DIGITAL SIMULATION OF CHLORIDE CONTAMINATION OF GROUNDWATER AT SHADOW LAWN SUBDIVISION, STARK COUNTY, OHIO

BY

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ABSTRACT

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Digital modeling technique of solute transport in groundwater was applied to a problem of chloride contamination of groundwater at Shadow Lawn Subdivision, Bethelem Township, Stark County, Ohio. A finite-difference solute transport model, known as USGS-MOCADI, and a finite-element solute transport model, known as SUTRA, were used to simulate the chloride contamination in the groundwater. Groundwater in the study area was contaminated by surface runoff with high chloride concentration from the County's salt storage facility. Some of the wells in the study area showed chloride concentration as high as 2820 mg/l during 1986. Chloride concentration was found to be high only in those wells with casing length set at 40 to 70 ft depth. The storage facility was abandoned in March, 1987 but chloride concentration is still high in the groundwater. As the source of contamination has been removed, chloride concentration will decrease naturally in the future. Historic data on piezometric head

in wells was not available, hence the models were calibrated for chloride concentrations only. The time when the chloride contamination first reached the groundwater is not known. The USGS-MOCADI model was calibrated and verified using the split data technique. The data used were recorded during 1986 to 1988. The calibrated model was then used to predict chloride concentrations in the future. SUTRA model was also used to predict chloride concentrations in the future. The SUTRA model was not calibrated independently. Instead, the calibrated and verified parameters from the USGS-MOCADI model were used in the SUTRA model. The predicted chloride concentrations by the two models were found to be identical. The models predicted that chloride concentrations will decrease to less than 250 mg/l by the year 2006. The calibrated models can be used in the future for various aquifer management programs in the study area especially for groundwater contamination protection programs.

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CHAPTER I

INTRODUCTION

The contamination of a groundwater resource is a serious problem that can have long-term economic and physical consequences and might not be easily remedied. Since the early 1970's a great deal of effort has been directed towards the understanding and quantification of physical and chemical processes which affect the transport of contaminants in groundwater.

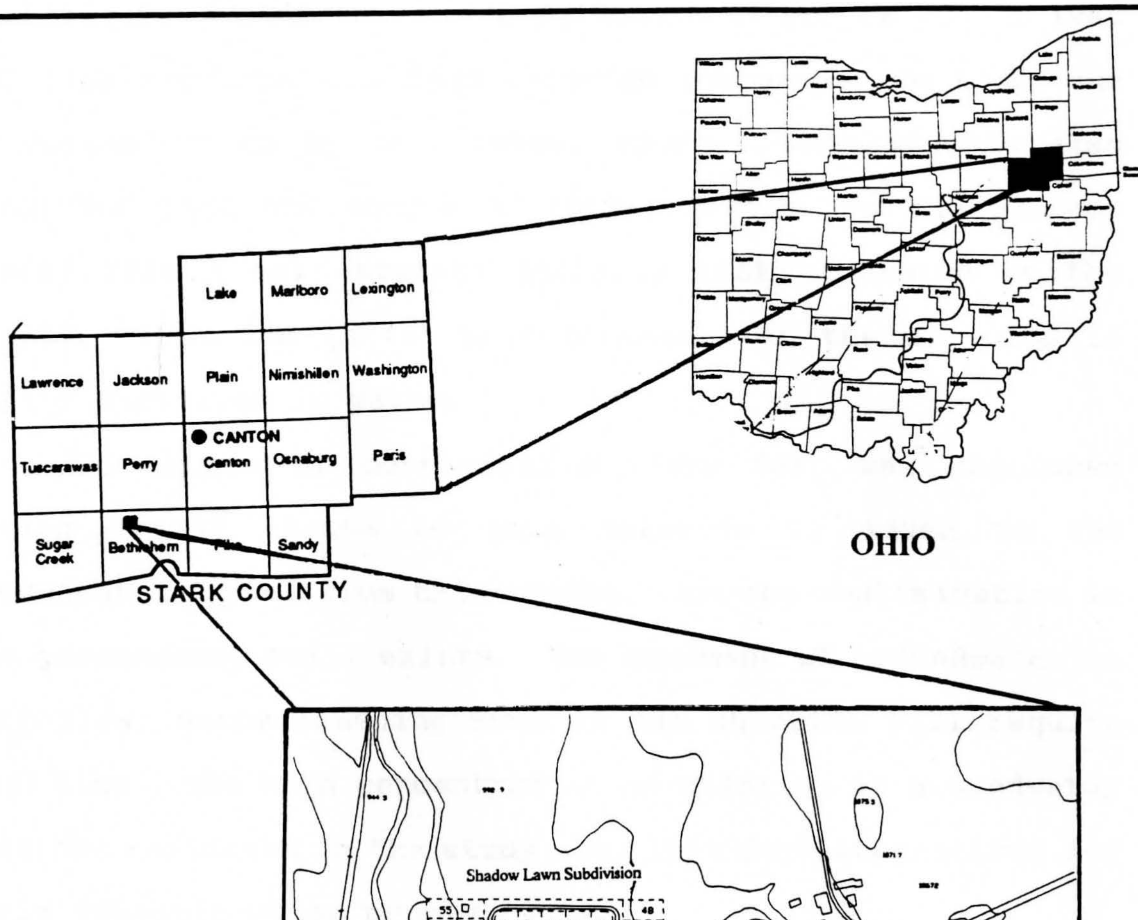
The solute transport in groundwater requires understanding of the process of groundwater flow and interaction of groundwater flow with the solute. Early groundwater flow models, such as the Theis equations (Theis, 1935), were simple and based on analytical solutions. The advent of high speed digital computation has spawned a new era in groundwater flow modeling such that solutions to previously unsolved modeling equations can now be approximated by numerical techniques. The digital computations made it possible to solve complex problems involving the groundwater flow and the solute transport encountered in field situation.

The groundwater solute transport model has been successfully used in many aquifer systems and the results of the model applications have proved it to be a very useful tool. In general, a groundwater solute transport model is helpful in the following aspects:

1) Planning and designing of projects to minimize groundwater contamination.
2) Estimating spatial and temporal variations of chemical concentrations in the aquifer.
3) Estimating the travel time of a contaminant from its source to a groundwater sink.
4) Designing an effective and efficient monitoring system for an aquifer.
5) Evaluating the physical and economic feasibility of various alternative reclamation plans for removing or preventing spreading of contaminations from an aquifer.

1.1 Background of study area

The study area, Shadow Lawn Subdivision, is located in Bethelem township, Stark County, Ohio (Figure 1-1). The area has 55 lots and all the households depend on the groundwater for domestic water supply. During 1986, EPA began monitoring the water quality of the wells and found that the concentration of chloride level was very high in some of the wells. The level of chloride concentration was observed to be more than 2500 mg/l in some of the wells. The secondary maximum chloride level in public water system is set at 250 mg/l by EPA. The chloride contamination problem became a subject of concern and the Stark County Engineer's office took the initiative to study the contamination problem. Two preliminary studies have been conducted so far. The



<u>Figure 1-1</u> : Location of the Study Area

preliminary studies conducted by Mosure & Syrakis Co. in 1988 and 1990 suspected the high chloride concentration to be due to contamination by an external source. The studies also concluded that the source of contamination was the surface runoff from a salt storage facility (SSF) operated by the County. Chloride is the main component in the salt and is easily dissolved in water.

The source of contamination, the SSF, was abandoned during 3/1987, hence no more chloride is added to the groundwater system from this source. But the contamination in the groundwater still exists. The movement of groundwater is very slow, hence flushing down of the chloride will require long time. The high concentration of chloride in groundwater made the residents in the study area look for alternatives for their domestic water supply.

1.2 Objective and Scope of the Study

The main objective of the study is to construct and calibrate digital simulation models to simulate the chloride contamination transport in the study area. The study will focus on calibration of models to duplicate the observed concentrations and the calibrated models will be used to make future prediction of fate and transport of the chloride present in the groundwater. Two widely used and accepted contaminant transport models will be used to simulate the transport process. One is a finite difference model known as USGS-MOCADI, based on methods of characteristics (MOC) and the other is a finite element model known as SUTRA. The study will also include the following aspects of modeling:

1) Review of governing groundwater flow and solute transport equations and modeling techniques.
2) Adopt methodology for model development, calibration and verification.
3) Process hydro-geological data of the study area from the available information and assume the various parameters which are not available.
4) Predict movement of contaminants in future.

The study will be useful for management of the groundwater resource of the study area. The study will also assist in modeling similar types of problems elsewhere.

CHAPTER II

LITERATURE REVIEW

2.1 Mathematical Expressions Governing Groundwater Flow

Groundwater flow and storage are governed by established hydraulic principles. Darcy (1856) observed that the velocity of flow through porous media is directly proportional to the hydraulic gradient. The above finding is universally known as the Darcy law and is the basis of general groundwater flow equations.

Theis (1935) introduced an equation for non-steady state flow to the well based on an analogy with heat flow. Jacob (1950) derived the Theis equations by considering the Darcy law and law of continuity. The governing equation of groundwater flow derived by Jacob (1950) for transient two dimensional flow of a homogeneous compressible fluid through nonhomogeneous anisotropic aquifer, with principal axes aligned in x and y-directions, can be written as (Pinder et al., 1976):

$$\frac{\partial}{\partial x}(T_x\frac{\partial h}{\partial x}) + \frac{\partial}{\partial y}(T_y\frac{\partial h}{\partial y}) = S\,\frac{\partial h}{\partial t} + W(x,y,t) \tag{2-1}$$

The term T is known as transmissivity of the porous media and S is the storage coefficient. The transmissivity is the product of the hydraulic conductivity (K) and the saturated thickness (b) of the aquifer. Coefficient of Storage (S) is the product of Specific storage (S_s) and the saturated thickness (b) of the aquifer.

$$T = K b \tag{2-2}$$

$$S = S_s b \tag{2-3}$$

Jacob (1950) derived an expression for S_s

$$S_s = \gamma n \beta (1 + \frac{\alpha}{n\beta}) \tag{2-4}$$

Where α and β are compressibility of aquifer and water respectively. γ is the specific weight of water and n is porosity of porous media. De Wiest (1966) derived the expression for S_s by considering fixed boundaries of the control volume as:

$$S_s = \gamma [(1-n) \alpha + \beta] \tag{2-5}$$

In case of unconfined aquifers, expression for the coefficient of storage (S) is given by Hantush (1964).

$$S = S_y + \gamma n \beta b (1 + \frac{\alpha}{n\beta}) \tag{2-6}$$

Where S_y is the specific yield of the aquifer. Usually the term $\gamma n\beta b(1+\alpha/n\beta)$ is negligible in comparison with S_y and S under unconfined conditions for all practical purposes is taken as specific yield (S_y).

The term W(x,y,t) is the volume flux per unit area. If only the fluxes of direct withdrawal or recharge and steady leakage into or out of the aquifer through a confining layer and stream bed or lake bed are considered, then W(x,y,t) can be written as:

$$W(x,y,t) = Q(x,y,t) - \frac{K_z}{m}(H_s - h) \tag{2-7}$$

Where

Q = Rate of withdrawal (+) or recharge (-) (L/T)

K_z = Vertical Hydraulic conductivity of confining layer (L/T)

m = Thickness of confining layer (L)

H_s = Hydraulic head in the source bed (L)

Expression for average seepage velocity is derived by Lohman (1972).

$$V_x = -\frac{K_x}{n}\frac{\partial h}{\partial x} \tag{2-8}$$

The governing equation of groundwater flow (Eq. 2-1) is a second-order partial differential equation which describes the flow phenomenon but it contains no information related to any specific case of flow. Hence the equation has infinite numbers of feasible solutions. In order to obtain one particular solution to a problem concerned, supplementary information which includes a specification of initial conditions and of boundary conditions should be provided. Initial conditions refers to the distribution of the values of the considered state variable at some initial time, usually taken as t=0, at all points within the considered problem domain. Boundary condition describes the interaction between the problem domain and its environment.

2.2 Mathematical Expressions Governing Solute Transport

Movement of contaminants in groundwater occurs due to advection and dispersion. The transport at the same velocity as groundwater of dissolved solids is called advective transport. Dispersion refers to mixing and spreading caused in part by molecular diffusion and in part by variation in velocity within the porous media. The advection-dispersion governing equation of solute transport for two dimensional flow problem is given by Wang and Anderson (1979).

$$\frac{\partial}{\partial x}\left(nD_{11}\frac{\partial C}{\partial x} + nD_{12}\frac{\partial C}{\partial y}\right) + \frac{\partial}{\partial y}\left(nD_{21}\frac{\partial C}{\partial x} + nD_{22}\frac{\partial C}{\partial y}\right)$$

$$- \frac{\partial}{\partial x}(nCv_x) - \frac{\partial}{\partial y}(nCv_y) - C'\frac{W}{b} + n\sum_{k=1}^{s} R_k = n\frac{\partial C}{\partial t} \qquad (2\text{-}9)$$

Where

n = Porosity of porous media

C = Solute concentration in mass per unit volume of water

D_{ij} = Dispersion coefficient rotated from local to global coordinates.

V_x, V_y = Velocity of flow in x and y directions respectively.

C' = Concentration of solute in the source or sink fluid.

W = Volume flow rate per unit aquifer area

b = Thickness of aquifer

R_k = Rate of production or decay of the solute in reaction k of s different reactions.

In each point in the aquifer the term D_{ij} is given by

$$D_{22} = D_L\cos^2\theta + D_T\sin^2\theta \tag{2-10}$$

$$D_{22} = D_L\sin^2\theta + D_T\cos^2\theta \tag{2-11}$$

$$D_{12} = D_{21} = (D_L - D_T)\sin\theta\cos\theta \tag{2-12}$$

Where D_L and D_T are the Longitudinal and transverse dispersion coefficient, respectively and θ is the counterclockwise rotation angle from global to local coordinates. Scheidegger (1961) showed that for an isotropic aquifer, the dispersion coefficients can be defined in terms of longitudinal (α_L) and transverse (α_T) dispersivities.

$$D_L = \alpha_L\ |V| \tag{2-13}$$

$$D_T = \alpha_T\ |V| \tag{2-14}$$

Where. $|V|$ is the magnitude of the velocity (L/T)

In practical applications, dispersion caused by molecular diffusion is negligible. In the above governing equation this factor is neglected. Here the dispersion caused by large scaled heterogeneities within the aquifer is considered as the transport mechanism of the solute by dispersion.

2.3 Solutions to the Groundwater Flow Equations

The solution to the governing equation for groundwater flow in two dimension, Eq. (2-1), can be obtained either by analytical methods or by numerical techniques. In practical problems numerical techniques are extensively used due to the complex nature of the problems. The complexity arises because of the irregular shape of the boundaries, the spatial variability of the coefficients appearing in the equations and in the boundary conditions, the non-uniformity of the initial conditions and the nonanalytic form of the various source and sink terms. Analytical solutions are suited only for relatively simple problems which rarely occur in field situations.

Numerical techniques extensively used in the groundwater modeling are finite-difference and finite-element methods. The finite-difference method was the first method to be used for the systematic numerical solution of partial differential equations. In the 1960's a more powerful numerical method, the finite-element method, was developed. The finite-element method is more flexible than the finite-difference method in respect to representation of the field geometry.

2.3.1 Finite-Difference Method

The finite difference method consists of an approximation of partial derivatives by algebraic expressions involving the values of the dependent variables at a limited number of selected points. The approximation results in a series of algebraic equations written in terms of the values of the dependent variables. The series of the algebraic equation then can be solved by any suitable method. The finite-difference method requires that the area of interest be subdivided by a grid into a number of smaller subareas. The finite difference method utilizes a rectangular grid. For the uniformly spaced, rectangular, block centered finite difference grid, in which nodes are defined at the centers of the rectangular cells, Pinder and Bredehoeft (1968) showed that Eq. (2-1) may be approximated by following implicit finite-difference equation.

$$T_{x[i-1/2,j]}\left[\frac{h_{i-1,j,k} - hi,j,k}{(\Delta x)^2}\right] + T_{x[i+1/2,j]}\left[\frac{h_{i+1,j,k} - hi,j,k}{(\Delta x)^2}\right]$$

$$+ T_{y[i,j-1/2]}\left[\frac{h_{i,j-1,k} - hi,j,k}{(\Delta y)^2}\right] + T_{x[i,j+1/2]}\left[\frac{h_{i,j+1,k} - hi,j,k}{(\Delta y)^2}\right]$$

$$= S\left[\frac{h_{i,j,k} - h_{i,j,k-1}}{\Delta t}\right] + \frac{q_{w(i,j)}}{\Delta x \Delta y} \frac{K_z}{m}[H_{s(i,j)} - hi,j,k] \tag{2-15}$$

Where

i,j,k = Indices in the x, y and time dimensions

$\Delta x, \Delta y, \Delta t$ = Increments in the x, y and time dimensions

q_w = Volumetric rate of withdrawal or recharge at node (i,j) (L^3/T)

Here k represents the new time level and k-1 represents the previous time level. The velocity of groundwater flow can be computed by following explicit finite difference form of the Eq. (2-1).

$$V_{x(i,j)} = \frac{K_{x(i,j)}}{n}\left[\frac{h_{i-1,j,k} - h_{i+1,j,k}}{2\Delta x}\right] \tag{2-16}$$

Similarly velocity in y-direction can be computed. Several techniques are available to solve the finite-difference equation (Eq. 2-15). The iterative alternating-direction implicit procedure (ADI) is used in the early models by Pinder (1969) and Trescott (1973). For many field problems

ADI is convergent and efficient in computation but it may be difficult to obtain a solution for some problems in steady state simulation involving extremely variable coefficients (Trescott et al., 1976).

Trescott et al. (1976) also used the line successive over-relaxation method (LSOR) to solve the finite-difference equation. LSOR is similar to iterative ADI, but, instead of alternating directions from one iteration level to the next, the solution is oriented either along rows or along columns for the duration of the simulation. The solution is oriented in the direction of larger coefficients in the coefficient matrix.

Another powerful method of solving the finite-difference equation is the strongly implicit procedure (SIP) which was introduced by Stone (1968). It has been shown that SIP converges faster than ADI or LSOR for problems involving heterogeneous and anisotropic media (Trescott et al., 1976).

2.3.2 Finite-Element Method

The finite-element method can be implemented with a variety of element shapes compared to the rectangular type of cells in the finite-difference method. Galerkin's method of weighted residual approach is widely used to approximate the differential equations. The dependent variables within each element are defined in terms of the nodal values by a interpolation function and combined together with the appropriate boundary conditions to yield a series of time dependent linear first order differential equations defining the dependent variables throughout the problem domain. The series of the linear deferential equations are then solved generally by the finite-difference method to yield the unknown values at new time step.

In the finite element method, using Galerkin method of weighted residual approach, a trial solution for piezometric head is first formulated (Wang and Anderson, 1982).

$$\hat{h} = \sum_{L=1}^{NNODE} h_L(t)\ N_L(x,y) \tag{2-17}$$

The above trial solution is substituted in the governing flow equation with the residual, weighted by each of the basis functions, and equated to zero. For the homogeneous and isotropic aquifer media with no source and sink term , it can be shown that:

$$\iint_D \left(\frac{\partial^2 \hat{h}}{\partial x^2} + \frac{\partial^2 \hat{h}}{\partial y^2} - \frac{S}{T}\frac{\partial \hat{h}}{\partial t}\right) N_L(x,y)\, dxdy = 0 \tag{2-18}$$

Where L = 1,2,.. NNODE and the integration is done over the domain D. The Eq. (2-18) can be integrated by parts to reduce the order of derivative by one.

$$\iint_D \left(\frac{\partial \hat{h}}{\partial x}\frac{\partial N_L}{\partial x} + \frac{\partial \hat{h}}{\partial y}\frac{\partial N_L}{\partial y}\right) dxdy + \iint_D \frac{S}{T}\frac{\partial \hat{h}}{\partial t} N_l dxdy$$

$$= \int_\Gamma \left(\frac{\partial \hat{h}}{\partial x} n_x + \frac{\partial \hat{h}}{\partial y} n_y\right) N_L\, d\sigma \tag{2-19}$$

Here Γ is the boundary of the problem domain. n_x and n_y are the components of a unit vector normal to the boundary and σ is an integration variable representing distance along the boundary in a counterclockwise sense. The above Eq. (2-19) can be written in matrix form as

$$[G]\{h\} + [P]\{\frac{\partial h}{\partial t}\} = \{f\} \tag{2-20}$$

Where [G] represents the conductance matrix, which depends on the shape of elements. [P] is a square matrix which accounts for the storage term and {f} is a column matrix representing the boundary conditions.

The steps involved in solving Eq. (2-20) are summarized as follows:

1) Initially, element interpolation function N_L is defined for each element. The definition of N_L is dependent on shape of element considered. Most commonly used element shapes are triangular and quadrilateral.
2) The [G] and [P] matrices are computed for each element by solving the respective part of integration shown in Eq.(2-19). Global matrices of [G] and [P] are formed by summing the contribution of each element in the problem domain.
3) The Eq. (2-20) is then solved using the finite-difference method using certain time intervals.

2.3.3 Other Methods

Other methods available to solve the governing equations of groundwater flow are the boundary integral equation method (BIEM) (Bear and Verruijt, 1987) and the analytical element method (Strack, 1987). The BIEM is basically restricted to regions with homogeneous soil and fluid properties as it uses a fundamental solution for a singularity in a homogeneous field. The analytical element method uses superposition to generate the analytical solution of a certain problem, expressed as a sum of basic solutions, each with a number of possibly unknown parameters. As a large variety of basic solutions is available or can be constructed, the analytical element method can be used for large variety of problems. The method primarily applies to homogeneous regions; its application in the field requires considerable amount of theoretical expertise.

2.4 Solutions to the Solute Transport Equations

Several numerical methods are available to solve the governing equation for solute transport. Early solutions to the solute transport equation used a finite-difference approximation. The finite-difference method has difficulty with solute transport formulation for an advection dominated system as the method is incapable of accurately approximating a hyperbolic partial differential equation (Miller & Weber, 1985). Methods of characteristics and finite-element method are extensively used.

2.4.1 Methods of Characteristic

Numerical errors in the solution by the finite-difference method can be minimized by using method of characteristics in conjunction with the finite-difference method. Applications of the method of characteristics in field problem have been studied by Konikov & Bredehoft (1978). In method of the characteristics the partial differential equation for the solute transport is first replaced by a set of ordinary differential equations and then solved by using the finite-difference method. Following the derivation of Konikov & Bredehoeft, the solute transport equation Eq. (2-9) is replaced by the following sets of differential equations:

$$\frac{dx}{dt} = V_x \tag{2-21}$$

$$\frac{dy}{dt} = V_y \tag{2-22}$$

$$\frac{dC}{dt} = \frac{1}{b}\frac{\partial}{\partial x}(nD_{11}\frac{\partial C}{\partial x} + nD_{12}\frac{\partial C}{\partial y}) + \frac{\partial}{\partial y}(nD_{21}\frac{\partial C}{\partial x} + nD_{22}\frac{\partial C}{\partial y}) + F \tag{2-23}$$

Where

$$F = \frac{C(S\frac{\partial h}{\partial t} + W - n\frac{\partial b}{\partial t}) - C'W + n\sum_{k=1}^{s} R_k}{nb} \tag{2-24}$$

In the Konikow & Bredehoeft (1978) equation the solute was assumed to be non reactive, so no reaction term R_k was included. The Eq. (2-21) and Eq. (2-22) are related to changes in concentration caused by convective transport alone and are solved by the movement of particles. Certain numbers of particles, usually 4 to 16 particles, are placed in the each cell of the finite-difference grid and for each time step every particle is moved a distance proportional to the length of the time increment and the velocity at the location of particle. The moving particles simulate advective transport because the concentration at each node of the grid will change with each time step as different particles having different concentrations enter and leave the area of that cell. The Eq. (2-24) is related to changes in concentration caused by hydrodynamic dispersion, fluid source, divergence of velocity, changes in saturated thickness and changes caused by reactions. The Eq. (2-23) is solved by using the explicit finite difference approximation. The explicit solution of the Eq. (2-23) requires time step size to be small. Reddell & Sunada (1970) showed that the time step size should be least of the values given by following relationships.

$$\Delta t \leq Min \left[\frac{0.5}{\frac{D_x}{(\Delta x)^2} + \frac{D_y}{(\Delta y)^2}} \right] \qquad (2\text{-}25)$$

$$\Delta t \leq Min \left[\frac{n\, b_{i,j,k}}{W_{i,j,k}} \right] \qquad (2\text{-}26)$$

$$\Delta t \leq \frac{\gamma \Delta x}{(V_x)_{max}} \quad or \quad \frac{\gamma \Delta y}{(V_y)_{max}} \qquad (2\text{-}27)$$

Where γ is the maximum cell distance per particle move.

2.4.2 Finite Element Method

The finite element solution method for solute transport equation is similar to the method used to solve the governing groundwater flow equations. For a homogeneous medium, where the dispersion coefficient and porosity are independent of the position of an element, the Eq. (2-9) can be written as:

$$D_L \frac{\partial^2 C}{\partial x^2} + D_T \frac{\partial^2 C}{\partial y^2} - \bar{v}_x \frac{\partial C}{\partial x} = \frac{\partial C}{\partial t} \tag{2-28}$$

Where $\bar{V}_x$ is the average linear velocity. A trial solution $\hat{C}$ is substituted in the above equation and the residual of trial solution $\hat{C}$, weighted by each of the basis functions, is equated to zero.

$$\iint_D \left(D_L \frac{\partial^2 \hat{C}}{\partial x^2} + D_T \frac{\partial^2 \hat{C}}{\partial y^2} - \bar{V}_x \frac{\partial \hat{C}}{\partial x} - \frac{\partial \hat{C}}{\partial t}\right) N_L(x,y)\, dxdy = 0 \tag{2-29}$$

Where L = 1,2,.. NNODE and the integration is done over the domain D. The Eq. (2-29) can be integrated by parts to reduce the order of derivative by one.

$$\iint_D \left(D_L \frac{\partial \hat{C}}{\partial x}\frac{\partial N_L}{\partial x} + D_T \frac{\partial \hat{C}}{\partial y}\frac{\partial N_L}{\partial y} + \hat{V}_x \frac{\partial \hat{C}}{\partial x} N_L + \frac{\partial \hat{C}}{\partial t} N_L\right) dxdy$$

$$= \int_\Gamma \left(D_L \frac{\partial \hat{C}}{\partial x} n_x + D_T \frac{\partial \hat{C}}{\partial y} n_y\right) N_L d\sigma \tag{2-30}$$

Where Γ is the boundary of the problem domain. n_x and n_y are the components of a unit vector normal to the boundary and σ is an integration variable representing distance along the boundary in a counterclockwise sense. The above Eq. (2-30) can be written in matrix form as:

$$[G]\{C\} + [U]\{C\} + [P]\{\frac{\partial C}{\partial t}\} = \{f\} \tag{2-31}$$

Where {C} is the column matrix of nodal concentrations and $\{\partial C/\partial t\}$ is the column matrix of the time derivative of nodal concentrations. The square matrices [G], [U] and [P] corresponds to individual terms in the integral on the left-hand side of Eq. (2-29) The column matrix {f} corresponds to the boundary integral on the right-hand side. The Eq. (2-31) is solved by using the finite-difference method.

2.5 Aquifer Parameter Determination

Modeling of an aquifer involves the solution of the governing equations of groundwater flow, Eq. (2-1), and solute transport equation, Eq. (2-9) for a problem domain. Modeling of aquifer requires specification of the following aquifer parameters.

1. Transmissivity (T) and Storage coefficient (S)
2. Aquifer Dispersivity
3. Boundary and initial conditions

2.5.1 Transmissivity and Storage Coefficient.

The hydro-geologic properties of an aquifer, the Transmissivity (T) and the Storage coefficient (S), are determined by means of pumping test. The value of T and S for an isotropic confined aquifer with fully penetrating wells can be estimated from unsteady state pumping test by using the type-curve graphical method devised by Theis (1935). Jacob and Cooper (1946) proposed a straight line semi-graphical method for the condition when the semi-logarithm plot of drawdown versus time is a straight line. The Theis and Jacob methods are still widely used. Many researchers have proposed methods of estimating T and S for variety of aquifer conditions (e.g., Papadopulos, 1965; Walton, 1962; Boulton, 1963; Prickett, 1965).

The type-curve methods devised in early stages require a considerable amount of effort in plotting the pumping test data and matching plot with the type curves. Recently computerized methods for determination of aquifer parameters are formulated. Saleem (1970) applied the principle of minimization of the sum of the weighted square of difference between the observed drawdown and drawdown calculated using the Theis equation and treating the aquifer parameters as decision variables. Khan (1982) showed use of a regression method based on Jacob's (1946) approximation to find T and S. Gupta and Joshi (1984) proposed a computerized method of estimating T and S based on the Theis type-curve graphical method. Mukhopahhyay (1985) presented a method based on the least square method of matching pumping test data with Theis type-curves. Sen (1986) devised a slope matching method to estimate T and S for non-leaky and leaky aquifer systems.

All the methods delineated above require a pumping test to find T and S but in many cases, especially those of a reconnaissance type, pumping test data are not available or are expensive to perform for the study concerned. In such cases, the specific capacity of wells provides the only basis for estimating the transmissivity of the aquifer tapped by the wells. The specific capacity of a well is defined as discharge per unit time. Theis et al. (1962) presented a graphical method of estimating T from the specific capacity of wells. Bradbury and Rothschild (1987) presented a computerized method of estimating T and included well loss and partial penetration factor in the estimation. The Theis et al. (1962) method is based on the Jacob equation given as:

$$T = \frac{Q}{4\pi d} \ln\left(\frac{2.25Tt}{r^2 S}\right) \tag{2-32}$$

Where

T = Transmissivity (L^2/T)

Q = Discharge (L^3/T)

d = Drawdown in well (L)

t = Pumping period (T)

S = Storage Coefficient (dimensionless)

r = Radius of the pumping well (L)

Solution of Eq. (2-32) cannot be obtained directly. Theis et al. (1962) proposed a graphical solution to the equation.

In most of the cases, wells penetrate less than the full thickness of the aquifer. Specific capacity depends on the ratio of penetration to the aquifer thickness. Hence correction of partial penetration is essential before estimating transmissivity from Eq. (2-32). For unsteady drawdown in a partially penetrating well, Sternberg (1973) showed that:

$$T = \frac{Q}{4\pi d} \ln\left(\frac{2.25Tt}{r^2 S} + 2S_p\right) \tag{2-33}$$

Where S_p is partial penetration factor given by:

$$S_p = \frac{1-L/b}{L/b}[\ln(b/r) - G(L/b)] \tag{2-34}$$

Where

b = Aquifer thickness (ft)

L = Length of open interval (ft)

G(L/b) = Function of L/b ratio

Bradbury and Rothschild (1985) presented a polynomial expression for G(L/b) as:

$$G(L/b) = 2.948 - 7.363(L/b) + 11.447(L/b)^2 - 4.6745(L/b)^3 \tag{2-35}$$

In Eq. (2-32) the term for well loss can also be included. Csallany and Walton (1963) developed an expression for the well loss.

$$S_w = C\,Q^2 \tag{2-36}$$

Where, S_w is the well loss (L) and C is the well loss constant (T^2/L^5). Csallany and Walton presented a method to evaluate C from step-drawdown data. With partial penetration and well loss correction the Eq. (2-32) becomes:

$$T = \frac{Q}{4\pi(d-s_w)}\ln(\frac{2.25Tt}{r^2S} + 2S_p) \tag{2-37}$$

The Eq. (2-37) can be solved for T by assuming suitable values for S. As the Eq. (2-37) can be used to solve for T only, subjective judgement of value of S is required based on aquifer condition. Here T depends on the logarithm of the inverse of S, hence change in value of S has very little effect on change in value of T. A computer program is developed to estimate T and included in APPENDIX A. The computer program does not require an initial guess value of T, as required by the previous program proposed by Bradbury and Rothschild (1985).

2.5.2 Aquifer Dispersivity

Early methods of determination of field dispersivity involved laboratory testing. In the laboratory method, a nonreactive tracer is passed through a cylindrical sample collected from a borehole. The dispersivity of the sample is then evaluated by fitting solutions of the advection-dispersion equation (Eq. 2-9) to the experimentally determined breakthrough curve. The longitudinal dispersivity value obtained from the laboratory testing is in the range of 0.01 to 2 cm for unconsolidated geological materials (Freeze & Cherry ,1979). It is generally accepted that longitudinal and transverse dispersivities under field conditions are larger than those indicated by tests on the borehole samples. The greater difference in values of dispersivities in the field and laboratory testing is due to effects of large scale heterogeneities on the macroscopic flow field, which can not be represented in the borehole samples. Many studies on simulation of migration of contaminants in groundwater have used longitudinal dispersivity values as large as 100m and transverse dispersivity values as large as 50m (e.g., Konikow and Bredehoeft, 1974; Konikow, 1977)

For a field problem, dispersivity measurement at the field is more appropriate than laboratory testing. Fried (1975) formulated test procedures and the mathematical basis for analysis of the data from single-well withdrawal-injection test, natural-gradient test and two well recirculation withdrawal-injection tests. Zuber (1974) proposed a two-well pulse test method. In the two-well pulse test, a tracer is introduced into a well situated within the drawdown cone caused by pumping of a second well. Concentration response data from the pumping is then used to compute dispersivity for the segment of the formation between the wells.

The dispersivity value obtained from a given field experiment depends on the mathematical model used in the analysis and the scale of the experiment (Zuber, 1974). Also different type of field condition require different scales and different methods of field experiment.

2.5.3 Boundary and Initial conditions

Usually the physical boundaries of an aquifer system are larger than the aquifer area intended for modeling. Modeling of an aquifer requires specification of physical boundary and an artificial boundary to be introduced. Generally boundaries are of two types: constant flux and constant head boundary. These two types of boundaries can be used to represent artificial and physical boundaries of an aquifer. A constant flux boundary can be used to represent the aquifer underflow, well withdrawals and injections. A special case of constant flux boundary is the no-flow boundary representing the physical barrier to the flow. A constant head boundary is used to represent the parts of an aquifer where the head will not change with time. A constant head boundary may be a stream or part of an aquifer located beyond the influence of hydraulic stresses.

Modeling of an aquifer also requires specification of the initial conditions. The initial conditions can be determined either from the field data or from the previous simulation results. Simulation results are sensitive to the initial conditions (Konikow & Bredehoeft, 1977). In case of transient flow simulation, changes in water level take place not only due to aquifer stresses but also due to specification of initial conditions (Trescott et al., 1976).

2.5.4 Inverse Methods

Pumping test methods of determination of aquifer parameters are expensive and time consuming. A regional scale aquifer modeling requires a considerable number of pumping tests to find the parameters representing the whole aquifer system. Usually the parameters determined from pumping tests are not used directly in the model but are modified during calibration process so as to duplicate the field results.

With inverse methods of aquifer parameter determination, a subjective set of parameters is first inserted into the aquifer model and the calculated response of the model is compared with the actual historic data observed in the field. Subsequently the parameters are adjusted and the model is run till the predicted and actual field values are close enough. The inverse method can be used to determine T and S, values of dispersivities, estimate boundary condition, estimate initial condition and estimate aquifer stresses.

Early inverse method used trial and error procedure to adjust the parameters (Pinder and Bredehoeft, 1968). In the trial and error method a model is run with certain subjective value of parameters and the result is compared with the field value. The parameters are adjusted subjectively based on the knowledge of the modeler and information available till the results are close enough to the field value. Successive estimation of parameters also can be done by formulating a objective function of error and adjusting the parameters so as to minimize the error. Later methods of inverse problem are described by Neuman (1973), Labadie (1975), Khan (1983). Use of the inverse method in parameter identification for solute transport model is treated by Streclker and Chu (1986).

2.6 Groundwater Solute Transport Models

2.6.1 USGS-MOCADI model

The model was developed by Konikow and Bredehoeft for USGS in 1978. The model couples the groundwater flow equation, Eq. (2-1), with the solute transport equation, Eq. (2-9). It uses alternating direction implicit (ADI) procedure to solve the finite-difference approximation of groundwater flow and methods of characteristics (MOC) to solve the solute transport equation. The modelling technique used in the USGS-

MOCADI has been successfully used in numerous simulations of fate and transport of conservative solute in confined and unconfined aquifers (e.g., Konikow, 1977; Warner, 1979; Nichols, 1979). Detailed documentation of the USGS-MOCADI model is given by Konikow and Bredehoeft (1978). Some of the important features of the model are summarized below:

1) The model is based on a rectangular, block centered, finite-difference grid. The numerical technique used in the model requires the area of interest to be surrounded by a no-flow boundary.

2) It allows specification of any numbers of injection or withdrawal wells and of spatially varying diffuse recharge or discharge, saturated thickness, transmissivity, boundary conditions and initial head and concentrations.

3) Three type of boundary conditions can be specified in the model. No-flow boundaries are designed by specifying transmissivity equal to zero at the appropriate nodes. Constant head boundaries are designed by specifying the leakage coefficient to be 1. The model then computes the rate of leakage into or out of the designated constant head node to maintain the aquifer at the specified constant head altitude.

4) Different type of nodes are designated by specifying node identification codes. Node identification code can be used to specify

different combinations of recharge or discharge conditions, concentration of inflow or outflow water, leakage into or out of the aquifer and boundary conditions.

5) Mass balance calculations are performed after a specified time increment to help check the numerical accuracy and precision of the solution. Two methods of error estimation in mass balance are incorporated in the model to take into account different rates of total fluxes and initial mass of solute in the aquifer system.

6) The model uses an optimization routine to minimize numerical dispersion resulting from the numerical method of solution of the governing solute transport equation.

7) The model can be used for areal or cross-sectional modeling of two-dimensional flow. It can be used for modeling transient and steady state flow. The steady state flow modeling is done by specifying the storage coefficient (S) equal to zero.

8) Model can be used to simulate both confined and unconfined aquifer systems. The model assumes the aquifer to be unconfined if the coefficient of storage is greater than 0.005.

The USGS-MOCADI model is simple and efficient in computation. It exhibits flexibility for further modification as required by the field conditions. However, there are some limitations to the model:

1) The requirement of uniform grid size creates difficulty in modeling an area with irregular boundaries.

2) The model cannot be applied to cross-section modeling where the upper boundary of the system is the water table.

The USGS-MOCADI model is based on certain assumptions and application of the model to field conditions requires evaluation of the assumption before applying the model to the field problem concerned. Following are the assumptions made by the USGS-MOCADI model:

1) Darcy law is valid and the hydraulic head gradient is the only significant driving mechanism for fluid flow.

2) The porosity and hydraulic conductivity of the aquifer are constant with time and porosity is uniform in space.

3) Gradients of fluid density, viscosity and temperature do not affect the velocity distribution.

4) No chemical reactions occur that affect the fluid properties and the aquifer properties.

5) Ionic and molecular diffusion are negligible contributors to the total dispersion.

6) Vertical variations in head and concentration are negligible.

7) The aquifer is homogeneous and isotropic with respect to the coefficient of longitudinal and transverse dispersivity.

2.6.2 Saturated-Unsaturated Transport Model (SUTRA)

The Saturated-Unsaturated Transport (SUTRA) model was developed by Voss for USGS in 1984. The model employs a two dimensional hybrid finite-element and integrated finite-difference method to approximate the governing equations of groundwater flow and solute transport. The model can be used in simulation of fluid pressure and fluid density dependent saturated or unsaturated groundwater flow, solute transport and thermal energy transport in the groundwater as well as in the solid matrix of an aquifer. The model is capable of simulating solute that is subjected to equilibrium adsorption on the porous matrix and solute that is subjected to both first-order and zero-order production or decay. Detailed documentation of the model is given by Voss (1984). Some of the important features of SUTRA are as follows:

1) The model requires an area of interest to be divided into numbers of quadrilateral elements defined by four nodes at the corners. The element may be of different sizes.
2) The model requires nodes-wise specification of fluid pressure (piezometric head), aquifer thickness and porosity. Permeability and dispersivity are specified in element-wise basis.

3) The permeability in each element is described by maximum and minimum permeability and by the angle of maximum permeability direction from the positive x axis. The model then computes the permeability tensor in global directions.

4) Longitudinal and Transverse dispersivities are specified in element-wise basis. Storage coefficient is computed by specified fluid and aquifer compressibilities and thickness of the aquifer for each element. Hence the storage coefficient is not necessarily constant for the entire aquifer.

5) The model is incorporated with linear, Freundlich and Langmuir isotherms equilibrium sorption process for a single solute species.

6) Variable density of fluid, caused by change in solute concentration, can be specified for solute transport.

7) The boundary conditions can be defined as constant head, constant flux and no-flow boundaries. The no-flow boundary is specified by specifying very low permeability for the element concerned.

As the model is based on finite element methods of solving the governing equations, the model exhibits greater flexibility in defining irregular boundary of an aquifer. The model can be effectively used in cross section modeling with upper boundary as water table.

CHAPTER III

THE DESCRIPTION OF STUDY AREA

The study area, Shadow Lawn subdivision, is located in Bethlehem Township, Stark County, Ohio. The major source of domestic water supply in the area is the groundwater. All of the resident have private wells.

The study area covers about 0.46 square miles. The area slopes towards the west with an average slope of 5.6%. The highest and lowest elevations are 1075 ft and 925 ft above mean sea level respectively. A creek is located on the western boundary of the area which drains surface runoff from the area and discharges it into the Tuscarawas river. The details of the study area are presented in Figure 3-1.

3.1 Glacial and Bedrock Geology

The glacial deposit of the study area consists mainly of Hayesville end moraine and partly of outwash valley deposit, both of them classified as of Wisconsinan age (Delong and White, 1963). The outwash valley deposits in the area contain stratified, well sorted and well washed sand and gravel that may be over 200 feet thick. The Hayesville end moraine contains sand and clayey silt with a few cobbles or boulders.

The bedrock exposed in the study area is Pottsville Group of the Pennsylvanian system (Delong and White, 1963). The group is generally characterized by alternating layers of

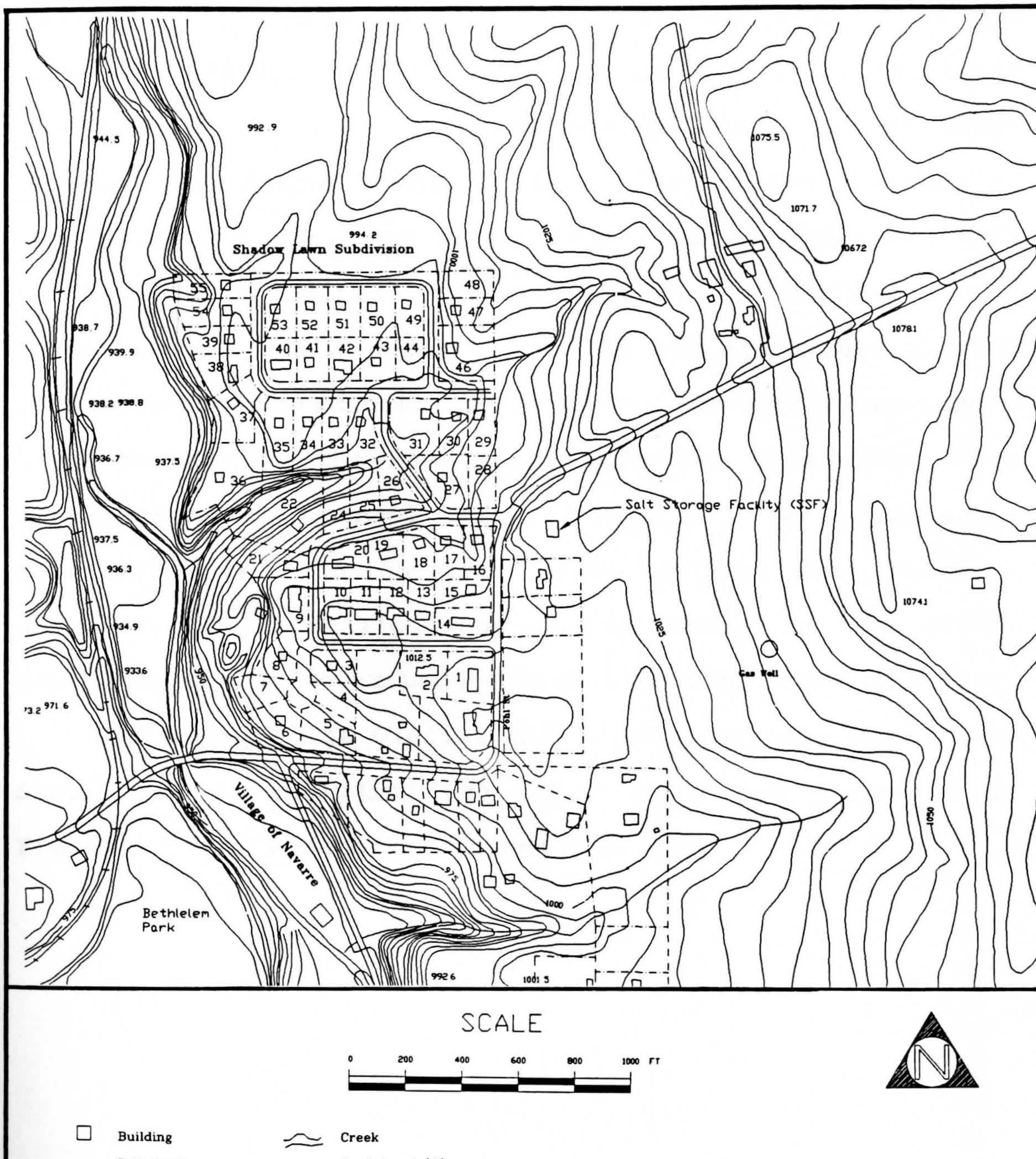


Figure 3-1 : Details of the Study Area

moderately fractured sandstone, limestone, shale, coal and clay. The sandstone and shale units have variable thickness and often grade laterally into shaley sandstones or sandy shales. The Sharon Conglomerate is the lowermost member of the Pottsville Group and is not exposed at the surface. The thickness of the Sharon Conglomerates varies considerable in space because it was deposited on the steeply eroded surface of Mississippian bedrock (Sedam, 1973). Overlying the Sharon Conglomerates is the Massillon sandstone, consisting of a coarse-grained, channel fill sandstone that varies in thickness from 30 to 100 feet. Above the Massillon, the rock units of the Pottsville group consist mostly of thin shales and sandy shales inter bedded with limestone, coal and clay.

Portions of the Glacial and Bedrock geology map of the Stark County, including the study area, are presented in Figure 3-2 and Figure 3-3, respectively.

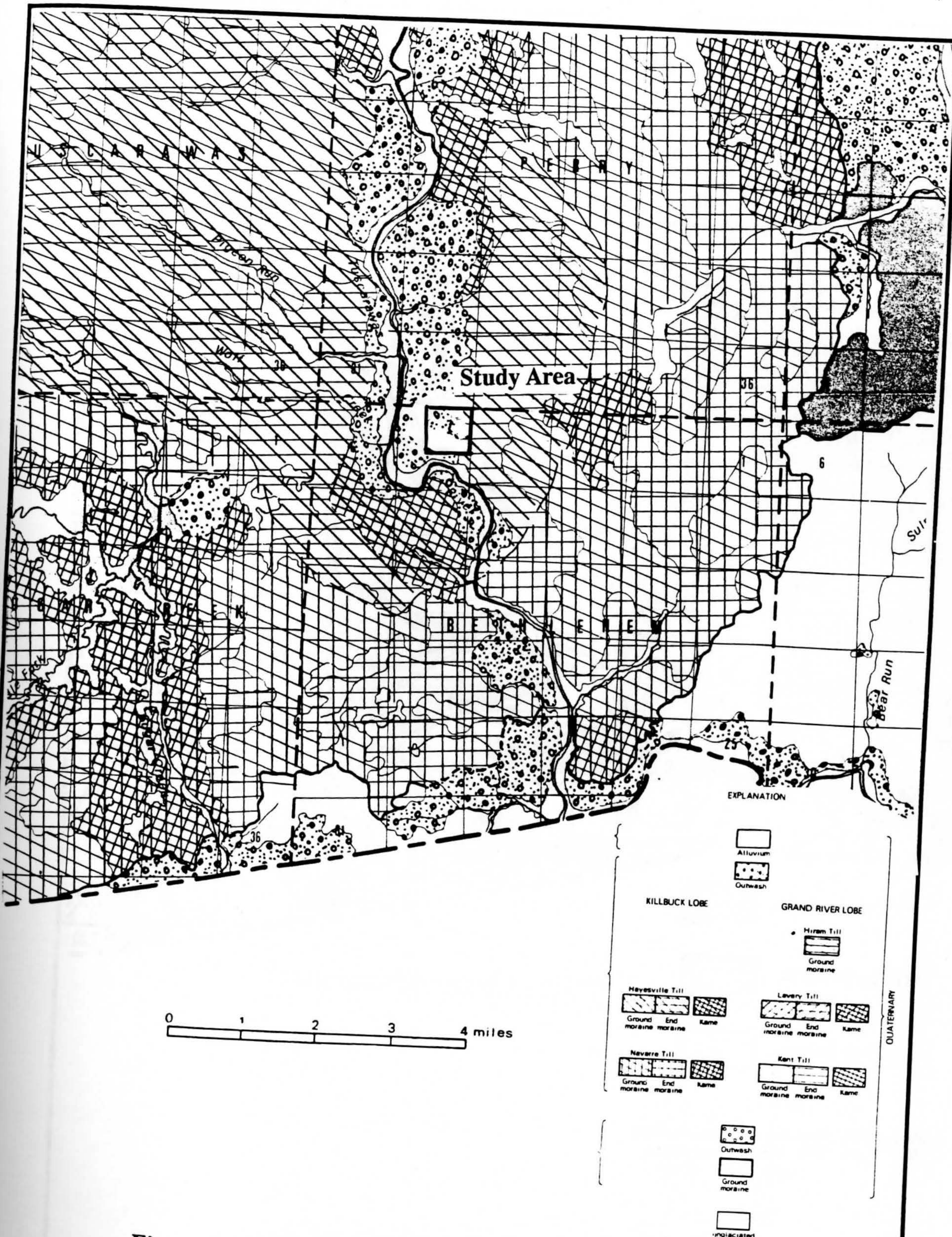


Figure 3-2 : Glacial Geology Map of Area Surrounding the Study Area (Delong and White, 1963)

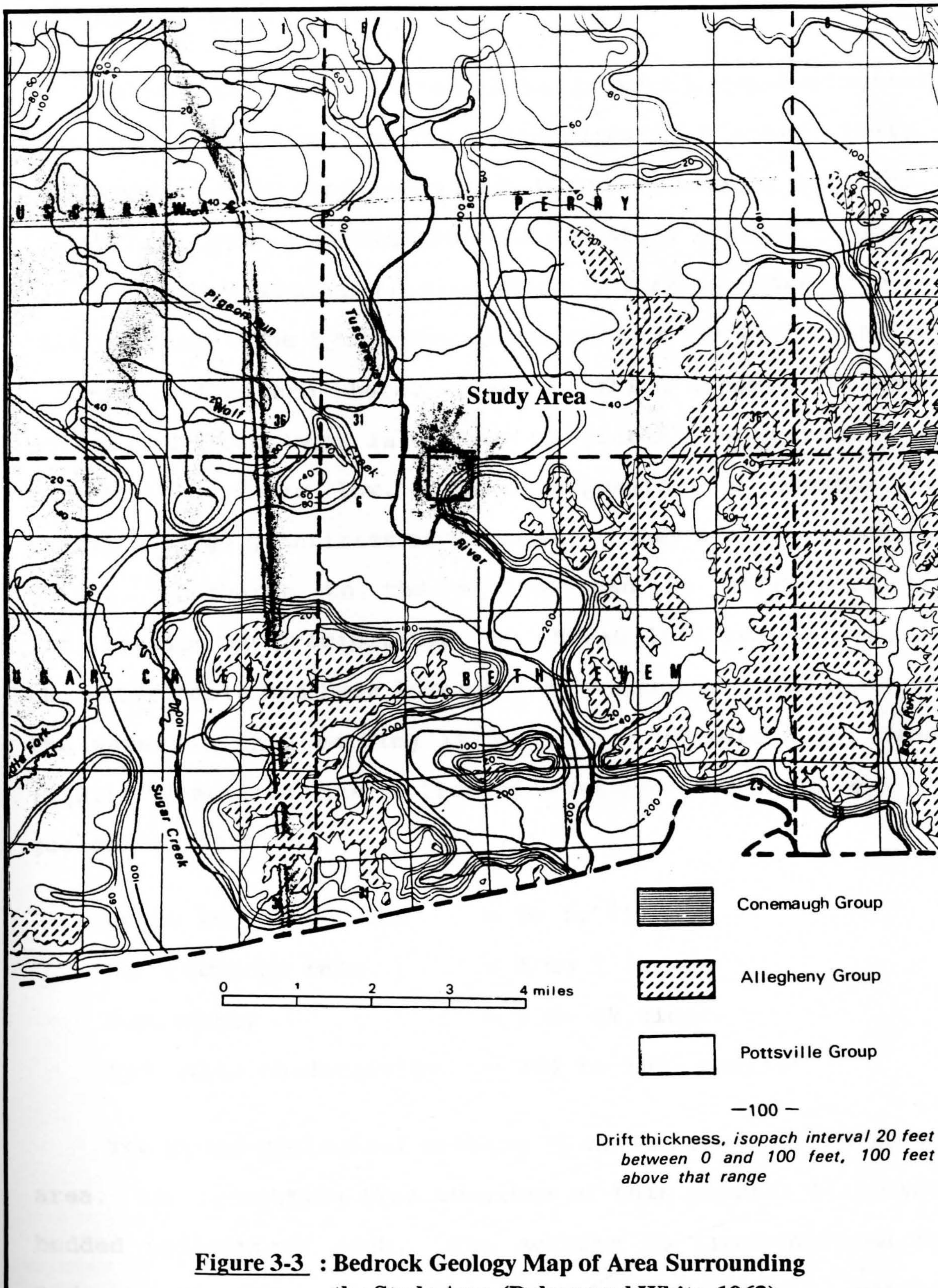


Figure 3-3 : Bedrock Geology Map of Area Surrounding the Study Area (Delong and White, 1963)

3.2 Hydrogeology

Willams (1991) identified nine different hydro-geological settings in the Stark county. According to Willams (1991), the study area is composed of two hydro-geological settings, 7D and 7G. Upper northwest part of the study area falls under the 7D hydro-geological setting which is further classified as 7D16 setting. The hydro-geological setting 7D is located in a buried valley and characterized by thick deposits of sand and gravel that were laid down by glacial meltwater in a former topographic low. These deposits are capable of yielding large quantities of water where they are sufficiently thick. Recharge to the aquifer can be attributed to infiltration by precipitation or stream infiltration, where the water table has been lowered due to pumping. The depth of the water in this setting is extremely variable. Williams (1991) identified the following features for 7D16 hydro-geological setting.

Depth to water Table	= 50 to 75 ft
Net recharge rate	= 4 to 7 in/yr
Topography	= 2 to 6% slope
Hydraulic conductivity	= 700 to 1000 gpd/ft^2

The hydro-geological setting 7G covers most of the study area. The 7G setting area consists of thin glacial till over bedded sedimentary rock. The setting is characterized by moderate to steep topography and deposits of thin, patchy glacial till overlying alternating layers of sedimentary rocks. The till is generally less than 20 feet thick and consists of varying amounts of unsorted clay, silt and sand with some pebbles and cobbles. Groundwater is obtained primarily from sandstones and sandy shales, along the bedding planes and in the intersecting vertical fractures. Shale and clay layers can form aquitards, and perched groundwater may be developed for domestic water supplies. Recharge is moderate due to increased capacity of soil material to retain and discharge precipitation. The area is further classified as 7G9 setting. Williams (1991) identified the following features for 7G9 hydro-geological setting.

Depth to water Table	= 50 to 75 ft
Net recharge rate	= 2 to 4 in/yr
Topography	= 2 to 6% slope
Hydraulic conductivity	= 100 to 300 gpd/ft^2

Walker (1979), in his report on groundwater resources of Stark County, identified that groundwater can be obtained from sandstone and sandy shale in the study area. Walker (1979) estimated the maximum reliable yield in the area to be 25 gallons per minute.

3.3 Contamination Background

The Ohio EPA began monitoring the water quality of the wells on a quarterly basis in April 1986. The laboratory analysis of the water samples revealed high concentrations of iron, manganese and total dissolved solids in all of the wells. The tests also revealed a very high concentration of chloride in some of the wells. The chloride concentration ranged from 20 mg/l to 2550 mg/l. The distribution of chloride concentration varied from well to well. Mosure & Syrakis Co. (1988) conducted a preliminary study of the chloride contamination problem during 1988. Following are the major findings of the study:

1) Entire aquifer of subdivision is high in iron, manganese and TDS. The higher concentrations of these parameters are common in groundwater and it may be the characteristics of the aquifer. Summary of water sample tests is presented in Table 3-1.
2) Distribution of chloride concentration indicates that high concentration of chloride is not a characteristic of the aquifer. It was suspected that chloride must have been introduced into the aquifer from outside source.
3) Chloride concentration was found to be higher in wells with casings set at 40 to 70 feet and lower in wells with casings set deeper than 80 feet.
4) Locations of the wells in relation to the salt storage facility (SSF) are directly related to level of the chloride concentration. The wells located to the north and west of the SSF revealed higher concentrations. The locations of the contaminated wells are presented in Figure 3-4.

Table 3-1 : Summary of Water Sample Tests

Lot #	SAMPLING DATES																				
	04/01/86			04/03/86			09/22/86			10/21/86			02/17/87			06/09/87			01/08/88		
	Mn ug/l	Fe ug/l	Cl mg/l	Mn ug/l	Fe ug/l	Cl mg/l	Mn ug/l	Fe ug/l	Cl mg/l	Mn ug/l	Fe ug/l	Cl mg/l	Mn ug/l	Fe ug/l	Cl mg/l	Mn ug/l	Fe ug/l	Cl mg/l	Mn ug/l	Fe ug/l	Cl mg/l
6				70	820	62															
14																360	1240	247			
16										105	2430	27	710	18700	3160						
21													30	280	103						
25	420	3440	721				430	3320	637				365	2610	520	330	2940	529	310	2400	540
28	640	7970	2550				660	8890	2590				690	8330	2400	NA	7290	2260			
29	40	790	2820				25	560	2540				< 10	< 50	268	< 10	NA	112			
31																< 10	70	59			
35																65	1180	54			
36																225	4990	322	240	4800	420
37																100	1280	46			
41	195	3460	159				285	6230	220				303	40000	157						
43	350	9260	107				825	3290	685				775	3220	670			661	700	610	480
46																30	830	120			
47	870	2880	740				360	4810	134				350	5060	43						
51	55	670	458				60	640	< 20				45	640	196						
53																115	1130	4			
55	19	1760	20																		

NA - Not Available

Source: Mosure & Syrakis Co., 1988, 1990

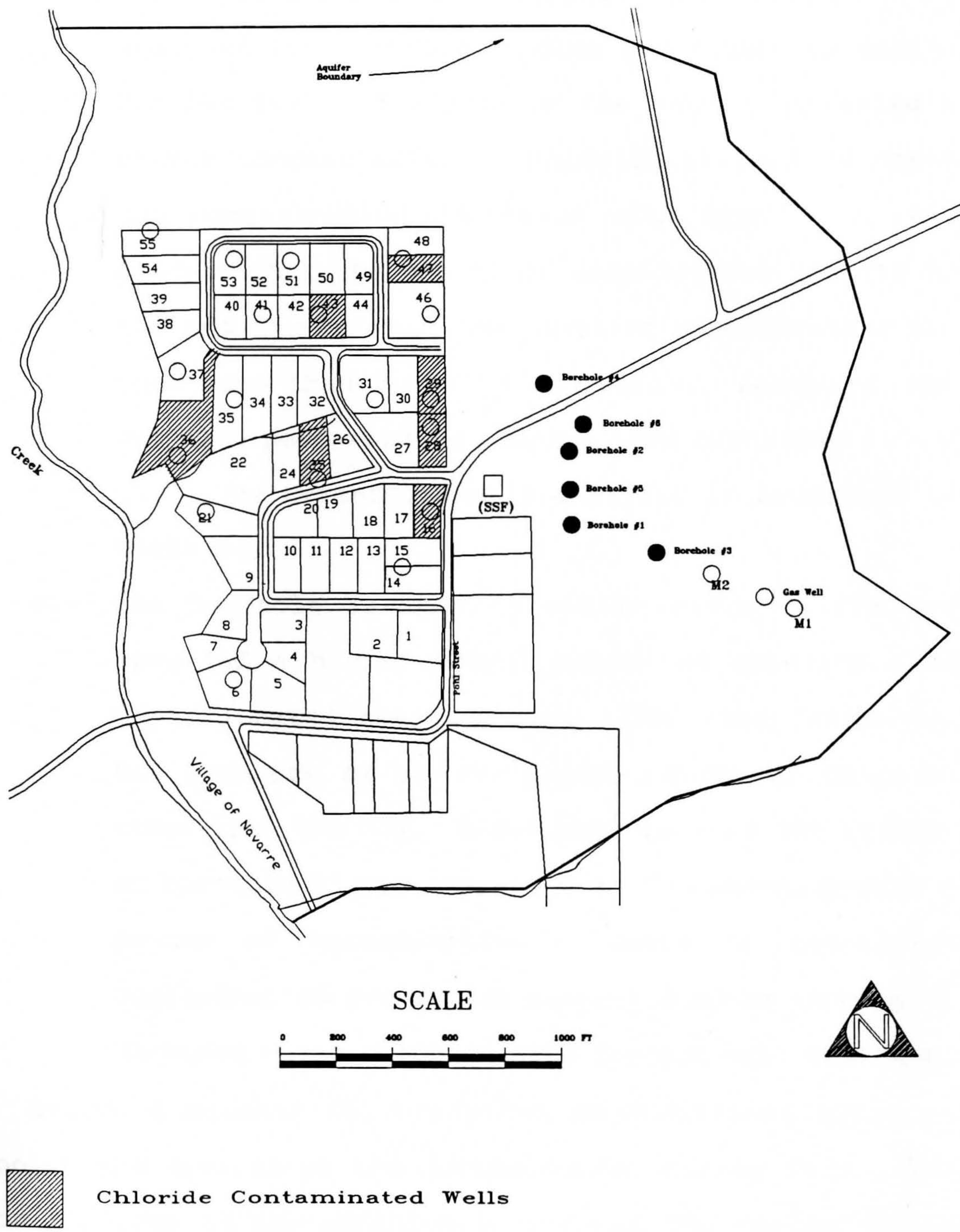


Figure 3-4 : Location of Contaminated wells and Boreholes

5) Samples at different depths from four boreholes were taken from the vicinity of the SSF and analyzed for chloride, sodium and potassium during October 1987. Analysis of the samples revealed a higher concentration of chloride at shallow depth and concentration decreased with depth. It was evident that the source of chloride was located at the ground surface. The level of concentration was much more than found on the wells. Leachate test was also performed in samples from boreholes #1 and #2. The borehole sample analysis is presented in Table 3-2.

6) The borehole #3 located 450 ft north of the SSF revealed a higher concentration of chloride than those located near the SSF. The study suspected the presence of an additional source of chloride other than the SSF. A gas well located 450 ft east of borehole #3 was suspected as the second possible source of contamination. Cause of additional contamination source was suspected to be improperly disposed brine solution used for gas well drilling.

Mosure & Syrakis Co. conducted an additional study to pinpoint the sources of the contamination during 1990. The major findings of the additional study on the contamination problem are as follows:

1) Hydraulic gradient in the aquifer is in the westerly direction, hence the source of the

pollution should be located east of the most easterly contaminated wells lot 16, 28 and 29. Closest potential source of contamination is the SSF.

2) Chloride laden surface runoff from the SSF continuously flowed into unlined ditches which then carried it along Pohl street and then through the Shadow Lawn Subdivision before discharging it into the main creek. During its meandering journey through the subdivision, chloride laden water must have infiltrated the underlying aquifer.

3) Field inspection revealed that the SSF is located at a high elevation and ground sloped in all four directions. It is suspected that some of the surface runoff laden with chloride must have flowed east of the SSF towards borehole #3, but couldn't have reached far enough because of the change in ground slope towards the west. Hence the water must have seeped into the soil. The borehole sample analysis of borehole #3 revealed higher a gradient of concentration with respect to the depth, which explains the fact that there was not enough water to carry the chloride deep into the ground. Hence the higher concentration in the borehole #3 may not be due to gas well drilling as suspected in the previous study.

Table 3-2 : Summary of Borehole Sample Tests

Results of Borehole Soil Sample Tests   Date : 10/14/87

Depth	Chloride Contents (mg/kg)			
	Borehole #1	Borehole #2	Borehole #3	Borehole #4
3.5 to 6.0 ft	3100	3700	15000	2400
8.5 to 11.0 ft	2300	3100	11000	3500
13.5 to 15.0 ft	1000	3400	15000	2000
18.5 to 20.0 ft	1700	3100	13000	870
22.0 to 22.5 ft	-	-	8500	250
23.5 to 25.0 ft	1200	1600	-	-
28.5 to 30.0 ft	500	2400	-	-

Results of Leachate Tests

Depth	Chloride Contents (mg/l)			
	Borehole #1	Borehole #2	Borehole #5	Borehole #6
	10/14/87	10/14/87	03/22/90	03/22/90
4.5 to 6.0 ft	170	140	27	57
18.5 to 20.0 ft	63	53	110	85

Source: Mosure & Syrakis Co., 1988, 1990

4) The gas well was ruled out as a source of contamination. Brine solution used for drilling the well was in fact stored in unlined ditches, before hauling away, for four days during November of 1983. Duration of four days storage in the ditches is not enough for infiltration of chloride to such an extent as found in the aquifer.

5) The SSF was abandoned in March 1987. During March 1990, an additional leachate test was performed in new borehole #5 and borehole #6 located near old boreholes #1 and #2 respectively. Chloride concentrations in the two boreholes were found to be decreasing with the depth, which is the reverse of the results from the test of boreholes #1 and #2 in october 1987. As the source of contamination is already being removed, no more chloride was added to the ground, hence the chloride in the upper part of soil is being flushed away or seeped deeper. The results of tests are presented in Table 3-2.

The previous studies concluded that the cause of chloride contamination in the subdivision is the chloride laden surface runoff from the SSF. The salt storage facility is where the County mixes and stores the road salt used for de-icing of County roads in the winter months. The County had been mixing the road salt outside.

CHAPTER IV

DATA PROCESSING

4.1 Hydro-geological information.

General hydro-geological information of the area is available based on the regional scale study (e.g., Delong & white, 1963; Groenewold, 1974; Walker, 1979; Williams ,1991). No previous site-specific hydro-geological studies have been conducted in the study area. Well drilling logs are available for most of the residential wells in the area. The well drilling logs are the only means of accessing the site specific hydro-geological characteristics of the study area. The well drilling logs of the wells are presented in Figure 4-1.

The well logs indicate that the thickness of the glacial deposit of sand and gravel varies greatly in the wells. The well logs of lot no 31, 35, 36, 37, 41, 51, and 55 reveal a thick gravel and sand layer underlaid by shale and sandstone. The well logs of lot 16, 25, 28, 43, 46 and 47 reveal thin layer of gravel and sand as compared to the wells located westward direction from these wells.

Generally the upper gravel and sand layers are underlaid by alternate layers of clay or shale layers and sandstone layers. The thickness of shale and sandstone layers is observed vary greatly from well to well.

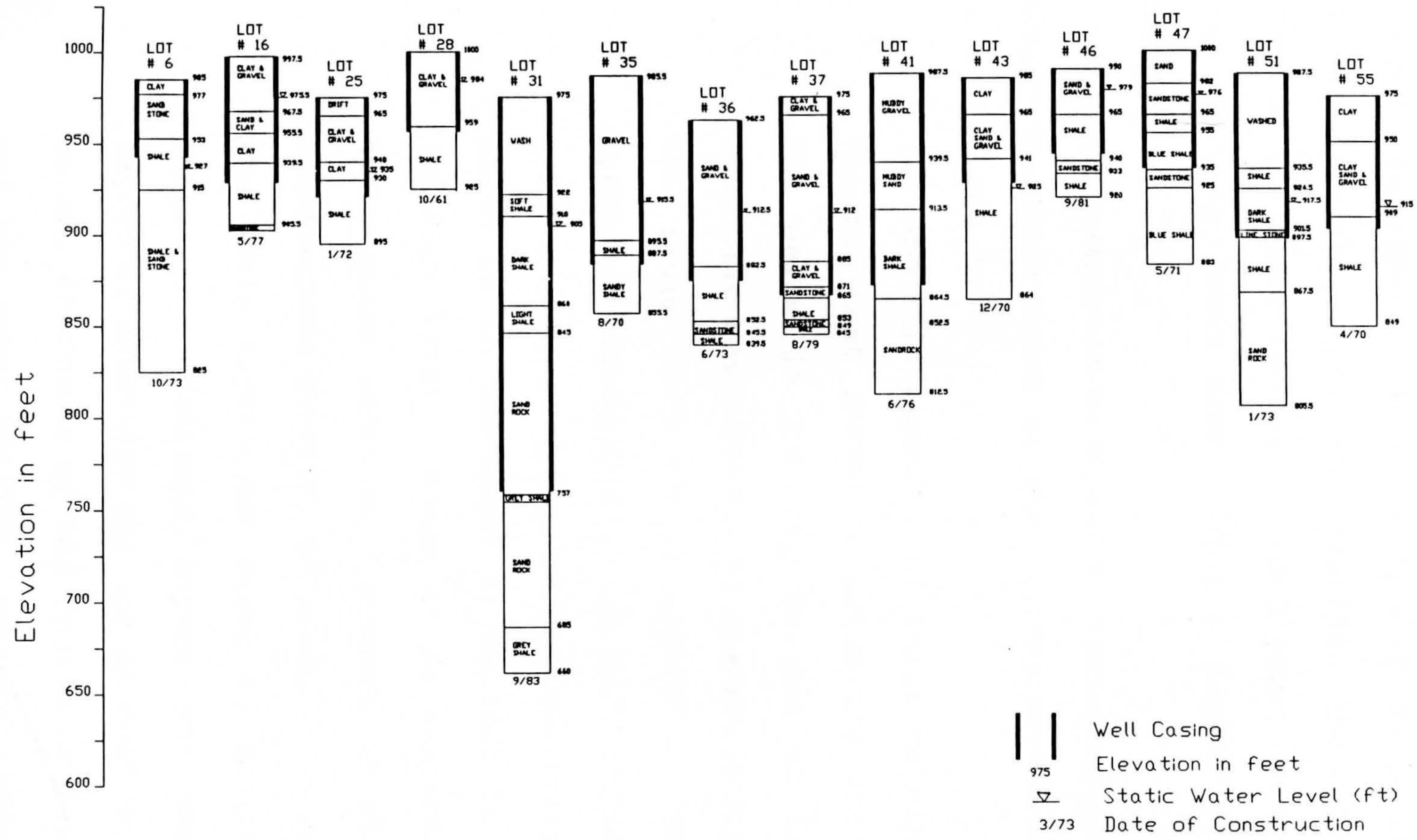


Figure 4-1 : **Well Drilling Logs**

The extent of well casing and depth of the wells indicate that all of the wells tap water from the underlying shale layer and the sandstone layers. None of the wells taps water from the upper gravel and sand deposits. The wells in lot 25, 28, and 43 tap water from the shale layers. Other wells seem to be tapping water from multiple layers of shale and sandstone.

From the available information, following general hydrogeologic characteristics of the aquifer system of the study area are observed:

1) The specific capacity of wells obtained from the pumping test conducted after the construction of the wells in lot 25, 28 and 43 indicate the hydraulic conductivity of the shale layer to be in the range of 5 to 14 gpd/ft^2 . The computed hydraulic conductivity is much higher than the representative hydraulic conductivity of shale which is in the range of 0.00001 to 0.1 gpd/ft^2 (Walton, 1970) . Hence it is suspected that the upper shale layer is fractured or it contains a considerable quantity of sand.
2) The shale layers can serve as aquitard for the underlying sandstone layers and the different layers of sandstone may act as confined aquifer.
3) As the thickness of the confining layer of shale and the water bearing layer of sandstone varies greatly and at some places is very thin (lots 37 &

47), the confined and the unconfined conditions for the different layers of entire aquifer in the study area cannot be clearly distinguished. Due to the thinness of shale layer at some places, a considerable amount of infiltration can occur in between the layers creating an unconfined condition.

3) The depth of wells in the area varies greatly so the bedrock geology of the area is not available for the greater depth in all parts of the area. The well in lot 31 is 315 ft deep and it indicates the existence of alternating layers of sandstone and shale with varying thickness.

Elevations of different layer of sandstone and shale for the entire aquifer in the study area were computed by using a contouring method based on the elevation of each layer in the well logs. Generalized cross sections through sections A-A, B-B, C-C as indicated in Figure 4-2 are presented in Figure 4-3. The hydrogeology of the aquifer can be interpreted as follows:

1) Treat each sandstone layer as confined individual aquifer system, separated by the overlying and underlying shale layers and treat the upper layer of gravel and sand deposit as the unconfined aquifer. Determine Piezometric head, transmissivity and thickness of each aquifer system. Determine Leakage into and out of each

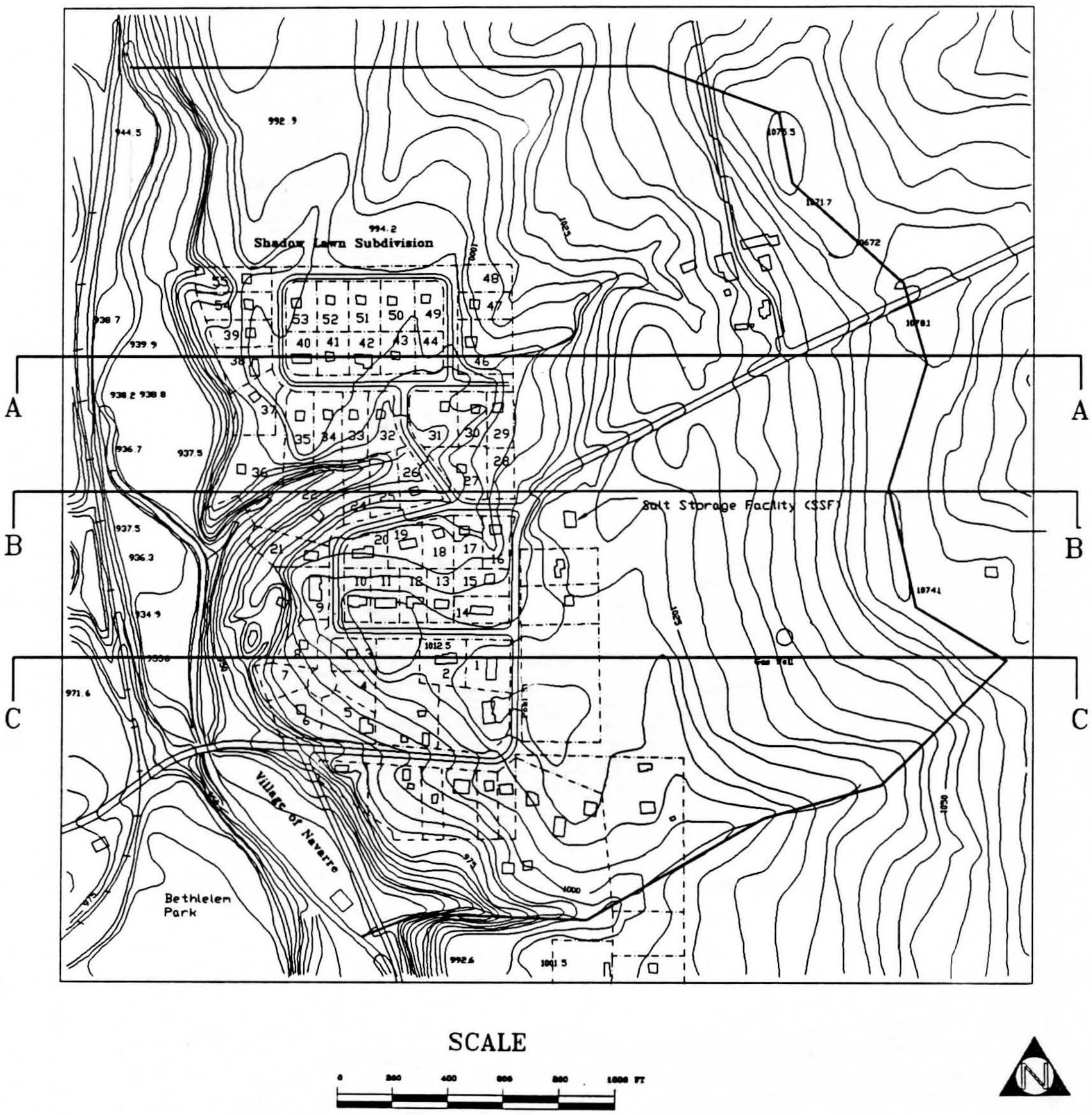


Figure 4-2 : **Locations of Cross Sections**

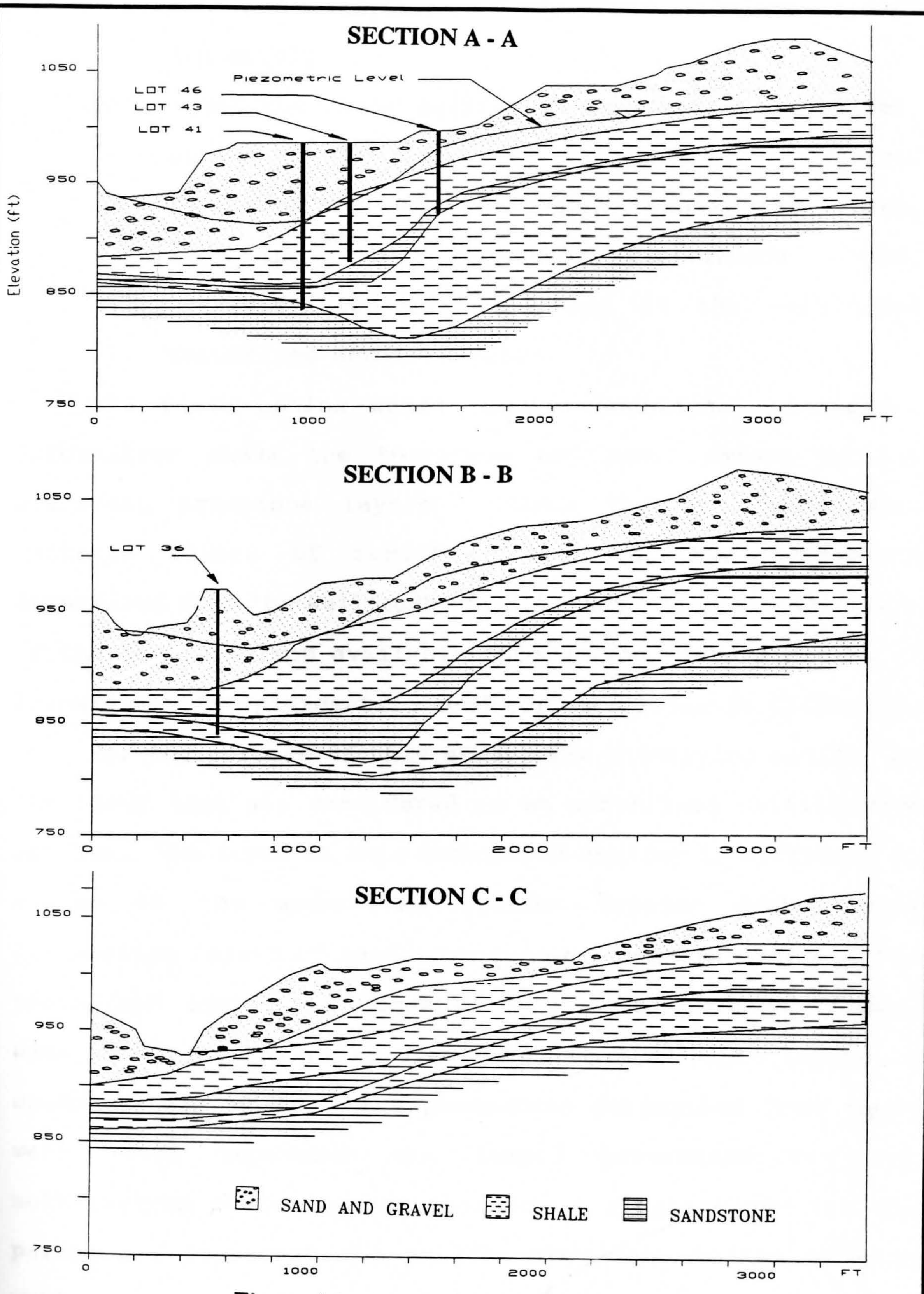


Figure 4-3 : Generalized Cross Sections

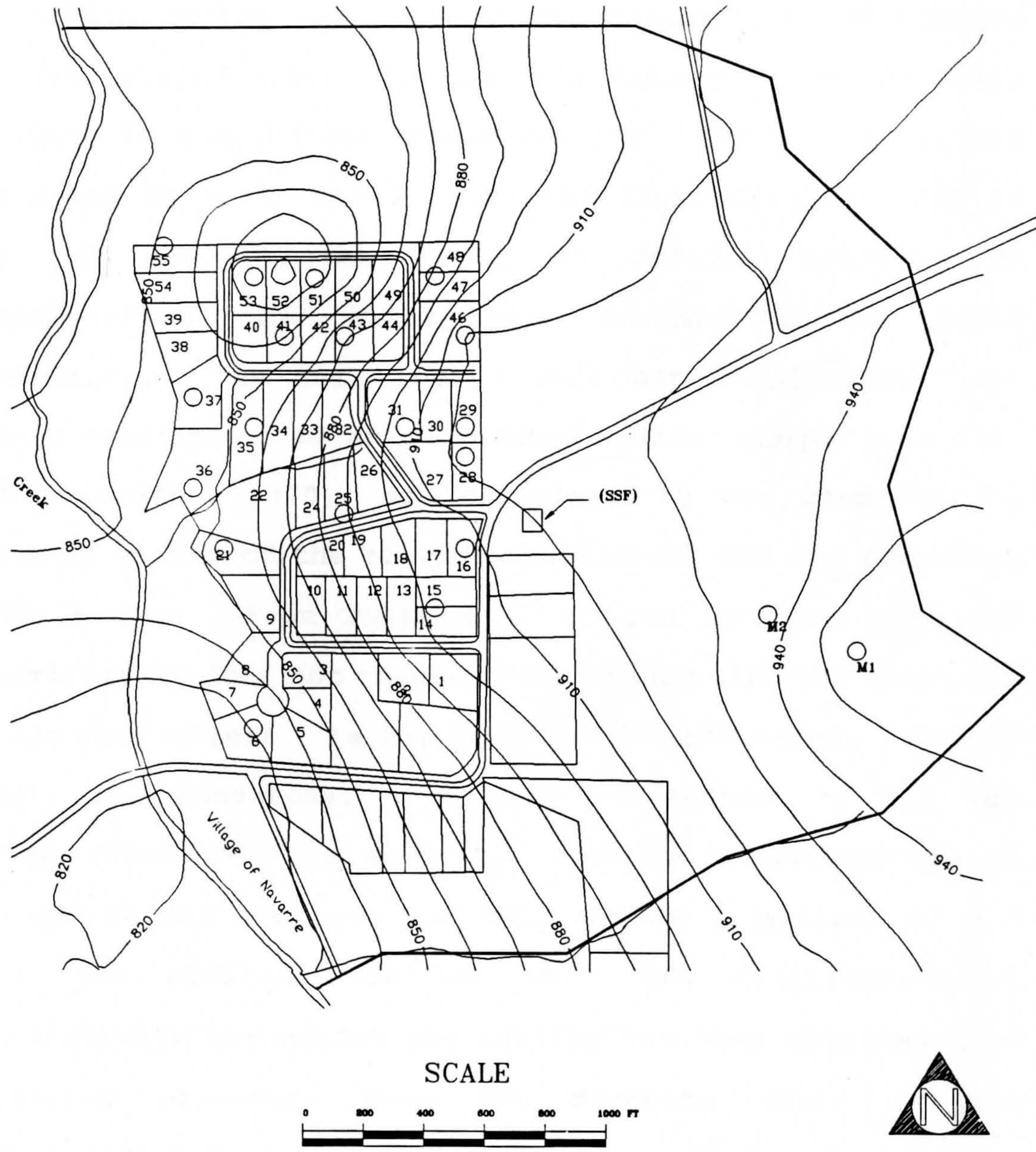
sandstone layer. Model each aquifer system separately.

2) Treat the whole aquifer as an unconfined aquifer, neglecting the effect of some degree of confined condition of the different sandstone layers. Determine the combined piezometric head, transmissivity and thickness of the considered unconfined aquifer system.

The first option would require additional geological information about the thickness and areal extent of the different sandstone layers. Since the well penetrates multiple layers of sandstone aquifers, the parameters determined from the well logs will reflect the combined effect of the layers. From available information, determination of transmissivity, piezometric head for each layer is difficult.

For the purpose of this study, the underlying aquifer of the study area was considered as an unconfined multilayered aquifer. The depth of this unconfined aquifer is difficult to assess as the underlying aquifer extends deeper with alternating layers of sandstone and shale. The bottom of the unconfined aquifer was thus assumed as the bottom of each well. Most of the wells draw water from multiple layers of sandstone and shale. The parameters determined from these wells will represent the lumped parameters for the multilayered system rather than for a single layer and the parameters represent the aquifer above the bottom of each well.

The plot of the bottom elevation of the aquifer was obtained by a contouring method based on the total depth of each well. The well in lot 31 is much deeper than other wells in the study area. In the study the well in lot 31 was not considered while computing the bottom elevation of the aquifer. The bottom elevation of the unconfined aquifer system is presented in Figure 4-4.



Contour Interval 10 ft.

Figure 4-4 : Bottom Elevation of Aquifer in the Study Area

4.2 Transmissivity (T) and Storage Coefficient (S)

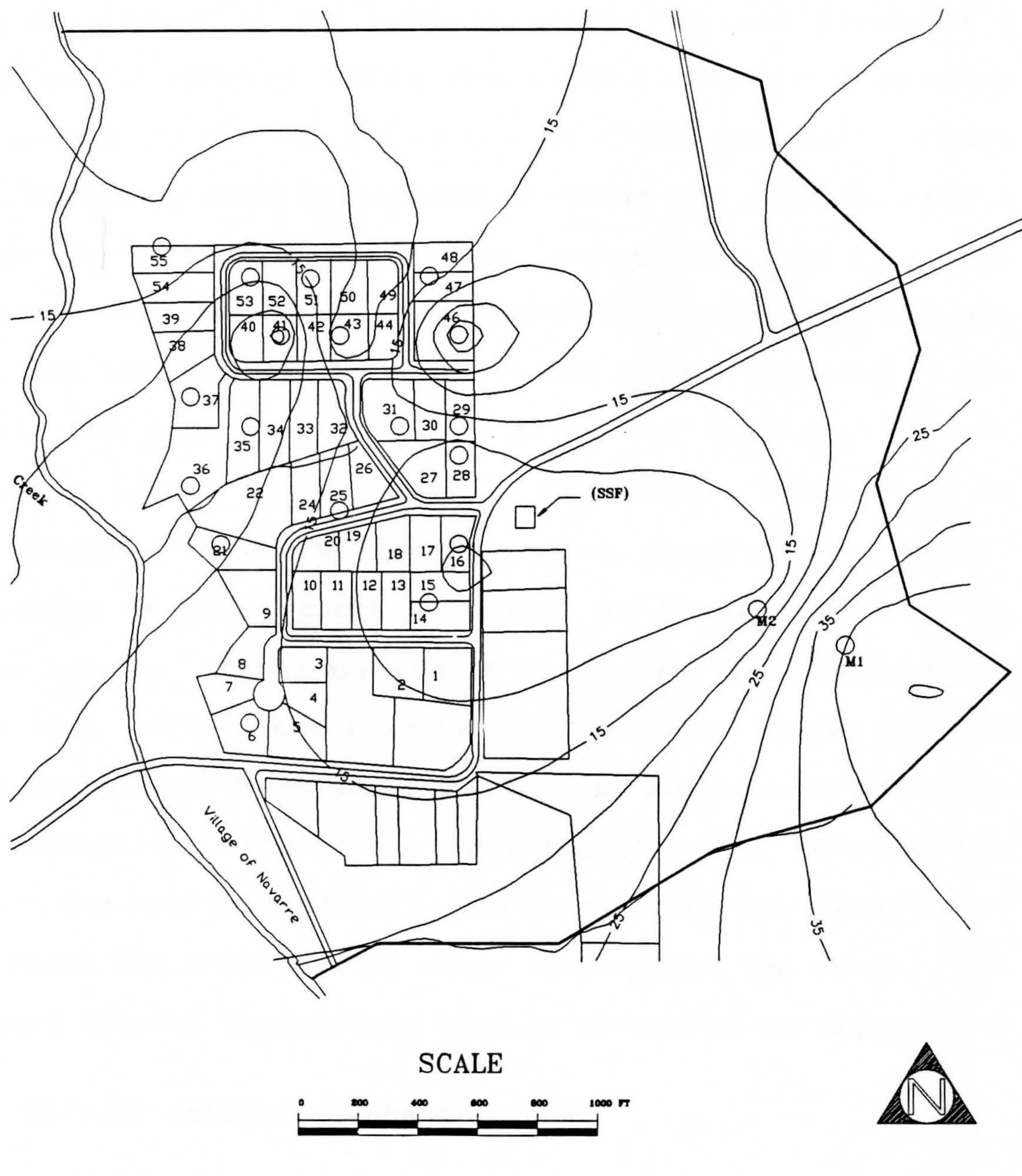
No data on the pumping test were available for the Shadow Lawn Subdivision area. The specific capacities of the wells were used to compute the transmissivity. The Eq. (2-37) was programmed to solve for T using the iterative procedure as shown in APPENDIX A. For an initial estimate of transmissivity, the wells were assumed to be fully penetrating. The well losses were not considered. The storage coefficient of an unconfined aquifer ranges from 0.02 to 0.3 (Walton, 1970), so transmissivity was computed for different values of the storage coefficient and are presented in Table 4-1. From Table 4-1, it can be seen that the transmissivity does not change considerably with the change in storage coefficient. As the aquifer consists mainly of sand, gravel, and sandstone, a storage coefficient of 0.2 was assumed throughout the aquifer. Maximum transmissivity of 2922 gpd/ft was computed for Well M1 and a minimum of 267 gpd/ft was obtained for lot 15. The distribution of transmissivity throughout the aquifer was then obtained by a contouring procedure from the discrete value of the transmissivity from each well and is presented in Figure 4-5. The aquifer was assumed to be isotropic so the transmissivity in x and y-directions were taken as equal.

Table 4.1 : Transmissivity Values from Specific Capacity of wells

Well ID	Q (gpm)	D (in)	s (ft)	t (hrs)	Transmissivity (T) (gpd/ft)			
					Storage Coefficient (S)			
					0.05	0.10	0.20	0.30
Lot 15	9.0	5.0	23.0	1.0	340	304	267	245
Lot 16	10.0	5.0	20.0	0.5	405	358	310	281
Lot 28	10.0	5.0	15.0	0.5	565	503	440	402
Lot 36	15.0	5.0	7.0	0.3	2030	1835	1637	1519
Lot 37	13.0	6.5	7.0	0.5	1696	1526	1353	1250
Lot 41	20.0	5.0	9.0	1.0	2431	2233	2032	1914
Lot 43	8.0	4.0	20.0	2.0	408	372	335	314
Lot 46	10.0	4.0	4.0	0.5	2693	2470	2244	2110
Lot 47	10.0	5.0	15.0	2.0	685	626	565	529
Lot 55	8.0	4.0	10.0	1.0	816	744	671	628
Well M1	10.0	5.0	3.0	0.5	3523	3225	2922	2744
Well M2	10.0	5.0	20.0	0.5	405	358	310	281

Q - Discharge Rate During Pumping Test
D - Diameter of the Well
s - Drawdown Reported
t - Time of Pumping

Transmissivity obtained with Storage Coefficient of 0.2 is adopted.



Contour Interval 5×10^{-4} ft^2/s

Transmissivity values are shown in 1×10^{-4} ft^2/s

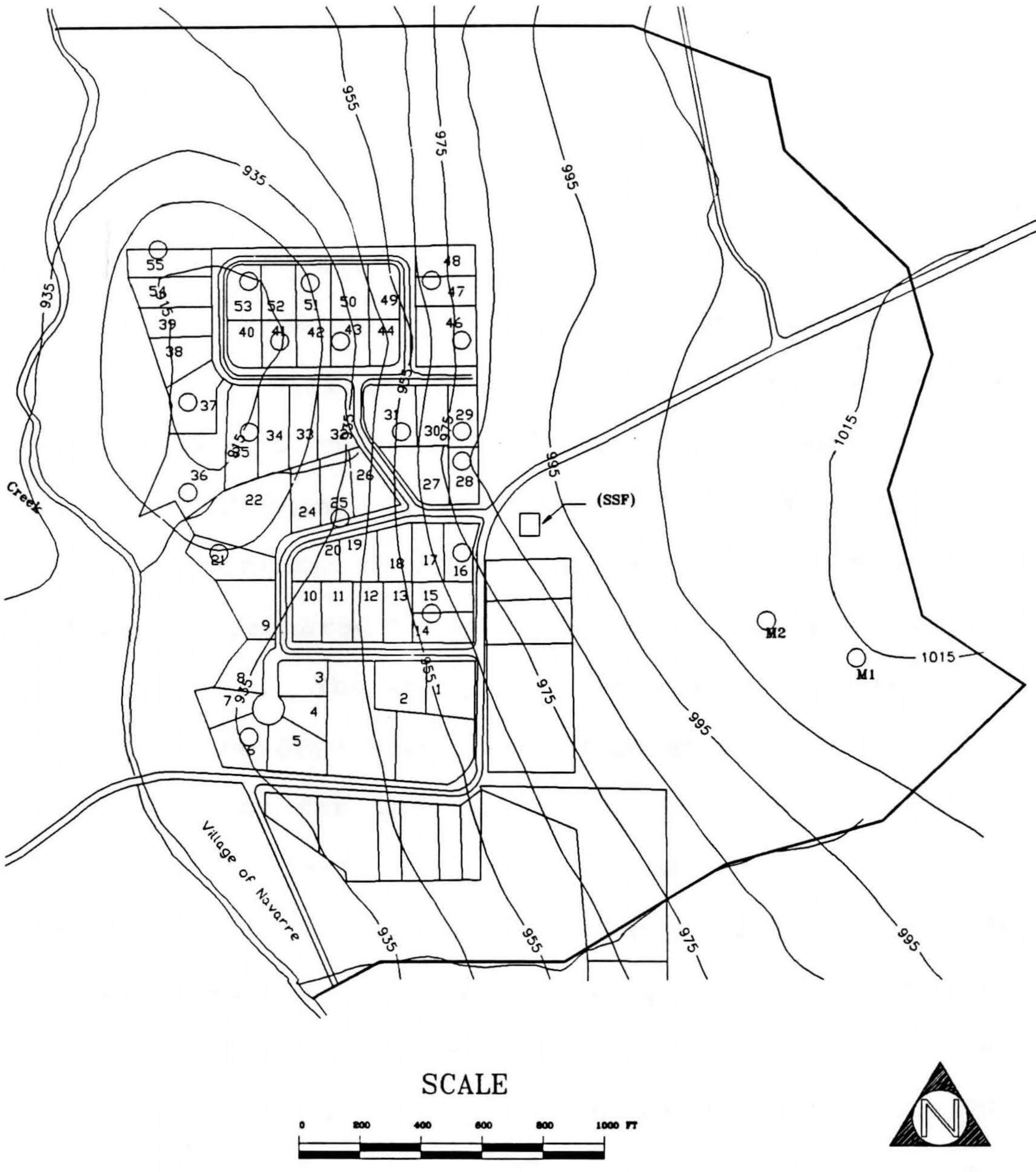
<u>Figure 4-5</u> : Transmissivity Distribution Map

4.3 Initial Piezometric Heads

Simulation of the aquifer model requires piezometric heads at all nodes of the aquifer taken at the same time which can be used as the initial condition of the aquifer. No data on piezometric head measurement on wells are available for a given time. Static water level is available for each well when it was constructed. The wells were constructed between 1963 and 1990, hence the static water levels reported do not entail the same time period. Since the time span of the reported static water levels is large, there may be considerable impact of local pumping, seasonal and yearly variation of water table elevation in the observed static water levels. In the absence of the piezometric head for the same time period, the reported static water levels are the only option left to estimate the initial piezometric heads for the simulation, even though the assumption will considerably affect the head prediction by the model. The bed elevation of the creek was taken as the water level along the creek. The assumed initial piezometric head is presented in Figure 4-6.

4.4 Initial Chloride Concentrations

There are means available to determine exactly the concentration of chloride in the aquifer prevailing before the contamination started. Some wells show the contamination levels as low as 20 mg/l (Lot 55). Hence an initial concentration of 20 mg/l was assumed throughout the simulation area.



Contour Interval 10 ft.

Figure 4-6 : Initail Peizometric Head Distribution Map

4.5 Recharge and Discharge estimate

The major source of recharge to the underlying aquifer is precipitation. The data from the U. S. Weather Bureau Station at the Akron-Canton Airport shows a 30-year (1951-1980) average precipitation of 35.9 inches. Pettyjohn and Henning (1979) estimated the average effective recharge rate during a year of normal precipitation for different hydro-geologic regions in Ohio. Williams (1991) estimated the net recharge rate for different regions of Stark County based on the Pettyjohn and Henning (1979) report and from some site specific observations in Stark County. Based on williams (1991), the net recharge for the subdivision ranges from 2 to 7 inches per year. The study area is moderately sloped and the surface is covered with light vegetation hence there is higher opportunity for infiltration. In this study, a net recharge rate of 7 inches per year was adopted.

All the wells located in the Subdivision are used for domestic water supply purpose. No measurement of discharge is available for wells. Total water requirement for a family can be estimated on per capita consumption basis. Here, a family size of four is estimated per well and based on the per capita consumption, total water requirement is computed. For rural domestic use per capita consumption was taken as 73 gal/day (Viessman and Hammer, 1985). In addition to domestic use, lawn sprinkling demand was taken to be 35% of domestic use. Total consumption was worked out as 53 cubic feet per day per well.

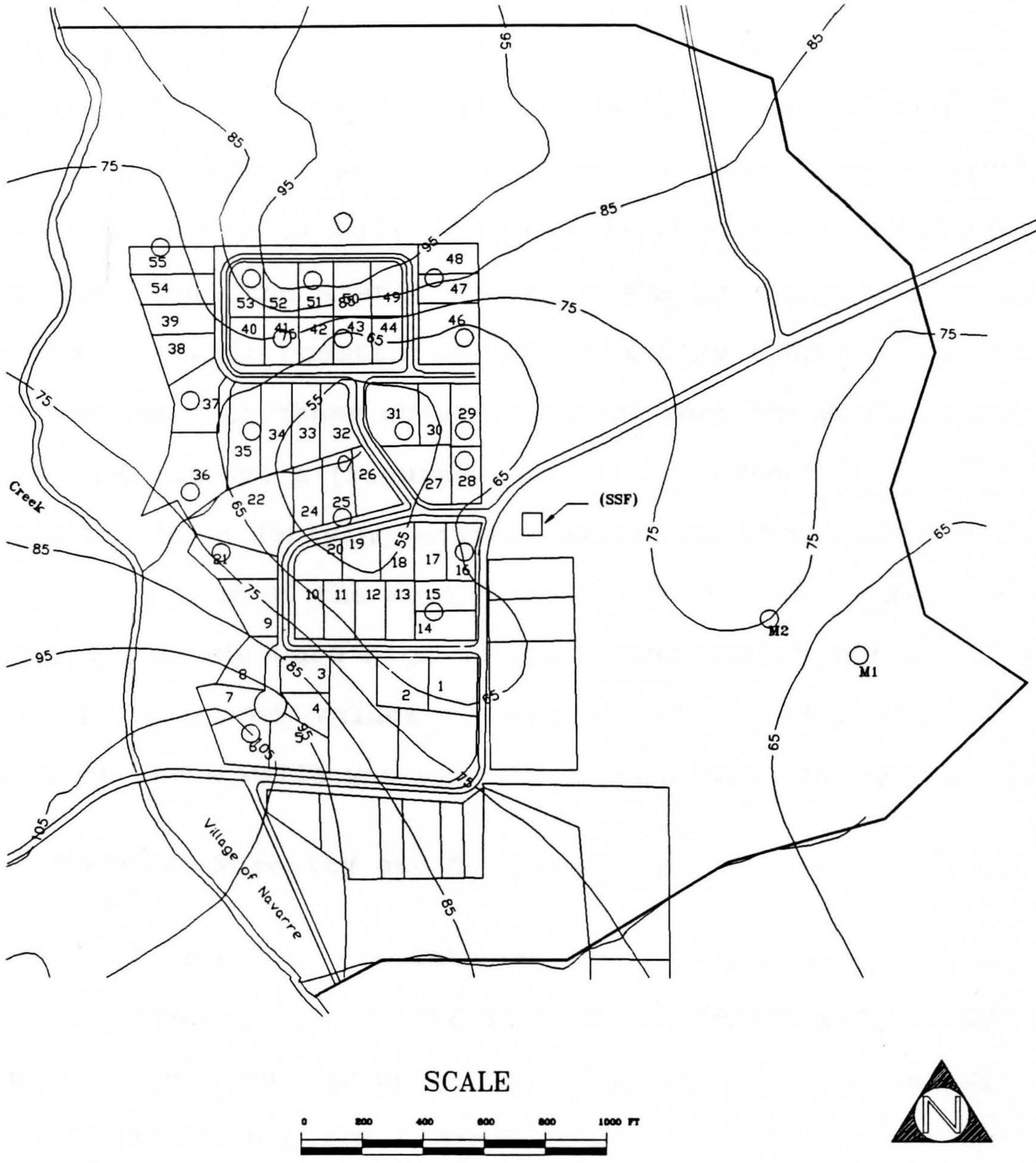
Pumping is done on an as-required basis to cover the daily water requirement and usually pumping time is on the order of a few hours a day. Hence use of the pumping rate of each well for 24 hours will over estimate the amount of water pumped. For the modeling purpose, a constant pumping rate of 0.00061 cubic feet per second was used based on 24 hours pumping requirement to pump the daily requirement of 53 cubic feet of water. Discharge also occurs along the creek. Since the rate of discharge in the creek from groundwater could not be estimated from available information, the creek was treated as a constant head boundary. The discharge into the creek would be computed by model so as to keep the head constant along the boundary.

4.6 Saturated thickness

Based on the bottom elevation of the unconfined aquifer, the saturated thickness was obtained by subtracting the bottom profile from the assumed piezometric heads profile. The assumed saturated thickness of aquifer in the study area is presented in Figure 4-7. The maximum thickness of the aquifer is 105 ft and its minimum thickness is 40 ft.

4.7 Boundary Conditions

The aquifer was assumed to be bounded by a constant head boundary along the creek and the no flow boundary by the ridge at the east side. Artificial boundaries were assumed at the north and south end of the study area. The north and south



Contour Interval 10 ft.

Figure 4-7 : Saturated Thickness Distribution Map

boundaries are located far from the possible pumping effect of the wells, hence these boundaries were treated as no flow boundaries.

The well logs of lot 35, 31,36,37,51 revealed a low static water table level compared to the static water level reported nearby these wells. The wells were constructed many years apart but the static water levels in these wells are observed to remain constant despite the time span. The creek bed elevation near these wells is higher than the static water levels in these wells (Figure 4-6). It is suspected that high leakage to the underlying aquifer exists at these locations. During early runs of the model it was observed that predicted piezometric heads were high in this area, which contradicts the field observed values. Hence in the model the area covered by these wells was assumed to be a constant head zone.

4.8 Effective Porosity and Dispersivity

As the aquifer consists mainly of gravel, sand and sandstone, the porosity of the aquifer was arbitrarily assumed as 0.3. Previous studies on similar type of aquifer simulation have used longitudinal dispersivity values as large as 328 ft and transverse dispersivity values as large as 164 ft (e.g., Konikow and Bredehoeft, 1974; Konikow, 1977). In this study, an initial guess of 100 ft was assumed for longitudinal dispersivity. The ratio of longitudinal to transverse dispersivity was assumed as 0.4.

CHAPTER V

MODEL APPLICATION

5.1 Model Application Methodology

The amount of information available and different field conditions make each model application unique. In this study, the initial conditions could not be defined properly. Since the piezometric heads for the initial condition were taken as the static water level reported in the well logs, the head loss predicted by the model will not only depend on the aquifer stresses and hydrologic properties of aquifer but also on the initial piezometric head assumed.

The wells were constructed at different time periods, hence pumping from the aquifer varied from time to time. This type of situation can be incorporated in the model by specifying different pumping periods. Due to the absence of historical data on the piezometric heads and due to unknown time of start of contamination, the calibration of the model with the different pumping periods will be complicated. Due to the complex nature of the problem, it was assumed that all the wells started operating simultaneously.

The time when the contaminant entered the groundwater is difficult to define. The source of the contamination is at the surface and the groundwater near the source of contamination is 20 - 50 ft deep from the surface. The contaminants may have taken considerable time to reach the groundwater because of unsaturated flow through the ground. The travel time through the unsaturated zone not only depends on the hydraulic properties of the zone but also in the recharge rate which is not constant throughout the period.

The chloride concentration of the surface runoff from the SSF is not available hence the concentration of water reaching the groundwater system could not be determined. In spite the source of contamination is known, the extent of area through which contaminants seeped into the groundwater is difficult to define clearly.

In view of the information available and the objective of the study, the following model application methodology is formulated.

1) Modeling will not be done for unsaturated flow from the surface to the groundwater. Modeling will be done only for the saturated portion of aquifer assuming that the chloride has already reached the groundwater.

2) Transient state flow modeling will be done for the groundwater flow and advection-dispersion transport modeling will be done for chloride transport. The chloride will be considered as conservative, non adsorbable solute.

3) No historic data on piezometric head distribution in the wells are available so models will not be calibrated for the predicted piezometric head.

However, model parameters are adjusted to reduce the impractical drawdown predicted by the model. The extent of this calibration process cannot be justified as no data are available for comparison.

4) Calibration will be done for concentration distribution only. Contaminants distribution varies greatly with respect to the depth. As all the wells tap water at different depths, the contamination levels in all the wells cannot be used for calibration of the two-dimensional model. Only the wells tapping the upper fractured shale layer (lot 25,28,29 and 43) will be used for calibration. The distribution of concentration observed in these wells is not sufficient for generating a contour map of observed concentrations. The comparison between the model predicted and the observed concentration will be made at these wells only, instead of general patterns of contaminant distribution.

5) Since the start of contamination and concentration level of seepage water are not known, the model will be run with an arbitrary concentration and arbitrary extent of the contamination source along with the assumed initial conditions. The ratio of the predicted concentration and observed concentration on a chosen date will be determined for each well for various times from the start of

simulation.

6) The model parameters, transmissivity and dispersitivies, and the locations of the contamination source will be adjusted, till the ratio of observed and model predicted concentration is the same for all four wells. This will calibrate the distribution of the chloride in the aquifer for the chosen date.

7) The elapsed time from the start of simulation will then be deducted from the chosen date and date of start of the contamination in groundwater will be determined. For the concentration level of seepage water, the initial assumed concentration will be divided by the ratio of predicted to observed concentration obtained from step 4.

8) The adjusted parameters obtained in the above steps will be used for the verification of the model prediction and further simulation. Model parameters will be changed if the predicted values disagree with the field values.

9) As the source of contamination is no longer present, further simulation will be done from the date of removal of contamination source. This simulation will predict the transport of the contaminants already present in the aquifer.

10) The models used in the study are based on different approaches; calibration will be done for the USGS-

MOCADI model only. The calibrated parameters then will be used in the SUTRA to verify the application of SUTRA for the simulation process.

5.2 USGS-MOCADI Model Construction

The application of USGS-MOCADI model requires the study area to be divided into a uniform rectangular grid. Here grid size of 200 ft in x and y-directions was chosen. The area was divided into 324 cells, with 18 cells in x and y-directions. The x axis direction is in the east-west direction as the general flow pattern is towards west. The grid for USGS-MOCADI along with recharge area, contaminant source and boundary conditions, is presented in Figure 5-1.

It can be seen in the Figure 5-1 that some wells are not located at the center of each cell due to the restriction of uniform grid size requirement. Such wells were approximated by equivalent wells in the center of cells as shown in Figure 5-2

The finite-difference grid was superimposed with the transmissivity, saturated thickness, initial piezometric head maps and value for each node obtained. In addition to these, the following variables were assigned for simulation:

1) Maximum number of particle per cell was taken as 6400. High initial numbers of particles reduce the mass balance error. In the model, Initial number of particles per cell was adopted as 16, which is the highest initial number of particles permitted by

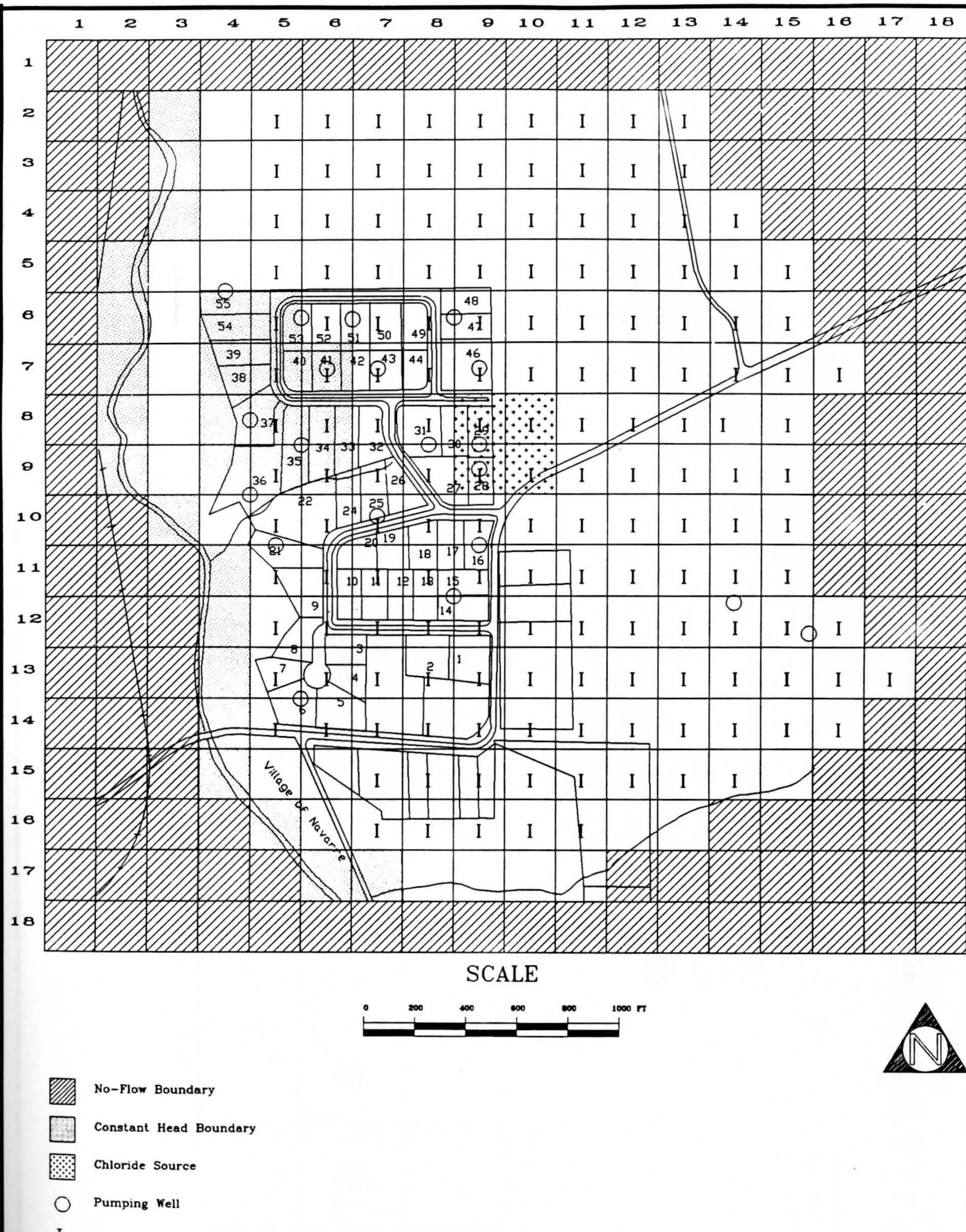


Figure 5-1 : **Finite-Difference Grid for USGS-MOCADI Model**

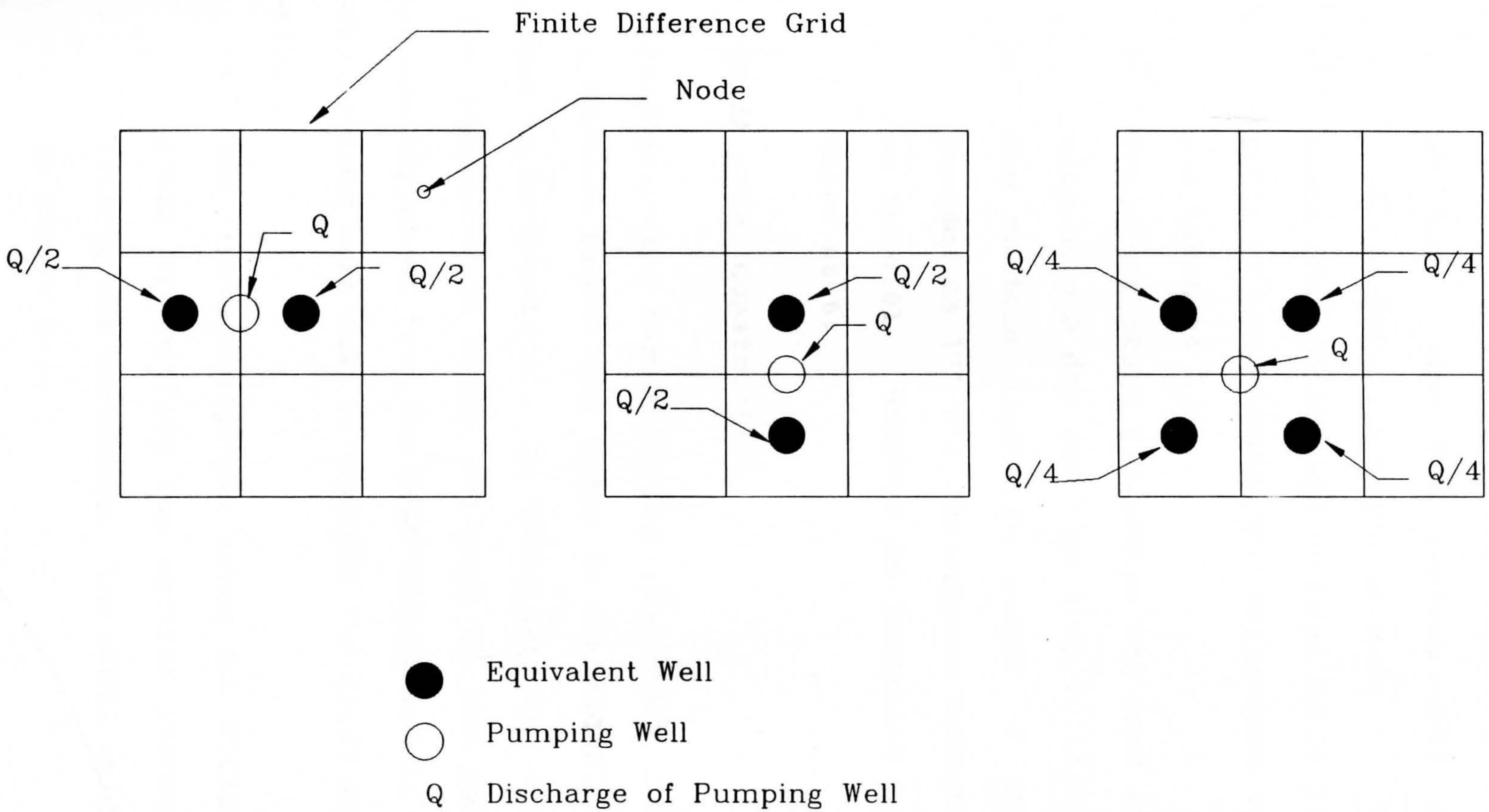


Figure 5-2 : Equivalent Wells Representation

the model. The model results in less mass balance error with maximum cell distance per particle move of 0.5, hence the maximum cell distance per particle move was taken as 0.5.

2) Since the aquifer was assumed to be isotropic, the ratio of longitudinal and transverse transmissivity was taken as 1.0.

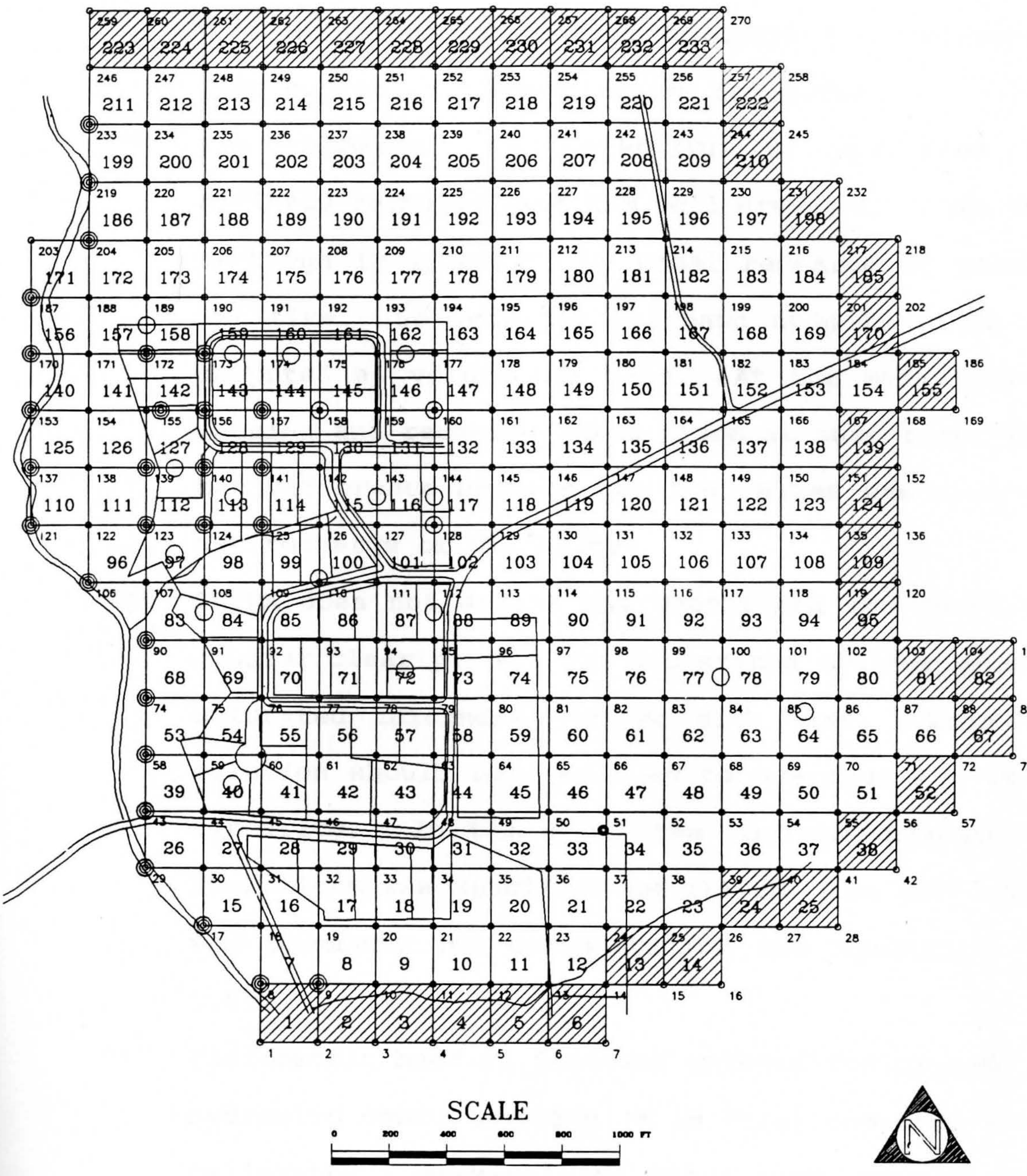
3) Transient state simulation was used with time step size of one day and time step multiplier of 1.15.

4) The maximum allowable number of iterations was assumed as 175 and convergence criteria were taken to be 0.01. Numbers of iteration parameters was taken as 6.

5.3 SUTRA Model Construction

To compare the result between the MOCADI and SUTRA models on a node-wise basis, the nodes in the MOCADI and SUTRA are required to be identical. As SUTRA requires some parameters in the element-wise basis and some in the node-wise basis which are different from the USGS-MOCADI model, the following approximations were made to keep the two grids as identical as possible:

1) The finite-difference nodes for MOCADI was used in SUTRA by shifting the aquifer boundary by 100 ft towards the northeast. The SUTRA grid is presented in Figure 5-3.



◎ Constant Head Nodes

o Node

○ Pumping Wells

16 Element Number

67 Node Number

▨ No-Flow Boundary

Figure 5-3 : Finite-Element Grid for SUTRA Model

2) The average of the nodal transmissivity values of USGS-MOCADI nodes was used to compute the element-wise hydraulic conductivities for SUTRA.

3) The recharge in USGS-MOCADI is specified by diffused recharge over the cell area. In SUTRA the recharge is specified by nodal recharge in volume per time. So recharge for each node in SUTRA is computed as volume per time. At the nodes where pumping and recharge takes place at same time, the net difference between the two values was used as net recharge or discharge.

4) SUTRA does not define the unconfined and confined aquifer clearly. For the unconfined aquifer, where saturated thickness changes with time, iterative solution should be specified to overcome the non-linearity. In the model the maximum numbers of iterations was specified as 175 and the tolerance for pressure and concentration was specified as 0.01.

5) Piezometric head in feet was entered for pressure, hydraulic conductivities (K in ft/s) computed from calibrated transmissivity value were entered for permeability, and the concentration in ppm was entered for mass fraction concentration by making the following adjustments in input data:

Fluid density = 1.0 slug/ft^3

Viscosity of fluid = 1.0 lb.s/ft^2

6) SUTRA computes the specific pressure storativity (S_{op}) from the given data of porous matrix compressibility, fluid compressibility and porosity of the medium (Eq. 2-5) The storage coefficient for each element is then computed. The storage coefficient is considered as variable throughout the aquifer in contrast to the constant storage coefficient used in USGS-MOCADI. To replace the storage coefficient in SUTRA by the 0.2 constant storage coefficient used for USGS-MOCADI, the following adjustment in parameters were made:

   Average thickness of aquifer (b) = 75 ft

   Solid matrix compressibility (α) = 3.8×10^{-3} ft s^2/lb

   Fluid compressibility (β) = 6.56×10^{-10} ft s^2/lb

   The value of β is the actual value for water, but the value of α used is different from the actual values of compressibility of the aquifer materials. The adjustment in value of α had to be made due to assumed value of fluid density and acceleration of gravity. The above approximation gives a storage coefficient nearly equal to 0.2 throughout the aquifer.

7) The solute was considered to be conservative and no adsorption was specified. The change in Fluid density with change in concentration was neglected.

8) The aquifer was assumed to be isotropic so maximum

and minimum permeability were assumed to be equal.

9) The fractional upstream weight, pressure boundary condition and concentration boundary condition were specified as 0, 0.01 and 0.01 respectively, which are the recommended values for the model.

10) As areal two dimensional modeling is done, the magnitude of gravitational acceleration vector was taken as zero.

5.4 Model Calibration

The USGS-MOCADI model was calibrated to duplicate the concentration observed in the well of lot 25, 28, 29,and 43 only. The trial and error calibration technique was used, in which the aquifer parameters were adjusted till the required condition was met. The calibration process is summarized below:

1) The contamination source, the SSF, is located in cell 10,10. Initially a contamination source was placed in cell north to the SSF in cell 9,9 and 10,9. The concentration of the source was arbitrarily assigned as 1000 mg/l.

2) The model was run for 20 years of time period with time step of one day and time step multiplier of 1.15. The predicted drawdown by the model was found to be very unrealistic. The model predicted drawdown on the order of 50 ft for some of the nodes. Hence the transmissivity values were changed and the model was run, till the predicted drawdown was reduced to 10-20 ft in the period of 20 years. The high drawdown prediction may be due to the assumed initial condition of piezometric heads. But there were no means to correct the errors as there were no data to compare with for corrections. So the initial estimate of piezometric heads was not changed; instead, the transmissivity values were changed to reduce

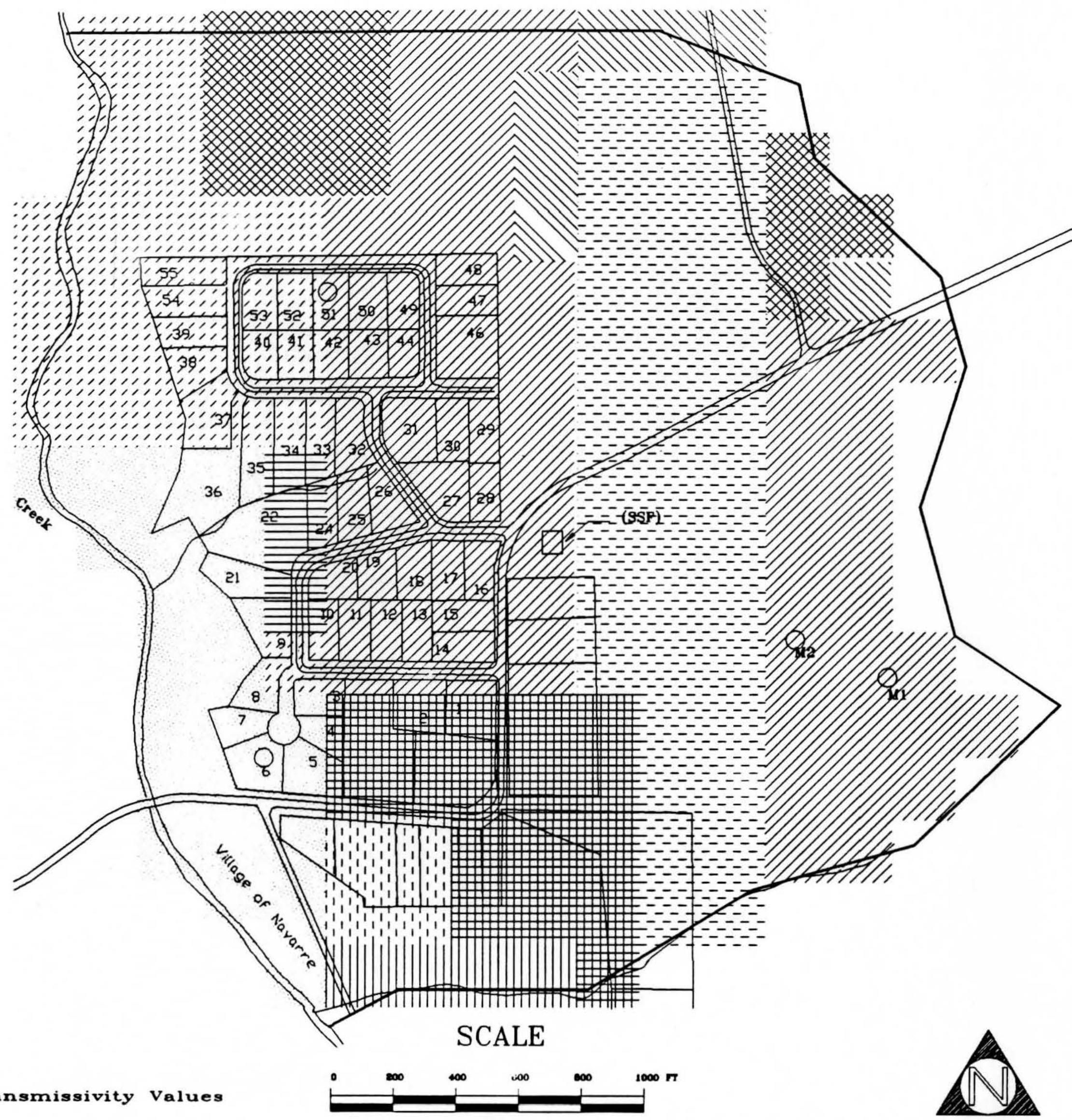
6) The initial guess of concentration of 1000 mg/l was then divided by the matched ratio of predicted concentration and the observed concentration and then the model is run to get the actual concentration distribution for the modeled area for 4/1/86 and 9/22/1986.

7) The condition at the end of model run in step (6) then assumed as the condition prevailing at 9/22/1986 and it was considered as the initial condition for the further simulation.

8) It is mentioned in the previous report that the source of contamination was removed in 3/87. Observation of the trend of contamination levels in the wells (Table 3-1) indicated that the contamination started decreasing from 9/86. This may be due to the lower amount of precipitation and less opportunity of infiltration during winter months. In the model, it was assumed that the contamination source was removed in 1/87. Model was run without contamination source from 1/87 onwards.

9) The model-predicted concentration for 2/17/87, 6/9/87 and 1/8/88 was found to be close to the actual concentration observed in the wells.

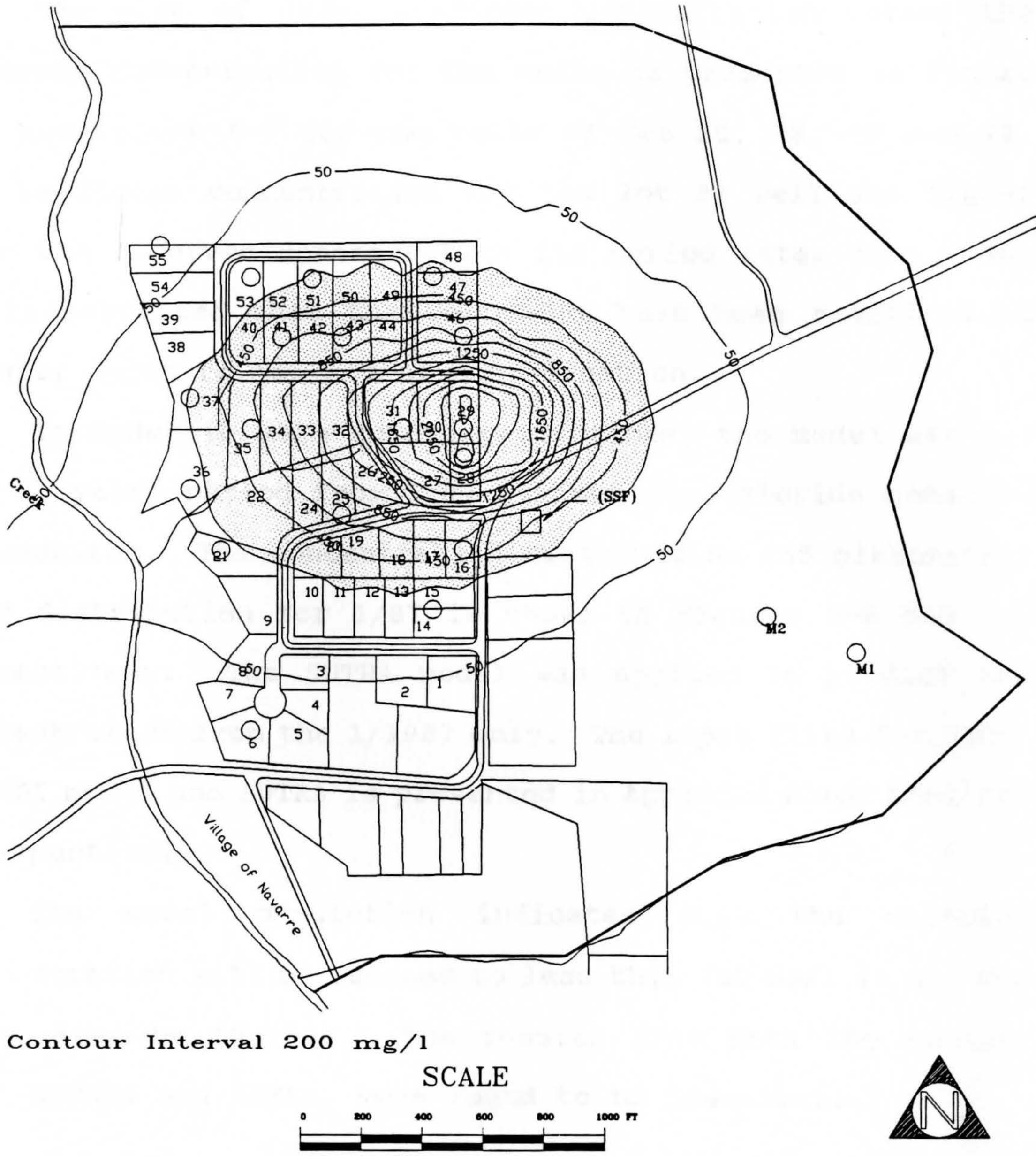
The calibrated transmissivity distribution for the model area is shown in Figure 5-4. The model-predicted concentration distribution for 9/86 is presented in Figure 5-5



Transmissivity Values

- 3 x 10^{-4} ft^2/s
- 4 x 10^{-4} ft^2/s
- 4.5 x 10^{-4} ft^2/s
- 6.0 x 10^{-4} ft^2/s
- 7.5 x 10^{-4} ft^2/s
- 8.5 x 10^{-4} ft^2/s
- 9.0 x 10^{-4} ft^2/s
- 9.5 x 10^{-4} ft^2/s
- 10 x 10^{-4} ft^2/s
- 11 x 10^{-4} ft^2/s

Figure 5-4 : Calibrated Transmissivity Distribution Map



Chloride Concentration greater than 250 mg/l

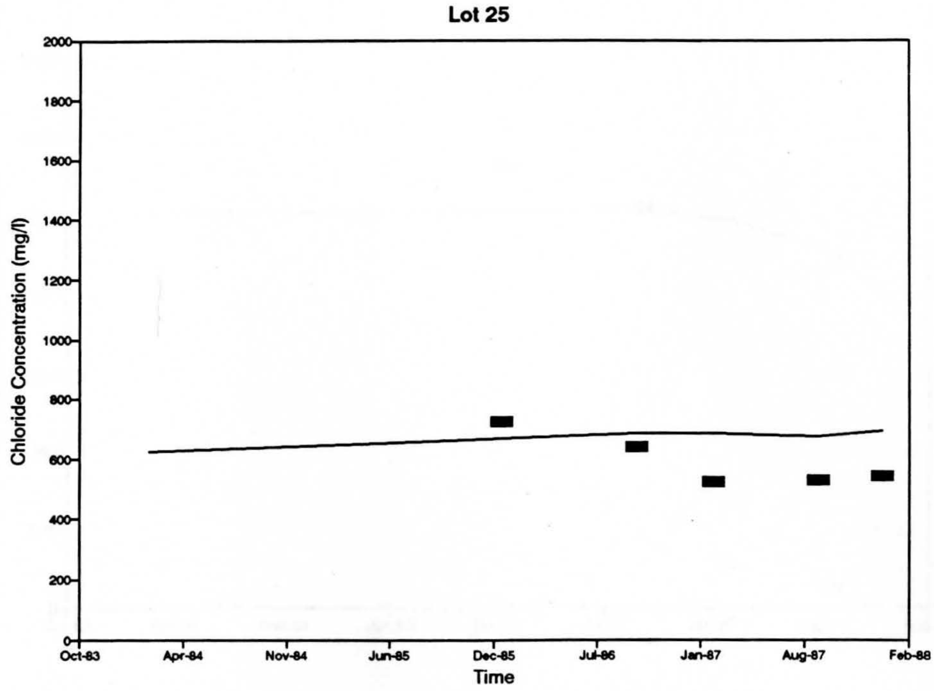
Figure 5-5 : Predicted Chloride Concentration Distribution for 9/1986 (USGS-MOCADI model)

5.5 Model Predictions

The plot of model predicted concentration verses the observed concentration for the wells is presented in Figure 5-6 and Figure 5-7 for the wells of lot 25, 28, 29 and 43. The predicted concentration for the lot 29 well was higher than the observed concentration for period later than 9/86. It is suspected that the well must have been redrilled to greater depth to get rid of contamination.

In order to make future predictions, the model was run for 30 years period from 1/87 without any chloride added to groundwater. The concentration distribution and piezometric head distribution for 1/87 is shown in Figures 5-8 and 5-9 respectively. The SUTRA model was applied to predict the concentration from the 1/1987 only. The input files for USGS-MOCADI model and SUTRA is presented in Appendix B and Appendix C respectively.

The model prediction indicates that the chloride concentration will be reduced to less than 250 mg/l in all the study area by 10/2006. The results from both the models, USGS-MOCADI and SUTRA, were found to be identical.



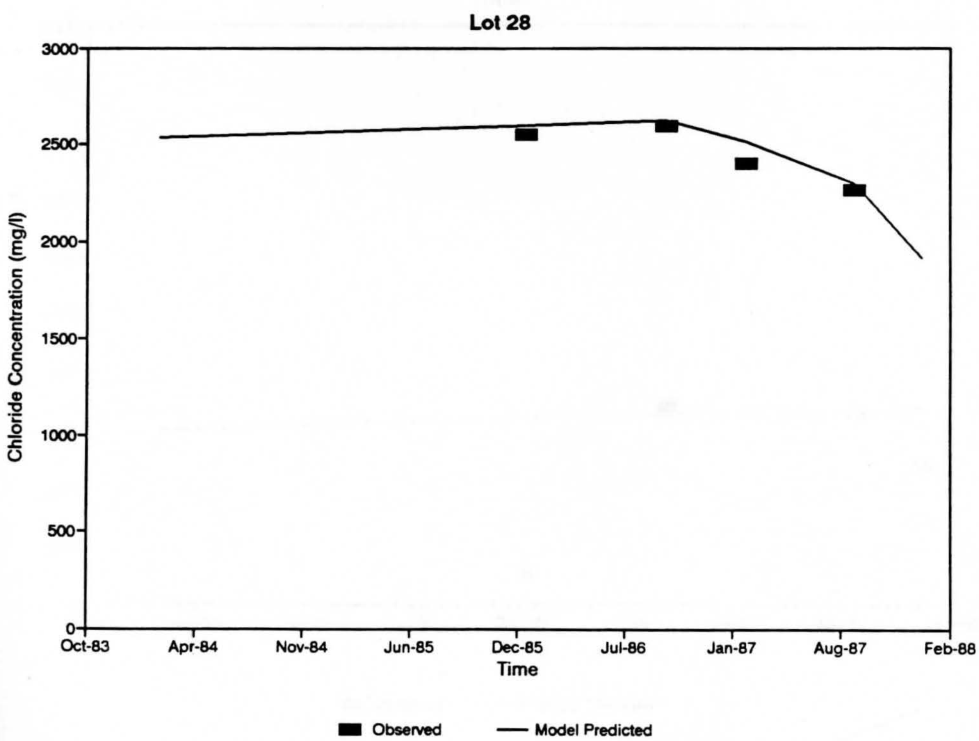


Figure 5-6 : Observed and USGS-MOCADI Model Predicted Concentration for Lot 25 and Lot 28

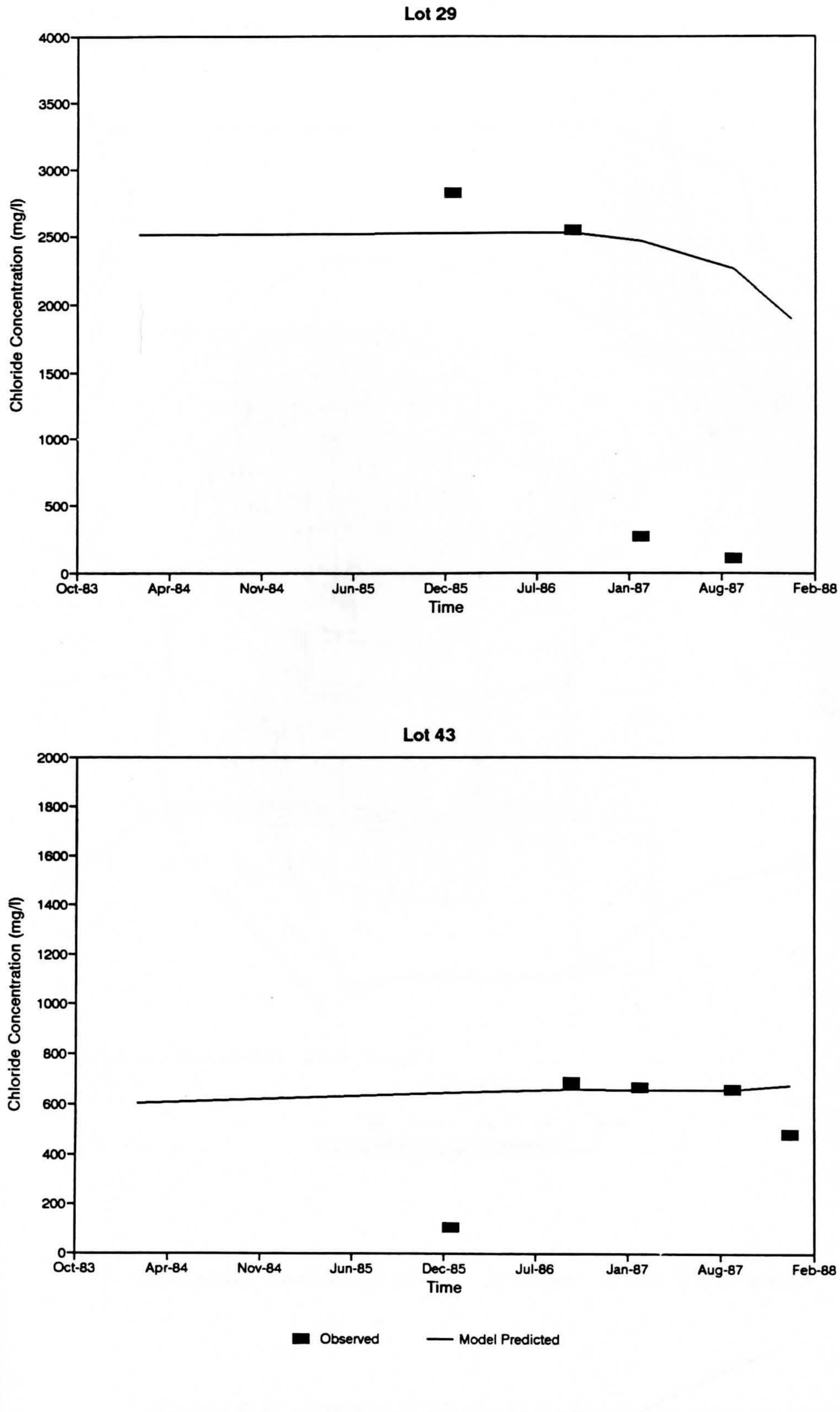
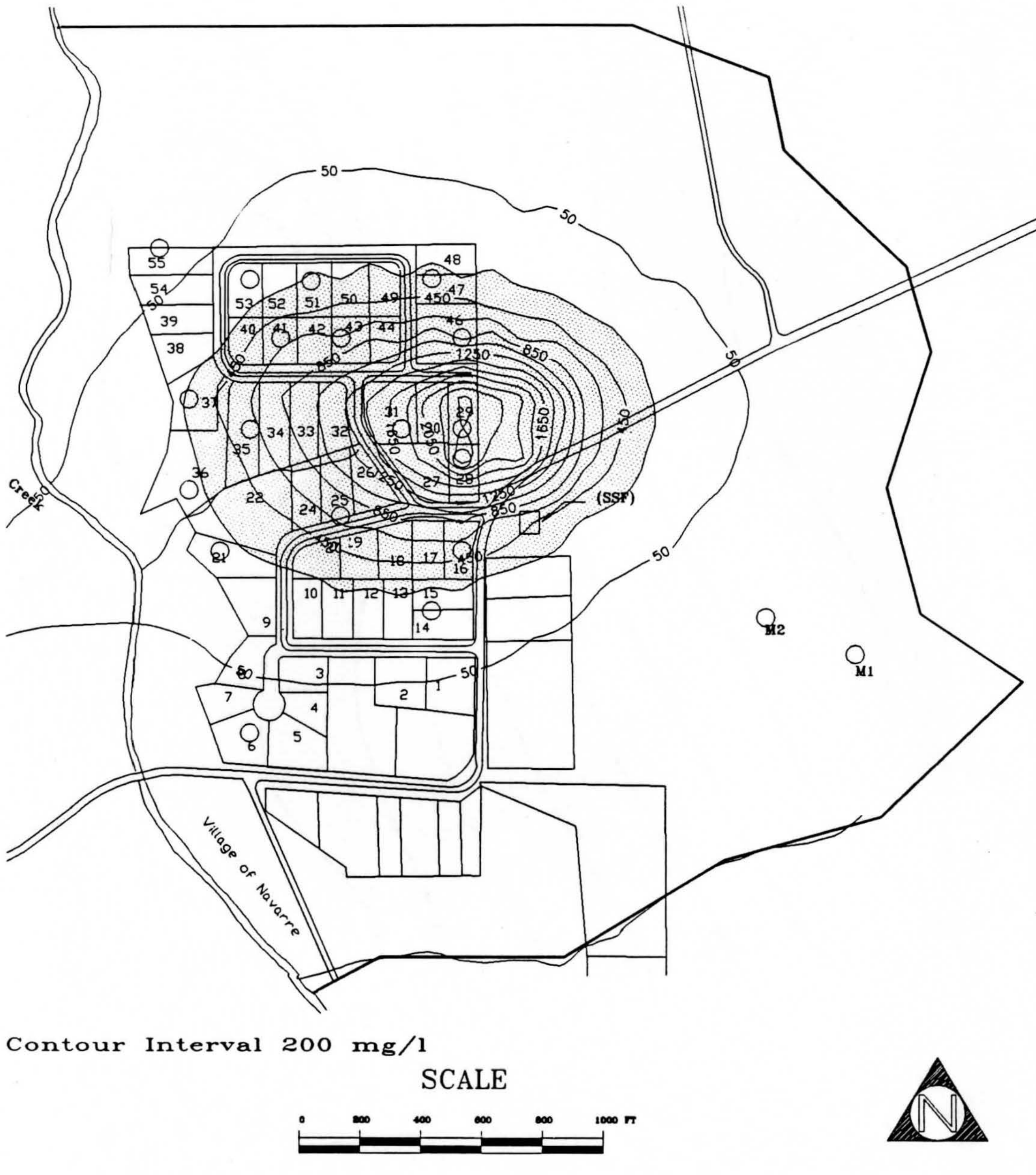


Figure 5-7 : **Observed and USGS-MOCADI Model Predicted Concentration for Lot 29 and Lot 43**



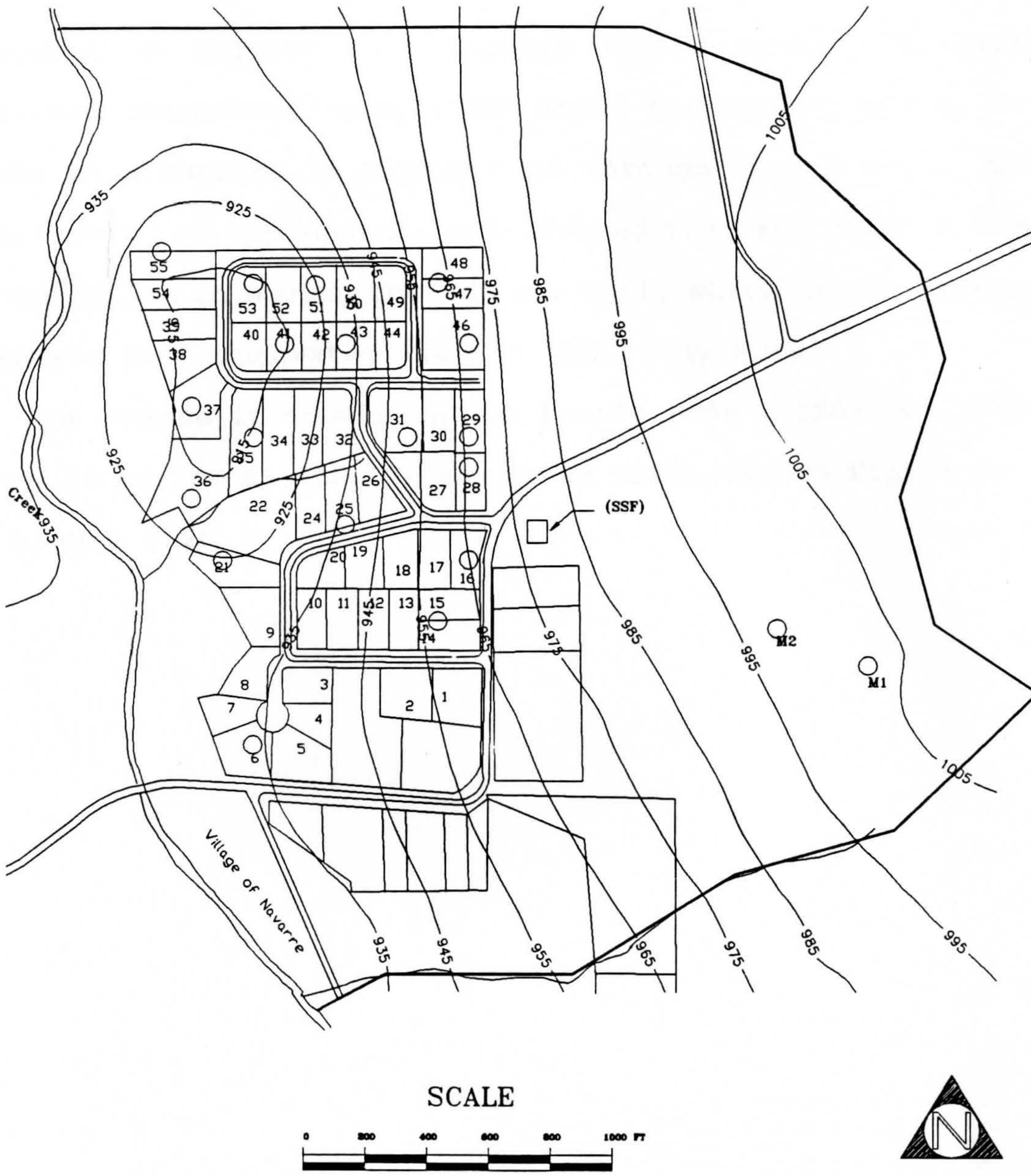
Contour Interval 200 mg/l

SCALE

0 200 400 600 800 1000 FT

Chloride Concentration greater than 250 mg/l

Figure 5-8 : Predicted Chloride Concentration Distribution for 1/1987 (USGS-MOCADI model)



Contour Interval 10 ft.

Figure 5-9 : Predicted Peizometric Heads Distribution for 1/1987 (USGS-MOCADI model)

Predicted Concentration distribution by USGS-MOCADI model for 2/1987, 1/1988, 8/1992, 10/1996, 1/2000 and 3/2004 is presented in Figures 5-10 through Figure 5-15. Similarly predicted concentration by SUTRA model for 2/1987, 8/1992 and 1/2000 is presented in Figure 5-16 through Figure 5-18. The distribution of concentration indicated that the area of high concentration is moving towards the west, which is the general direction of groundwater flow in the study area.

The change in concentration levels from 1/1987 to 1/2017 for wells in lot 25, 28, 29 and 43 is presented in Figure 5-19 and Figure 5-20.

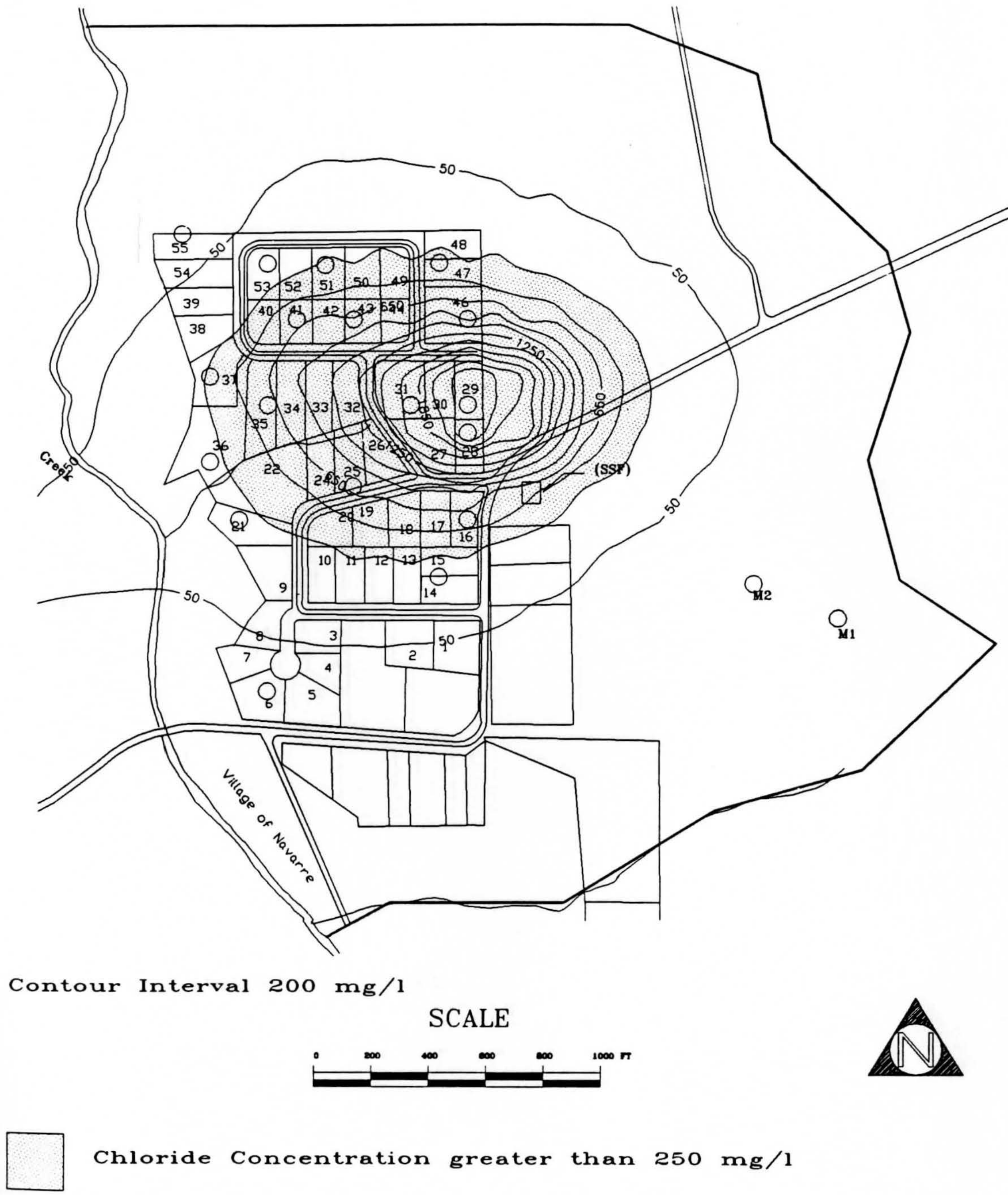
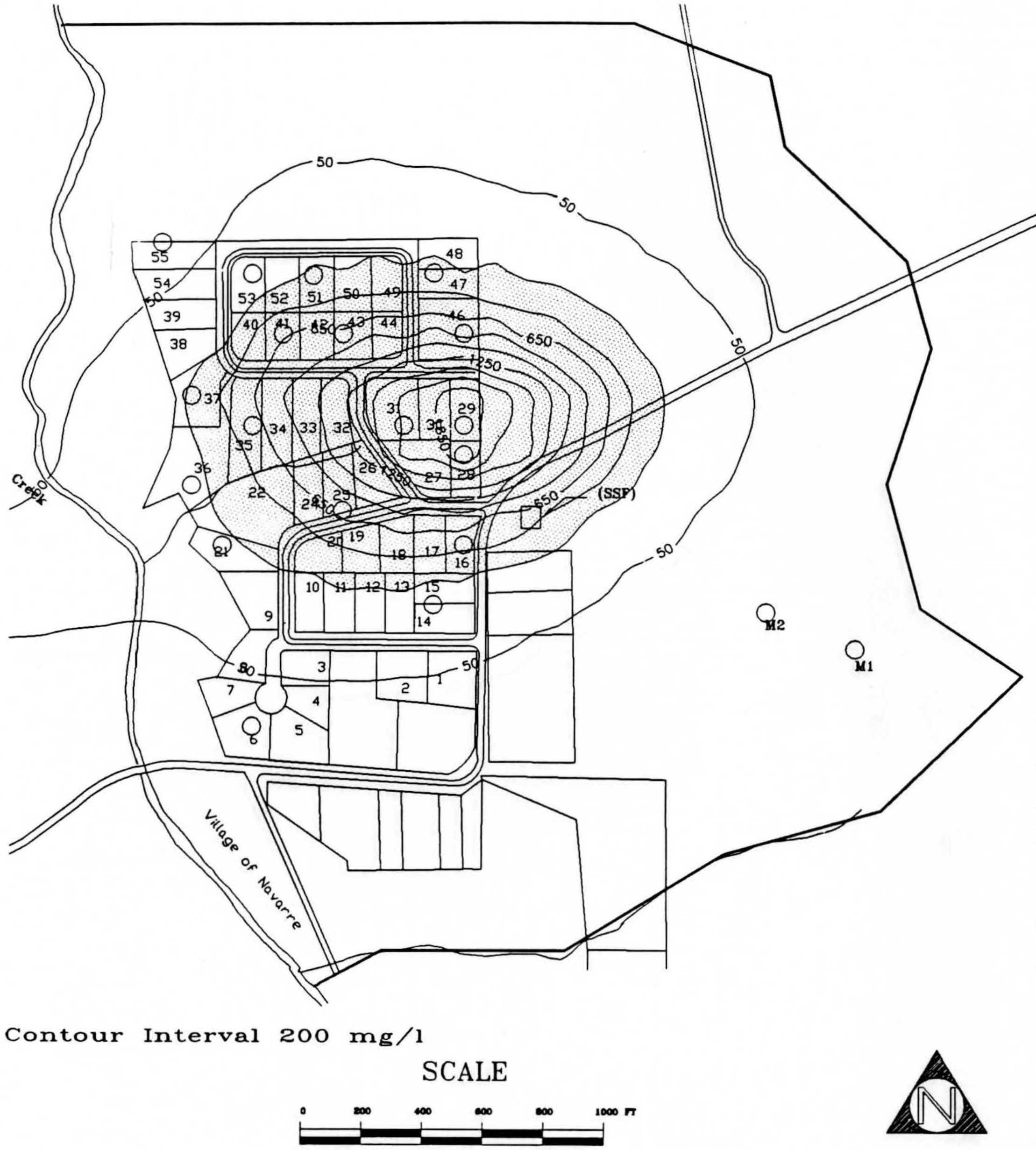


Figure 5-10 : Predicted Chloride Concentration Distribution for 2/1987 (USGS-MOCADI model)



Chloride Concentration greater than 250 mg/l

Figure 5-11 : **Predicted Chloride Concentration Distribution for 1/1988 (USGS-MOCADI model)**

Contour Interval 200 mg/l

SCALE

0 200 400 600 800 1000 FT

Chloride Concentration greater than 250 mg/l

Figure 5-12 : Predicted Chloride Concentration Distribution for 8/1992 (USGS-MOCADI model)

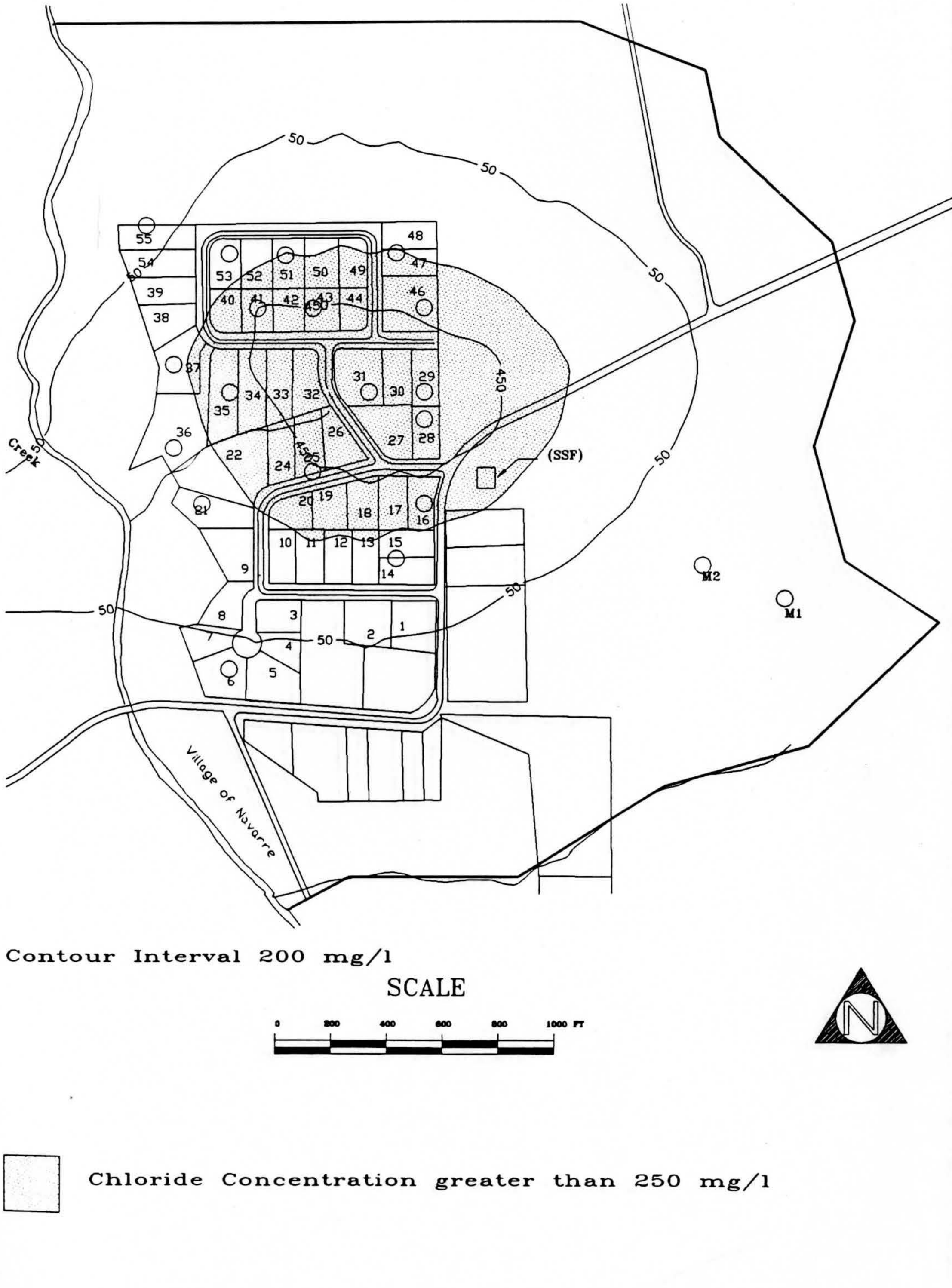
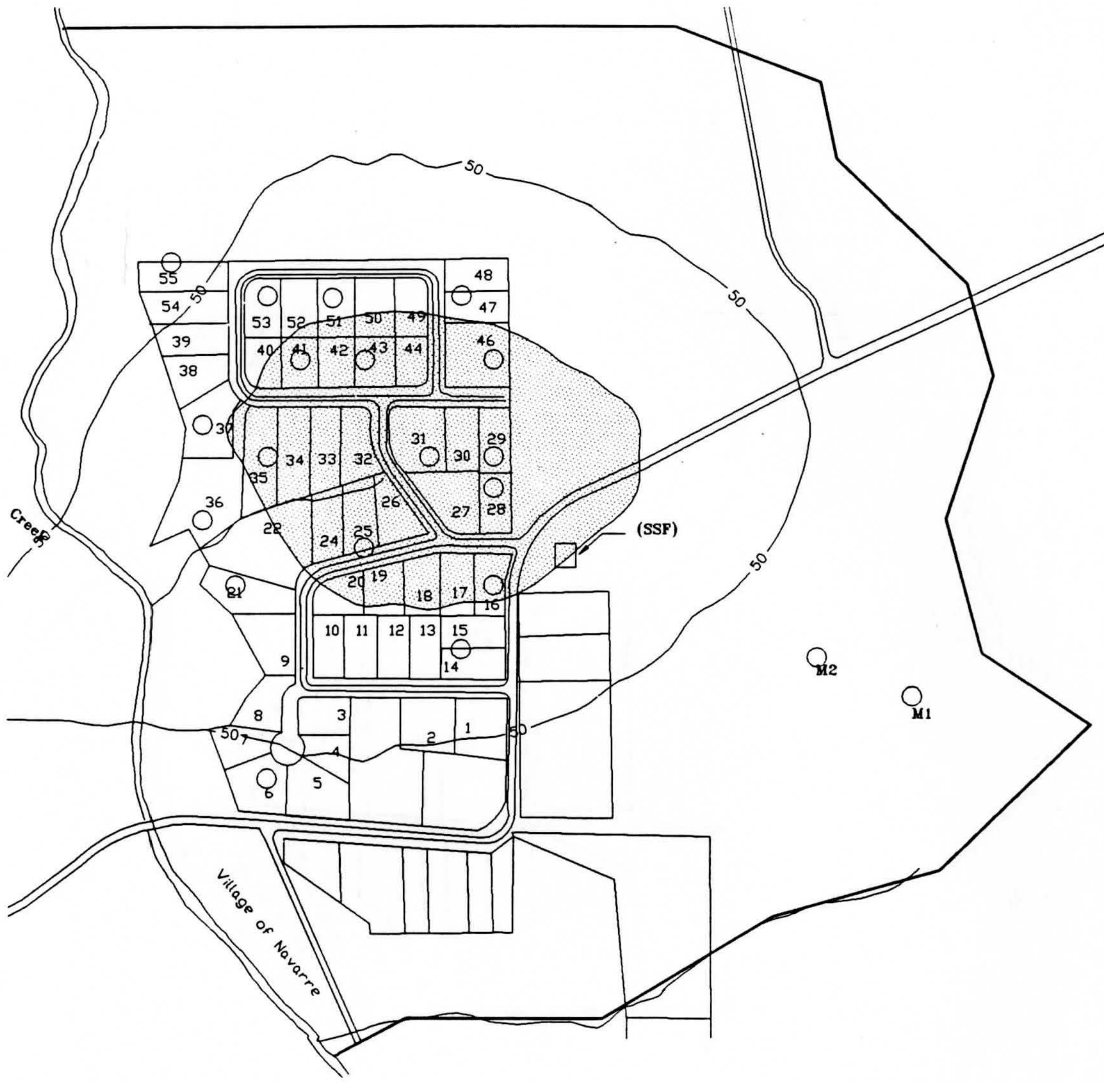


Figure 5-13 : Predicted Chloride Concentration Distribution for 10/1996 (USGS-MOCADI model)



Contour Interval 200 mg/l

SCALE

0 200 400 600 800 1000 FT

Chloride Concentration greater than 250 mg/l

Figure 5-14 : Predicted Chloride Concentration Distribution for 1/2000 (USGS-MOCADI model)

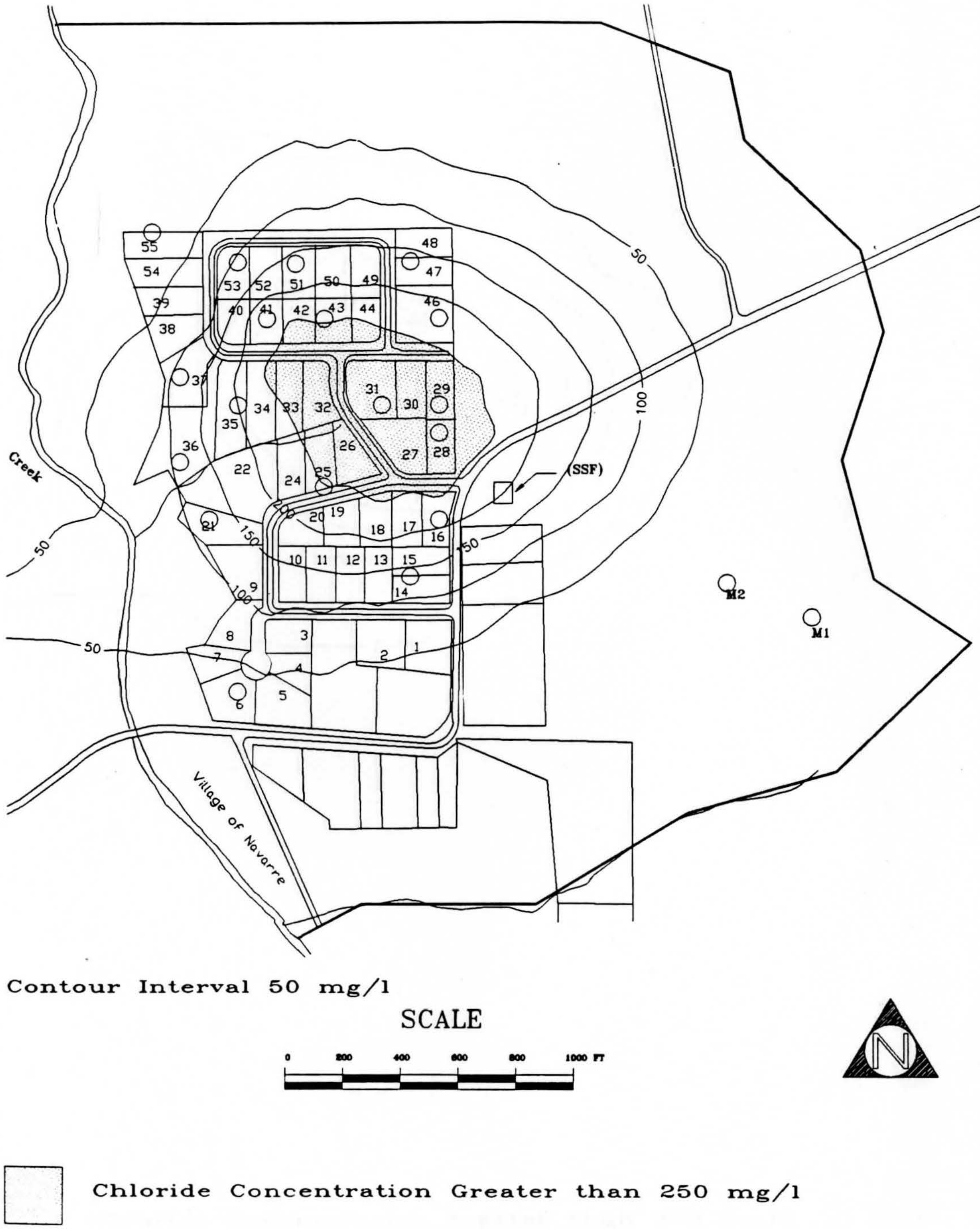
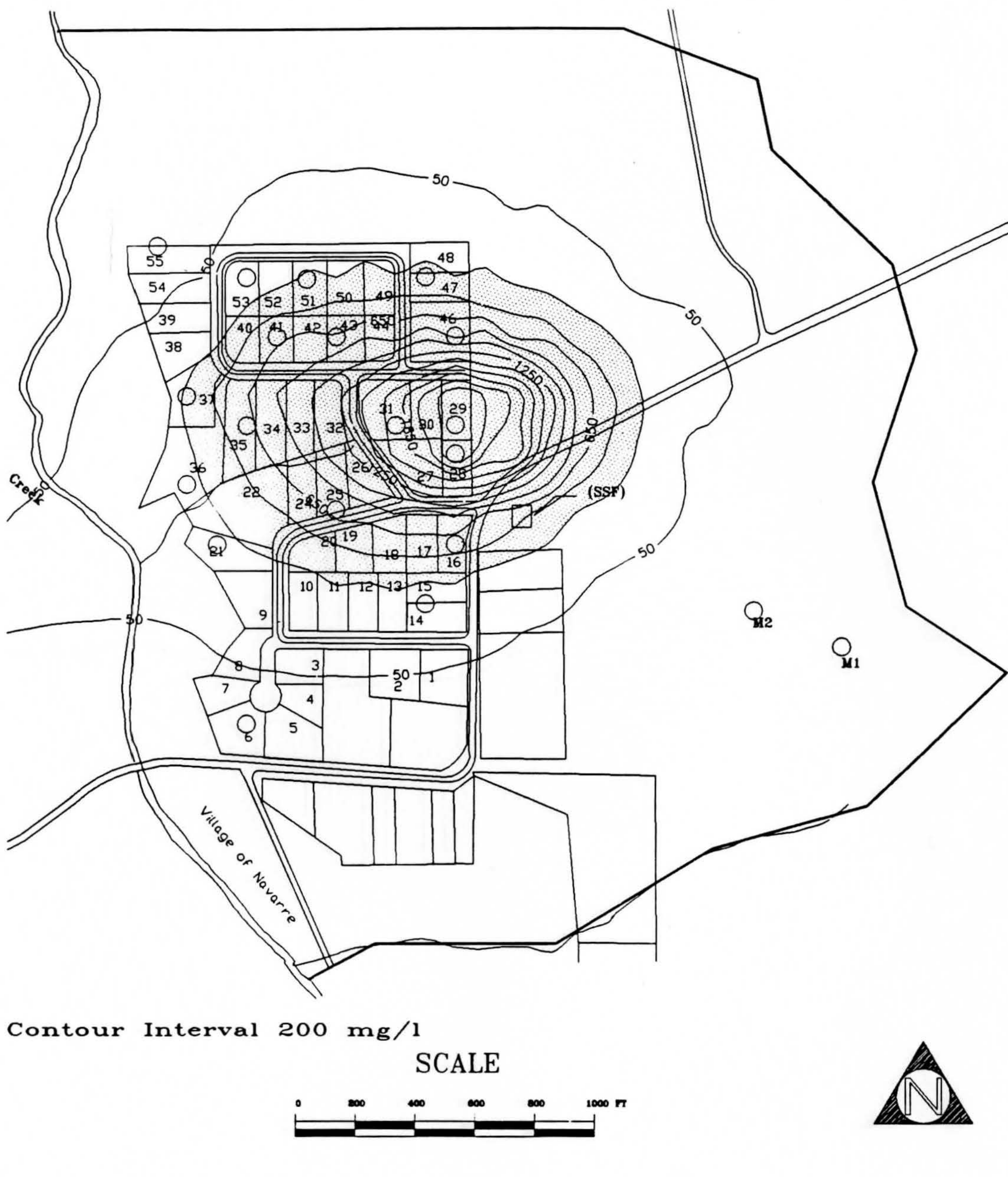


Figure 5-15 : Predicted Chloride Concentration Distribution for 3/2004 (USGS-MOCADI model)



Chloride Concentration greater than 250 mg/l

<u>Figure 5-16</u> : Predicted Chloride Concentration Distribution for 2/1987 (SUTRA model)

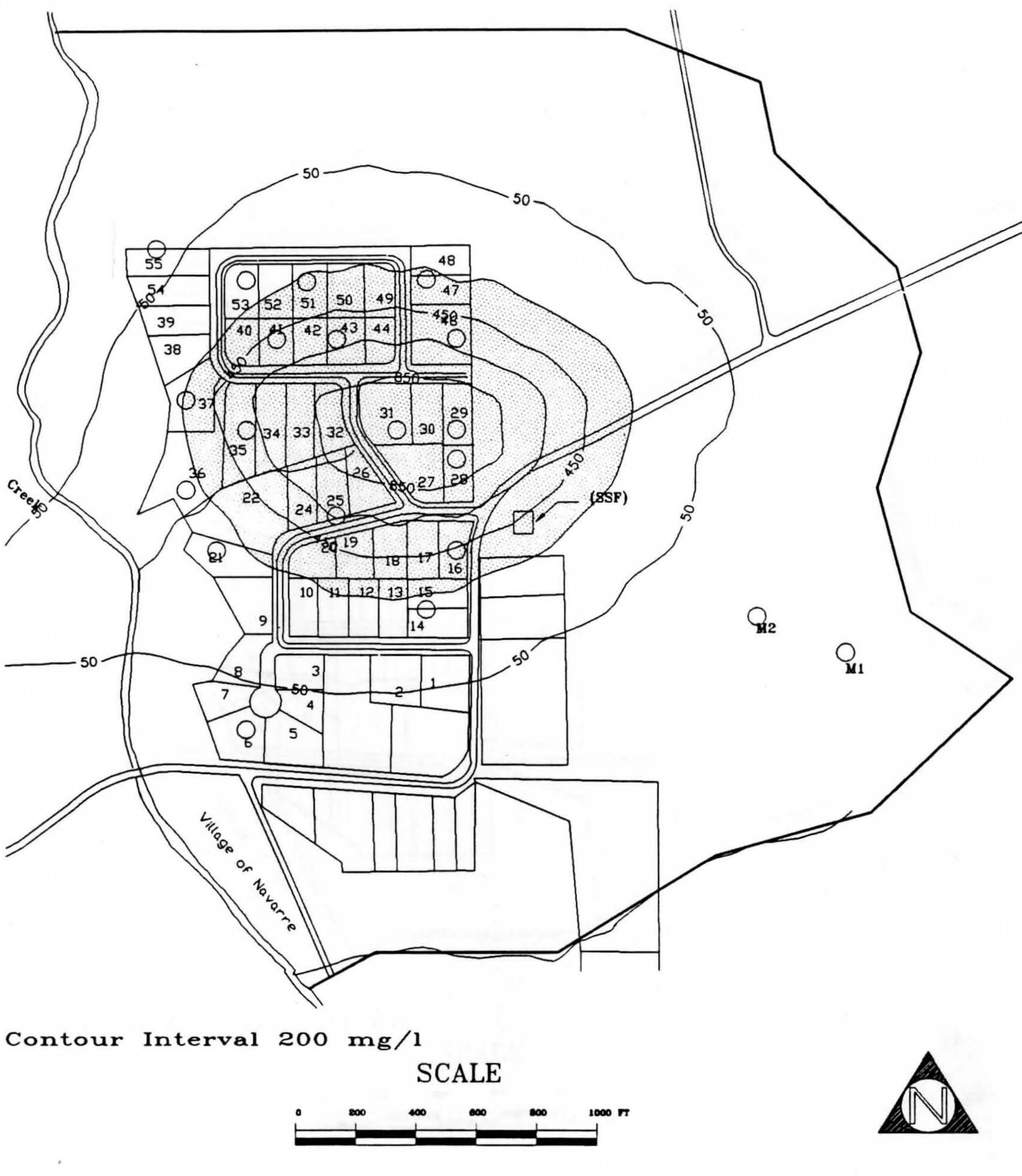
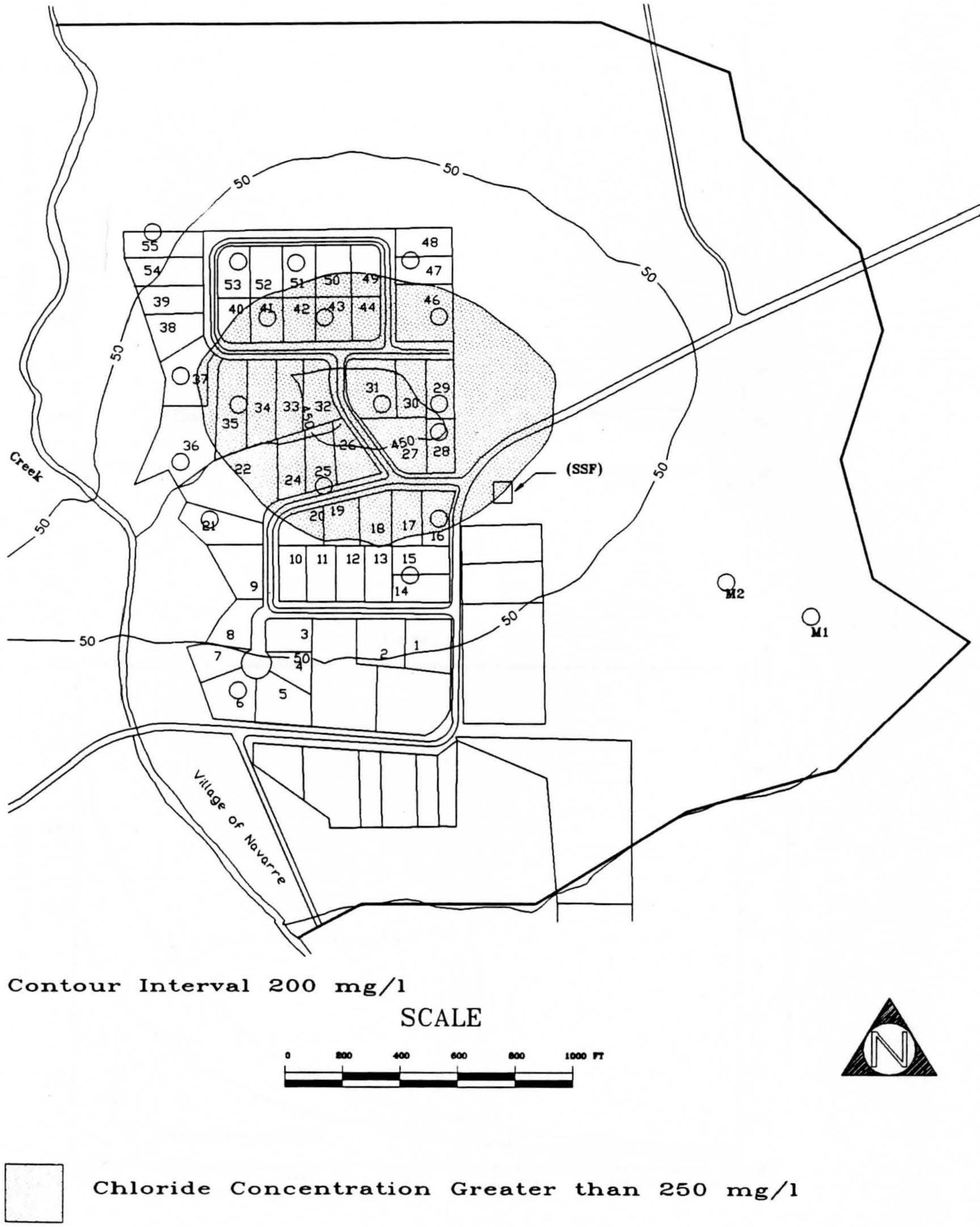
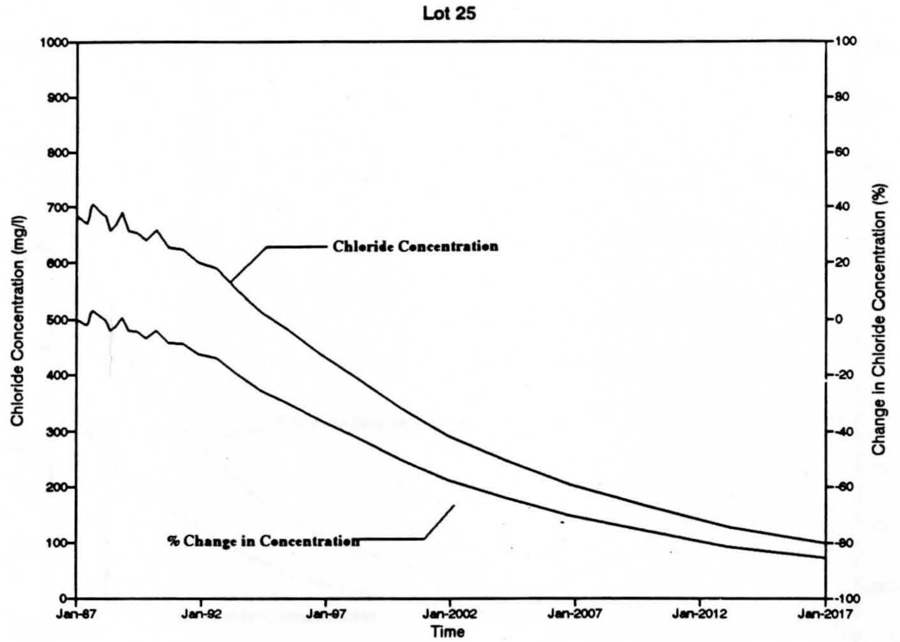


Figure 5-17 : Predicted Chloride Concentration Distribution for 8/1992 (SUTRA model)



<u>Figure 5-18</u> : Predicted Chloride Concentration Distribution for 1/2000 (SUTRA model)



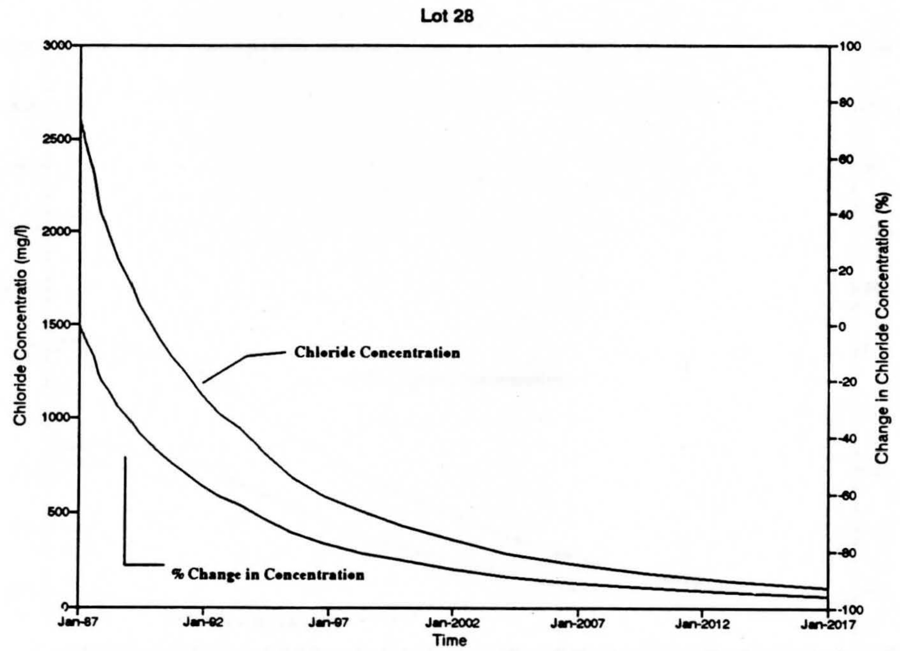
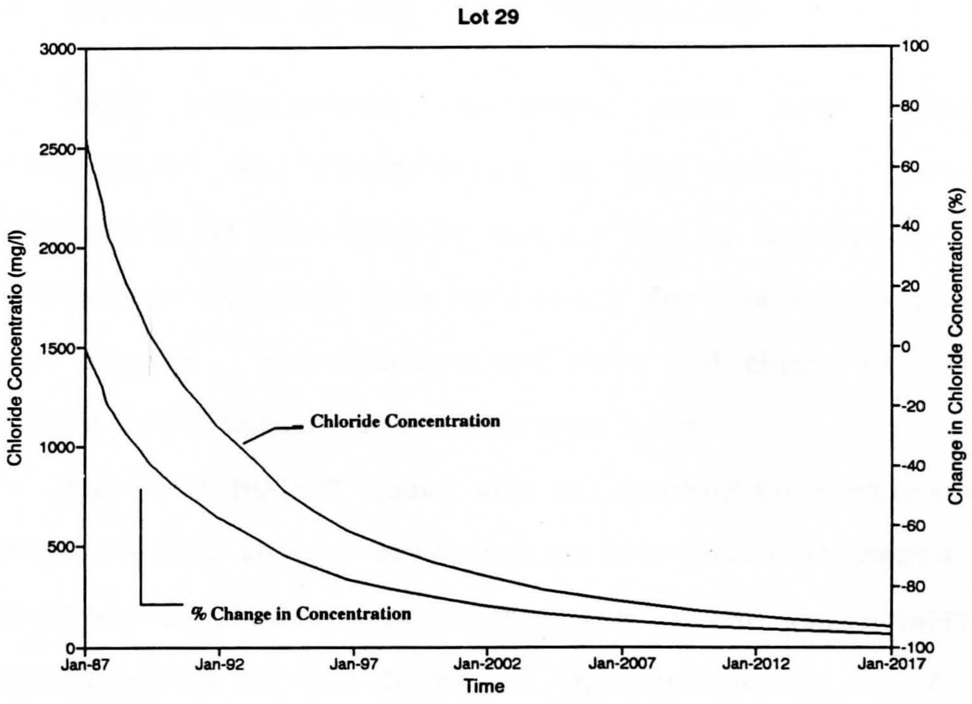
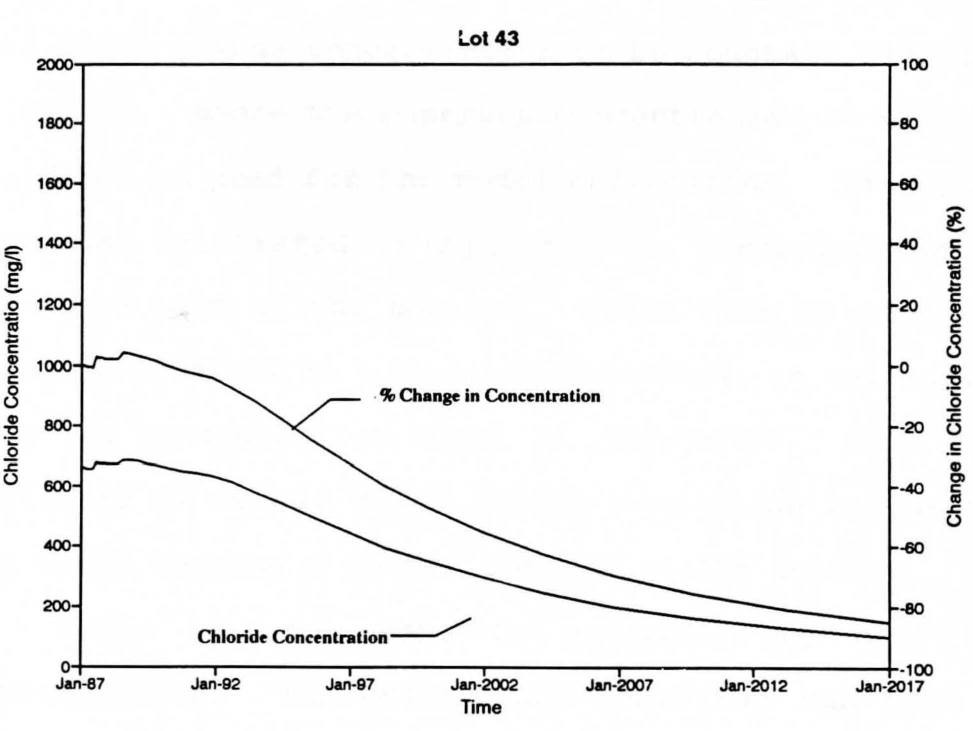


Figure 5-19 : Predicted Chloride Concentration for Lot 25 and Lot 28 for period of 1/1987 to 1/2017 (USGS-MOCADI model)





<u>Figure 5-20</u> : Predicted Chloride Concentration for Lot 29 and Lot 43 for period of 1/1987 to 1/2017 (USGS-MOCADI model)

5.6 Discussions on the Model Application

Many adjustments in input data were made during construction and calibration of the models. Some of the adjustments in data were necessary due to absence of available information and some were necessary for the application of the model itself. The assumptions made and their effects on the model's application are discussed here.

The USGS-MOCADI model was calibrated to duplicate the few concentration levels observed in the wells at certain dates. The observed chloride concentration in the wells reflects the concentration at the depth of the aquifer at which the well taps the water. In the study, two dimensional models were used which assume concentration to be constant throughout the thickness. Hence the observed concentration in all the wells could not be used for the model calibration. The USGS-MOCADI model was calibrated to duplicate the concentration level in the upper part of the aquifer. There will be some extent of chloride movement in a vertical direction, as indicated by the chloride concentration level in deep wells. This factor is neglected in models so no future prediction can be made for the wells tapping a deeper portion of the aquifer.

There was no means to estimate the start of the contamination. The USGS-MOCADI model was run from assumed initial conditions and assumed a source concentration of 1000 mg/l. The model was run till the ratio of predicted to observed concentration in the four wells, for 9/22/1986, was the same. The ratio was found to be 0.0606 and the time was

19.761 years. This implies that the input concentration source was 16500 mg/l and the start date of chloride contamination of groundwater was 23/12/1966. The input level of infiltrating water calculated above seems to be high. As the event happened in the past, there is no way to trace the concentration level of the infiltrating water during 1966. The chloride concentration predicted by the model and the observed concentration do agree for the four wells but it may not hold true for the entire area.

During the calibration process, the initial value of transmissivity had to be changed considerably except near the creek (see Figure 4-5 and Figure 5-4). More changes in transmissivity value were made near the ridge of the study area. The probable reasons for such changes in Transmissivity are:

1) The transmissivity value determined from the specific capacity of wells reveals the transmissivity of the aquifer portion through which it draws water. But in the model, the transmissivity value was assumed for the entire depth of the aquifer, which is always less than the value determined from the specific capacity of the wells.
2) Some of the wells tap water from the sandstone layers which are under some degree of confined condition, so the transmissivity value indicated by the specific capacity of the wells will be higher

than for the assumed unconfined condition.

3) In application of methods for determining transmissivity from the specific capacity of the wells, wells losses and partial penetration factors were neglected. This assumption also leads to erroneous transmissivity values.

In the model, the wells were assumed to exist since the start of simulation. But the wells were constructed at different periods. This assumption will create more stress in aquifer. The discharge of the wells was computed on the basis of 24 hours operation, but the wells are generally operated a few hours a day to meet the daily demand of water, hence the pumping rate will be higher than the pumping rate assumed in the model. The actual drawdown will be higher and will be localized due to a higher rate of pumping. This localized drawdown could not be reproduced in the model.

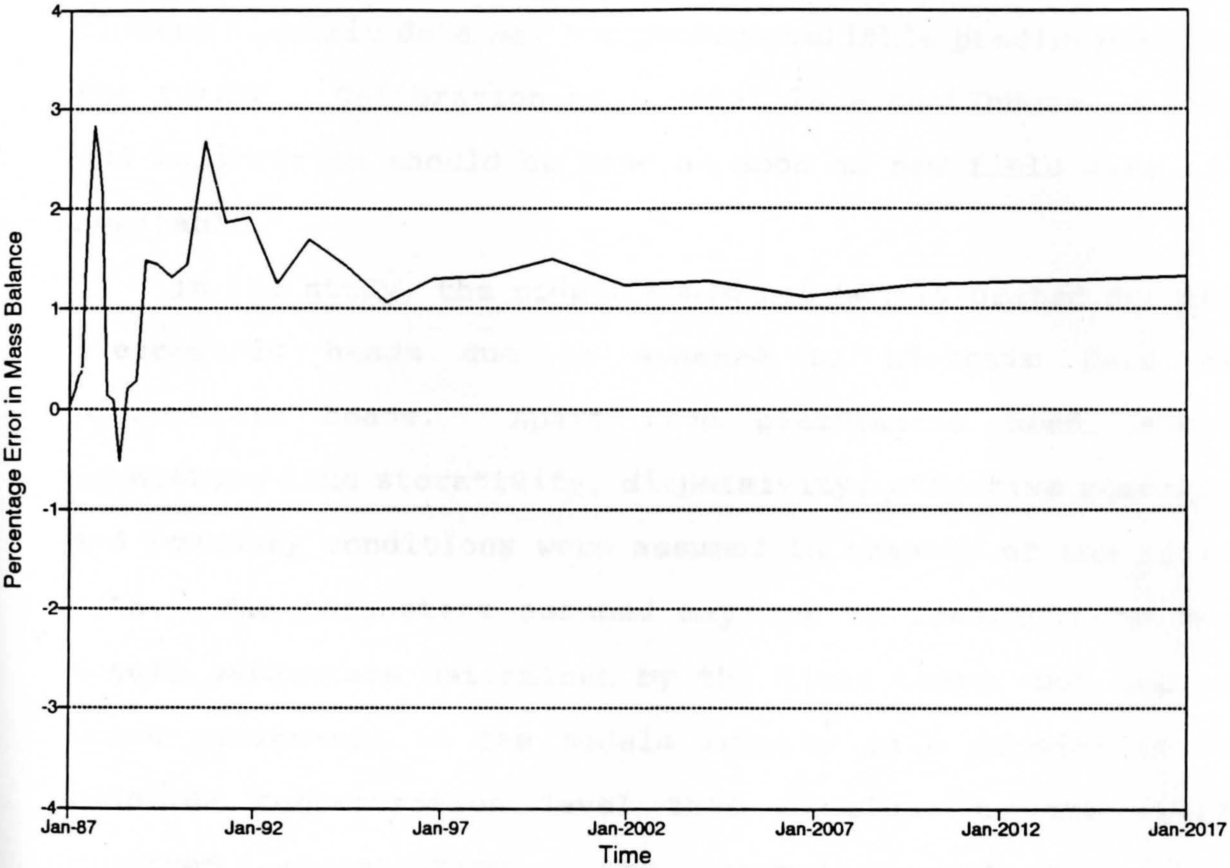
Some assumptions regarding the location of the wells had to be made to accommodate the wells in finite-difference grid of USGS-MOCADI. As the wells were estimated by equivalent wells the amount of withdraw is spread over larger area which in turn reduces the predicted drawdown.

In the model, recharge due to precipitation was assumed to be constant throughout the year. Most of the precipitation occurs in few months of a year, hence during a higher precipitation period, the movement of chloride will be higher and during winter months when the precipitation and infiltration opportunity is less, the movement will be very slow. The variable rate of movement of chloride contamination is not predicted by the models.

The chloride source was assumed to be removed since 1/1987 and during simulation it was assumed that no more chloride has been added to the groundwater since 1/1987. There may be a considerable amount of chloride present in the unsaturated zone of the aquifer. The infiltrating water through the unsaturated zone will contain varying amount of chloride depending upon the infiltration rate and the time. Hence some chloride is continuously added to the groundwater even though the surface source of chloride is no longer present. This fact is not incorporated in the models.

The chloride was assumed to be conservative and non-adsorbate solute. The chloride may undergo some extent of adsorption to the solid matrix of the aquifer. The loss of chloride due to adsorption to the solid matrix is not considered in the models.

The models use numerical techniques to solve the governing equations, hence some numerical errors are always included in the predictions. The models incorporate a mass balance check routine to estimate the induced errors in calculations. The mass balance error in the USGS-MOCADI model was found to be less than 4%. The mass balance error during the simulation from 1/1987 to 1/2117 is presented in Figure 5-21.



<u>Figure 5-21</u> : Percantage Errors in Chloride Mass Balance for USGS-MOCADI Model

One of the main advantages of a model application is to delineate the amount of information that should be available for successful application of the model. The data requirements of the model are different for different field conditions. Extreme variation of parameters and variations in observed field data requires a different amount of historic data for calibration of a model. A model calibrated using limited historic data may not produce reliable predictions for the future. Calibration of a model is a continuous process and calibration should be done as soon as new field data are available.

In the study, the models could not be calibrated for the piezometric heads due to absence of historic data of piezometric heads. Apart from piezometric head, other parameters like storativity, dispersivity, effective porosity and boundary conditions were assumed in absence of the field data. The parameters assumed may not be identical to the actual parameters determined by the field tests, but use of these parameters in the models results in a prediction of chloride concentration level that is close to the field observed concentration. The assumed parameters can be referred to as surrogate parameters.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Digital modelling of solute transport in groundwater was applied to the chloride contamination problem of Shadow Lawn Subdivision, Bethelem Township, Stark County, Ohio. Two types of digital solute transport models were used to simulate the contamination problem. The USGS-MOCADI, a finite-difference model, was calibrated and used to predict the future concentration. The SUTRA, a finite-element model, was used to predict the future concentration by using the USGS-MOCADI calibrated parameters.

The source of the chloride contamination in the study area was identified as the chloride laden surface runoff from the salt storage facility (SSF). The source of contamination was abandoned during 3/1987 but the chloride concentration is still high in the aquifer. The concentration will decrease naturally in future due to movement of chloride by advection and dispersion. The decrease of chloride will also occur due to dilution by aquifer recharge and pumping. One of the objectives of the present study was to delineate the time period by which the chloride will be flushed away naturally to the level of 250 mg/l, which is the maximum limit of chloride for drinking water. The USGS-MOCADI model was calibrated to duplicate the few available field observation data during 1986 to 1988. The calibrated USGS-MOCADI model and SUTRA model were then used to predict the chloride concentrations at various time in the future.

The conclusions of the application of the digital solute transport simulation of the study can be summarized as follows:

1) The study area is underlaid by glacial deposit of gravel and sand of thickness ranging from 20 ft to 90 ft with greater thickness along the creek. Underlying the gravel and sand deposit are alternating layers of shale and sandstone. Some portions of the sandstone layers act as confined aquifers. Most of the residential wells tap water from the shale and sandstone layers. The upper layer, 40 to 70 feet deep section of aquifer, is heavily contaminated by the chloride.

2) The underlying aquifer was assumed to be an unconfined aquifer. Bottom of the aquifer at each well was assumed to be the bottom of each well. Initial piezometric heads were computed by using the static water level reported for each well.

3) The creek was considered as constant head boundary and the ridge was considered as no-flow boundary. The northern and southern boundaries were artificially assumed as no-flow boundaries. Transmissivity values were determined from the specific capacity of the wells.

4) The start of contamination and concentration of

infiltrating water is not known. Historic piezometric data were not available so models could not be calibrated for piezometric heads.

5) The USGS-MOCADI model was constructed with grid size of 200 x 200 ft. The model was calibrated by the trial and error method to duplicate the field observed concentration. Arbitrary values of concentrations and arbitrary locations of infiltration to the groundwater were chosen and model parameters were adjusted.

6) Considerable change in transmissivity had to be made, especially near the ridge of the study area. The longitudinal and transverse dispersivities, determined by a trial and error procedure during the calibration process, were found to be 250 ft and 100 ft respectively.

7) The USGS-MOCADI model predicted concentrations were close to the field observed concentrations for lot 25, 28 and 43.

8) Future predictions of chloride concentration were made from 1/1987 to 1/2017 without chloride added to the groundwater. Results from USGS-MOCADI and SUTRA model were found to be identical.

9) The chloride concentration is predicted to be less than 250 mg/l everywhere in the study area by 10/2006.

The calibrated models can be used in the future for various aquifer management programs in the study area, especially for groundwater contamination protection programs. Models can be used in the testing of various other possible contamination sources and its future impact on the aquifer. The models can also be calibrated for piezometric head distribution in the future when sufficient historic data on piezometric heads become available.

REFERENCES

Bear, J., 1979, Hydraulics of Groundwater, McGraw-Hill International Book Company.

Bear, J. and Verruijt, A., 1987, Modeling Groundwater Flow and Pollution, D. Reidel Publishing Company.

Boulton, N.S., 1963, Analysis of Data from Nonequillibrium Pumping Tests Allowing for Delayed Yield from Storage, Proceedings of Institute of Civil Engineers, Vol. 26, No. 6693.

Bradbury, K.R. and Rothschild, E.R., 1985, A Computerized Technique for Estimating the Hydraulic Conductivity of Aquifers from Specific Capacity Data, Groundwater, Vol. 23, No. 2.

Csallany, S. and Walton, W.C., 1963, Yields of Shallow Dolomite Wells in Northern Illinois, Illinois State Water Survey Report of Investigation No. 46.

Delong, R.L. and White, G.W., 1963, Geology of Stark County, Ohio Geological Survey, Bulletin No. 61.

De Wiest, R.J.M., 1966, The Storage Coefficient and the Equations of Groundwater Flow, Journal of Geophysics Research, Vol. 71, No. 4.

Freeze, R. A. and Cherry, J. A., 1979, Groundwater, Prentice-Hall Inc, Englewood Cliffs, N.J.

Fried, J.J., 1975, Groundwater Pollution, Elsevier, Amsterdam.

Groenewold, G.H., 1974, Hydrogeologic and Other Considerations Related to the Selection of Sanitary landfill Sites in Ohio, Department of Natural Resources, Division of Geological Survey, Ohio.

Gupta, A.D and Joshi, S.G., 1984, Algorithm for Theis Solution, Groundwater, Vol. 22, No. 2.

Hantush, M. S., 1964, Advances in Hydroscience, Academic Press Inc, New York.

Jacob, C.E., 1950, Engineering Hydraulics, John Wiley & Sons Inc, New york.

Jacob, C.E. and Cooper, H.S., 1946, A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well-field History, Trans American Geophysics Union, Vol. 27, No 4.

Khan, I.A., 1982, Determination of Aquifer Parameters Using Regression Analysis, Groundwater, Vol.18, No. 2.

Khan, I.A., 1983, Inverse problem in Groundwater, National Science Foundation,

Konikow, L.F. and Bredehoeft, J.D., 1978, Computer Model of Two Dimensional Solute Transport and Dispersion in Groundwater, US Geological Survey, Chapter C2, Book 7.

Konikow, L.F. and Bredehoeft, J.D., 1974, Modeling Flow and Chemical Quality Changes in an Irrigated Stream-Aquifer System, Water Resources Research, Vol. 10, No. 3.

Konikow, L.F., 1977, Modeling Chloride Movement in the Alluvial Aquifer at the Rocky Mountain Arsenal, Colorado, US Geological Survey Water Supply Paper 2044.

Labadie, J.W., 1975, A surrogate Parameter Approach to Modeling Groundwater Basins, Water Resources Bulletin, Vol. 11, No. 1.

Lohman, S.W., 1972, Groundwater Hydraulics, US Geological Survey, Professional Paper 708.

Miller, C.T. and Weber, W.J., 1985, Tutorial-Modeling Contaminant Fate and Transport in Groundwater Systems, Computer Applications in Water Resources, ASCE.

Mosure & Syrakis Co., 1988, Shadow Lawn Subdivision-Groundwater Contamination Interim Report, Mosure & Syrakis Co., Youngstown, Ohio.

Mosure & Syrakis Co., 1990, Shadow Lawn Subdivision-Groundwater Contamination Phase III Report, Mosure & Syrakis Co., Youngstown, Ohio.

Mukhopadhyay, A., 1985, Automated Derivation of Parameters in a Nonleaky Confined Aquifer with Transient Flow, Groundwater, Vol. 23, No. 6.

Neuman, W.R., 1973, Calibration of Distributed Parameter Groundwater Flows Models Viewed as a Multiple-Objective decision Process Under Uncertainty, Water Resources Research, Vol. 9, No. 4.

Nicholos, W.D., 1979, Simulation Analysis of the Unconfined Aquifer, Raft River Geothermal Area, Idaho-Utah, US Geological Survey Water Supply Paper 2060.

Papadopulos, I.S., 1965, Nonsteady Flow to a Well in an Infinite Anisotropic Aquifer, Symp. Intern. Assoc. Sci. Hydrology, Dubrovinik.

Pettyjohn, W.A. and Henning, R., 1979, Preliminary estimate of Regional Effective Groundwater Recharge Rates in Ohio, Water Resources Center, Ohio State University.

Pinder, G. F. and Bredehoeft, J.D., 1968, Application of the Digital Computer for Aquifer Evaluation, Water Resources Research, Vol. 4, No. 5.

Pinder, G.F., 1969, An Iterative Digital Model for Aquifer Evaluation, US Geological Survey Open File Report.

Prickett, T. A., 1965, Type-curve Solution to Aquifer Tests Under Water-table Conditions, Groundwater, Vol. 3, No. 3

Reddell, D.L. and Sunada, D.K., 1970, Numerical Simulation of Dispersion in Groundwater Aquifers, Colorado State University Hydrology Paper 41.

Saleem, Z.A., 1970, A Computer Method for Pumping Test Analysis, Groundwater, Vol. 8, No. 5.

Scheidegger, A.E., 1961, General Theory of Dispersion in Porous Media, Journal of Geophysics Research, Vol. 66, No. 10.

Sedam, A.C., 1973, Hydrogeology of the Pottsville Formation in Northeastern Ohio, US Geological Survey, Hydrologic Investigation Atlas HA-494.

Sen, Z., 1986, Determination of Aquifer Parameters by Slope-Matching Method, Groundwater, Vol. 24, No. 2.

Stone, H. K., 1968, Iterative Solution of Implicit Approximations of Multidimensional Partial Differential Equations, Journal of Numerical Analysis, Vol. 5, No 3.

Strack, O.D.L., 1987, Groundwater Mechanics, Prentice-Hall, Englewood Cliffs, N.J.

Strecker, E.W. and Chu, W., 1986, Parameter Identification of a Groundwater Contaminant Transport Model, Groundwater, Vol. 24, No. 1.

Theis et al, 1962, Estimating the Transmissivity of Aquifer from the Specific Capacity of Wells, US Geological Survey Water Supply Paper 1536-I.

Theis, C.V., 1935, The Relation Between the Lowering of Piezometric Surface and the Rate and Duration of Discharge of a Well using Groundwater, Trans American Geophysics Union, 16th Annual Meeting.

Trescott, P.C. et al, 1976, Finite-Difference Model for Aquifer Simulation in Two Dimensions with Results of Numerical Experiments, US Geological Survey, Chapter C1, Book 7.

Trescott, P.C., 1973, Iterative Digital Model for Aquifer Evaluation, US Geological Survey Open File Report.

Viessman, W. and Hammer, M.J., 1985, Water Supply and Pollution Control, Harper $ Row Publishers, New york.

Voss, C.I., 1984, Saturated-Unsaturated Transport, US Geological Survey, National Center, Reston, Virginia.

Walker, A.C., 1979, Groundwater Resources of Stark County, Ohio Department of Natural Resources.

Walton, W.C., 1962, Selected Analytical Methods of Well and Aquifer Evaluation, Illinois State Water Survey Bulletin, No. 49.

Walton, W.C., 1970, Groundwater Resource Evaluation, McGraw-Hill International Book Company.

Wang, H.F. and Anderson, M.P., 1982, Introduction to Groundwater Modeling - Finite Difference and Finite Element Methods, W. H. Freemen and Company, San Francisco.

Warner, J.W., 1979, Digital Transport Model Study of DIMP Groundwater Contamination at Rocky Mountain Arsenal, Colorado, US Department of the Army.

Williams, S., 1991, Groundwater Pollution Potential of Stark County, Ohio, Groundwater Water Pollution Potential report no. 6, Ohio Department of Natural Resources.

Zuber, A., 1974, Theoretical Possibilities of the Two-Well Pulse Method, International Atomic Energy Agency, Report SM-182/45.

APPENDIX A

Computer program for computing Transmissivity from Specific capacity of a well.

```
' Computation of Transmissivity from specific capacity of wells
' Programmed by Prashant Malla, summer 1992
' This program uses the concept put forward by Theis et al.,1962
' Some modification suggested by Bradbury and Rothschild in 1985, ground water,
' vol 23, No 2, march-april 1985 is also included.

' Dimensions
D = 25
        DIM Q(D), Q$(D), S(D), S$(D), T(D), T$(D), L(D), L$(D), B(D), B$(D)
        DIM ST(D), ST$(D), well$(D), WELLN$(D), C$(D), C(D), TRAN(D), Y(D), DY(D)
        DIM alpha(D), beta(D), gamma(D), sp(D), sw(D), g(D), LB(D), D(D), D$(D)

'Default File Names
        dfile$ = "TRANS.DAT"
        file$ = dfile$

MAIN:
        COLOR 15, 1
        CLS
        LOCATE 2, 25: PRINT "Transmissivity Calculation by using"
        LOCATE   3, 29: PRINT "Specific Capacity of wells"
        LOCATE 6, 26: COLOR 12, 1: PRINT "*** M A I N   M E N U ***"
        COLOR 13, 1: LOCATE 8, 20: PRINT CHR$(201); STRING$(35, 205); STRING$(1, 187)
        LOCATE 16, 20: PRINT CHR$(200); STRING$(35, 205); STRING$(1, 188)
        FOR I = 9 TO 15: LOCATE I, 20: PRINT CHR$(186)
        LOCATE I, 56: PRINT CHR$(186)
        NEXT I

MENU:
        COLOR 15, 1
        LOCATE 9, 23: PRINT "   1 - Create New Data File"
        LOCATE 11, 23: PRINT "   2 - Edit Existing Data File"
        LOCATE 13, 23: PRINT "   3 - Perform Calculation"
        LOCATE 15, 23: PRINT "   4 - Quit to DOS "

ENTRY:
        COLOR 14, 1
        LOCATE 20, 23: INPUT "Enter Your Selection :", S$
        IF S$ = "" THEN GOTO ENTRY
        IF ASC(S$) > 52 OR ASC(S$) < 49 THEN GOTO ENTRY
        ON VAL(S$) GOTO CREATE, OLDFILE, COMPUTE, QUIT

CREATE:
        COLOR 15, 1
        CLS

ENTERN:
        LOCATE 1, 25: PRINT "Transmissivity Calculation by using"
        LOCATE 2, 30: PRINT "Specific Capacity of wells"
        PRINT
        PRINT
        PRINT "   ----------------------------------------------------------------------"
        PRINT "   No  Well    Q      D      s      t      L      b      C      S  "
        PRINT "       ID    (gpm)  (in)   (ft)   (Hrs)   (ft)   (ft)              "
        PRINT "   ----------------------------------------------------------------------"
        LOCATE 18, 1: PRINT " ----------------------------------------------------------------------------"
        COLOR 11, 1
        PRINT "   Q - Discharge in gpm     D - Well Diameter (in)    s - Drawdown (ft)"
        PRINT "   t - Time of pumping (Hrs)        L - Length of Open interval (ft)"
        PRINT "   b - Thickness of Aquifer ft      S - Assumed storativity"
```

```
        PRINT "    C - Well Loss coefficient (sec^2/ft^5)  If not available put C=0"

        COLOR 15, 1
        LOCATE   4, 55: INPUT "File Name :", filen$
        IF filen$ = "" THEN file$ = dfile$ ELSE file$ = filen$
        LOCATE 4, 66: PRINT file$

        LOCATE 4, 5: INPUT "No of Wells to Analyse :", N
        IF N < 1 THEN GOTO ENTERN

        r = 9
        FOR I = 1 TO N
        IF r > 17 THEN GOSUB clea
        LOCATE r, 4: PRINT I
        LOCATE r, 9: INPUT "", well$(I)
        LOCATE r, 17: INPUT "", Q(I): LOCATE r, 17: PRINT USING "###.#"; Q(I)
        LOCATE r, 25: INPUT "", D(I): LOCATE r, 25: PRINT USING "###.#"; D(I)
        LOCATE r, 33: INPUT "", S(I): LOCATE r, 33: PRINT USING "###.#"; S(I)
        LOCATE r, 42: INPUT "", T(I): LOCATE r, 42: PRINT USING "###.#"; T(I)
        LOCATE r, 51: INPUT "", L(I): LOCATE r, 51: PRINT USING "####.#"; L(I)
        LOCATE r, 59: INPUT "", B(I): LOCATE r, 59: PRINT USING "####.#"; B(I)
        LOCATE r, 67: INPUT "", C(I): LOCATE r, 67: PRINT USING "###.#"; C(I)
        LOCATE r, 73: INPUT "", STO$(I): IF STO$(I) = "" THEN ST(I) = ST(1) ELSE ST(I) = VAL(STO$(I))
        LOCATE r, 73: PRINT USING "#.##^^^^"; ST(I)
        r = r + 1
        NEXT I
        GOTO CHECK

EDIT:
        GOSUB CLEA
        LOCATE 4, 5: INPUT "No of Wells to Analyse :", NN$
        IF NN$ = "" THEN N = N ELSE N = VAL(NN$)
        PG = INT(N / 9)
        PN = 1
        IF N < 9 THEN PN(1) = N: GOTO 10
        FOR I = 1 TO PG
        PN(I) = I * 9
        NEXT I
        PN(PG + 1) = PN(PG) + (N - (PG * 9))
10 :
        FOR j = 1 TO PG + 1
        GOSUB clea
        FOR I = PN TO PN(j)

        LOCATE r, 4: PRINT I
        LOCATE r, 9: PRINT well$(I)
        LOCATE r, 17: PRINT USING "###.#"; Q(I)
        LOCATE r, 25: PRINT USING "###.#"; D(I)
        LOCATE r, 33: PRINT USING "###.#"; S(I)
        LOCATE r, 42: PRINT USING "###.#"; T(I)
        LOCATE r, 51: PRINT USING "####.#"; L(I)
        LOCATE r, 59: PRINT USING "####.#"; B(I)
        LOCATE r, 67: PRINT USING "###.#"; C(I)
        LOCATE r, 73: PRINT USING "#.##^^^^"; ST(I)
        r = r + 1
        NEXT I
        r = 9
        FOR I = PN TO PN(j)

        LOCATE r, 9: INPUT "", WELLN$(I)
        IF WELLN$(I) = "" THEN well$(I) = well$(I) ELSE well$(I) = WELLN$(I)
        LOCATE r, 9: PRINT well$(I)

        LOCATE r, 18: INPUT "", Q$(I)
        IF Q$(I) = "" THEN Q(I) = Q(I) ELSE Q(I) = VAL(Q$(I))
        LOCATE r, 17: PRINT USING "###.#"; Q(I)

        LOCATE r, 26: INPUT "", D$(I)
        IF D$(I) = "" THEN D(I) = D(I) ELSE D(I) = VAL(D$(I))
        LOCATE r, 25: PRINT USING "###.#"; D(I)

        LOCATE r, 34: INPUT "", S$(I)
```

```
        IF S$(I) = "" THEN S(I) = S(I) ELSE S(I) = VAL(S$(I))
        LOCATE r, 33: PRINT USING "###.#"; S(I)

        LOCATE r, 43: INPUT "", T$(I)
        IF T$(I) = "" THEN T(I) = T(I) ELSE T(I) = VAL(T$(I))
        LOCATE r, 42: PRINT USING "###.#"; T(I)

        LOCATE r, 52: INPUT "", L$(I)
        IF L$(I) = "" THEN L(I) = L(I) ELSE L(I) = VAL(L$(I))
        LOCATE r, 51: PRINT USING "####.#"; L(I)

        LOCATE r, 60: INPUT "", B$(I)
        IF B$(I) = "" THEN B(I) = B(I) ELSE B(I) = VAL(B$(I))
        LOCATE r, 59: PRINT USING "####.#"; B(I)

        LOCATE r, 68: INPUT "", C$(I)
        IF C$(I) = "" THEN C(I) = C(I) ELSE C(I) = VAL(C$(I))
        LOCATE r, 67: PRINT USING "###.#"; C(I)

        LOCATE r, 73: INPUT "", ST$(I)
        IF ST$(I) = "" THEN ST(I) = ST(I) ELSE ST(I) = VAL(ST$(I))
        LOCATE r, 73: PRINT USING "#.##^^^^"; ST(I)

        r = r + 1
        NEXT I

        r = 9
        PN = PN(j) + 1
        NEXT j
        GOTO CHECK

CONTINUE:
        OPEN file$ FOR OUTPUT AS #1
        LOCATE 23, 64: COLOR 17, 5: PRINT "Saving Data..."
        WRITE #1, N
        FOR I = 1 TO N
        WRITE #1, Q(I), D(I), S(I), T(I), L(I), B(I), C(I), ST(I)
        NEXT I
        CLOSE #1
        GOTO MAIN

COMPUTE:
        COLOR 15, 1
        CLS
        OPEN file$ FOR INPUT AS #1
        INPUT #1, N
        FOR I = 1 TO N
        INPUT #1, Q(I), D(I), S(I), T(I), L(I), B(I), C(I), ST(I)
        NEXT I
        CLOSE #1


' Unit Conversion

        FOR I = 1 TO N
        RA(I) = D(I) / 24
        T(I) = T(I) * 3600
        Q(I) = Q(I) / 449
        NEXT I

'computing G(L/B) function for partial penetration

        FOR I = 1 TO N
        LB(I) = L(I) / B(I)
        g(I) = 2.948 - 7.363 * LB(I) + 11.447 * LB(I) ^ 2 - 4.675 * LB(I) ^ 3
        sp(I) = (1 - LB(I)) / LB(I) * (LOG(B(I) / RA(I)) - g(I))
        NEXT I

'Computing well loss and net drawdown

        FOR I = 1 TO N
        sw(I) = C(I) * Q(I) ^ 2
```

```
        S(I) = S(I) - sw(I)
        NEXT I

'Computing constants

        FOR I = 1 TO N
        alpha(I) = Q(I) / (4 * 3.1416 * S(I))
        beta(I) = Q(I) / (4 * 3.1416 * S(I)) * LOG(2.25 * T(I) / (RA(I) ^ 2 * ST(I)))
        gamma(I) = alpha(I) * 2 * sp(I)
        NEXT I

        FOR I = 1 TO N
        cycle = 1
        TRAN(I) = 1.547336E-06 * 600000
        Y(I) = beta(I) + (alpha(I) * LOG(TRAN(I))) + gamma(I) - TRAN(I)

        IF Y(I) > 0 THEN GOSUB TEST1
        IF Y(I) < 0 THEN GOSUB TEST2


        DO WHILE ABS(Y(I)) > .000001
        LOCATE 10, 10: PRINT "Processing Well " + STR$(I)
        LOCATE 12, 10: PRINT "No of Iterations = " + STR$(cycle)
        LOCATE 14, 10: PRINT "Transmisivity = " + STR$(TRAN(I) * 7.48 * 3600 * 24) + "(gpd/ft)"
        Y(I) = beta(I) + (alpha(I) * LOG(TRAN(I))) + gamma(I) - TRAN(I)
        DY(I) = (alpha(I) / TRAN(I)) - 1
        TRAN(I) = TRAN(I) - (Y(I) / DY(I))
        cycle = cycle + 1
        LOOP
        NEXT I

        LOCATE 23, 10: INPUT "Press ENTER To Continue.....", a$
        CLS

        LOCATE 1, 25: PRINT "Transmissivity Calculation by using"
        LOCATE 2, 30: PRINT "Specific Capacity of wells"
        PRINT
        PRINT
        PRINT " ------------------------------------------------------------------------------"
        PRINT " No  Well      Q      D      s       t       L      b      C       S          T "
        PRINT "         ID     (gpm)  (in)   (ft)    (Hrs)    (ft)   (ft)                  (gpd/ft)"
        PRINT " ------------------------------------------------------------------------------"
        r = 9
        FOR I = 1 TO N
        LOCATE r, 2: PRINT I
        LOCATE r, 6: PRINT well$(I)
        LOCATE r, 13: PRINT USING "###.#"; Q(I) * 449
        LOCATE r, 20: PRINT USING "###.#"; D(I)
        LOCATE r, 27: PRINT USING "###.#"; S(I)
        LOCATE r, 35: PRINT USING "###.#"; T(I) / 3600
        LOCATE r, 41: PRINT USING "####.#"; L(I)
        LOCATE r, 49: PRINT USING "####.#"; B(I)
        LOCATE r, 56: PRINT USING "###.#"; C(I)
        LOCATE r, 63: PRINT USING "#.##^^^^"; ST(I)
        LOCATE r, 71: PRINT USING "########"; TRAN(I) * 7.48 * 3600 * 24

        r = r + 1
        IF r > 22 THEN CLS : r = 10
        NEXT I

PRCHECK:
        COLOR 12, 1: LOCATE 23, 25: INPUT "Do You Want to Print This (Y/N) :", PR$
        IF PR$ = "N" OR PR$ = "n" THEN GOTO MAIN
        IF PR$ = "Y" OR PR$ = "y" GOTO PRTN ELSE GOTO PRCHECK

PRTN:
        LPRINT TAB(25); "Transmissivity Calculation by using"
        LPRINT TAB(29); "Specific Capacity of wells"
        LPRINT "File Name :" + file$
        LPRINT
        LPRINT " ------------------------------------------------------------------------------"
        LPRINT " No  Well      Q      D      s       t       L      b      C       S          T "
```

```
        LPRINT "      ID    (gpm)  (in)   (ft)    (Hrs)   (ft)   (ft)                 (gpd/ft)"
        LPRINT " -----------------------------------------------------------------------------"
        FOR I = 1 TO N
        LPRINT TAB(2); I;
        LPRINT TAB(6); well$(I);
        LPRINT TAB(13); USING "###.#"; Q(I) * 449;
        LPRINT TAB(20); USING "###.#"; D(I);
        LPRINT TAB(27); USING "###.#"; S(I);
        LPRINT TAB(35); USING "###.#"; T(I) / 3600;
        LPRINT TAB(41); USING "####.#"; L(I);
        LPRINT TAB(49); USING "####.#"; B(I);
        LPRINT TAB(56); USING "###.#"; C(I);
        LPRINT TAB(63); USING "#.##^^^^"; ST(I);
        LPRINT TAB(71); USING "########"; TRAN(I) * 7.48 * 3600 * 24
        NEXT I
        GOTO main

OLDFILE:
        LOCATE 22, 20: PRINT "File to Edit" + " (Default=" + file$ + ")"
        LOCATE 22, 56: INPUT ":", fileo$
        IF fileo$ = "" THEN file$ = file$ ELSE file$ = fileo$
        OPEN file$ FOR INPUT AS #1
        INPUT #1, N
        FOR I = 1 TO N
        INPUT #1, Q(I), D(I), S(I), T(I), L(I), B(I), C(I), ST(I)
        NEXT I
        CLOSE #1
        GOTO EDIT

CHECK:
        COLOR 12, 1: LOCATE 23, 25: INPUT "Is the the Data correct (Y/N) :", YN$
        IF YN$ = "N" OR YN$ = "n" THEN PN = 1: GOTO EDIT
        IF YN$ = "Y" OR YN$ = "y" GOTO CONTINUE ELSE GOTO CHECK



QUIT:
        LOCATE 22, 23: INPUT "Are you sure (Y/N) :", Y$
        IF Y$ = "N" OR Y$ = "n" THEN GOTO MAIN
        SYSTEM

CLEA:
        COLOR 15, 1
        CLS
        r = 9
        LOCATE 1, 25: PRINT "Transmissivity Calculation by using"
        LOCATE 2, 30: PRINT "Specific Capacity of wells"

        PRINT
        PRINT "    No of Wells to Analyse : "; N

        LOCATE 4, 55: PRINT "File Name :"; file$
        PRINT "    ------------------------------------------------------------------"
        PRINT "    No   Well     Q      D      s      t      L      b      C     S   "
        PRINT "          ID    (gpm)   (in)    (ft)   (Hrs)   (ft)   (ft)             "
        PRINT "    ------------------------------------------------------------------"

        LOCATE 18, 1: PRINT " ---------------------------------------------------------------------"
        COLOR 11, 1
        PRINT "    Q - Discharge in gpm       D - Well Diameter (in)     s - Drawdown (ft)"
        PRINT "    t - Time of pumping (Hrs)          L - Length of Open interval (ft)"
        PRINT "    b - Thickness of Aqu  ifer ft        S - Assumed storativity"
        PRINT "    C - Well Loss coefficient (sec^2/ft^5)  If not available put C=0"
        COLOR 15, 1
        RETURN

TEST1:
        DO WHILE Y(I) > 0 AND TRAN(I) > 0
        TRAN(I) = TRAN(I) - (1000 * 1.547336E-06)
        IF TRAN(I) > 0 THEN Y(I) = beta(I) + (alpha(I) * LOG(TRAN(I))) + gamma(I) - TRAN(I)
        LOOP
        TRAN(I) = TRAN(I) + (1.54733E-03)
```

```
        RETURN

TEST2:
        DO WHILE Y(I) < 0 AND TRAN(I) > 0
        TRAN(I) = TRAN(I) - (1000 * 1.547336E-06)
        IF TRAN(I) > 0 THEN Y(I) = beta(I) + (alpha(I) * LOG(TRAN(I))) + gamma(I) - TRAN(I)
        LOOP
        TRAN(I) = TRAN(I) + (1.54733E-03)
        RETURN
```

APPENDIX - B

Input data file for USGS-MOCADI model.

```
SALT CONTAMINATION STUDY ** STARK COUNTY OHIO ,1992** TRANSIENT FLOW
 100   1  18  186400   1   6   5 175  31  16   3   0   0   0   0   0
30.00.0100  .30 250.0.200 1.1586400 200. 200.  .40  .50 1.00
 9 9
 7 7
 9 7
 710
 9 8
 9 9 .91E-03 .00
 7 7 .61E-03 .00
 4 6 .30E-03 .00
 4 5 .30E-03 .00
 710 .61E-03 .00
 9 8 .30E-03 .00
 514 .15E-03 .00
 513 .15E-03 .00
 614 .15E-03 .00
 614 .15E-03 .00
 511 .30E-03 .00
 510 .45E-03 .00
 410 .15E-03 .00
 4 9 .30E-03 .00
 5 9 .45E-03 .00
 6 9 .15E-03 .00
 4 8 .15E-03 .00
 5 8 .30E-03 .00
 6 8 .15E-03 .00
 5 6 .30E-03 .00
 6 6 .61E-03 .00
 7 6 .30E-03 .00
 8 6 .30E-03 .00
 9 6 .30E-03 .00
 6 7 .61E-03 .00
 9 7 .61E-03 .00
 910 .30E-03 .00
 911 .45E-03 .00
 811 .15E-03 .00
 812 .15E-03 .00
 912 .15E-03 .00
1  .0001
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 9.0 9.0 6.0 6.0 6.0 3.0 3.0 3.0 4.0 4.0 4.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 9.0 9.0 6.0 6.0 6.0 3.0 3.0 4.0 4.5 4.5 4.5 0.0 0.0 0.0 0.0 0.0
0.0 0.0 9.0 9.0 6.0 6.0 6.0 3.0 3.0 4.0 4.5 4.5 4.5 6.0 0.0 0.0 0.0 0.0
0.0 9.0 9.0 9.0 9.0 9.0 3.0 3.0 3.0 4.0 4.5 4.5 4.5 6.0 6.0 0.0 0.0 0.0
0.0 9.0 9.0 9.0 9.0 9.0 3.0 3.0 3.0 3.0 4.5 4.5 4.5 6.0 4.0 0.0 0.0 0.0
0.0 9.0 9.0 9.0 9.0 9.0 3.0 3.0 3.0 3.0 4.5 4.5 4.5 3.0 3.0 3.0 0.0 0.0
0.0 9.0 9.0 9.0 9.0 9.0 3.0 3.0 3.0 3.0 4.5 4.5 4.5 3.0 3.0 0.0 0.0 0.0
0.0 11.011.011.011.010.03.0 3.0 3.0 3.0 4.5 4.5 4.5 3.0 3.0 0.0 0.0 0.0
0.0 0.0 11.011.011.010.03.0 3.0 3.0 3.0 4.5 4.5 4.5 3.0 3.0 0.0 0.0 0.0
0.0 0.0 0.0 11.011.010.03.0 3.0 3.0 3.0 4.5 4.5 4.5 3.0 3.0 0.0 0.0 0.0
0.0 0.0 0.0 11.011.09.0 3.0 3.0 3.0 3.0 4.5 4.5 4.5 3.0 3.0 3.0 0.0 0.0
0.0 0.0 0.0 11.011.011.07.5 7.5 7.5 7.5 7.5 4.5 4.5 3.0 3.0 3.0 3.0 0.0
0.0 0.0 0.0 11.011.011.07.5 7.5 7.5 7.5 7.5 4.5 4.5 3.0 3.0 3.0 0.0 0.0
0.0 0.0 0.0 11.011.011.08.5 8.5 7.5 7.5 7.5 4.5 4.5 3.0 3.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 11.011.08.5 8.5 7.5 7.5 7.5 4.5 4.5 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 11.09.5 9.5 9.5 9.5 7.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
```

```
1  10.0
0.00.00.00 _ 00.00.00.00.00.00.00.00.00.00.00.00.00.00.0
0.00.08.48 _ 58.99.39.69.98.88.88.78.48.10.00.00.00.00.0
0.00.08.08 _ 38.99.49.710.9.08.88.78.48.10.00.00.00.00.0
0.00.07.67 _ 57.88.59.610.9.49.39.08.68.48.50.00.00.00.0
0.07.37.17 _ 28.59.810.9.88.88.38.48.18.18.17.50.00.00.0
0.07.26.86 _ 88.110.10.8.77.57.57.87.97.97.87.40.00.00.0
0.07.37.06 _ 97.37.56.26.94.86.06.87.27.47.47.37.20.00.0
0.07.57.26 _ 96.55.95.34.84.55.36.36.87.07.16.90.00.00.0
0.07.97.77 _ 36.55.44.54.44.15.46.06.56.76.96.60.00.00.0
0.00.08.27 _ 77.05.74.84.95.65.96.26.56.76.76.40.00.00.0
0.00.00.08 _ 57.86.75.75.55.86.26.36.36.46.95.90.00.00.0
0.00.00.09 _ 49.08.06.95.75.56.26.26.26.36.15.04.60.00.0
0.00.00.010.10.9.58.27.16.56.46.36.26.15.75.25.15.20.0
0.00.00.010.11.10.9.08.17.57.06.66.46.25.95.65.60.00.0
0.00.00.010.10.10.9.58.58.07.57.06.76.36.46.00.00.00.0
0.00.00.00 _010.10.9.58.98.37.77.36.96.50.00.00.00.00.0
0.00.00.00 _00.010.9.59.38.88.27.40.00.00.00.00.00.0
0.00.00.00 _00.00.00.00.00.00.00.00.00.00.00.00.00.0
1  .175E-07
0.0 0.0 0. 0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0. 0 0.0 -1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.10.0 0.0 0.0 0.0 0.0
0.0 0.0 0. 0 0.0 -1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.10.0 0.0 0.0 0.0 0.0
0.0 0.0 0. 0 0.0 -1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.10.0 0.0 0.0 0.0
0.0 0.0 0. 0 0.0 -1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.10.0 0.0 0.0
0.0 0.0 0. 0 0.0 -1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.10.0 0.0 0.0
0.0 0.0 0. 0 0.0 -1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.10.0 0.0
0.0 0.0 0. 0 0.0 -1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.10.0 0.0 0.0
0.0 0.0 0. 0 0.0 -1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.10.0 0.0 0.0
0.0 0.0 0. 0 0.0 -1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.10.0 0.0 0.0
0.0 0.0 0. 0 0.0 -1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.10.0 0.0 0.0
0.0 0.0 0. 0 0.0 -1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.10.0 0.0
0.0 0.0 0. 0 0.0 -1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.10.0
0.0 0.0 0. 0 0.0 0.0 -1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.1-1.10.0 0.0
0.0 0.0 0. 0 0.0 0.0 0.0 0.0 -1.1-1.1-1.1-1.1-1.1-1.1-1.10.0 0.0 0.0 0.0
0.0 0.0 0. 0 0.0 0.0 0.0 0.0 -1.1-1.1-1.1-1.10.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0. 0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0. 0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
1  1.00
0000000000 00000000
0010000000 00000000
0010000000 00000000
0010000000 00000000
0103300000 00000000
0103330000 00000000
0103330000 00000000
0103330022 00000000
0103330022 00000000
0010330000 00000000
0001000000 00000000
0001000000 00000000
0001000000 00000000
0001000000 00000000
0001000000 00000000
0000100000 00000000
0000011000 00000000
0000000000 00000000
 1  1.00        20.0       .000      0
 2  0.00        .000       .000      0
 3  1.00        20.0       .000      0
```

```
1  1.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 943.942.944.948.954.965.977.988.995.999.10020.0 0.0 0.0 0.0 0.0
0.0 0.0 942.940.941.945.952.963.977.987.994.999.10020.0 0.0 0.0 0.0 0.0
0.0 0.0 941.934.933.938.948.961.975.987.994.999.100310060.0 0.0 0.0 0.0
0.0 938.932.922.921.927.941.958.973.985.994.999.1004100710080.0 0.0 0.0
0.0 937.928.915.913.916.934.954.970.984.993.999.1004100710090.0 0.0 0.0
0.0 936.926.916.912.914.931.952.968.982.992.998.10031007101010130.0 0.0
0.0 935.926.916.912.918.932.951.967.981.991.997.1002100610080.0 0.0 0.0
0.0 934.928.917.914.921.934.952.966.980.989.995.1000100410070.0 0.0 0.0
0.0 0.0 933.925.920.926.937.952.966.978.987.993.998.100210050.0 0.0 0.0
0.0 0.0 0.0 932.929.931.940.953.964.975.984.990.995.100010040.0 0.0 0.0
0.0 0.0 0.0 931.932.935.942.952.962.972.979.986.992.998.100310050.0 0.0
0.0 0.0 0.0 930.933.936.943.951.959.967.974.982.989.995.1001100510080.0
0.0 0.0 0.0 929.932.936.941.949.957.964.971.978.985.992.998.10030.0 0.0
0.0 0.0 0.0 928.930.934.939.946.954.961.967.974.981.990.994.0.0 0.0 0.0
0.0 0.0 0.0 0.0 927.930.934.942.950.957.963.970.976.0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 927.927.939.948.954.958.0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
1  1.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 20.018.015.014.014.014.013.013.013.013.013.00.0 0.0 0.0 0.0 0.0
0.0 0.0 20.019.017.019.019.017.015.014.013.013.013.00.0 0.0 0.0 0.0 0.0
0.0 0.0 21.022.024.035.035.032.027.021.017.014.013.012.00.0 0.0 0.0 0.0
0.0 21.023.025.036.072.091.086.073.052.033.022.016.013.012.00.0 0.0 0.0
0.0 24.026.030.053.0162.244.254.245.179.105.50.026.016.012.00.0 0.0 0.0
0.0 29.039.062.0191.600.660.760.802.562.318.129.55.025.013.012.00.0 0.0
0.0 36.055.0102.488.853.1197174125032056799.270.91.032.015.00.0 0.0 0.0
0.0 40.063.0102.351.707.1156172626172059759.248.80.026.014.00.0 0.0 0.0
0.0 0.0 59.0128.250.424.686.852.893.545.247.99.039.017.012.00.0 0.0 0.0
0.0 0.0 0.0 80.0167.206.291.314.290.174.75.033.018.012.011.00.0 0.0 0.0
0.0 0.0 0.0 35.066.091.098.095.083.053.029.017.013.011.010.010.00.0 0.0
0.0 0.0 0.0 23.024.032.034.033.029.022.016.013.011.011.010.010.010.00.0
0.0 0.0 0.0 18.019.019.019.018.017.014.013.012.011.011.011.010.00.0 0.0
0.0 0.0 0.0 18.017.017.016.015.014.013.012.012.012.013.013.00.0 0.0 0.0
0.0 0.0 0.0 0.0 17.017.015.014.014.013.014.014.014.00.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 17.016.015.015.015.015.00.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
```

APPENDIX - C

Table C-1 : Input data file for SUTRA model (Initial Conditions - Unit D55)

0.0000E+00			
9.2700E+02	9.2700E+02	9.3900E+02	9.4800E+02
9.5400E+02	9.5800E+02	9.5800E+02	9.2700E+02
9.2700E+02	9.3900E+02	9.4800E+02	9.5400E+02
9.5800E+02	9.5800E+02	9.5800E+02	9.5800E+02
9.2700E+02	9.3000E+02	9.3400E+02	9.4200E+02
9.5000E+02	9.5700E+02	9.6300E+02	9.7000E+02
9.7600E+02	9.7600E+02	9.7600E+02	9.7600E+02
9.2800E+02	9.3000E+02	9.3400E+02	9.3900E+02
9.4600E+02	9.5400E+02	9.6100E+02	9.6700E+02
9.7400E+02	9.8100E+02	9.9000E+02	9.9400E+02
9.9400E+02	9.9400E+02	9.2900E+02	9.3200E+02
9.3600E+02	9.4100E+02	9.4900E+02	9.5700E+02
9.6400E+02	9.7100E+02	9.7800E+02	9.8500E+02
9.9200E+02	9.9800E+02	1.0030E+C3	1.0030E+03
1.0030E+03	9.3000E+02	9.3300E+02	9.3600E+02
9.4300E+02	9.5100E+02	9.5900E+02	9.6700E+02
9.7400E+02	9.8200E+02	9.8900E+02	9.9500E+02
1.0010E+03	1.0050E+03	1.0080E+03	1.0080E+03
1.0080E+03	9.3100E+02	9.3200E+02	9.3500E+02
9.4200E+02	9.5200E+02	9.6200E+02	9.7200E+02
9.7900E+02	9.8600E+02	9.9200E+02	9.9800E+02
1.0030E+03	1.0050E+03	1.0050E+03	1.0050E+03
1.0050E+03	9.3200E+02	9.2900E+02	9.3100E+02
9.4000E+02	9.5300E+02	9.6400E+02	9.7500E+02
9.8400E+02	9.9000E+02	9.9500E+02	1.0000E+03
1.0040E+03	1.0040E+03	1.0040E+03	1.0040E+03
1.0040E+03	9.3300E+02	9.2500E+02	9.2000E+02
9.2600E+02	9.3700E+02	9.5200E+02	9.6600E+02
9.7800E+02	9.8700E+02	9.9300E+02	9.9800E+02
1.0020E+03	1.0050E+03	1.0050E+03	1.0050E+03
9.3400E+02	9.2800E+02	9.1700E+02	9.1400E+02
9.2100E+02	9.3400E+02	9.5200E+02	9.6600E+02
9.8000E+02	9.8900E+02	9.9500E+02	1.0000E+03
1.0040E+03	1.0070E+03	1.0070E+03	1.0070E+03
9.3500E+02	9.2600E+02	9.1600E+02	9.1200E+02
9.1800E+02	9.3200E+02	9.5100E+02	9.6700E+02
9.8100E+02	9.9100E+02	9.9700E+02	1.0020E+03
1.0060E+03	1.0080E+03	1.0080E+03	1.0080E+03
9.3600E+02	9.2600E+02	9.1600E+02	9.1200E+02
9.1400E+02	9.3100E+02	9.5200E+02	9.6800E+02
9.8200E+02	9.9200E+02	9.9800E+02	1.0030E+03
1.0070E+03	1.0100E+03	1.0130E+03	1.0130E+03
1.0130E+03	9.3700E+02	9.2800E+02	9.1500E+02
9.1300E+02	9.1600E+02	9.3400E+02	9.5400E+02
9.7000E+02	9.8400E+02	9.9300E+02	9.9900E+02
1.0040E+03	1.0070E+03	1.0090E+03	1.0090E+03
1.0090E+03	1.0090E+03	9.3800E+02	9.3200E+02
9.2200E+02	9.2100E+02	9.2700E+02	9.4100E+02
9.5800E+02	9.7300E+02	9.8500E+02	9.9400E+02
9.9900E+02	1.0040E+03	1.0070E+03	1.0080E+03
1.0080E+03	1.0080E+03	9.4100E+02	9.4100E+02
9.3400E+02	9.3300E+02	9.3800E+02	9.4800E+02
9.6100E+02	9.7500E+02	9.8700E+02	9.9400E+02
9.9900E+02	1.0030E+03	1.0060E+03	1.0060E+03
1.0060E+03	1.0060E+03	9.4200E+02	9.4000E+02
9.4100E+02	9.4500E+02	9.5200E+02	9.6300E+02
9.7700E+02	9.8700E+02	9.9400E+02	9.9900E+02
1.0020E+03	1.0020E+03	1.0020E+03	1.0020E+03
9.4300E+02	9.4200E+02	9.4400E+02	9.4800E+02

Table C-1 Contd..

9.5400E+02	9.6500E+02	9.7700E+02	9.8800E+02
9.9500E+02	9.9900E+02	1.0020E+03	1.0020E+03
1.0020E+03	9.4300E+02	9.4200E+02	9.4400E+02
9.4800E+02	9.5400E+02	9.6500E+02	9.7700E+02
9.8800E+02	9.9500E+02	9.9900E+02	1.0020E+03
1.0020E+03	1.0020E+03	9.4300E+02	9.4200E+02
9.4400E+02	9.4800E+02	9.5400E+02	9.6500E+02
9.7700E+02	9.8800E+02	9.9500E+02	9.9900E+02
1.0020E+03	1.0020E+03		
1.7000E+01	1.6000E+01	1.5000E+01	1.5000E+01
1.5000E+01	1.5000E+01	1.5000E+01	1.7000E+01
1.6000E+01	1.5000E+01	1.5000E+01	1.5000E+01
1.5000E+01	1.5000E+01	1.5000E+01	1.5000E+01
1.7000E+01	1.7000E+01	1.5000E+01	1.4000E+01
1.4000E+01	1.3000E+01	1.4000E+01	1.4000E+01
1.4000E+01	1.4000E+01	1.4000E+01	1.4000E+01
1.8000E+01	1.7000E+01	1.7000E+01	1.6000E+01
1.5000E+01	1.4000E+01	1.3000E+01	1.2000E+01
1.2000E+01	1.2000E+01	1.3000E+01	1.3000E+01
1.3000E+01	1.3000E+01	1.8000E+01	1.9000E+01
1.9000E+01	1.9000E+01	1.8000E+01	1.7000E+01
1.4000E+01	1.3000E+01	1.2000E+01	1.1000E+01
1.1000E+01	1.1000E+01	1.0000E+01	1.0000E+01
1.0000E+01	2.3000E+01	2.4000E+01	3.2000E+01
3.4000E+01	3.3000E+01	2.9000E+01	2.2000E+01
1.6000E+01	1.3000E+01	1.1000E+01	1.1000E+01
1.0000E+01	1.0000E+01	1.0000E+01	1.0000E+01
1.0000E+01	3.5000E+01	6.6000E+01	9.1000E+01
9.8000E+01	9.5000E+01	8.3000E+01	5.3000E+01
2.9000E+01	1.7000E+01	1.3000E+01	1.1000E+01
1.0000E+01	1.0000E+01	1.0000E+01	1.0000E+01
1.0000E+01	8.0000E+01	1.6700E+02	2.0600E+02
2.9100E+02	3.1400E+02	2.9000E+02	1.7400E+02
7.5000E+01	3.3000E+01	1.8000E+01	1.2000E+01
1.1000E+01	1.1000E+01	1.1000E+01	1.1000E+01
1.1000E+01	5.9000E+01	1.2800E+02	2.5000E+02
4.2400E+02	6.8600E+02	8.5200E+02	8.9300E+02
5.4500E+02	2.4700E+02	9.9000E+01	3.9000E+01
1.7000E+01	1.2000E+01	1.2000E+01	1.2000E+01
4.0000E+01	6.3000E+01	1.0200E+02	3.5100E+02
7.0700E+02	1.1560E+03	1.7260E+03	2.6170E+03
2.0590E+03	7.5900E+02	2.4800E+02	8.0000E+01
2.6000E+01	1.4000E+01	1.4000E+01	1.4000E+01
3.6000E+01	5.5000E+01	1.0200E+02	4.8800E+02
8.5300E+02	1.1970E+03	1.7410E+03	2.5030E+03
2.0560E+03	7.9900E+02	2.7000E+02	9.1000E+01
3.2000E+01	1.5000E+01	1.5000E+01	1.5000E+01
2.9000E+01	3.9000E+01	6.2000E+01	1.9100E+02
6.0000E+02	6.6000E+02	7.6000E+02	8.0200E+02
5.6200E+02	3.1800E+02	1.2900E+02	5.5000E+01
2.5000E+01	1.3000E+01	1.2000E+01	1.2000E+01
1.2000E+01	2.4000E+01	2.6000E+01	3.0000E+01
5.3000E+01	1.6200E+02	2.4400E+02	2.5400E+02
2.4500E+02	1.7900E+02	1.0500E+02	5.0000E+01
2.6000E+01	1.6000E+01	1.2000E+01	1.2000E+01
1.2000E+01	1.2000E+01	2.1000E+01	2.3000E+01
2.5000E+01	3.6000E+01	7.2000E+01	9.1000E+01
8.6000E+01	7.3000E+01	5.2000E+01	3.3000E+01
2.2000E+01	1.6000E+01	1.3000E+01	1.2000E+01
1.2000E+01	1.2000E+01	2.1000E+01	2.1000E+01
2.2000E+01	2.4000E+01	3.5000E+01	3.5000E+01
3.2000E+01	2.7000E+01	2.1000E+01	1.7000E+01
1.4000E+01	1.3000E+01	1.2000E+01	1.2000E+01
1.2000E+01	1.2000E+01	2.0000E+01	1.9000E+01
1.7000E+01	1.9000E+01	1.9000E+01	1.7000E+01
1.5000E+01	1.4000E+01	1.3000E+01	1.3000E+01
1.3000E+01	1.3000E+01	1.3000E+01	1.3000E+01
2.0000E+01	1.8000E+01	1.5000E+01	1.4000E+01
1.4000E+01	1.4000E+01	1.3000E+01	1.3000E+01
1.3000E+01	1.3000E+01	1.3000E+01	1.3000E+01

Table C-1 Contd..

1.3000E+01	2.0000E+01	1.8000E+01	1.5000E+01
1.4000E+01	1.4000E+01	1.4000E+01	1.3000E+01
1.3000E+01	1.3000E+01	1.3000E+01	1.3000E+01
1.3000E+01	1.3000E+01	2.0000E+01	1.8000E+01
1.5000E+01	1.4000E+01	1.4000E+01	1.4000E+01
1.3000E+01	1.3000E+01	1.3000E+01	1.3000E+01
1.3000E+01	1.3000E+01		

Table C-2 : Input data file for SUTRA model (Unit D5)

```
SUTRA SOLUTE TRANSPORT SIMULATION
SALT CONTAMINATION SIMULATION
***** SHADOW LAWN **** STARK COUNTY **** OHIO ,1992
  270  233   37    0   31    0  159    0    4  365
    0    0    0    1    0
0.0000E+00     1.00000E-02     1.0000E-02
  100  8.6400000E+04  9.4672800E+08          11.1500E+00  3.1536000E+08     1     1
    5    1    1    1    0    0    1    1
       175 0.010E+00 0.010E+00
 6.560E-10 0.000E+00 0.000E+00 1.000E+00 0.000E+00 0.000E+00 1.000E+00
 3.800E-03 0.000E+00 0.000E+00 1.000E+00
NONE       0.000E+00 0.000E+00
 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 0.000E+00 0.000E+00
NODE       1.000E+00 1.000E+00 1.000E+00 3.000E-01
    1    0 1.150E+03 1.050E+03 1.000E+02 1.000E+00
    2    0 1.350E+03 1.050E+03 9.500E+01 1.000E+00
    3    0 1.550E+03 1.050E+03 9.300E+01 1.000E+00
    4    0 1.750E+03 1.050E+03 8.800E+01 1.000E+00
    5    0 1.950E+03 1.050E+03 8.200E+01 1.000E+00
    6    0 2.150E+03 1.050E+03 7.400E+01 1.000E+00
    7    0 2.350E+03 1.050E+03 7.400E+01 1.000E+00
    8    0 1.150E+03 1.250E+03 1.000E+02 1.000E+00
    9    0 1.350E+03 1.250E+03 9.500E+01 1.000E+00
   10    0 1.550E+03 1.250E+03 9.300E+01 1.000E+00
   11    0 1.750E+03 1.250E+03 8.800E+01 1.000E+00
   12    0 1.950E+03 1.250E+03 8.200E+01 1.000E+00
   13    0 2.150E+03 1.250E+03 7.400E+01 1.000E+00
   14    0 2.350E+03 1.250E+03 7.400E+01 1.000E+00
   15    0 2.550E+03 1.250E+03 7.400E+01 1.000E+00
   16    0 2.750E+03 1.250E+03 7.400E+01 1.000E+00
   17    0 9.500E+02 1.450E+03 1.060E+02 1.000E+00
   18    0 1.150E+03 1.450E+03 1.020E+02 1.000E+00
   19    0 1.350E+03 1.450E+03 9.500E+01 1.000E+00
   20    0 1.550E+03 1.450E+03 8.900E+01 1.000E+00
   21    0 1.750E+03 1.450E+03 8.300E+01 1.000E+00
   22    0 1.950E+03 1.450E+03 7.700E+01 1.000E+00
   23    0 2.150E+03 1.450E+03 7.300E+01 1.000E+00
   24    0 2.350E+03 1.450E+03 6.900E+01 1.000E+00
   25    0 2.550E+03 1.450E+03 6.500E+01 1.000E+00
   26    0 2.750E+03 1.450E+03 6.500E+01 1.000E+00
   27    0 2.950E+03 1.450E+03 6.500E+01 1.000E+00
   28    0 3.150E+03 1.450E+03 6.500E+01 1.000E+00
   29    0 7.500E+02 1.650E+03 1.080E+02 1.000E+00
   30    0 9.500E+02 1.650E+03 1.080E+02 1.000E+00
   31    0 1.150E+03 1.650E+03 1.050E+02 1.000E+00
   32    0 1.350E+03 1.650E+03 9.500E+01 1.000E+00
   33    0 1.550E+03 1.650E+03 8.500E+01 1.000E+00
   34    0 1.750E+03 1.650E+03 8.000E+01 1.000E+00
   35    0 1.950E+03 1.650E+03 7.500E+01 1.000E+00
   36    0 2.150E+03 1.650E+03 7.000E+01 1.000E+00
   37    0 2.350E+03 1.650E+03 6.700E+01 1.000E+00
   38    0 2.550E+03 1.650E+03 6.300E+01 1.000E+00
   39    0 2.750E+03 1.650E+03 6.400E+01 1.000E+00
   40    0 2.950E+03 1.650E+03 6.000E+01 1.000E+00
   41    0 3.150E+03 1.650E+03 6.000E+01 1.000E+00
   42    0 3.350E+03 1.650E+03 6.000E+01 1.000E+00
   43    0 7.500E+02 1.850E+03 1.080E+02 1.000E+00
   44    0 9.500E+02 1.850E+03 1.100E+02 1.000E+00
   45    0 1.150E+03 1.850E+03 1.030E+02 1.000E+00
   46    0 1.350E+03 1.850E+03 9.000E+01 1.000E+00
   47    0 1.550E+03 1.850E+03 8.100E+01 1.000E+00
   48    0 1.750E+03 1.850E+03 7.500E+01 1.000E+00
   49    0 1.950E+03 1.850E+03 7.000E+01 1.000E+00
   50    0 2.150E+03 1.850E+03 6.600E+01 1.000E+00
   51    0 2.350E+03 1.850E+03 6.400E+01 1.000E+00
   52    0 2.550E+03 1.850E+03 6.200E+01 1.000E+00
   53    0 2.750E+03 1.850E+03 5.900E+01 1.000E+00
```

Table C-2 Contd...

54	0	2.950E+03	1.850E+03	5.600E+01	1.000E+00
55	0	3.150E+03	1.850E+03	5.600E+01	1.000E+00
56	0	3.350E+03	1.850E+03	5.600E+01	1.000E+00
57	0	3.550E+03	1.850E+03	5.600E+01	1.000E+00
58	0	7.500E+02	2.050E+03	1.030E+02	1.000E+00
59	0	9.500E+02	2.050E+03	1.030E+02	1.000E+00
60	0	1.150E+03	2.050E+03	9.500E+01	1.000E+00
61	0	1.350E+03	2.050E+03	8.200E+01	1.000E+00
62	0	1.550E+03	2.050E+03	7.100E+01	1.000E+00
63	0	1.750E+03	2.050E+03	6.500E+01	1.000E+00
64	0	1.950E+03	2.050E+03	6.400E+01	1.000E+00
65	0	2.150E+03	2.050E+03	6.300E+01	1.000E+00
66	0	2.350E+03	2.050E+03	6.200E+01	1.000E+00
67	0	2.550E+03	2.050E+03	6.100E+01	1.000E+00
68	0	2.750E+03	2.050E+03	5.700E+01	1.000E+00
69	0	2.950E+03	2.050E+03	5.200E+01	1.000E+00
70	0	3.150E+03	2.050E+03	5.100E+01	1.000E+00
71	0	3.350E+03	2.050E+03	5.200E+01	1.000E+00
72	0	3.550E+03	2.050E+03	5.200E+01	1.000E+00
73	0	3.750E+03	2.050E+03	5.200E+01	1.000E+00
74	0	7.500E+02	2.250E+03	9.400E+01	1.000E+00
75	0	9.500E+02	2.250E+03	9.000E+01	1.000E+00
76	0	1.150E+03	2.250E+03	8.000E+01	1.000E+00
77	0	1.350E+03	2.250E+03	6.900E+01	1.000E+00
78	0	1.550E+03	2.250E+03	5.700E+01	1.000E+00
79	0	1.750E+03	2.250E+03	5.500E+01	1.000E+00
80	0	1.950E+03	2.250E+03	6.200E+01	1.000E+00
81	0	2.150E+03	2.250E+03	6.200E+01	1.000E+00
82	0	2.350E+03	2.250E+03	6.200E+01	1.000E+00
83	0	2.550E+03	2.250E+03	6.300E+01	1.000E+00
84	0	2.750E+03	2.250E+03	6.100E+01	1.000E+00
85	0	2.950E+03	2.250E+03	5.000E+01	1.000E+00
86	0	3.150E+03	2.250E+03	4.600E+01	1.000E+00
87	0	3.350E+03	2.250E+03	4.600E+01	1.000E+00
88	0	3.550E+03	2.250E+03	4.600E+01	1.000E+00
89	0	3.750E+03	2.250E+03	4.600E+01	1.000E+00
90	0	7.500E+02	2.450E+03	8.500E+01	1.000E+00
91	0	9.500E+02	2.450E+03	7.800E+01	1.000E+00
92	0	1.150E+03	2.450E+03	6.700E+01	1.000E+00
93	0	1.350E+03	2.450E+03	5.700E+01	1.000E+00
94	0	1.550E+03	2.450E+03	5.500E+01	1.000E+00
95	0	1.750E+03	2.450E+03	5.800E+01	1.000E+00
96	0	1.950E+03	2.450E+03	6.200E+01	1.000E+00
97	0	2.150E+03	2.450E+03	6.300E+01	1.000E+00
98	0	2.350E+03	2.450E+03	6.300E+01	1.000E+00
99	0	2.550E+03	2.450E+03	6.400E+01	1.000E+00
100	0	2.750E+03	2.450E+03	6.900E+01	1.000E+00
101	0	2.950E+03	2.450E+03	5.900E+01	1.000E+00
102	0	3.150E+03	2.450E+03	5.900E+01	1.000E+00
103	0	3.350E+03	2.450E+03	5.900E+01	1.000E+00
104	0	3.550E+03	2.450E+03	5.900E+01	1.000E+00
105	0	3.750E+03	2.450E+03	5.900E+01	1.000E+00
106	0	5.500E+02	2.650E+03	8.200E+01	1.000E+00
107	0	7.500E+02	2.650E+03	7.700E+01	1.000E+00
108	0	9.500E+02	2.650E+03	7.000E+01	1.000E+00
109	0	1.150E+03	2.650E+03	5.700E+01	1.000E+00
110	0	1.350E+03	2.650E+03	4.800E+01	1.000E+00
111	0	1.550E+03	2.650E+03	4.900E+01	1.000E+00
112	0	1.750E+03	2.650E+03	5.600E+01	1.000E+00
113	0	1.950E+03	2.650E+03	5.900E+01	1.000E+00
114	0	2.150E+03	2.650E+03	6.200E+01	1.000E+00
115	0	2.350E+03	2.650E+03	6.500E+01	1.000E+00
116	0	2.550E+03	2.650E+03	6.700E+01	1.000E+00
117	0	2.750E+03	2.650E+03	6.700E+01	1.000E+00
118	0	2.950E+03	2.650E+03	6.400E+01	1.000E+00
119	0	3.150E+03	2.650E+03	6.400E+01	1.000E+00
120	0	3.350E+03	2.650E+03	6.400E+01	1.000E+00
121	0	3.500E+02	2.850E+03	7.900E+01	1.000E+00
122	0	5.500E+02	2.850E+03	7.700E+01	1.000E+00
123	0	7.500E+02	2.850E+03	7.300E+01	1.000E+00

Table C-2 Contd...

124	0	9.500E+02	2.850E+03	6.500E+01	1.000E+00
125	0	1.150E+03	2.850E+03	5.400E+01	1.000E+00
126	0	1.350E+03	2.850E+03	4.500E+01	1.000E+00
127	0	1.550E+03	2.850E+03	4.400E+01	1.000E+00
128	0	1.750E+03	2.850E+03	4.100E+01	1.000E+00
129	0	1.950E+03	2.850E+03	5.400E+01	1.000E+00
130	0	2.150E+03	2.850E+03	6.000E+01	1.000E+00
131	0	2.350E+03	2.850E+03	6.500E+01	1.000E+00
132	0	2.550E+03	2.850E+03	6.700E+01	1.000E+00
133	0	2.750E+03	2.850E+03	6.900E+01	1.000E+00
134	0	2.950E+03	2.850E+03	6.600E+01	1.000E+00
135	0	3.150E+03	2.850E+03	6.600E+01	1.000E+00
136	0	3.350E+03	2.850E+03	6.600E+01	1.000E+00
137	0	3.500E+02	3.050E+03	7.500E+01	1.000E+00
138	0	5.500E+02	3.050E+03	7.200E+01	1.000E+00
139	0	7.500E+02	3.050E+03	6.900E+01	1.000E+00
140	0	9.500E+02	3.050E+03	6.500E+01	1.000E+00
141	0	1.150E+03	3.050E+03	5.900E+01	1.000E+00
142	0	1.350E+03	3.050E+03	5.300E+01	1.000E+00
143	0	1.550E+03	3.050E+03	4.800E+01	1.000E+00
144	0	1.750E+03	3.050E+03	4.500E+01	1.000E+00
145	0	1.950E+03	3.050E+03	5.300E+01	1.000E+00
146	0	2.150E+03	3.050E+03	6.300E+01	1.000E+00
147	0	2.350E+03	3.050E+03	6.800E+01	1.000E+00
148	0	2.550E+03	3.050E+03	7.000E+01	1.000E+00
149	0	2.750E+03	3.050E+03	7.100E+01	1.000E+00
150	0	2.950E+03	3.050E+03	6.900E+01	1.000E+00
151	0	3.150E+03	3.050E+03	6.900E+01	1.000E+00
152	0	3.350E+03	3.050E+03	6.900E+01	1.000E+00
153	0	3.500E+02	3.250E+03	7.300E+01	1.000E+00
154	0	5.500E+02	3.250E+03	7.000E+01	1.000E+00
155	0	7.500E+02	3.250E+03	6.900E+01	1.000E+00
156	0	9.500E+02	3.250E+03	7.300E+01	1.000E+00
157	0	1.150E+03	3.250E+03	7.500E+01	1.000E+00
158	0	1.350E+03	3.250E+03	6.200E+01	1.000E+00
159	0	1.550E+03	3.250E+03	6.900E+01	1.000E+00
160	0	1.750E+03	3.250E+03	4.800E+01	1.000E+00
161	0	1.950E+03	3.250E+03	6.000E+01	1.000E+00
162	0	2.150E+03	3.250E+03	6.800E+01	1.000E+00
163	0	2.350E+03	3.250E+03	7.200E+01	1.000E+00
164	0	2.550E+03	3.250E+03	7.400E+01	1.000E+00
165	0	2.750E+03	3.250E+03	7.400E+01	1.000E+00
166	0	2.950E+03	3.250E+03	7.300E+01	1.000E+00
167	0	3.150E+03	3.250E+03	7.200E+01	1.000E+00
168	0	3.350E+03	3.250E+03	7.200E+01	1.000E+00
169	0	3.550E+03	3.250E+03	7.200E+01	1.000E+00
170	0	3.500E+02	3.450E+03	7.200E+01	1.000E+00
171	0	5.500E+02	3.450E+03	6.800E+01	1.000E+00
172	0	7.500E+02	3.450E+03	6.800E+01	1.000E+00
173	0	9.500E+02	3.450E+03	8.100E+01	1.000E+00
174	0	1.150E+03	3.450E+03	1.000E+02	1.000E+00
175	0	1.350E+03	3.450E+03	1.000E+02	1.000E+00
176	0	1.550E+03	3.450E+03	8.700E+01	1.000E+00
177	0	1.750E+03	3.450E+03	7.500E+01	1.000E+00
178	0	1.950E+03	3.450E+03	7.500E+01	1.000E+00
179	0	2.150E+03	3.450E+03	7.800E+01	1.000E+00
180	0	2.350E+03	3.450E+03	7.900E+01	1.000E+00
181	0	2.550E+03	3.450E+03	7.900E+01	1.000E+00
182	0	2.750E+03	3.450E+03	7.800E+01	1.000E+00
183	0	2.950E+03	3.450E+03	7.400E+01	1.000E+00
184	0	3.150E+03	3.450E+03	7.400E+01	1.000E+00
185	0	3.350E+03	3.450E+03	7.400E+01	1.000E+00
186	0	3.550E+03	3.450E+03	7.400E+01	1.000E+00
187	0	3.500E+02	3.650E+03	7.300E+01	1.000E+00
188	0	5.500E+02	3.650E+03	7.100E+01	1.000E+00
189	0	7.500E+02	3.650E+03	7.200E+01	1.000E+00
190	0	9.500E+02	3.650E+03	8.500E+01	1.000E+00
191	0	1.150E+03	3.650E+03	9.800E+01	1.000E+00
192	0	1.350E+03	3.650E+03	1.050E+02	1.000E+00
193	0	1.550E+03	3.650E+03	9.800E+01	1.000E+00

Table C-2 Contd...

194	0	1.750E+03	3.650E+03	8.800E+01	1.000E+00
195	0	1.950E+03	3.650E+03	8.300E+01	1.000E+00
196	0	2.150E+03	3.650E+03	8.400E+01	1.000E+00
197	0	2.350E+03	3.650E+03	8.100E+01	1.000E+00
198	0	2.550E+03	3.650E+03	8.100E+01	1.000E+00
199	0	2.750E+03	3.650E+03	8.100E+01	1.000E+00
200	0	2.950E+03	3.650E+03	7.500E+01	1.000E+00
201	0	3.150E+03	3.650E+03	7.500E+01	1.000E+00
202	0	3.350E+03	3.650E+03	7.500E+01	1.000E+00
203	0	3.500E+02	3.850E+03	7.600E+01	1.000E+00
204	0	5.500E+02	3.850E+03	7.600E+01	1.000E+00
205	0	7.500E+02	3.850E+03	7.500E+01	1.000E+00
206	0	9.500E+02	3.850E+03	7.800E+01	1.000E+00
207	0	1.150E+03	3.850E+03	8.500E+01	1.000E+00
208	0	1.350E+03	3.850E+03	9.600E+01	1.000E+00
209	0	1.550E+03	3.850E+03	1.020E+02	1.000E+00
210	0	1.750E+03	3.850E+03	9.400E+01	1.000E+00
211	0	1.950E+03	3.850E+03	9.300E+01	1.000E+00
212	0	2.150E+03	3.850E+03	9.000E+01	1.000E+00
213	0	2.350E+03	3.850E+03	8.600E+01	1.000E+00
214	0	2.550E+03	3.850E+03	8.400E+01	1.000E+00
215	0	2.750E+03	3.850E+03	8.500E+01	1.000E+00
216	0	2.950E+03	3.850E+03	8.500E+01	1.000E+00
217	0	3.150E+03	3.850E+03	8.500E+01	1.000E+00
218	0	3.350E+03	3.850E+03	8.500E+01	1.000E+00
219	0	5.500E+02	4.050E+03	8.000E+01	1.000E+00
220	0	7.500E+02	4.050E+03	8.300E+01	1.000E+00
221	0	9.500E+02	4.050E+03	8.900E+01	1.000E+00
222	0	1.150E+03	4.050E+03	9.400E+01	1.000E+00
223	0	1.350E+03	4.050E+03	9.700E+01	1.000E+00
224	0	1.550E+03	4.050E+03	1.000E+02	1.000E+00
225	0	1.750E+03	4.050E+03	9.000E+01	1.000E+00
226	0	1.950E+03	4.050E+03	8.800E+01	1.000E+00
227	0	2.150E+03	4.050E+03	8.700E+01	1.000E+00
228	0	2.350E+03	4.050E+03	8.400E+01	1.000E+00
229	0	2.550E+03	4.050E+03	8.100E+01	1.000E+00
230	0	2.750E+03	4.050E+03	8.100E+01	1.000E+00
231	0	2.950E+03	4.050E+03	8.100E+01	1.000E+00
232	0	3.150E+03	4.050E+03	8.100E+01	1.000E+00
233	0	5.500E+02	4.250E+03	8.400E+01	1.000E+00
234	0	7.500E+02	4.250E+03	8.500E+01	1.000E+00
235	0	9.500E+02	4.250E+03	8.900E+01	1.000E+00
236	0	1.150E+03	4.250E+03	9.300E+01	1.000E+00
237	0	1.350E+03	4.250E+03	9.600E+01	1.000E+00
238	0	1.550E+03	4.250E+03	9.900E+01	1.000E+00
239	0	1.750E+03	4.250E+03	8.800E+01	1.000E+00
240	0	1.950E+03	4.250E+03	8.800E+01	1.000E+00
241	0	2.150E+03	4.250E+03	8.700E+01	1.000E+00
242	0	2.350E+03	4.250E+03	8.400E+01	1.000E+00
243	0	2.550E+03	4.250E+03	8.100E+01	1.000E+00
244	0	2.750E+03	4.250E+03	8.100E+01	1.000E+00
245	0	2.950E+03	4.250E+03	8.100E+01	1.000E+00
246	0	5.500E+02	4.450E+03	8.400E+01	1.000E+00
247	0	7.500E+02	4.450E+03	8.500E+01	1.000E+00
248	0	9.500E+02	4.450E+03	8.900E+01	1.000E+00
249	0	1.150E+03	4.450E+03	9.300E+01	1.000E+00
250	0	1.350E+03	4.450E+03	9.600E+01	1.000E+00
251	0	1.550E+03	4.450E+03	9.900E+01	1.000E+00
252	0	1.750E+03	4.450E+03	8.800E+01	1.000E+00
253	0	1.950E+03	4.450E+03	8.800E+01	1.000E+00
254	0	2.150E+03	4.450E+03	8.700E+01	1.000E+00
255	0	2.350E+03	4.450E+03	8.400E+01	1.000E+00
256	0	2.550E+03	4.450E+03	8.100E+01	1.000E+00
257	0	2.750E+03	4.450E+03	8.100E+01	1.000E+00
258	0	2.950E+03	4.450E+03	8.100E+01	1.000E+00
259	0	5.500E+02	4.650E+03	8.400E+01	1.000E+00
260	0	7.500E+02	4.650E+03	8.500E+01	1.000E+00
261	0	9.500E+02	4.650E+03	8.900E+01	1.000E+00
262	0	1.150E+03	4.650E+03	9.300E+01	1.000E+00
263	0	1.350E+03	4.650E+03	9.600E+01	1.000E+00

Table C-2 Contd...

264	0	1.550E+03	4.650E+03	9.900E+01	1.000E+00			
265	0	1.750E+03	4.650E+03	8.800E+01	1.000E+00			
266	0	1.950E+03	4.650E+03	8.800E+01	1.000E+00			
267	0	2.150E+03	4.650E+03	8.700E+01	1.000E+00			
268	0	2.350E+03	4.650E+03	8.400E+01	1.000E+00			
269	0	2.550E+03	4.650E+03	8.100E+01	1.000E+00			
270	0	2.750E+03	4.650E+03	8.100E+01	1.000E+00			
ELEMENT		1.000E+00	1.000E+00	0.000E+00	2.500E+02	2.500E+02	1.000E+02	1.000E+02
1	0	1.051E-15	1.051E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
2	0	1.011E-15	1.011E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
3	0	1.050E-15	1.050E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
4	0	1.118E-15	1.118E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
5	0	1.090E-15	1.090E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
6	0	1.014E-15	1.014E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
7	0	1.020E-05	1.020E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
8	0	9.677E-06	9.677E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
9	0	9.915E-06	9.915E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
10	0	1.030E-05	1.030E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
11	0	1.046E-05	1.046E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
12	0	9.310E-06	9.310E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
13	0	8.511E-15	8.511E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
14	0	8.633E-15	8.633E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
15	0	1.045E-05	1.045E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
16	0	9.824E-06	9.824E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
17	0	9.341E-06	9.341E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
18	0	9.496E-06	9.496E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
19	0	9.524E-06	9.524E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
20	0	1.017E-05	1.017E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
21	0	8.602E-06	8.602E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
22	0	6.818E-06	6.818E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
23	0	6.420E-06	6.420E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
24	0	5.906E-15	5.906E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
25	0	6.000E-15	6.000E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
26	0	1.014E-05	1.014E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
27	0	1.033E-05	1.033E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
28	0	9.669E-06	9.669E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
29	0	9.117E-06	9.117E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
30	0	9.657E-06	9.657E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
31	0	1.000E-05	1.000E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
32	0	1.068E-05	1.068E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
33	0	8.989E-06	8.989E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
34	0	7.031E-06	7.031E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
35	0	6.048E-06	6.048E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
36	0	5.021E-06	5.021E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
37	0	5.172E-06	5.172E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
38	0	5.172E-15	5.172E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
39	0	1.038E-05	1.038E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
40	0	1.071E-05	1.071E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
41	0	1.000E-05	1.000E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
42	0	9.259E-06	9.259E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
43	0	1.027E-05	1.027E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
44	0	1.095E-05	1.095E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
45	0	1.141E-05	1.141E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
46	0	9.412E-06	9.412E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
47	0	7.229E-06	7.229E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
48	0	6.276E-06	6.276E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
49	0	5.357E-06	5.357E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
50	0	5.581E-06	5.581E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
51	0	5.581E-06	5.581E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
52	0	5.556E-15	5.556E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
53	0	1.128E-05	1.128E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
54	0	1.141E-05	1.141E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
55	0	9.356E-06	9.356E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
56	0	7.527E-06	7.527E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
57	0	8.468E-06	8.468E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
58	0	8.537E-06	8.537E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
59	0	8.964E-06	8.964E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
60	0	8.434E-06	8.434E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
61	0	7.258E-06	7.258E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
62	0	6.198E-06	6.198E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00

Table C-2 Contd...

63	0	5.455E-06	5.455E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
64	0	6.030E-06	6.030E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
65	0	6.154E-06	6.154E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
66	0	6.122E-06	6.122E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
67	0	6.122E-15	6.122E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
68	0	1.268E-05	1.268E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
69	0	1.302E-05	1.302E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
70	0	9.158E-06	9.158E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
71	0	5.042E-06	5.042E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
72	0	5.333E-06	5.333E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
73	0	5.063E-06	5.063E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
74	0	6.024E-06	6.024E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
75	0	7.200E-06	7.200E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
76	0	7.143E-06	7.143E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
77	0	5.837E-06	5.837E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
78	0	5.021E-06	5.021E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
79	0	5.607E-06	5.607E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
80	0	5.714E-06	5.714E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
81	0	5.714E-15	5.714E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
82	0	5.714E-15	5.714E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
83	0	1.419E-05	1.419E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
84	0	1.544E-05	1.544E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
85	0	1.135E-05	1.135E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
86	0	5.742E-06	5.742E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
87	0	5.505E-06	5.505E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
88	0	5.106E-06	5.106E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
89	0	6.098E-06	6.098E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
90	0	7.115E-06	7.115E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
91	0	6.950E-06	6.950E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
92	0	5.618E-06	5.618E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
93	0	4.633E-06	4.633E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
94	0	4.878E-06	4.878E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
95	0	4.878E-15	4.878E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
96	0	1.424E-05	1.424E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
97	0	1.544E-05	1.544E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
98	0	1.707E-05	1.707E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
99	0	1.275E-05	1.275E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
100	0	6.452E-06	6.452E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
101	0	6.316E-06	6.316E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
102	0	5.714E-06	5.714E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
103	0	6.383E-06	6.383E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
104	0	7.143E-06	7.143E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
105	0	6.818E-06	6.818E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
106	0	5.556E-06	5.556E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
107	0	4.511E-06	4.511E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
108	0	4.615E-06	4.615E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
109	0	4.615E-15	4.615E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
110	0	1.320E-05	1.320E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
111	0	1.375E-05	1.375E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
112	0	1.471E-05	1.471E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
113	0	1.605E-05	1.605E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
114	0	1.185E-05	1.185E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
115	0	6.316E-06	6.316E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
116	0	6.742E-06	6.742E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
117	0	6.218E-06	6.218E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
118	0	6.522E-06	6.522E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
119	0	7.031E-06	7.031E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
120	0	6.667E-06	6.667E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
121	0	5.415E-06	5.415E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
122	0	4.364E-06	4.364E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
123	0	4.444E-06	4.444E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
124	0	4.444E-15	4.444E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
125	0	1.241E-05	1.241E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
126	0	1.286E-05	1.286E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
127	0	1.304E-05	1.304E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
128	0	1.324E-05	1.324E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
129	0	9.639E-06	9.639E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
130	0	5.172E-06	5.172E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
131	0	5.714E-06	5.714E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
132	0	5.825E-06	5.825E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00

Table C-2 Contd...

133	0	6.148E-06	6.148E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
134	0	6.642E-06	6.642E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
135	0	6.338E-06	6.338E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
136	0	5.190E-06	5.190E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
137	0	4.181E-06	4.181E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
138	0	4.240E-06	4.240E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
139	0	4.255E-15	4.255E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
140	0	1.272E-05	1.272E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
141	0	1.309E-05	1.309E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
142	0	1.237E-05	1.237E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
143	0	1.094E-05	1.094E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
144	0	7.122E-06	7.122E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
145	0	3.774E-06	3.774E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
146	0	4.301E-06	4.301E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
147	0	4.651E-06	4.651E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
148	0	5.338E-06	5.338E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
149	0	6.061E-06	6.061E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
150	0	5.921E-06	5.921E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
151	0	5.902E-06	5.902E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
152	0	5.351E-06	5.351E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
153	0	4.778E-06	4.778E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
154	0	4.795E-06	4.795E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
155	0	4.795E-15	4.795E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
156	0	1.268E-05	1.268E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
157	0	1.290E-05	1.290E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
158	0	1.176E-05	1.176E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
159	0	9.890E-06	9.890E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
160	0	5.955E-06	5.955E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
161	0	3.077E-06	3.077E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
162	0	3.448E-06	3.448E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
163	0	4.050E-06	4.050E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
164	0	5.000E-06	5.000E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
165	0	5.590E-06	5.590E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
166	0	5.625E-06	5.625E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
167	0	6.583E-06	6.583E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
168	0	7.143E-06	7.143E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
169	0	6.711E-06	6.711E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
170	0	6.711E-15	6.711E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
171	0	1.216E-05	1.216E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
172	0	1.224E-05	1.224E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
173	0	1.065E-05	1.065E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
174	0	8.671E-06	8.671E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
175	0	6.250E-06	6.250E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
176	0	3.741E-06	3.741E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
177	0	3.141E-06	3.141E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
178	0	3.911E-06	3.911E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
179	0	4.857E-06	4.857E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
180	0	5.279E-06	5.279E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
181	0	5.422E-06	5.422E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
182	0	6.344E-06	6.344E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
183	0	7.362E-06	7.362E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
184	0	7.500E-06	7.500E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
185	0	7.500E-15	7.500E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
186	0	1.146E-05	1.146E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
187	0	9.231E-06	9.231E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
188	0	6.936E-06	6.936E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
189	0	6.452E-06	6.452E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
190	0	4.557E-06	4.557E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
191	0	3.109E-06	3.109E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
192	0	3.836E-06	3.836E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
193	0	4.749E-06	4.749E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
194	0	5.187E-06	5.187E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
195	0	5.373E-06	5.373E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
196	0	5.891E-06	5.891E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
197	0	6.325E-06	6.325E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
198	0	6.325E-15	6.325E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
199	0	1.084E-05	1.084E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
200	0	8.671E-06	8.671E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
201	0	6.575E-06	6.575E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
202	0	6.316E-06	6.316E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00

Table C-2 Contd...

203	0	4.592E-06	4.592E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
204	0	3.183E-06	3.183E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
205	0	3.672E-06	3.672E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
206	0	4.429E-06	4.429E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
207	0	4.971E-06	4.971E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
208	0	5.152E-06	5.152E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
209	0	5.247E-06	5.247E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
210	0	5.247E-15	5.247E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
211	0	1.065E-05	1.065E-05	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
212	0	8.621E-06	8.621E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
213	0	6.593E-06	6.593E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
214	0	6.349E-06	6.349E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
215	0	4.615E-06	4.615E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
216	0	3.209E-06	3.209E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
217	0	3.409E-06	3.409E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
218	0	4.000E-06	4.000E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
219	0	4.678E-06	4.678E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
220	0	4.848E-06	4.848E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
221	0	4.938E-06	4.938E-06	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
222	0	4.938E-15	4.938E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
223	0	1.065E-15	1.065E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
224	0	8.621E-15	8.621E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
225	0	6.593E-15	6.593E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
226	0	6.349E-15	6.349E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
227	0	4.615E-15	4.615E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
228	0	3.209E-15	3.209E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
229	0	3.409E-15	3.409E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
230	0	4.000E-15	4.000E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
231	0	4.678E-15	4.678E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
232	0	4.848E-15	4.848E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
233	0	4.938E-15	4.938E-15	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00

20	7.700000E-04	0.000000E+00
21	7.700000E-04	0.000000E+00
22	7.700000E-04	0.000000E+00
23	7.700000E-04	0.000000E+00
33	7.700000E-04	0.000000E+00
34	7.700000E-04	0.000000E+00
35	7.700000E-04	0.000000E+00
36	7.700000E-04	0.000000E+00
37	7.700000E-04	0.000000E+00
38	7.700000E-04	0.000000E+00
39	7.700000E-04	0.000000E+00
45	6.200000E-04	0.000000E+00
46	7.700000E-04	0.000000E+00
47	7.700000E-04	0.000000E+00
48	7.700000E-04	0.000000E+00
49	7.700000E-04	0.000000E+00
50	7.700000E-04	0.000000E+00
51	7.700000E-04	0.000000E+00
52	7.700000E-04	0.000000E+00
53	7.700000E-04	0.000000E+00
54	7.700000E-04	0.000000E+00
55	7.700000E-04	0.000000E+00
59	6.200000E-04	0.000000E+00
60	6.200000E-04	0.000000E+00
61	7.700000E-04	0.000000E+00
62	7.700000E-04	0.000000E+00
63	7.700000E-04	0.000000E+00
64	7.700000E-04	0.000000E+00
65	7.700000E-04	0.000000E+00
66	7.700000E-04	0.000000E+00
67	7.700000E-04	0.000000E+00
68	7.700000E-04	0.000000E+00
69	7.700000E-04	0.000000E+00
70	7.700000E-04	0.000000E+00
71	7.700000E-04	0.000000E+00
75	7.700000E-04	0.000000E+00
76	7.700000E-04	0.000000E+00
77	7.700000E-04	0.000000E+00
78	6.200000E-04	0.000000E+00

Table C-2 Contd...

79	6.200000E-04	0.000000E+00
80	7.700000E-04	0.000000E+00
81	7.700000E-04	0.000000E+00
82	7.700000E-04	0.000000E+00
83	7.700000E-04	0.000000E+00
84	7.700000E-04	0.000000E+00
85	7.700000E-04	0.000000E+00
86	7.700000E-04	0.000000E+00
91	4.700000E-04	0.000000E+00
92	7.700000E-04	0.000000E+00
93	7.700000E-04	0.000000E+00
94	6.200000E-04	0.000000E+00
95	3.200000E-04	0.000000E+00
96	7.700000E-04	0.000000E+00
97	7.700000E-04	0.000000E+00
98	7.700000E-04	0.000000E+00
99	7.700000E-04	0.000000E+00
100	7.700000E-04	0.000000E+00
101	7.700000E-04	0.000000E+00
108	3.200000E-04	0.000000E+00
109	7.700000E-04	0.000000E+00
110	1.600000E-04	0.000000E+00
111	7.700000E-04	0.000000E+00
112	4.700000E-04	0.000000E+00
113	7.700000E-04	0.000000E+00
114	7.700000E-04	0.000000E+00
115	7.700000E-04	0.000000E+00
116	7.700000E-04	0.000000E+00
117	7.700000E-04	0.000000E+00
118	7.700000E-04	0.000000E+00
124	3.200000E-04	0.000000E+00
125	6.200000E-04	0.000000E+00
126	7.700000E-04	0.000000E+00
127	7.700000E-04	0.000000E+00
128	-1.400000E-04	0.000000E+00
129	7.700000E-04	0.000000E+00
130	7.700000E-04	0.000000E+00
131	7.700000E-04	0.000000E+00
132	7.700000E-04	0.000000E+00
133	7.700000E-04	0.000000E+00
134	7.700000E-04	0.000000E+00
140	4.700000E-04	0.000000E+00
141	6.200000E-04	0.000000E+00
142	7.700000E-04	0.000000E+00
143	7.700000E-04	0.000000E+00
144	4.700000E-04	0.000000E+00
145	7.700000E-04	0.000000E+00
146	7.700000E-04	0.000000E+00
147	7.700000E-04	0.000000E+00
148	7.700000E-04	0.000000E+00
149	7.700000E-04	0.000000E+00
150	7.700000E-04	0.000000E+00
156	7.700000E-04	0.000000E+00
157	1.600000E-04	0.000000E+00
158	1.600000E-04	0.000000E+00
159	7.700000E-04	0.000000E+00
160	1.600000E-04	0.000000E+00
161	7.700000E-04	0.000000E+00
162	7.700000E-04	0.000000E+00
163	7.700000E-04	0.000000E+00
164	7.700000E-04	0.000000E+00
165	7.700000E-04	0.000000E+00
166	7.700000E-04	0.000000E+00
167	7.700000E-04	0.000000E+00
173	4.700000E-04	0.000000E+00
174	1.600000E-04	0.000000E+00
175	4.700000E-04	0.000000E+00
176	4.700000E-04	0.000000E+00
177	4.700000E-04	0.000000E+00
178	7.700000E-04	0.000000E+00

Table C-2 Contd...

179	7.700000E-04	0.000000E+00
180	7.700000E-04	0.000000E+00
181	7.700000E-04	0.000000E+00
182	7.700000E-04	0.000000E+00
183	7.700000E-04	0.000000E+00
190	7.700000E-04	0.000000E+00
191	7.700000E-04	0.000000E+00
192	7.700000E-04	0.000000E+00
193	7.700000E-04	0.000000E+00
194	7.700000E-04	0.000000E+00
195	7.700000E-04	0.000000E+00
196	7.700000E-04	0.000000E+00
197	7.700000E-04	0.000000E+00
198	7.700000E-04	0.000000E+00
199	7.700000E-04	0.000000E+00
200	7.700000E-04	0.000000E+00
206	7.700000E-04	0.000000E+00
207	7.700000E-04	0.000000E+00
208	7.700000E-04	0.000000E+00
209	7.700000E-04	0.000000E+00
210	7.700000E-04	0.000000E+00
211	7.700000E-04	0.000000E+00
212	7.700000E-04	0.000000E+00
213	7.700000E-04	0.000000E+00
214	7.700000E-04	0.000000E+00
215	7.700000E-04	0.000000E+00
221	7.700000E-04	0.000000E+00
222	7.700000E-04	0.000000E+00
223	7.700000E-04	0.000000E+00
224	7.700000E-04	0.000000E+00
225	7.700000E-04	0.000000E+00
226	7.700000E-04	0.000000E+00
227	7.700000E-04	0.000000E+00
228	7.700000E-04	0.000000E+00
229	7.700000E-04	0.000000E+00
235	7.700000E-04	0.000000E+00
236	7.700000E-04	0.000000E+00
237	7.700000E-04	0.000000E+00
238	7.700000E-04	0.000000E+00
239	7.700000E-04	0.000000E+00
240	7.700000E-04	0.000000E+00
241	7.700000E-04	0.000000E+00
242	7.700000E-04	0.000000E+00
243	7.700000E-04	0.000000E+00
72	-3.000000E-04	0.000000E+00
189	-3.000000E-04	0.000000E+00
44	-1.500000E-04	0.000000E+00
107	-1.500000E-04	0.000000E+00
123	-3.000000E-04	0.000000E+00
139	-1.500000E-04	0.000000E+00

8	9.2700000E+02	2.0000000E-05
9	9.2700000E+02	2.0000000E-05
17	9.2700000E+02	2.0000000E-05
29	9.2800000E+02	2.0000000E-05
43	9.2900000E+02	2.0000000E-05
58	9.3000000E+02	2.0000000E-05
74	9.3100000E+02	2.0000000E-05
90	9.3200000E+02	2.0000000E-05
106	9.3300000E+02	2.0000000E-05
121	9.3400000E+02	2.0000000E-05
137	9.3500000E+02	2.0000000E-05
153	9.3600000E+02	2.0000000E-05
170	9.3700000E+02	2.0000000E-05
187	9.3800000E+02	2.0000000E-05
203	9.4100000E+02	2.0000000E-05
204	9.4100000E+02	2.0000000E-05
219	9.4200000E+02	2.0000000E-05
233	9.4300000E+02	2.0000000E-05
172	9.1500000E+02	2.0000000E-05

Table C-2 Contd...

173	9.1300000E+02	2.0000000E-05
155	9.1600000E+02	2.0000000E-05
156	9.1200000E+02	2.0000000E-05
157	9.1400000E+02	2.0000000E-05
139	9.1600000E+02	2.0000000E-05
140	9.1200000E+02	2.0000000E-05
141	9.1800000E+02	2.0000000E-05
123	9.1700000E+02	2.0000000E-05
124	9.1400000E+02	2.0000000E-05
125	9.2100000E+02	2.0000000E-05
108	9.2000000E+02	2.0000000E-05
109	9.2600000E+02	2.0000000E-05

	1														
128	158	110	144	0	0	0	0	0	0	0	0	0	0	0	0
1	1	2	9	8											
2	2	3	10	9											
3	3	4	11	10											
4	4	5	12	11											
5	5	6	13	12											
6	6	7	14	13											
7	8	9	19	18											
8	9	10	20	19											
9	10	11	21	20											
10	11	12	22	21											
11	12	13	23	22											
12	13	14	24	23											
13	14	15	25	24											
14	15	16	26	25											
15	17	18	31	30											
16	18	19	32	31											
17	19	20	33	32											
18	20	21	34	33											
19	21	22	35	34											
20	22	23	36	35											
21	23	24	37	36											
22	24	25	38	37											
23	25	26	39	38											
24	26	27	40	39											
25	27	28	41	40											
26	29	30	44	43											
27	30	31	45	44											
28	31	32	46	45											
29	32	33	47	46											
30	33	34	48	47											
31	34	35	49	48											
32	35	36	50	49											
33	36	37	51	50											
34	37	38	52	51											
35	38	39	53	52											
36	39	40	54	53											
37	40	41	55	54											
38	41	42	56	55											
39	43	44	59	58											
40	44	45	60	59											
41	45	46	61	60											
42	46	47	62	61											
43	47	48	63	62											
44	48	49	64	63											
45	49	50	65	64											
46	50	51	66	65											
47	51	52	67	66											
48	52	53	68	67											
49	53	54	69	68											
50	54	55	70	69											
51	55	56	71	70											
52	56	57	72	71											
53	58	59	75	74											
54	59	60	76	75											

Table C-2 Contd...

55	60	61	77	76
56	61	62	78	77
57	62	63	79	78
58	63	64	80	79
59	64	65	81	80
60	65	66	82	81
61	66	67	83	82
62	67	68	84	83
63	68	69	85	84
64	69	70	86	85
65	70	71	87	86
66	71	72	88	87
67	72	73	89	88
68	74	75	91	90
69	75	76	92	91
70	76	77	93	92
71	77	78	94	93
72	78	79	95	94
73	79	80	96	95
74	80	81	97	96
75	81	82	98	97
76	82	83	99	98
77	83	84	100	99
78	84	85	101	100
79	85	86	102	101
80	86	87	103	102
81	87	88	104	103
82	88	89	105	104
83	90	91	108	107
84	91	92	109	108
85	92	93	110	109
86	93	94	111	110
87	94	95	112	111
88	95	96	113	112
89	96	97	114	113
90	97	98	115	114
91	98	99	116	115
92	99	100	117	116
93	100	101	118	117
94	101	102	119	118
95	102	103	120	119
96	106	107	123	122
97	107	108	124	123
98	108	109	125	124
99	109	110	126	125
100	110	111	127	126
101	111	112	128	127
102	112	113	129	128
103	113	114	130	129
104	114	115	131	130
105	115	116	132	131
106	116	117	133	132
107	117	118	134	133
108	118	119	135	134
109	119	120	136	135
110	121	122	138	137
111	122	123	139	138
112	123	124	140	139
113	124	125	141	140
114	125	126	142	141
115	126	127	143	142
116	127	128	144	143
117	128	129	145	144
118	129	130	146	145
119	130	131	147	146
120	131	132	148	147
121	132	133	149	148
122	133	134	150	149
123	134	135	151	150
124	135	136	152	151

Table C-2 Contd...

125	137	138	154	153
126	138	139	155	154
127	139	140	156	155
128	140	141	157	156
129	141	142	158	157
130	142	143	159	158
131	143	144	160	159
132	144	145	161	160
133	145	146	162	161
134	146	147	163	162
135	147	148	164	163
136	148	149	165	164
137	149	150	166	165
138	150	151	167	166
139	151	152	168	167
140	153	154	171	170
141	154	155	172	171
142	155	156	173	172
143	156	157	174	173
144	157	158	175	174
145	158	159	176	175
146	159	160	177	176
147	160	161	178	177
148	161	162	179	178
149	162	163	180	179
150	163	164	181	180
151	164	165	182	181
152	165	166	183	182
153	166	167	184	183
154	167	168	185	184
155	168	169	186	185
156	170	171	188	187
157	171	172	189	188
158	172	173	190	189
159	173	174	191	190
160	174	175	192	191
161	175	176	193	192
162	176	177	194	193
163	177	178	195	194
164	178	179	196	195
165	179	180	197	196
166	180	181	198	197
167	181	182	199	198
168	182	183	200	199
169	183	184	201	200
170	184	185	202	201
171	187	188	204	203
172	188	189	205	204
173	189	190	206	205
174	190	191	207	206
175	191	192	208	207
176	192	193	209	208
177	193	194	210	209
178	194	195	211	210
179	195	196	212	211
180	196	197	213	212
181	197	198	214	213
182	198	199	215	214
183	199	200	216	215
184	200	201	217	216
185	201	202	218	217
186	204	205	220	219
187	205	206	221	220
188	206	207	222	221
189	207	208	223	222
190	208	209	224	223
191	209	210	225	224
192	210	211	226	225
193	211	212	227	226
194	212	213	228	227

Table C-2 Contd...

195	213	214	229	228
196	214	215	230	229
197	215	216	231	230
198	216	217	232	231
199	219	220	234	233
200	220	221	235	234
201	221	222	236	235
202	222	223	237	236
203	223	224	238	237
204	224	225	239	238
205	225	226	240	239
206	226	227	241	240
207	227	228	242	241
208	228	229	243	242
209	229	230	244	243
210	230	231	245	244
211	233	234	247	246
212	234	235	248	247
213	235	236	249	248
214	236	237	250	249
215	237	238	251	250
216	238	239	252	251
217	239	240	253	252
218	240	241	254	253
219	241	242	255	254
220	242	243	256	255
221	243	244	257	256
222	244	245	258	257
223	246	247	260	259
224	247	248	261	260
225	248	249	262	261
226	249	250	263	262
227	250	251	264	263
228	251	252	265	264
229	252	253	266	265
230	253	254	267	266
231	254	255	268	267
232	255	256	269	268
233	256	257	270	269