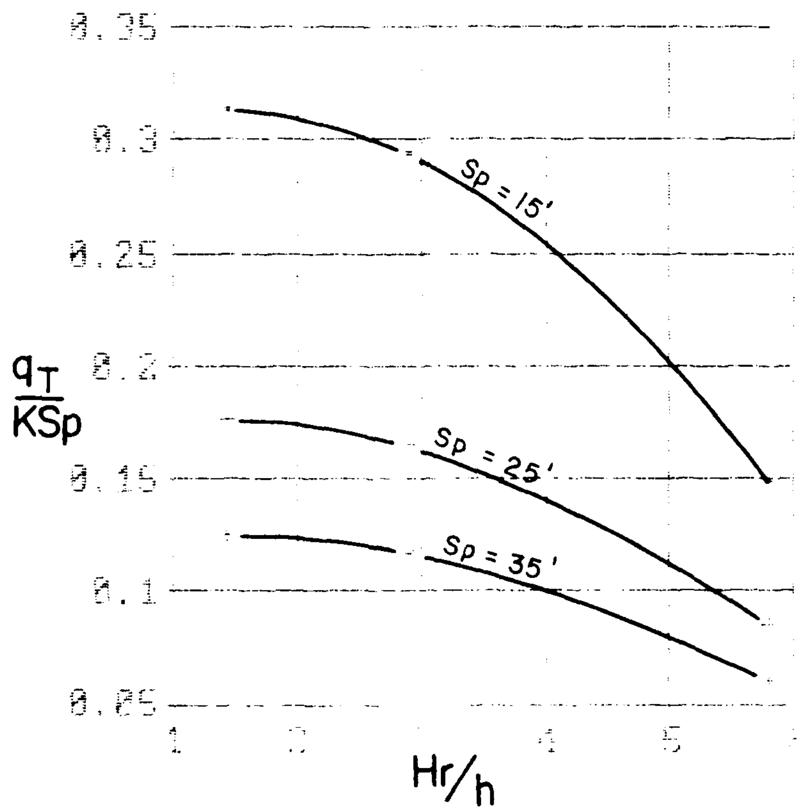

Figure 4.39 Dimensional Analysis, drain spacing.
Li = 80', Hr = 58', Dw = 2', K = 0.2 ft/day

Figure 4.40 shows the dimensional analysis results for the sloping impervious boundary. For this case, Li equal 80 feet, as depicted in the earlier plots for sloping aquifer for drain dischrge and free surface location, the trend is seen that for and increase in slope the discharge increases.

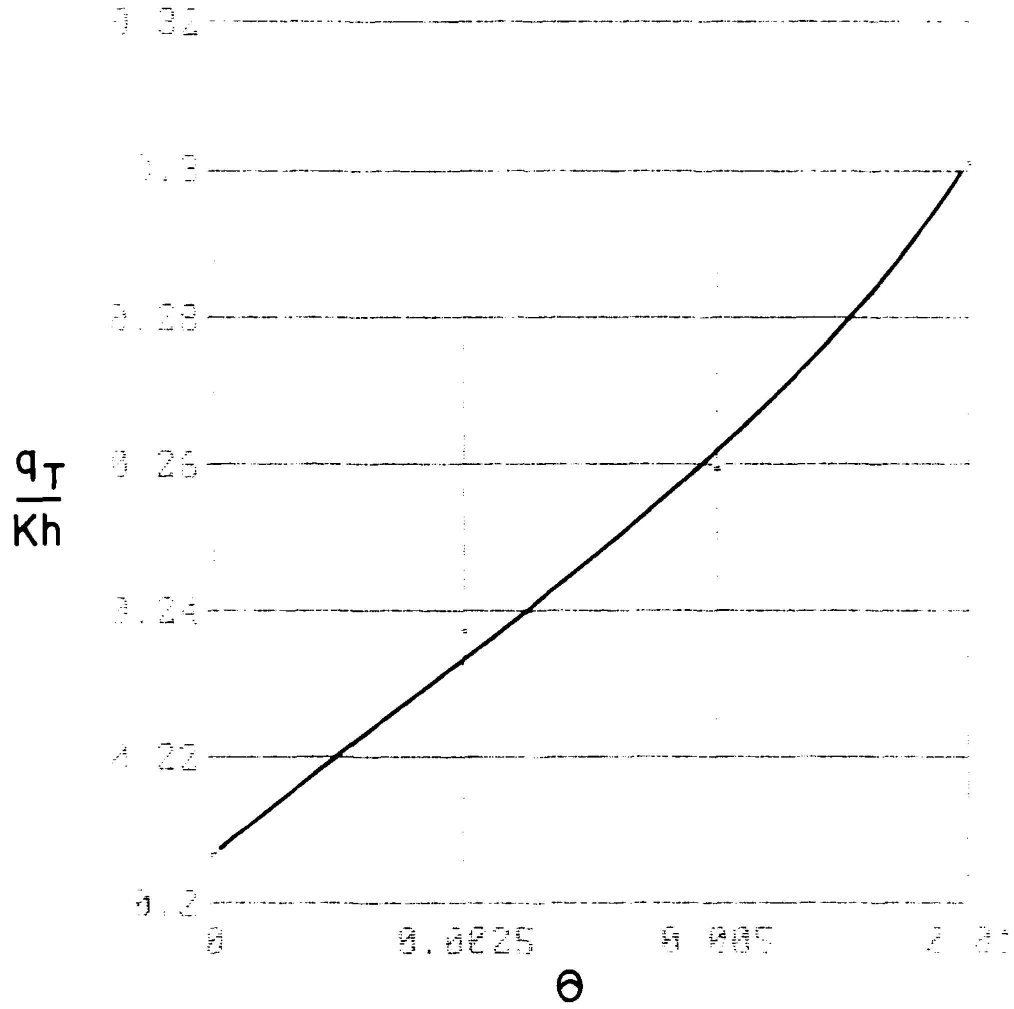

Figure 4.40 Dimesional Analysis, sloping impervious boundary.
Li = 80', Hr = 58', Sp = 25', Dw = 2, K = 0.2 ft/day

4.6 Summary

This chapter has included the results of many computer runs for the analysis of a building underdrain system. The importance of model sensitivity must be stressed, in that key variables may effect the results very significantly. In this model, it was found that the most crictical variables affecting the total discharges of the drains and location of the free surface was the distance from the constant head boundary to the drain system, Li, and thickness of the aquifer, Hr.

The results obtained appear to be reasonable and within limits of possible field occurances. However, using these results for quantifying flows and the free surface locations requires a very careful study and background investigation of all geometric configurations and soil conditions. It is intended that this study has presented the results in a manner that one can observe the effects of the variables studied on such a underdrain system.

In summary, the following observations are discussed for the variables used in this analysis.

<u>Constant Head Boundary Distance, Li</u>

As distance from the constant head boundary to the system increases the flow quantities increase for the drain system. In terms of a correlation with hydraulic head differential above the drain, as used by other authors, this model study shows that for a distance of approximately 15 times the head, discharge appears to decrease. In terms of gradient, this equates to a 1 over 15 ratio or 0.067 gradient. A slightly higher distance was observed in the analysis of this influence to location of the free surface.

Depth of Aquifer, Hr

The results show that with increased aquifer thickness the drain discharge increases, increasing very near to a linear relationship. It was also observed that for the very shallow thicknesses, the last drains collected very little flow. The height of the free surface is affected in the same fashion. With increased thickness of aquifer the height of the free surface increases between drains.

Drain Spacing, Sp

Drain spacing effects on discharge was greatly affected by the distance of the system from the constant head boundary. A substantial increase of 5 to 6 times the discharge was observed for the two distances used in the results presented. It was observed that as head increases, discharge increases for all drain spacings; and as drain spacing increases, discharge decreases. It was also observed that from the dimensional analysis, the most efficient drain spacing is for a spacing over head ratio of less than 2. The location of the free surface was observed to increase between drains as drain spacing is increased.

Drain Width, Dw

With increased drain width the discharge increases for all other variables constant. However, there must be a trade off for efficiency of the complete system. It appears that a drain width between 1 to 2 feet is the most effective width. This is also a plus from a standpoint that lateral seepage can be easily drained into thinner trenches or deeper constructed drains.

Slope of Impervious Boundary, θ

For the distance of the constant head boundary to the drain system equal to 80 feet, the drain discharge was observed to increase with increased slope. However, for the distance, Li equal to 400 feet, the maximum discharge occurs at a slope between 5 to 10 percent. This occurance is not fully understood and perhaps should be further studied to develope some reasoning. This requires that careful consideration of specific boundary geometries be used in model studies for seepage analysis.

CHAPTER 5

CONCLUSSION

In this day and age, more and more sites are chosen for buildings and engineered structures that are less desirable to work with from a standpoint of site conditions, poor soils and water problems. A less desirable site may easily be where the groundwater table is very near to the surface. Therfore the building's design must incorporate some thought into how the groundwater will be handled and what effects it may have on the structure.

Engineers faced with the analysis of seepage for buildings to be built below the groundwater table must consider such conditions of uplift pressures, critical velocities, seepage control of the water itself or particle migration. Hopefully the design will enhance stability of the structure and prolong the usefulness and life of the structure.

In performing the literature review on this topic, it was found that many authors and researchers are more and more relying on and developing computor models to perform the analysis of complex seepage problems. With the use of general seepage theory and mathematical representation of the seepage theories, the computer programs can quickly and efficiently aid the endgineer in studying the flow conditions. As in this study, the analysis of one particular seepage problem using a finite element program made it possible to study many key variables and develope many relationships.

For this study, underdrain systems for buildings built below the groundwater table were researched. By using a finite element program, and by developing a mesh for this particular flow matrix, many variables of the analysis were studied. It was found that the model could easily be used to efficiently and accurately study these variables. [illegible] dicharge of the system and location of the free [illegible] studied in detail versus the [illegible]

This research has attempted [illegible]
and useful criteria [illegible]
seepage problem. [illegible]
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variables of the [illegible]
author must [illegible]
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the engineer [illegible]
parameters [illegible]

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APPENDIX A-1

USER'S MANUAL FOR
ARAL SEEPAGE PROGRAM

I. INTRODUCTION:

This seepage program is a finite element model for solving unconfined or confined two dimensional or axisymetric seepage problems. For unconfined flow analysis the model iterates by moving the free surface nodes to the phreatic level.

In general, the program allows for the porous soil mass to be divided into discrete elements and nodes using either a vertical plane model(two-dimensional,x-y) or axisymmetric grid structure. Then applying known boundary conditions, the program simultaneously solves for each element, the continuity equation which satisfies Darcy's Law.

Figure 1 shows a very simple case of a two dimensional unconfined steady state condition which can serve as an example. In this example the free surface location is unknown and the user must begin the process by initiallizing the input by approximating the location. Then the program will iterate to the free surface level until the free surface converges to satisfy the equations of flow.

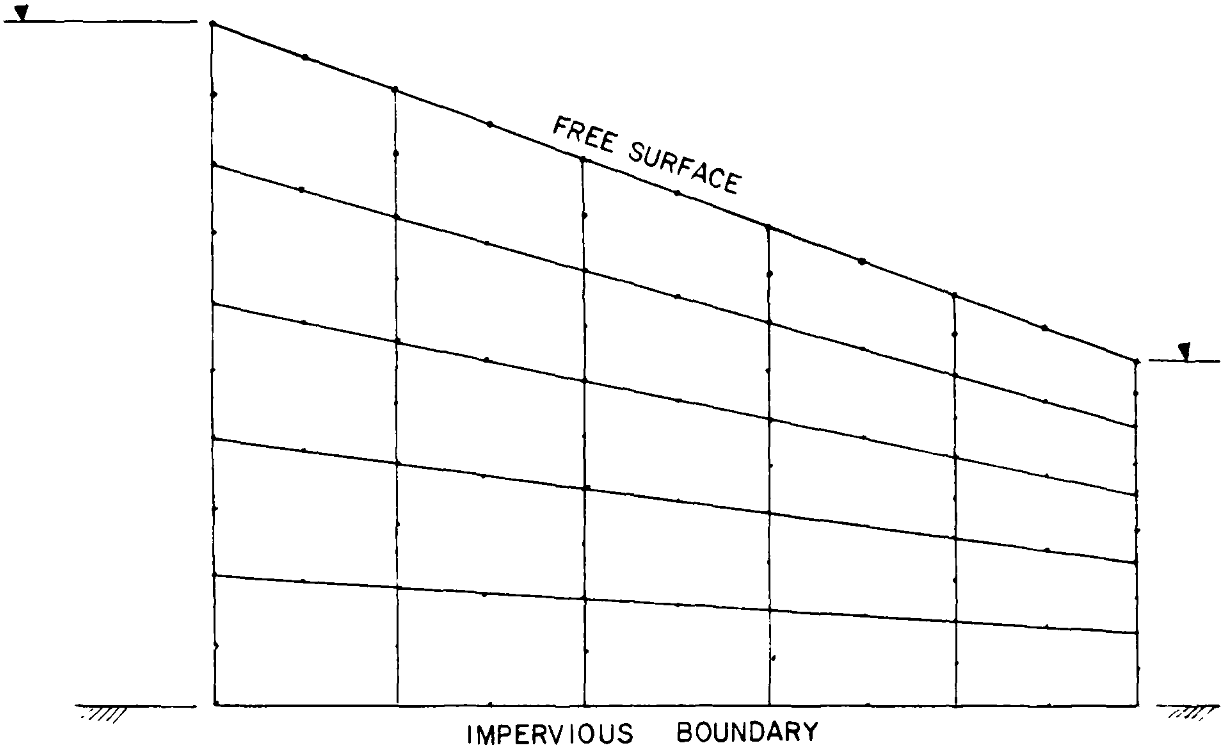


Figure 1 Example Grid for Unconfined Flow Continum.

II. PROGRAM EXECUTION AND ANALYSIS:

The user has the option of performing a two dimensional problem or an axisymmetric problem. The two dimensional case simply show b figure 1 will serve as an example to explain the parameters. An axisymetric application might be a well source problem looking at stratified soils having varying permeabilities at different elevations through the porous media.

III. BOUNDARY CONDITIONS OF FLOW:

The potential, ϕ, of flow must be defined as some directional function

$$\phi = f(x,y,z,t)$$

A Dirichlet boundary condition is where the piezometric head, h is constant, or

$$h = f(x,y,z,t)$$

is solved for at a particular point. This boundary condition occurs whenever the flow domain is adjacent to an open body of fluid. Since the piezometric head is constant at the open body of water, the piezometric head of the porous media at the interface will be constant. This boundary condition denotes a non- zero flux or flow is to be considered possible.

Another boundary condition for flow potential is the Neuman boundaries. This is the case where flow cannot move through the porous media at a specific point defined, i.e. an impervious layer of stratum.

IV. FINITE ELEMENT GRID NOTATION:

The porous soil mass to be analysed must be divided into a grid of elements and nodes. The program uses any shape second-order isoparametric element, shown by figure 2 as a quadralateral element containing four corner nodes and four midpoint nodes.

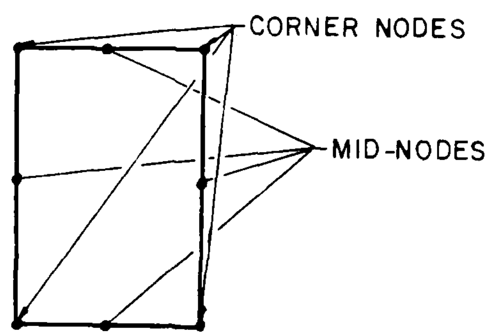


Figure 2 Element and Node Notation.

The nodes must be numbered from some beginning corner, preferably the number one node should be at the bottom left corner of the mesh. Then node numbering increases to the end of each column, beginning at the bottom of each column throughout the mesh. One can see the numbering scheme by the examples presented. Elements are numbered the same as the nodes.

The program automatically generates nodes at equal spacing between corner nodes which are defined by the user. This feature requires that careful attention be made to the node numbering scheme once corner nodes have been established. This feature is good for creating finer mesh grids in particular areas of interest.

Base elements are used to create stationary reference elements typically at the bottom of the mesh or away from the free surface elements. These elements are also used to define changes in hydraulic conductivity in the x and y directions(Kx and Ky).

The free surface or phreatic surface of a media is defined by the user as a first approximation of it's actual location. In the case of a cutoff wall, shown in Figure 3, there is no free surface and the seepage model solves for the flow characteristics of each element and node. However, in the case of a dam as shown in Figure 3, the free surface is unknown and the program will solve for the phreatic surface where the fluid pressure is at atmospheric pressure. In confined aquifers the water pressures would possible be higher than atmospheric pressure.

Seepage faces are defined by the user to denote a boundary or where seepage is to be allowed. Here flow is qunatified and the model solves for the velocity and discharge at this face.

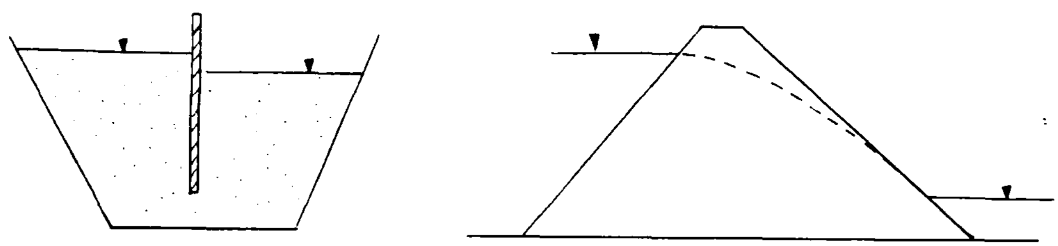


Figure 3 Example of confined flow and unconfined flow.

Permeability of the porous media often depends on the direction of flow. For the condition of soil matrix being anisotropic the velocities and gradients are generally not parallel. For this condition the velocities can be written in the Darcy Law form:

$$Vx = -Kxx \frac{\partial h}{\partial x}$$

$$Vy = -Kyy \frac{\partial h}{\partial y}$$

$$Vz = -Kzz \frac{\partial h}{\partial z}$$

Normally the hydraulic conductivity of teh media is similar in the y direction. Therfore treatment of this normal condition requires use of only two direcetions. For this simplification, the program uses the notation of the two dimensional case. Figure 4 shows the notation that should be used for describing the hydraulic conductivity conditions.

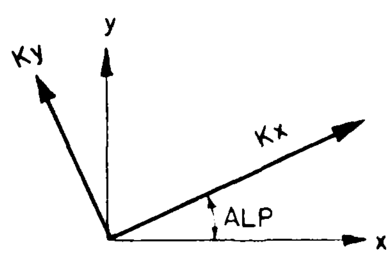


Figure 4 Hydraulic Conductivity Notation.

V. INPUT VARIABLES AND DATA INPUT

Input can be given in unformated notation where each data input is seperated by a comma or space. Careful attention, however, must be made to use the apppropriate number input data per line as described by this guide.

Title and Type Problem Card.

TITLE The title can be up to 72 characters.

DIMEN Flow problem e problem is a two dimensional analysis input 2 and for an axisymetric problem input 1.

Plane Flow Problem	2
Axisymetric Problem	1

FERR Having performed a sensitivity of the model or decided on an error critiria, input the error required.

Control cards

NNPC Total number of corner nodal points.
These nodes are used to define corners of elements which are defined by input coordinates. Nodes that are not listed will be generated between two corner nodes for each vertical column or row deliniation.

NELEMC Total number of base elements.
Base elements are typically at the bottom of a series of elements that change the hydraulic conductivity of the elements above these base elements. These elements are established as reference elements for the program to describe permeability of each element.

NFBOC Total number of Neuman Boundary Faces.
A Neuman face is defined as a line of nodes that may create a barrior or impervious wall for the flow. If two corner nodes define a line of several nodes that makes an impervious barrier, this is one Neuman Boundary face.

NFFS Total number of corner nodes on the free surface.
The user must specify particular corner nodes which reflect the first approximation of the unknown free surface. The program uses these nodes and the midpoint nodes to converge to the free surface.

ITGIV Number of iterations desired.
This is a safety feature for possible input errors and computor time limitation.

NPBDC Total number of Dirichlet Boundary faces.
Flow is allowed at these faces. Do not count the mid point nodes as part of the face.

NSPFAC Total number of seepage faces with Dirichlet boundaries. For each face defined by two corner nodes for the NPBDC input variable a NSPFAC value should be given. As in

NPBDC = 2 NSPFAC = 1

NPBDC = 3 NSPFAC = 2

ITIME Time variable. Input 0 = time independent.
This is used for transient computation and is not used in steady state computations.

Corner Node Location Cards

Corner node number (n)

x(n) x coordinate of node(n)

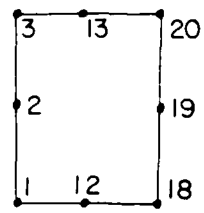
y(n) y coordinate of node(n)

Note: There should be NNPC number of these cards. Use appropriate dimensions, i.e. feet, meters which will be carried throughout the remaining input variables.

NPMIS Enter a "1" or "0" where
1 - additional nodes are to be generated after this node.
0 - no nodes will be generated after this node.

Base Reference Elements Identification Cards

NOD For each base element(N), give a counter-clockwise numbering for each node in the element.

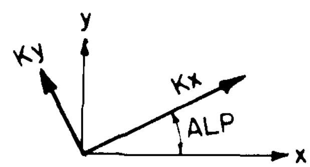


NMIS Total number of elements above the base element before the next base element.

XK(N) Hydraulic conductivity of the elements defined by the base element in the x direction.

YK(N) Hydraulic conductivity in the y direction.

ALP(N) Angle of possible stratification or plane of soil matrix with the horizontal.



Note: There should be NELEMC number of these cards provided.

Neuman Boundary Condition Cards

NSTART The beginning or lowest corner node number of each Neuman Boundary defined.

BVAL The Neuman Boundary value that defines the known potential height or water level measured from the datum reference line of the coordinate system.

NBSAME Total number of boundary faces having same Neuman boundary condition. Each face is a line made by two corner nodes of the same Neuman boundary.

NINC The number of nodal number increases or numerical difference to the next corner node from node NSTART. Do not count mid-nodes only corner nodes.

Note: There should be NFBOC cards provided for this set.

Dirichlet Boundary Condition Cards

NSTAR The beginning or lowest corner node number which defines each Dirichlet boundary.

DBVAL The Dirichlet boundary value that defines the potential or water level height measured from the data reference elevation of the coordinate system.

NDSAME Total number of boundary faces of this Dirichlet boundary condition. Each face is counted between corner nodes defining the boundary or number of elements.

NDINC The number of nodal number increases or numerical difference to the next corner node from node NSTAR.

NMID The number of nodal number increases from the NSTAR to the next mid-node.

Note: There should be NFBDC cards provided for this set.

Free Surface Nodal Cards (Maximum 16 pairs per card)

NFFSA Free surface corner node number.

NFBOT Node number of the bottom of the movable section of the grid that defines the limits of moving nodes for NFFSA.

Note: There should be NFFS pairs of node numbers given for a maximum of 16 pairs per card. Use as many cards as required. The bottom node (NFBOT) defines the bottom of a seepage face corresponding to the grid geometry and corner node defining the free surface. The program uses this band of nodes and elements to converge on the free surface.

Mid-point Free Surface Nodal Cards.

NPFSM The mid-point nodal numbers between corner nodes defining the free surface (NPFS - 1).

Seepage Face Cards

NSPC Beginning node number of the defined seepage face.

NSSAME Number of seepage faces defined by elements for this seepage face NSPC.

NSINC Node numbering increase between nodes defined by NSSAME.

Note: There should be NSPFAC cards provided for this set.

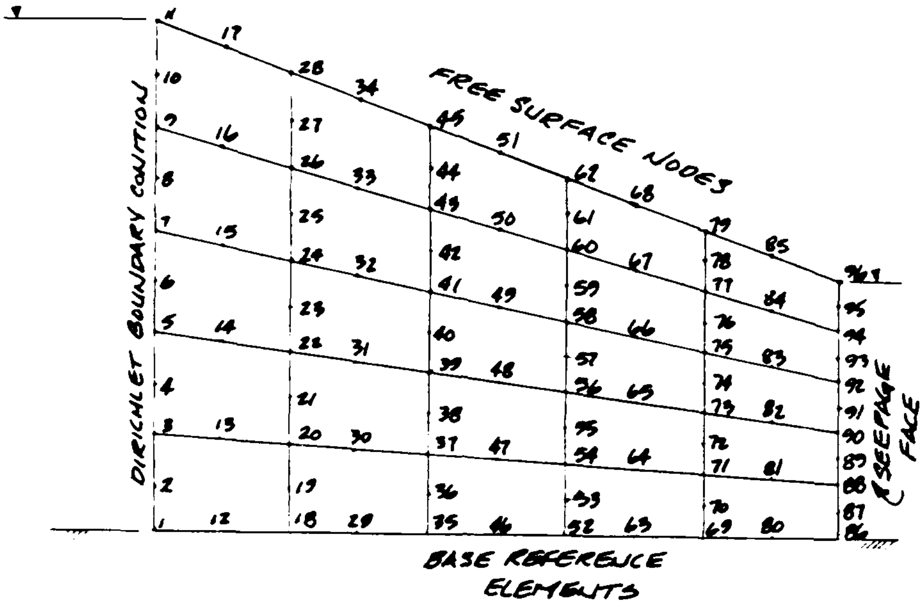
Statement and End Card

End of Problem Statement should be less than 72 characters and end with a period.

NDIMEN Input a "3" to end the problem.

ERR Specify any error as for FERR.

UNCONFINED FLOW EXAMPLE PROBLEM



Title and Type Problem Card

TITLE - SILTY SAND DAM

DIMEN - 2 (two dimensional)
FERR - 0.01 (error criterion is 0.01)

Control Cards

NMPC - 12 (corner nodes are 18, 52 35, 45, 52, 62, 69, 79, 86 and 96)
NELEMC- 5 (five base elements - shaded)
NPBOC - 0 (no Neuman Boundaries)
NPFS - 6 (6 nodal points on the free surface - 11, 28, 45, 62, 79 and 96)
ITGIV - 50 (maximum number of iterations)
NPBDC - 2 (There are two faces with Dirichlet boundary conditions, the left side and the right side of the mesh which forms the dam)
NSPFAC- 1 (There is one seepage face - on the right side where flow is to be considered.)
ITIME - 0 (Time independent for steady state conditions)

Corner Node Location Cards

1,0,0,1

Where, the first node is number 1 having an x coordinate of 0 and a y coordinate of 0. Generation of additional nodes will follow.

11,0,110,0

Where, node 11 is at the end of the first column at coordinates 0 and 110 and no generation is required for other nodes in this column.

18,200,0,1
28,200,99,0
35,400,0,1
45,400,88,0
52,600,0,1
62,600,77,0
69,800,0,1
79,800,66,0
86,1000,0,1
96,1000,55,0

Base Reference Elements Identification Cards

1,12,18,19,20,13,3,2,4,0.002,0.002,0

Counter clockwise numbering of nodes for each element and the permeability, 0.002 ft/day for this base element and 4 elements above the base element.

18,29,35,36,37,30,20,19,4,0.002,0.002,0
35,46,52,53,54,47,37,36,4,0.002,0.002,0
52,63,69,70,71,64,54,53,4,0.002,0.002,0
69,80,86,87,88,81,71,70,4,0.002,0.002,0

Neuman Boundary Condition Cards

None specified, so no cards will be provided

Dirichlet Boundary Condition Cards

1,110,5,2,1
86,55,5,2,1

The first node of the first Dirichlet Boundary is node 1 and the DBVAL value is 110 feet. There are 5 elements on this face that makes this Dirichlet boundary condition, NDSAME = 5. NDINC equals 2 for the nodal number increase for the consecutive elements, as in 3 - 1, 5 - 3, 7 - 5, etc. NMID equals 1 for the node numbering increase between successive nodes.

Free Surface Nodal Cards

11,1,28,18,45,35,62,52,79,69,96,86

Here the total mesh is allowed to move, where the user may fix the bottom nodes at any level in the mesh.

Mid-point Free Surface Nodal Cards

17,34,51,68,85

Seepage Face Cards

86,2,2

The seepage is prescribed to start at node 86, NSFC = 86, and there are 2 elements for this seepage face. NSINC is equal to 2 as there is a two nodal increase between element corner nodes, as is 88 - 86 and 90 - 88.

Statement and End Card

END OF SILTY SAND DAM.
3,.001

```
SILTY SAND DAM .
2,0.01
12,5,0,6,50,2,1,0
1,0,0,1
11,0,110,0
18,200,0,1
28,200,99,0
35,400,0,1
45,400,88,0
52,600,0,1
62,600,77,0
69,800,0,1
79,800,66,0
86,1000,0,1
96,1000,55,0
1,12,18,19,20,13,3,2,4,0.002,0.002,0
18,29,35,36,37,30,20,19,4,0.002,0.002,0
35,46,52,53,54,47,37,36,4,0.002,0.002,0
52,63,69,70,71,64,54,53,4,0.002,0.002,0
69,80,86,87,88,81,71,70,4,0.002,0.002,0
1,110,5,2,1
86,55,5,2,1
11,1,28,18,45,35,62,52,79,69,96,86
17,34,51,68,85
86,2,2
END OF SILTY SAND DAM.
3,0.01
```

SILTY SAND DAM .

DIMEN = 2 FERR = .01000

NNPC = 12 NELEMC = 5 NPBOC = 0 NPFS = 6 ITGIV = 50 NPSDC = 2 NSPFAC = 1 ITIME = 0

GENERATED NODAL POINT DATA AND (X)-(Y) COORDINATES

NODE 1	X= 0.0000	Y= 0.0000
NODE 3	X= 0.0000	Y= 22.0000
NODE 5	X= 0.0000	Y= 44.0000
NODE 7	X= 0.0000	Y= 66.0000
NODE 9	X= 0.0000	Y= 88.0000
NODE 11	X= 0.0000	Y= 110.0000
NODE 18	X= 200.0000	Y= 0.0000
NODE 20	X= 200.0000	Y= 19.8000
NODE 22	X= 200.0000	Y= 39.6000
NODE 24	X= 200.0000	Y= 59.4000
NODE 26	X= 200.0000	Y= 79.2000
NODE 28	X= 200.0000	Y= 99.0000
NODE 35	X= 400.0000	Y= 0.0000
NODE 37	X= 400.0000	Y= 17.6000
NODE 39	X= 400.0000	Y= 35.2000
NODE 41	X= 400.0000	Y= 52.8000
NODE 43	X= 400.0000	Y= 70.4000
NODE 45	X= 400.0000	Y= 88.0000
NODE 52	X= 600.0000	Y= 0.0000
NODE 54	X= 600.0000	Y= 15.4000
NODE 56	X= 600.0000	Y= 30.8000
NODE 58	X= 600.0000	Y= 46.2000
NODE 60	X= 600.0000	Y= 61.6000
NODE 62	X= 600.0000	Y= 77.0000
NODE 69	X= 800.0000	Y= 0.0000
NODE 71	X= 800.0000	Y= 13.2000
NODE 73	X= 800.0000	Y= 26.4000
NODE 75	X= 800.0000	Y= 39.6000
NODE 77	X= 800.0000	Y= 52.8000
NODE 79	X= 800.0000	Y= 66.0000
NODE 86	X= 1000.0000	Y= 0.0000
NODE 88	X= 1000.0000	Y= 11.0000
NODE 90	X= 1000.0000	Y= 22.0000
NODE 92	X= 1000.0000	Y= 33.0000
NODE 94	X= 1000.0000	Y= 44.0000
NODE 96	X= 1000.0000	Y= 55.0000

NUMBER OF NODAL POINTS... 96

NUMBER OF ELEMENTS....... 25

ELE. NO. NODAL POINTS

1	1	12	18	19	20	13	3	2	.20000E-02	.20000E-02	0.
2	3	13	20	21	22	14	5	4	.20000E-02	.20000E-02	0.
3	5	14	22	23	24	15	7	6	.20000E-02	.20000E-02	0.
4	7	15	24	25	26	16	9	8	.20000E-02	.20000E-02	0.
5	9	16	26	27	28	17	11	10	.20000E-02	.20000E-02	0.
6	18	29	35	36	37	30	20	19	.20000E-02	.20000E-02	0.
7	20	30	37	38	39	31	22	21	.20000E-02	.20000E-02	0.
8	22	31	39	40	41	32	24	23	.20000E-02	.20000E-02	0.
9	24	32	41	42	43	33	26	25	.20000E-02	.20000E-02	0.
10	26	33	43	44	45	34	28	27	.20000E-02	.20000E-02	0.
11	35	46	52	53	54	47	37	36	.20000E-02	.20000E-02	0.
12	37	47	54	55	56	48	39	38	.20000E-02	.20000E-02	0.
13	39	48	56	57	58	49	41	40	.20000E-02	.20000E-02	0.
14	41	49	58	59	60	50	43	42	.20000E-02	.20000E-02	0.
15	43	50	60	61	62	51	45	44	.20000E-02	.20000E-02	0.
16	52	63	69	70	71	64	54	53	.20000E-02	.20000E-02	0.
17	54	64	71	72	73	65	56	55	.20000E-02	.20000E-02	0.
18	56	65	73	74	75	66	58	57	.20000E-02	.20000E-02	0.
19	58	66	75	76	77	67	60	59	.20000E-02	.20000E-02	0.
20	60	67	77	78	79	68	62	61	.20000E-02	.20000E-02	0.
21	69	80	86	87	88	81	71	70	.20000E-02	.20000E-02	0.
22	71	81	88	89	90	82	73	72	.20000E-02	.20000E-02	0.
23	73	82	90	91	92	83	75	74	.20000E-02	.20000E-02	0.
24	75	83	92	93	94	84	77	76	.20000E-02	.20000E-02	0.
25	77	84	94	95	96	85	79	78	.20000E-02	.20000E-02	0.

DIRICHLET BOUNDARY CONDITION DATA

NODES	RESPECTIVE DIRICHLET BOUNDARY CONDITIONS	
1- 2	110.0000	110.0000
3- 4	110.0000	110.0000
5- 6	110.0000	110.0000
7- 8	110.0000	110.0000
9- 10	110.0000	110.0000
11- 10	110.0000	110.0000
86- 87	55.0000	55.0000
88- 89	55.0000	55.0000
90- 91	55.0000	55.0000
92- 93	55.0000	55.0000
94- 95	55.0000	55.0000
96- 95	55.0000	55.0000

NODAL POINTS ON FREE SURFACE

11 17 28 34 45 51 62 68 79 85 96 0

SEEPAGE FACE NODAL POINT DATA
CONSECUTIVE NODE NUMBERS ON THE SEEPAGE FACE

86- 88
88- 90

ITER = 1

NEW COORDINATES OF THE FREE SURFACE LINE

```
NODE: 79    X =  800.0000    Y =  69.5371
NODE: 62    X =  600.0000    Y =  81.7768
NODE: 45    X =  400.0000    Y =  92.3734
NODE: 28    X =  200.0000    Y = 101.7151
NODE: 11    X =    0.0000    Y = 110.0000
```

CONVERGENCE CHECK ERROR = .1710E-02

NODE	X COORDINATE	Y COORDINATE	V-POTENTIAL	X-VELOCITY	Y-VELOCITY	TOTAL VELO.	PRES. COEF
1	0.0000	0.0000	110.0000	-.8318E-04	-.1125E-08	.8318E-04	
2	0.0000	11.0000	110.0000	-.8315E-04	-.1587E-15	.8315E-04	
3	0.0000	22.0000	110.0000	-.8308E-04	.8251E-07	.8308E-04	
4	0.0000	33.0000	110.0000	-.8298E-04	0.	.8298E-04	
5	0.0000	44.0000	110.0000	-.8279E-04	.1758E-06	.8279E-04	
6	0.0000	55.0000	110.0000	-.8255E-04	0	.8255E-04	
7	0.0000	66.0000	110.0000	-.8227E-04	.2920E-08	.8227E-04	
8	0.0000	77.0000	110.0000	-.8191E-04	0.	.8191E-04	
9	0.0000	88.0000	110.0000	-.8149E-04	.4499E-08	.8149E-04	
10	0.0000	99.0000	110.0000	-.8099E-04	.1058E-15	.8099E-04	
11	0.0000	110.0000	110.0000	-.8045E-04	.7677E-08	.8045E-04	
12	100.0000	0.0000	105.7709	-.8600E-04	-.2139E-07	.8600E-04	
13	100.0000	21.1715	105.7743	-.8595E-04	.5574E-06	.8595E-04	
14	100.0000	42.3430	105.7848	-.8582E-04	.1131E-05	.8583E-04	
15	100.0000	63.5145	105.8024	-.8560E-04	.1739E-05	.8562E-04	
16	100.0000	84.6860	105.8283	-.8530E-04	.2403E-05	.8533E-04	
17	100.0000	105.8575	105.8638	-.8491E-04	.3223E-05	.8497E-04	
18	200.0000	0.0000	101.4005	-.8895E-04	.1186E-07	.8895E-04	
19	200.0000	10.1715	101.4014	-.8895E-04	.3873E-06	.8895E-04	
20	200.0000	20.3430	101.4044	-.8895E-04	.8187E-06	.8895E-04	
21	200.0000	30.5145	101.4092	-.8895E-04	.1157E-05	.8896E-04	
22	200.0000	40.6860	101.4162	-.8895E-04	.1630E-05	.8896E-04	
23	200.0000	50.8575	101.4248	-.8896E-04	.1909E-05	.8898E-04	
24	200.0000	61.0291	101.4356	-.8896E-04	.2431E-05	.8899E-04	
25	200.0000	71.2006	101.4480	-.8898E-04	.2622E-05	.8902E-04	
26	200.0000	81.3721	101.4622	-.8899E-04	.3206E-05	.8905E-04	
27	200.0000	91.5436	101.4780	-.8904E-04	.3255E-05	.8910E-04	
28	200.0000	101.7151	101.4954	-.8904E-04	.3964E-05	.8913E-04	
29	300.0000	0.0000	96.8349	-.9358E-04	.6799E-09	.9358E-04	
30	300.0000	19.4088	96.8392	-.9354E-04	.8735E-06	.9355E-04	
31	300.0000	38.8177	96.8518	-.9350E-04	.1745E-05	.9352E-04	
32	300.0000	58.2265	96.8730	-.9343E-04	.2611E-05	.9346E-04	
33	300.0000	77.6354	96.9026	-.9332E-04	.3468E-05	.9339E-04	
34	300.0000	97.0442	96.9408	-.9318E-04	.4331E-05	.9328E-04	
35	400.0000	0.0000	92.0447	-.9801E-04	-.4037E-08	.9801E-04	
36	400.0000	9.2373	92.0459	-.9801E-04	.4921E-06	.9801E-04	
37	400.0000	18.4747	92.0492	-.9800E-04	.9788E-06	.9800E-04	
38	400.0000	27.7120	92.0549	-.9798E-04	.1475E-05	.9799E-04	
39	400.0000	36.9494	92.0629	-.9795E-04	.1957E-05	.9797E-04	
40	400.0000	46.1867	92.0731	-.9792E-04	.2454E-05	.9795E-04	
41	400.0000	55.4240	92.0855	-.9788E-04	.2933E-05	.9792E-04	
42	400.0000	64.6614	92.1002	-.9783E-04	.3423E-05	.9789E-04	
43	400.0000	73.8987	92.1172	-.9778E-04	.3906E-05	.9786E-04	
44	400.0000	83.1361	92.1362	-.9772E-04	.4369E-05	.9782E-04	
45	400.0000	92.3734	92.1575	-.9765E-04	.4874E-05	.9777E-04	
46	500.0000	0.0000	86.9674	-.1043E-03	.2146E-08	.1043E-03	
47	500.0000	17.4150	86.9922	-.1043E-03	.1113E-05	.1043E-03	
48	500.0000	34.8300	87.0086	-.1043E-03	.2223E-05	.1043E-03	
49	500.0000	52.2451	87.0306	-.1042E-03	.3326E-05	.1042E-03	
50	500.0000	69.6601	87.0642	-.1040E-03	.4420E-05	.1041E-03	
51	500.0000	87.0751	87.1073	-.1039E-03	.5508E-05	.1040E-03	
52	600.0000	0.0000	81.6116	-.1106E-03	-.6594E-08	.1106E-03	
53	600.0000	8.1777	81.6129	-.1106E-03	.6378E-06	.1106E-03	
54	600.0000	16.3554	81.6168	-.1106E-03	.1270E-05	.1106E-03	
55	600.0000	24.5330	81.6234	-.1106E-03	.1910E-05	.1106E-03	
56	600.0000	32.7107	81.6325	-.1105E-03	.2539E-05	.1106E-03	
57	600.0000	40.8884	81.6441	-.1105E-03	.3171E-05	.1105E-03	
58	600.0000	49.0661	81.6584	-.1104E-03	.3802E-05	.1105E-03	
59	600.0000	57.2438	81.6751	-.1103E-03	.4405E-05	.1104E-03	
60	600.0000	65.4214	81.6944	-.1102E-03	.5053E-05	.1103E-03	
61	600.0000	73.5991	81.7160	-.1101E-03	.5569E-05	.1103E-03	
62	600.0000	81.7768	81.7401	-.1100E-03	.6295E-05	.1102E-03	
63	700.0000	0.0000	75.8434	-.1202E-03	.3217E-09	.1202E-03	
64	700.0000	15.1314	75.8489	-.1202E-03	.1461E-05	.1202E-03	
65	700.0000	30.2628	75.8655	-.1201E-03	.2916E-05	.1201E-03	
66	700.0000	45.3942	75.8932	-.1200E-03	.4358E-05	.1201E-03	
67	700.0000	60.5256	75.9322	-.1199E-03	.5782E-05	.1200E-03	
68	700.0000	75.6570	75.9827	-.1197E-03	.7233E-05	.1199E-03	
69	800.0000	0.0000	69.5822	-.1301E-03	.1615E-07	.1301E-03	
70	800.0000	6.9537	69.5835	-.1301E-03	.8277E-06	.1301E-03	
71	800.0000	13.9074	69.5880	-.1300E-03	.1849E-05	.1300E-03	
72	800.0000	20.8611	69.6049	-.1299E-03	.2461E-05	.1299E-03	
73	800.0000	27.8149	69.6151	-.1298E-03	.3671E-05	.1298E-03	
74	800.0000	34.7686	69.6275	-.1296E-03	.4024E-05	.1297E-03	
75	800.0000	41.7223	69.6431	-.1294E-03	.5431E-05	.1295E-03	
76	800.0000	48.6760	69.6606	-.1292E-03	.5456E-05	.1293E-03	
77	800.0000	55.6297	69.6810	-.1288E-03	.7083E-05	.1290E-03	
78	800.0000	62.5834	69.7030	-.1286E-03	.8670E-05	.1287E-03	
79	800.0000	69.5371	69.7274	-.1282E-03	.8670E-05	.1285E-03	
80	900.0000	0.0000	62.6858	-.1459E-03	-.1108E-06	.1459E-03	
81	900.0000	12.4537	62.6925	-.1460E-03	.1723E-05	.1460E-03	
82	900.0000	24.9074	62.7129	-.1460E-03	.3476E-05	.1461E-03	
83	900.0000	37.3611	62.7475	-.1462E-03	.5290E-05	.1463E-03	
84	900.0000	49.8148	62.7972	-.1464E-03	.7196E-05	.1466E-03	
85	900.0000	62.2686	62.8634	-.1466E-03	.9437E-05	.1469E-03	
86	1000.0000	0.0000	55.0000	-.1615E-03	-.1787E-06	.1615E-03	
87	1000.0000	5.5000	55.0000	-.1616E-03	.1058E-15	.1616E-03	
88	1000.0000	11.0000	55.0000	-.1617E-03	.5021E-08	.1617E-03	
89	1000.0000	16.5000	55.0000	-.1620E-03	-.1058E-15	.1620E-03	
90	1000.0000	22.0000	55.0000	-.1623E-03	.1034E-05	.1623E-03	
91	1000.0000	27.5000	55.0000	-.1629E-03	0.	.1629E-03	
92	1000.0000	33.0000	55.0000	-.1634E-03	.1627E-05	.1634E-03	
93	1000.0000	38.5000	55.0000	-.1642E-03	0.	.1642E-03	
94	1000.0000	44.0000	55.0000	-.1649E-03	.2319E-05	.1650E-03	
95	1000.0000	49.5000	55.0000	-.1661E-03	0	.1661E-03	
96	1000.0000	55.0000	55.0000	-.1688E-03	.3328E-05	.1688E-03	

SEEPAGE FACE COMPUTATION RESULTS

```
NB =   86   NE =   88   AVE. VEL = .16180E-03   DS = .11000E+02   DQ = .17778E-02
       TOTAL DISCHARGE =     .17778E-02
NB =   88   NE =   90   AVE. VEL = .16202E-03   DS = .11000E+02   DQ = .17822E-02
       TOTAL DISCHARGE =     .35600E-02
```

END OF SILTY SAND DAM

DIMEN = 3   PERR = .01000

APPENDIX B-1

SAMPLE INPUT
AND OUTPUT

```
 RUN ADS2    SP = 25 FEET    DEPTH = 20 FEET  K = .2.  DEPTH = 58'.
2,0.0001
93,30,0,30,20,6,5,0
1,-340,0,1
5,-340,34,1
11,-340,78.0,0
18,-200,0,1
22,-200,34,1
28,-200,78.0,0
35,-80,0,1
39,-80,34,1
45,-80,77.0,0
52,0,0,1
56,0,34,1
62,0,74.0,0
69,50,0,1
73,50,34,1
79,50,71.0,0
86,58.75,0,1
90,58.75,34,1
96,59.0,58.0,0
103,62.0,0,1
107,62.0,34,1
113,61.0,58.0,0
120,66.0,0,1
124,66.0,34,1
130,65.0,60.0,0
137,70.0,0,1
141,70.0,34,1
147,69.0,60.0,0
154,74.0,0,1
158,74.0,34,1
164,75.0,60.0,0
171,78.0,0,1
175,78.0,34,1
181,79.0,60.0,0
188,82.0,0,1
192,82.0,34,1
198,83.0,58.0,0
205,86.0,0,1
209,86.0,34,1
215,85.0,58.0,0
222,90.0,0,1
226,90.0,34,1
232,89.0,60.0,0
239,94.0,0,1
243,94.0,34,1
249,93.0,60.0,0
256,98.0,0,1
260,98.0,34,1
266,99.0,60.0,0
273,102.0,0,1
277,102.0,34,1
283,103.0,60.0,0
290,106.0,0,1
294,106.0,34,1
300,107.0,58.0,0
307,110.0,0,1
311,110.0,34,1
317,109.0,58.0,0
```

```
324,114.0,0,1
328,114.0,34,1
334,113.0,60.0,0
341,118.0,0,1
345,118.0,34,1
351,117.0,60.0,0
358,122.0,0,1
362,122.0,34,1
368,123.0,60.0,0
375,126.0,0,1
379,126.0,34,1
385,127.0,60.0,0
392,130.0,0,1
396,130.0,34,1
402,131.0,58.0,0
409,134.0,0,1
413,134.0,34,1
419,133.0,58.0,0
426,138.0,0,1
430,138.0,34,1
436,137.0,60.0,0
443,142.0,0,1
447,142.0,34,1
453,141.0,60.0,0
460,146.0,0,1
464,146.0,34,1
470,147.0,60.0,0
477,150.0,0,1
481,150.0,34,1
487,151.0,60.0,0
494,154.0,0,1
498,154.0,34,1
504,155.0,58.0,0
511,156.0,0,1
515,156.0,34,1
521,156.0,58.0,0
1,12,18,19,20,13,3,2,4,0.2,0.2,0.0
18,29,35,36,37,30,20,19,4,0.2,0.2,0.0
35,46,52,53,54,47,37,36,4,0.2,0.2,0.0
52,63,69,70,71,64,54,53,4,0.2,0.2,0.0
69,80,86,87,88,81,71,70,4,0.2,0.2,0.0
86,97,103,104,105,98,88,87,4,0.2,0.2,0.0
103,114,120,121,122,115,105,104,4,0.2,0.2,0.0
120,131,137,138,139,132,122,121,4,0.2,0.2,0.0
137,148,154,155,156,149,139,138,4,0.2,0.2,0.0
154,165,171,172,173,166,156,155,4,0.2,0.2,0.0
171,182,188,189,190,183,173,172,4,0.2,0.2,0.0
188,199,205,206,207,200,190,189,4,0.2,0.2,0.0
205,216,222,223,224,217,207,206,4,0.2,0.2,0.0
222,233,239,240,241,234,224,223,4,0.2,0.2,0.0
239,250,256,257,258,251,241,240,4,0.2,0.2,0.0
256,267,273,274,275,268,258,257,4,0.2,0.2,0.0
273,284,290,291,292,285,275,274,4,0.2,0.2,0.0
290,301,307,308,309,302,292,291,4,0.2,0.2,0.0
307,318,324,325,326,319,309,308,4,0.2,0.2,0.0
324,335,341,342,343,336,326,325,4,0.2,0.2,0.0
341,352,358,359,360,353,343,342,4,0.2,0.2,0.0
358,369,375,376,377,370,360,359,4,0.2,0.2,0.0
375,386,392,393,394,387,377,376,4,0.2,0.2,0.0
392,403,409,410,411,404,394,393,4,0.2,0.2,0.0
```

```
409,420,426,427,428,421,411,410,4,0.2,0.2,0.0
426,437,443,444,445,438,428,427,4,0.2,0.2,0.0
443,454,460,461,462,455,445,444,4,0.2,0.2,0.0
460,471,477,478,479,472,462,461,4,0.2,0.2,0.0
477,488,494,495,496,489,479,478,4,0.2,0.2,0.0
494,505,511,512,513,506,496,495,4,0.2,0.2,0.0
1,78.0,5,2,1
96,58.0,1,17,6
198,58.0,1,17,6
300,58.0,1,17,6
402,58.0,1,17,6
504,58.0,1,17,6
11,5,28,22,45,39,62,56,79,73,96,90,113,107,130,124
147,141,164,158,181,175,198,192,215,209,232,226,249,243,266,260
283,277,300,294,317,311,334,328,351,345,368,362,385,329,402,396
419,413,436,430,453,447,470,464,487,481,504,498
17,34,51,68,85,102,119,136,153,170,187,204,221,238,255,272
289,306,323,340,357,374,391,408,425,442,459,476,493
96,1,17,198,1,17,300,1,17,402,1,17,504,1,17
SP=25..K = .2..D = 20 FT...END OF PROBLEM.
3,0.0001
```

```
1            RUN AD52   SP = 25 FEET   DEPTH = 20 FEET  K = .2.  DEPTH = 58'.
NDIMEN =         2          FERR =    .00010

  NNPC = 93   NELEMC = 30   NPBDC =  0   NPFS = 30   ITGIV = 20   NPBDC =  8   NSPFAC =  5   ITIME =  0
   GENERATED NODAL POINT DATA AND (X)-(Y) COORDINATES
             NODE   1    X=  -340.0000    Y=    0.0000
             NODE   3    X=  -340.0000    Y=   17.0000
             NODE   5    X=  -340.0000    Y=   34.0000
             NODE   7    X=  -340.0000    Y=   48.6667
             NODE   9    X=  -340.0000    Y=   63.3333
             NODE  11    X=  -340.0000    Y=   78.0000
             NODE  18    X=  -200.0000    Y=    0.0000
             NODE  20    X=  -200.0000    Y=   17.0000
             NODE  22    X=  -200.0000    Y=   34.0000
             NODE  24    X=  -200.0000    Y=   48.6667
             NODE  26    X=  -200.0000    Y=   63.3333
             NODE  28    X=  -200.0000    Y=   78.0000
             NODE  35    X=   -80.0000    Y=    0.0000
             NODE  37    X=   -80.0000    Y=   17.0000
             NODE  39    X=   -80.0000    Y=   34.0000
             NODE  41    X=   -80.0000    Y=   48.3333
             NODE  43    X=   -80.0000    Y=   62.6667
             NODE  45    X=   -80.0000    Y=   77.0000
             NODE  52    X=     0.0000    Y=    0.0000
             NODE  54    X=     0.0000    Y=   17.0000
             NODE  56    X=     0.0000    Y=   34.0000
             NODE  58    X=     0.0000    Y=   47.3333
             NODE  60    X=     0.0000    Y=   60.6667
             NODE  62    X=     0.0000    Y=   74.0000
             NODE  69    X=    50.0000    Y=    0.0000
             NODE  71    X=    50.0000    Y=   17.0000
             NODE  73    X=    50.0000    Y=   34.0000
             NODE  75    X=    50.0000    Y=   46.3333
             NODE  77    X=    50.0000    Y=   58.6667
             NODE  79    X=    50.0000    Y=   71.0000
             NODE  86    X=    55.7500    Y=    0.0000
             NODE  88    X=    55.7500    Y=   17.0000
             NODE  90    X=    55.7500    Y=   34.0000
             NODE  92    X=    55.8333    Y=   42.0000
             NODE  94    X=    55.9167    Y=   50.0000
             NODE  96    X=    56.0000    Y=   58.0000
             NODE 103    X=    62.0000    Y=    0.0000
             NODE 105    X=    62.0000    Y=   17.0000
             NODE 107    X=    62.0000    Y=   34.0000
             NODE 109    X=    61.6667    Y=   42.0000
             NODE 111    X=    61.3333    Y=   50.0000
             NODE 113    X=    61.0000    Y=   58.0000
             NODE 120    X=    66.0000    Y=    0.0000
             NODE 122    X=    66.0000    Y=   17.0000
             NODE 124    X=    66.0000    Y=   34.0000
             NODE 126    X=    65.6667    Y=   42.6667
             NODE 128    X=    65.3333    Y=   51.3333
             NODE 130    X=    65.0000    Y=   60.0000
             NODE 137    X=    70.0000    Y=    0.0000
             NODE 139    X=    70.0000    Y=   17.0000
             NODE 141    X=    70.0000    Y=   34.0000
             NODE 143    X=    69.6667    Y=   42.6667
             NODE 145    X=    69.3333    Y=   51.3333
             NODE 147    X=    69.0000    Y=   60.0000
             NODE 154    X=    74.0000    Y=    0.0000
             NODE 156    X=    74.0000    Y=   17.0000

             NODE 158    X=    74.0000    Y=   34.0000
             NODE 160    X=    74.3333    Y=   42.6667
             NODE 162    X=    74.6667    Y=   51.3333
             NODE 164    X=    75.0000    Y=   60.0000
             NODE 171    X=    78.0000    Y=    0.0000
             NODE 173    X=    78.0000    Y=   17.0000
             NODE 175    X=    78.0000    Y=   34.0000
             NODE 177    X=    78.3333    Y=   42.6667
             NODE 179    X=    78.6667    Y=   51.3333
             NODE 181    X=    79.0000    Y=   60.0000
             NODE 188    X=    82.0000    Y=    0.0000
             NODE 190    X=    82.0000    Y=   17.0000
             NODE 192    X=    82.0000    Y=   34.0000
             NODE 194    X=    82.3333    Y=   42.0000
             NODE 196    X=    82.6667    Y=   50.0000
             NODE 198    X=    83.0000    Y=   58.0000
             NODE 205    X=    86.0000    Y=    0.0000
             NODE 207    X=    86.0000    Y=   17.0000
             NODE 209    X=    86.0000    Y=   34.0000
             NODE 211    X=    85.6667    Y=   42.0000
             NODE 213    X=    85.3333    Y=   50.0000
             NODE 215    X=    85.0000    Y=   58.0000
             NODE 222    X=    90.0000    Y=    0.0000
             NODE 224    X=    90.0000    Y=   17.0000
             NODE 226    X=    90.0000    Y=   34.0000
             NODE 228    X=    89.6667    Y=   42.6667
             NODE 230    X=    89.3333    Y=   51.3333
             NODE 232    X=    89.0000    Y=   60.0000
             NODE 239    X=    94.0000    Y=    0.0000
             NODE 241    X=    94.0000    Y=   17.0000
             NODE 243    X=    94.0000    Y=   34.0000
             NODE 245    X=    93.6667    Y=   42.6667
             NODE 247    X=    93.3333    Y=   51.3333
             NODE 249    X=    93.0000    Y=   60.0000
             NODE 256    X=    98.0000    Y=    0.0000
             NODE 258    X=    98.0000    Y=   17.0000
             NODE 260    X=    98.0000    Y=   34.0000
             NODE 262    X=    98.3333    Y=   42.6667
             NODE 264    X=    98.6667    Y=   51.3333
             NODE 266    X=    99.0000    Y=   60.0000
             NODE 273    X=   102.0000    Y=    0.0000
             NODE 275    X=   102.0000    Y=   17.0000
             NODE 277    X=   102.0000    Y=   34.0000
             NODE 279    X=   102.3333    Y=   42.6667
             NODE 281    X=   102.6667    Y=   51.3333
             NODE 283    X=   103.0000    Y=   60.0000
             NODE 290    X=   106.0000    Y=    0.0000
             NODE 292    X=   106.0000    Y=   17.0000
             NODE 294    X=   106.0000    Y=   34.0000
             NODE 296    X=   106.3333    Y=   42.0000
             NODE 298    X=   106.6667    Y=   50.0000
             NODE 300    X=   107.0000    Y=   58.0000
             NODE 307    X=   110.0000    Y=    0.0000
             NODE 309    X=   110.0000    Y=   17.0000
             NODE 311    X=   110.0000    Y=   34.0000
             NODE 313    X=   109.6667    Y=   42.0000
             NODE 315    X=   109.3333    Y=   50.0000
             NODE 317    X=   109.0000    Y=   58.0000
             NODE 324    X=   114.0000    Y=    0.0000
             NODE 326    X=   114.0000    Y=   17.0000
             NODE 328    X=   114.0000    Y=   34.0000
             NODE 330    X=   113.6667    Y=   42.6667
             NODE 332    X=   113.3333    Y=   51.3333
             NODE 334    X=   113.0000    Y=   60.0000
             NODE 341    X=   118.0000    Y=    0.0000
             NODE 343    X=   118.0000    Y=   17.0000
```

NODE 345	X=	118.0000	Y=	34.0000
NODE 347	X=	117.6667	Y=	42.6667
NODE 349	X=	117.3333	Y=	51.3333
NODE 351	X=	117.0000	Y=	60.0000
NODE 358	X=	122.0000	Y=	0.0000
NODE 360	X=	122.0000	Y=	17.0000
NODE 362	X=	122.0000	Y=	34.0000
NODE 364	X=	122.3333	Y=	42.6667
NODE 366	X=	122.6667	Y=	51.3333
NODE 368	X=	123.0000	Y=	60.0000
NODE 375	X=	126.0000	Y=	0.0000
NODE 377	X=	126.0000	Y=	17.0000
NODE 379	X=	126.0000	Y=	34.0000
NODE 381	X=	126.3333	Y=	42.6667
NODE 383	X=	126.6667	Y=	51.3333
NODE 385	X=	127.0000	Y=	60.0000
NODE 392	X=	130.0000	Y=	0.0000
NODE 394	X=	130.0000	Y=	17.0000
NODE 396	X=	130.0000	Y=	34.0000
NODE 398	X=	130.3333	Y=	42.0000
NODE 400	X=	130.6667	Y=	50.0000
NODE 402	X=	131.0000	Y=	58.0000
NODE 409	X=	134.0000	Y=	0.0000
NODE 411	X=	134.0000	Y=	17.0000
NODE 413	X=	134.0000	Y=	34.0000
NODE 415	X=	133.6667	Y=	42.0000
NODE 417	X=	133.3333	Y=	50.0000
NODE 419	X=	133.0000	Y=	58.0000
NODE 426	X=	138.0000	Y=	0.0000
NODE 428	X=	138.0000	Y=	17.0000
NODE 430	X=	138.0000	Y=	34.0000
NODE 432	X=	137.6667	Y=	42.6667
NODE 434	X=	137.3333	Y=	51.3333
NODE 436	X=	137.0000	Y=	60.0000
NODE 443	X=	142.0000	Y=	0.0000
NODE 445	X=	142.0000	Y=	17.0000
NODE 447	X=	142.0000	Y=	34.0000
NODE 449	X=	141.6667	Y=	42.6667
NODE 451	X=	141.3333	Y=	51.3333
NODE 453	X=	141.0000	Y=	60.0000
NODE 460	X=	146.0000	Y=	0.0000
NODE 462	X=	146.0000	Y=	17.0000
NODE 464	X=	146.0000	Y=	34.0000
NODE 466	X=	146.3333	Y=	42.6667
NODE 468	X=	146.6667	Y=	51.3333
NODE 470	X=	147.0000	Y=	60.0000
NODE 477	X=	150.0000	Y=	0.0000
NODE 479	X=	150.0000	Y=	17.0000
NODE 481	X=	150.0000	Y=	34.0000
NODE 483	X=	150.3333	Y=	42.6667
NODE 485	X=	150.6667	Y=	51.3333
NODE 487	X=	151.0000	Y=	60.0000
NODE 494	X=	154.0000	Y=	0.0000
NODE 496	X=	154.0000	Y=	17.0000
NODE 498	X=	154.0000	Y=	34.0000
NODE 500	X=	154.3333	Y=	42.0000
NODE 502	X=	154.6667	Y=	50.0000
NODE 504	X=	155.0000	Y=	58.0000
NODE 511	X=	158.0000	Y=	0.0000
NODE 513	X=	158.0000	Y=	17.0000
NODE 515	X=	158.0000	Y=	34.0000
NODE 517	X=	158.0000	Y=	42.0000
NODE 519	X=	158.0000	Y=	50.0000
NODE 521	X=	158.0000	Y=	58.0000

1 NUMBER OF NODAL POINTS... 521

NUMBER OF ELEMENTS....... 150

ELE. NO. NODAL POINTS

1	1	12	18	19	20	13	3	2	.20000E+00	.20000E+00	0.
2	3	13	20	21	22	14	5	4	.20000E+00	.20000E+00	0.
3	5	14	22	23	24	15	7	6	.20000E+00	.20000E+00	0.
4	7	15	24	25	26	16	9	8	.20000E+00	.20000E+00	0.
5	9	16	26	27	28	17	11	10	.20000E+00	.20000E+00	0.
6	18	29	35	36	37	30	20	19	.20000E+00	.20000E+00	0.
7	20	30	37	38	39	31	22	21	.20000E+00	.20000E+00	0.
8	22	31	39	40	41	32	24	23	.20000E+00	.20000E+00	0.
9	24	32	41	42	43	33	26	25	.20000E+00	.20000E+00	0.
10	26	33	43	44	45	34	28	27	.20000E+00	.20000E+00	0.
11	35	46	52	53	54	47	37	36	.20000E+00	.20000E+00	0.
12	37	47	54	55	56	48	39	38	.20000E+00	.20000E+00	0.
13	39	48	56	57	58	49	41	40	.20000E+00	.20000E+00	0.
14	41	49	58	59	60	50	43	42	.20000E+00	.20000E+00	0.
15	43	50	60	61	62	51	45	44	.20000E+00	.20000E+00	0.
16	52	63	69	70	71	64	54	53	.20000E+00	.20000E+00	0.
17	54	64	71	72	73	65	56	55	.20000E+00	.20000E+00	0.
18	56	65	73	74	75	66	58	57	.20000E+00	.20000E+00	0.
19	58	66	75	76	77	67	60	59	.20000E+00	.20000E+00	0.
20	60	67	77	78	79	68	62	61	.20000E+00	.20000E+00	0.
21	69	80	86	87	88	81	71	70	.20000E+00	.20000E+00	0.
22	71	81	88	89	90	82	73	72	.20000E+00	.20000E+00	0.
23	73	82	90	91	92	83	75	74	.20000E+00	.20000E+00	0.
24	75	83	92	93	94	84	77	76	.20000E+00	.20000E+00	0.
25	77	84	94	95	96	85	79	78	.20000E+00	.20000E+00	0.
26	86	97	103	104	105	98	88	87	.20000E+00	.20000E+00	0.
27	88	98	105	106	107	99	90	89	.20000E+00	.20000E+00	0.
28	90	99	107	108	109	100	92	91	.20000E+00	.20000E+00	0.
29	92	100	109	110	111	101	94	93	.20000E+00	.20000E+00	0.
30	94	101	111	112	113	102	96	95	.20000E+00	.20000E+00	0.
31	103	114	120	121	122	115	105	104	.20000E+00	.20000E+00	0.
32	105	115	122	123	124	116	107	106	.20000E+00	.20000E+00	0.
33	107	116	124	125	126	117	109	108	.20000E+00	.20000E+00	0.
34	109	117	126	127	128	118	111	110	.20000E+00	.20000E+00	0.
35	111	118	128	129	130	119	113	112	.20000E+00	.20000E+00	0.
36	120	131	137	138	139	132	122	121	.20000E+00	.20000E+00	0.
37	122	132	139	140	141	133	124	123	.20000E+00	.20000E+00	0.
38	124	133	141	142	143	134	126	125	.20000E+00	.20000E+00	0.
39	126	134	143	144	145	135	128	127	.20000E+00	.20000E+00	0.
40	128	135	145	146	147	136	130	129	.20000E+00	.20000E+00	0.
41	137	148	154	155	156	149	139	138	.20000E+00	.20000E+00	0.
42	139	149	156	157	158	150	141	140	.20000E+00	.20000E+00	0.
43	141	150	158	159	160	151	143	142	.20000E+00	.20000E+00	0.
44	143	151	160	161	162	152	145	144	.20000E+00	.20000E+00	0.
45	145	152	162	163	164	153	147	146	.20000E+00	.20000E+00	0.
46	154	165	171	172	173	166	156	155	.20000E+00	.20000E+00	0.
47	156	166	173	174	175	167	158	157	.20000E+00	.20000E+00	0.
48	158	167	175	176	177	168	160	159	.20000E+00	.20000E+00	0.
49	160	168	177	178	179	169	162	161	.20000E+00	.20000E+00	0.
50	162	169	179	180	181	170	164	163	.20000E+00	.20000E+00	0.
51	171	182	188	189	190	183	173	172	.20000E+00	.20000E+00	0.
52	173	183	190	191	192	184	175	174	.20000E+00	.20000E+00	0.
53	175	184	192	193	194	185	177	176	.20000E+00	.20000E+00	0.
54	177	185	194	195	196	186	179	178	.20000E+00	.20000E+00	0.
55	179	186	196	197	198	187	181	180	.20000E+00	.20000E+00	0.
56	188	199	205	206	207	200	190	189	.20000E+00	.20000E+00	0.
57	190	200	207	208	209	201	192	191	.20000E+00	.20000E+00	0.
58	192	201	209	210	211	202	194	193	.20000E+00	.20000E+00	0.
59	194	202	211	212	213	203	196	195	.20000E+00	.20000E+00	0.
60	196	203	213	214	215	204	198	197	.20000E+00	.20000E+00	0.

62	207	217	224	225	226	218	209	208	.20000E+00	20000E+00	0
63	209	218	226	227	228	219	211	210	.20000E+00	.20000E+00	0
64	211	219	228	229	230	220	213	212	.20000E+00	.20000E+00	0
65	213	220	230	231	232	221	215	214	.20000E+00	.20000E+00	0.
66	222	233	239	240	241	234	224	223	.20000E+00	.20000E+00	0
67	224	234	241	242	243	235	226	225	.20000E+00	.20000E+00	0
68	226	235	243	244	245	236	228	227	.20000E+00	.20000E+00	0.
69	228	236	245	246	247	237	230	229	.20000E+00	.20000E+00	0
70	230	237	247	248	249	238	232	231	.20000E+00	.20000E+00	0.
71	239	250	256	257	258	251	241	240	.20000E+00	.20000E+00	0.
72	241	251	258	259	260	252	243	242	.20000E+00	.20000E+00	0.
73	243	252	260	261	262	253	245	244	.20000E+00	.20000E+00	0.
74	245	253	262	263	264	254	247	246	.20000E+00	.20000E+00	0.
75	247	254	264	265	266	255	249	248	.20000E+00	.20000E+00	0.
76	256	267	273	274	275	268	258	257	.20000E+00	.20000E+00	0.
77	258	268	275	276	277	269	260	259	.20000E+00	.20000E+00	0.
78	260	269	277	278	279	270	262	261	.20000E+00	.20000E+00	0.
79	262	270	279	280	281	271	264	263	.20000E+00	.20000E+00	0.
80	264	271	281	282	283	272	266	265	.20000E+00	.20000E+00	0.
81	273	284	290	291	292	285	275	274	.20000E+00	.20000E+00	0.
82	275	285	292	293	294	286	277	276	.20000E+00	.20000E+00	0.
83	277	286	294	295	296	287	279	278	.20000E+00	.20000E+00	0.
84	279	287	296	297	298	288	281	280	.20000E+00	.20000E+00	0.
85	281	288	298	299	300	289	283	282	.20000E+00	.20000E+00	0.
86	290	301	307	308	309	302	292	291	.20000E+00	.20000E+00	0.
87	292	302	309	310	311	303	294	293	.20000E+00	.20000E+00	0.
88	294	303	311	312	313	304	296	295	.20000E+00	.20000E+00	0.
89	296	304	313	314	315	305	298	297	.20000E+00	.20000E+00	0.
90	298	305	315	316	317	306	300	299	.20000E+00	.20000E+00	0.
91	307	318	324	325	326	319	309	308	.20000E+00	.20000E+00	0.
92	309	319	326	327	328	320	311	310	.20000E+00	.20000E+00	0.
93	311	320	328	329	330	321	313	312	.20000E+00	.20000E+00	0.
94	313	321	330	331	332	322	315	314	.20000E+00	.20000E+00	0.
95	315	322	332	333	334	323	317	316	.20000E+00	.20000E+00	0.
96	324	335	341	342	343	336	326	325	.20000E+00	.20000E+00	0.
97	326	336	343	344	345	337	328	327	.20000E+00	.20000E+00	0.
98	328	337	345	346	347	338	330	329	.20000E+00	.20000E+00	0.
99	330	338	347	348	349	339	332	331	.20000E+00	.20000E+00	0.
100	332	339	349	350	351	340	334	333	.20000E+00	.20000E+00	0.
101	341	352	358	359	360	353	343	342	.20000E+00	.20000E+00	0.
102	343	353	360	361	362	354	345	344	.20000E+00	.20000E+00	0.
103	345	354	362	363	364	355	347	346	.20000E+00	.20000E+00	0.
104	347	355	364	365	366	356	349	348	.20000E+00	.20000E+00	0.
105	349	356	366	367	368	357	351	350	.20000E+00	.20000E+00	0.
106	358	369	375	376	377	370	360	359	.20000E+00	.20000E+00	0.
107	360	370	377	378	379	371	362	361	.20000E+00	.20000E+00	0.
108	362	371	379	380	381	372	364	363	.20000E+00	.20000E+00	0.
109	364	372	381	382	383	373	366	365	.20000E+00	.20000E+00	0.
110	366	373	383	384	385	374	368	367	.20000E+00	.20000E+00	0.
111	375	386	392	393	394	387	377	376	.20000E+00	.20000E+00	0.
112	377	387	394	395	396	388	379	378	.20000E+00	.20000E+00	0.
113	379	388	396	397	398	389	381	380	.20000E+00	.20000E+00	0.
114	381	389	398	399	400	390	383	382	.20000E+00	.20000E+00	0.
115	383	390	400	401	402	391	385	384	.20000E+00	.20000E+00	0.
116	392	403	409	410	411	404	394	393	.20000E+00	.20000E+00	0.
117	394	404	411	412	413	405	396	395	.20000E+00	.20000E+00	0.
118	396	405	413	414	415	406	398	397	.20000E+00	.20000E+00	0.
119	398	406	415	416	417	407	400	399	.20000E+00	.20000E+00	0.
120	400	407	417	418	419	408	402	401	.20000E+00	.20000E+00	0.
121	409	420	426	427	428	421	411	410	.20000E+00	.20000E+00	0.
122	411	421	428	429	430	422	413	412	.20000E+00	.20000E+00	0.
123	413	422	430	431	432	423	415	414	.20000E+00	.20000E+00	0.
124	415	423	432	433	434	424	417	416	.20000E+00	.20000E+00	0.
125	417	424	434	435	436	425	419	418	.20000E+00	.20000E+00	0.
126	426	437	443	444	445	438	428	427	.20000E+00	.20000E+00	0.
127	428	438	445	446	447	439	430	429	.20000E+00	.20000E+00	0.

128	430	439	447	448	449	440	432	431	.20000E+00	.20000E+00	0.
129	432	440	449	450	451	441	434	433	.20000E+00	.20000E+00	0.
130	434	441	451	452	453	442	436	435	.20000E+00	.20000E+00	0.
131	443	454	460	461	462	455	445	444	.20000E+00	.20000E+00	0.
132	445	455	462	463	464	456	447	446	.20000E+00	.20000E+00	0.
133	447	456	464	465	466	457	449	448	.20000E+00	.20000E+00	0.
134	449	457	466	467	468	458	451	450	.20000E+00	.20000E+00	0.
135	451	458	468	469	470	459	453	452	.20000E+00	.20000E+00	0.
136	460	471	477	478	479	472	462	461	.20000E+00	.20000E+00	0.
137	462	472	479	480	481	473	464	463	.20000E+00	.20000E+00	0.
138	464	473	481	482	483	474	466	465	.20000E+00	.20000E+00	0.
139	466	474	483	484	485	475	468	467	.20000E+00	.20000E+00	0.
140	468	475	485	486	487	476	470	469	.20000E+00	.20000E+00	0.
141	477	488	494	495	496	489	479	478	.20000E+00	.20000E+00	0.
142	479	489	496	497	498	490	481	480	.20000E+00	.20000E+00	0.
143	481	490	498	499	500	491	483	482	.20000E+00	.20000E+00	0.
144	483	491	500	501	502	492	485	484	.20000E+00	.20000E+00	0.
145	485	492	502	503	504	493	487	486	.20000E+00	.20000E+00	0.
146	494	505	511	512	513	506	496	495	.20000E+00	.20000E+00	0.
147	496	506	513	514	515	507	498	497	.20000E+00	.20000E+00	0.
148	498	507	515	516	517	508	500	499	.20000E+00	.20000E+00	0.
149	500	508	517	518	519	509	502	501	.20000E+00	.20000E+00	0.
150	502	509	519	520	521	510	504	503	.20000E+00	.20000E+00	0.

DIRICHLET BOUNDARY CONDITION DATA

0NODES	RESPECTIVE DIRICHLET BOUNDARY CONDITIONS	
. 1- 2	78.0000	78.0000
. 3- 4	78.0000	78.0000
. 5- 6	78.0000	78.0000
. 7- 8	78.0000	78.0000
. 9- 10	78.0000	78.0000
. 11- 10	78.0000	78.0000
. 96-102	58.0000	58.0000
.113-102	58.0000	58.0000
.198-204	58.0000	58.0000
.215-204	58.0000	58.0000
.300-306	58.0000	58.0000
.317-306	58.0000	58.0000
.402-408	58.0000	58.0000
.419-408	58.0000	58.0000
.504-510	58.0000	58 0000
.521-510	58.0000	58.0000

0

NODAL POINTS ON FREE SURFACE

11	17	28	34	45	51	62	68	79	85	96	102	113	119	130	136	147	153	164	170
181	187	198	204	215	221	232	238	249	255	266	272	283	289	300	306	317	323	334	340
351	357	368	374	385	391	402	408	419	425	436	442	453	459	470	476	487	493	504	0

SEEPAGE FACE NODAL POINT DATA
CONSECUTIVE NODE NUMBERS ON THE SEEPAGE FACE

. 96-113
.198-215
.300-317
.402-419
.504-521

ITER = 1

NEW COORDINATES OF THE FREE SURFACE LINE

NODE=487	X = 150.9272	Y = 58.1066
NODE=470	X = 146.9281	Y = 58.1298
NODE=453	X = 141.0718	Y = 58.1328
NODE=436	X = 137.0726	Y = 58.1120
NODE=419	X = 133.0000	Y = 58.0000
NODE=402	X = 131.0000	Y = 58.0000
NODE=385	X = 126.8874	Y = 58.1392
NODE=368	X = 122.9298	Y = 58.1696
NODE=351	X = 118.7876	Y = 58.3161
NODE=334	X = 113.0710	Y = 58.1648
NODE=317	X = 109.0000	Y = 58.0000
NODE=300	X = 107.0000	Y = 58.0000
NODE=283	X = 102.9313	Y = 58.2145
NODE=266	X = 98.9335	Y = 58.2707
NODE=249	X = 93.0656	Y = 58.2937
NODE=232	X = 89.0671	Y = 58.2580
NODE=215	X = 85.0000	Y = 58.0000
NODE=198	X = 83.0000	Y = 58.0000
NODE=181	X = 78.9382	Y = 58.3928
NODE=164	X = 74.9424	Y = 58.5028
NODE=147	X = 69.0554	Y = 58.5808
NODE=130	X = 65.0578	Y = 58.4976
NODE=113	X = 61.0000	Y = 58.0000
NODE= 96	X = 59.0000	Y = 58.0000
NODE= 79	X = 50.0000	Y = 59.6559
NODE= 62	X = 0.0000	Y = 62.3918
NODE= 45	X = -80.0000	Y = 66.1504
NODE= 28	X = -200.0000	Y = 71.6308
NODE= 11	X = -340.0000	Y = 78.0000

ITER = 2

NEW COORDINATES OF THE FREE SURFACE LINE

NODE=487	X = 150.9285	Y = 58.1412
NODE=470	X = 146.9298	Y = 58.1776
NODE=453	X = 141.0699	Y = 58.1621
NODE=436	X = 137.0712	Y = 58.1489
NODE=419	X = 133.0000	Y = 58.0000
NODE=402	X = 131.0000	Y = 58.0000
NODE=385	X = 126.9023	Y = 58.1946
NODE=368	X = 122.9316	Y = 58.2272
NODE=351	X = 118.7316	Y = 58.3036
NODE=334	X = 113.0693	Y = 58.1981
NODE=317	X = 109.0000	Y = 58.0000
NODE=300	X = 107.0000	Y = 58.0000
NODE=283	X = 102.9334	Y = 58.2572
NODE=266	X = 98.9366	Y = 58.3514
NODE=249	X = 93.0622	Y = 58.3835
NODE=232	X = 89.0643	Y = 58.3281
NODE=215	X = 85.0000	Y = 58.0000
NODE=198	X = 83.0000	Y = 58.0000
NODE=181	X = 78.9410	Y = 58.4852
NODE=164	X = 74.9469	Y = 58.6185
NODE=147	X = 69.0503	Y = 58.6934
NODE=130	X = 65.0535	Y = 58.6066
NODE=113	X = 61.0000	Y = 58.0000
NODE= 96	X = 59.0000	Y = 58.0000
NODE= 79	X = 50.0000	Y = 59.6616
NODE= 62	X = 0.0000	Y = 62.6569
NODE= 45	X = -80.0000	Y = 66.6218
NODE= 28	X = -200.0000	Y = 72.1276
NODE= 11	X = -340.0000	Y = 78.0000

ITER = 3

NEW COORDINATES OF THE FREE SURFACE LINE

NODE=487	X = 150.9285	Y = 58.1410
NODE=470	X = 146.9299	Y = 58.1772
NODE=453	X = 141.0699	Y = 58.1616
NODE=436	X = 137.0712	Y = 58.1485
NODE=419	X = 133.0000	Y = 58.0000
NODE=402	X = 131.0000	Y = 58.0000
NODE=385	X = 126.9016	Y = 58.1934
NODE=368	X = 122.9316	Y = 58.2271
NODE=351	X = 118.7340	Y = 58.2398
NODE=334	X = 113.0690	Y = 58.2046
NODE=317	X = 109.0000	Y = 58.0000
NODE=300	X = 107.0000	Y = 58.0000
NODE=283	X = 102.9333	Y = 58.2871
NODE=266	X = 98.9369	Y = 58.3506
NODE=249	X = 93.0622	Y = 58.3822
NODE=232	X = 89.0643	Y = 58.3280
NODE=215	X = 85.0000	Y = 58.0000
NODE=198	X = 83.0000	Y = 58.0000
NODE=181	X = 78.9410	Y = 58.4855
NODE=164	X = 74.9469	Y = 58.6183
NODE=147	X = 69.0504	Y = 58.6906
NODE=130	X = 65.0538	Y = 58.6082
NODE=113	X = 61.0000	Y = 58.0000
NODE= 96	X = 59.0000	Y = 58.0000
NODE= 79	X = 50.0000	Y = 59.6764
NODE= 62	X = 0.0000	Y = 62.6654
NODE= 45	X = -80.0000	Y = 66.6380
NODE= 28	X = -200.0000	Y = 72.1238
NODE= 11	X = -340.0000	Y = 78.0000

CONVERGENCE CHECK ERROR = .6227E-06

ONODE	X COORDINATE	Y COORDINATE	V-POTENTIAL	X-VELOCITY	Y-VELOCITY	TOTAL VELO.	PRES. COEF.
1	-340.0000	0.0000	78.0000	-.8214E-02	-.1203E-04	.8214E-02	
2	-340.0000	8.5000	78.0000	-.8211E-02	-.9763E-14	.8211E-02	
3	-340.0000	17.0000	78.0000	-.8202E-02	.9118E-06	.8202E-02	
4	-340.0000	25.5000	78.0000	-.8186E-02	0.	.8186E-02	
5	-340.0000	34.0000	78.0000	-.8165E-02	.2002E-04	.8165E-02	
6	-340.0000	41.3333	78.0000	-.8141E-02	-.5670E-14	.8141E-02	
7	-340.0000	48.6667	78.0000	-.8112E-02	.3061E-04	.8112E-02	
8	-340.0000	56.0000	78.0000	-.8077E-02	0.	.8077E-02	
9	-340.0000	63.3333	78.0000	-.8035E-02	.4631E-04	.8035E-02	
10	-340.0000	70.6667	78.0000	-.7987E-02	.1701E-13	.7987E-02	
11	-340.0000	78.0000	78.0000	-.7935E-02	.7687E-04	.7936E-02	
12	-270.0000	0.0000	75.0770	-.8490E-02	-.2286E-05	.8490E-02	
13	-270.0000	17.0000	75.0801	-.8484E-02	.6305E-04	.8485E-02	
14	-270.0000	34.0000	75.0894	-.8466E-02	.1287E-03	.8468E-02	
15	-270.0000	47.6673	75.1019	-.8447E-02	.1844E-03	.8449E-02	
16	-270.0000	61.3746	75.1194	-.8418E-02	.2453E-03	.8422E-02	
17	-270.0000	75.0619	75.1427	-.8383E-02	.3210E-03	.8389E-02	
18	-200.0000	0.0000	72.0570	-.8784E-02	.1514E-05	.8784E-02	
19	-200.0000	8.5000	72.0579	-.8784E-02	.4465E-04	.8784E-02	
20	-200.0000	17.0000	72.0609	-.8783E-02	.8459E-04	.8784E-02	
21	-200.0000	25.5000	72.0656	-.8783E-02	.1343E-03	.8784E-02	
22	-200.0000	34.0000	72.0723	-.8782E-02	.1664E-03	.8784E-02	
23	-200.0000	40.3540	72.0783	-.8783E-02	.2084E-03	.8786E-02	
24	-200.0000	46.7079	72.0855	-.8784E-02	.2572E-03	.8788E-02	
25	-200.0000	53.0619	72.0935	-.8786E-02	.2867E-03	.8790E-02	
26	-200.0000	59.4158	72.1025	-.8788E-02	.3227E-03	.8794E-02	
27	-200.0000	65.7698	72.1121	-.8793E-02	.3187E-03	.8798E-02	
28	-200.0000	72.1238	72.1228	[illegible]	[illegible]	[illegible]	

29	-140.0000	0.0000	69.3839	-.9155E-02	-.1832E-05	.9155E-02
30	-140.0000	17.0000	69.3882	-.9154E-02	.1010E-03	.9155E-02
31	-140.0000	34.0000	69.3912	-.9150E-02	.2023E-03	.9152E-02
32	-140.0000	45.7838	69.3953	-.9144E-02	.2719E-03	.9148E-02
33	-140.0000	57.5873	69.4138	-.9136E-02	.3413E-03	.9142E-02
34	-140.0000	69.3809	69.4383	-.9125E-02	.4127E-03	.9134E-02
35	-80.0000	0.0000	66.5638	-.9535E-02	.5036E-05	.9535E-02
36	-80.0000	8.5000	66.5648	-.9532E-02	.5471E-04	.9533E-02
37	-80.0000	17.0000	66.5684	-.9529E-02	.1109E-03	.9530E-02
38	-80.0000	25.5000	66.5742	-.9522E-02	.1684E-03	.9523E-02
39	-80.0000	34.0000	66.5828	-.9514E-02	.2378E-03	.9517E-02
40	-80.0000	39.4397	66.5891	-.9507E-02	.2801E-03	.9510E-02
41	-80.0000	44.8793	66.5967	-.9500E-02	.3119E-03	.9505E-02
42	-80.0000	50.3190	66.6052	-.9492E-02	.3290E-03	.9497E-02
43	-80.0000	55.7587	66.6146	-.9482E-02	.3820E-03	.9490E-02
44	-80.0000	61.1983	66.6251	-.9476E-02	.4008E-03	.9484E-02
45	-80.0000	66.6380	66.6384	-.9468E-02	.4627E-03	.9479E-02
46	-40.0000	0.0000	64.6314	-.9763E-02	-.5981E-05	.9763E-02
47	-40.0000	17.0000	64.6357	-.9779E-02	.8098E-04	.9779E-02
48	-40.0000	34.0000	64.6492	-.9816E-02	.1898E-03	.9818E-02
49	-40.0000	44.2206	64.6625	-.9838E-02	.2704E-03	.9842E-02
50	-40.0000	54.4411	64.6805	-.9858E-02	.3684E-03	.9863E-02
51	-40.0000	64.6617	64.7032	-.9866E-02	.4783E-03	.9867E-02
52	0.0000	0.0000	62.6567	-.1004E-01	.3670E-04	.1004E-01
53	0.0000	8.5000	62.6575	-.1006E-01	-.2212E-04	.1006E-01
54	0.0000	17.0000	62.6566	-.1011E-01	.9814E-05	.1011E-01
55	0.0000	25.5000	62.6548	-.1016E-01	-.8484E-05	.1016E-01
56	0.0000	34.0000	62.6581	-.1023E-01	.1720E-03	.1023E-01
57	0.0000	38.7809	62.6588	-.1022E-01	.7471E-04	.1022E-01
58	0.0000	43.5618	62.6597	-.1019E-01	.3803E-03	.1019E-01
59	0.0000	48.3427	62.6628	-.1011E-01	.1585E-03	.1011E-01
60	0.0000	53.1236	62.6673	-.1000E-01	.5009E-03	.1002E-01
61	0.0000	57.9045	62.6760	-.9934E-02	.3843E-03	.9940E-02
62	0.0000	62.6854	62.6847	-.9845E-02	.6486E-03	.9866E-02
63	25.0000	0.0000	61.4413	-.9317E-02	-.1753E-04	.9317E-02
64	25.0000	17.0000	61.4189	-.9550E-02	-.6004E-03	.9569E-02
65	25.0000	34.0000	61.3836	-.1032E-01	-.9883E-03	.1037E-01
66	25.0000	43.0801	61.3383	-.1098E-01	-.9703E-03	.1102E-01
67	25.0000	52.1203	61.3276	-.1171E-01	-.4325E-03	.1172E-01
68	25.0000	61.1604	61.3488	-.1200E-01	.5424E-03	.1202E-01
69	50.0000	0.0000	60.3294	-.8245E-02	-.3823E-04	.8245E-02
70	50.0000	8.5000	60.3164	-.8354E-02	-.7076E-03	.8368E-02
71	50.0000	17.0000	60.2683	-.8562E-02	-.1397E-02	.8675E-02
72	50.0000	25.5000	60.1917	-.9086E-02	-.2273E-02	.9378E-02
73	50.0000	34.0000	60.0761	-.9857E-02	-.3017E-02	.1031E-01
74	50.0000	38.2792	60.0026	-.1060E-01	-.3670E-02	.1122E-01
75	50.0000	42.5585	59.9180	-.1143E-01	-.3881E-02	.1207E-01
76	50.0000	46.8377	59.8288	-.1284E-01	-.4097E-02	.1361E-01
77	50.0000	51.1169	59.7437	-.1480E-01	-.3333E-02	.1517E-01
78	50.0000	55.3962	59.6624	-.1579E-01	-.1686E-02	.1587E-01
79	50.0000	59.6754	59.6754	-.1288E-01	.4458E-02	.1363E-01
80	54.3750	0.0000	60.1568	-.7705E-02	.1647E-04	.7705E-02
81	54.3750	17.0000	60.0909	-.7941E-02	-.1880E-02	.8091E-02
82	54.3750	34.0000	59.8740	-.8892E-02	-.3817E-02	.9600E-02
83	54.4167	42.2792	59.6686	-.1017E-01	-.5186E-02	.1141E-01
84	54.4583	50.5585	59.4148	-.1447E-01	-.8348E-02	.1671E-01
85	54.5000	58.8377	59.1949	-.3732E-01	-.4808E-03	.3732E-01
86	58.7500	0.0000	59.9923	-.7303E-02	.9302E-05	.7303E-02
87	58.7500	8.5000	59.9781	-.7378E-02	-.8288E-03	.7424E-02
88	58.7500	17.0000	59.9219	-.7478E-02	-.1651E-02	.7658E-02
89	58.7500	25.5000	59.8290	-.7778E-02	-.2763E-02	.8252E-02
90	58.7500	34.0000	59.6870	-.8153E-02	-.3898E-02	.9066E-02
91	58.7917	38.0000	59.5960	-.8488E-02	-.4978E-02	.9838E-02
92	58.8333	42.0000	59.4846	-.8823E-02	-.5920E-02	.1063E-01
93	58.8750	46.0000	59.3433	-.9875E-02	-.8385E-02	.1280E-01
94	58.9167	50.0000	59.1480	-.1014E-01	-.8827E-02	.1344E-01
95	58.9583	54.0000	58.8309	-.1760E-01	-.2844E-01	.3345E-01
96	59.0000	58.0000	58.0000	-.3146E-01	-.4442E-01	.5443E-01
97	60.3750	0.0000	59.9335	-.7160E-02	.1473E-04	.7160E-02
98	60.3750	17.0000	59.8817	-.7314E-02	-.1878E-02	.7604E-02
99	60.3750	34.0000	59.6220	-.7846E-02	-.4032E-02	.8821E-02
100	60.2500	42.0000	59.4240	-.8323E-02	-.5846E-02	.1023E-01
101	60.1250	50.0000	59.0906	-.8930E-02	-.8116E-02	.1207E-01
102	60.0000	58.0000	58.0000	-.1582E-12	-.4982E-01	.4982E-01
103	62.0000	0.0000	59.8760	-.6982E-02	.1535E-04	.6982E-02
104	62.0000	8.5000	59.8561	-.7046E-02	-.8583E-03	.7097E-02
105	62.0000	17.0000	59.8030	-.7122E-02	-.1704E-02	.7323E-02
106	62.0000	25.5000	59.7067	-.7311E-02	-.2864E-02	.7852E-02
107	62.0000	34.0000	59.5695	-.7527E-02	-.4098E-02	.8569E-02
108	61.8333	38.0000	59.4735	-.7682E-02	-.5144E-02	.9228E-02
109	61.6667	42.0000	59.3665	-.7841E-02	-.6019E-02	.9883E-02
110	61.5000	46.0000	59.2306	-.7581E-02	-.8552E-02	.1144E-01
111	61.3333	50.0000	59.0371	-.8068E-02	-.9853E-02	.1228E-01
112	61.1667	54.0000	58.7425	.9281E-03	-.2589E-01	.2591E-01
113	61.0000	58.0000	58.0000	.2283E-01	-.4219E-01	.4797E-01
114	64.0000	0.0000	59.8070	-.6802E-02	.1364E-04	.6802E-02
115	64.0000	17.0000	59.7329	-.6902E-02	-.1733E-02	.7116E-02
116	64.0000	34.0000	59.4862	-.7142E-02	-.4142E-02	.8256E-02
117	63.8756	42.1010	59.2803	-.7064E-02	-.6066E-02	.9324E-02
118	63.3512	50.2021	58.9732	-.4492E-02	-.9924E-02	.1089E-01
119	63.0268	58.3031	58.4487	.3146E-01	-.1060E-01	.3319E-01
120	66.0000	0.0000	59.7399	-.6596E-02	.1414E-04	.6596E-02
121	66.0000	8.5000	59.7215	-.6625E-02	-.8816E-03	.6684E-02
122	66.0000	17.0000	59.6650	-.6673E-02	-.1785E-02	.6900E-02
123	66.0000	25.5000	59.5663	-.6736E-02	-.2821E-02	.7342E-02
124	66.0000	34.0000	59.4187	-.6779E-02	-.4159E-02	.7953E-02
125	65.8423	38.1010	59.3270	-.6671E-02	-.5089E-02	.8391E-02
126	65.6845	42.2021	59.2185	-.6548E-02	-.6063E-02	.8923E-02
127	65.5268	46.3031	59.0853	-.5435E-02	-.7331E-02	.9126E-02
128	65.3691	50.4041	58.9264	-.4142E-02	-.9823E-02	.1066E-01
129	65.2113	54.5051	58.7241	.3735E-02	-.7884E-02	.8525E-02
130	65.0536	58.6062	58.6082	.8784E-02	-.1045E-02	.8846E-02
131	68.0000	0.0000	59.6749	-.6387E-02	.1284E-04	.6387E-02
132	68.0000	17.0000	59.5994	-.6438E-02	-.1771E-02	.6678E-02
133	68.0000	34.0000	59.3508	-.6409E-02	-.4140E-02	.7630E-02
134	67.6840	42.2161	59.1589	-.5987E-02	-.5852E-02	.8372E-02
135	67.3680	50.4323	58.8870	-.3552E-02	-.8189E-02	.8928E-02
136	67.0520	58.6484	58.6710	.4250E-02	-.1138E-02	.4400E-02
137	70.0000	0.0000	59.6120	-.6192E-02	.1284E-04	.6192E-02
138	70.0000	8.5000	59.5933	-.6198E-02	-.8915E-03	.6262E-02
139	70.0000	17.0000	59.5382	-.6215E-02	-.1781E-02	.6465E-02
140	70.0000	25.5000	59.4369	-.6175E-02	-.2914E-02	.6828E-02
141	70.0000	34.0000	59.2865	-.6066E-02	-.4106E-02	.7342E-02
142	69.8417	38.1151	59.2006	-.5879E-02	-.4857E-02	.7626E-02
143	69.6835	42.2302	59.0980	-.5620E-02	-.5633E-02	.7957E-02
144	69.5252	46.3453	58.9800	-.4724E-02	-.6131E-02	.7740E-02
145	69.3669	50.4604	58.8531	-.3380E-02	-.6679E-02	.7477E-02
146	69.2086	54.5755	58.7397	-.1103E-02	-.3990E-02	.4139E-02
147	69.0504	58.6906	58.6907	.6178E-03	-.4498E-03	.7641E-03
148	72.0000	0.0000	59.5511	-.5986E-02	.1099E-04	.5986E-02
149	72.0000	17.0000	59.4753	-.5976E-02	-.1783E-02	.6236E-02
150	72.0000	34.0000	59.2294	-.5753E-02	-.4051E-02	.7036E-02
151	71.9995	42.2182	59.0368	-.5243E-02	-.5387E-02	.7526E-02
152	71.9991	50.4363	58.8058	-.3933E-02	-.5776E-02	.6988E-02
153	71.9986	58.6545	58.6782	-.2460E-02	-.2478E-03	.2472E-02
154	74.0000	0.0000	59.4922	-.5784E-02	.1064E-04	.5784E-02
155	74.0000	8.5000	59.4738	-.5771E-02	-.8891E-03	.5839E-02
156	74.0000	17.0000	59.4187	-.5769E-02	-.1760E-02	.6028E-02
157	74.0000	25.5000	59.3184	-.5643E-02	-.2881E-02	.6327E-02
158	74.0000	34.0000	59.1738	-.5488E-02	-.3966E-02	.6788E-02
159	74.1678	38.1030	59.0810	-.5221E-02	-.4583E-02	.6947E-02

161	74.4734	46.3081	58.6843	-.4883E-02	-.5333E-02	.7084E-02
162	74.6312	50.4122	58.7510	-.4618E-02	-.5408E-02	.7048E-02
163	74.7890	54.5152	58.6573	-.4918E-02	-.3048E-02	.5786E-02
164	74.9468	58.6183	58.6183	-.5217E-02	-.1124E-03	.5218E-02
165	76.0000	0.0000	59.4358	-.5575E-02	.8030E-05	.5575E-02
166	76.0000	17.0000	59.3803	-.5821E-02	-.1770E-02	.5798E-02
167	76.0000	34.0000	59.1203	-.5171E-02	-.3812E-02	.6484E-02
168	76.3146	42.1806	58.9283	-.4722E-02	-.5081E-02	.6921E-02
169	76.6293	50.3613	58.7054	-.4095E-02	-.5771E-02	.7440E-02
170	76.9439	58.5419	58.5563	-.7866E-02	-.4186E-03	.7878E-02
171	78.0000	0.0000	59.3807	-.5378E-02	.8494E-05	.5378E-02
172	78.0000	8.5000	59.3823	-.5348E-02	-.8784E-03	.5420E-02
173	78.0000	17.0000	59.3062	-.5312E-02	-.1758E-02	.5594E-02
174	78.0000	25.5000	59.2101	-.5141E-02	-.2779E-02	.5844E-02
175	78.0000	34.0000	59.0700	-.4907E-02	-.3832E-02	.6226E-02
176	78.1569	38.0776	58.9624	-.4890E-02	-.4381E-02	.6419E-02
177	78.3137	42.1552	58.8841	-.4451E-02	-.4851E-02	.6587E-02
178	78.4705	46.2327	58.7751	-.4547E-02	-.5317E-02	.6997E-02
179	78.6273	50.3103	58.6901	-.4624E-02	-.6235E-02	.7763E-02
180	78.7842	54.3879	58.5341	-.8267E-02	-.4458E-02	.9392E-02
181	78.9410	58.4665	58.4884	-.1055E-01	-.2813E-03	.1055E-01
182	80.0000	0.0000	59.3281	-.5169E-02	.9889E-05	.5169E-02
183	80.0000	17.0000	59.2544	-.5080E-02	-.1736E-02	.5368E-02
184	80.0000	34.0000	59.0224	-.4637E-02	-.3744E-02	.5960E-02
185	80.3235	42.0776	58.8421	-.4231E-02	-.4799E-02	.6398E-02
186	80.6470	50.1552	58.6133	-.4919E-02	-.5923E-02	.7699E-02
187	80.9705	58.2327	58.3159	-.2358E-01	-.6619E-02	.2424E-01
188	82.0000	0.0000	59.2774	-.4677E-02	.6271E-05	.4677E-02
189	82.0000	8.5000	59.2593	-.4935E-02	-.8555E-03	.5008E-02
190	82.0000	17.0000	59.2046	-.4880E-02	-.1713E-02	.5172E-02
191	82.0000	25.5000	59.1118	-.4689E-02	-.2875E-02	.5381E-02
192	82.0000	34.0000	58.9773	-.4393E-02	-.3661E-02	.5712E-02
193	82.1667	38.0000	58.8953	-.4155E-02	-.4191E-02	.5901E-02
194	82.3333	42.0000	58.8027	-.3892E-02	-.4631E-02	.6049E-02
195	82.5000	46.0000	58.6984	-.3800E-02	-.5661E-02	.6818E-02
196	82.6667	50.0000	58.5700	-.3148E-02	-.4890E-02	.5816E-02
197	82.8333	54.0000	58.4088	-.6949E-02	-.1396E-01	.1559E-01
198	83.0000	58.0000	58.0000	-.1637E-01	-.2302E-01	.2826E-01
199	84.0000	0.0000	59.2287	-.4771E-02	.4760E-05	.4771E-02
200	84.0000	17.0000	59.1570	-.4658E-02	-.1647E-02	.4952E-02
201	84.0000	34.0000	58.9347	-.4140E-02	-.3559E-02	.5457E-02
202	84.0000	42.0000	58.7715	-.3847E-02	-.4527E-02	.5913E-02
203	84.0000	50.0000	58.5519	-.2934E-02	-.4799E-02	.5626E-02
204	84.0000	58.0000	58.0000	-.9095E-13	-.2489E-01	.2489E-01
205	86.0000	0.0000	59.1819	-.4589E-02	.3647E-05	.4588E-02
206	86.0000	8.5000	59.1644	-.4535E-02	-.8269E-03	.4610E-02
207	86.0000	17.0000	59.1115	-.4469E-02	-.1656E-02	.4766E-02
208	86.0000	25.5000	59.0221	-.4229E-02	-.2553E-02	.4939E-02
209	86.0000	34.0000	58.8946	-.3921E-02	-.3455E-02	.5226E-02
210	85.8333	38.0000	58.8236	-.3886E-02	-.3986E-02	.5402E-02
211	85.6667	42.0000	58.7420	-.3424E-02	-.4405E-02	.5579E-02
212	85.5000	46.0000	58.6480	-.2906E-02	-.5309E-02	.6132E-02
213	85.3333	50.0000	58.5308	-.3012E-02	-.4958E-02	.5801E-02
214	85.1667	54.0000	58.3760	.1581E-02	-.1321E-01	.1330E-01
215	85.0000	58.0000	58.0000	.1186E-01	-.2139E-01	.2448E-01
216	88.0000	0.0000	59.1372	-.4363E-02	.2349E-05	.4363E-02
217	88.0000	17.0000	59.0680	-.4263E-02	-.1626E-02	.4564E-02
218	88.0000	34.0000	58.8566	-.3867E-02	-.3353E-02	.4984E-02
219	87.6774	42.0547	58.7083	-.3101E-02	-.4263E-02	.5272E-02
220	87.3548	50.1093	58.5124	-.1281E-02	-.5624E-02	.5871E-02
221	87.0322	58.1640	58.2375	.1661E-01	-.5649E-02	.1761E-01
222	90.0000	0.0000	59.0943	-.4209E-02	.1099E-05	.4209E-02
223	90.0000	8.5000	59.0773	-.4151E-02	-.7979E-03	.4227E-02
224	90.0000	17.0000	59.0285	-.4077E-02	-.1588E-02	.4378E-02
225	90.0000	25.5000	58.9412	-.3822E-02	-.2420E-02	.4524E-02
226	90.0000	34.0000	58.8208	-.3499E-02	-.3248E-02	.4774E-02
227	89.6441	38.0547	58.7533	-.3209E-02	-.3682E-02	.4869E-02
228	89.5881	42.1093	58.6773	-.2907E-02	-.4099E-02	.5026E-02
229	89.5322	46.1640	58.5918	-.2158E-02	-.4482E-02	.4975E-02
230	89.3762	50.2187	58.4989	-.1382E-02	-.5381E-02	.5556E-02
231	89.2203	54.2734	58.3919	.2501E-02	-.4118E-02	.4818E-02
232	89.0643	58.3280	58.3280	.5210E-02	-.7602E-03	.5265E-02
233	92.0000	0.0000	59.0533	-.4008E-02	-.5239E-06	.4008E-02
234	92.0000	17.0000	58.9888	-.3872E-02	-.1583E-02	.4176E-02
235	92.0000	34.0000	58.7869	-.3293E-02	-.3141E-02	.4551E-02
236	91.6878	42.1184	58.6493	-.2700E-02	-.3890E-02	.4739E-02
237	91.3755	50.2369	58.4656	-.1236E-02	-.4574E-02	.4738E-02
238	91.0633	58.3561	58.3676	.2720E-02	-.6284E-03	.2791E-02
239	94.0000	0.0000	59.0141	-.3837E-02	-.2307E-05	.3837E-02
240	94.0000	8.5000	58.9978	-.3783E-02	-.7659E-03	.3860E-02
241	94.0000	17.0000	58.9490	-.3708E-02	-.1530E-02	.4011E-02
242	94.0000	25.5000	58.8680	-.3451E-02	-.2284E-02	.4139E-02
243	94.0000	34.0000	58.7549	-.3132E-02	-.3037E-02	.4362E-02
244	93.8437	38.0837	58.6922	-.2894E-02	-.3387E-02	.4413E-02
245	93.6874	42.1274	58.6229	-.2576E-02	-.3893E-02	.4602E-02
246	93.5311	46.1911	58.5485	-.2028E-02	-.3759E-02	.4271E-02
247	93.3748	50.2548	58.4734	-.1288E-02	-.3828E-02	.4040E-02
248	93.2185	54.3185	58.4095	-.1700E-03	-.2249E-02	.2258E-02
249	93.0622	58.3822	58.3822	.6828E-03	-.2333E-03	.7213E-03
250	96.0000	0.0000	58.9768	-.3848E-02	-.4859E-05	.3848E-02
251	96.0000	17.0000	58.9130	-.3518E-02	-.1499E-02	.3821E-02
252	96.0000	34.0000	58.7245	-.2956E-02	-.2939E-02	.4166E-02
253	95.9998	42.1221	58.5941	-.2480E-02	-.3509E-02	.4277E-02
254	95.9996	50.2443	58.4538	-.1708E-02	-.3390E-02	.3796E-02
255	95.9994	58.3664	58.3790	-.1078E-02	-.1499E-03	.1088E-02
256	98.0000	0.0000	58.9412	-.3479E-02	-.7852E-05	.3479E-02
257	98.0000	8.5000	58.9254	-.3432E-02	-.7365E-03	.3510E-02
258	98.0000	17.0000	58.8787	-.3362E-02	-.1482E-02	.3686E-02
259	98.0000	25.5000	58.8019	-.3114E-02	-.2152E-02	.3785E-02
260	98.0000	34.0000	58.6958	-.2811E-02	-.2839E-02	.3995E-02
261	98.1561	38.0584	58.6335	-.2581E-02	-.3087E-02	.4024E-02
262	98.3122	42.1169	58.5695	-.2350E-02	-.3347E-02	.4090E-02
263	98.4683	46.1753	58.4986	-.2182E-02	-.3309E-02	.3961E-02
264	98.6244	50.2338	58.4289	-.2113E-02	-.3232E-02	.3861E-02
265	98.7805	54.2922	58.3739	-.2432E-02	-.1839E-02	.3047E-02
266	98.9366	58.3506	58.3506	-.2891E-02	-.1121E-03	.2894E-02
267	100.0000	0.0000	58.9074	-.3290E-02	-.1218E-04	.3290E-02
268	100.0000	17.0000	58.8480	-.3185E-02	-.1428E-02	.3491E-02
269	100.0000	34.0000	58.6665	-.2658E-02	-.2747E-02	.3821E-02
270	100.3117	42.1029	58.5435	-.2270E-02	-.3251E-02	.3965E-02
271	100.6233	50.2059	58.4059	-.2296E-02	-.3459E-02	.4132E-02
272	100.9350	58.3088	58.3178	-.4190E-02	-.3509E-03	.4204E-02
273	102.0000	0.0000	58.8754	-.3126E-02	-.1910E-04	.3126E-02
274	102.0000	8.5000	58.8598	-.3097E-02	-.7108E-03	.3178E-02
275	102.0000	17.0000	58.8150	-.3042E-02	-.1395E-02	.3347E-02
276	102.0000	25.5000	58.7423	-.2806E-02	-.2027E-02	.3461E-02
277	102.0000	34.0000	58.6427	-.2621E-02	-.2659E-02	.3664E-02
278	102.1556	38.0445	58.5845	-.2338E-02	-.2906E-02	.3730E-02
279	102.3111	42.0890	58.5215	-.2153E-02	-.3169E-02	.3832E-02
280	102.4667	46.1335	58.4540	-.2205E-02	-.3302E-02	.3970E-02
281	102.6222	50.1780	58.3848	-.2254E-02	-.3731E-02	.4360E-02
282	102.7778	54.2226	58.3102	-.4409E-02	-.2739E-02	.5189E-02
283	102.9333	58.2671	58.2670	-.5914E-02	-.4139E-03	.5928E-02
284	104.0000	0.0000	58.8451	-.2931E-02	-.3140E-04	.2931E-02
285	104.0000	17.0000	58.7855	-.2880E-02	-.1362E-02	.3186E-02
286	104.0000	34.0000	58.6182	-.2378E-02	-.2674E-02	.3605E-02
287	104.3222	42.0445	58.5009	-.2081E-02	-.3073E-02	.3700E-02
288	104.6444	50.0890	58.3809	-.2483E-02	-.3593E-02	.4367E-02
289	104.9667	58.1335	58.1814	-.1336E-01	-.3723E-02	.1389E-01
290	106.0000	0.0000	58.8189	-.2783E-02	-.5064E-04	.2783E-02
291	106.0000	8.5000	58.6009	-.2778E-02	-.6666E-03	.2864E-02
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

293	106.0000	25.5000	58.6668	-.2518E-02	-.1808E-02	.3160E-02
294	106.0000	34.0000	58.5951	-.2250E-02	-.2482E-02	.3357E-02
295	106.1667	38.0000	58.5409	-.2074E-02	-.2755E-02	.3448E-02
296	106.3333	42.0000	58.4814	-.1891E-02	-.2987E-02	.3519E-02
297	106.5000	46.0000	58.4162	-.1639E-02	-.3511E-02	.3883E-02
298	106.6667	50.0000	58.3380	-.1489E-02	-.3008E-02	.3347E-02
299	106.8333	54.0000	58.2417	-.3755E-02	-.8282E-02	.9103E-02
300	107.0000	58.0000	58.0000	-.9243E-02	-.1388E-01	.1651E-01
301	108.0000	0.0000	58.7803	-.2528E-02	-.9047E-04	.2528E-02
302	108.0000	17.0000	58.7308	-.2598E-02	-.1292E-02	.2901E-02
303	108.0000	34.0000	58.5734	-.2114E-02	-.2414E-02	.3209E-02
304	108.0000	42.0000	58.4883	-.1771E-02	-.2900E-02	.3398E-02
305	108.0000	50.0000	58.3298	-.1371E-02	-.2940E-02	.3244E-02
306	108.0000	58.0000	58.0000	-.1137E-12	-.1488E-01	.1488E-01
307	110.0000	0.0000	58.7682	-.2337E-02	-.1530E-03	.2342E-02
308	110.0000	8.5000	58.7475	-.2489E-02	-.7150E-03	.2571E-02
309	110.0000	17.0000	58.7054	-.2491E-02	-.1252E-02	.2788E-02
310	110.0000	25.5000	58.6408	-.2250E-02	-.1795E-02	.2878E-02
311	110.0000	34.0000	58.5528	-.1995E-02	-.2336E-02	.3072E-02
312	109.8333	38.0000	58.5052	-.1822E-02	-.2599E-02	.3174E-02
313	109.6667	42.0000	58.4519	-.1658E-02	-.2823E-02	.3274E-02
314	109.5000	46.0000	58.3922	-.1352E-02	-.3362E-02	.3624E-02
315	109.3333	50.0000	58.3187	-.1407E-02	-.3022E-02	.3333E-02
316	109.1667	54.0000	58.2282	.1285E-02	-.7938E-02	.8042E-02
317	109.0000	58.0000	58.0000	.7261E-02	-.1289E-01	.1479E-01
318	112.0000	0.0000	58.7449	-.1837E-02	-.2877E-03	.1860E-02
319	112.0000	17.0000	58.6817	-.2305E-02	-.1182E-02	.2595E-02
320	112.0000	34.0000	58.5338	-.1863E-02	-.2280E-02	.2929E-02
321	111.6782	42.0341	58.4358	-.1490E-02	-.2738E-02	.3115E-02
322	111.3563	50.0683	58.3131	-.4155E-03	-.3373E-02	.3398E-02
323	111.0345	58.1024	58.1483	.1024E-01	-.3875E-02	.1095E-01
324	114.0000	0.0000	58.7275	-.1831E-02	-.5666E-03	.1923E-02
325	114.0000	8.5000	58.6985	-.2271E-02	-.8016E-03	.2408E-02
326	114.0000	17.0000	58.6593	-.2239E-02	-.1132E-02	.2509E-02
327	114.0000	25.5000	58.5980	-.2008E-02	-.1581E-02	.2624E-02
328	114.0000	34.0000	58.5156	-.1760E-02	-.2189E-02	.2807E-02
329	113.8448	38.0341	58.4706	-.1580E-02	-.2405E-02	.2878E-02
330	113.6897	42.0683	58.4210	-.1397E-02	-.2637E-02	.2984E-02
331	113.5345	46.1024	58.3667	-.9654E-03	-.2817E-02	.2977E-02
332	113.3794	50.1365	58.3089	-.5309E-03	-.3294E-02	.3336E-02
333	113.2242	54.1707	58.2440	.1794E-02	-.2519E-02	.3075E-02
334	113.0690	58.2048	58.2045	.3442E-02	-.8313E-03	.3482E-02
335	115.8282	1.5994	58.7040	-.2537E-02	-.7537E-03	.2646E-02
336	115.8282	17.8903	58.6342	-.2123E-02	-.1167E-02	.2422E-02
337	115.8282	34.1812	58.4981	-.1849E-02	-.2132E-02	.2895E-02
338	115.5180	42.1949	58.4072	-.1289E-02	-.2530E-02	.2840E-02
339	115.2087	50.2085	58.3034	-.4419E-03	-.2867E-02	.2901E-02
340	114.9015	58.2222	58.2298	.1997E-02	-.4215E-03	.2041E-02
341	117.8524	3.1988	58.6891	-.3035E-02	-.3114E-03	.3051E-02
342	117.8524	10.9897	58.6481	-.2128E-02	-.7581E-03	.2258E-02
343	117.8524	18.7806	58.6102	-.1980E-02	-.1202E-02	.2299E-02
344	117.8524	26.5715	58.5544	-.1772E-02	-.1650E-02	.2422E-02
345	117.8524	34.3624	58.4818	-.1554E-02	-.2080E-02	.2596E-02
346	117.4993	38.3418	58.4397	-.1397E-02	-.2248E-02	.2646E-02
347	117.3462	42.3215	58.3942	-.1227E-02	-.2428E-02	.2721E-02
348	117.1932	46.3010	58.3463	-.9123E-03	-.2435E-02	.2600E-02
349	117.0401	50.2805	58.2987	-.4770E-03	-.2447E-02	.2493E-02
350	116.8871	54.2601	58.2565	.2232E-03	-.1441E-02	.1458E-02
351	116.7340	58.2396	58.2410	.7815E-03	-.1638E-03	.7989E-03
352	119.8282	1.5994	58.6369	-.2028E-02	.2284E-03	.2041E-02
353	119.8282	17.8903	58.5948	-.1888E-02	-.1118E-02	.2199E-02
354	119.8282	34.1812	58.4672	-.1452E-02	-.2004E-02	.2474E-02
355	119.8284	42.1986	58.3809	-.1168E-02	-.2314E-02	.2593E-02
356	119.8307	50.2150	58.2906	-.7814E-03	-.2183E-02	.2319E-02
357	119.8329	58.2333	58.2431	-.4526E-03	-.9900E-04	.4633E-03
358	122.0000	0.0000	58.6214	-.1119E-02	.6611E-04	.1121E-02
359	122.0000	8.5000	58.6117	-.1782E-02	-.4699E-03	.1848E-02
360	122.0000	17.0000	58.5797	-.1793E-02	-.1021E-02	.2037E-02
361	122.0000	25.5000	58.5284	-.1580E-02	-.1483E-02	.2153E-02
362	122.0000	34.0000	58.4537	-.1356E-02	-.1833E-02	.2382E-02
363	122.1553	38.0378	58.4123	-.1236E-02	-.2072E-02	.2413E-02
364	122.3106	42.0757	58.3681	-.1117E-02	-.2228E-02	.2490E-02
365	122.4659	46.1135	58.3224	-.1056E-02	-.2182E-02	.2426E-02
366	122.6212	50.1514	58.2783	-.1070E-02	-.2130E-02	.2384E-02
367	122.7765	54.1892	58.2424	-.1345E-02	-.1219E-02	.1815E-02
368	122.9318	58.2271	58.2270	-.1574E-02	-.1159E-03	.1579E-02
369	123.4825	1.5994	58.6114	-.1694E-02	-.2567E-03	.1713E-02
370	123.4825	17.8903	58.5628	-.1833E-02	-.1040E-02	.1838E-02
371	123.4825	34.1812	58.4421	-.1282E-02	-.1901E-02	.2293E-02
372	123.8008	42.1909	58.3586	-.1085E-02	-.2197E-02	.2450E-02
373	124.1096	50.2005	58.2683	-.1181E-02	-.2254E-02	.2535E-02
374	124.4187	58.2102	58.2132	-.2269E-02	-.2257E-03	.2280E-02
375	124.8850	3.1988	58.5920	-.2275E-02	-.9945E-04	.2277E-02
376	124.8850	10.9897	58.5782	-.1653E-02	-.5690E-03	.1755E-02
377	124.8850	18.7806	58.5461	-.1532E-02	-.1088E-02	.1866E-02
378	124.8850	26.5715	58.4984	-.1383E-02	-.1478E-02	.2023E-02
379	124.8850	34.3624	58.4311	-.1214E-02	-.1870E-02	.2230E-02
380	125.1377	38.2242	58.3917	-.1122E-02	-.2014E-02	.2305E-02
381	125.2905	42.3060	58.3484	-.1031E-02	-.2169E-02	.2402E-02
382	125.4433	46.2779	58.3049	-.1102E-02	-.2208E-02	.2468E-02
383	125.5960	50.2497	58.2600	-.1206E-02	-.2372E-02	.2662E-02
384	125.7488	54.2216	58.2163	-.2322E-02	-.1587E-02	.2813E-02
385	125.9016	58.1934	58.1934	-.2869E-02	.2834E-04	.2870E-02
386	127.4825	1.5994	58.5627	-.1623E-02	.3643E-03	.1664E-02
387	127.4825	17.8903	58.5321	-.1418E-02	-.9911E-03	.1731E-02
388	127.4825	34.1812	58.4182	-.1108E-02	-.1808E-02	.2119E-02
389	127.8119	42.1530	58.3383	-.9568E-03	-.2118E-02	.2324E-02
390	128.1313	50.1249	58.2445	-.1277E-02	-.2469E-02	.2780E-02
391	128.4506	58.0967	58.1372	-.7862E-02	-.2033E-02	.7928E-02
392	130.0000	0.0000	58.5454	-.9911E-03	.3660E-03	.1028E-02
393	130.0000	8.5000	58.5460	-.1276E-02	-.3088E-03	.1311E-02
394	130.0000	17.0000	58.5194	-.1288E-02	-.9150E-03	.1580E-02
395	130.0000	25.5000	58.4721	-.1145E-02	-.1327E-02	.1753E-02
396	130.0000	34.0000	58.4059	-.1001E-02	-.1745E-02	.2012E-02
397	130.1667	38.0000	58.3693	-.9175E-03	-.1913E-02	.2122E-02
398	130.3333	42.0000	58.3285	-.8307E-03	-.2060E-02	.2221E-02
399	130.5000	46.0000	58.2837	-.8389E-03	-.2411E-02	.2552E-02
400	130.6667	50.0000	58.2307	-.6569E-03	-.2145E-02	.2244E-02
401	130.8333	54.0000	58.1638	-.2235E-02	-.5674E-02	.6098E-02
402	131.0000	58.0000	58.0000	-.5708E-02	-.9140E-02	.1078E-01
403	132.0000	0.0000	58.5399	-.6795E-03	.1787E-03	.6975E-03
404	132.0000	17.0000	58.5074	-.1143E-02	-.8828E-03	.1444E-02
405	132.0000	34.0000	58.3971	-.9091E-03	-.1706E-02	.1934E-02
406	132.0000	42.0000	58.3220	-.7535E-03	-.2027E-02	.2162E-02
407	132.0000	50.0000	58.2271	-.6014E-03	-.2058E-02	.2144E-02
408	132.0000	58.0000	58.0000	-.1137E-12	-.1005E-01	.1005E-01
409	134.0000	0.0000	58.5278	-.9298E-03	.9135E-04	.9343E-03
410	134.0000	8.5000	58.5221	-.1027E-02	-.3855E-03	.1091E-02
411	134.0000	17.0000	58.4965	-.1064E-02	-.8521E-03	.1363E-02
412	134.0000	25.5000	58.4511	-.9475E-03	-.1272E-02	.1586E-02
413	134.0000	34.0000	58.3884	-.8277E-03	-.1669E-02	.1863E-02
414	133.8333	38.0000	58.3540	-.7465E-03	-.1842E-02	.1988E-02
415	133.6667	42.0000	58.3190	-.6753E-03	-.1989E-02	.2100E-02
416	133.5000	46.0000	58.2737	-.5106E-03	-.2354E-02	.2409E-02
417	133.3333	50.0000	58.2226	-.5821E-03	-.2102E-02	.2181E-02
418	133.1667	54.0000	58.1576	.1229E-02	-.5515E-02	.5650E-02
419	133.0000	58.0000	58.0000	.5240E-02	-.8872E-02	.1030E-01
420	136.0000	0.0000	58.5190	-.6560E-03	.5327E-04	.6587E-03
421	136.0000	17.0000	58.4865	-.9433E-03	-.8353E-03	.1260E-02
422	136.0000	34.0000	58.3808	-.7396E-03	-.1635E-02	.1795E-02
423	135.6788	42.0249	58.3098	-.5636E-03	-.1952E-02	.2031E-02

425	136.0388	58.0747	58.1084	.7438E-02	-.2802E-02	.7981E-02
426	138.0000	0.0000	58.5107	-.8082E-03	.2888E-04	.8087E-03
427	138.0000	8.5000	58.5031	-.8350E-03	-.3885E-03	.9208E-03
428	138.0000	17.0000	58.4778	-.8467E-03	-.6225E-03	.1180E-02
429	138.0000	25.5000	58.4338	-.7818E-03	-.1224E-02	.1442E-02
430	138.0000	34.0000	58.3738	-.9830E-03	-.1604E-02	.1735E-02
431	137.8452	38.0249	58.3404	-.8638E-03	-.1749E-02	.1843E-02
432	137.6904	42.0498	58.3041	-.6030E-03	-.1907E-02	.1972E-02
433	137.5356	46.0747	58.2647	-.2535E-03	-.2018E-02	.2034E-02
434	137.3808	50.0997	58.2233	-.1835E-06	-.2325E-02	.2325E-02
435	137.2260	54.1246	58.1775	.1583E-02	-.1774E-02	.2388E-02
436	137.0712	58.1495	58.1495	.2701E-02	-.3646E-03	.2726E-02
437	140.0000	0.0000	58.5031	-.7191E-03	.1894E-04	.7193E-03
438	140.0000	17.0000	58.4597	-.7392E-03	-.8136E-03	.1099E-02
439	140.0000	34.0000	58.3874	-.5810E-03	-.1576E-02	.1679E-02
440	139.6902	42.0552	58.2985	-.4322E-03	-.1850E-02	.1899E-02
441	139.3804	50.1104	58.2235	.3370E-04	-.2034E-02	.2034E-02
442	139.0706	58.1656	58.1711	.1810E-02	-.2781E-03	.1833E-02
443	142.0000	0.0000	58.4963	-.6395E-03	.9172E-05	.6396E-03
444	142.0000	8.5000	58.4881	-.6455E-03	-.3933E-03	.7558E-03
445	142.0000	17.0000	58.4628	-.6449E-03	-.8081E-03	.1032E-02
446	142.0000	25.5000	58.4203	-.5839E-03	-.1187E-02	.1323E-02
447	142.0000	34.0000	58.3620	-.5089E-03	-.1551E-02	.1632E-02
448	141.8450	38.0303	58.3299	-.4534E-03	-.1670E-02	.1730E-02
449	141.6900	42.0605	58.2954	-.3820E-03	-.1799E-02	.1842E-02
450	141.5350	46.0908	58.2592	-.2450E-03	-.1787E-02	.1803E-02
451	141.3800	50.1211	58.2238	-.2820E-04	-.1770E-02	.1770E-02
452	141.2249	54.1514	58.1943	.3788E-03	-.1031E-02	.1098E-02
453	141.0699	58.1816	58.1816	.6899E-03	-.9847E-04	.6969E-03
454	144.0000	0.0000	58.4904	-.5476E-03	.5188E-05	.5477E-03
455	144.0000	17.0000	58.4589	-.5455E-03	-.7898E-03	.9582E-03
456	144.0000	34.0000	58.3573	-.4348E-03	-.1530E-02	.1591E-02
457	144.0000	42.0598	58.2911	-.3489E-03	-.1764E-02	.1798E-02
458	143.6999	50.1196	58.2220	-.2378E-03	-.1861E-02	.1876E-02
459	143.3999	58.1794	58.1858	-.1514E-03	-.7667E-04	.1696E-03
460	146.0000	0.0000	58.4853	-.4599E-03	.2413E-05	.4599E-03
461	146.0000	8.5000	58.4770	-.4588E-03	-.3928E-03	.6040E-03
462	146.0000	17.0000	58.4519	-.4840E-03	-.7946E-03	.9152E-03
463	146.0000	25.5000	58.4102	-.4137E-03	-.1181E-02	.1232E-02
464	146.0000	34.0000	58.3533	-.3647E-03	-.1513E-02	.1557E-02
465	146.1550	38.0295	58.3214	-.3348E-03	-.1624E-02	.1658E-02
466	146.3100	42.0591	58.2873	-.3088E-03	-.1744E-02	.1771E-02
467	146.4649	46.0886	58.2519	-.3470E-03	-.1718E-02	.1753E-02
468	146.6199	50.1181	58.2178	-.4464E-03	-.1686E-02	.1743E-02
469	146.7749	54.1477	58.1893	-.7288E-03	-.9733E-03	.1222E-02
470	146.9299	58.1772	58.1772	-.9718E-03	-.8381E-04	.9752E-03
471	148.0000	0.0000	58.4612	-.3889E-03	.1008E-05	.3889E-03
472	148.0000	17.0000	58.4478	-.3800E-03	-.7902E-03	.8843E-03
473	148.0000	34.0000	58.3500	-.2932E-03	-.1501E-02	.1529E-02
474	148.3097	42.0530	58.2844	-.2732E-03	-.1748E-02	.1769E-02
475	148.6195	50.1061	58.2125	-.5172E-03	-.1874E-02	.1944E-02
476	148.9292	58.1591	58.1641	-.1613E-02	-.2425E-03	.1629E-02
477	150.0000	0.0000	58.4780	-.2785E-03	-.7739E-07	.2785E-03
478	150.0000	8.5000	58.4597	-.2744E-03	-.3911E-03	.4778E-03
479	150.0000	17.0000	58.4447	-.2700E-03	-.7868E-03	.8318E-03
480	150.0000	25.5000	58.4038	-.2475E-03	-.1145E-02	.1171E-02
481	150.0000	34.0000	58.3474	-.2210E-03	-.1492E-02	.1508E-02
482	150.1548	38.0235	58.3160	-.2181E-03	-.1818E-02	.1833E-02
483	150.3095	42.0470	58.2820	-.2122E-03	-.1758E-02	.1769E-02
484	150.4643	46.0705	58.2454	-.3549E-03	-.1839E-02	.1873E-02
485	150.6190	50.0940	58.2074	-.4978E-03	-.2088E-02	.2148E-02
486	150.7738	54.1175	58.1661	-.1817E-02	-.1582E-02	.2409E-02
487	150.9285	58.1410	58.1410	-.2792E-02	-.3342E-03	.2812E-02
488	152.0000	0.0000	58.4757	-.1837E-03	-.4839E-06	.1837E-03
489	152.0000	17.0000	58.4425	-.1790E-03	-.7840E-03	.8041E-03
490	152.0000	34.0000	58.3486	-.1492E-03	-.1486E-02	.1493E-02
491	152.3214	42.0235	58.2802	-.1630E-03	-.1767E-02	.1784E-02
492	152.6428	50.0470	58.2013	-.8024E-03	-.2081E-02	.2188E-02
493	152.9643	58.0705	58.0977	-.7006E-02	-.2307E-02	.7378E-02
494	154.0000	0.0000	58.4743	-.9229E-04	-.9248E-06	.9229E-04
495	154.0000	8.5000	58.4660	-.9125E-04	-.3900E-03	.4006E-03
496	154.0000	17.0000	58.4412	-.8880E-04	-.7824E-03	.7878E-03
497	154.0000	25.5000	58.4003	-.8240E-04	-.1138E-02	.1141E-02
498	154.0000	34.0000	58.3444	-.7412E-04	-.1481E-02	.1483E-02
499	154.1667	38.0000	58.3134	-.7120E-04	-.1630E-02	.1632E-02
500	154.3333	42.0000	58.2791	-.6423E-04	-.1749E-02	.1750E-02
501	154.5000	46.0000	58.2415	-.1323E-03	-.2067E-02	.2071E-02
502	154.6667	50.0000	58.1962	.3065E-04	-.1782E-02	.1783E-02
503	154.8333	54.0000	58.1397	-.1449E-02	-.4846E-02	.5057E-02
504	155.0000	58.0000	58.0000	-.4890E-02	-.7955E-02	.9372E-02
505	155.0000	0.0000	58.4740	-.4592E-04	-.1044E-05	.4594E-04
506	155.0000	17.0000	58.4408	-.4453E-04	-.7822E-03	.7835E-03
507	155.0000	34.0000	58.3442	-.3823E-04	-.1482E-02	.1482E-02
508	155.1667	42.0000	58.2790	-.1555E-04	-.1756E-02	.1756E-02
509	155.3333	50.0000	58.1967	.9821E-04	-.1728E-02	.1730E-02
510	155.5000	58.0000	58.0000	.2728E-12	-.6766E-02	.6766E-02
511	156.0000	0.0000	58.4738	-.1306E-06	-.1111E-05	.1116E-05
512	156.0000	8.5000	58.4655	.1049E-06	-.3889E-03	.3889E-03
513	156.0000	17.0000	58.4407	-.4220E-06	-.7821E-03	.7821E-03
514	156.0000	25.5000	58.3998	.1669E-06	-.1137E-02	.1137E-02
515	156.0000	34.0000	58.3441	.3085E-07	-.1483E-02	.1483E-02
516	156.0000	38.0000	58.3130	.1768E-05	-.1628E-02	.1628E-02
517	156.0000	42.0000	58.2790	.2865E-05	-.1765E-02	.1765E-02
518	156.0000	46.0000	58.2409	.2016E-04	-.2062E-02	.2063E-02
519	156.0000	50.0000	58.1969	.9435E-04	-.1778E-02	.1780E-02
520	156.0000	54.0000	58.1358	.1197E-03	-.4822E-02	.4823E-02
521	156.0000	58.0000	58.0000	-.3156E-04	-.8859E-02	.8859E-02

SEEPAGE FACE COMPUTATION RESULTS

NB = 96 NE = 113 AVE. VEL = .51200E-01 DS = .20000E+01 DQ = .10240E+00

TOTAL DISCHARGE = .10240E+00
NB = 113 NE = 198 AVE. VEL = .38107E-01 DS = .22000E+02 DQ = .83830E+00

TOTAL DISCHARGE = .94070E+00
NB = 198 NE = 215 AVE. VEL = .26352E-01 DS = .20000E+01 DQ = .52704E-01

TOTAL DISCHARGE = .99340E+00
NB = 215 NE = 300 AVE. VEL = .20481E-01 DS = .22000E+02 DQ = .45058E+00

TOTAL DISCHARGE = .14440E+01
NB = 300 NE = 317 AVE. VEL = .15649E-01 DS = .20000E+01 DQ = .31299E-01

TOTAL DISCHARGE = .14753E+01
NB = 317 NE = 402 AVE. VEL = .12784E-01 DS = .22000E+02 DQ = .28126E+00

TOTAL DISCHARGE = .17566E+01
NB = 402 NE = 419 AVE. VEL = .10583E-01 DS = .20000E+01 DQ = .21166E-01

TOTAL DISCHARGE = .17778E+01
NB = 419 NE = 504 AVE. VEL = .98810E-02 DS = .22000E+0‾ DQ = .21738E+00

TOTAL DISCHARGE = .19951E+01
NB = 504 NE = 521 AVE VEL = .80157E-02 DS = .10000E+01 DQ = .80157E-02

TOTAL DISCHARGE = .20042E+01
1 SP:25 K = .2..D = 20 FT...END OF PROBLEM.

NDIMEN = 3 FERR = .00010

END
1-87
DTIC