5-2001

Artificial Recharge of Groundwater as a Water Management Option for Eastern Maine

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ARTIFICIAL RECHARGE OF GROUNDWATER AS A WATER MANAGEMENT OPTION FOR EASTERN MAINE

By

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B.S. North Carolina A&T State University, 1997

A THESIS

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Science

(in Bio-Resource Engineering)

The Graduate School

The University of Maine

May, 2001

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An Abstract of the Thesis Presented
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The declining population of Atlantic salmon in eastern Maine has brought the wild blueberry industry's irrigation practice of pumping water directly from ponds and streams under scrutiny. Restrictions on pumping from streams has prompted the industry to seek new water resources. One resource with potential to assist the industry to meet its irrigation needs is groundwater. However, preliminary research has shown that groundwater is not capable of completely satisfying irrigation needs.

To evaluate the potential that artificially recharging the groundwater during spring run-off to retain the water for later use as irrigation, the groundwater software Visual MODFLOW was applied. Inputs necessary to describe the hydrogeologic properties of the Pineo Ridge delta in Washington County, Maine were made. Once calibration was achieved, the model was used to simulate the effects that the artificial recharge of groundwater (ARG) had on the hydrodynamics of the system. Water was recharged into the aquifer during April and May (225 L/s (4050 gpm) for 45 days) when spring flows

generally make water available in nearby ponds, streams, and rivers. Then, in July and August when water is limited and needed for irrigation, the water was removed from the aquifer by pumping. The study site shows potential in that it was capable of supporting 7 pumping wells for 80 days at 8 L/s (125 gpm) each.

Once the potential of the Pineo Ridge recharge site had been evaluated, three of the hydrogeologic parameters; hydraulic conductivity, storativity, and distance to a surface-water body, of the aquifer were adjusted to determine the impact that each had on the groundwater system. The goal of this evaluation was to determine the extent that each controlled the overall success or failure of an ARG site.

Finally, the values for the parameters that yielded the most favorable results were applied to one simulation. Again, recharge was applied at 225 L/s (4050 gpm) for 45 days during April and May. The resulting simulation characterized an aquifer system capable of supporting 10 wells each yielding 12.8 L/s (200 gpm) for 80 days without reducing the groundwater table in the aquifer by more than 30 cm (1 ft) from observed elevations.

From this study some general guidelines with which to evaluate potential ARG sites were determined. Aquifers with hydraulic conductivity values between 1e-4 m/s (30 ft/day) and 1.8e-4 m/s (50 ft/day) have the greatest potential for this application. Recovery of water through pumping is difficult in aquifers with specific yield values less than 0.2. Finally, the extent that the distance between the recharge site and a nearby surface-water body might assist or hinder the blueberry producers ability to recover the recharged water needs to be evaluated on a case-by-case basis.

ACKNOWLEDGMENTS

I would like to express my appreciation and thanks to everyone who has helped me in the accomplishment of this Master's program.

My sincere thanks extend to my thesis advisor, Dr. Warren Hedstrom for allowing me the freedom to make this study my own and for providing insight when "my own" went askew. I also extend my thanks to my thesis co-advisors, Dr. Willem Brutsaert, and Dr. Andrew Reeve, for their support and guidance throughout this process.

A very special thanks goes to David Brooks and the employees of Jasper Wyman and Son, for offering helpful suggestions and providing access to the information and resources that made this study possible.

Finally, the warmest thanks to my family and friends. You have stood by and supported me through what has undoubtedly been the most trying time in my life. Without you, none of this would have been possible.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

The production and processing of the lowbush blueberry (*Vaccinium angustifolium*) contributes $70 million annually to Maine's economy, employs nearly 8,000 people, and provides much needed income to economically challenged areas within the state. As the state's third largest agricultural crop and 25% of the world's total annual crop, Maine's production of blueberries is the largest in North America (Yarborough, 1997; Dalton, 2001). Over the past five years, annual production from 12,000 ha (30,000 acres) has yielded an average of 33.9 million kg (74.5 million lbs) of blueberries per year (Yarborough, 2001). Studies have shown that proper management including fertilizer application, bees, and irrigation has increased average yields more than fourfold over the past 30 years to over 8960 kg/ha (8,000 lb/acre) (Yarborough, 2001; Koehler, 2000). Although no formal research on the effects of irrigation has been published, the perception among growers is that irrigation is one of the most significant factors in the yield increase and is the most significant in stabilizing yields from year to year (Olday, 2001). Consequently, over the past fifteen years the blueberry industry in Maine has invested heavily in irrigation systems, pumps and power units, impoundment construction, well installation, and streambank pumping sites.

In 1995, concerns over decreases in the population of the Atlantic salmon prompted Governor Angus King to sign an executive order appointing the Maine Atlantic Salmon Task Force. The task force was charged with the development of the

Atlantic Salmon Conservation Plan (Plan) for the protection and recovery of the salmon in seven of Maine's rivers (Figure 1.1) (ASCP, 1997).

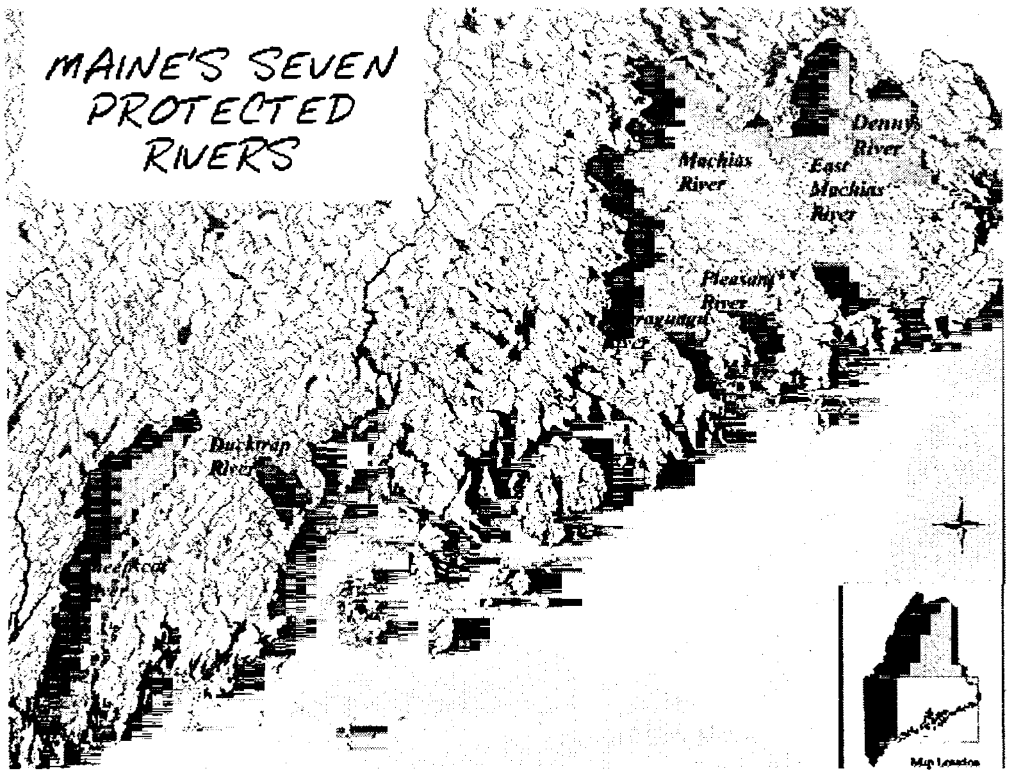


Figure 1.1 Maine's Seven Protected Rivers (MASC, 2000).

The Plan detailed a series of steps that state agencies are applying to the rivers to encourage the recovery and reproduction of the salmon. Although the plan acknowledged that the fate of the Atlantic salmon is ultimately out of the State's control, its purpose was to assure that all reasonable steps were taken to allow for the restoration of the salmon if international commercial fishing and ocean temperature conditions improved. One of the requirements dictated in the Plan was the development of a Water Use Management Plan (WUMP) for each of the seven watersheds. Of the seven

watersheds, three; the Narraguagus River, the Pleasant River, and Mopang Stream (a tributary of the Machias River), are under intensive blueberry production. Historically, the blueberry industry has relied on withdrawals from surface-water bodies; streams, impoundments, and ponds, as their primary source of irrigation water. Despite the fact that regulatory agencies, mainly the Maine Department of Environmental Protection (MDEP) and the Land Use Regulatory Commission (LURC), have required the industry to monitor its water usage, the recent concern over declining populations of Atlantic salmon has brought the industry's irrigation practices under scrutiny (Bell, 1999; Clancy, 1999; Young, 1999; Dalton and Criner, 2000; "Saving the Salmon", 1999).

Since early in the WUMP development process, groundwater was recognized to have great potential to satisfy the industry's needs. The United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) has estimated that the Pleasant River watershed alone contains 10,000 ha (39 sq mi) of significant sand and gravel aquifers capable of sustaining continuous groundwater pumping rates greater than 0.63 L/s (10 gpm) (NRCS, 1996). Coincidentally, these aquifers are underlying the majority of existing blueberry ground. In addition, groundwater exploration work performed by the major blueberry growers has resulted in wells that yield from 13 L/s to 130 L/s (200 gpm to 2000 gpm) (Horsley, 2001). Presently, at least two of the larger blueberry growers are using water wells as sources of irrigation water.

In 1990, University of Maine graduate student John W. Hale studied the aquifers of Pineo Ridge (Figure 1.2) and concluded that, although groundwater does have potential as an irrigation water source, it is not in its entirety the solution. Hale's research findings implied that under average conditions, the aquifer could provide 2.5

cm (1 in) of water per week for two months in the summer for 200 ha (500 acres) with minimal effect on the groundwater table. Under drought conditions however, the 2.5 cm (1 in) scenario would require 4 average years for the aquifer to return to equilibrium, and trying to irrigate 500 ha (1200 acres) had significant impact to the groundwater during a normal year and serious long-term effects during a dry year (Hale, 1990). Hale (1990) concluded that the Pineo Ridge aquifer has the potential to hold significant volumes of water in storage, but the recharge to those aquifers is insufficient for large scale pumping, particularly during dry years.

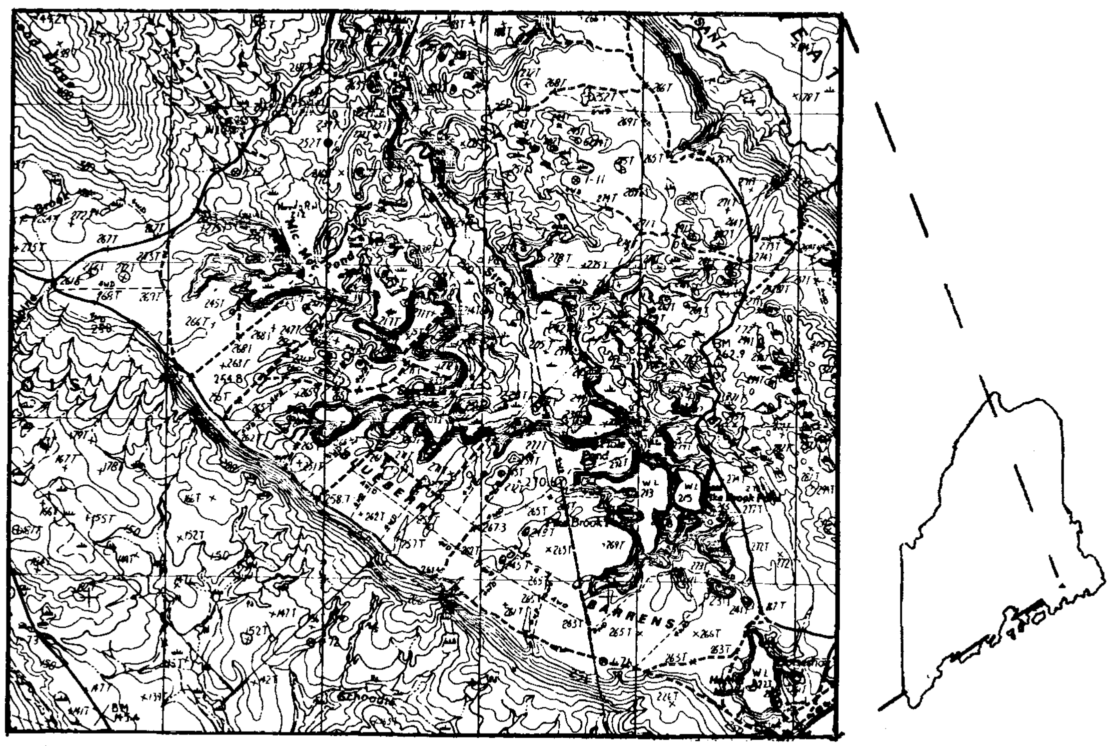


Figure 1.2 Pineo Ridge.

Since groundwater is currently being used as a source of irrigation water but the widespread use of groundwater to satisfy the need for irrigating blueberries is in doubt,

a reasonable question is: How can the volume of the water in the aquifer be increased to meet the needs of blueberry irrigation? One method of accomplishing this is the artificial recharge of groundwater or ARG. ARG is a water management tool that borrows water during times of surplus and places it into storage to be utilized during times of shortage. Preliminary studies have suggested the artificial recharge of groundwater as a water management option to assist in satisfying the needs of the watershed (Horsely, 2001). The NRCS has determined that the retention of a relatively small portion of the high spring flows could yield the equivalent of 5 cm (2 in) of rainfall, or 8.3 billion liters (2.2 billion gallons) in the Pleasant and Narraguagus River watersheds (NRCS, 1996).

This study evaluates the sand and gravel aquifers (specifically Pineo Ridge) of Eastern Maine as sites for artificial recharge of groundwater. The primary objective of this study is to provide water resources management information relating the capacity of the aquifer to store and retain artificially recharged waters and the recoverability of the waters for use in irrigation at a later date. The objectives of this study include:

1. The development and validation of a computer model to simulate the effect that artificial recharge has on the groundwater system of Pineo Ridge, Washington County, Maine.
2. Performance of a sensitivity analysis to determine the effect that various hydrologic parameters have on ARG.
3. Formulation of a set of guidelines for which potential ARG sites can be assessed.

Chapter 2

LITERATURE REVIEW

The practice of augmenting groundwater through artificial recharge is longstanding and well documented. The earliest usages were to provide public drinking water supplies. Two examples of this are a tunnel built along the River Clyde in 1820 to supply potable water to Glasgow, Scotland and an open basin near the Garonne in 1820 for Toulouse, France (Huisman and Olsthoorn, 1983). Since the early 19^{th} century, numerous techniques and applications for ARG have been developed. Today, the analysis of the effectiveness of these various techniques can be performed with computer models. Literature describing these developments was reviewed and pertinent information is outlined in this chapter. This chapter is organized with the following sections: Artificial recharge of groundwater, Geology of Downeast Maine, Models as Water Management Tools, and Model Selection.

Artificial Recharge of Groundwater

The artificial recharge of groundwater (ARG) is a process by which excess water is purposely directed into the ground to rebuild or augment groundwater supplies. It is accomplished by one of three methods: spreading on the surface, injecting water through recharge wells, or by altering natural conditions to increase infiltration (NRC, 1994). Stated simply, ARG uses the aquifer to store water in times of water surplus to meet demand in times of shortage (NRC, 1994). Over the past several decades, ARG

has been successfully used in numerous locations as a tool for managing water resources (Huisman and Olsthoorn, 1983).

In the hydrologic cycle (Figure 2.1), water falls on the ground as precipitation. Some of it evaporates, some runs off to nearby surface-water bodies, and the remainder infiltrates the soil, entering the groundwater cycle (Figure 2.2). Groundwater may be removed by pumping or is naturally discharged through a spring or as flow into a surface-water body. Eventually a portion returns to the atmosphere as evaporation or transpiration and continues through the hydrologic cycle. The purpose of ARG is simply to increase the quantity of water that enters the aquifer at a specific site.

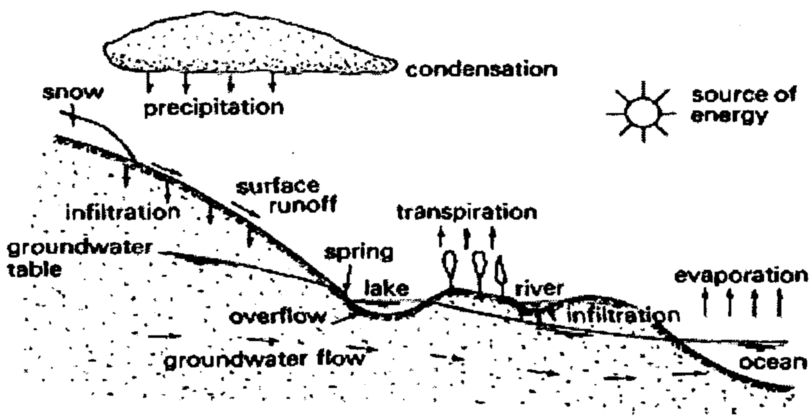


Figure 2.1 Hydrologic Cycle (Huisman and Olsthoorn, 1983).

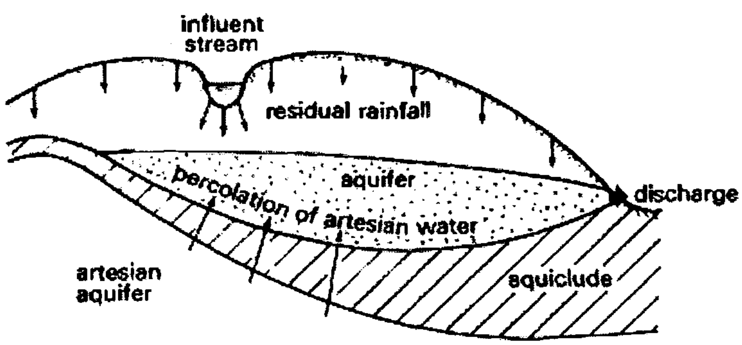


Figure 2.2 Groundwater Cycle (Huisman and Olsthoorn, 1983).

Methods to Artificially Recharge the Groundwater

Groundwater recharge methods are classified as one of three general types: indirect, direct subsurface, direct surface (Asano, 1985). Whether used independently or in combination, the approach chosen should be based on soil characteristics, aquifer and water-table properties, climate, environmental constraints, and, to a lesser degree, the quality of the recharge water (Johnson and Finlayson, 1989).

Indirect Recharge. Indirect groundwater recharge is achieved through manipulation of an aquifer's natural properties or conditions to encourage ARG. As shown in Figure 2.3, the drawdown in the water table caused by pumping of the well causes increased infiltration from the nearby river. Although not commonly referred to as ARG, this form is predominantly used as a method of obtaining potable water, but also can be used as a treatment method for polluted waters. Around the world, this process has been used to remove contaminants such as organic carbon, heavy metals, and microbial organisms (Gibert et al., 1993). Numerous studies have been performed to evaluate the

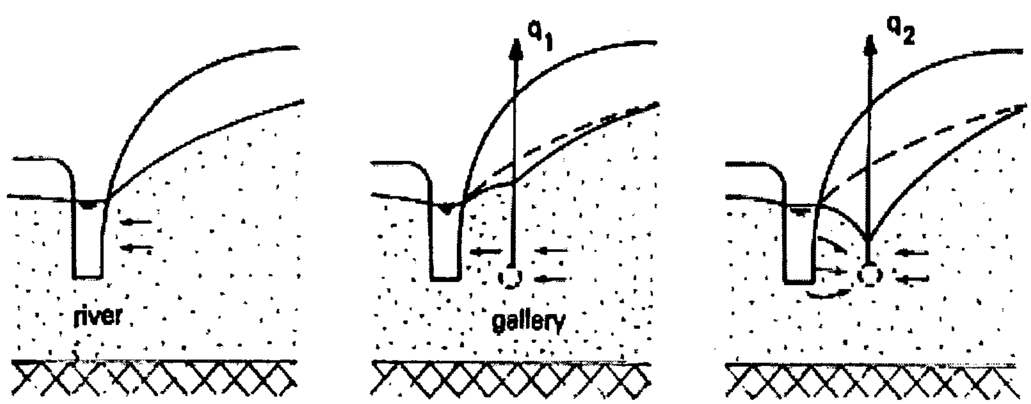


Figure 2.3 Indirect Recharge of Groundwater (Huisman and Olsthoorn, 1983).

effectiveness of various bank sediments and microbial packs in removing a multitude of contaminants (Preuss and Nehrkorn, 1996; Schmidt, 1996).

Direct Subsurface Recharge. Recharge to confined aquifers and aquifers overlain by soils with low permeability generally requires recharge or "injection" wells (Figure 2.4). Similar in construction to pumping wells, recharge wells are screened, and may require gravel packing (in unconsolidated aquifers). A basic requirement of recharge wells is the need to treat recharge water to remove all suspended particles in order to

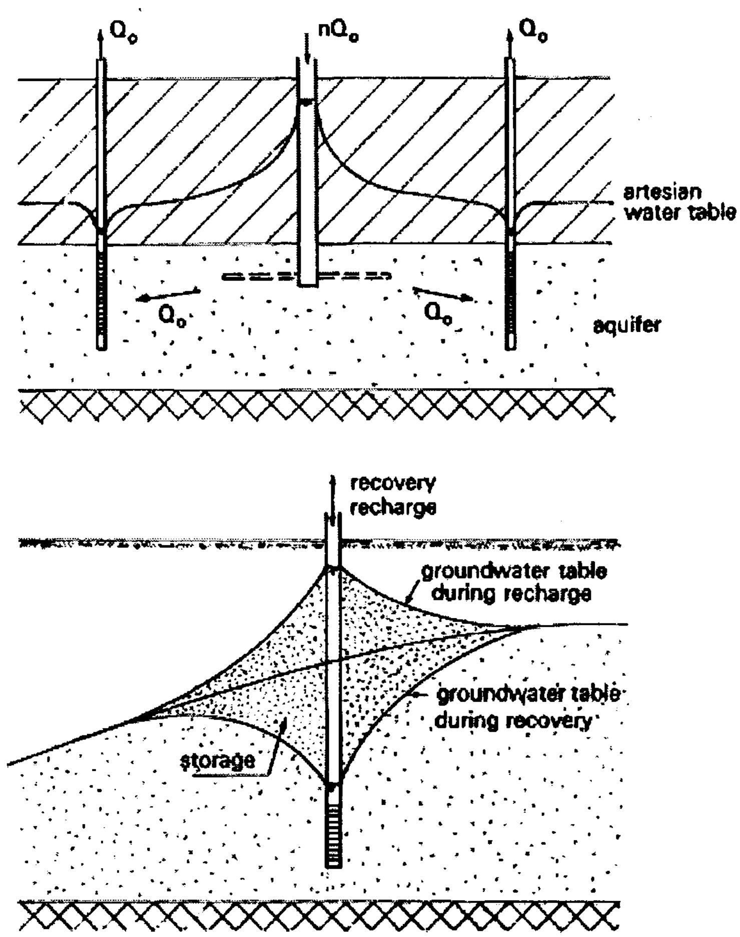


Figure 2.4 Direct Subsurface Recharge of Groundwater (Huisman and Olsthoorn, 1983).

reduce clogging of the pores at the recharge site. Inevitably, clogging will occur and periodic redevelopment will be necessary, and thus, recharge through injection wells is considerably more expensive than with infiltration basins (Johnson and Finlayson, 1989).

In 1996 an experiment to evaluate the use of subsurface injection, storage, and recovery of water in the lower Floridian aquifer was performed. The experiment, near Lake Okeechobee, Florida, was designed to determine the recoverability of injected water in an effort to use the aquifer as a transmission line to southern Florida. Several cycles of injecting water followed by pumping were performed and as more cycles of the experiment were performed, the percentage of recoverable water increased (Quinones-Aponte et al., 1996).

Direct Surface Recharge. If soils are permeable and the aquifer is unconfined, infiltration basins are generally the method of choice for ARG. Infiltration basins (Figure 2.5) can be constructed or may exist as natural depressions. In the blueberry barrens kettle holes exist and may serve as direct surface recharge sites, as will be presented later.

When direct recharge is practiced, the amount of water that enters the aquifer is controlled by three factors (Figure 2.5): the infiltration rate, the percolation rate, and the capacity for horizontal water movement (Huisman and Olsthoorn, 1983). The infiltration rate is the rate at which the surface layer allows the water to enter the soil. The percolation rate is the rate at which water moves downward through the soil profile. Generally, in homogeneous soil profiles the infiltration rate is nearly equal to the

percolation rate early in the recharge process, but clogging (from suspended particles, algal growth, and microbial activity) at the surface will cause a reduction in the infiltration rate. The capacity of horizontal water movement is determined from the flow pattern of the water and the soil's transmissivity (Huisman and Olsthoorn, 1983). Transmissivity is the measure of the amount of water that can be transmitted horizontally by the saturated thickness of the aquifer per unit of hydraulic gradient (Fetter, 1980).

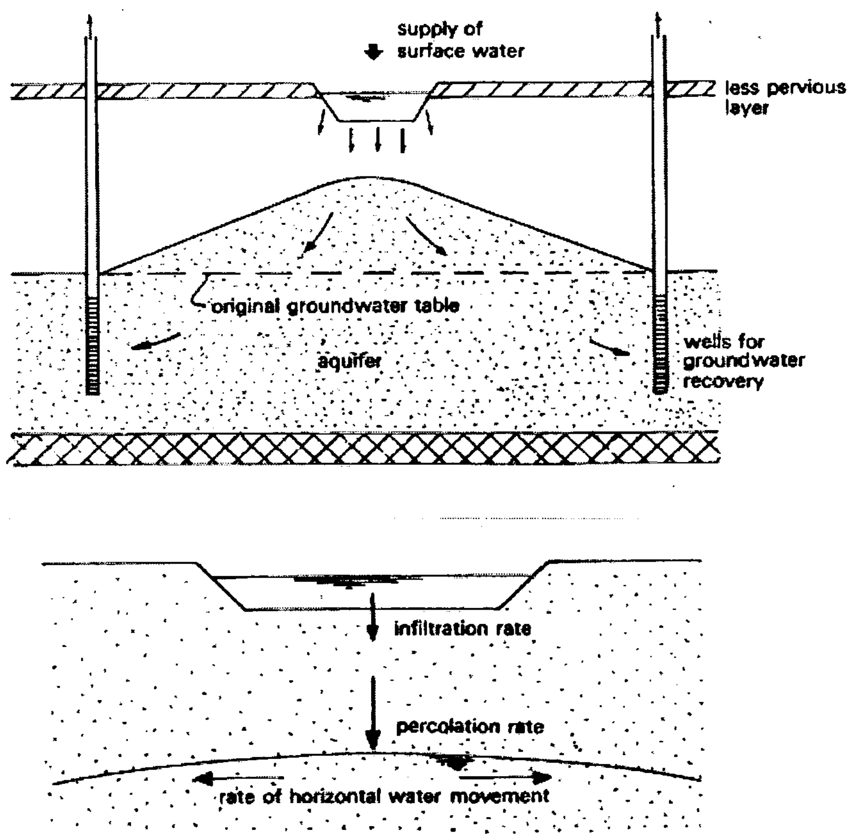


Figure 2.5 Direct Surface Recharge of Groundwater (Huisman and Olsthoorn, 1983).

In an effort to reduce groundwater nitrate contamination and combat a declining water table of the Central Platte region of Nebraska, researchers have been

experimenting with groundwater recharge since 1992. The initial field experiments not only showed a dramatic rise of the water table, but a significant decrease in agro-chemicals and nutrients in the groundwater as well (Ma and Spalding, 1997). Furthermore, municipalities throughout the world have had success with this form of recharge as a treatment of reclaimed wastewater. Since 1975, the East Meadow Artificial Recharge Facility in Nassua County, Long Island, NY has been using infiltration basins to recharge the aquifer while simultaneously providing treatment. A 15-month study evaluating the groundwater mounding and chemical effects of the recharge on the groundwater determined that as a result of the treatment, the levels of nitrogen and several low-molecular-weight hydrocarbons decreased to levels that were well within drinking water standards (Schneider et al., 1987).

Geology of Eastern Maine

Brief History of Glaciation

At the end of the Wisconsinan glaciation, the retreat of the Laurentide Ice Sheet left in its wake the geologic features of coastal Maine (Weddle et al., 1988). During the ice retreat, a period of global climatic warming increased melting and caused a worldwide rise in sea level. The extreme weight and pressure of the ice sheet depressed the earth's crust and allowed the seawaters to follow the glacier as far inland as Millinocket, Maine (Figure 2.6). As the glacier melted, soil and rock debris collected in it during its advance was released and deposited on the bedrock surface as a

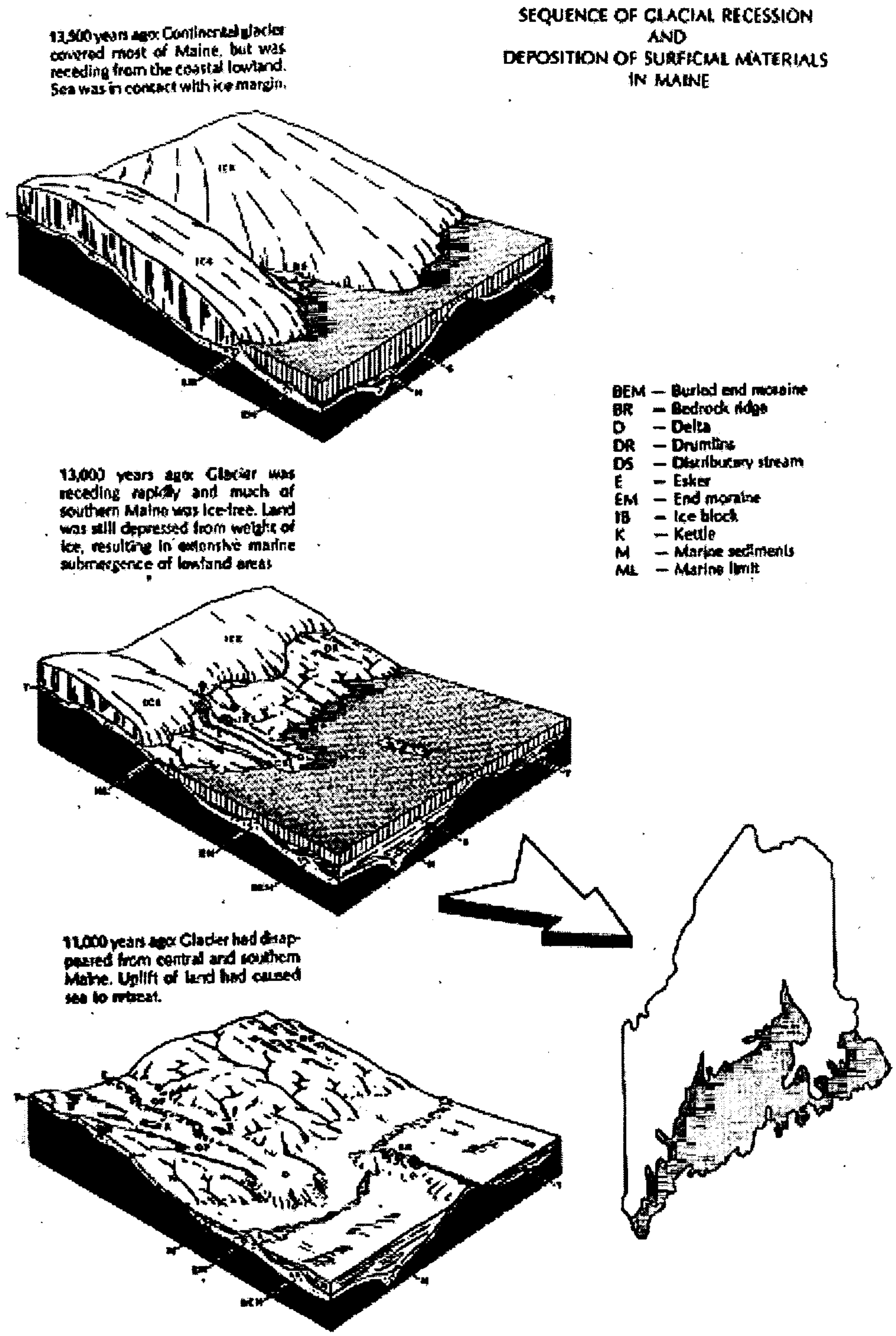


Figure 2.6 Sequence of Glacial Recession and Emergence of Delta (Borns, 1982).

discontinuous layer (Figure 2.7). The deposited glaciofluvial, glaciolacustrine, and glaciomarine sediments are the surviving record of the ice retreat (Weddle et al., 1988; Thompson, 1979).

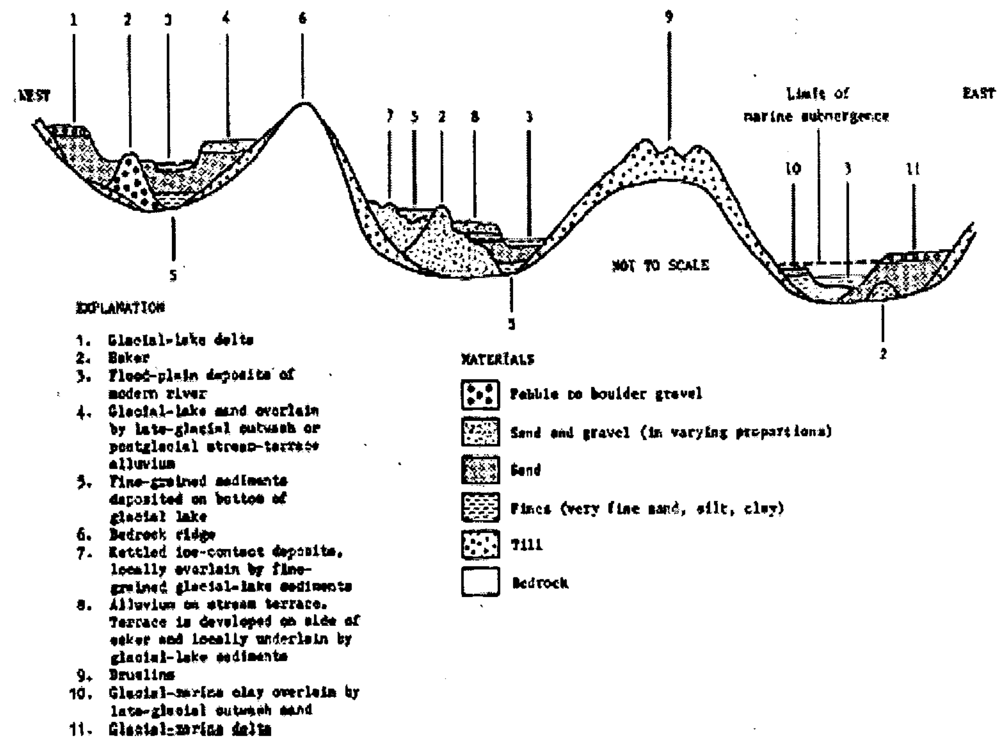


Figure 2.7 Stratigraphic Relationships in Glacial Deposits (Weddle et al., 1988).

Surficial Geology

The Pineo Ridge Delta is a glaciomarine delta that formed 12,000 years ago. "The term glaciomarine delta refers to a delta deposited in the marine environment from meltwater and sediment derived directly or indirectly from a glacier" (Borns, 1981). Borns (1981) explains the formations of deltas further (Figure 2.8),

"when sediment-laden streams flow into a still body of water, they deposit the layers of deltaic sediments in a characteristic manner. The stream deposits on the top of the delta, called topset beds, are thin, nearly horizontal, overbank deposits of the stream's distributaries. Thicker foreset beds accumulate on the front of the delta over which the stream's sediments are dumped. These layers generally accumulate at angles of 25° or less from the horizontal. The finest particles remain in suspension for a relatively long time and ultimately come to rest as clay and silt-rich bottomset beds in front of the advancing foreset beds."

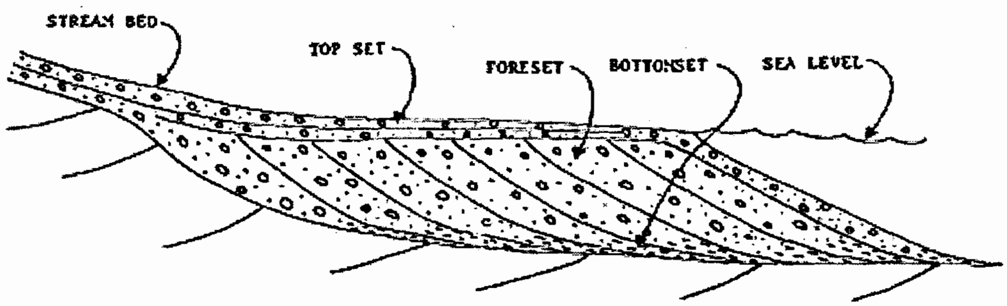


Figure 2.8 Typical Deltaic Cross Section (Borns, 1981).

In addition to displaying classic deltaic formation, Pineo Ridge also displays some other particularly well-formed features (Figure 2.9), these include (Borns, 1981): (sites listed are not all-inclusive, just easily accessed and well-developed examples).

1. The northern margin, or "ice contact margin", was deposited while in direct contact with the glacier. This type of deposition followed by a collapse as the glacier finally dissipated, resulted in a north face that is characterized by steep slopes, irregular and chaotic topography, and pits

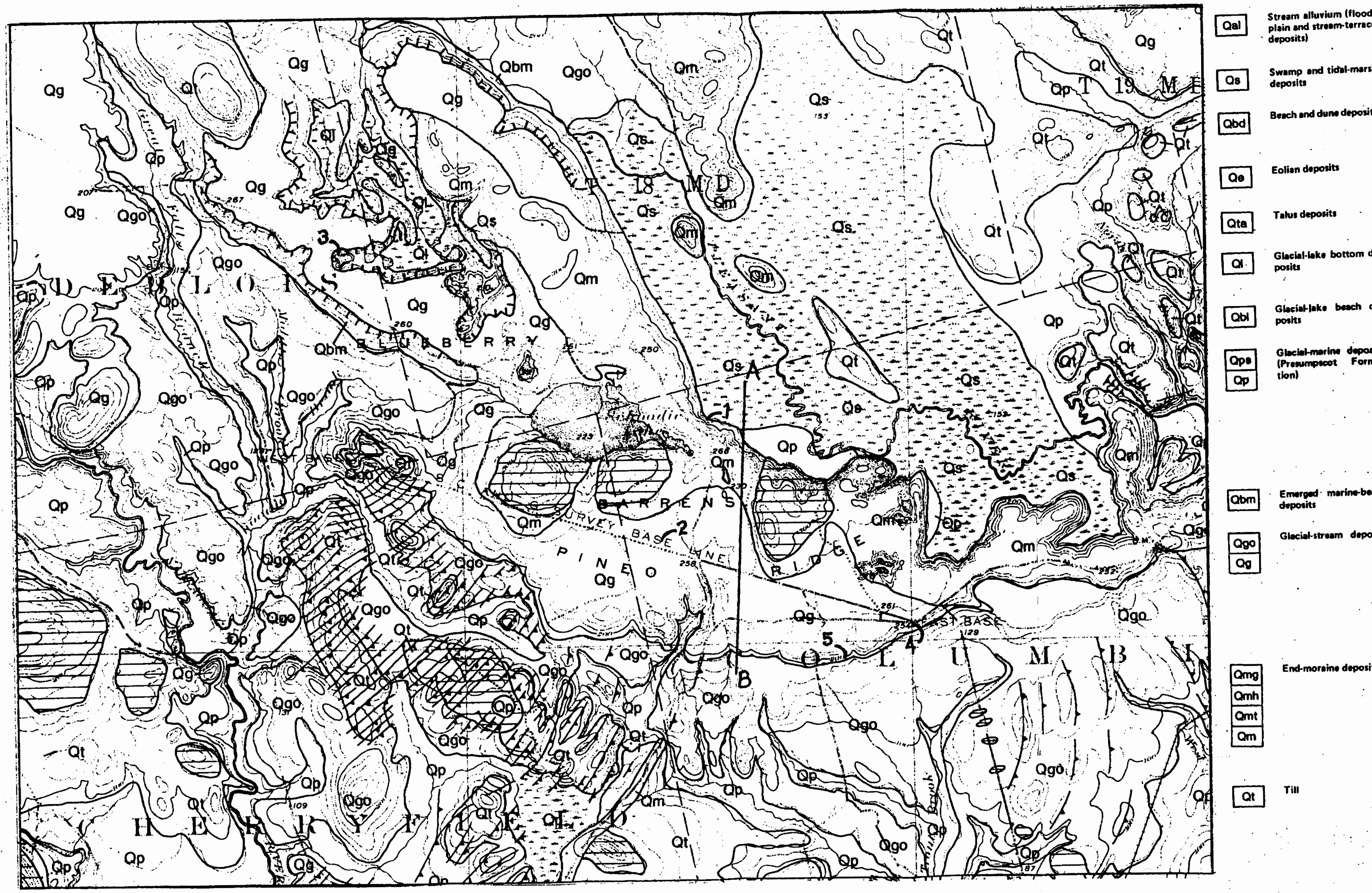


Figure 2.9 Surficial Geology of Pineo Ridge Delta, Washington County, Maine.
Line A-B is the line of geologic cross section shown in Figure 2.10 (Borns, 1981).

and mounds from 5 m to 15 m (15 to 50 feet) in relief.

2. Channels varying in depths and widths from 1 m to 2 m (3 ft to 6 ft) and 5 m to 10 m (15 ft to 30 ft) respectively were formed by sediments that were carried away from the glacier by meltwaters. Although abandoned and dry now, these channels are common across the surface of the delta.

3. During late glacial times (12,000 to 15,000 years ago), the retreating margin of the Laurentide Ice Sheet was in direct contact with the sea. Icebergs broke off from the glacier and much the same as they do today in Greenland and Antarctica. This resulted in the formation of large closed depressions called "kettle holes" on the seaward side of the delta, which developed when large pieces of the iceberg would become grounded or would break off while the delta was still building forward. Eventually, the deltaic sediments would surround the piece and when it melted away, a large depression was left in the surface. Kettle holes vary considerably in size and shape depending on the size of the iceberg.

4. The southern edge, or distal margin, of the delta displays shoreline features. After the delta stopped building seaward and glacial melting relieved the stress on the earth's crust, the delta emerged (Figure 2.10). As the sea dropped, wave-cut cliffs, wave-built platforms, and numerous beach ridges were left. The delta's seaward facing margin was formed when the sea level was 80 m (250 ft) above present day mean sea level and is characterized by a 7 m (21 ft) high wave-cut cliff. Several beach ridges running parallel to and below the cliff were formed from wave action against the cliff.

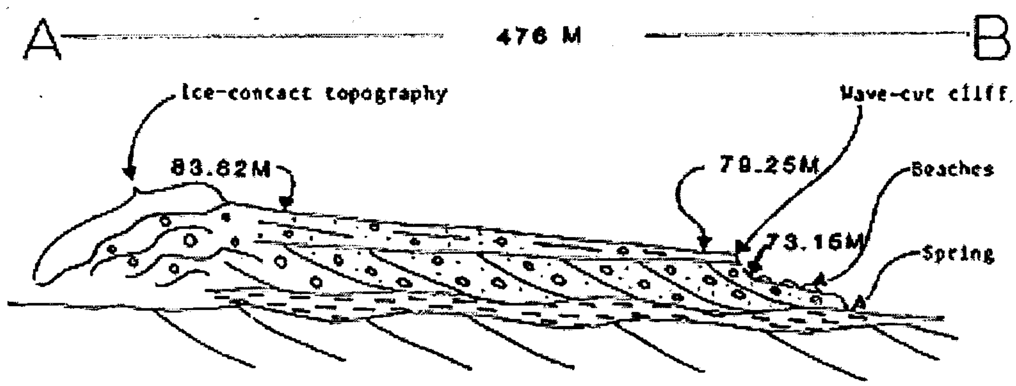


Figure 2.10 Geologic Cross Section of Pineo Ridge Delta along Line A-B (Figure 2.9) showing prominent figures (Borns, 1981).

5. The internal sediments and stratigraphy produced springs in the distal margin of the emerged delta. Many intermittently flowing springs on the southern margin of the delta have long been recognized and studied. Water falling on the surface of the delta infiltrates into the ground and descends through the coarse topset and foreset layers until it reaches the water table. The impermeable bottomset layer retards vertical flow and redirects it along horizontal planes. Groundwater travels along these bottomset beds and discharges at the face of the delta, forming springs. Over time, the flowing water undercuts the delta, eroding large gullies into it.

Bedrock Geology

Information about the bedrock of Pineo Ridge is limited. Borns (1982) mapped three areas of outcropped bedrock. All three define the extent of the terminal moraine of the northern portion of the deposit and are believed to have played a significant role in stopping the glacial readvance.

A reconnaissance map of the bedrock geology of the Cherryfield Quadrangle shows that the bedrock of Pineo Ridge is granitic from the Devonian Era or of more recent origin (Figure 2.11) (Gilman, 1961).

Models as Water Management Tools

Models have been used for decades to better understand and predict groundwater flow. Shaw and Southwell are credited with the first applications of numerical simulation to a subsurface flow problem in 1941 (van der Heijde et al., 1988). The advent of high speed digital computers, along with the subsequent and ongoing development of analytical and numerical models for both surface and groundwater systems, has lead to widespread use of these tools for water management. By predicting and illustrating alternative solutions, computer models have saved innumerable man-hours and capital (Loucks, 1981).

A generally accepted definition of a "model" is: "a non-unique simplified description of an existing physical system"(van der Heijde et al., 1988). This definition is extremely broad and captures a multitude of different types of models. However,

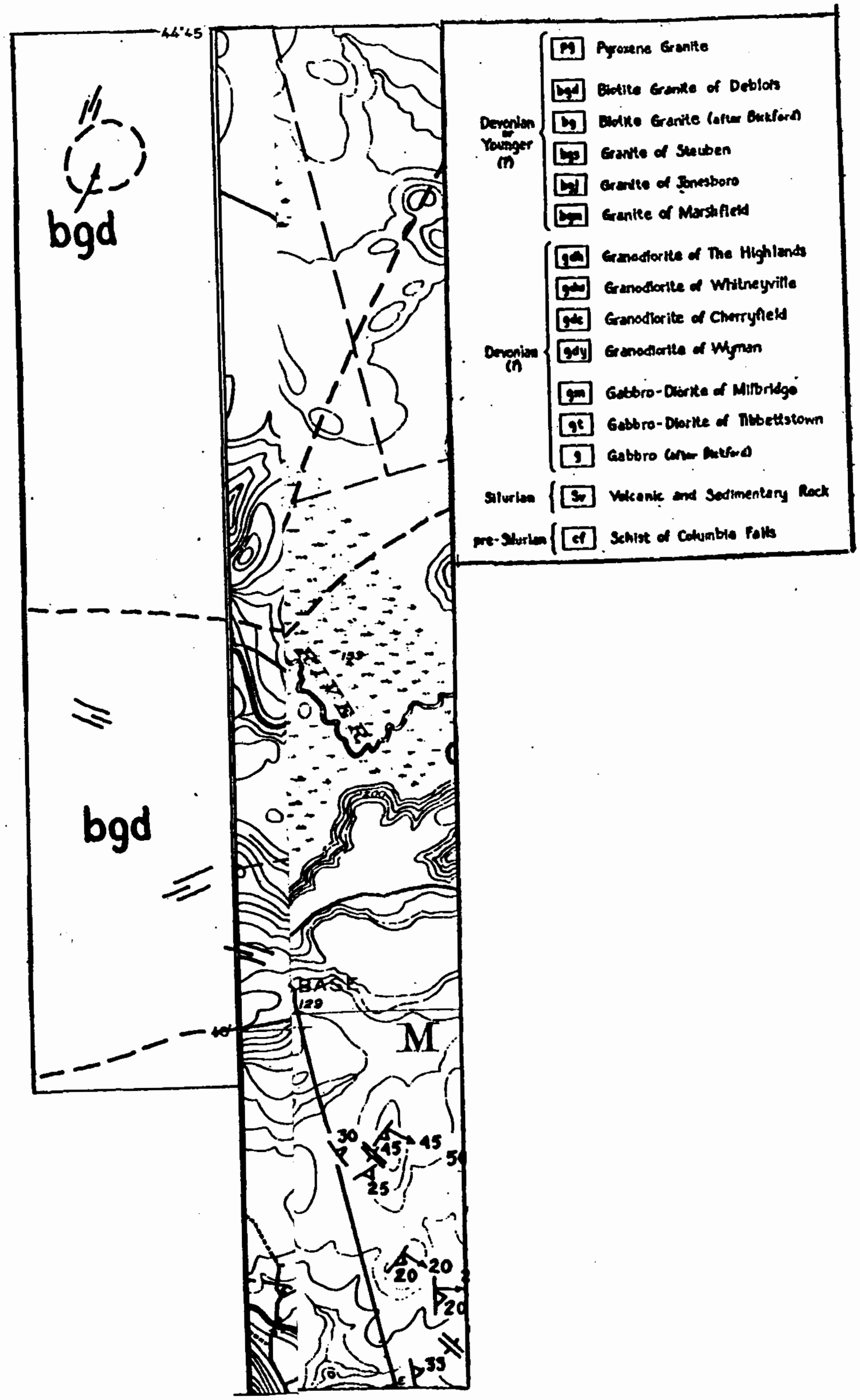


Figure 2.11 Bedrock
(Gilman, 1961).

groundwater modeling is generally associated with numerical and analytical models. A more descriptive definition for a numerical groundwater model is: "a mathematical description of the processes active in a groundwater system, coded in a programming language, together with a quantification of the groundwater system it simulates in the form of boundary conditions and parameters" (van der Heijde et al., 1988).

Model Selection

The Environmental Protection Agency (EPA) has determined that four major problem areas exist among models. These problems, listed in order of importance are (Bachmat et al., 1978):

1. Accessibility - Many models are not accessible to potential users. Increasing accessibility not only improves the quality of the modeling but also improves the training of the modelers.
2. Communication - Management must become more involved in problem definition and model applications if model outputs are to become more useful as management tools.
3. Data Inadequacies - Particular attention needs to be paid to identifying the data that is essential to solving the particular problem. Improvements in data collection methods are needed.
3. Model Inadequacies - The development of models for areas where scientific understanding is limited should only be encouraged after scientific understanding improves.

For this study on the artificial recharge of groundwater, a model was needed that could address soil characteristics and stratigraphy, recharge, pumping, evapotranspiration, and groundwater flow.

A program that fits all of these criteria is the Modular Three-Dimensional Finite-Difference Ground-water Flow Model or MODFLOW. MODFLOW was developed by the United States Geologic Survey (USGS) and is easily accessed free of charge from the Internet.

In 1994, Waterloo Hydrogeologic, a private software developer, released an graphical version of MODFLOW called Visual MODFLOW (Guiger and Franz, 1998). Visual MODFLOW is considerably more "friendly" to users and more efficient in its application. "Specifically designed to increase modeling productivity and decrease the complexities typically associated with building three-dimensional groundwater flow and contaminant transport models", Visual MODFLOW has rapidly replaced its predecessor among consulting firms, educational institutions, and government agencies around the world (Guiguer and Franz, 1998). Upon consideration of all of this information, Visual MODFLOW was selected as the computer simulation program for this study evaluating the effects of artificially recharging the groundwater in the aquifers of eastern Maine.

Chapter 3

METHODOLOGY

The artificial recharge of groundwater from surface waters to retain those waters for later use requires some prediction of its success. With the application of the computer program Visual MODFLOW to this problem, an evaluation of the recharged water that is available for irrigation can be accomplished. This chapter provides a description of Visual MODFLOW and the information and steps required to apply it to this study.

Description of Visual MODFLOW

Interface

The interface of Visual MODFLOW is divided into three modules, the Input Module, the Run Module, and the Output Module. The Input Module provides users with the ability to create a graphical three-dimensional representation of the study area. The modeler can assign values directly to the study area and the software creates the appropriate files. The Run Module allows the user to alter the parameters and options that are run specific, such as the solver package, recharge and re-wetting applications and the tolerances for convergence. The Output Module provides the user with the ability to display all of the modeling and calibration results. Although Visual MODFLOW graphically represents the study area, the inputs, and the outputs, the files

are translated and processed by the 1996 version of MODFLOW, or MODFLOW 96 (Guiguer and Franz, 1998). For this reasons, the assumptions and computational procedures of the Visual MODFLOW are equivalent to that of MODFLOW 96.

MODFLOW 96

MODFLOW 96 (Harbaugh and McDonald, 1996), the Modular Three-Dimensional Finite-Difference Groundwater Flow Model is coded in Fortran 77. It is capable of simulating steady state and transient flow in regularly or irregularly shaped layers that can be confined, unconfined, or some combination. Flows from external sources, recharge, evapotranspiration, drains, rivers, as well as properties of the groundwater system such as hydraulic conductivity, storage and anisotropy can all be varied in the model. The assumption governing MODFLOW is that the study area can be divided into blocks and that the properties within the block can be characterized uniformly (Harbaugh and McDonald, 1996). Mathematically, three-dimensional flow of water through a saturated porous medium can be represented by the following partial differential equation (Kresic, 1997):

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right)=S_s\frac{\partial h}{\partial t}+W \qquad \text{Eq. 1}$$

Where

K_{xx}, K_{yy} and K_{zz} are the principal components of the hydraulic conductivity along the x, y, and z coordinate axes and are assumed to be parallel to the major axes of hydraulic conductivity [l/t];

h is the potentiometric head [l];

W is the volumetric flux per unit volume and represents sources and/or sinks of water [t^{-1}];

S_s is the specific storage of the porous medium [l^{-1}];

t is time [t].

Equation 1 assumes saturate groundwater flow and therefore limits MODFLOW's capacity to simulate vadose zone flow. For some study sites, this limitation may have a significant impact on MODFLOW's prediction capabilities, however for this study area, the water table is relatively near to the kettle hole bottom so unsaturated flow within the vadoze zone is minimal.

Additionally, Equation 1, in combination with head conditions at the boundaries of the system and initial hydraulic head conditions, creates a mathematical representation of a groundwater flow system. Since analytical solutions of this equation are not possible for complex systems, numerical models must be employed to obtain approximate solutions. Upon application of a finite-difference approach, the continuous system is replaced by a finite set of discrete points in space and time and the partial derivatives are replaced by points calculated from the differences in head values of adjacent points (Kresic, 1997).

To more accurately describe a groundwater system, MODFLOW 96 is equipped with supplemental packages to handle specific characteristics within the system. In this study, the most important was the drain package. The equation used in the drain package is (Anderson and Woessner, 1992):

$$Q_d = C_d(H - d) \qquad \text{Eq. 2}$$

Where:

Q_d is the volumetric flow rate at which water is removed from the system by the drain (l^3/t);

C_d is the hydraulic conductance of the interface between the drain and the aquifer (l^2/t);

H is the potentiometric head in the cell as determined by MODFLOW 96 (l);

d is the elevation of the drain (l).

After the parameters necessary to describe the system have been entered into MODFLOW, the user has four solution methods from which to choose. The one chosen for this study is the preconditioned conjugate-gradient package, PCG2, because it is the most efficient in its ability to solve simultaneous equations in both linear and non-linear systems (Guiguer and Franz, 1998).

Data Acquisition and Model Development

The development of the model required additional hydrogeologic information of the Pineo Ridge Delta, Washington County, Maine. The necessary information was identified and a strategy to acquire and input the data was developed and is as follows:

- Information Gathering
- Estimation of Hydrologic Parameters
- Model Calibration to Observed Groundwater Conditions and Field Test

- ARG Applied to the Study Area
- Evaluation of Hydrologic Parameters on the Artificial Recharge of Groundwater
- Ideal Site Application

Information Gathering

The first step in this study was to obtain and assemble the available information on the study area (Figure3.1). Topographic, bedrock, surficial geology, and significant sand and gravel aquifer maps of the Pineo Ridge area were purchased from the Maine Geologic Survey (MGS). Since Pineo Ridge is registered with the state as a critical area, a copy of the Maine State Planning Office Critical Areas Report (1989) was obtained. Harold Borns, a Professor of Geological Sciences, University of Maine, supplied an explanation of the formation of the delta.

The author spent a summer as a hydrologic intern with Jasper Wyman and Son and was actively involved with the WUMP process for nearly two years. This experience has yielded a better understanding of the water resources of the region and the water needs for irrigation.

Estimation of Hydrologic Parameters

To describe a groundwater system, the MODFLOW user must determine a number of hydrologic parameters that dictate how much water enters the groundwater

system and control its movement within it. The parameters required for this study were the recharge rates, hydraulic conductivity, and storage.

Recharge Rates. Inflow of water to a groundwater system is termed recharge. In an unaltered system or a system without a stress placed on it, recharge is that fraction of precipitation that infiltrates the soil and flows downward to the groundwater table, and

Figure 3.1 Site Plan of Study Area. Shaded region delineates approximate boundaries of the kettle hole.

the water that enters the ground from surface-water bodies (Anderson and Woessner, 1992). Since this study evaluates the artificial recharge of groundwater, it should be noted that after calibration, the study area will become an altered system.

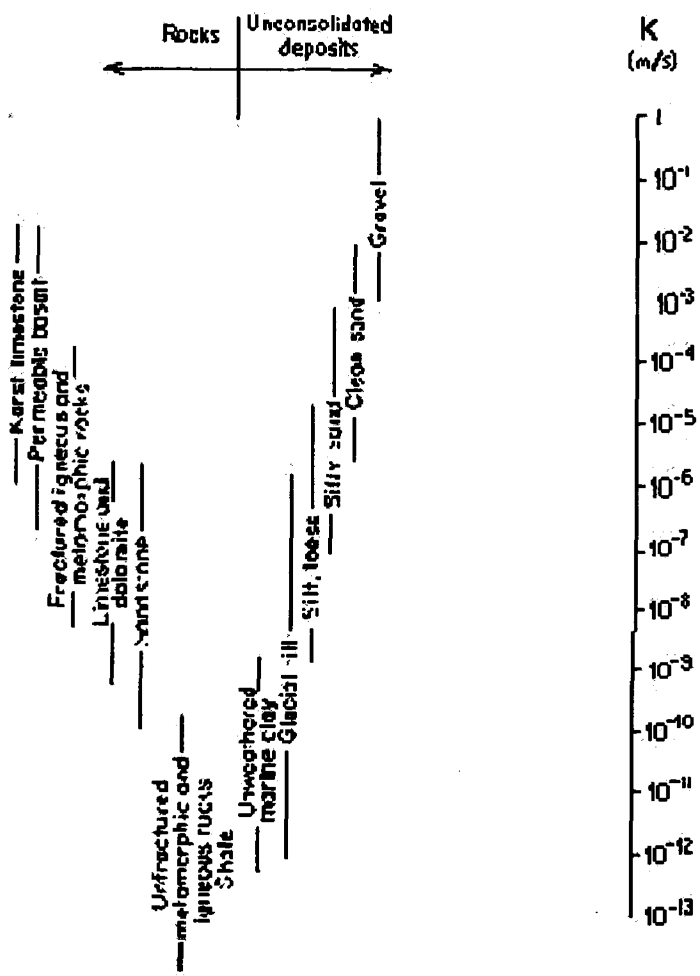
Initial simulations of the model were of the unaltered delta and therefore only focused on recharge from precipitation, which averages about 126 cm/yr (49.7 in/yr) (NRCS, 1996). Horsley and Witten (2001) estimates that on the sand and gravel aquifers, 70 cm/yr (28 in/yr) of precipitation becomes recharge and on the till and clay, 20 cm/yr (8 in/yr) will recharge the groundwater. According to R.G. Gerber, annual recharge rates in glacial outwash sand and gravel range between 50-60% of annual rainfall, and in tills range between 5-15% of total rainfall (R.G. Gerber, 1987; R.G. Gerber, 1996). Since these studies are in agreement, recharge values within these ranges were used for the initial calibration of the model. Finally, recharge to the study area from groundwater inflow must be evaluated. By extending the model boundaries out to constant head sources, i.e. surface-water bodies, and topographic watershed boundaries, the assumption that no groundwater inflow to the system along the boundaries could be made.

Hydraulic conductivity. Hydraulic conductivity, K, is the critical hydraulic property influencing groundwater flow through porous media. Specifically, it is a measure of "the rate of flow of water... through a unit cross-sectional area under a unit hydraulic gradient at the prevailing temperature" (Caswell, 1979). Thousands of measurements of hydraulic conductivity and permeability have been performed in both the laboratory and in the field. From these measurements, formulas relating grain size, sorting, shape,

and porosity to hydraulic conductivity have been developed (Domenico, 1998). Estimations of hydraulic conductivity based on soil texture are available from reference books which were the source of values not acquired from actual field tests (Table 3.1).

Despite the value of these formulas, the best estimates of hydraulic conductivity come from field tests in undisturbed soil. There have been eight wells installed in the study area as well as several exploratory borings. The boring logs (Appendix A) as well as the hydraulic conductivity tests of the wells were provided to this study and used to

Table 3.1 Ranges of Values for Hydraulic Conductivity, K (Freeze and Cherry, 1979).



determine the average hydraulic conductivity across the delta. From boring logs, discussions with Professor Borns, and inspecting the delta, hydraulic conductivity values of the remaining glacial till, lowland silt, clay, fractured bedrock, and the peat deposits were estimated as shown in Table 3.2.

Table 3.2 Hydraulic Conductivity Values of the Sediments of the Pineo Ridge Delta.

Soil/Rock	Hydraulic Conductivity, K	Source
Sand and Gravel	1e-4 m/s (30 ft/day)	Field data
Glacial Till	2.8e-5 m/s (8 ft/day)	Freeze and Cherry, 1979
Lowland Silt	3.5e-6 m/s (1 ft/day)	Freeze and Cherry, 1979
Fractured Bedrock	1.8e-6 m/s (0.5 ft/day)	Freeze and Cherry, 1979
Peat	2.5e-7 m/s (7.1e-2 ft/day)	Check, 2001

Storage. The storage of an aquifer is the volume of water the aquifer contains that can be released either through compression of the aquifer or by gravity drainage. Storage is a function of the specific storage and the specific yield of the aquifer and MODFLOW requires inputs for both of these properties (Anderson and Woessner, 1992).

Specific Storage (Ss). The volume of water that a unit volume of aquifer releases from storage under a unit decline in hydraulic head is known as specific storage (Freeze and Cherry, 1979). This quantity is generally small and dominates groundwater flow in confined aquifers. In an unconfined aquifer such as Pineo Ridge, the specific storage value is insignificant relative to that of the specific yield. For this study the value of 1e-4/m (3e-5/ft) was found to be reasonable (Anderson and Woessner, 1992).

Specific Yield (Sy). Specific yield is the measure of the volume of water released by gravity drainage in response to decline of the water table per unit area of porous material. Although subject to error and difficult to obtain, estimates can be acquired from pump tests (Anderson and Woessner, 1992). For this study, the value used for specific yield was based on charted values (Table 3.3) for sand and gravel and based on Table 3.3 a value of 0.2 was used as an initial estimate (Anderson and Woessner, 1992). However through calibration the value of 0.25 was determined to be more appropriate.

Table 3.3 Ranges of Values of Specific Yield (Sy) (Anderson and Woessner, 1992).

Material	No. of Analysis	Range of Specific Yield, Sy	Arithmetic Mean
Sandstone (fine)	47	0.02-0.40	0.21
Siltstone (medium)	10	0.12-0.41	0.27
Siltstone	13	0.01-0.33	0.12
Sand (fine)	287	0.01-0.46	0.33
Sand (medium)	297	0.16-0.46	0.32
Sand (coarse)	143	0.18-0.43	0.30
Gravel (fine)	33	0.13-0.40	0.28
Gravel (medium)	13	0.17-0.44	0.24
Gravel (coarse)	9	0.13-0.25	0.21
Silt	299	0.01-0.39	0.20
Clay	27	0.01-0.18	0.06
Limestone	32	0-0.36	0.14
Loess	5	0.14-0.22	0.18
Eolian sand	14	0.32-0.47	0.38

Model Calibration

The Pineo Ridge study area (Figure 3.2) was discretized into a 75 X 90 grid. This created 6750 equal sized cells each measuring 45.7 m X 45.7 m (150 ft X 150 ft). An average ground-surface elevation was assigned to each cell in the model. To accomplish this, the digital elevation model (DEM) for the Schoodic Lake Quadrangle was downloaded from the USGS website (USGS, 2000). The computer software, ERDAS Imagine, was used to calculate the ground-surface elevations and an output file of X,Y,Z coordinates was generated. This file was imported into Visual MODFLOW and the surface topography was interpolated from it (Figure 3.3). The domain was divided into the number of layers needed to represent the profile of the delta's deposits. After studying the maps from MGS, the well and boring logs, and talking with Dr. Borns, it was determined that sufficient data did not exist to warrant more than three layers, with the bottom being a fractured bedrock layer.

Recharge rates were established based on 25-year record of precipitation from the University of Maine's Blueberry Hill Farm located in Jonesboro, ME (Table 3.4). Located approximately 26 km (16 miles) east-southeast of the study area, Jonesboro is the closest and most complete weather record for the study area. Values for recharge rates were assigned to the top active layer of the model and hydraulic conductivity, and storativity values were assigned, as appropriate, to all three layers. To account for the rivers and ponds within the study area, the boundary of each were set as a constant head sources with an elevation equal to its average summer elevation. Finally, drains were placed along the southern and northern margins of the delta to simulate springs. This

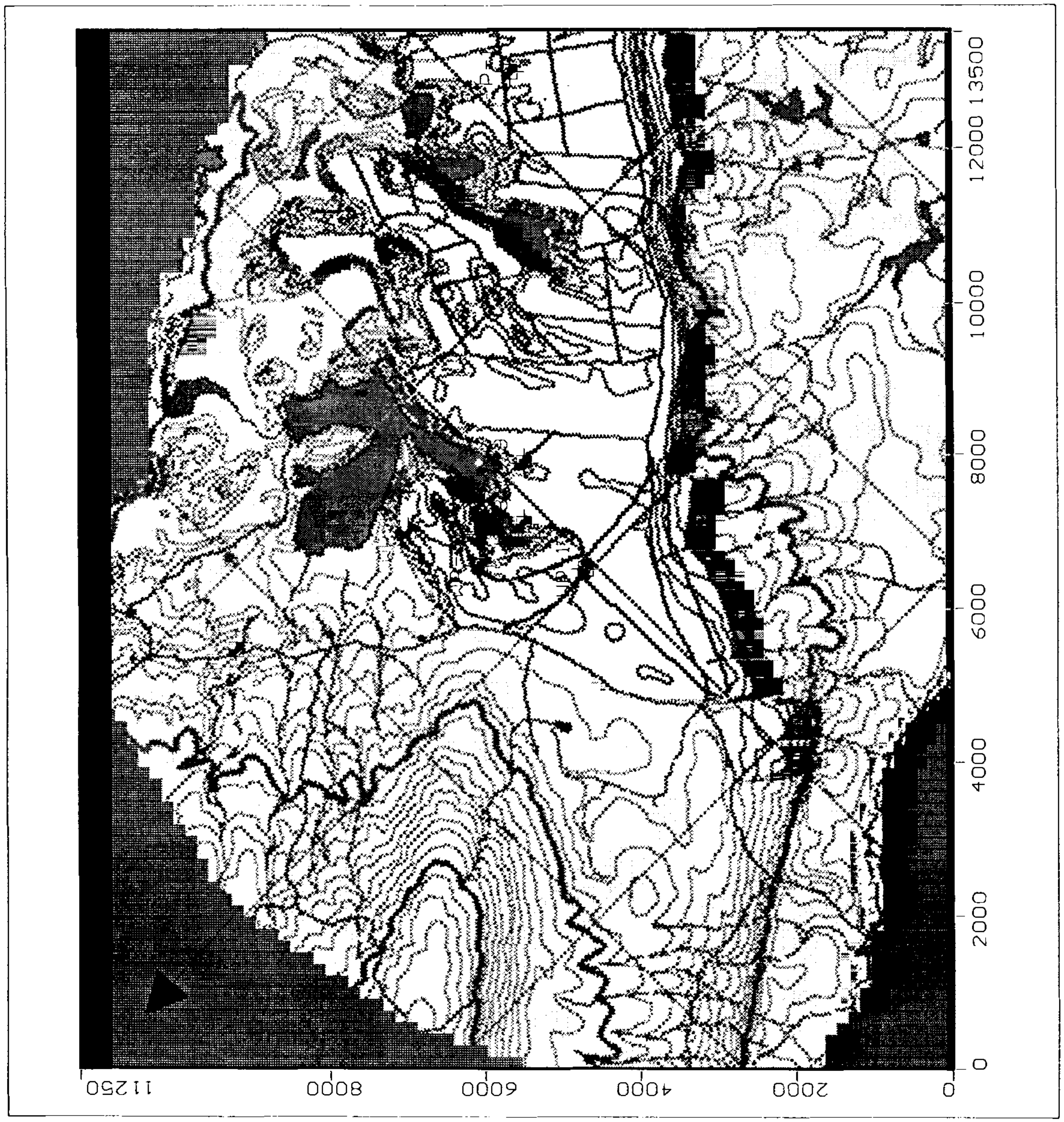


Figure 3.2 USGS Topographic Map of Study Area. Image was used as the background for Visual MODFLOW. For modeling purposes, study area was rotated to allow cross-sections to run parallel with or intersect perpendicularly to groundwater flow. (Units are feet)

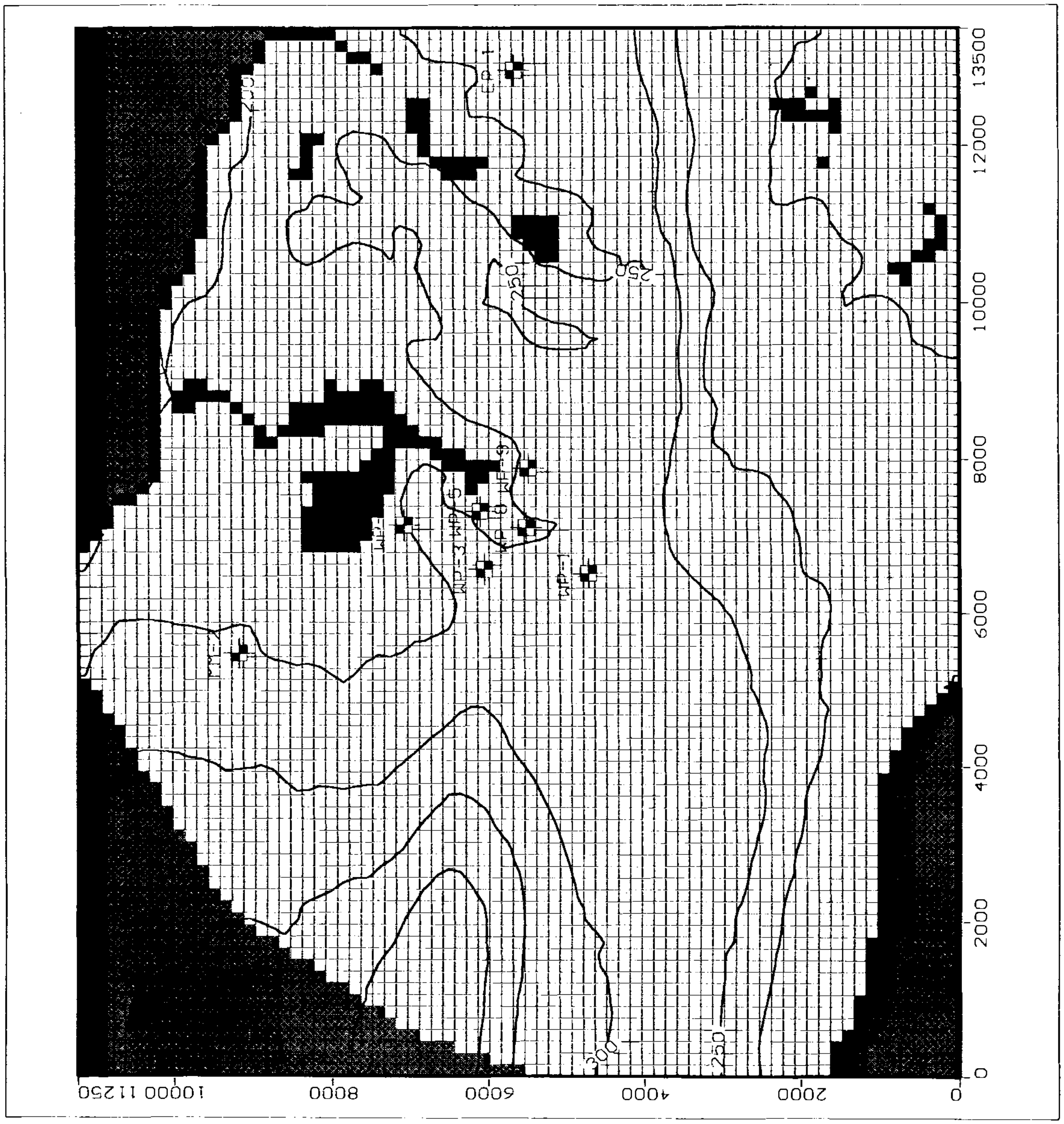


Figure 3.3 Topographic Map of the Study Area. Generated by Visual MODFLOW from DEM data (contour interval of 50 ft). ■denotes locations of surface-water bodies, shaded cells along outside boundaries are inactive cells. (Units are feet)

placement allowed excess water to be released from the aquifer when the calculated groundwater elevation exceeds the drain elevation, as previously described.

Table 3.4 Average Monthly Precipitation Data for Jonesboro, ME (1975-2000).

Month	Average Precipitation (mm)	Month	Average Precipitation (mm)
January	120.17	July	99.14
February	94.04	August	89.85
March	103.78	September	104.24
April	106.26	October	96.32
May	122.02	November	115.69
June	92.00	December	122.84
	Total	1266.35 mm	

Calibration. The purpose of calibration is to establish a model that can reproduce measured heads and flows. Calibration is often a trial and error process of adjusting parameters, generally hydraulic conductivity and recharge, until simulated hydraulic heads and flow rates approximate observed values (Anderson and Woessner, 1992). Model calibration and validation on the study area was achieved through several steps as shown in Table 3.5.

Steady-State Calibration. To calibrate the model, runs were simulated under steady-state conditions to match the calculated water-table elevations to that of the average observed water-table elevations for the summer of 2000 in the eight wells throughout the study area. Although the Water Year 2000 (October 1, 1999 – September 30, 2000) for Jonesboro, ME was slightly dryer than the 25-yr average

(Table 3.6), the difference is not substantial enough to have a significant impact on this study.

Table 3.5 Simulations Performed for Model Calibration and Validation.

Model Run	Purpose	Parameter(s) Determined
Steady State	Initial model calibration through adustment of the hydraulic conductivity values and recharge rates of the study area.	Hydraulic conductivity and recharge rates.
Transient	Model calibration through adjustment of the recharge rates over the study area and the storativity values of the delta.	Transient recharge rates, specific yield (Sy).
Field Test	Validation of the models capacity to accurately predict unnatural stresses placed on the study area.	Specific yield (Sy).

Table 3.6 Precipitation Record for Water Year 2000, Jonesboro, ME.

Month	Average Monthly Precipitation (mm)	Month	Average Monthly Precipitation (mm)
October 1999	93.22	April 2000	135.38
November 1999	122.17	May 2000	79.5
December 1999	128.52	June 2000	53.34
January 2000	123.44	July 2000	55.37
February 2000	93.47	August 2000	55.55
March 2000	118.36	September 2000	86.11
Total 1144.43 mm			

As previously stated, specific yield values are difficult to obtain and therefore the desire to eliminate specific yield as a variable coupled with the lack of water

elevation data from late fall through early spring dictated that the initial calibration be made under steady-state conditions. Several runs, each involving adjustments of recharge rates and hydraulic conductivity, were made until a final calibration was achieved. Once calibrated, the calculated hydraulic heads were used as initial heads for all transient simulations.

Transient Calibration. Transient simulations were performed to acquire transient recharge rates and to refine the storativity values of the aquifer. In unconfined aquifers, the storativity is closely approximated by the specific yield (Sy) of the sediments. All transient model runs followed the USGS water year, beginning on October 1st (day 1) and end on September 30th (day 365). Transient runs in this study were performed with a time step of 1 day and with the time steps assembled into 8 stress periods corresponding to the times of the year that are significant to this study. Stress period 1 was used to account for fall and winter recharge. Stress period 2 represents the time of year when the ground is no longer frozen and an ample supply of recharge water is available in ponds and rivers, therefore ARG would be applied to the model. During stress period 3, no stresses were to be placed on the aquifer. Stress period 4 corresponds to the time of the blueberry-growing season when irrigation is generally needed and therefore groundwater pumping will be applied to the model. Stress periods 5 through 8 will be used to simulate an ARG field experiment that was performed at the study site. All transient runs and case studies were performed with the stress periods and corresponding recharge values as delineated in Table 3.7 unless otherwise noted.

Table 3.7 Stress Periods and Corresponding Recharges for All Transient Simulations.

			Total Recharge (mm) (Yearly Total)			
			Sand/Grav	Till/Sand	Till	Peat
Stress Period	Start Day	End Day	(644.79)	(257.91)	(193.43)	(773.74)
1	1 (10/1)	179 (3/28)	493.61	197.44	148.08	592.33
2	180 (3/29)	224 (5/12)	79.00	31.60	23.70	94.79
3	225 (5/11)	269 (6/26)	59.50	23.80	17.85	71.40
4	270 (6/27)	349 (9/14)	0.00	0.00	0.00	0.00
5	350 (9/15)	353 (9/18)	2.90	1.16	0.87	3.48
6	354 (9/19)	357 (9/22)	3.25	1.30	0.97	3.90
7	358 (9/23)	361 (9/26)	3.67	1.47	1.10	4.41
8	362 (9/27)	365 (9/30)	2.86	1.14	0.86	3.43

<u>Field Test</u>. In September 2000 (stress period 5) a field test (Appendix C) to more accurately define the storage properties and hydraulic conductivity of the aquifer was performed. For four days water was pumped into a kettle hole from the nearby pond (Figure 3.1). The hydraulic head in the aquifer was monitored in six nearby wells, all located within 300 m (1000 ft) of the kettle hole. Although the rates and the duration of the pumping were varied, the total water pumped was approximately equal to 1 m (3.3 ft) of rainfall over the bottom, approximately 1 ha (2.5 acres) in size, of the kettle hole's basal area. Other data determined from this field test were the approximate surface topography contours of the first three feet of depth of the kettle hole, and the infiltration rate of the aquifer.

It should be noted that the bottom of the kettle hole is lined with peat. The low hydraulic conductivity of the peat, 2.5e-7 m/s (0.071 ft/day), relative to that of the

surrounding sand and gravel, 1.3e-4 m/s (35 ft/day) restricted the flow of the recharge water mostly to horizontal flow through the sides of the kettle hole.

To validate the capability of the model to simulate unnaturally occurring stresses on the study area, the model was run to simulate the field test. The specific yield of the delta was adjusted until a reasonable calibration to the observed head values was achieved. The calibrated value for specific yield, 0.25, was used for all other runs in this study unless otherwise stated.

Application of ARG to the Study Area

Before attempting an evaluation of the hydrogeologic parameters governing ARG sites, a model run simulating the artificial recharge of groundwater in the study area was performed. The purpose of this run was to determine realistic ranges of hydrogeologic parameters for the sand and gravel aquifers found in eastern Maine.

For this model run, the parameters determined from the transient calibration and the field test simulation were applied to the study area. From day 180 to day 225 (stress period 2), 28 L/s (450 gpm) of recharge was applied to each of the 9 cells representing the kettle hole. The rate of 28 L/s per cell or 252 L/s total was acquired through trial and error and represents the rate that would create the maximum stage in the pond dictated by the topography of the kettle hole. From day 270 to day 350 (stress period 4), groundwater was pumped from the 6 wells surrounding the kettle hole. In the model, the wells were conditioned to only allow the water table to be lowered 30 cm (1

ft) below that observed in August of 2000. The pumping rates of the wells were increased in increments of 1.6 L/s (25 gpm) until the maximum rate was achieved.

From this model run, it was apparent that a large quality of the recharged water was migrating in a southeasterly direction down the delta and was therefore not recoverable with the existing wells. An additional well, WP-10, was added to the model to capture the "lost" recharged water. The location of the WP-10 is shown in Figure 3.4.

Evaluation of the Hydrogeologic Parameters Governing the Artificial Recharge of Groundwater

An evaluation of the hydraulic parameters that dominate the artificial recharge of groundwater was performed. The purpose of the evaluation was to draw relationships between a parameter and its relevance to the success or failure of an ARG site. The relationships will be used to develop guidelines for evaluating potential artificial recharge sites. The parameters that were evaluated are hydraulic conductivity, specific yield, and the distance to a nearby surface-water body (Table 3.8). The base model used for all case studies was that obtained from the second transient calibration and the field test validation model runs.

For all model runs, the recharge rate applied during stress period 2 to the cells representing the kettle hole was fixed at 28 L/s (450 gpm) and the peat layer in the bottom of the kettle hole was replaced with sand and gravel to increase vertical flow in the groundwater recharge. In all model runs the pumping rates of the 7 wells (six

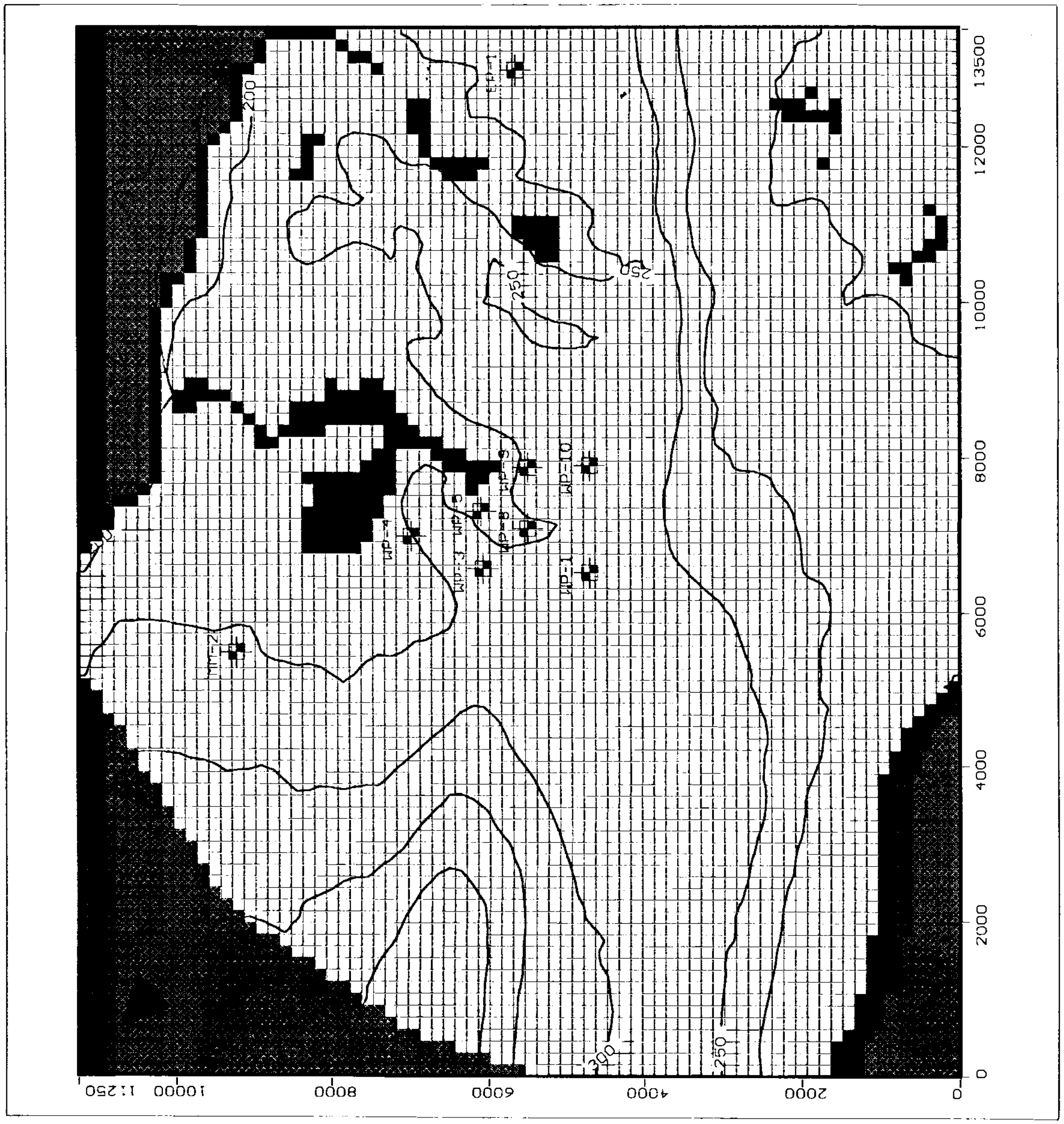


Figure 3.4 Study Area with the Addition of WP-10. (Units are in feet)

Table 3.8 Evaluation of Hydrogeologic Parameters.

Case Number	Relationship Established:	Parameter Determined
1	The hydraulic conductivity of the aquifer and its capacity to form and maintain a groundwater mound.	Ideal hydraulic conductivity of an ARG site.
2	The specific yield of the delta and the recoverability through pumping of the recharged water.	Ideal specific yield for ARG.
3	The maximum groundwater mound and its distance from a nearby surface-water body.	The effect that linear distance to a surface-water body from a recharge site has on groundwater mound building and retention.

existing wells and WP-10) were set equal to each other and collectively increased in increments of 1.6 L/s (25 gpm).

Case 1: Hydraulic Conductivity. The hydraulic conductivity of the delta was varied in increments of 1.8e-5 m/s (5 ft/day) to determine the value that would not only allow a significant water-table mound to be built, but would also maintain the largest proportion of the mound through the end of stress period 4. Too small of a hydraulic conductivity would inhibit water entry and movement and too large of a hydraulic conductivity would allow rapid dissipation of the water stored in the aquifer. For this case, the specific yield of the delta was set to the value (0.25) obtained from the field test calibration, and the distance from the kettle hole to nearby surface-water body remained constant. Since the quantity of water recharged remained constant for all model runs, the ideal hydraulic

conductivity value was that which allowed the recharge water to infiltrate into and be retained in the aquifer, and then allowed it to be removed through pumping.

Case 2: Specific Yield. Within the typical range of sand and gravel aquifers (Figure 3.4), the specific yield of the delta was increased by increments of 0.05 until the value that allowed the greatest percentage of the recharge water to be removed by pumping was determined. A low value of specific yield would inhibit removal by pumping by creating a large cone of depression and therefore dewatering of the aquifer. For this case, the values for hydraulic conductivity were set to those obtained from the transient calibration (Table 3.2), and the distance from the kettle hole to nearby surface-water body remained constant. The quantity of water recharged remained constant for all model runs, therefore the ideal specific yield was that which allowed the largest percentage of the recharge water to be removed through pumping.

Case 3: Distance to a Surface-Water Body. Since the kettle hole being evaluated is adjacent to a large pond, some difficulty was experienced in developing a groundwater mound and retaining it. As groundwater elevations increased, the groundwater flow would "short-circuit" into the pond. To counter this in the simulations, the southwestern lobe of the pond was moved away from the kettle hole and replaced with native materials, effectively placing 300 m (1000 ft) of sand and gravel between the kettle hole and the pond (Figure 3.5). Four simulations, each positioning the surface-water feature approximately 60 m (200 ft) farther away from the kettle hole than the previous simulation, were run. For all model runs, the values of hydraulic conductivity

obtained from the transient calibration were used (Table 3.2) and the specific yield (0.25) obtained from the field test validation was used.

Ideal Site Evaluation

Upon the completion of cases 1 through 3, the hydraulic properties of an ideal groundwater recharge site were identified. For this simulation, the values of the parameters that yielded the most favorable results for groundwater storage were applied to one simulation; hydraulic conductivity value of 1.4e-4 m/s (40 ft/day), a specific yield value of 0.40, and a distance of 300 m (1000 ft) between the kettle hole and the pond). The recharge rate applied to the cells of the kettle hole during stress period 2 was increased until the maximum groundwater mound was achieved and a pond was maintained in the kettle hole. The model was run and the outputs evaluated. Pumping wells were added to the system as appropriate and the model was run again. The pumping wells only operated during stress period 4 (day 270 to day 350) and pumping rates were increased until the groundwater conditions returned to those observed during August of 2000 in the unaltered aquifer.

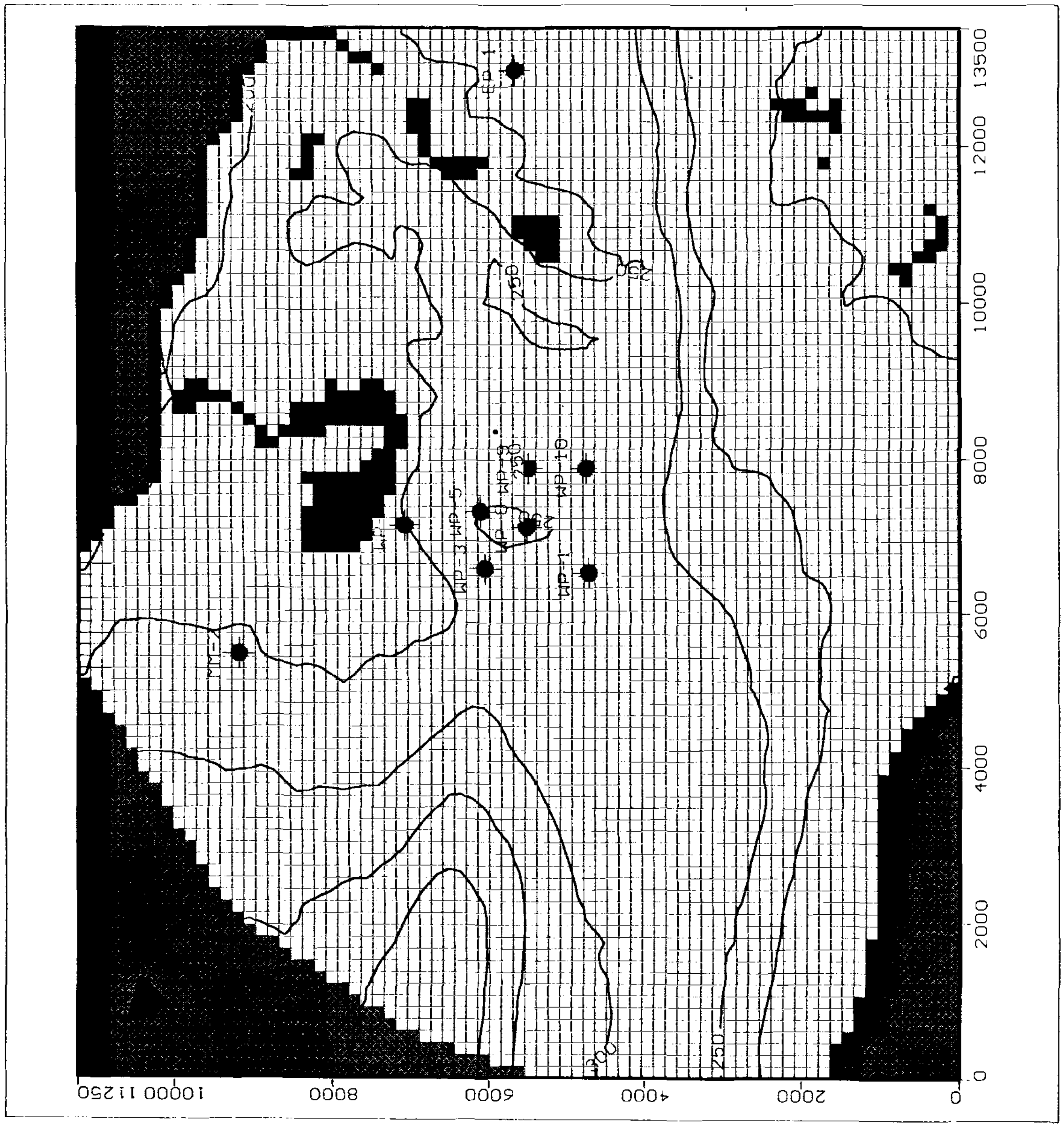


Figure 3.5 Topographic Map of Study Area for Case 3. A portion of the adjacent surface-water body has been replaced with aquifer, effectively placing approximately 300 m (1000 ft) of aquifer between the nearby pond and kettle hole.

Chapter 4

RESULTS AND DISCUSSION

Model Calibration

The model must first demonstrate a capacity to simulate conditions that are naturally occurring in order to establish confidence in its ability to accurately simulate conditions that are not naturally occurring. The calibration of this groundwater model was performed in three steps: steady-state calibration, transient calibration, and calibration to the field test.

Steady-State Calibration

The model was run in steady-state conditions under the average recharge rates (Appendix. E). After calibration, hydraulic conductivity values for the sand and gravel of the delta ranged from 1.3e-4 m/s (35 ft/day) to 1.9e-4 m/s (50 ft/day) and for the till, which is rather permeable, a hydraulic conductivity of 1.9e-5 m/s (5 ft/day) was determined. Recharge rates and conductance terms for the drains (springs) were adjusted until the calculated groundwater contour map (Figure 4.1) approximated the groundwater contour map created from the average water levels in the wells and surface waters within the study area for the summer of 2000. In regions at the toe of the delta, difficulty was experienced in trying to decrease the calculated water table to elevations below that of the surface elevations. The conductance and the elevations of the springs

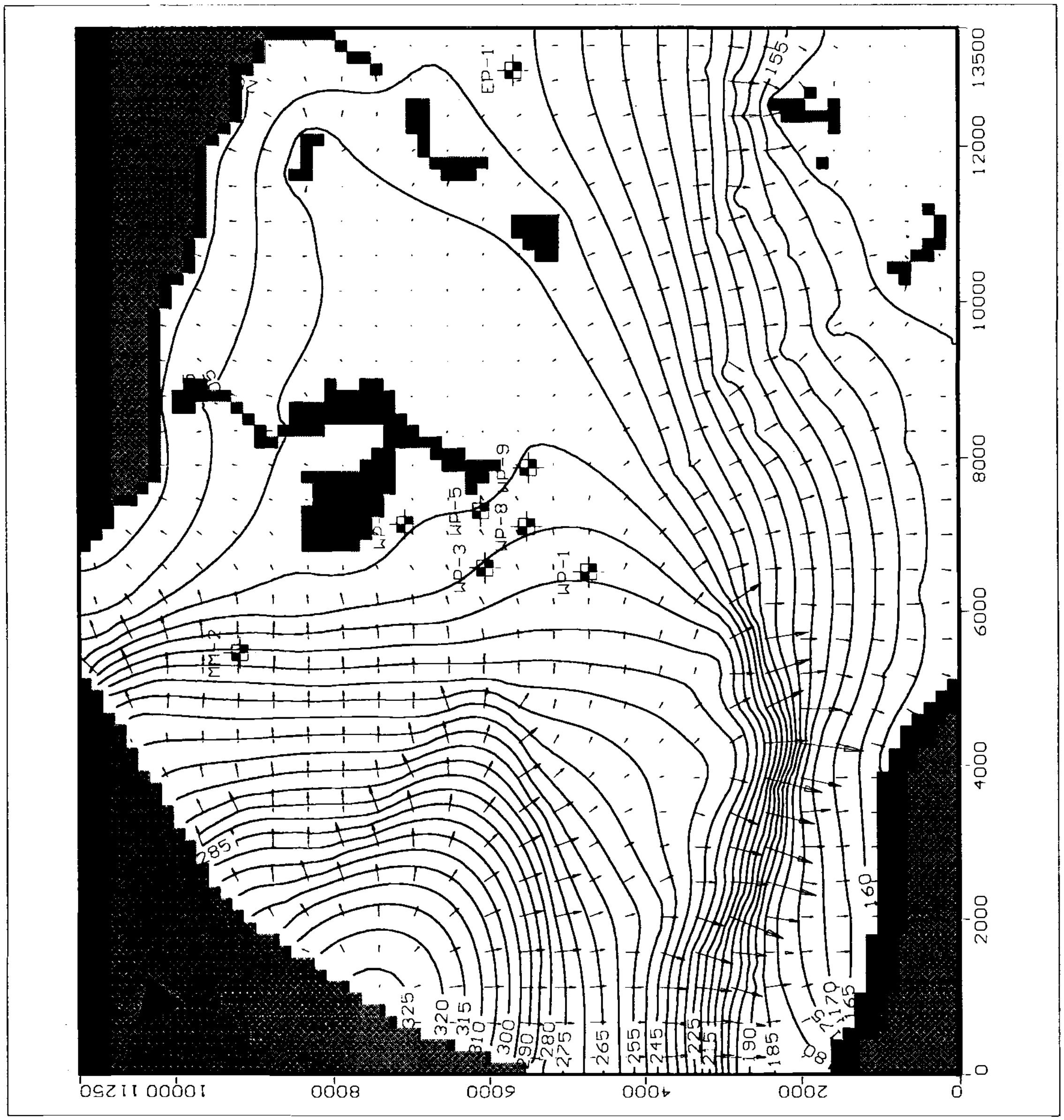


Figure 4.1 Groundwater Contour Map for Steady-State Calibration. Contour interval is 5 feet (all units are in feet) and arrows indicate relative magnitude of groundwater velocity.

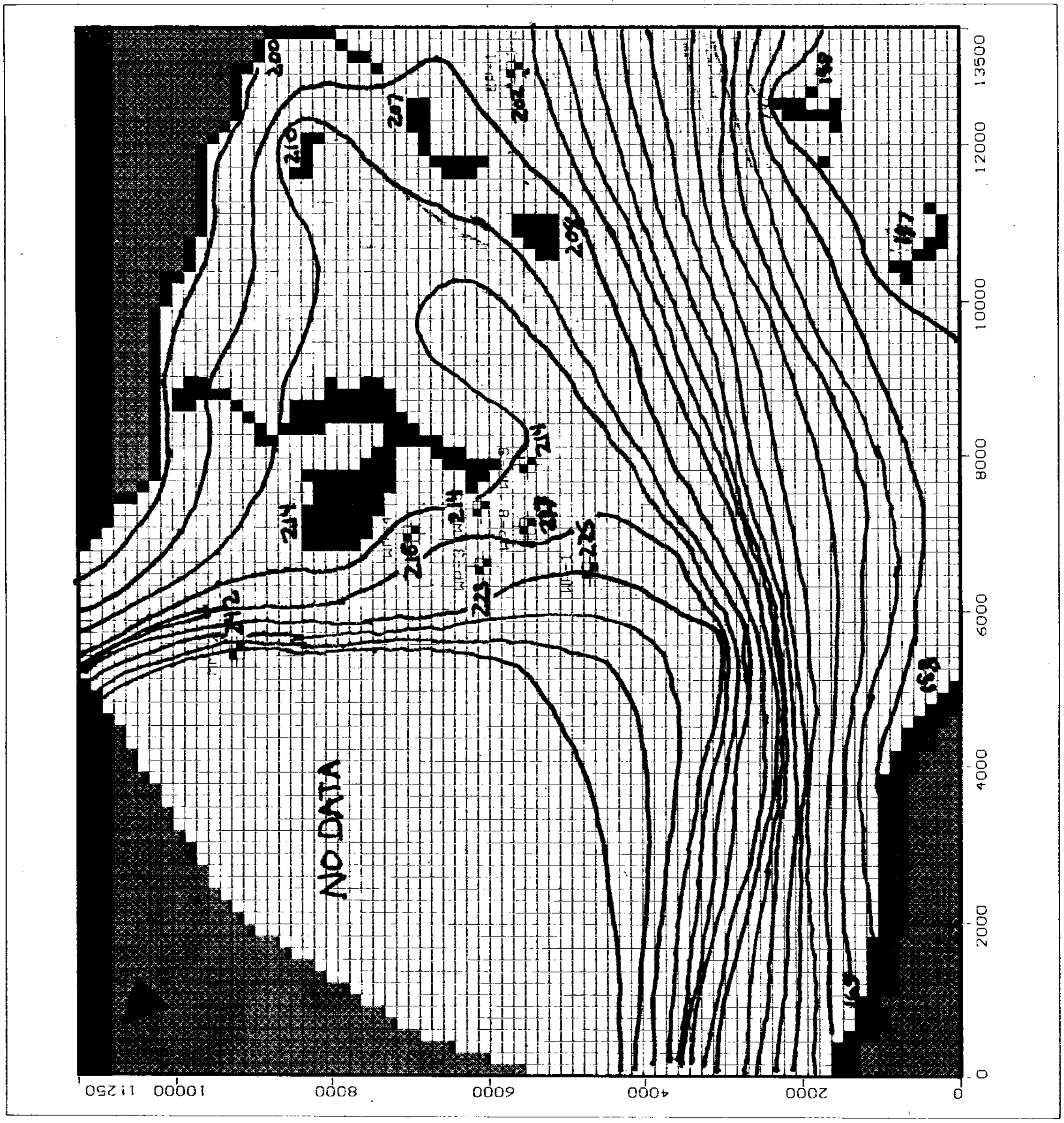


Figure 4.2 Groundwater Contour Map Observed during Summer 2000. Generated from the average water level data gathered from the wells and surface-water bodies during summer 2000. Contour interval is 5 feet (all units are in feet).

(drains) were adjusted until the groundwater elevations were decreased to a reasonable height. It should be noted that the spring conductance terms were determined during the calibration process and are not from field data.

The water elevations observed during the summer of 2000 were plotted against those calculated by Visual MODFLOW and a straight-line with 1:1 slope was drawn (Figure 4.3). With the exception of the point having the largest observed head (monitoring well MM-2), all points fell within the 95% confidence interval. It should be noted that the surface elevation of MM-2 was not determined by survey, but rather by a global positioning system (GPS) with a confidence interval of +/- 1.6 m (+/- 5 ft). Also, MM-2 is not on the delta and is not going to be influenced or be an influence on this study of ARG.

Transient Calibration

The transient calibration was performed in two steps. The first (Appendix E) used the average recharge rates, the springs, and the hydraulic conductivity from the steady calibration. This allowed the focus to be placed completely on defining the specific yield (Sy), of the delta (Figure 4.4). Once this calibration was achieved, the second transient calibration (Appendix E) was performed (Figures 4.5, 4.6, and 4.7). For this calibration the recharge rates were adjusted to more accurately represent the seasonal changes experienced in eastern Maine (Table 3.8).

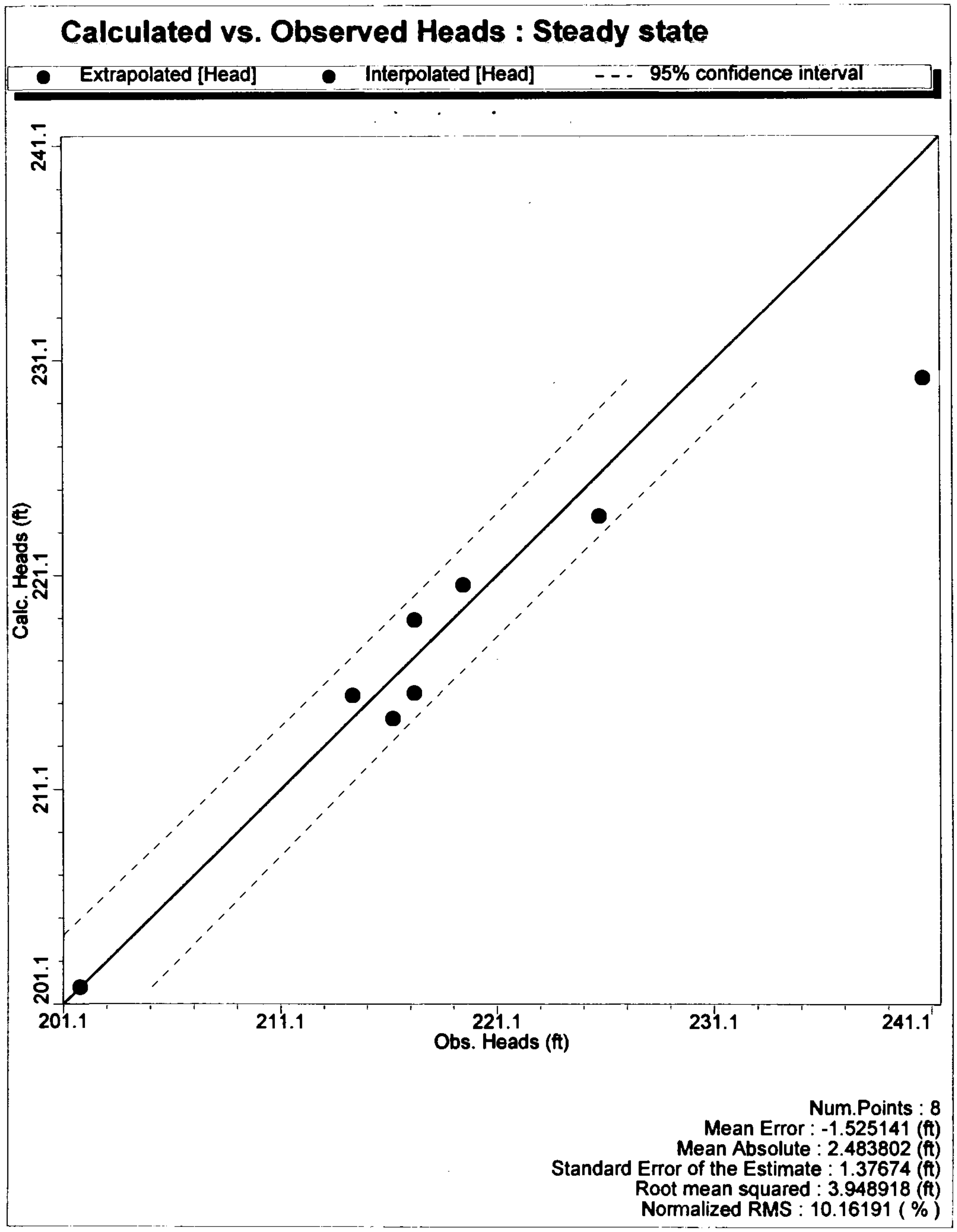


Figure 4.3 Model Calibration Plot for Steady-State Calibration. Calculated vs. Observed Heads. Points that lie on the line with slope of 1:1 are in "perfect" agreement.

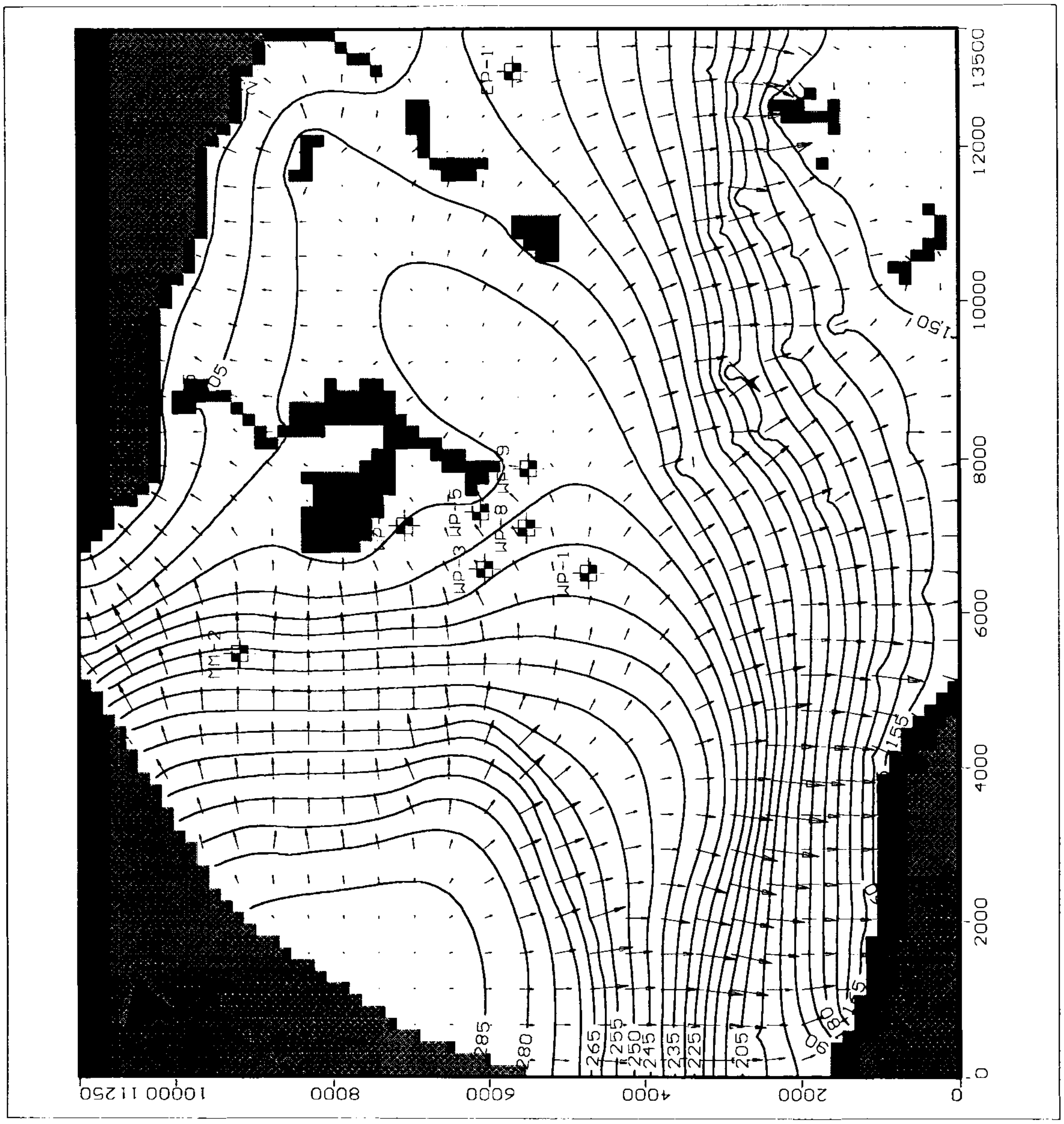


Figure 4.4 Groundwater Contour Map - Transient Calibration, Average. Results calculated during transient calibration of model using average water level data from summer 2000. Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity.

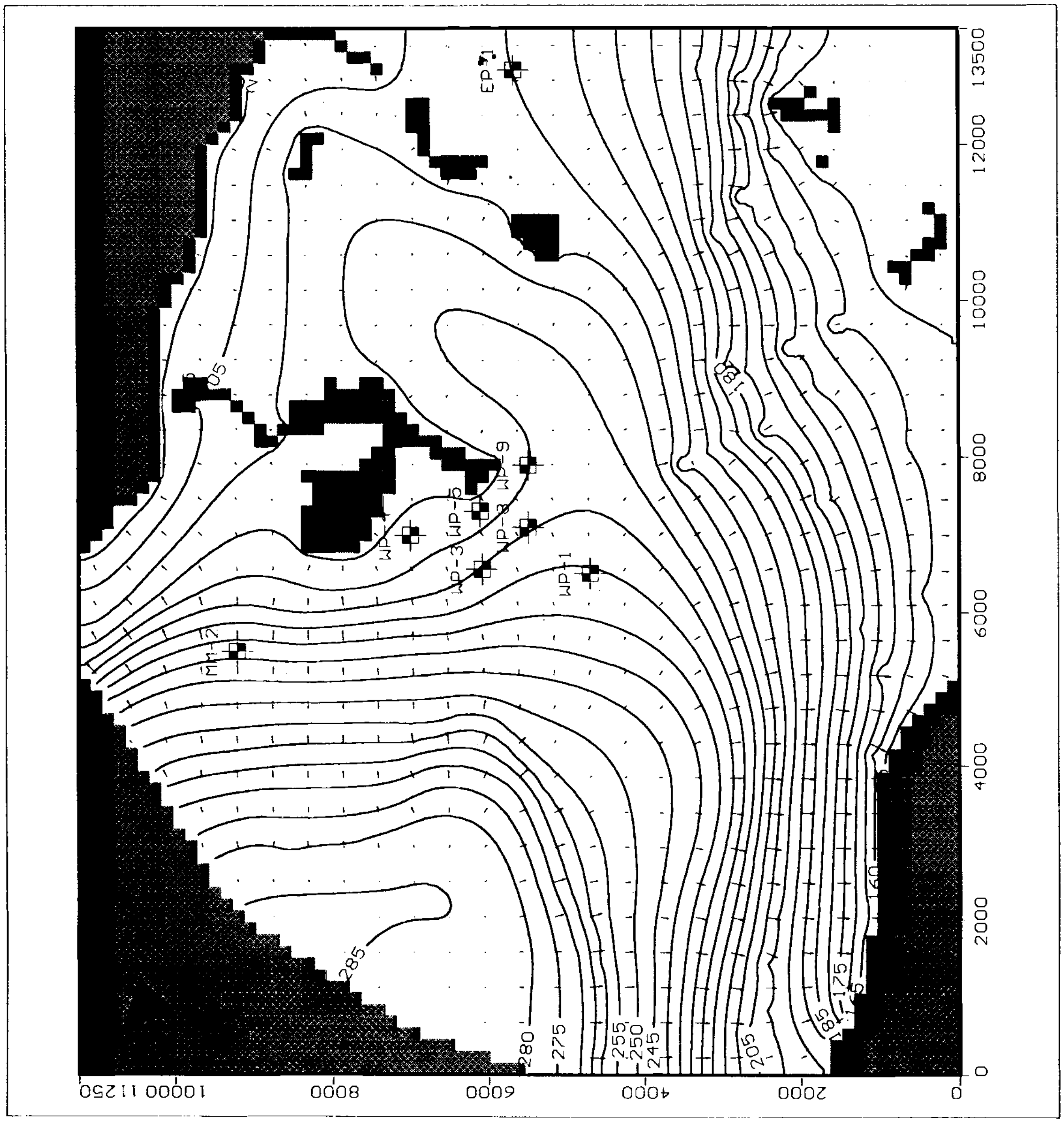


Figure 4.5 Groundwater Contour Map - Transient Calibration, Stress Period 2. Results calculated during transient calibration of model using water level data from summer 2000. Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity.

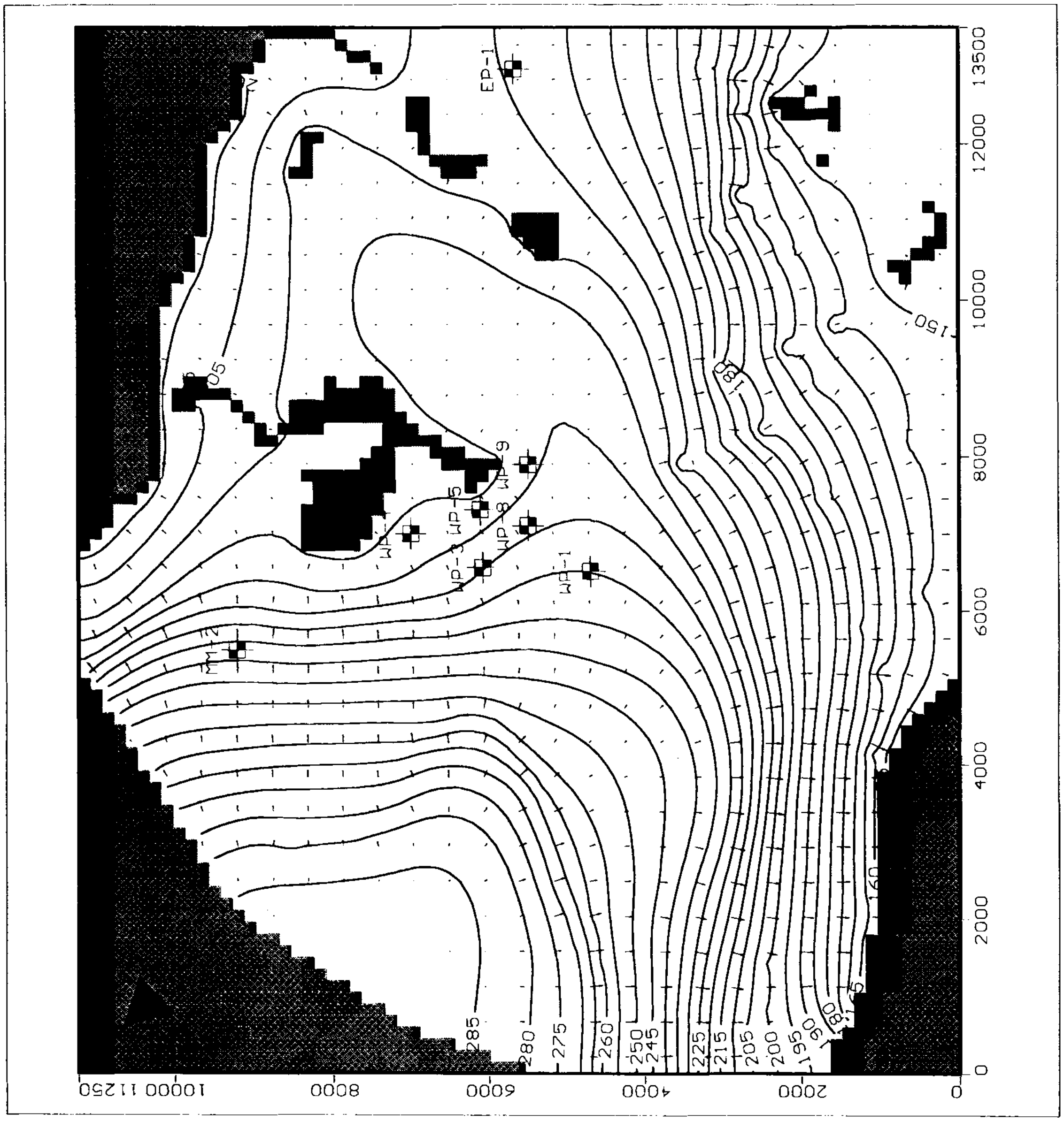


Figure 4.6 Groundwater Contour Map - Transient Calibration, Stress Period 3. Results calculated during transient calibration of model using water level data from summer 2000. Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity.

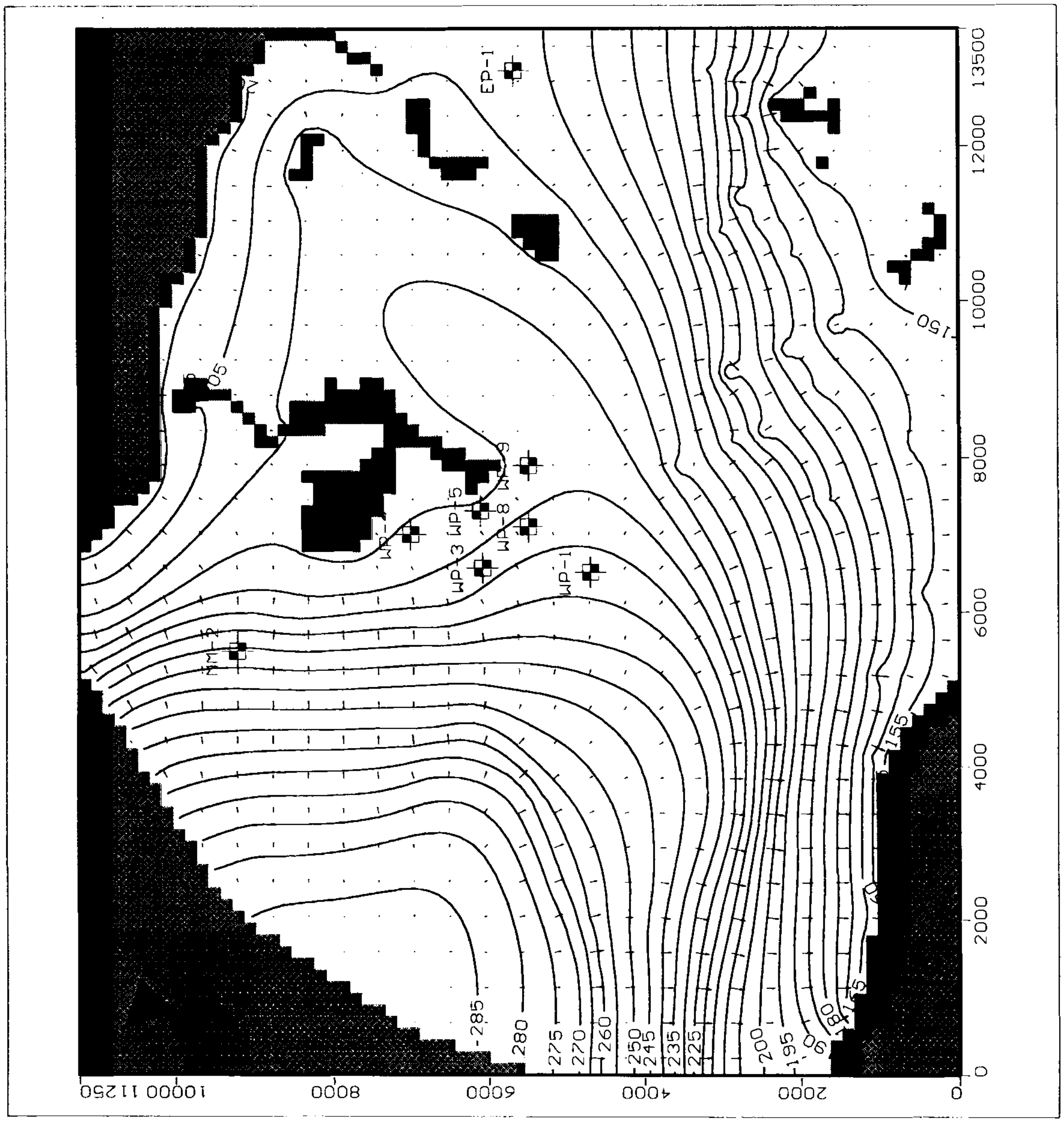


Figure 4.7 Groundwater Contour Map - Transient Calibration, Stress Period 4. Results calculated during transient calibration of model using average water level data from summer 2000. Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity.

As a check for model calibration, the observed groundwater levels in the wells were plotted against the calculated groundwater levels in the wells (Figure 4.8). This plot confirmed the model's capability to illustrate trends in the groundwater cycle.

Neither of the two transient calibrations required any adjustment of the values of hydraulic conductivity or coefficients of discharge for the springs. The calibrated value for the specific yield of the delta was determined to be 0.25. Generally, changes in the recharge rates had a greater effect on changes in the water table during long stress periods whereas the specific yield affected the rate at which the water levels changed.

Field Test Calibration

The final calibration of the model was a simulation of the field test carried out in September of 2000 (Figures 4.9, 4.10, 4.11 and 4.12). As described in Chapter 3, the field test placed an unnatural stress on the groundwater system by flooding the kettle hole with water for a period of four days. This rapid flooding of the kettle hole was the equivalent of 8400 cm/yr (3300 in/yr) of rainfall, but the calibrated recharge rate of 7500 cm/yr (2950 in/yr) was found to most accurately represent the observed reaction of the groundwater system. This 11% discrepancy is most likely a combined result of the following factors, however the peat liner in the kettle hole is assumed to be the most influencing of the four factors:

1. Peat in bottom of kettle hole absorbs and retains a large quantity of water during the initial stages of the field test.

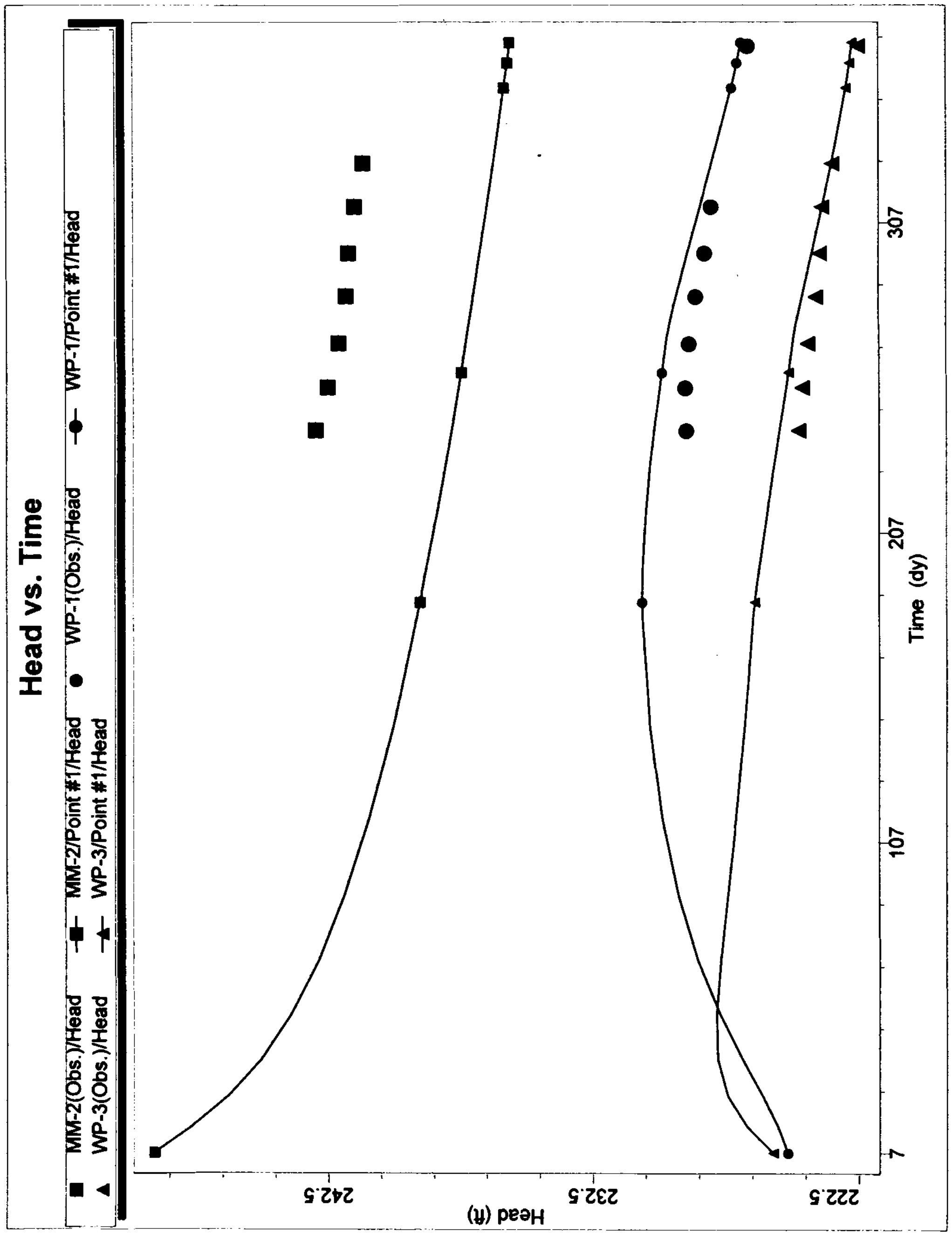


Figure 4.8 Head vs. Time. Observed water levels plotted against calculated water levels over time to demonstrate model capacity to simulate groundwater trends.

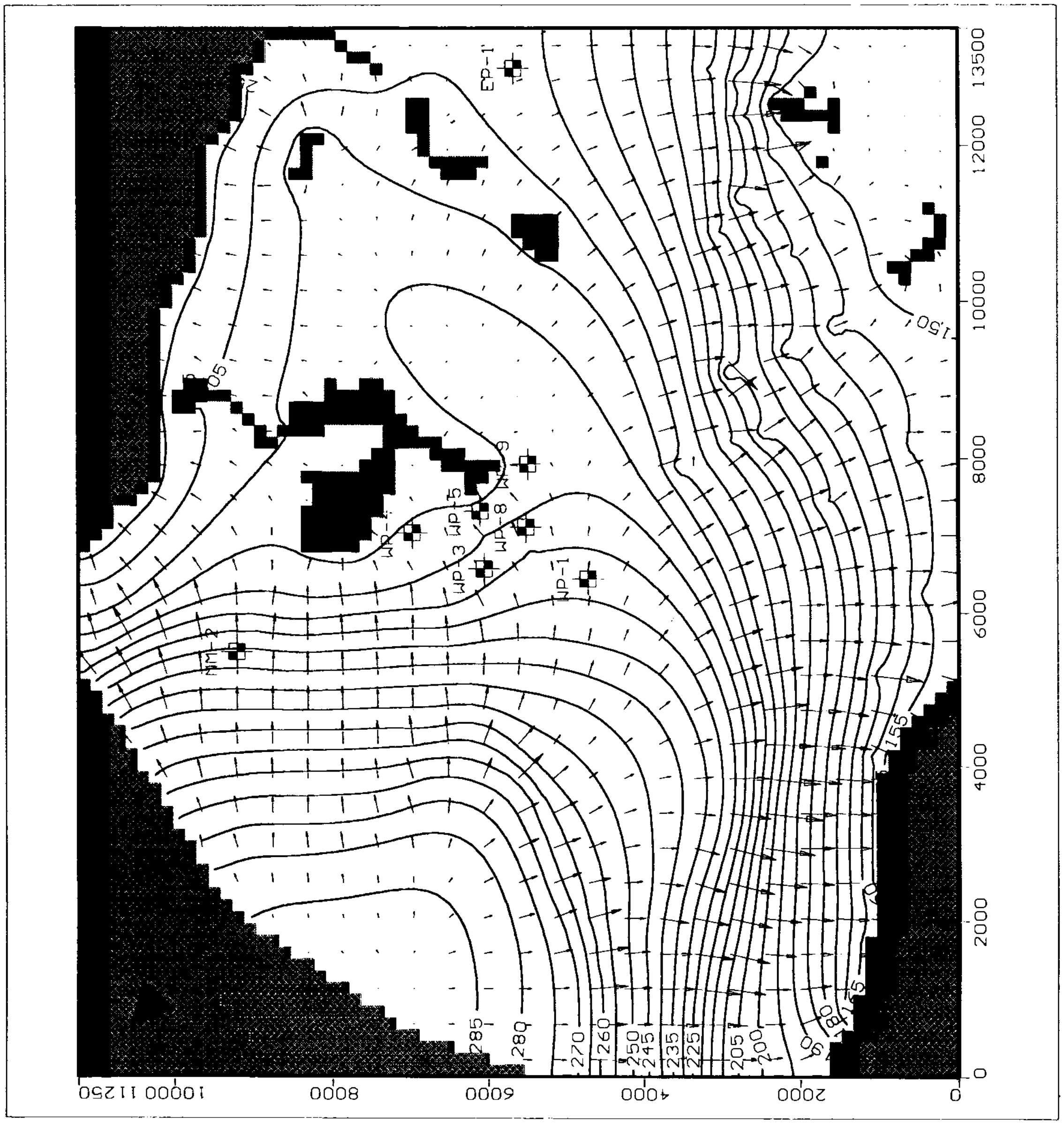


Figure 4.9 Groundwater Contour Map - Field Test, Stress Period 5. Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity. Note slight deflections in contour lines (220 ft and 225 ft) in the kettle hole.

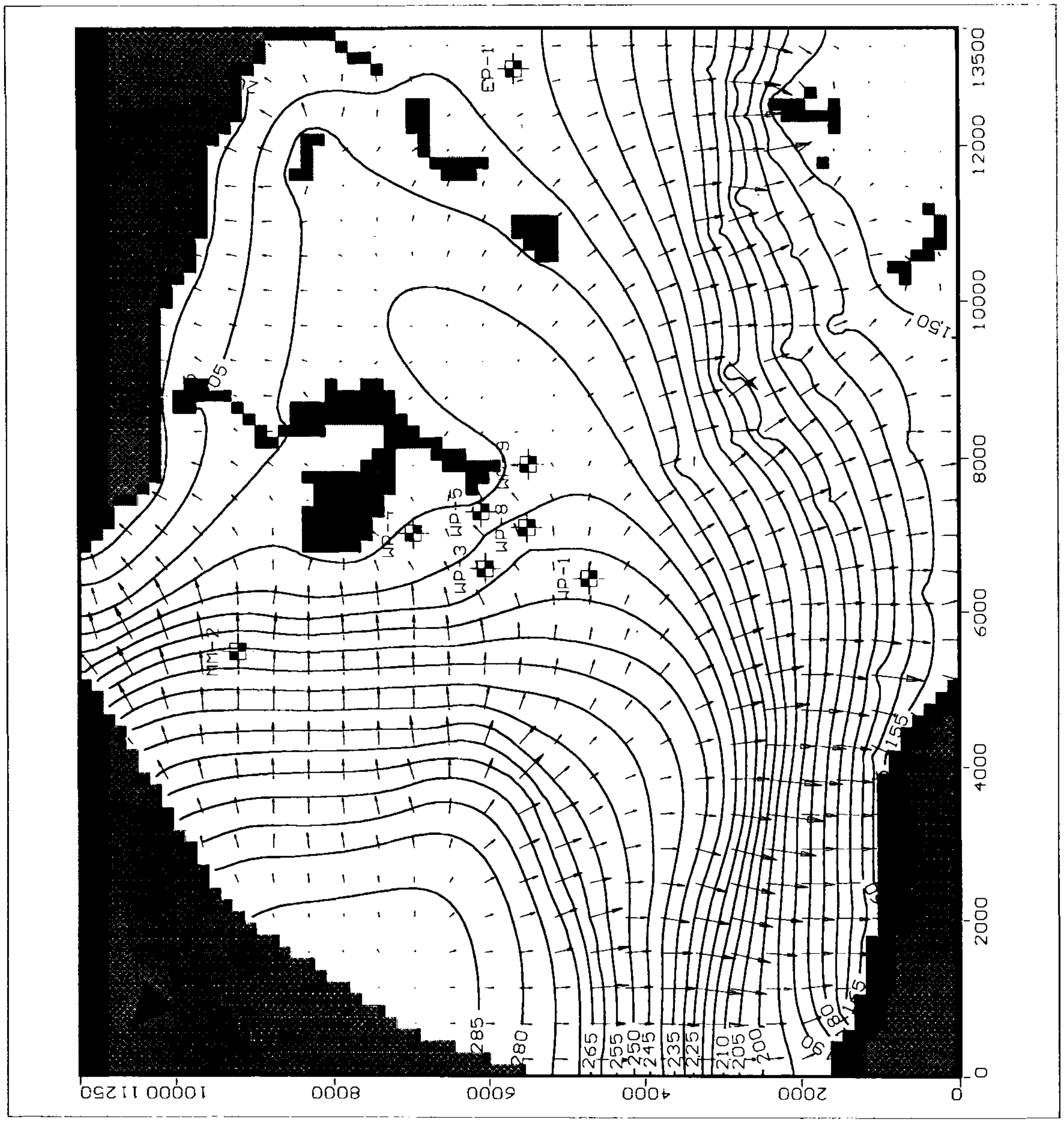


Figure 4.10 Groundwater Contour Map - Field Test, Stress Period 6. Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity. Note slight deflections in contour lines (220 ft and 225 ft) in the kettle hole.

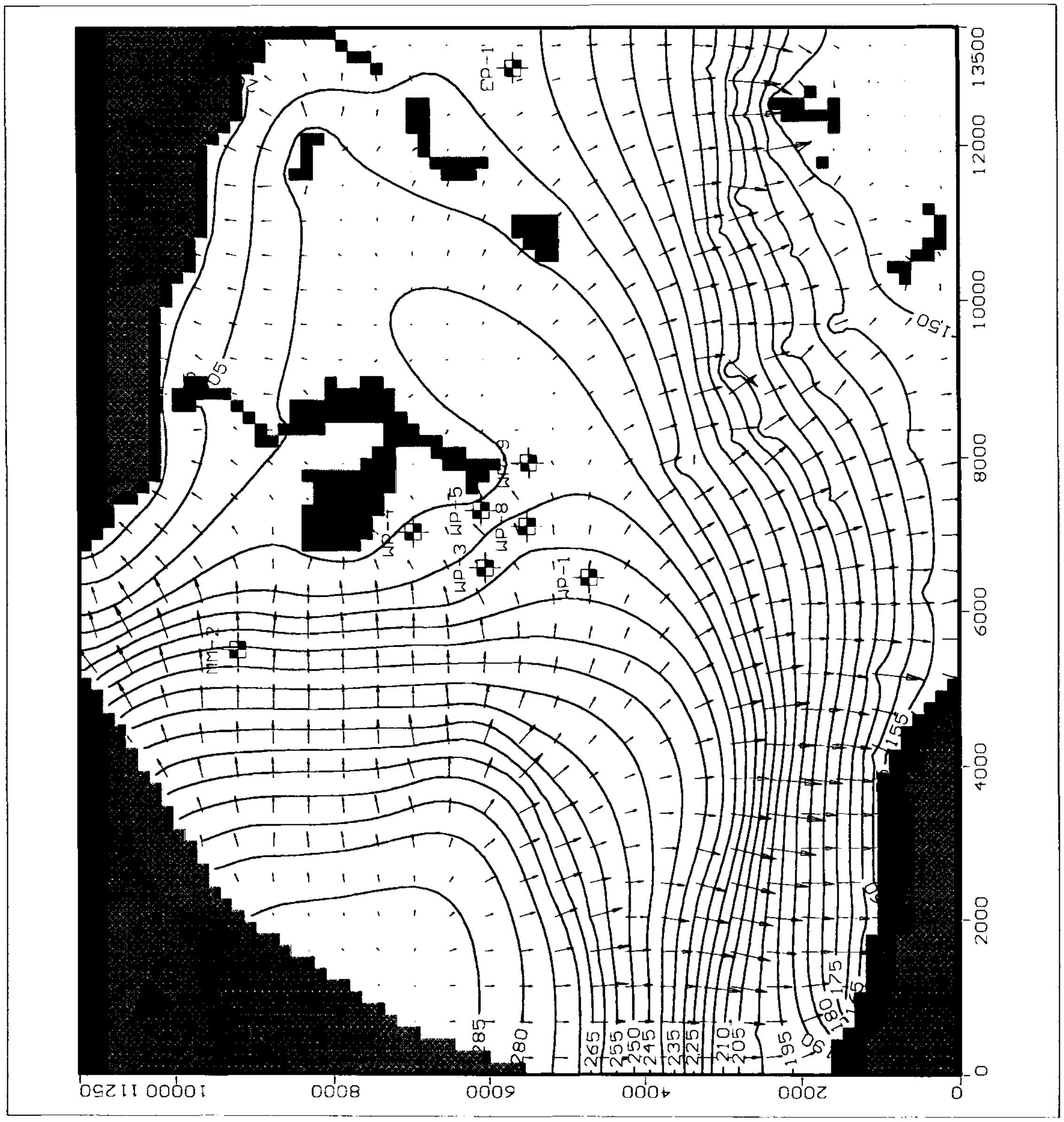


Figure 4.11 Groundwater Contour Map - Field Test, Stress Period 7. Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity.

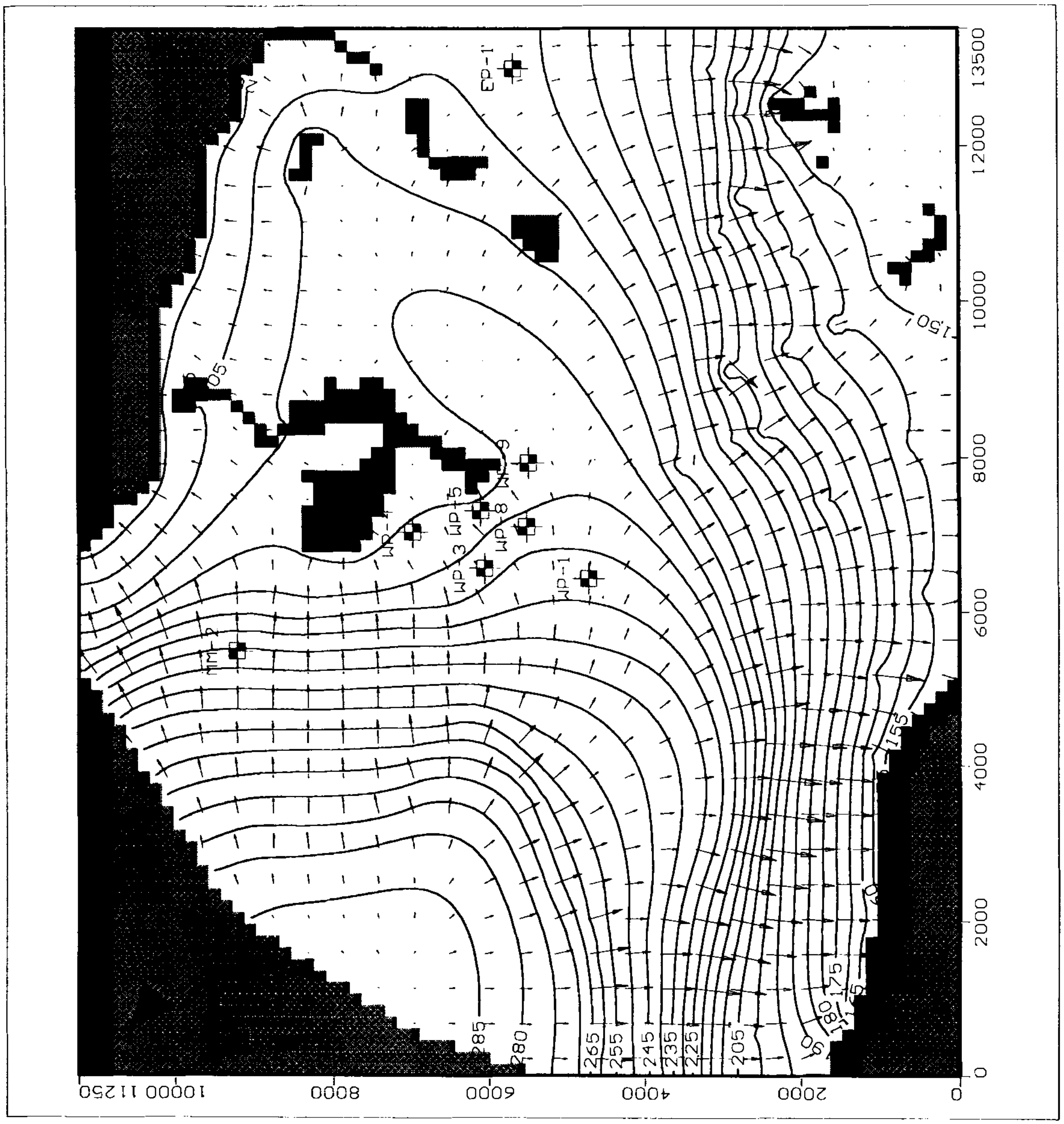


Figure 4.12 Groundwater Contour Map - Field Test, Stress Period 8. Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity.

2. As much as 30 cm (1 ft) of water remained in the hole one-week after the pumping of water was stopped.
3. Evaporation of recharge water during the test (approximately 2.5 cm (1in)).
4. Vadose zone flow during initial stages of the field test.

Application of ARG to the Study Area

To determine realistic values of the hydrogeologic parameters for later use in the study, a simulation that artificially recharged the groundwater of the study area was performed. In addition to providing some realistic values for recharge rates to the kettle hole and to recovery rates, or pumping rates of the aquifer, the simulation provided two other insights into the study (Figures 4.13, 4.14 and 4.15).

First, the model confirmed that the close proximity of a nearby surface-water body would inhibit the ability of the aquifer to build and retain any substantial groundwater mound. At this location, it was shown that when the hydraulic head in the kettle hole approached an elevation of approximately 71.6 m (235 ft); a stage of about 4.5 m (15 ft) above the bottom surface of the kettle hole, the water began to rapidly flow through the sand and gravel and into the adjacent pond. Although a significant quantity of the artificially recharged water was lost due to this "short-circuiting" effect, the aquifer did retain enough water to maintain the water elevation in the adjacent pond at July 2000 levels through the end of stress period 4 (mid-September). This fact implies that limited recharging of kettle holes in close proximity to surface-water bodies, might have greater value as a tool for replenishing the surface-water bodies as it is drawn down from

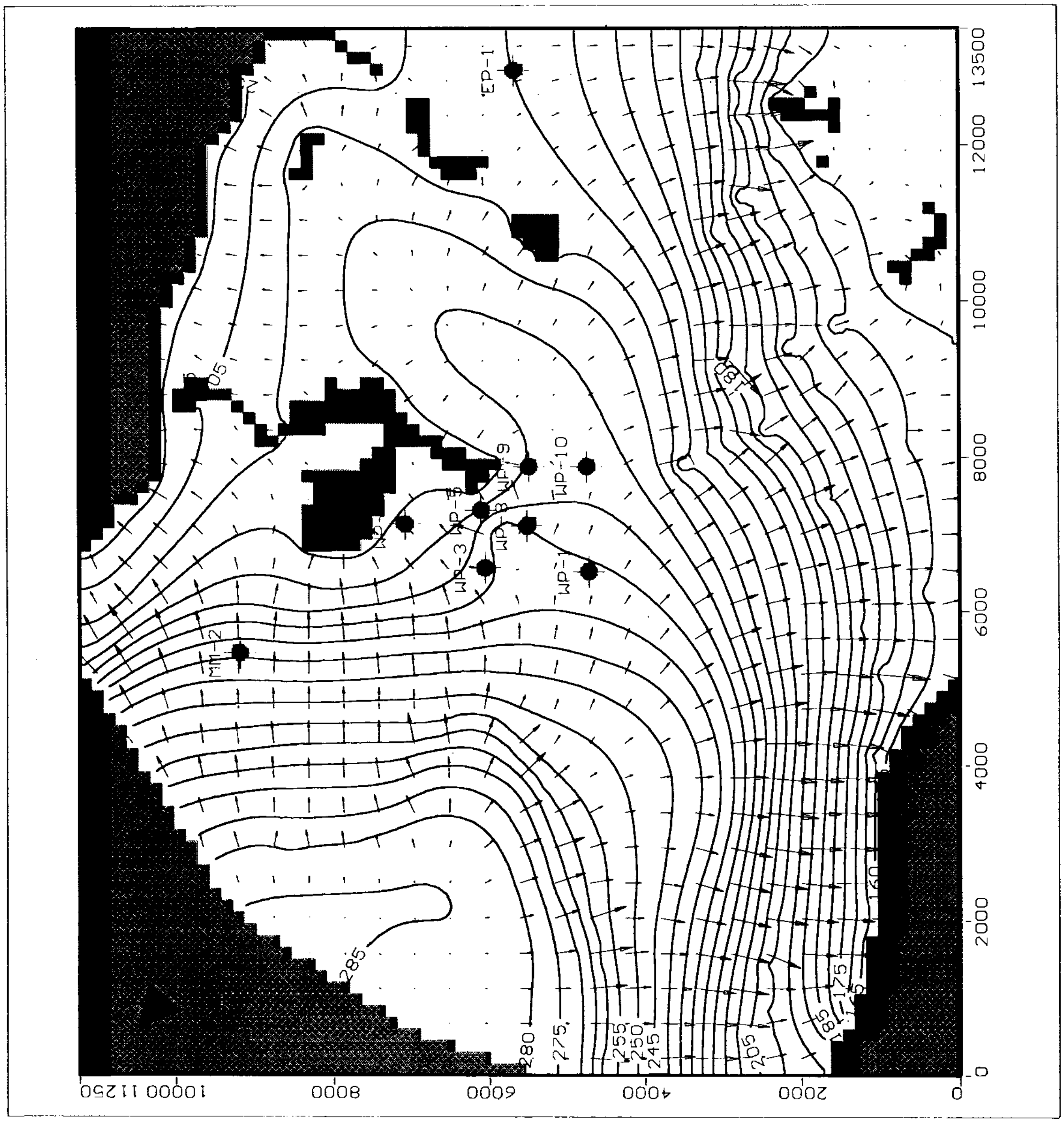


Figure 4.13 Groundwater Contour Map - ARG at Study Area, Stress Period 2. For 45 days, 252 L/s (4050 gpm) of water was applied to the kettle hole as recharge. Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity.

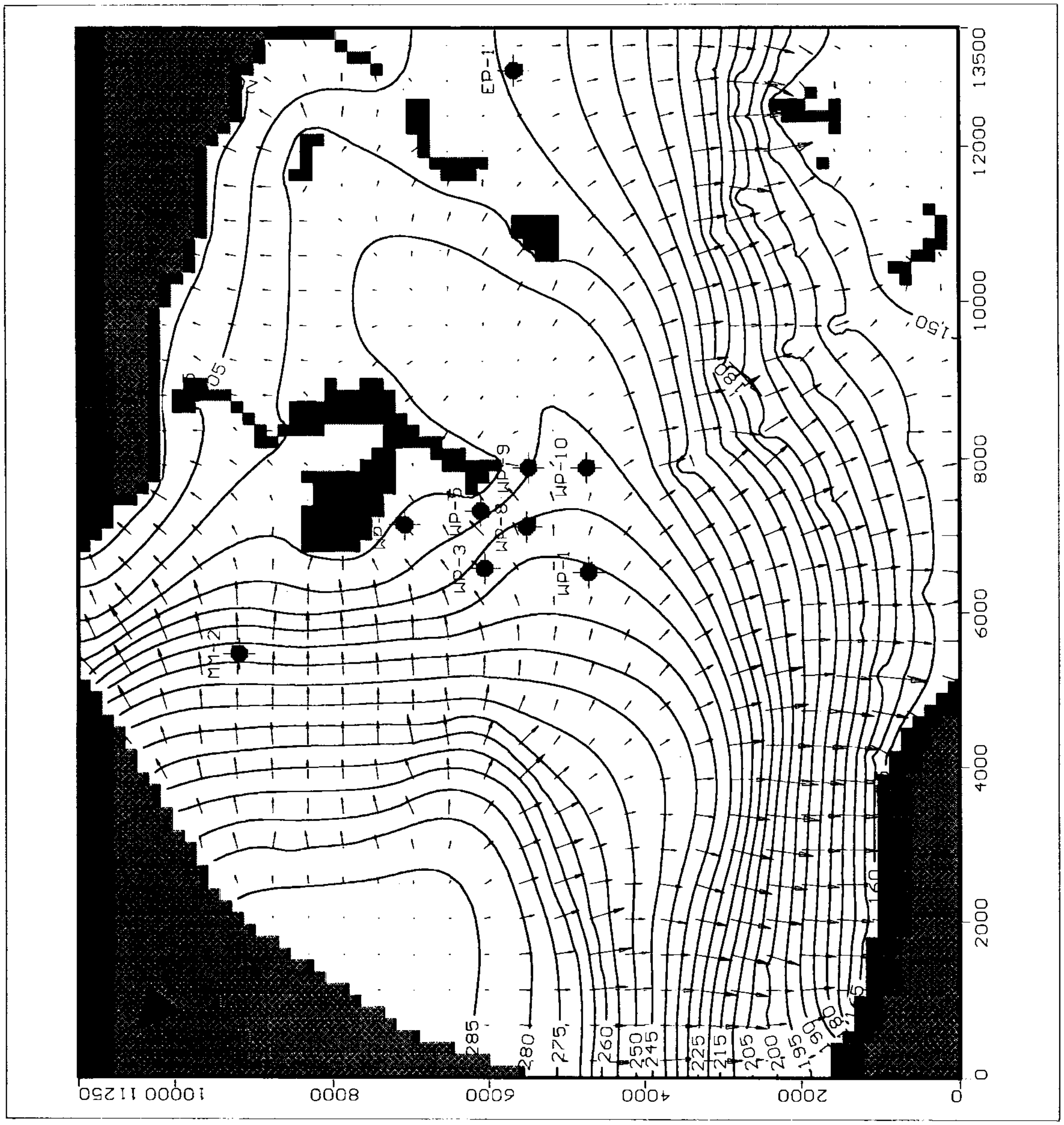


Figure 4.14 Groundwater Contour Map - ARG at Study Area, Stress Period 3. Contour interval is 5 feet (all units are in feet), groundwater flow arrows indicate recharge water moving away from the kettle hole.

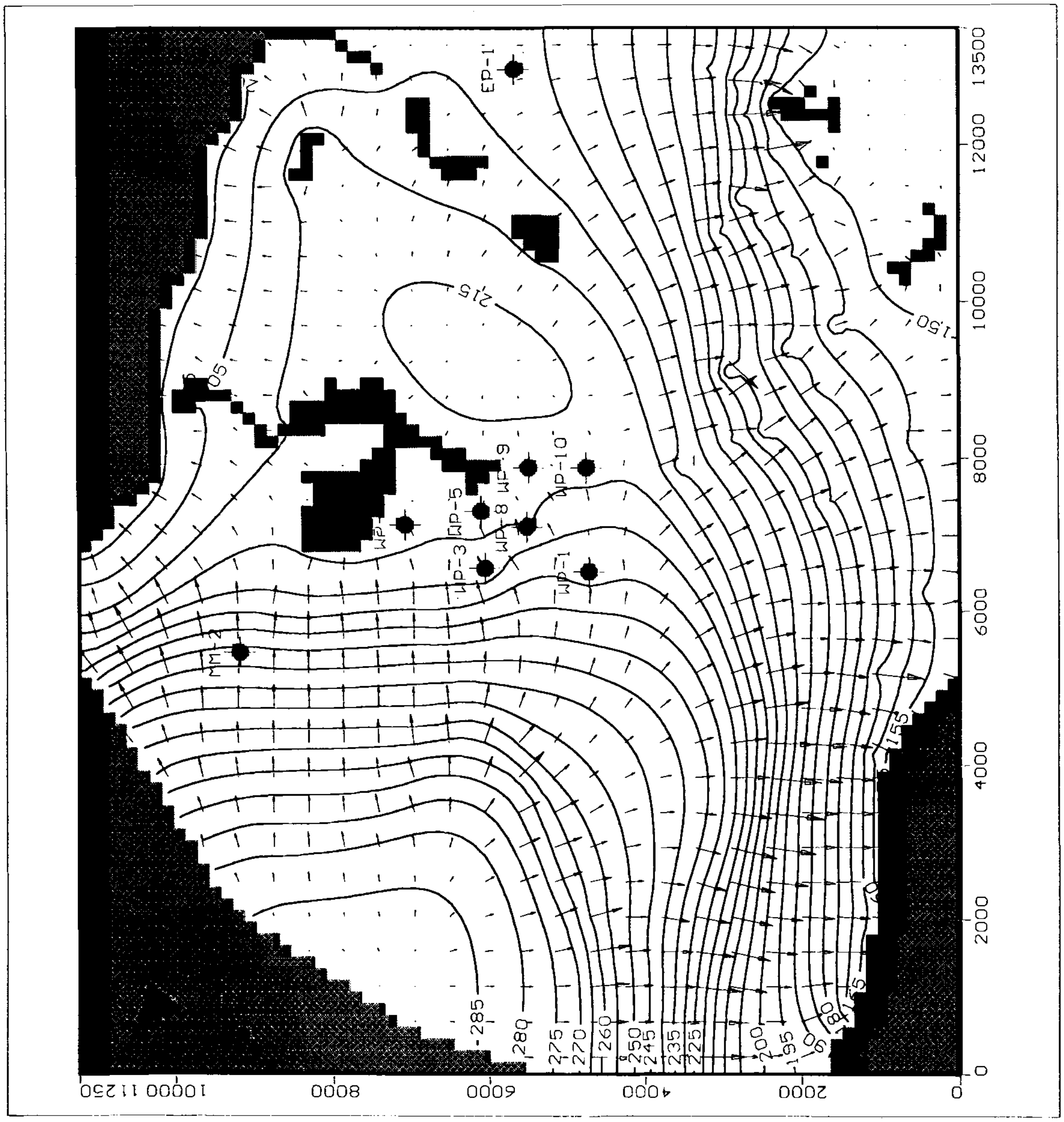


Figure 4.15 Groundwater Contour Map - ARG at Study Area, Stress Period 4. For 80 days, water was removed from the aquifer by 7 wells with each pumping 7.8 L/s (125 gpm). Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity.

direct irrigation withdrawals rather than removing the recharged water through pumping wells.

Second, the simulation showed a significant shift in the groundwater contours directly to the south of the kettle hole. This shift implied that a large quantity of the recharged water was moving past well WP-8 between the recharging time and the recovery time (stress period 2 and stress period 4, respectively) and flows south-southeast down the delta. Since this water was not recoverable with the existing well system, the decision was madeto insert an additional well, WP-10, into the model approximately 300 m (1000 ft) south of the kettle hole (refer to Chapter 3, Figure 3.3 for location of WP-10).

Evaluation of the Hydrogeologic Parameters Governing the Artificial Recharge of Groundwater

As outlined in Chapter 3, an evaluation of the effect that the dominating hydrogeologic parameters might have on an ARG site was performed. For all cases the base model determined from the second transient calibration and field test calibration was used and only one parameter was varied. The maximum pumping rates were determined as the hydrogeologic parameter was varied.

Case 1: Hydraulic Conductivity

The evaluation of hydraulic conductivity (Figures 4.16, 4.17, and 4.18) indicated that aquifers with hydraulic conductivity values below 1.0 e-4 m/s (30 ft/day) were not viable because they would inhibit the infiltration of recharge water into the ground and would not allow groundwater removal through reasonable pumping rates (Table 4.1). Conversely, hydraulic conductivity values greater than 1.6e-4 m/s (40 ft/day) permitted a large percentage of the recharge water to dissipate rapidly from the aquifer and discharge into the adjacent pond. Recharge water not lost to the pond migrated away from the recharge site making recovery by pumping difficult.

Table 4.1 Results from Case 1: Hydraulic Conductivity Evaluation.

Hydraulic Conductivity	Maximum Pumping Rate
5.3e-5 m/s (15 ft/day)	3.2 L/s (50 gpm)
7.1e-5 m/s (20 ft/day)	3.2 L/s (50 gpm)
8.8e-5 m/s (25 ft/day)	4.8 L/s (75 gpm)
1.1e-4 m/s (30 ft/day)	6.3 L/s (100 gpm)
1.2e-4 m/s (35 ft/day)	7.9 L/s (125 gpm)
1.4e-4 m/s (40 ft/day)	9.5 L/s (150 gpm)
1.6e-4 m/s (45 ft/day)	6.3 L/s (100 gpm)
1.8e-4 m/s (50 ft/day)	3.2 L/s (50 gpm)

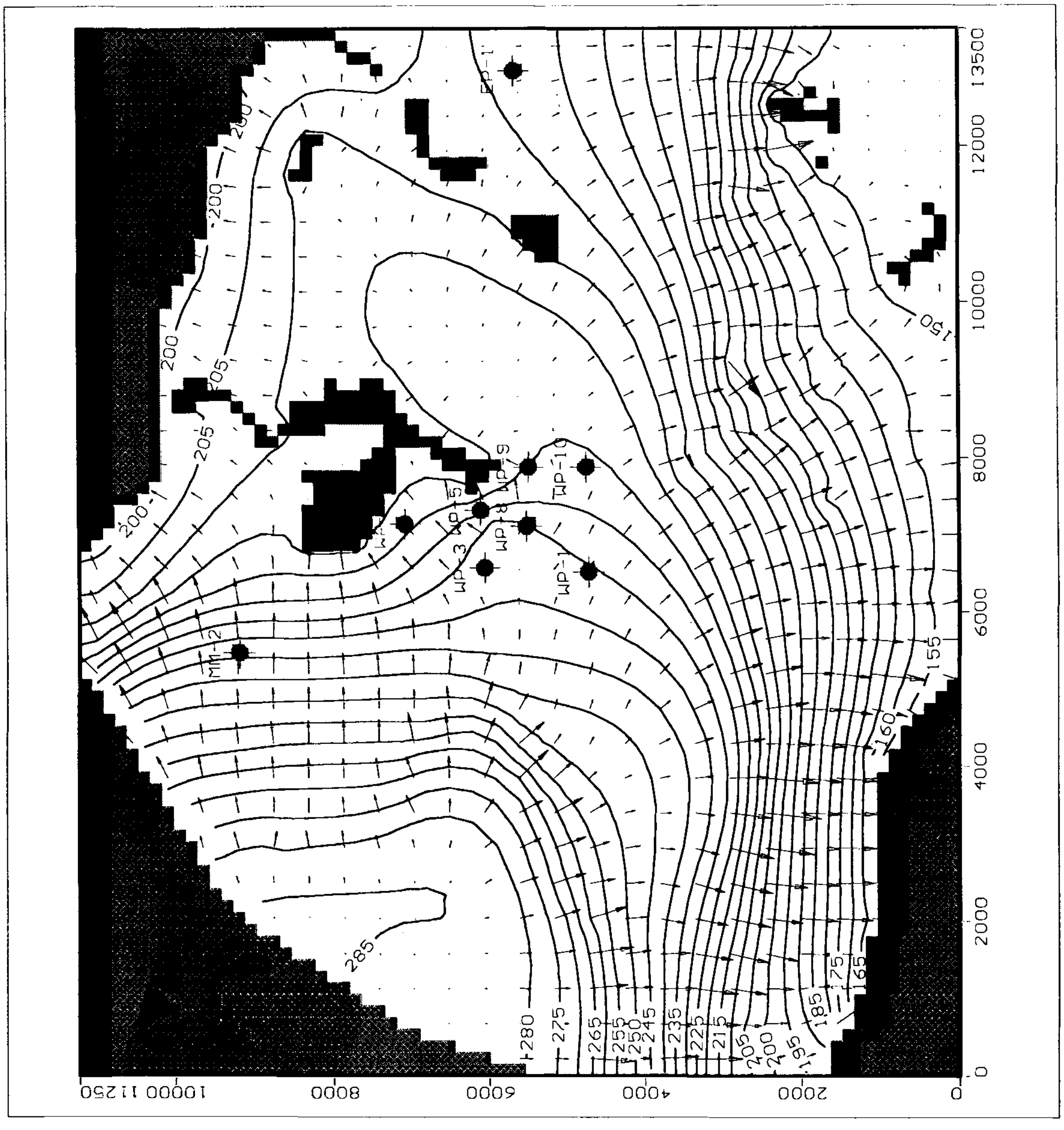


Figure 4.16 Groundwater Contour Map - Case 1, Stress Period 2. Hydraulic Conductivity of the aquifer was set to 1.4e-4 m/s (40 ft/day). For 45 days, 252 L/s (4050 gpm) of water was applied to the kettle hole as recharge. Contour interval is 5 feet (all units are in feet), arrows indicate magnitude of groundwater flow velocity.

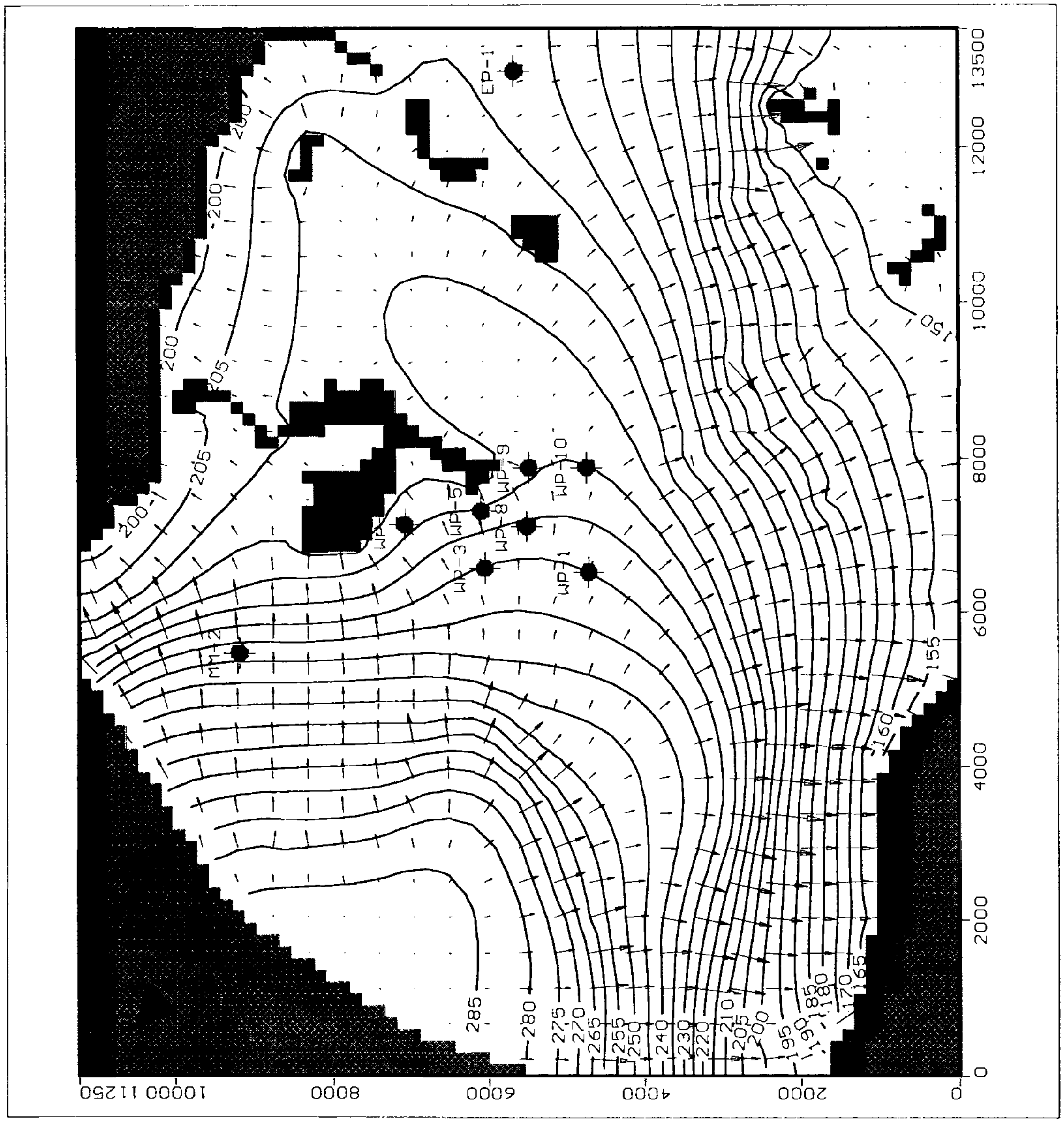


Figure 4.17 Groundwater Contour Map - Case 1, Stress Period 3. Hydraulic Conductivity of the aquifer was set to 1.4e-4 m/s (40 ft/day). Flow arrows indicate recharged water moving away from kettle hole. Contour interval is 5 feet (all units are in feet), arrows indicate magnitude of groundwater flow velocity.

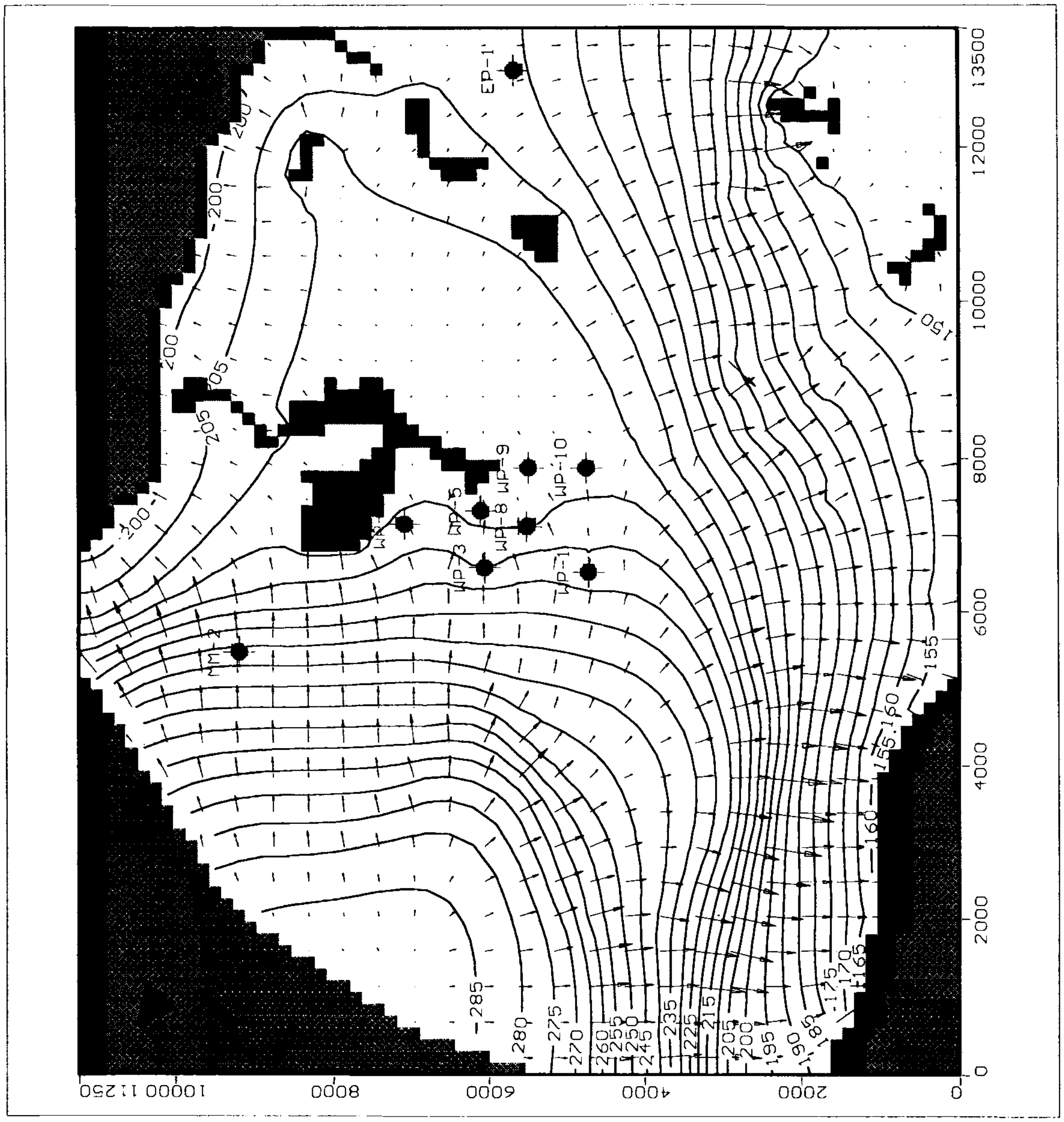


Figure 4.18 Groundwater Contour Map - Case 1, Stress Period 4. Hydraulic Conductivity of the aquifer was set to 1.4e-4 m/s (40 ft/day). For 80 days, water was removed from the aquifer by 7 wells with each pumping 9.5 L/s (150 gpm). Contour interval is 5 feet (all units are in feet), arrows indicate magnitude of groundwater flow velocity.

Case 2: Specific Yield

Within the typical range of values for specific yield (Table 3.4) for sand and gravel aquifers, the results from the specific yield evaluation indicated that values of specific yield less than 0.1 would limit the recovery of recharge water through pumping. In model runs (Figures 4.19, 4.20, and 4.21) with low values, a cone of depression formed that was so large that it impacted areas outside the influence of the ARG. Nonetheless, a direct relationship between the specific yield of an aquifer and the ease of water removal by pumping from that aquifer was demonstrated (Table 4.2). The largest value of specific yield simulated was 0.50 and resulted in a well yield of 11 L/s (200 gpm). However, it is not a value that is present in the types of geologic deposits found in eastern Maine. Since the value of 0.40 is largest value for S_y that one might expect to find in eastern Maine, that is the largest value that can be reasonably applied to this study.

Table 4.2 Results from Case 2: Specific Yield Evaluation.

Specific Yield	Maximum Pumping Rate
0.10	6.3 L/s (100 gpm)
0.15	7.9 L/s (125 gpm)
0.20	9.5 L/s (150 gpm)
0.25	9.5 L/s (150 gpm)
0.30	9.5 L/s (150 gpm)
0.35	11.1 L/s (175 gpm)
0.40	11.1 L/s (175 gpm)
0.45	11.1 L/s (175 gpm)
0.50	12.6 L/s (200 gpm)

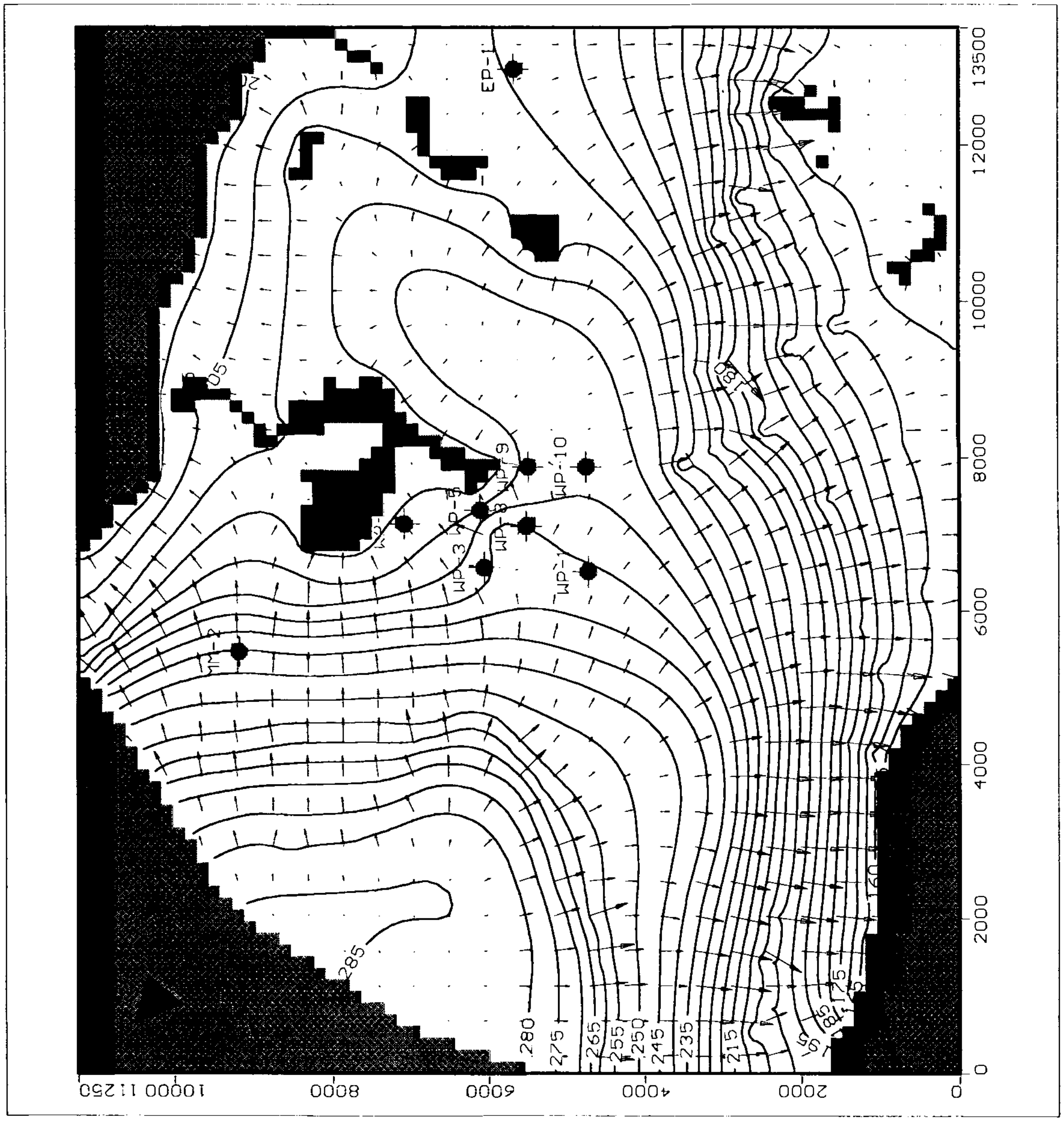


Figure 4.19 Groundwater Contour Map - Case 2, Stress Period 2. Specific yield value of 0.40 was applied to the aquifer. For 45 days, 252 L/s (4050 gpm) of water was applied to the kettle hole as recharge. Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity.

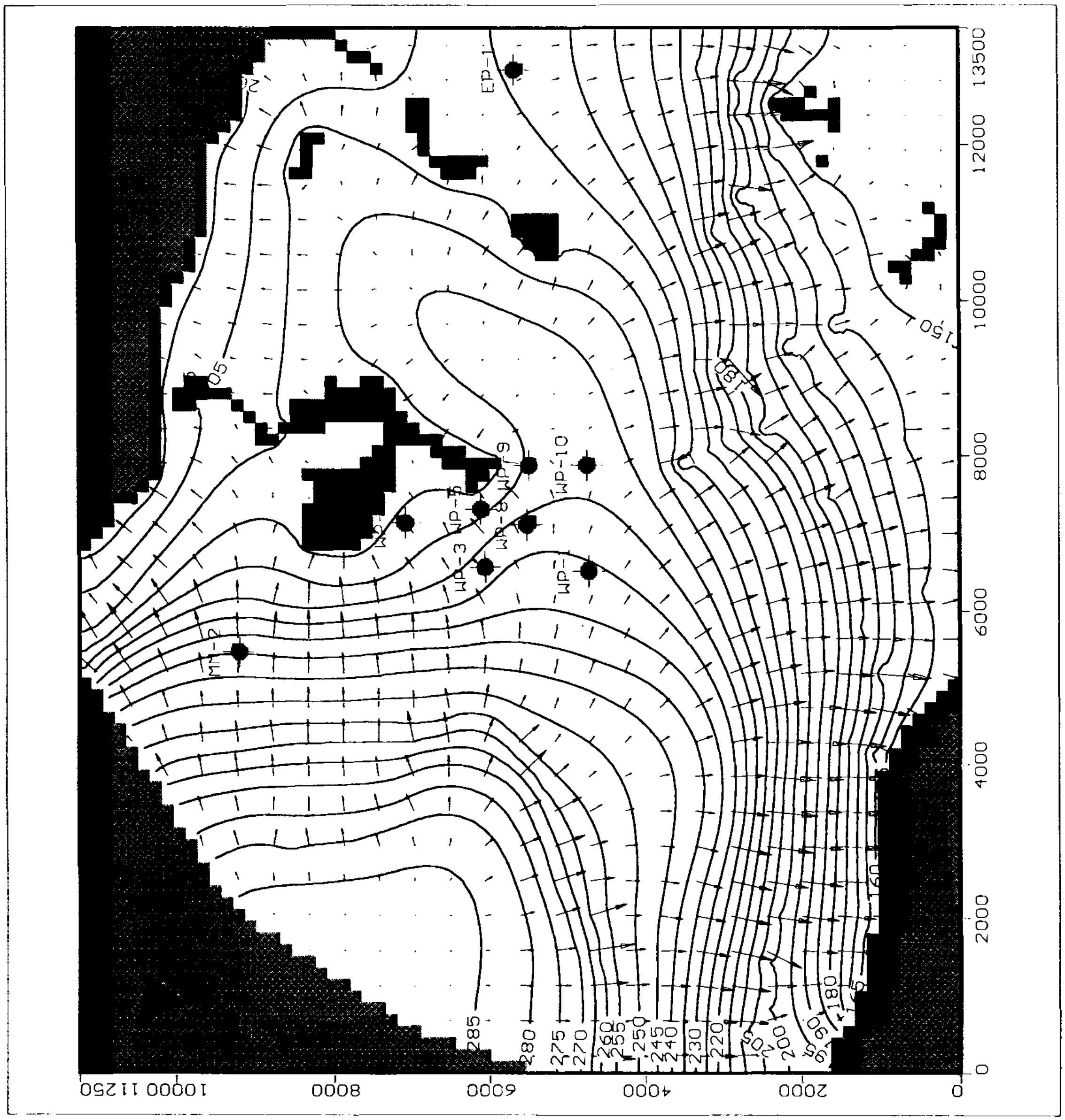


Figure 4.20 Groundwater Contour Map - Case 2, Stress Period 3. Specific yield value of 0.40 was applied to the aquifer. Flow arrows show recharged water migrating away from the kettle hole. Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity.

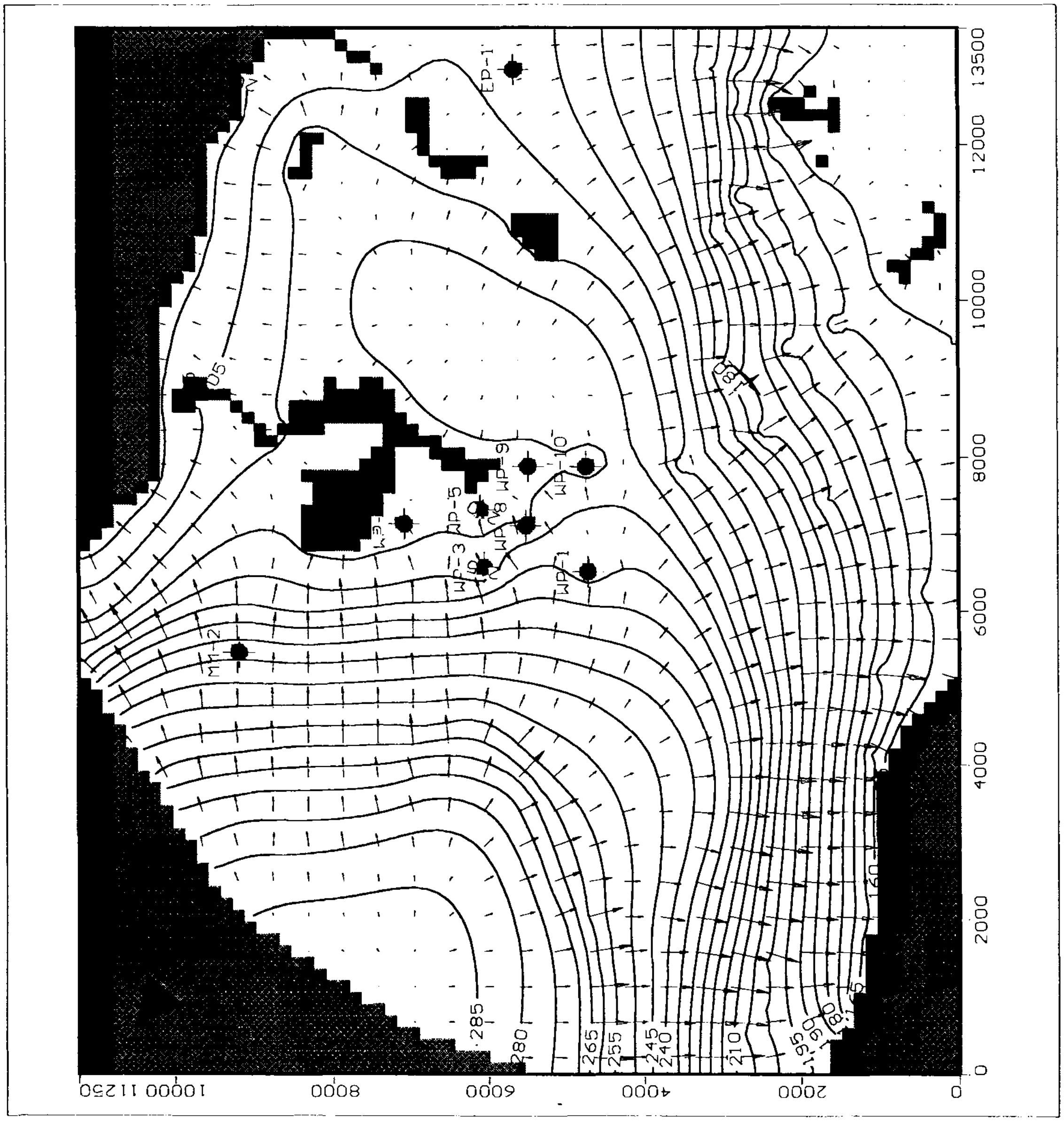


Figure 4.21 Groundwater Contour Map - Case 2, Stress Period 4. Specific yield value of 0.40 was applied to the aquifer. For 80 days, water was removed from the aquifer by 7 wells with each pumping 11.1 L/s (175 gpm). Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity.

Case 3: Distance to a Surface-Water Body

The evaluation of the effect of a nearby surface-water body on a recharge site provided insight into the success or failure of a site. Unlike cases 1 and 2, case 3 completely altered the groundwater flow pattern (Figures 4.22, 4.23, and 4.24). By increasing the distance between the kettle hole and the pond, the flow pattern in the immediate vicinity of the kettle hole was no longer governed by the pond. Additionally, the groundwater flow pattern in the center of the delta shifted from that common in a delta; where flow is perpendicular to the general direction of the delta and toward the sides, to one more consistent with that of an esker; where flow is parallel to the general direction of the delta. These factors increased the retention capacity of the aquifer and the recovery of the recharged water by the down-gradient wells. However, the recovery of the water was limited as the distance from the pond increased (Table 4.3). The installation of a well or wells between the kettle hole and the surface-water body would be required to fully take advantage of the available water.

Table 4.3 Results from Case 3: Distance to Surface-Water Body Evaluation.

Approximate Distance of Kettle Hole from Adjacent Pond	Maximum Pumping Rate
80 m (250 ft)	7.9 L/s (125 gpm)
140 m (450 ft)	9.5 L/s (150 gpm)
200 m (650 ft)	11.1 L/s (175 gpm)
260 m (850 ft)	11.1 L/s (175 gpm)
300 m (1000 ft)	11.1 L/s (175 gpm)

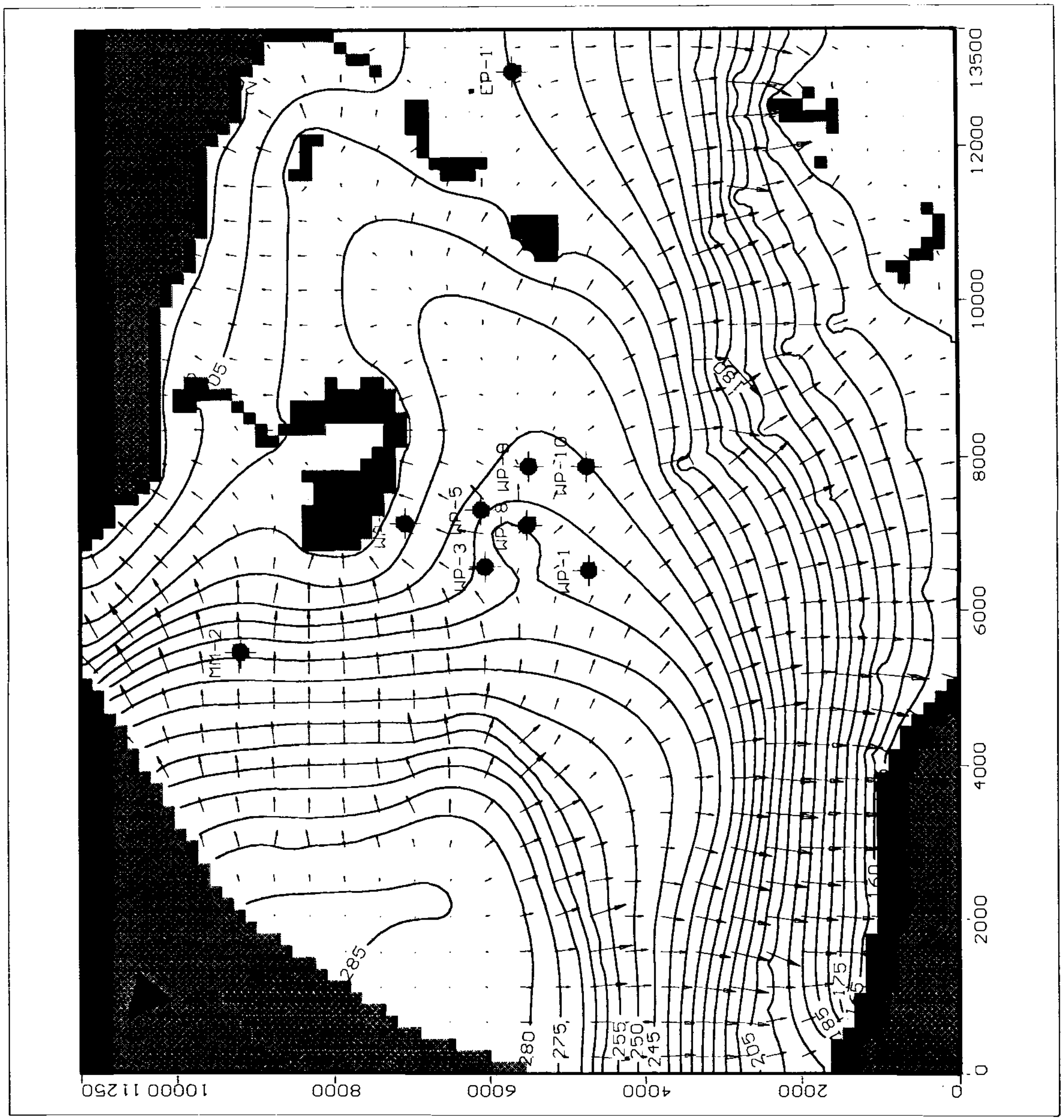


Figure 4.22 Groundwater Contour Map - Case 3, Stress Period 2. Distance between recharge site and surface-water body increased to 300 m (1000 feet). For 45 days, 252 L/s (4050 gpm) of water was applied to the kettle hole as recharge. Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity.

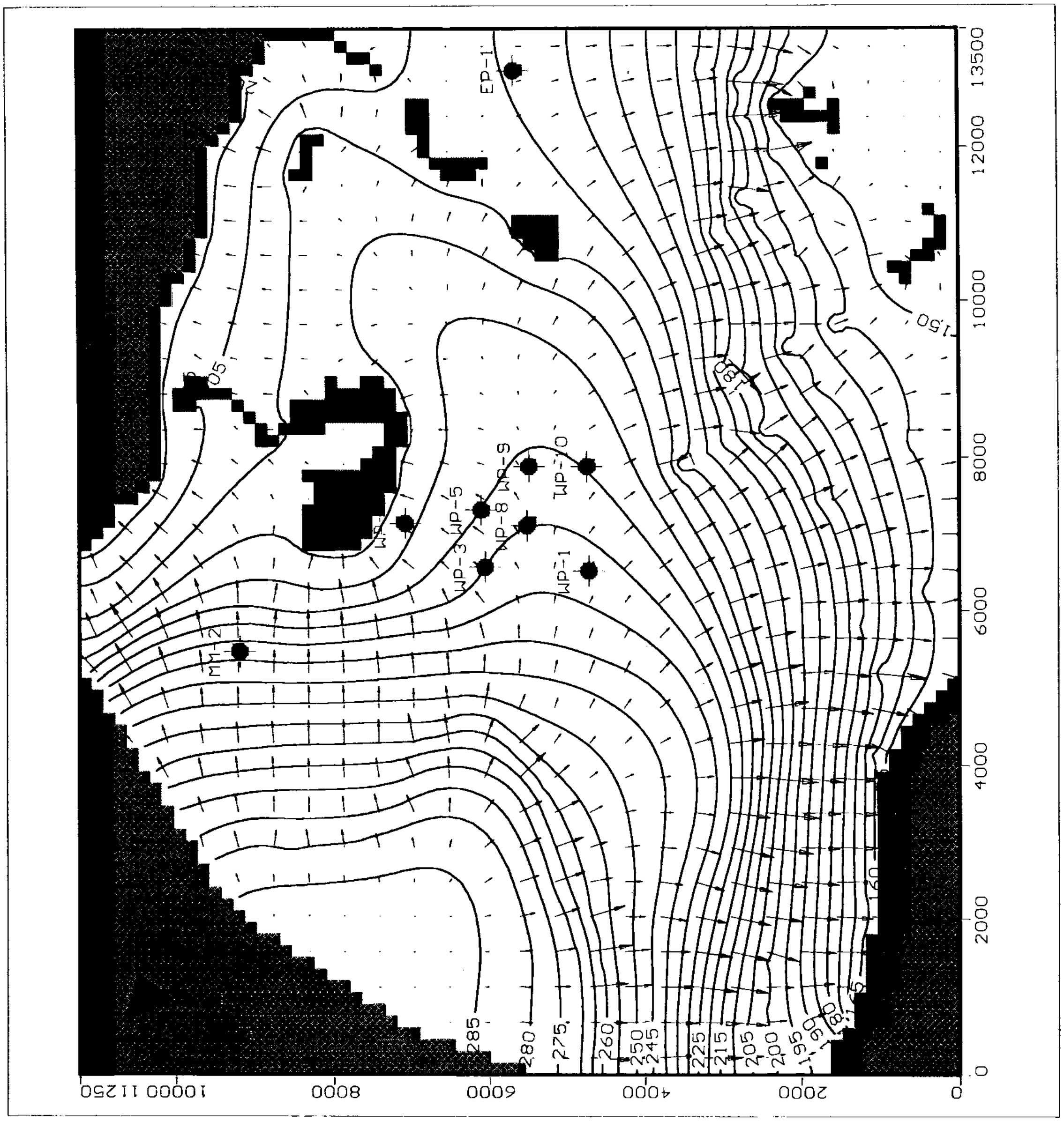


Figure 4.23 Groundwater Contour Map - Case 3, Stress Period 3. Distance between recharge site and surface-water body increased to 300 m (1000 feet). Flow arrows indicate recharge water moving away from kettle hole. Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity.

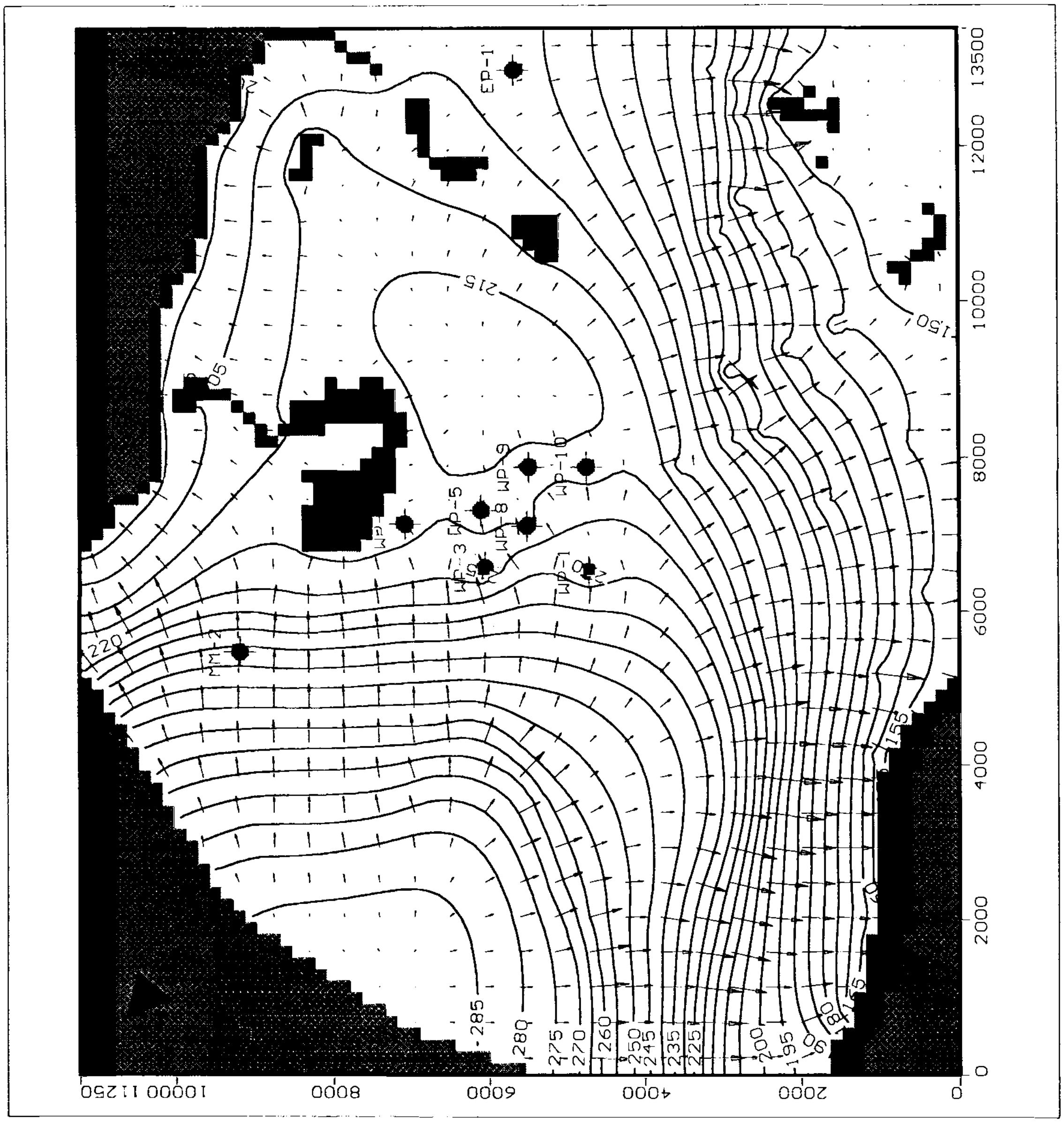


Figure 4.24 Groundwater Contour Map - Case 3, Stress Period 4. Distance between recharge site and surface-water body increased to 300 m (1000 feet). For 80 days, water was removed from the aquifer by 7 wells with each pumping 11.1 L/s (175 gpm). Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity.

Ideal Site Application

Simulations were run using the values for the hydraulic parameters that yielded the most favorable results. A recharge site with such parameters could not only sustain pumping rates of 12.7 L/s (200 gpm) in the 7 recovery wells discussed so far (Figures 4.25, 4.26, and 4.27), but could also withstand the installation of 3 additional wells at the same pumping rate (Figure 4.28). Doubling the recharge rate to the kettle hole during stress period 2 from 4750 cm/yr (1870 in/yr or 450 gpm/cell) to 9500 cm/yr (3740 in/yr or 900 gpm/cell) did not significantly increase the recoverability of the recharge water during stress period 4 without adding more wells (Figures 4.29, 4.30, and 4.31).

Table 4.4 Results from Ideal Site Application.

Recharge Rates and Number of Pumping Wells	Maximum Pumping Rate per Well
4750 cm/yr with 7 wells	12.7 L/s (200 gpm)
4750 cm/yr with 10 wells	12.7 L/s (200 gpm)
9500 cm/yr with 10 wells	12.7 L/s (200 gpm)

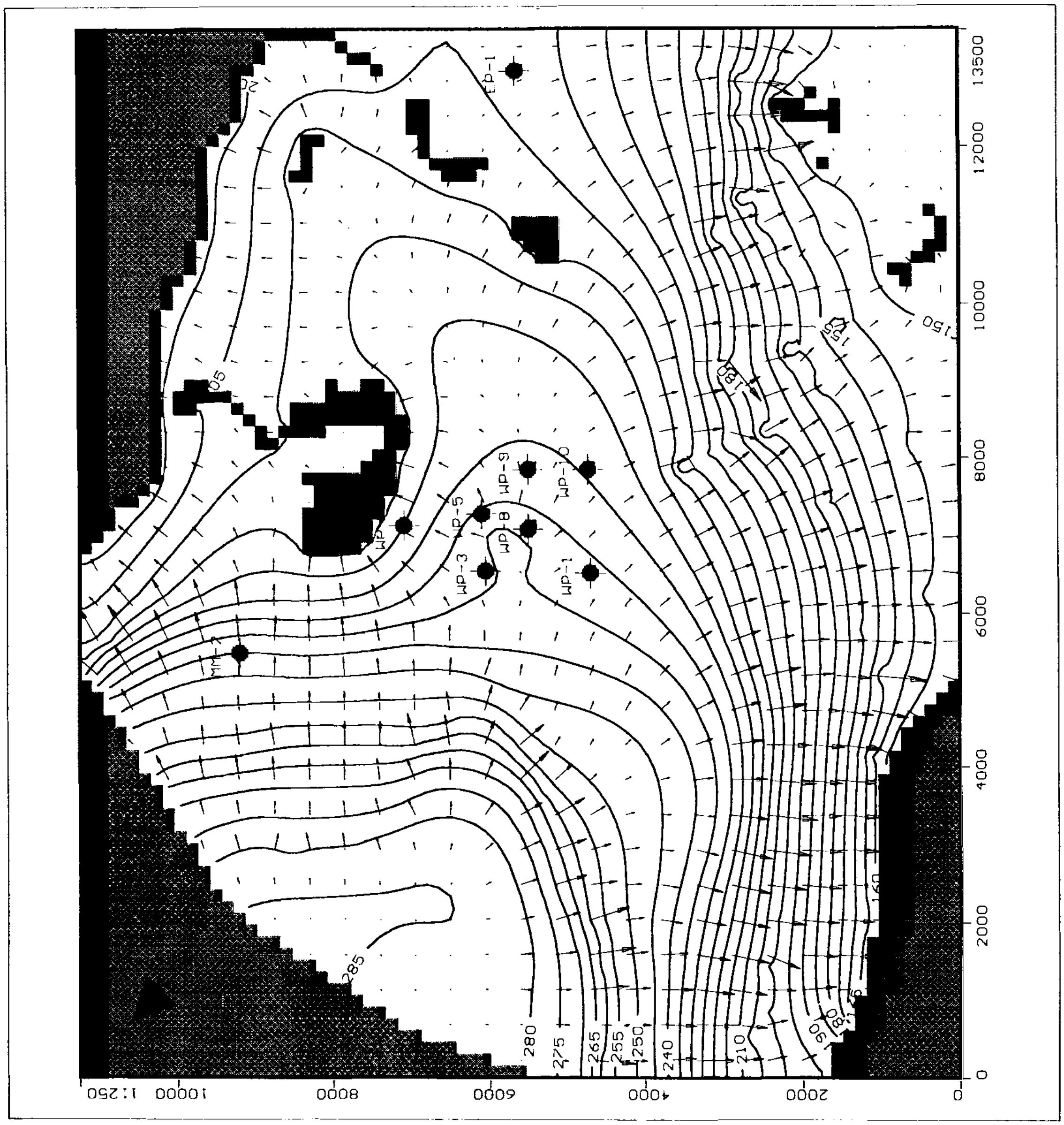


Figure 4.25 Groundwater Contour Map - Ideal Site, Stress Period 2. For 45 days, 252 L/s (4050 gpm) was applied to the kettle hole. Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity.

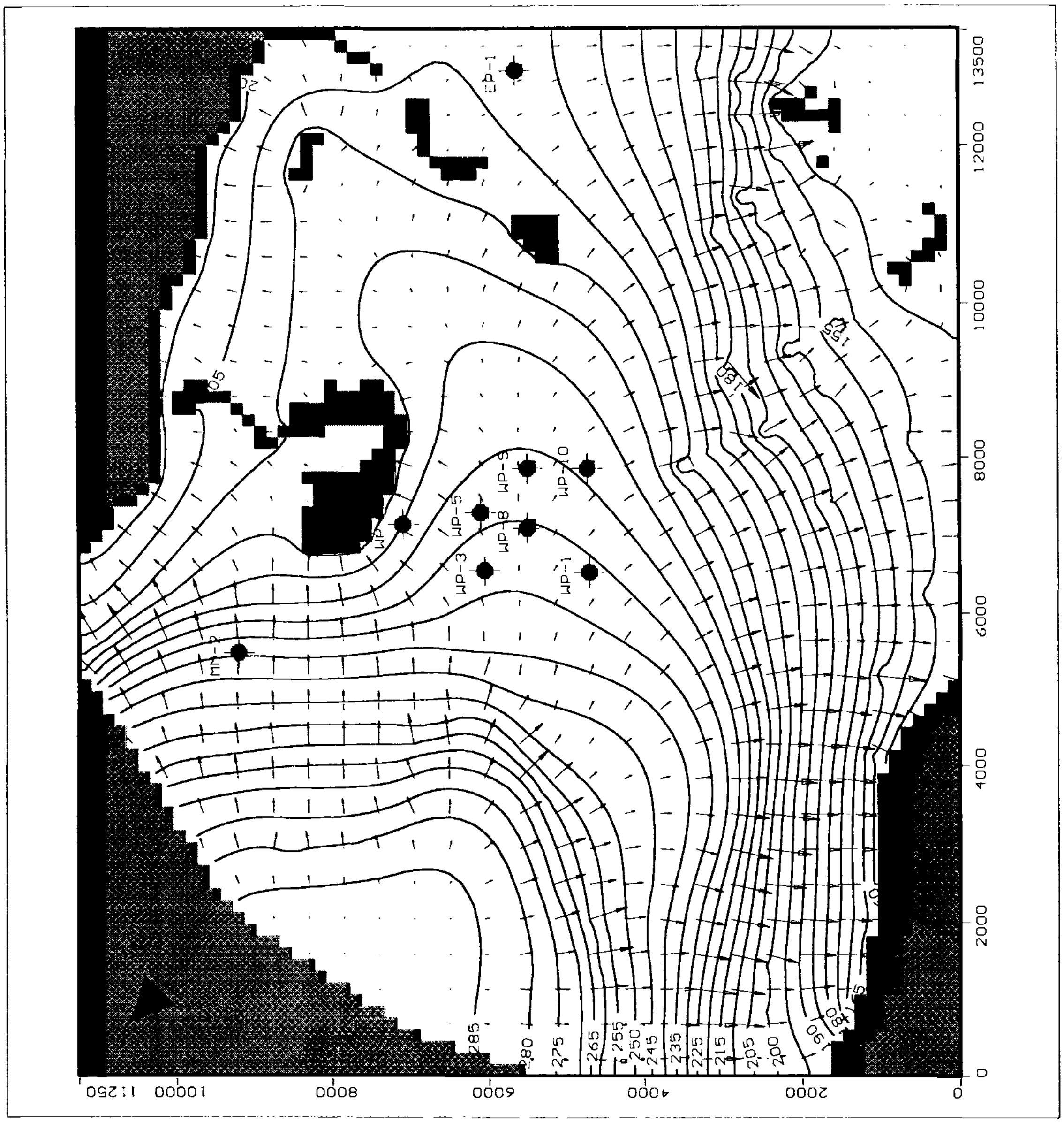


Figure 4.26 Groundwater Contour Map - Ideal Site, Stress Period 3. Flow arrows indicate recharge water moving away from recharge site. Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity.

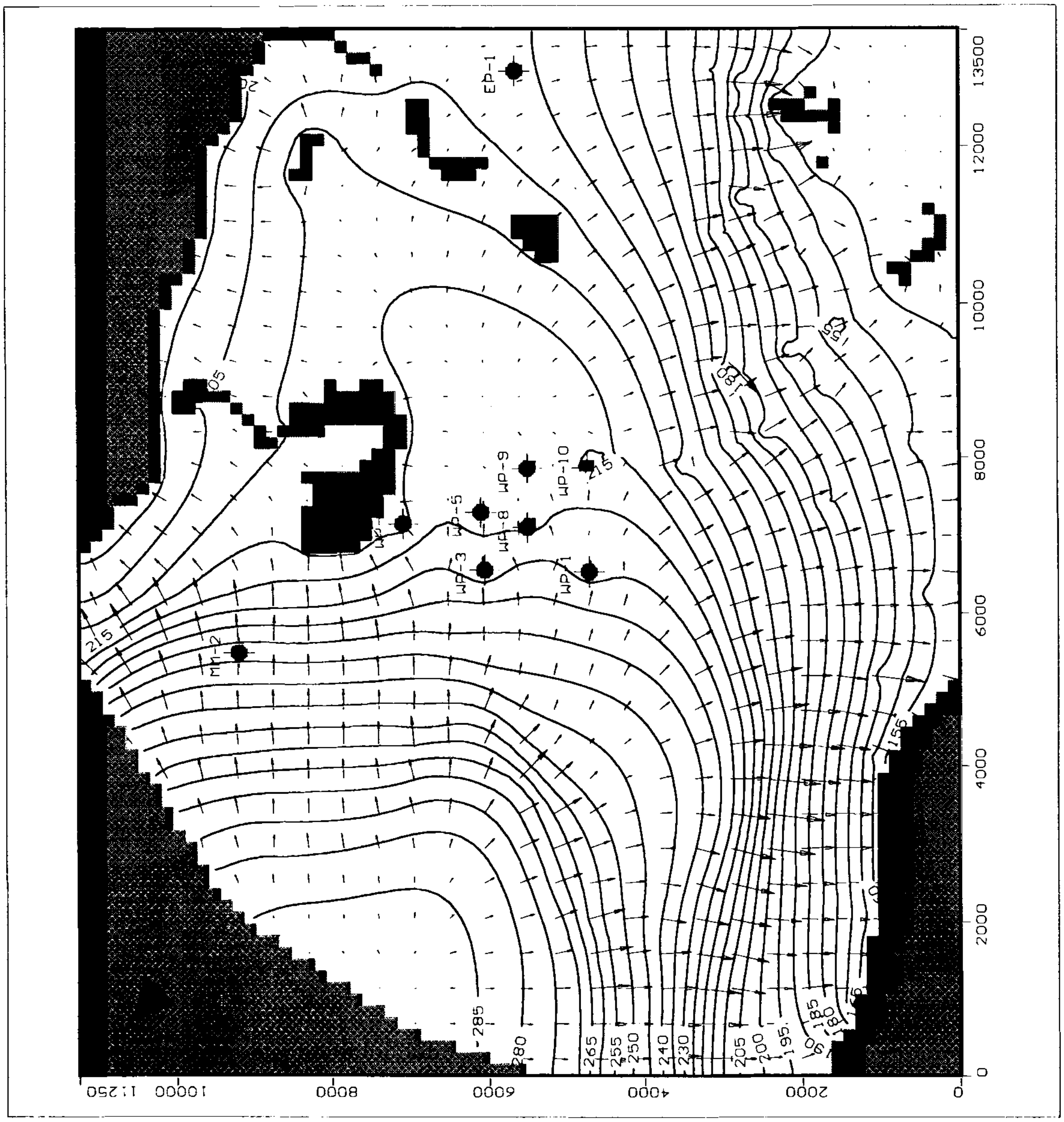


Figure 4.27 Groundwater Contour Map - Ideal Site, Stress Period 4. For 80 days, water was removed from the aquifer by 7 wells with each pumping 12.6 L/s (200 gpm). Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity.

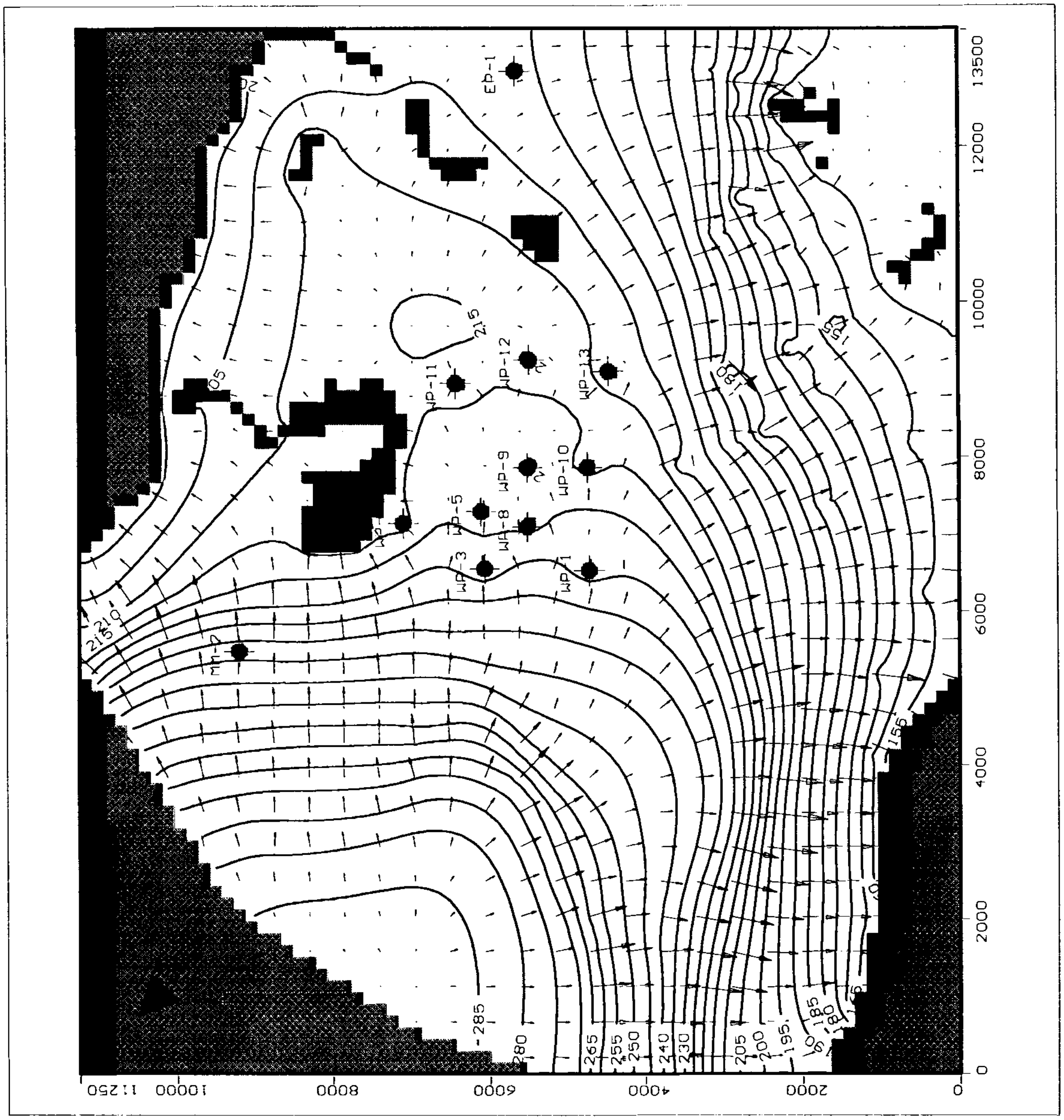


Figure 4.28 Groundwater Contour Map - Ideal Site, Stress Period 4. Stress Periods 2 and 3 are identical to those of Figures 4.25 and 4.26, respectively. For 80 days, water was removed from the aquifer by 10 wells with each pumping 12.6 L/s (200 gpm). Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow direction.

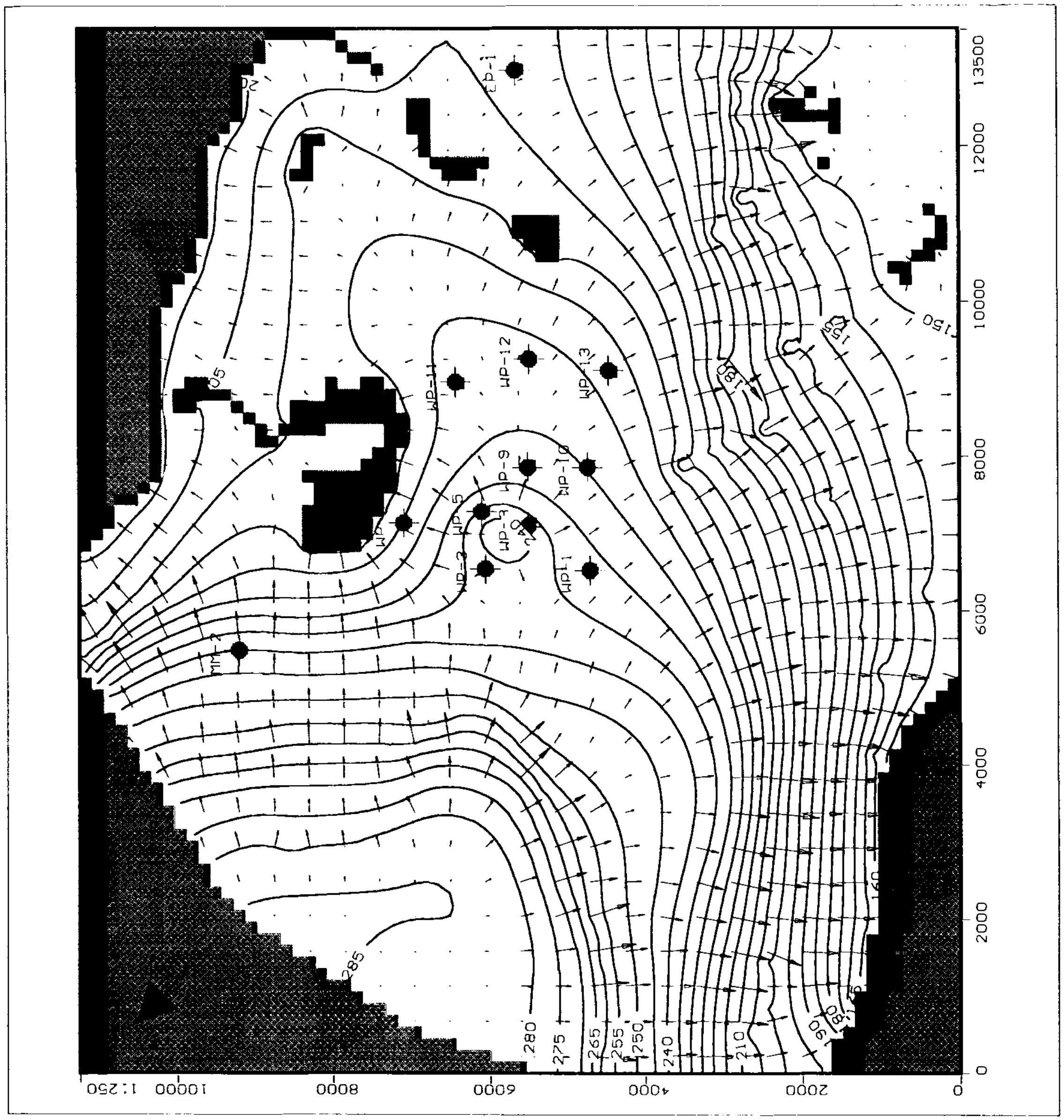


Figure 4.29 Groundwater Contour Map - Ideal Site, Stress Period 2. For 45 days, 504 L/s (8100 gpm) of water was applied to the kettle hole as recharge. Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity.

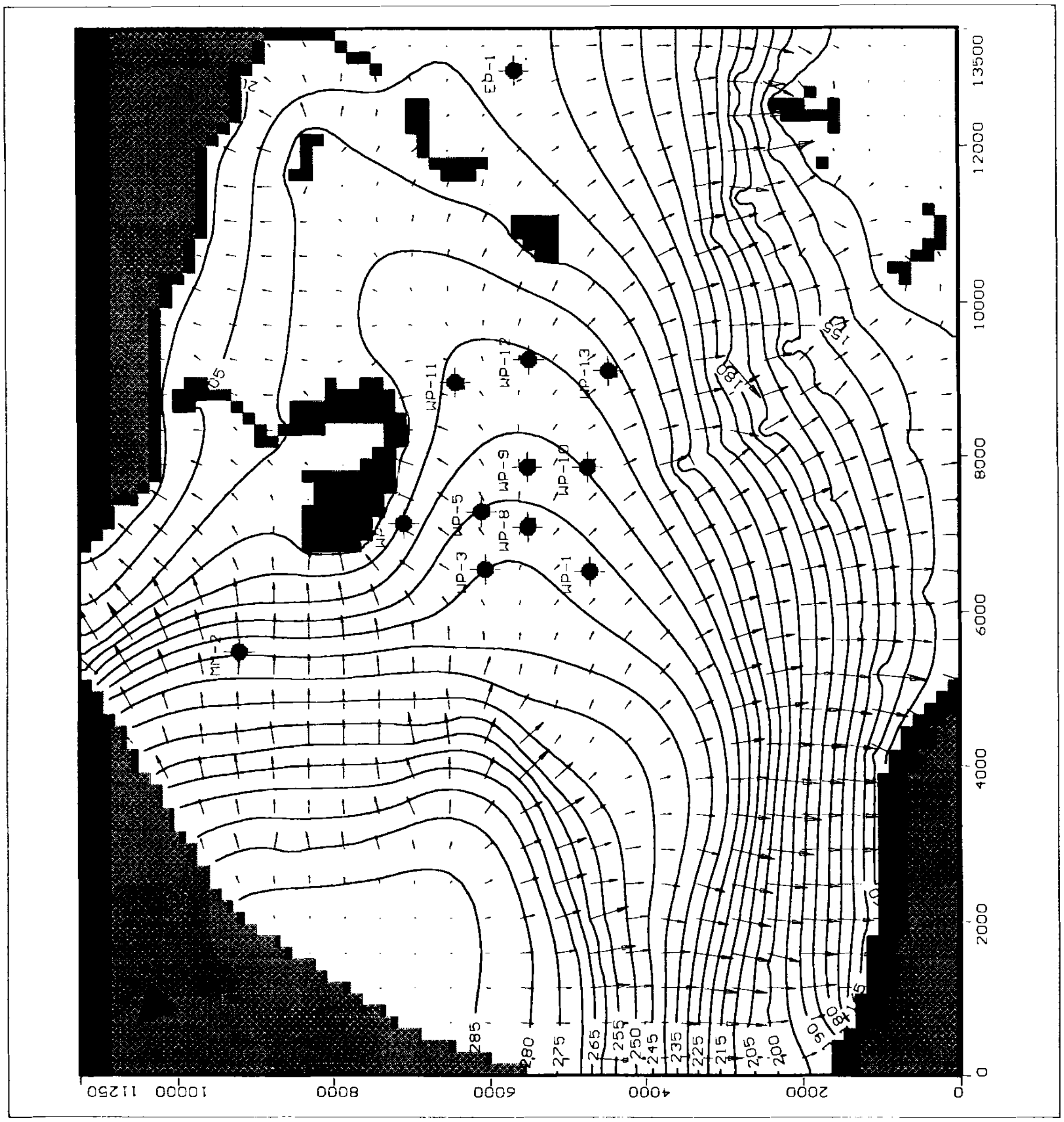


Figure 4.30 Groundwater Contour Map - Ideal Site, Stress Period 3. Flow arrows indicate recharge water moving away from site. Contour interval of 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity.

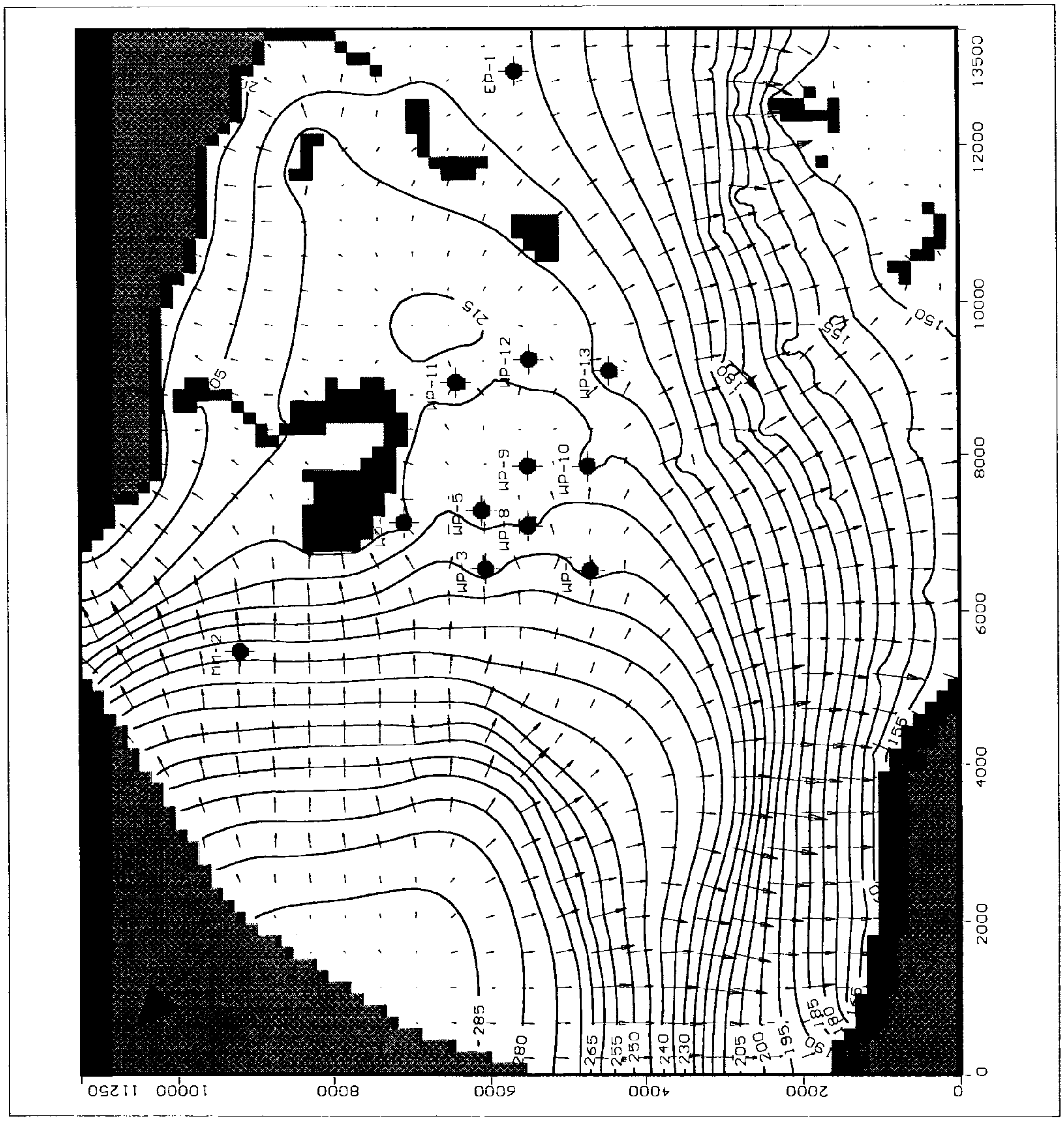


Figure 4.31 Groundwater Contour Map - Ideal Site, Stress Period 4. For 80 days, water was removed from the aquifer by 10 wells with each pumping 12.6 L/s (200 gpm). Contour interval is 5 feet (all units are in feet), arrows indicate relative magnitude of groundwater flow velocity.

Guidelines for Evaluating a Potential ARG Site

From these simulations of ARG, several conclusions were developed as what aquifer characteristics are needed for a successful site. First, a site must have a hydraulic conductivity that allows the recharge water to infiltrate and move within the soil profile but not so far from the recharge site that recovery by pumping becomes difficult. Aquifers with hydraulic conductivity values within the range of 1.1e-4 m/s (30 ft/day) and 1.4e-4 m/s (40 ft/day) would be the most suitable for ARG in eastern Maine's aquifers. Second, the site should have a specific yield value that large enough to keep the cone of depression induced during pumping to a minimum size, therefore reducing the likelihood of aquifer dewatering. Finally, the distance between the recharge site and a nearby surface-water body needs to be evaluated on a case-by-case basis. If the blueberry producer wanted to use the surface-water body as a source of irrigation water, then the distance between it and the recharge site could be considerably less than if the producer wanted to pump from the groundwater.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY

Conclusions

This study evaluated the potential of artificially recharging groundwater to assist the wild blueberry growers of eastern Maine with their irrigation water needs. The results of this study lead to several conclusions, as follows:

1. The groundwater program Visual MODFLOW is capable of modeling the groundwater system of the Pineo Ridge delta. After calibration utilizing observed conditions, it could then be utilized in a predictive manner.

2. The Pineo Ridge delta has hydrogeologic properties that allow the artificial recharge of groundwater. With hydraulic conductivity values in the 7.1e-5 m/s to 1.8e-4 m/s (20 ft/day to 50 ft/day, respectively) range and a specific yield value of 0.25, the delta shows great potential for ARG, however a well field may be necessary for maximum recovery.

3. The presence of numerous sand and gravel aquifers in eastern Maine with hydrogeologic properties similar to Pineo Ridge implies that ARG has the potential to assist the wild blueberry industry in meeting its irrigation water needs. However, the success or failure of ARG is reliant on specific characteristics of the site and therefore ARG sites need to be evaluated on a case-by-case basis to best match the site with the needs of the grower. From

this study some general guidelines with which to evaluate potential ARG sites were determined. If pumping is the method of choice for recovering recharged water, a successful ARG site should have hydraulic conductivity values between 1e-4 m/s (30 ft/day) and 1.6e-4 m/s (40 ft/day) in order to allow recharge and recovery of the water. Recovery of water through pumping is difficult in aquifers with specific yield values less than 0.2, however, if the grower prefers to use ARG to augment surface water flows such that direct withdrawals from the surface water would be possible, specific yield is not as important in potential site evaluation. Finally, recharge sites do not have be a great distance from surface-water bodies to be effective, in fact, distances of only 200 m (650 ft) were shown to be adequate in greatly increasing the recoverability of the recharged water.

4. For all model runs performed for this study, the water elevation in the pond adjacent to the recharge site was elevated throughout stress periods 2-8 (mid-spring through early fall) over the corresponding observed elevations during the summer of 2000. This implies that ARG in the spring may have the potential to augment surface water levels and flows throughout the summer and early fall. This could maintain the water elevation in the surface water through the irrigation period such that direct withdrawals from surface-water bodies are possible or augment nearby rivers and streams during the dry summer months, thereby providing some minimal level of stress relief to aquatic life such as the Atlantic salmon.

Recommendations for Further Study

Artificial recharge of groundwater could play a major role in balancing not only the irrigation water needs of the blueberry growers, but those of the salmon populations as well. Recommendations for further study include:

1. The elevated water table created as a result of artificially recharging the groundwater could have an impact on nearby surface-water bodies or wetlands. For instance, low-flows in nearby rivers and streams during the summer months may be augmented, thereby relieving stress on aquatic life such as the Atlantic salmon, or elevated water elevations in wetland may redefine the wetland boundaries or upset the ecological balance of the system. Since these effects may be positive or negative, they should be evaluated on a site-by-site basis.
2. ARG is often used as a treatment method for waters of impaired quality. The potential of sand and gravel aquifers of eastern Maine to act as a treatment media for these waters is unknown. Further study could identify alternate sources of recharge water, such as wastewater treatment facilities.
3. As with any commodity, the production of wild blueberries is driven by profits. An economic analysis of ARG relative to blueberry production is needed to determine the economic feasibility of ARG for blueberry producers.

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APPENDICES

Appendix A

BORING LOGS

EP-1

GOODWIN WELL DRILLING, INC.

DRILLERS LOG

CUSTOMER:

OWNER: SAME

TOWN: DEBLOIS

DATE STARTED: 6/21/99

DATE FINISHED: 6/23/99

JOB #: 99100 **HOLE#:** EP 1

DRILLER: PETER ELLINGWOOD

HELPER: CALVIN GILBERT

LOCATION

DATE & TIME	INTERVAL FROM	INTERVAL TO	SAMPLE #	DESCRIPTION
6/21/99 2:30 - 6:30				DRILLED 6" PILOT HOLE USING MUD ROTARY
	0	40		ROCKS AND SOME GRAVEL, MUD LOSS WAS HIGH & THICK
	40	42		ROCKS AND SOME GRAVEL, MUD LOSS WAS HIGH & THICK
	42	44		ROCKS AND SOME GRAVEL, MUD LOSS WAS HIGH & THICK
	44	46		ROCKS AND SOME GRAVEL, MUD LOSS WAS HIGH & THICK
	46	48		ROCKS AND SOME GRAVEL, MUD LOSS WAS HIGH & THICK
	48	50		ROCKS, MUD LOSS WAS HIGH & THICK
	50	52		ROCKS, VERY LITTLE GRAVEL, HIGH & THICK MUD LOSS
	52	54		ROCKS, VERY LITTLE GRAVEL, HIGH & THICK MUD LOSS
	54	56		ROCKS, HIGH & THICK MUD LOSS
6/22/99 8:00 - 1:00	56	58		ROCKS, HIGH & THICK MUD LOSS
	58	60		GRAVEL & ROCK, HIGH & THICK MUD LOSS
	60	62		THINNED DRILLING MUD OUT @ 60', GRAVEL
	62	64		GRAVEL, SOME ROCKS, SLIGHT MUD LOSS
	64	66		GRAVEL, SLIGHT MUD LOSS
	66	68		GRAVEL, NO MUD LOSS

GOODWIN WELL DRILLING, INC.

DRILLERS LOG

DATE & TIME	INTERVAL FROM	INTERVAL TO	SAMPLE #	DESCRIPTION
	68	70		GRAVEL, NO MUD LOSS
	70	72		ROCKS & GRAVEL, NO MUD LOSS
	72	74		GRAVEL, NO MUD LOSS
	74	76		LOSE GRAVEL, NO MUD LOSS
	76	78		LOSE GRAVEL, NO MUD LOSS
	78	80		GRAVEL & ROCKS TIGHT, NO MUD LOSS, MODERATE DESANDING
	80	82		GRAVEL & ROCKS TIGHT, NO MUD LOSS, MODERATE DESANDING
	82	84		GRAVEL & ROCKS TIGHT, NO MUD LOSS, MODERATE DESANDING
	84	86		GRAVEL & ROCKS TIGHT, NO MUD LOSS, MODERATE DESANDING
	86	88		GRAVEL LOSE, LIGHT MUD LOSS, MODERATE DESANDING
	88	90		GRAVEL LOSE, LIGHT MUD LOSS, MODERATE DESANDING
	90	92		GRAVEL LOSE, LIGHT MUD LOSS, MODERATE DESANDING
	92	94		GRAVEL LOSE, LIGHT MUD LOSS, MODERATE DESANDING
	94	96		GRAVEL LOSE, LIGHT MUD LOSS, MODERATE DESANDING
	96	98		GRAVEL LOSE, NO MUD LOSS, MODERATE DESANDING
	98	100		GRAVEL TIGHT, LIGHT MUD LOSS, MODERATE DESANDING
	100	102		GRAVEL TIGHT, LIGHT MUD LOSS, MODERATE DESANDING
	102	104		GRAVEL, MODERATE DESANDING
	104	106		GRAVEL & ROCKS TIGHT, NO MUD LOSS, MODERATE DESANDING
	106	108		GRAVEL TIGHT, NO MUD LOSS, MODERATE DESANDING
	108	110		GRAVEL & SAND, MODERATE DESANDING
	110	112		GRAVEL & SAND, CLAY, MODERATE DESANDING
	112	114		GRAVEL & SAND, CLAY, MODERATE DESANDING
	114	116		GRAVEL & TRACES OF CLAY, MODERATE DESANDING

GOODWIN WELL DRILLING, INC.

DRILLERS LOG

DATE & TIME	INTERVAL FROM	TO	SAMPLE #	DESCRIPTION
	116	118		GRAVEL & ROCKS, SOME MUD LOSS, MODERATE DESANDING
	120	122		GRAVEL & SILT, SOME MUD LOSS, MODERATE DESANDING
	122	124		GRAVEL & ROCKS, NO MUD LOSS, MODERATE DESANDING
	124	126		GRAVEL & ROCKS, NO MUD LOSS, MODERATE DESANDING
	126	128		GRAVEL & ROCKS TIGHT, NO MUD LOSS, MODERATE DESANDING
	128	130		GRAVEL, MODERATE DESANDING
	130	132		GRAVEL, MODERATE DESANDING
	132	134		GRAVEL, MODERATE DESANDING
	134	136		GRAVEL, MODERATE DESANDING
	136	138		GRAVEL, MODERATE DESANDING
	138	140		GRAVEL, SOME MUD LOSS, MODERATE DESANDING
	140	142		GRAVEL & ROCK, NO MUD LOSS, MODERATE DESANDING
	142	144		GRAVEL & ROCKS, NO MUD LOSS
	144	146		GRAVEL & ROCKS, TRACE OF CLAY, NO MUD LOSS
	146	148		GRAVEL & ROCKS, A LOT OF CLAY, NO MUD LOSS
	148	150		GRAVEL & ROCKS, NO MUD LOSS
	150	152		GRAVEL & ROCKS, TRACE OF CLAY, NO MUD LOSS
	152	154		GRAVEL & ROCKS, TRACE OF CLAY, NO MUD LOSS
	154	156		ROCKS, NO MUD LOSS
	156	158		GRAVEL, NO MUD LOSS
	158	159		GRAVEL & ROCKS, NO MUD LOSS

GOODWIN WELL DRILLING, INC.

DRILLERS LOG

DATE & TIME	INTERVAL FROM	TO	SAMPLE #	DESCRIPTION
6/22/99 1:00 - 5:00	0	106		OPENED 6" BOREHOLE TO 8 3/4 USING MUD ROTARY
5:00 - 6:30				INSTALLED 12' X 6" PIPE SIZE, 30 SLOT, S.S SCREEN ON 95' OF 6" STEEL
				CASING. SCREEN SET BETWEEN 94' & 106'. CASING STICKS UP 1'.6".
6/23/99 8:45 - 4:15				JETTED WELL WITH WATER, USING 95' OF 6" CASING.
				JETTED @ 25 PSI - 0 GPM
				JETTED @ 50 PSI - 7 GPM @ 80'
				JETTED @ 50 PSI - 10 GPM @ 80'
				JETTED @ 75 - 100 PSI - 15 GPM @ 80', 55' STATIC WATER LEVEL WITH
				INLINE LIGHT.
				JETTED @ 125 - 150 PSI - 20 GPM. NO RETURNS WHEN JETTING,
				MOVING FINES WHEN BLOWING ON WELL.
				JETTED 175 - 205 PSI - 20 GPM. NO RETURNS WHEN JETTING, MOVING
				SOME FINES WHEN BLOWING ON WELL.
				99100.BPTW1

EP-7

GOODWIN WELL DRILLING, INC.
DRILLERS LOG

CUSTOMER:

OWNER: SAME

TOWN: DEBLOIS

DATE STARTED: 7/1/99

DATE FINISHED: 7/1/99

JOB #: 99107 **HOLE#:** EP · 7

DRILLER: PETER ELLINGWOOD

HELPER: CALVIN GILBERT

LOCATION

SEE SEVEE & MAHER MAPS

DATE & TIME	INTERVAL FROM	TO	SAMPLE #	DESCRIPTION
7/1/99 2:00 - 5:30				DRILLED 6" PILOT BOREHOLE USING MUD ROTARY
	0	5		GRAVEL & SAND, LOW MUD LOSS, LIGHT DESAND
	5	10		CLAY, NO MUD LOSS, LIGHT DESAND
	10	15		SAND, NO MUD LOSS, LIGHT DESAND
	15	20		SAND, NO MUD LOSS, HEAVY DESAND
	20	25		CLAY, LOW MUD LOSS, HEAVY DESAND
	25	30		SAND, LOW MUD LOSS, LIGHT DESAND
	30	35		SAND, LOW MUD LOSS, LIGHT DESAND
	35	40		SAND, LOW MUD LOSS, HEAVY DESAND
	40	45		SAND, LOW MUD LOSS, HEAVY DESAND
	45	50		SAND & CLAY, LOW MUD LOSS, LIGHT DESAND
	50	55		SAND & SILT, LOW MUD LOSS, LIGHT DESAND, MIXED MUD
	55	60		SAND & CLAY, LOW MUD LOSS, LIGHT DESAND
	60	65		CLAY, LOW MUD LOSS, LIGHT DESAND
	65	70		CLAY, LOW MUD LOSS, MODERATE DESAND
	70	75		FINE, SAND & CLAY, NO MUD LOSS, MODERATE DESAND

GOODWIN WELL DRILLING, INC.

DRILLERS LOG

DATE & TIME	INTERVAL FROM	INTERVAL TO	SAMPLE #	DESCRIPTION
	75	80		FINE SAND & CLAY, LOW MUD LOSS, LIGHT DESAND
	80	85		SAND & CLAY, LOW MUD LOSS, MODERATE DESAND
	85	90		CLAY, LOW MUD LOSS, HEAVY DESAND
	90	95		CLAY, LOW MUD LOSS, HEAVY DESAND
	95	100		CLAY & SAND, LOW MUD LOSS, HEAVY DESAND
	100	105		FINE SAND & CLAY, LIGHT TO MODERATE FLUID LOSS, HEAVY DESAND
	105	110		FINE SAND & CLAY, LIGHT MUD LOSS, HEAVY DESAND
	110	115		CLAY, FINE SAND, LOW MUD LOSS, HEAVY DESAND
	115	120		CLAY, LOW MUD LOSS, HEAVY DESAND
	120	124		CLAY, LOW MUD LOSS, HEAVY DESAND
	124	125		ROCKS, NO MUD LOSS
	125	130		ROCKS, NO MUD LOSS
	130	132		BEDROCK, NO MUD LOSS
				DAVE BACK FILLED BORE HOLE WITH NATIVE MATERIAL

PROJECT	WYMAN BLUEBERRIES	JOB NO.	99011	BORING NO.	MM-1
DATE COMPLETED	7/26/99	DATE INSTALLED	7/26/99	DRILLING METHOD	MUD-ROTARY
GROUND SURFACE ELEVATION	see map	DRILLING CONTRACTOR	GOODWIN	LOGGED BY	DWB
BOREHOLE DIAMETER (IN)		ROCK CORE DIAMETER (IN)		SHEET	1 OF ?

DEPTH (FT)	SAMPLE NO.	MATERIAL DESCRIPTION	BLOW COUNTS	MUD LOSS (GPM)	DRILLER'S LOG	INSTRUMENT LOG
0	-	SAND & GRAVEL	-	-	G	
1	-		-	-	.	
2	-	F-FC BROWN SILTY SAND	-	-	.	
3	-	&	-	-	.	
4	-	GRAVEL	-	-	.	
5	-		-	-	.	
6	-		-	-	.	
7	-	SAND & GRAVEL	-	-	.	
8	-		-	-	.	
9	-	M-VC GRAY SAND	-	-	.	
10	-	&	-	NONE	.	
11	-	F-GRAVEL	-	.	S & G	
12	-		-	.	.	
13	-		-	.	.	
14	-		-	.	.	
15	-		-	.	.	
16	-	...BECOMING SILTY	-	.	S, SLT, & R	
17	-		-	.	.	
18	-		-	.	.	
19	-		-	.	.	
20	-		-	.	.	
21	-		-	.	R, G, & SLT	
22	-	SAND & GRAVEL	-	.	.	
23	-		-	.	R & SLT	
24	-	F-VC CLAYEY GRAY SAND	-	.	.	
25	-	&	-	.	.	
26	-	F-GRAVEL	-	.	.	
27	-		-	.	R & C	
28	-		-	.	.	
29	-		-	.	R, G, & C	
30	-		-	.	.	
31	-		-	.	R & C	
32	-	SAND	-	.	.	
33	-		-	.	R, S, & C	
34	-	F-C CLAYEY GRAY SAND	-	.	.	
35	-		-	.	R	
36	-		-	.	.	
37	-		-	-	BR?	
38	-		-	-	.	
39	-		-	-	.	
40	B.O.E. 39'					
41		BEDROCK				
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43		BLACK & WHITE GRANITIC				
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NOTES:

MATERIAL
G=GRAVEL
S=SAND
SLT=SILT
CLY=CLAY

SIZE
F=FINE
M=MEDIUM
C=COARSE
V=VERY

MUD LOSS
H=HIGH
L=LOW

PURGED, STATIC WATER @ 13'

PROJECT	WYMAN BLUEBERRIES	*JOB NO.*	99011	*BORING NO.*	MM-2
DATE COMPLETED	7/28/99	*DATE INSTALLED*	7/28/99	*DRILLING METHOD*	MUD-ROTARY
GROUND SURFACE ELEVATION	see map	*DRILLING CONTRACTOR*	GOODWIN	*LOGGED BY*	DWB
BOREHOLE DIAMETER (IN)		*ROCK CORE DIAMETER (IN)*		*SHEET*	1 OF ?

DEPTH (FT)	SAMPLE NO.	MATERIAL DESCRIPTION	BLOW COUNTS	MUD LOSS (GPM)	DRILLER'S LOG	INSTRUMENT LOG
0	-	<u>SAND & GRAVEL</u>	-	-	-	
1	-		-	-	-	
2	-	M-VC TAN SAND	-	-	-	
3	-	&	-	-	-	
4	-	C-GRAVEL-SOME COBBLES	-	-	-	
5	-		-	-	-	
6	-		-	-	-	
7	-	<u>SAND & GRAVEL</u>	-	-	-	
8	-		-	-	-	
9	-	M-VC GRAY SAND	-	-	-	
10	-	&	-	-	-	
11	-	C-GRAVEL-SOME COBBLES	-	-	-	
12	-		-	-	-	
13	-		-	-	-	
14	-	STATIC WATER @ 13'	-	-	-	
15	-		-	-	-	
16	-		-	-	-	
17	-		-	-	-	
18	-		-	-	-	
19	-		-	-	-	
20	-		-	-	-	
21	-		-	-	-	
22	-		-	-	-	
23	-		-	-	-	
24	-		-	-	-	
25	-		-	-	-	
26	-		-	-	-	
27	-		-	-	-	
28	-		-	-	-	
29	-		-	-	-	
30	-		-	-	-	
31	-		-	-	-	
32	-	<u>SAND & GRAVEL</u>	-	-	-	
33	-		-	-	-	
34	-	F-VC GRAY SAND	-	-	-	
35	-	&	-	-	-	
36	-	GRAVEL	-	-	-	
37	-		-	-	-	
38	-		-	-	-	
39	-		-	-	-	
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NOTES:

MATERIAL
G=GRAVEL
S=SAND
SLT=SILT
CLY=CLAY

SIZE
F=FINE
M=MEDIUM
C=COARSE
V=VERY

MUD LOSS
H=HIGH
L=LOW

PURGED, STATIC WATER @ 13'

MM-3

GOODWIN WELL DRILLING, INC.

DRILLERS LOG

CUSTOMER:

OWNER: SAME

TOWN: DEBLOIS

DATE STARTED: 7/29/99

DATE FINISHED: 7/29/99

JOB #: 99233 HOLE: MM-3

DRILLER: PETER ELLINGWOOD

HELPER: CALVIN GILBERT

LOCATION

DATE & TIME	INTERVAL FROM	INTERVAL TO	SAMPLE #	DESCRIPTION
7/29/99 9:15 - 11:20				DRILL 6" PILOT BOREHOLE USING MUD ROTARY
	0	5		GRAVEL LIGHT MUD LOSS
	5	10		SAND & GRAVEL LIGHT MUD LOSS
	10	15		ROCKS NO MUD LOSS LIGHT DESAND
	15	20		ROCKS & GRAVEL LIGHT MUD LOSS
	20	22		ROCKS NO MUD LOSS
	22	24		ROCKS & SILT NO MUD LOSS
	24	26		BEDROCK
	26	28		BEDROCK & SMALL FRACTURE AT 27' WITH SILT
	28	30		BEDROCK
				TO BE BACKFILLED BY THE FARM WITH NATIVE MATERIAL

MM-4

GOODWIN WELL DRILLING, INC.
DRILLERS LOG

CUSTOMER:

OWNER: SAME

TOWN: DEBLOIS

DATE STARTED: 7/30/99

DATE FINISHED: 7/30/99

JOB #: 99234 HOLE: MM-4

DRILLER: PETER ELLINGWOOD

HELPER: CALVIN GILBERT

LOCATION

DATE & TIME	INTERVAL FROM	TO	SAMPLE #	DESCRIPTION		
7/30/99 7:30				DRILLED 6" PILOT BOREHOLE USING MUD ROTARY		
	0	5		GRAVEL & ROCKS	NO MUD LOSS	
	5	10		GRAVEL & SAND	NO MUD LOSS	
	10	15		ROCKS & GRAVEL	NO MUD LOSS	
	15	20		ROCKS & GRAVEL	NO MUD LOSS	
	20	22		ROCKS	NO MUD LOSS	
	22	24		GRAVEL & SILT	NO MUD LOSS	HEAVY DESAND
	24	26		ROCKS	NO MUD LOSS	HEAVY DESAND
	26	28		ROCKS	NO MUD LOSS	HEAVY DESAND
	28	30		ROCKS & SILT	NO MUD LOSS	HEAVY DESAND
	30	32		ROCKS & SILT	NO MUD LOSS	HEAVY DESAND
	32	34		ROCKS & SILT	NO MUD LOSS	HEAVY DESAND
	34	36		ROCKS & SILT	NO MUD LOSS	HEAVY DESAND
	36	37		ROCKS & SILT	NO MUD LOSS	HEAVY DESAND
	37	39		BEDROCK	NO MUD LOSS	HEAVY DESAND
				TO BE BACKFILLED BY THE FARM WITH NATIVE MATERIALS		

MM-5

GOODWIN WELL DRILLING, INC.

DRILLERS LOG

CUSTOMER:

OWNER: SAME

TOWN: DEBLOIS

DATE STARTED: 7/30/99

DATE FINISHED: 7/30/99

JOB #: 99235 HOLE: MM-5

DRILLER: PETER ELLINGWOOD

HELPER: CALVIN GILBERT

LOCATION

DATE & TIME	INTERVAL FROM	TO	SAMPLE #	DESCRIPTION
7/30/99 @ 10:30				DRILLED 6" BOREHOLE USING MUD ROTARY
	0	5		SILT & CLAY
	5	10		GRAVEL & CLAY NO MUD LOSS
	10	15		GRAVEL, ROCKS, & SILT NO MUD LOSS
	15	20		GRAVEL & ROCKS FLUID LOSS AT 18', HEAVY MUD LOSS
				COURSE GRAVEL 3/8" HEAVY MUD LOSS
	20	22		COURSE GRAVEL LIGHT MUD LOSS
	22	24		ROCKS NO MUD LOSS
	24	26		ROCKS & GRAVEL NO MUD LOSS
	26	28		ROCKS & GRAVEL NO MUD LOSS
	28	30		BEDROCK @ 29' NO MUD LOSS
				BACKFILLED WITH NATIVE MATERIAL

MM-6

GOODWIN WELL DRILLING, INC.

DRILLERS LOG

CUSTOMER:

OWNER: SAME

TOWN: DEBLOIS

DATE STARTED: 7/29/99

DATE FINISHED: 7/29/99

JOB #: 99236 **HOLE:** MM-6

DRILLER: PETER ELLINGWOOD

HELPER: CALVIN GILBERT

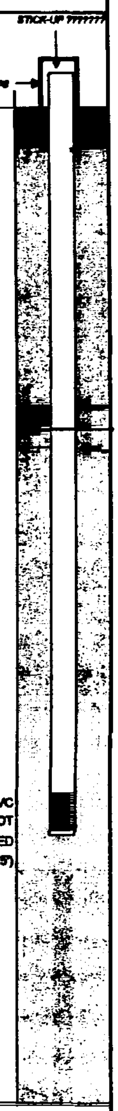
LOCATION

DATE & TIME	INTERVAL FROM	INTERVAL TO	SAMPLE #	DESCRIPTION
7/29/99 12:00 - 2:10				DRILLED 6" PILOT BOREHOLE USING MUD ROTARY
	0	5		SAND & SILT & GRAVEL NO MUD LOSS
	5	10		GRAVEL & SILT NO MUD LOSS
	10	15		GRAVEL & SILT NO MUD LOSS
	15	20		GRAVEL & SILT & ROCKS NO MUD LOSS, HEAVY DESAND
	20	22		BEDROCK LIGHT MUD LOSS
	22	24		BEDROCK NO MUD LOSS
	24	26		BEDROCK NO MUD LOSS
	26	28		BEDROCK NO MUD LOSS
	28	30		BEDROCK NO MUD LOSS
				TO BE BACKFILLED BY THE FARM USING NATIVE MATERIALS.

PROJECT	WYMAN BLUEBERRIES	JOB NO.	98011	BORING NO.	WP-1
DATE COMPLETED	7/8/98	DATE INSTALLED	7/8/98	DRILLING METHOD	MUD-ROTARY
GROUND SURFACE ELEVATION	SEE MAP	DRILLING CONTRACTOR	GOODWIN	LOGGED BY	DWB
BOREHOLE DIAMETER (IN)	6	ROCK CORE DIAMETER (IN)		SHEET	OF 9

DEPTH (FT)	SAMPLE NO.	DESCRIPTION	GEOLOGIC UNIT	MUD LOSS (GPM)	BLOW COUNTS	DEPTH (FT)	INSTRUMENT LOG
0	-	M-VC BROWN SAND & GRAVEL W/ COBBLES	SAND & GRAVEL	LOW		0	BENTONITE SEAL
	-			-			NATIVE MATERIAL
10	-	M-VC GRAY SAND & GRAVEL		-		10	
	-			8 (M)			
20	-			20 (H)		20	
30	-			12 (M)		30	
	-	...SOME COBBLES		-			
40	-			30 (H)		40	
	-			NONE			
50	-			-		50	
60	-			3 (L)		60	FILTER SAND
	-	SILTY F-C GRAY SAND	SILTY SAND	-			
70	-			-		70	2" PVC 10 SLOT SCREENED (70-75')
80	-			-		80	NATIVE MATERIAL
	-	SILTY-FC GRAY SAND SOME GRAVEL & COBBLES		NONE			
90	-			-		90	
	-	BEDROCK	BEDROCK	-			
100	-	BLACK-WHITE GRANITE		-		100	

B.O.E. @ 101'



B.O.E. @ 101'

NOTES:

GRAIN SIZE
F=FINE
M=MEDIUM
C=COARSE
VC=VERY COARSE
VF=VERY FINE

GOODWIN WELL DRILLING, INC.
DRILLERS LOG

CUSTOMER:

OWNER: SAME

TOWN: DEBLOIS

DATE STARTED: 7/29/99

DATE FINISHED: 7/29/99

JOB #: 99239 HOLE: WP-2

DRILLER: PETER ELLINGWOOD

HELPER: CALVIN GILBERT

LOCATION

DATE & TIME	INTERVAL FROM	INTERVAL TO	SAMPLE #	DESCRIPTION
7/29/99 3:00 - 5:00				DRILLED 6" PILOT BOREHOLE USING MUD ROTARY
	0	5		GRAVEL & SILT
	5	10		BEDROCK AT 7'
	10	15		BEDROCK
	15	20		BEDROCK
	20	21		BEDROCK
	0	7		6" ROLLER BIT
	0	7		OPEN UP TO 8 3/4"
	7	21		6"
5:20				BACK FILLING BOREHOLE
				TWO SACKS ENVIROPLUG

PROJECT	JOB NO. 00039	BORING NO. WP - 3	
DATE COMPLETED 3/28/00	DATE WELLS INSTALLED 3/28/00	DRILLING METHOD HOLLOW STEM AUGER	
GROUND SURFACE ELEVATION (FT)	DRILLING CONTRACTOR MTB	LOGGED BY MSR	
BOREHOLE DIAMETER (IN) 5"	ROCK CORE DIAMETER (IN) N/A	SHEET 1 OF 1	

DEPTH (FT)	SAMPLE NO.	MATERIAL DESCRIPTION	N (BPF)				
		TOPSOIL					STEEL PROTECTIVE CASING
		SAND					
	1D	BROWN FINE TO COARSE SAND AND GRAVEL, SOME SILT	44				
10	2D		31				
	3D	BROWN VERY FINE TO FINE SAND, SOME SILT	31				BACKFILL WITH CUTTINGS FROM BOREHOLE
20	4D		30				
	5D	BROWN MEDIUM TO COARSE SAND SOME FINE SAND, TRACE SILT	30				
30	6D		27				
	7D	BROWN VERY FINE TO FINE SAND, SOME SILT, TRACE MEDIUM SAND	[illegible]				
40	8D		24				
	9D		13				BENTONITE CHIPS (TYP)
50	10D						FILTER SAND
	MS	.... BECOMING COARSER					2" Ø SCHD 40 PVC
60		BOE AT 60 FEET					
70							

INSTRUMENT LOG

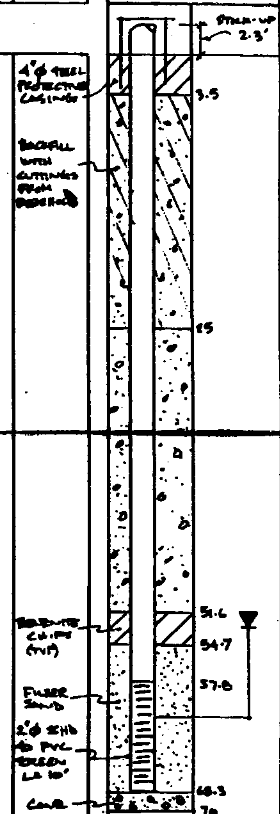
NOTES

5/90

PROJECT	JOB NO. 00039	BORING NO. WP-4
DATE COMPLETED 3/30/00	DATE WELLS INSTALLED 3/30/00	DRILLING METHOD WASHED BORING
GROUND SURFACE ELEVATION (FT)	DRILLING CONTRACTOR MTB	LOGGED BY MSR
BOREHOLE DIAMETER (IN) 4"	ROCK CORE DIAMETER (IN) N/A	SHEET 1 OF 1

DEPTH (FT)	SAMPLE NO.	MATERIAL DESCRIPTION	N (BPF)
		TOPSOIL	
	1D	SAND BROWN GRAVELLY FINE TO COARSE SAND, TRACE SILT, TRACE COBBLE	37
10	2D		33
	MS		28
20	3D		38
	4D	···· BECOMING LESS GRAVELLY	46
30	5D		33
	6D		49
40	MS		53
	7D		39
50	8D	BROWN FINE TO MEDIUM SAND, TRACE SILT, TRACE COARSE SAND	57
	9D		66
60	10D	59.8 GLACIAL TILL BROWN SILTY, GRAVELLY, FINE TO COARSE SAND, SOME COBBLES, SOME BOULDERS	130/5
	R-1		
70		70 BOE AT 70.0 FEET	

INSTRUMENT LOG



NOTES

BPF = BLOWS PER FOOT

MS = MISSED SAMPLE

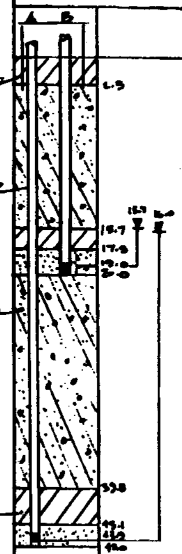
N = STANDARD PENETRATION TEST (SPT) VALUE

▼ = WATER LEVEL ON 4/7/00

PROJECT		JOB NO. 00039	BORING NO. WP-5
DATE COMPLETED 3/31/00	DATE WELLS INSTALLED 3/31/00	DRILLING METHOD Washed Boring	
GROUND SURFACE ELEVATION (FT)	DRILLING CONTRACTOR MTB	LOGGED BY MSR	
BOREHOLE DIAMETER (IN) 4"	ROCK CORE DIAMETER (IN) N/A	SHEET 1 OF 1	

DEPTH (FT)	SAMPLE NO.	MATERIAL DESCRIPTION	N (BPF)
	1D	SAND Brown silty, gravelly fine to coarse sand trace cobble	18
	2D		70
	3D		82
	4D	GRAVEL Brown sandy gravel, trace silt, trace cobble	42
	5D		31
10	6D		16
	7D		25
	8D	SAND Gravelly fine to coarse sand with layers of uniform fine to coarse sand trace silt	36
	MS		22
	9D		34
20	10D		34
	11D	Orange, manganese? staining	26
	MS		25
	12D	Very fine to medium sand, trace silt	14
	13D		20
30	14D	Some coarse sand and gravel layers	10
	15D		23
	16D		23
	17D		24
40	18D		28
	19D		50
	20D		53
		BOE AT 45 FEET	
50			

INSTRUMENT LOG



NOTES

N = Standard Penetration Test Value

BPF = Blows Per Foot

MS = Missed Sample

▼ = Water level measurement on 4/7/00

PROJECT	JOB NO. 00039	BORING NO. WP-6
DATE COMPLETED 4/3/00	DATE WELLS INSTALLED N/A	DRILLING METHOD WASHED BORING
GROUND SURFACE ELEVATION (FT)	DRILLING CONTRACTOR MTB	LOGGED BY MSR
BOREHOLE DIAMETER (IN) 4"	ROCK CORE DIAMETER (IN) N/A	SHEET 1 OF 1

DEPTH (FT)	SAMPLE NO.	MATERIAL DESCRIPTION	N (BPF)					INSTRUMENT LOG
	1D	TOPSOIL	15					
	2D	SAND	71					
	3D	BROWN FINE TO COARSE SAND AND GRAVEL, TRACE SILT	88					
	MS		43					
10	4D		24				BACKFILL WITH CUTTINGS FROM BOREHOLE	
	5D		22					
	6D	[illegible] TO COARSE SAND, TRACE GRAVEL, TRACE SILT	[illegible]					
	7D		20					
20	8D	BROWN GRAVELLY FINE TO COARSE SAND, TRACE SILT	15					
	MS		24					
	9D		27					
30	10D		22					(34) ▼
		[illegible]						
	11D	BROWN FINE TO COARSE SAND, TRACE SILT, TRACE GRAVEL	35					
40	12D		37					
	13D		26					47
50		BOE AT 47 FEET						
60								

NOTES

(34) ▼ BASED ON OBSERVED WATER LEVEL IN BORE HOLE

5/90

PROJECT	JOB NO. 00039	BORING NO. WP-7
DATE COMPLETED 4/5/00	DATE WELLS INSTALLED 4/5/00	DRILLING METHOD WASHED BORING
GROUND SURFACE ELEVATION (FT)	DRILLING CONTRACTOR KTB	LOGGED BY MSR
BOREHOLE DIAMETER (IN) 4"	ROCK CORE DIAMETER (IN) N/A	SHEET 1 OF 1

DEPTH (FT)	SAMPLE NO.	MATERIAL DESCRIPTION	N (BPF)	INSTRUMENT LOG
	1D	TOPSOIL	9	
	2D	SAND	47	
	3D	BROWN GRAVELLY FINE	24	
	4D	TO COARSE SAND,	60	
	5D	TRACE SILT	95	
10	6D		52	
	7D		24	
	MS		16	
	8D	GRAVEL COARSE SANDY GRAVEL SOME FINE TO MEDIUM	17	BACKFILL WITH CUTTINGS FROM BOREHOLE
20	9D	SAND, TRACE SILT	43	
	10D	SAND BROWN FINE TO COARSE	18	
	MS	SAND, SOME GRAVEL,	20	
	MS	TRACE SILT	27	
	11D	SOME FINE SAND LAYERS	14	
30	12D	BROWN GRAVELLY FINE	18	
	13D	TO COARSE SAND,	17	
	14D	TRACE SILT	24	(37.1) ▼
	15D		38	
	16D		24	
40	17D	BROWN FINE TO	21	
	18D	COARSE SAND,	17	
		SOME GRAVEL,		
		TRACE SILT		
	19D		13	
50				
	20D	BROWN GRAVELLY	12	
		MEDIUM TO COARSE SAND		
		SOME FINE SAND TRACE SILT		
	21D		21	
60				
	22D	BROWN FINE TO MEDIUM SAND, SOME COARSE SAND, TRACE GRAVEL	21	
		BROWN FINE TO		
	MS	COARSE SAND, TRACE	29	
		SILT		
70	23D	SOME GRAVEL	26	

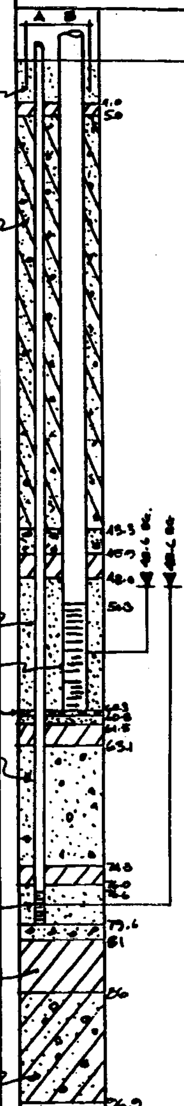
NOTES (37.1) ▼ OBSERVED WATER LEVEL IN BOREHOLE ON 4/5/00 (CASING WAS AT 38'6")

5/90

PROJECT		JOB NO. 00039		BORING NO. WP-8	
DATE COMPLETED 4/7/00		DATE WELLS INSTALLED 4/7/00		DRILLING METHOD WASHED BORING	
GROUND SURFACE ELEVATION (FT)		DRILLING CONTRACTOR MTB		LOGGED BY MSK	
BOREHOLE DIAMETER (IN) 4" SOIL, 3" ROCK		ROCK CORE DIAMETER (IN) 2"			SHEET 1 OF 1

DEPTH (FT)	SAMPLE NO.	MATERIAL DESCRIPTION	N (BPF)
		TOPSOIL	
		SAND	
	1D	BROWN GRAVELLY FINE TO COARSE SAND TRACE SILT, TRACE COBBLE	33
10	2D		33
	3D	BROWN MEDIUM TO COARSE SAND AND GRAVEL, TRACE SILT, TRACE FINE SAND	19
20	4D		12
	5D		16
30	6D		22
	7D		26
40	8D	... BECOMING LESS COARSE	41
	9D		68
50	10D	BROWN FINE TO COARSE SAND, SOME GRAVEL TRACE SILT, WITH SOME SILTY FINE SAND LAYERS	28
	11D		25
60	12D		25
	13D		37
70	14D	BROWN FINE TO VERY FINE SILTY SAND, SOME MEDIUM SAND, TRACE SILT, WITH SOME SILT LAYERS	38
	15D		61
80	16D	80 GLACIAL TILL BROWN SILTY FINE TO COARSE SAND, SOME GRAVEL, TRACE COBBLE	49
	17D		130
90	18D	90.7	116, 50/.2
	R-1	BEDROCK N/E	
	R-2		
		BOE AT 96.9 FEET	
100			

INSTRUMENT LOG



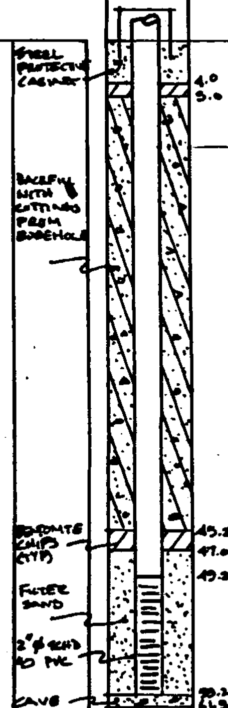
NOTES

5/90

PROJECT		JOB NO. 00039	BORING NO. WP-9
DATE COMPLETED 4/7/00	DATE WELLS INSTALLED 4/7/00	DRILLING METHOD WASHED BORING	
GROUND SURFACE ELEVATION (FT)	DRILLING CONTRACTOR MTB	LOGGED BY MSR	
BOREHOLE DIAMETER (IN) 4"	ROCK CORE DIAMETER (IN) N/A	SHEET 1 OF 1	

DEPTH (FT)	SAMPLE NO.	MATERIAL DESCRIPTION	N (BPF)
0		TOPSOIL	
		SAND	
	1D	BROWN GRAVELLY FINE TO COARSE SAND, TRACE SILT, TRACE COBBLE	78
10	2D		25
	3D	GRAVEL	27
20	4D	BROWN MEDIUM TO COARSE SANDY GRAVEL SOME FINE SAND, TRACE SILT	25
	5D	SAND BROWN FINE TO COARSE SAND, SOME GRAVEL	30
30	6D	BROWN VERY FINE, TO MEDIUM SAND, TRACE COARSE SAND, TRACE SILT, TRACE GRAVEL	48
	7D		44
40	8D		54
	9D		56
50	10D		59
	11D		51
60	12D	61.5	50
		BOE AT 61.5 FEET	
70			

INSTRUMENT LOG



NOTES

9/90

Appendix B

PRECIPITATION RECORD FOR JONESBORO, ME

FORM B-91

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

STATION: JONESBORO
MONTH: OCT. YR. 99
STATE: MAINE
COUNTY: WASHINGTON
RIVER:
TIME (local) OF OBSERVATION: TEMP. 7A PRECIPITATION 7A
STANDARD TIME IN USE: EDT
TYPE OF RIVER GAGE:
ELEVATION OF RIVER GAGE ZERO: Ft.
FLOOD STAGE: Ft.
NORMAL POOL STAGE: Ft.

Date	Max.	Min.	At Obsn.	Precip. 24-hr amount	Weather: Fog	Remarks
1	NA	NA	42	.05		CLEAR
2	65	42	42	0		CLEAR
3	65	42	46	0		CLOUDY
4	66	41	42	0		CLOUDY
5	44	37	37	1.60	X	CLOUDY
6	47	37	41	T		CLOUDY
7	53	33	35	0		CLEAR
8	53	28	29	0		CLEAR
9	56	29	55	0		CLOUDY
10	63	40	46	.08		CLEAR
11	61	46	52	.19		PT. CLOUDY
12	63	36	43	0		PT. CLOUDY
13	63	43	56	.16		RAIN
14	56	32	36	.73		CLEAR
15	58	35	40	0		CLEAR
16	60	40	43	T		PT. CLOUDY
17	60	39	41	T		PT. CLOUDY
18	68	41	46	.42		RAIN
19	68	29	29	.32		CLEAR
20	45	29	38	0		CLOUDY
21	49	38	43	.46	X	CLOUDY
22	56	32	33	0		CLEAR
23	66	33	49	.06	X	RAIN
24	59	43	43	.60		CLEAR
25	56	31	32	0		CLEAR
26	46	29	38	0		PT. CLOUDY
27	57	37	37	0		CLEAR
28	53	25	25	0		CLEAR
29	47	25	39	0		CLEAR
30	59	29	29	0		CLEAR
31	55	29	35	0		CLOUDY
Sum	1707	1050		3.07		

CONDITION OF RIVER AT GAGE

A. Obstructed by rough ice.
B. Frozen, but open at gage.
C. Upper surface of smooth ice.
D. Ice gorge above gage.
E. Ice gorge below gage.
F. Shore ice.
G. Floating ice.
H. Pool stage.

CHECK BAR (For wire-weight) NORMAL CK. BAR
READING | DATE

OBSERVER

SUPERVISING OFFICE: GYX

STATION INDEX NO.: 17-4183-3

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

FORM B-91

STATION (Climatology): JONESBORO
MONTH: NOV. YR. 99
STATE: MAINE
COUNTY: WASHINGTON
RIVER:
TIME (local) OF OBSERVATION RIVER:
TEMP: 7A
PRECIPITATION: 7A
STANDARD TIME IN USE: DST
TYPE OF RIVER GAGE:
ELEVATION OF RIVER GAGE ZERO: Ft.
FLOOD STAGE: Ft.
NORMAL POOL STAGE: Ft.

Date	Max.	Min.	At Obsn.	Rain, melted snow, etc. (Ins. and hundredths)	Snow, ice pellets, hail (Ins. and tenths)	Snow, ice pellets, hail, ice on ground (Ins.)	Weather (X)	Remarks (Special observations, etc.)
1	59	39	40	0				CLEAR
2	64	40	48	0				CLEAR
3	60	49	59	0				CLOUDY
4	62	42	42	1.52				CLEAR
5	50	36	38	0				CLEAR
6	55	38	41	0				CLEAR
7	55	28	28	0				CLEAR
8	44	26	27	0				CLEAR
9	39	20	23	0				CLEAR
10	51	23	45	0.				CLOUDY
11	52	25	25	.09	T	T		CLEAR
12	34	16	16	0		T		CLEAR
13	33	16	33	.14		0		RAIN
14	41	33	38	.31				CLOUDY
15	50	36	36	1.04				CLOUDY
16	43	29	30	0				CLEAR
17	38	27	27	0				PT CLOUDY
18	36	25	29	0				CLOUDY
19	37	29	32	0				CLOUDY
20	52	32	32	0				PT. CLOUDY
21	53	49	51	.80			Thunder X	CLOUDY
22	54	43	43	00			Fog X	CLEAR
23	55	43	50	0			Fog X	CLOUDY
24	65	40	44	0				CLOUDY
25	56	44	45	.16			Fog X	CLOUDY
26	57	45	48	T			Fog X	CLOUDY
27	51	46	50	.32				CLOUDY
28	53	35	35	.43				CLEAR
29	47	27	30	0				CLEAR
30	44	21	22	0				CLEAR
31								
Sum	1489	1002		4.81	T			

CHECK BAR (For wire-weight) NORMAL CHECK BAR: READING / DATE

CONDITION OF RIVER AT GAGE
A. Obstructed by rough ice.
B. Frozen, but open at gage.
C. Upper surface of smooth ice.
D. Ice gorge above gage.
E. Ice gorge below gage.
F. Shore ice.
G. Floating ice.
H. Pool stage.

OBSERVER:

SUPERVISING OFFICE: GYX

STATION INDEX NO.: 17-4183-3.

STATION	JC [illegible]ESBORO	MONTH DEC.	19 99	FORM B-91	U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NATIONAL WEATHER SERVICE
STATE MAINE	COUNTY WASHINGTON	RIVER			
TIME (local) OF OBSERVATION RIVER	TEMP. 7A	PRECIPITATION 7A	STANDARD TIME IN USE DST		
TYPE OF RIVER GAGE	ELEVATION OF RIVER GAGE ZERO Ft.	FLOOD STAGE Ft.	NORMAL POOL STAGE Ft.		

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

DATE	Temperature F. Max.	Min.	At Obsn.	Rain, melted snow, etc. (in.)	Snow, ice pellets, hail (in.)	Snow, ice pellets, hail, ice on ground (in.)	Weather: Fog	Remarks
1	35	22	22	0				CLOUDY
2	28	22	28	0				CLOUDY
3	37	26	28	0				Mostly Sunny
4	44	28	35	T				CLOUDY
5	42	34	38	.01				CLOUDY
6	51	38	51	0				CLOUDY
7	56	46	46	.86				CLOUDY
8	46	33	34	2.10			X	CLEAR
9	45	23	23	0				CLEAR
10	42	23	27	0				CLOUDY
11	51	30	32	.26				CLOUDY
12	38	30	30	.14	1.0	1.0		CLOUDY
13	40	37	37	.03		0		CLOUDY
14	42	34	34	T				CLOUDY
15	38	27	28	0				CLOUDY
16	39	26	39	0				CLOUDY
17	47	31	32	.32				CLEAR
18	40	22	22	0				CLEAR
19	32	9	9	0				CLEAR
20	30	9	11	0				CLEAR
21	50	12	49	.68				CLOUDY
22	49	28	28	0				CLOUDY
23	32	16	16	0				CLEAR
24	29	12	12	0				CLEAR
25	24	0	0	0				CLEAR
26	33	0	33	0				CLOUDY
27	39	20	23	0				CLOUDY
28	24	2	3	0				CLEAR
29	19	2	12	0				Pt. Cloudy
30	33	10	33	.10	1.5	1.5		CLOUDY
31	44	8	8	0		T		CLEAR
SUM	1199	657	SUM	5.06	2.5			

CONDITION OF RIVER AT GAGE

A. Obstructed by rough ice. B. Frozen, but open at gage. C. Upper surface of smooth ice. D. Ice gorge above gage. E. Ice gorge below gage. F. Shore ice. G. Floating ice. H. Pool stage.

CHECK BAR (For wire-weight) NORMAL CK. BAR — READING — DATE

OBSERVER

SUPERVISING OFFICE: GYX

STATION INDEX NO.: 17-4183-3

WS FORM B-91 (12-93)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

Station: JONESBORO
Month: JAN
Year: 2000
State: MAINE
County: WASHINGTON
River:
Time (local) of observation: Temp. 7A; Precipitation 7A
Standard time in use: EST
Type of river gage:
Elevation of river gage zero: Ft.
Flood stage: Ft.
Normal pool stage: Ft.

Date	Temp. Max.	Temp. Min.	Temp. At Obsn	24-hr Precip. (rain, melted snow, etc.)	Snow, ice pellets, hail (ins.)	Snow, ice pellets, hail on ground at obsn (ins.)	Remarks
1	21	8	21	0		T	PT CLOUDY
2	34	21	37	0		1	PT. CLOUDY
3	48	37	47	.28		0	CLOUDY
4	52	29	33	.02			CLOUDY
5	54	33	34	1.26			CLOUDY
6	34	8	4	0			CLEAR
7	38	9	35	.10			CLOUDY
8	38	24	24	T			CLEAR
9	NA	NA	NA	0			PT. CLOUDY
10	NA	NA	25	0			CLEAR
11	49	25	41	.94			CLEAR
12	57	33	33	.03			CLOUDY
13	34	17	17	0			CLEAR
14	23	-2	-2	0			CLEAR
15	10	-8	-8	0			CLEAR
16	17	-8	17	1.00	2	9	CLOUDY
17	NA	NA	NA	.20	1	10	CLOUDY
18	NA	NA	2	0		10	PT. CLOUDY
19	10	-6	-6	0		10	CLEAR
20	15	-7	-7	0		10	CLEAR
21	17	-5	11	0		10	CLOUDY
22	11	-1	-1	.38	4	14	PT. CLOUDY
23	NA	NA	NA	0		14	CLEAR
24	NA	NA	21	T	T	14	CLOUDY
25	32	16	17	0		14	CLOUDY
26	45	17	42	.65	2	14	CLOUDY
27	41	22	22	T		6	CLOUDY
28	23	-2	-2	0		6	CLEAR
29	21	-2	6	T		6	CLEAR
30	KA	NA	NA	0		6	CLEAR
31	NA	NA	35	0		5	CLOUDY
Sum	718	260		4.86	16		

CONDITION OF RIVER AT GAGE

A. Obstructed by rough ice.
B. Frozen, but open at gage.
C. Upper surface of smooth ice.
D. Ice gorge above gage.
E. Ice gorge below gage.
F. Shore ice.
G. Floating ice.
H. Pool stage.

CHECK BAR (For wire-weight) NORMAL CK. BAR

Reading / Date

Observer

Supervising office: GYX

Station index no.: 17-4183-3

WS FORM B-91 (12-93)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

STATION: JONESBORO
MONTH: FEB. 2000
STATE: MAINE
COUNTY: WASHINGTON
RIVER:
TIME (local) OF OBSERVATION: RIVER — TEMP. 7A — PRECIPITATION 7A
STANDARD TIME IN USE: DST
TYPE OF RIVER GAGE:
ELEVATION OF RIVER GAGE ZERO: Ft.
FLOOD STAGE: Ft.
NORMAL POOL STAGE: Ft.

Date	Temp. Max.	Temp. Min.	Temp. At Obsn.	Precip. Rain, melted snow, etc. (Ins. and hundredths)	Snow, ice pellets, hail (Ins. and tenths)	Snow, ice pellets, hail, ice on ground (Ins.)	Weather: Fog	Remarks (Special observations, etc.)
1	42	27	28	.55	T	5		CLEAR
2	38	14	14	0		5		PT. CLOUDY
3	21	5	6	0		5		PT. CLOUDY
4	23	2	3	0		5		PT. CLOUDY
5	NA	NA	NA	0		5		CLEAR
6	NA	NA	NA	0		5		CLEAR
7	NA	NA	28	0		5		CLOUDY
8	37	-3	-2	0		5		CLEAR
9	31	-3	31	0		5		PT. CLOUDY
10	37	16	16	T	T	5		CLEAR
11	34	17	34	T		5		CLOUDY
12	NA	NA	NA	.53		4		CLEAR
13	NA	NA	NA	0		4		PT. CLOUDY
14	NA	NA	28	.02	.5	4		CLOUDY SNOW
15	48	24	29	1.60	2	4		CLOUDY
16	35	16	19	0		4		CLOUDY
17	37	13	13	.21	1	4		CLEAR
18	17	-6	-2	0		4		PT. CLOUDY
19	24	-2	24	.41	7	11		SNOW
20	26	20	21	.04	1	11		CLOUDY
21	28	12	12	0		10		CLEAR
22	31	4	5	0		10		CLEAR
23	38	4	38	0		10		PT. CLOUDY
24	44	34	34	0		5		PT. CLOUDY
25	55	28	29	0		4		CLOUDY
26	40	26	28	0		3		CLEAR
27	44	28	40	0		2	X	CLEAR
28	46	42	44	0		2	X	CLOUDY
29	51	35	35	.32		1		CLOUDY
30								
31								
Sum	827	353		3.68	11.50			

CHECK BAR (For wire-weight) NORMAL CK. BAR — READING — DATE

CONDITION OF RIVER AT GAGE
A. Obstructed by rough ice.
B. Frozen, but open at gage.
C. Upper surface of smooth ice.
D. Ice gorge above gage.
E. Ice gorge below gage.
F. Shore ice.
G. Floating ice.
H. Pool stage.

OBSERVER:

SUPERVISING OFFICE: GYX

STATION INDEX NO.: 17-4183-3

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

WS FORM B-91 (12-83)

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

STATION: JONESBORO — MARCH 2000
STATE: MAINE — COUNTY: WASHINGTON — RIVER:
TIME OF OBSERVATION: TEMP. 7A — PRECIPITATION 7A — STANDARD TIME IN USE: DST
TYPE OF RIVER GAGE: — ELEVATION OF RIVER GAGE ZERO: Ft. — FLOOD STAGE: Ft. — NORMAL POOL STAGE: Ft.

Date	Temp. Max.	Temp. Min.	Temp. At Obsn.	Precip. 24-hr Rain, melted snow, etc.	Snow, ice pellets, hail	Snow on ground at Ob.	Weather (Calendar Day)	Remarks
1	40	34	35	T		1		CLOUDY
2	47	33	33	0		T	X (Fog)	CLOUDY
3	35	31	31	.40	3	3		CLOUDY, SNOW
4	32	31	36	.141	2	2		Cloudy
5	NA	NA	NA	.02		T		CLOUDY
6	NA	NA	31	.02		T		CLOUDY
7	36	25	27	T		T		CLOUDY
8	52	27	28	0		0		PT. CLOUDY
9	45	31	37	0				CLOUDY
10	44	26	27	.16	T	T	X (Thunder)	CLOUDY
11	33	17	20	0		T		CLEAR
12	NA	NA	NA	.55	2	2		CLOUDY
13	NA	NA	28	1.02		1		CLEAR
14	37	13	16	0		T		CLEAR
15	39	22	37	0		0		PT. CLOUDY
16	49	39	45	0				CLOUDY
17	58	22	23	.71	3	3		CLOUDY, SNOW
18	25	9	9	.31	2	5		CLEAR
19	NA	NA	NA	0		5		CLEAR
20	NA	NA	21	0		3		CLOUDY
21	45	21	26	0		3		CLOUDY
22	48	26	28	0		1		CLEAR
23	53	30	34	0		1		CLEAR
24	53	35	37	0		T		CLEAR
25	55	28	31	0		T		CLEAR
26	51	31	42	.104		0	X (Fog)	Cloudy
27	58	32	36	0				CLEAR
28	55	35	44	T				Cloudy
29	55	35	41	.93				CLOUDY
30	47	35	39	.08				CLEAR
31	51	31	33	0				PT. CLOUDY
Sum	1149	702		4.66	12.00			

CONDITION OF RIVER AT GAGE

CHECK BAR (For wire-weight) NORMAL CK. BAR — READING — DATE

OBSERVER

SUPERVISING OFFICE: GYX

STATION INDEX NO.: 17-4183-3

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

WS FORM B-91

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

STATION: JONESBORO		MONTH: APRIL	YEAR: 2000	
STATE: TN (illegible)	COUNTY: WASHINGTON	RIVER:		
STREAM (local) OF OBSERVATION RIVER:	TIME TEMP.: 7A	PRECIPITATION: 7A	STANDARD TIME IN USE: DST	
TYPE OF RIVER GAGE:	ELEVATION OF RIVER GAGE ZERO: ft.	FLOOD STAGE: ft.	NORMAL POOL STAGE: ft.	

DATE	TEMPERATURE F. MAX.	MIN.	AT OBSN.	PRECIPITATION 24-HR AMOUNTS Rain, melted snow, etc. (in. and hundredths)	Snow, ice pellets, hail (in. and tenths)	At Ob. Snow, ice pellets, hail, ice on ground (in.)	WEATHER Fog	River Stage	REMARKS (Special observations, etc.)
1	49	30	32	.01					CLEAR
2	NA	NA	NA	0					PT. CLOUDY
3	NA	NA	38	.17			X		CLOUDY
4	56	38	44	.27			X		CLOUDY
5	49	43	44	.58			X		CLOUDY
6	51	31	32	.12					CLEAR
7	51	31	35	.03					CLOUDY
8	51	33	40	T					CLOUDY
9	56	40	52	0					CLOUDY
10	55	33	34	.25					CLOUDY
11	46	28	27	.03					CLEAR
12	47	37	33	.24					CLOUDY
13	47	27	28	0					CLEAR
14	47	27	29	0					CLEAR
15	NA	NA	NA	0					CLOUDY
16	NA	NA	NA	0					CLEAR
17	NA	NA	NA	0					CLEAR
18	NA	NA	27	0					CLEAR
19	48	28	38	0					CLOUDY
20	42	36	37	.07					CLOUDY
21	58	36	38	0					CLOUDY
22	49	37	37	.32					CLOUDY
23	NA	NA	NA	0					CLOUDY
24	NA	NA	40	3.09			X		CLOUDY
25	43	32	34	.11					CLOUDY
26	42	29	32	0					CLOUDY
27	50	32	34	.03					CLOUDY
28	41	33	35	.02					CLOUDY
29	50	35	40	0					CLEAR
30	57	39	43	T					CLOUDY
31									
SUM	1080	731		5.33					

CONDITION OF RIVER AT GAGE

A. Obstructed by rough ice.
B. Frozen, but open at gage.
C. Upper surface of smooth ice.
D. Ice gorge above gage.
E. Ice gorge below gage.
F. Shore ice.
G. Floating ice.
H. Pool stage.

CHECK BAR (For wire-weight) NORMAL CK. BAR — READING — DATE

OBSERVER

SUPERVISING OFFICE

STATION INDEX NO. 17-4-83-3

NATIONAL WEATHER SERVICE

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

MAY 2000

Station: ...MING (?) | County: WASHINGTON | Month: MAY 2000
Temp.: 7A | Precipitation: 7A | Standard time in use: DST

Date	Max.	Min.	At Obsn.	24-hr Precip.	Fog	Thunder	Remarks
1	56	31	36	0			CLEAR
2	58	37	45	0			CLOUDY
3	60	31	36	0			CLEAR
4	57	37	42	0			CLEAR
5	55	43	45	.02			CLOUDY
6	72	45	49	0			CLEAR
7	73	45	45	T			CLOUDY
8	61	45	50	.26		X	CLOUDY
9	74	49	49	.10			CLOUDY
10	47	36	37	.40			CLOUDY
11	46	37	42	.11	X		CLOUDY, RAIN
12	48	39	42	.60			CLOUDY
13	61	35	41	0			CLEAR
14	55	41	45	.24		X	CLOUDY
15	57	41	47	0			CLEAR
16	63	38	44	0			CLEAR
17	66	43	45	0			CLOUDY
18	64	45	50	0			CLOUDY
19	56	42	49	.43			CLEAR
20	57	35	36	0			CLEAR
21	63	42	50	0			PT CLOUDY
22	65	47	49	.01			CLOUDY
23	62	42	44	0			CLOUDY
24	52	39	45	.11			CLOUDY
25	52	46	50	.52			CLOUDY
26	53	46	52	.33			PT. CLOUDY
27	70	48	53	0			"
28	67	45	48	0			"
29	59	45	47	0			CLOUDY
30	68	37	44	0			CLEAR
31	61	43	47	0			CLOUDY
Sum	1848	1295		3.13			

CONDITION OF RIVER AT GAGE

A. Obstructed by rough ice. B. Frozen, but open at gage. C. Upper surface of smooth ice. D. Ice gorge above gage. E. Ice gorge below gage. F. Shore ice. G. Floating ice. H. Pool stage.

CHECK BAR (For wire-weight) NORMAL CK. BAR — READING — DATE

OBSERVER

SUPERVISING OFFICE

STATION INDEX NO. 11-4183-3

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

FORM B-91

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

STATION: JONESBORO	MONTH: JUNE	YEAR: 2000			
STATE: MAINE	COUNTY: WASHINGTON	RIVER:			
TIME (local) OF OBSERVATION RIVER:	TEMP.: 7A	PRECIPITATION: 7A	STANDARD TIME IN USE: DST		
TYPE OF RIVER GAGE:	ELEVATION OF RIVER GAGE ZERO: Ft.	FLOOD STAGE: Ft.	NORMAL POOL STAGE: Ft.		

DATE	TEMP. MAX.	TEMP. MIN.	TEMP. AT OBSN.	24-HR PRECIP. (Rain, melted snow, etc.)	Snow, ice pellets, hail	Snow, ice pellets, hail, ice on ground	Fog	Ice Pellets	Glaze	Thunder	Hail	Damaging Winds	REMARKS
1	59	47	54	0									CLOUDY
2	84	54	59	0									PT. CLOUDY
3	70	50	55	T									CLOUDY
4	NA	NA	NA	0									CLOUDY
5	NA	NA	49	.03									CLOUDY
6	64	40	32	0									PT CLOUDY
7	54	42	44	.23									CLOUDY
8	57	43	48	.22									CLEAR
9	68	48	57	.03									PT. CLOUDY
10	75	51	55	T									CLOUDY
11	60	44	48	.44									RAIN
12	48	38	43	.10									PT. CLOUDY
13	61	40	47	0									PT. CLOUDY
14	67	45	52	0									CLEAR
15	64	46	52	0									CLOUDY
16	59	52	54	.01			X						CLOUDY
17	71	54	61	0						X			CLEAR
18	84	53	60	.05									CLEAR
19	73	55	57	.08									CLOUDY
20	72	51	57	0									PT. CLOUDY
21	80	55	59	0									CLOUDY
22	73	56	57	.55			X						CLOUDY
23	81	57	65	0									CLEAR
24	82	55	64	0									CLEAR
25	77	53	65	0									CLEAR
26	72	58	62	.06			X			X			CLOUDY
27	81	55	57	0			X						CLOUDY
28	76	57	64	.05									CLEAR
29	82	55	61	0									PT. CLOUDY
30	73	53	56	0			X						CLOUDY
31													
SUM	1967	1407		1.85									

CONDITION OF RIVER AT GAGE
A. Obstructed by rough ice.
B. Frozen, but open at gage.
C. Upper surface of smooth ice.
D. Ice gorge above gage.
E. Ice gorge below gage.
F. Shore ice.
G. Floating ice.
H. Pool stage.

CHECK BAR (For wire-weight) NORMAL CK. BAR — READING — DATE

OBSERVER

SUPERVISING OFFICE

STATION INDEX NO. 17-4183-3

JULY 2000

TIME (local) OF OBSERVATION RIVER	TEMP.	PRECIPITATION	STANDARD TIME IN USE
	7A	7A	DST

TYPE OF RIVER GAGE	ELEVATION OF RIVER GAGE ZERO	FLOOD STAGE	NORMAL POOL STAGE
	Ft.	Ft.	Ft.

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

July 2000

DATE	TEMPERATURE F. 24 HRS. ENDING AT OBSERVATION MAX.	MIN.	AT OBSN.	PRECIPITATION 24-HR AMOUNTS Rain	Snow	At Obs. Snow on ground	WEATHER (Calendar Day) Fog	Ice Pellets	Glaze	Thunder	Hail	Damaging Winds	RIVER STAGE Condition	Gage Reading A.M.	Tendency	REMARKS (Special observations, etc.)
1	63	55	55	.25	0											CLOUDY
2	71	52	54	0	0		X									CLEAR
3	73	56	59	0	.01		X									CLOUDY
4	77	56	57	.01	.09		X									CLOUDY
5	75	57	63	.09	0					X						CLEAR
6	73	53	58	0	0											CLEAR
7	78	56	61	0	.02											CLOUDY
8	75	52	52	.02	0					X						PT. CLOUDY
9	65	50	55	0	.42											CLEAR
10	76	55	55	.42	.14		X									CLOUDY
11	73	58	59	.14	0					X						CLEAR
12	73	52	58	0	.05											CLEAR
13	82	52	60	.05	0											CLEAR
14	82	58	59	0	0.											CLOUDY
15	79	54	55	0	0											PT. CLOUDY
16	75	55	58	0	1.13											PT CLOUDY
17	71	55	59	1.13	0		X									CLOUDY
18	71	52	55	0	.10		X									CLOUDY
19	65	55	58	.10	0					X						PT. CLOUDY
20	73	46	54	0	0											CLEAR
21	74	49	56	0	0											CLEAR
22	78	56	61	0	.14											CLOUDY
23	61	55	57	.14	0		X									PT. CLOUDY
24	77	55	62	0	0											PT. CLOUDY
25	77	56	58	0	0											CLOUDY
26	79	56	58	0	0											PT. CLOUDY
27	80	55	56	0	.08		X									CLOUDY
28	65	56	60	.08	0											CLOUDY
29	73	60	65	0	0											PT CLOUDY
30	79	60	64	0	0											CLOUDY
31	79	54	59	0												PT. CLOUDY
	2293	1691	SUM	2.43												

CHECK BAR (For wire-weight) NORMAL CK. BAR

CONDITION OF RIVER AT GAGE

A. Obstructed by rough ice.
B. Frozen, but open at gage.
C. Upper surface of smooth ice.
D. Ice gorge above gage.
E. Ice gorge below gage
F. Shore ice.
G. Floating ice.
H. Pool stage.

READING | DATE

OBSERVER

SUPERVISING OFFICE

STATION INDEX NO. 17-4183-3

128

SUPERVISING OFFICE
STATION INDEX NO.

★ U.S. GOVERNMENT PRINTING OFFICE: 1988—516-086

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STATION (Climatological): JONESBORO	MONTH: AUG.	YEAR: 2000	WS FORM B-91 (7-88)
STATE: MAINE	COUNTY: WASHINGTON	RIVER	
TIME (local) OF OBSERVATION RIVER	TEMP.: 7A	PRECIPITATION: 7A	STANDARD TIME IN USE: DST
TYPE OF RIVER GAGE	ELEVATION OF RIVER GAGE ZERO Ft.	FLOOD STAGE Ft.	NORMAL POOL STAGE Ft.

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

DATE	Temp. MAX.	Temp. MIN.	AT OBSN.	Precip. 24-hr amount (rain, melted snow, etc.)	Snow, ice pellets, hail	Snow, ice pellets, hail on ground	Fog	Ice Pellets	Glaze	Thunder	Hail	Damaging Winds	River stage	REMARKS
1	74	51	53	0	.02									PT. CLOUDY
2	74	54	58	.02	.05									CLOUDY
3	61	58	61	.05	0		X							CLOUDY
4	71	60	64	0	0		X							CLOUDY
5	82	55	57	0	0									CLEAR
6	79	55	58	0	.01									CLEAR
7	80	58	60	.01	.26		X							CLOUDY
8	66	59	66	.24 M	0		X							CLOUDY
9	85	61	63	0	.08									PT. CLOUDY
10	78	60	62	.08	.18		X							CLOUDY
11	80	51	55	.18	0									CLEAR
12	73	54	58	0	0									CLEAR
13	NA	NA	NA	0	0									PT. CLOUDY
14	NA	NA	67	0	.11									CLOUDY
15	68	61	65	.11	.11									CLOUDY
16	74	58	59	.11	.22		X							CLOUDY
17	67	58	58	.22	.01									PT. CLOUDY
18	73	46	50	.01	0									CLEAR
19	70	50	57	0	0		X							CLOUDY
20	69	50	55	0	.25									CLEAR
21	68	49	57	.25	0									CLEAR
22	75	48	49	0 M	0					X				CLEAR
23	78	50	56	0	.42									PT. CLOUDY
24	72	57	59	.42	.04		X							CLOUDY
25	74	55	56	.04	0									CLEAR
26	80	56	59	0	0									CLEAR
27	83	56	58	0	0									CLEAR
28	76	53	55	0	0									CLEAR
29	76	49	53	0 M	0									PT. CLOUDY
30	7	52	56	0	.25									CLOUDY
31														
SUM														

CHECK BAR (For wire-weight) NORMAL CK. BAR

WS FORM B-91 (7-89)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

STATION (Climatological): JONESBORO (River Station, if different)
MONTH: SEPT. 2000
STATE: MAINE — COUNTY: WASHINGTON — RIVER:
TIME (local) OF OBSERVATION RIVER — TEMP.: 7A — PRECIPITATION: 7A — STANDARD TIME IN USE: DST
TYPE OF RIVER GAGE — ELEVATION OF RIVER GAGE ZERO: Ft. — FLOOD STAGE: Ft. — NORMAL POOL STAGE: Ft.

Date	Temp. Max.	Temp. Min.	Temp. At Obsn.	Rain, melted snow, etc. (Ins. and hundredths)	Snow, ice pellets, hail (Ins. and tenths)	Snow, ice pellets, hail, ice on ground (Ins.)	Fog	Ice Pellets	Glaze	Thunder	Hail	Damaging Winds	Remarks
1	82	60	64	0	W		X						CLOUDY
2	71	59	59	0			X						CLOUDY
3	60	35	35	.47			X						CLOUDY
4	64	55	58	.16			X						CLOUDY
5	61	40	41	T									CLEAR
6	64	36	38	0 M									CLEAR
7	67	38	45	0									CLOUDY
8	72	46	52	0									PT. CLOUDY
9	73	52	61	0			X						CLEAR
10	80	51	56	0									CLEAR
11	74	48	49	0									CLEAR
12	68	49	58	0									CLOUDY
13	68	60	63	.67 M			X						CLOUDY
14	74	46	47	.51									CLEAR
15	72	46	54	0									CLOUDY
16	64	52	52	.18			X						CLOUDY
17	67	46	50	0									CLEAR
18	64	30	32	0									PT. CLOUDY
19	73	50	51	0									PT. CLOUDY
20	67	51	58	0 M			X						CLOUDY
21	65	58	59	.03			X						CLOUDY
22	72	46	48	0			X						CLEAR
23	63	44	47	0									PT. CLOUDY
24	66	47	55	.45									CLOUDY
25	65	38	38	.08			X						CLEAR
26	60	38	40	0									CLOUDY
27	58	40	42	.04 M									CLEAR
28	64	42	48	0									CLOUDY
29	48	27	29	.10									CLEAR (FROST)
30													
31													
SUM													

Precipitation time notes: 6 — FROST; 29 — KILLING FROST

CHECK BAR (For wire-weight) NORMAL CK. BAR — READING — DATE

CONDITION OF RIVER AT GAGE
A. Obstructed by rough ice. B. Frozen, but open at gage. C. Upper surface of smooth ice. D. Ice gorge above gage. E. Ice gorge below gage. F. Shore ice. G. Floating ice. H. Pool stage.

OBSERVER

SUPERVISING OFFICE

STATION INDEX NO. 17-4183-3

Appendix C

WATER LEVEL DATA (SUMMER 2000)

Water Level Report

Surface Water Reservoir

Water Source Datum:	Reference Point	Reference Elevation (feet)	Reference
Fish Hatchery Dam CONUS	**Retaining Wall**	**201.17**	**NAD83**

Date/Time		Reading (feet)	Water Elevation	Operator
5/5/00	11:30	4.32	196.85	Robert Saunders
6/6/00	12:00	4.30	196.87	Robert Saunders
6/13/00	13:20	4.23	196.94	Robert Saunders
6/19/00	10:45	4.16	197.01	Robert Saunders
6/23/00	13:50	4.28	196.89	Robert Saunders
6/28/00	12:00	4.31	196.86	Robert Saunders
7/1/00	8:40	4.26	196.91	Robert Saunders
7/7/00	16:34	4.34	196.83	Robert Saunders
7/8/00	7:15	4.34	196.83	Robert Saunders
7/11/00	11:00	4.31	196.86	Robert Saunders
7/14/00	15:25	4.36	196.81	Robert Saunders
7/18/00	7:30	4.31	196.86	Robert Saunders
7/21/00	12:50	4.40	196.77	Robert Saunders
7/25/00	13:30	4.51	196.66	Robert Saunders
7/28/00	11:27	4.56	196.61	Robert Saunders
8/1/00	10:15	4.70	196.47	Robert Saunders
8/4/00	0:00	4.77	196.40	Robert Saunders
8/7/00	10:18	4.91	196.26	Robert Saunders
8/10/00	7:20	4.96	196.21	Robert Saunders
8/15/00	13:17	5.12	196.05	Robert Saunders
8/22/00	11:34	5.30	195.87	Robert Saunders
9/1/00	9:25	4.58	196.59	Robert Saunders
10/31/00	0:00	5.08	196.09	Robert Saunders

Water SourceReference PointReference Elevation (feet)Reference Datum:

Mic-Mac Pond SG CONUS	**Staff Gage**	**206.59**	**NAD83**

Date/Time		Reading (feet)	Water Elevation	Operator
5/5/00	11:15	7.75	214.34	Robert Saunders
6/6/00	11:30	8.08	214.67	Robert Saunders
6/13/00	14:40	8.08	214.67	Robert Saunders
6/19/00	11:30	8.06	214.65	Robert Saunders
6/23/00	13:30	8.00	214.59	Robert Saunders
6/28/00	8:45	7.88	214.47	Robert Saunders
7/1/00	8:10	7.85	214.44	Robert Saunders
7/7/00	11:20	7.69	214.28	Robert Saunders
7/8/00	7:00	7.67	214.26	Robert Saunders
7/11/00	10:20	7.67	214.26	Robert Saunders
7/14/00	15:45	7.63	214.22	Robert Saunders
7/18/00	7:45	7.79	214.38	Robert Saunders
7/21/00	13:00	7.73	214.32	Robert Saunders
7/25/00	14:15	7.58	214.17	Robert Saunders
7/28/00	11:40	7.35	213.94	Robert Saunders
8/1/00	9:30	7.06	213.65	Robert Saunders
8/4/00	0:00	6.98	213.57	Robert Saunders
8/7/00	10:09	6.81	213.40	Robert Saunders

8/10/00	6:40	6.81	213.40	Robert Saunders
8/15/00	13:29	6.75	213.34	Robert Saunders
8/22/00	9:50	6.67	213.26	Robert Saunders
8/29/00	12:00	6.04	212.63	Robert Saunders
10/12/00	0:00	4.52	211.11	Robert Saunders
10/31/00	0:00	4.38	210.97	Robert Saunders

Water Source	Reference Point	Reference Elevation (feet)	Reference Datum:
Pineo Pond	**Staff Gage**	**198.48**	**NAD83 CONUS**

Date/Time		Reading (feet)	Water Elevation	Operator
5/5/00	10:30	10.56	209.04	Robert Saunders
5/30/00	11:00	10.92	209.40	Robert Saunders
6/6/00	11:00	10.81	209.29	Robert Saunders
6/13/00	14:00	10.79	209.27	Robert Saunders
6/19/00	10:15	10.77	209.25	Robert Saunders
6/23/00	13:15	10.73	209.21	Robert Saunders
6/27/00	17:00	10.71	209.19	Robert Saunders
7/1/00	7:50	10.63	209.11	Robert Saunders
7/7/00	11:10	10.54	209.02	Robert Saunders
7/8/00	8:40	10.52	209.00	Robert Saunders
7/11/00	10:00	10.52	209.00	Robert Saunders
7/14/00	16:00	10.48	208.96	Robert Saunders
7/18/00	7:55	10.56	209.04	Robert Saunders
7/21/00	13:10	10.50	208.98	Robert Saunders
7/25/00	14:30	10.44	208.92	Robert Saunders
7/28/00	11:50	10.37	208.85	Robert Saunders
8/1/00	9:00	10.06	208.54	Robert Saunders
8/4/00	0:00	8.85	207.33	Robert Saunders
8/7/00	9:57	7.90	206.38	Robert Saunders
8/10/00	6:25	8.21	206.69	Robert Saunders
8/15/00	13:43	8.42	206.90	Robert Saunders
8/22/00	9:35	8.54	207.02	Robert Saunders
8/31/00	11:45	8.54	207.02	Robert Saunders
10/31/00	0:00	8.63	207.11	Robert Saunders

Water Source	Reference Point	Reference Elevation (feet)	Reference Datum:
Spectacle Pond	**Staff Gage**	**196.39**	**NAD83 CONUS**

Date/Time		Reading (feet)	Water Elevation	Operator
5/5/00	10:30	10.77	207.16	Robert Saunders
6/6/00	11:15	11.02	207.41	Robert Saunders
6/13/00	13:50	11.00	207.39	Robert Saunders
6/14/00	14:00	11.00	207.39	Robert Saunders
6/19/00	11:35	10.98	207.37	Robert Saunders
6/23/00	13:20	10.94	207.33	Robert Saunders
6/27/00	16:00	10.85	207.24	Robert Saunders
7/1/00	8:00	10.85	207.24	Robert Saunders
7/7/00	11:05	10.75	207.14	Robert Saunders
7/8/00	8:30	10.75	207.14	Robert Saunders
7/11/00	10:10	10.75	207.14	Robert Saunders
7/14/00	15:55	10.71	207.10	Robert Saunders

7/18/00	7:50	10.81	207.20	Robert Saunders
7/21/00	13:05	10.75	207.14	Robert Saunders
7/25/00	14:25	10.69	207.08	Robert Saunders
7/28/00	11:45	10.65	207.04	Robert Saunders
8/1/00	9:20	10.58	206.97	Robert Saunders
8/4/00	0:00	10.56	206.95	Robert Saunders
8/7/00	10:02	10.52	206.91	Robert Saunders
8/10/00	6:30	10.50	206.89	Robert Saunders
8/15/00	13:37	10.46	206.85	Robert Saunders
8/22/00	9:40	10.42	206.81	Robert Saunders
8/27/00	12:00	10.40	206.79	Robert Saunders
10/31/00	0:00	10.40	206.79	Robert Saunders

Flowing Surface Water

Water Source	Reference Point	Reference Elevation (feet)	Reference Datum:
Great Falls Branch	**Staff Gage**	**150**	**NAD83 CONUS**

Date/Time		Reading (feet)	Water Elevation	Operator
6/14/00	11:00	2.71	152.71	Robert Saunders
6/19/00	12:00	2.90	152.90	Robert Saunders
6/28/00	15:00	2.79	152.79	Robert Saunders
7/7/00	8:00	2.75	152.75	Robert Saunders
7/18/00	8:50	2.75	152.75	Robert Saunders
7/20/00	11:00	2.92	152.92	Robert Saunders
7/21/00	12:00	2.77	152.77	Robert Saunders
7/25/00	15:25	2.67	152.67	Robert Saunders
8/1/00	8:00	2.58	152.58	Robert Saunders
8/4/00	0:00	2.65	152.65	Robert Saunders
8/7/00	16:00	2.65	152.65	Robert Saunders
8/10/00	11:31	2.73	152.73	Robert Saunders
8/15/00	16:22	2.71	152.71	Robert Saunders
8/22/00	17:28	2.73	152.73	Robert Saunders
8/31/00	16:00	2.65	152.65	Robert Saunders

Well

Water Source	Reference Point	Reference Elevation (feet)	Reference Datum:
EP-1	**Top of Riser**	**257.83**	**NAD83 CONUS**

Date/Time		Reading (feet)	Water Elevation	Operator
5/30/00	0:00	55.32	202.51	Robert Saunders
6/13/00	0:00	55.45	202.38	Robert Saunders
6/27/00	0:00	55.61	202.22	Robert Saunders
7/11/00	0:00	55.74	202.09	Robert Saunders
7/25/00	0:00	55.97	201.86	Robert Saunders
8/7/00	0:00	56.09	201.74	Robert Saunders
8/22/00	0:00	56.42	201.41	Robert Saunders
10/31/00	0:00	57.43	200.40	Robert Saunders

Water Source Datum:	Reference Point	Reference Elevation (feet)	Reference
MM-2 CONUS	**Top of Riser**	**255.15**	**NAD83**

Date/Time		Reading (feet)	Water Elevation	Operator
5/30/00	0:00	12.22	242.93	Robert Saunders
6/13/00	0:00	12.67	242.48	Robert Saunders
6/27/00	0:00	13.08	242.07	Robert Saunders
7/11/00	0:00	13.36	241.79	Robert Saunders
7/25/00	0:00	13.45	241.70	Robert Saunders
8/7/00	0:00	13.69	241.46	Robert Saunders
8/22/00	0:00	14.00	241.15	Robert Saunders
10/31/00	0:00	14.96	240.19	Robert Saunders

Water Source Datum:	Reference Point	Reference Elevation (feet)	Reference
WP-1 CONUS	**Top of Riser**	**268.25**	**NAD83**

Date/Time		Reading (feet)	Water Elevation	Operator
5/30/00	0:00	41.32	226.93	Robert Saunders
6/13/00	0:00	41.27	226.98	Robert Saunders
6/27/00	0:00	41.42	226.83	Robert Saunders
7/11/00	0:00	41.67	226.58	Robert Saunders
7/25/00	0:00	42.00	226.25	Robert Saunders
8/7/00	0:00	42.24	226.01	Robert Saunders
9/29/00	0:00	43.64	224.61	Robert Saunders
10/12/00	0:00	43.96	224.29	Robert Saunders
10/30/00	0:00	44.38	223.87	Robert Saunders

Water Source Datum:	Reference Point	Reference Elevation (feet)	Reference
WP-3 CONUS	**Top of Riser**	**271.63**	**NAD83**

Date/Time		Reading (feet)	Water Elevation	Operator
5/30/00	0:00	46.91	224.72	Robert Saunders
6/13/00	0:00	47.03	224.60	Robert Saunders
6/27/00	0:00	47.24	224.39	Robert Saunders
7/11/00	0:00	47.54	224.09	Robert Saunders
7/25/00	0:00	47.70	223.93	Robert Saunders
8/7/00	0:00	47.78	223.85	Robert Saunders
8/22/00	0:00	48.17	223.46	Robert Saunders
9/29/00	0:00	49.15	222.48	Robert Saunders
10/12/00	0:00	49.52	222.11	Robert Saunders
10/30/00	0:00	49.94	221.69	Robert Saunders

Water Source	Reference Point	Reference Elevation (feet)	Reference Datum:
WP-4 CONUS	**Top of Riser**	**273.8**	**NAD83**

Date/Time		Reading (feet)	Water Elevation	Operator
5/30/00	0:00	56.18	217.62	Robert Saunders
6/13/00	0:00	56.38	217.42	Robert Saunders
6/27/00	0:00	56.56	217.24	Robert Saunders
7/11/00	0:00	56.87	216.93	Robert Saunders
7/25/00	0:00	57.05	216.75	Robert Saunders
8/7/00	0:00	57.46	216.34	Robert Saunders
8/22/00	0:00	57.67	216.13	Robert Saunders
9/29/00	0:00	58.79	215.01	Robert Saunders
10/12/00	0:00	59.03	214.77	Robert Saunders
10/30/00	0:00	59.30	214.50	Robert Saunders

Water Source	Reference Point	Reference Elevation (feet)	Reference Datum:
WP-5A CONUS	**Top of Riser**	**234.37**	**NAD83**

Date/Time		Reading (feet)	Water Elevation	Operator
5/30/00	0:00	19.25	215.12	Robert Saunders
6/13/00	0:00	19.20	215.17	Robert Saunders
6/27/00	0:00	19.39	214.98	Robert Saunders
7/11/00	0:00	19.62	214.75	Robert Saunders
7/25/00	0:00	19.70	214.67	Robert Saunders
8/7/00	0:00	19.98	214.39	Robert Saunders
8/22/00	0:00	20.49	213.88	Robert Saunders
9/29/00	0:00	22.31	212.06	Robert Saunders
10/12/00	0:00	22.50	211.87	Robert Saunders
10/30/00	0:00	22.75	211.62	Robert Saunders

Water Source	Reference Point	Reference Elevation (feet)	Reference Datum:
WP-8A CONUS	**Top of Riser**	**267.64**	**NAD83**

Date/Time		Reading (feet)	Water Elevation	Operator
5/30/00	0:00	49.10	218.54	Robert Saunders
6/13/00	0:00	49.20	218.44	Robert Saunders
6/27/00	0:00	49.42	218.22	Robert Saunders
7/11/00	0:00	49.58	218.06	Robert Saunders
7/25/00	0:00	49.77	217.87	Robert Saunders
8/7/00	0:00	50.08	217.56	Robert Saunders
8/22/00	0:00	50.38	217.26	Robert Saunders
9/29/00	0:00	51.87	215.77	Robert Saunders
10/12/00	0:00	52.04	215.60	Robert Saunders
10/30/00	0:00	52.40	215.24	Robert Saunders

Water Source Datum:	Reference Point	Reference Elevation (feet)	Reference
WP-9 CONUS	**Top of Riser**	**262.04**	**NAD83**

Date/Time		Reading (feet)	Water Elevation	Operator
6/13/00	0:00	46.39	215.65	Robert Saunders
6/27/00	0:00	46.60	215.44	Robert Saunders
7/11/00	0:00	46.76	215.28	Robert Saunders
7/25/00	0:00	46.92	215.12	Robert Saunders
8/7/00	0:00	47.34	214.70	Robert Saunders
8/22/00	0:00	47.66	214.38	Robert Saunders
10/12/00	0:00	49.48	212.56	Robert Saunders
10/30/00	0:00	49.75	212.29	Robert Saunders

Appendix D

FIELD TEST DATA

Notes							Monday. Started test 1pm						Adjusted pressure to increase flows			
	Elevation Reference (TOR or SG @ 0 ft)	Water Elevations to Notify SME	Water Levels to Notify SME	Reading	Elevation/ Flow Rate/ Pressure	Reading	Elevation/ Flow Rate/ Pressure	Reading	Elevation/ Flow Rate/ Pressure	Reading	Elevation/ Flow Rate/ Pressure	Reading	Elevation/ Flow Rate/ Pressure			
HOURLY																
WP-SG-1	222.33		2 feet ags			0.00	222.33	0.90	223.23			1.58	223.91			
WP-5A	234.37		up 0.1 feet	22.50	211.87	22.75	211.62	22.65	211.72			22.23	212.14			
WP-5B	234.41		up 0.1 feet	dry		dry		20.70	213.71			17.73	216.68			
Every 1-3 HR during da												(After 0.1 Foot Rise in WP-5 A or B)				
WP-10	216.64	213.70	2.9	dry		dry		dry		dry		4.81	211.83			
WP-11	217.56	214.70	2.9	dry		dry		dry		dry		dry				
WP-12	219.18	216.30	2.9	dry		dry		dry		dry		dry				
WP-13	217.94	215.20	2.7	dry		dry		dry		dry		dry				
WP-14	216.76	214.00	2.8	dry		dry		dry		dry		dry				
WP-15	221.43	216.80	4.6	dry		dry		dry		dry		dry				
WP-16	221.40	217.00	4.4	dry		dry		dry		dry		dry				
WP-17	221.79	219.00	2.8	dry		dry		dry		dry		dry				
WP-18	221.21	218.40	2.8	dry		dry		dry		dry		dry				
WP-19	221.30	none	none	dry		dry		dry		dry		dry				
WP-20	221.32	217.10	4.2	dry		dry		dry		dry		dry				
WP-21	226.23					dry						6.01	220.22			
WP-22	219.89		none													
DAILY																
WP-1	268.25		none	39.96	228.29	40.38	227.87					40.40	227.85			
WP-3	267.63		none	49.52	218.11	49.94	217.69					49.95	217.68			
WP-4	273.80		none	59.03	214.77	59.30	214.50					59.30	214.50			
WP-8A	267.64		none	52.04	215.60	52.40	215.24					52.30	215.34			
WP-8B	267.74		none	52.20	215.54	52.58	215.16					52.50	215.24			
WP-9	262.04		none	49.48	212.56	49.75	212.29					49.75	212.29			
Mic-Mac SG	206.59	209.00	2.50	4.52	211.11	4.38	210.97	4.38	210.97	4.38	210.97	4.38	210.97			
Evaporation Pan			none													
Rain Gage																
Pump Speed (rpm)			none			1,700		1,700		1,700		1,700		1,700		0
Pump Pressure (psi)			none			90		85		85		75		75		0
Flow Rate (gpm)			none				1,007		1,007		1,007		1,459		1,459	
Pressure (psi)						10.0		10.0		10.0		21.0		21.0		0.0
Pipe ID (in)	7.25	7.25														
Orifice ID	4.00	6.00														
Area	12.57	28.27														
Od/Pd	0.55	0.83														
C	0.60	0.87														

Table D.1 Data for Pineo Kettle Hole Pump Test (Page 1 of 4).

Notes					Shut down 12-1 to move pipe and build berm, started back up 1pm											
				Reading	Elevation/ Flow Rate/ Pressure	Reading	Elevation/ Flow Rate/ Pressure	Reading	Elevation/ Flow Rate/ Pressure	Reading	Elevation/ Flow Rate/ Pressure	Reading	Elevation/ Flow Rate/ Pressure	Reading	Elevation/ Flow Rate/ Pressure	Reading
HOURLY																
WP-SG-1				1.83	224.16	2.23	224.56	2.23	224.56	2.25	224.58	2.50	224.83	2.52	224.85	2.52
WP-5A				22.16	212.21					21.99	212.38	22.14	212.23			
WP-5B				17.54	216.87					18.30	216.11	19.42	214.99			
Every 1-3 HR during da																
WP-10				4.75	211.89					4.68	211.96	4.63	212.01	4.63	212.01	4.64
WP-11				dry		dry		dry		dry		dry		dry		dry
WP-12				dry		dry		dry		dry		dry		dry		dry
WP-13				dry		dry		dry		dry		dry		dry		dry
WP-14				4.80	211.96					4.78	211.98	4.78	211.98	4.78	211.98	4.76
WP-15				dry		dry		dry		dry		dry		dry		dry
WP-16				dry		dry		dry		dry		dry		dry		dry
WP-17				dry		dry		dry		dry		dry		dry		dry
WP-18				dry		dry		dry		dry		dry		dry		dry
WP-19				dry		dry		dry		dry		dry		dry		dry
WP-20				dry		dry		dry		dry		dry		dry		dry
WP-21												5.75	220.48	5.65	220.58	
WP-22														2.49	217.40	
DAILY																
WP-1												40.43	227.82			
WP-3												49.88	217.75			
WP-4												59.33	214.47			
WP-8A												51.80	215.84			
WP-8B												52.40	215.34			
WP-9												49.75	212.29			
Mic-Mac SG				4.38	210.97	4.38	210.97	4.38	210.97	4.33	210.92	4.27	210.86			4.25
Evaporation Pan																
Rain Gage																
Pump Speed (rpm)		0		1,700		1,700		1,500		1,500		1,500		1,500		1,500
Pump Pressure (psi)		0		75		75		70		70		70		70		70
Flow Rate (gpm)	0		0		1,459		1,459		712		712		712		712	
Pressure (psi)		0.0		21.0		21.0		5.0		5.0		5.0		5.0		5.0
Pipe ID (in)																
Orifice ID																
Area																
Od/Pd																
C																

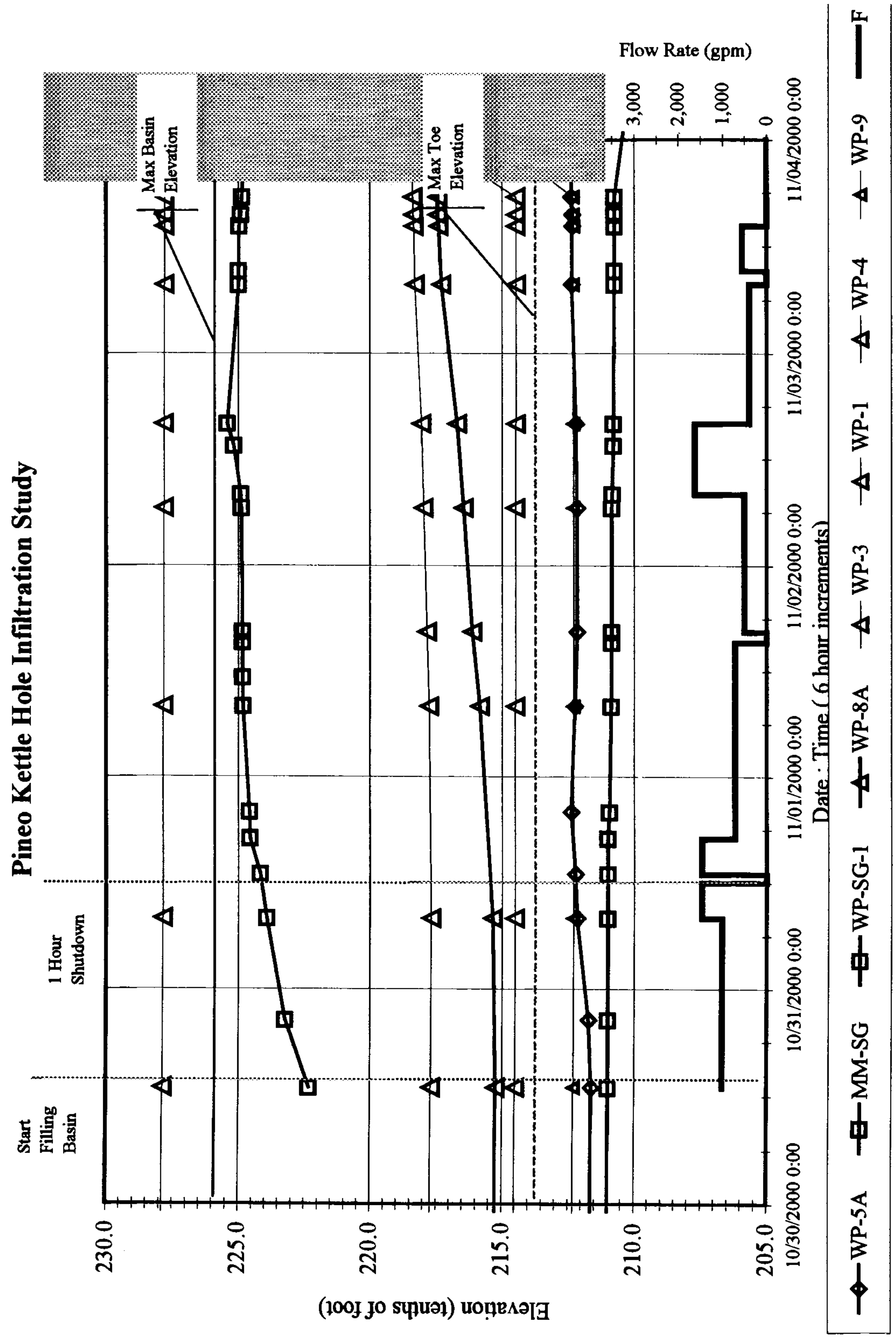
Table D.1 Data for Pineo Kettle Hole Pump Test (Page 2 of 4).

Notes	Shut down to move pipe 3:15pm						Started back up 4:30pm, adjuste pressure to reduce flow. Bypassing water						Adjusted pressure to increase flows. Bypassing water			
	Elevation/ Flow Rate/ Pressure					Reading	Elevation/ Flow Rate/ Pressure	Reading	Elevation/ Flow Rate/ Pressure	Reading	Elevation/ Flow Rate/ Pressure	Reading	Elevation/ Flow Rate/ Pressure	Reading	Elevation/ Flow Rate/ Pressure	Reading
HOURLY																
WP-SG-1	224.85					2.52	224.85	2.56	224.89	2.58	224.91	2.58	224.91	2.83	225.16	3.08
WP-5A						22.22	212.15	22.22	212.15							22.19
WP-5B						19.90	214.51	20.17	214.24							20.17
Every 1-3 HR during da																
WP-10	212.00					4.64	212.00	4.66	211.98							4.69
WP-11						dry		dry								dry
WP-12						dry		dry								dry
WP-13						dry		dry								dry
WP-14	212.00					4.76	212.00	4.76	212.00							4.76
WP-15						dry		dry								dry
WP-16						dry		dry								dry
WP-17						dry		dry								dry
WP-18						dry		dry								dry
WP-19						dry		dry								dry
WP-20						dry		dry								dry
WP-21						5.25	220.98	5.12	221.11							
WP-22						2.36	217.53	2.18	217.71							0.70
DAILY																
WP-1								40.44	227.81							40.45
WP-3						49.80	217.83	49.66	217.97							49.58
WP-4								59.33	214.47							59.34
WP-8A						51.53	216.11	51.19	216.45							50.95
WP-8B						51.77	215.97	51.45	216.29							51.23
WP-9								49.75	212.29							49.75
Mic-Mac SG	210.84					4.25	210.84	4.24	210.83	4.23	210.82	4.23	210.82	4.19	210.78	4.19
Evaporation Pan																
Rain Gage																
Pump Speed (rpm)		0		0		1,650		1,650		1,650		2,100		2,100		2,100
Pump Pressure (psi)		0		0		80		80		80		65		65		65
Flow Rate (gpm)	712		0		0		503		503		503		1,623		1,623	
Pressure (psi)		0.0		0.0		2.5		2.5		2.5		26.0		26.0		26.0
Pipe ID (in)																
Orifice ID																
Area																
Od/Pd																
C																

Table D.1 Data for Pineo Kettle Hole Pump Test (Page 3 of 4).

Notes			Adjusted pressure to reduce flow. Bypassing water		Pump shutdown at 7:45am. Lost water elevation overnight.						Pump back running, 9:15am battery problems. Adjusted pressures to		Shut Pump Down, Test Finished 2:15pm.			
	Elevation/ Flow Rate/ Pressure	Reading	Elevation/ Flow Rate/ Pressure	Reading	Elevation/ Flow Rate/ Pressure					Reading	Elevation/ Flow Rate/ Pressure	Reading	Elevation/ Flow Rate/ Pressure			
HOURLY																
WP-SG-1	225.41	3.08	225.41	2.65	224.98					2.65	224.98	2.63	224.96			
WP-5A	212.18			22.02	212.35							22.03	212.34			
WP-5B	214.24			19.75	214.66							19.74	214.67			
Every 1-3 HR during da																
WP-10	211.95			4.71	211.93							4.72	211.92			
WP-11				dry								dry				
WP-12				dry								dry				
WP-13				dry								dry				
WP-14	212.00			4.78	211.98							4.78	211.98			
WP-15				dry								dry				
WP-16				dry								dry				
WP-17				dry								dry				
WP-18				dry								dry				
WP-19				dry								dry				
WP-20				dry								dry				
WP-21				4.89	221.34							4.86	221.37			
WP-22	219.19			0.80	219.09							0.90	218.99			
DAILY																
WP-1	227.80			40.46	227.79							40.46	227.79			
WP-3	218.05			49.34	218.29							49.30	218.33			
WP-4	214.46			59.36	214.44							59.35	214.45			
WP-8A	216.69			50.35	217.29							50.26	217.38			
WP-8B	216.51			50.59	217.15							50.49	217.25			
WP-9	212.29			49.74	212.30							49.75	212.29			
Mic-Mac SG	210.78			4.15	210.74					4.15	210.74	4.15	210.74			
Evaporation Pan																
Rain Gage																
Pump Speed (rpm)		1,650		1,650		0		0		1,700		1,700				
Pump Pressure (psi)		65		65		0		0		80		80				
Flow Rate (gpm)	1,623		390		390		0		0		551		551			
Pressure (psi)		1.5		1.5		0.0		0.0		3.0		3.0				
Pipe ID (in)																
Orifice ID																
Area																
Od/Pd																
C																

Table D.1 Data for Pineo Kettle Hole Pump Test (Page 4 of 4).


Pineo Kettle Hole Infiltration Study
Start Filling Basin
1 Hour Shutdown
Max Basin Elevation
Max Toe Elevation
Flow Rate (gpm)
3,000
2,000
1,000
0
Elevation (tenths of foot)
230.0
225.0
220.0
215.0
210.0
205.0
10/30/2000 0:00
10/31/2000 0:00
11/01/2000 0:00
11/02/2000 0:00
11/03/2000 0:00
11/04/2000 0:00
Date : Time (6 hour increments)
WP-5A
MM-SG
WP-SG-1
WP-8A
WP-3
WP-1
WP-4
WP-9
F

BIOGRAPHY OF THE AUTHOR

Robert J. Saunders was born in Bennington, Vermont on April 28, 1975. He was raised in Rupert, Vermont and graduated in 1993 from Washington Academy in Salem, NY. Robert attended Hudson Valley Community College where he obtained an Associate's degree in Math and Science. In 1995, he transferred to North Carolina A&T State University to pursue a Bachelor's degree in Agricultural and Environmental Systems Engineering. At A&T, Robert became actively involved in the American Society of Agricultural Engineers and was inducted into the Alpha Epsilon honor society. He graduated Summa Cum Laude in 1997.

In the Fall of 1998, Robert was awarded a graduate research assistantship under the Bio-Resources Engineering program at the University of Maine. During his tenure in Maine, he became involved with the American Society of Civil Engineers, and the National Society of Professional Engineers, and was recruited to represent the department in the Association of Graduate Students.

Early in 2001, Robert accepted an Environmental Engineer position with The Louis Berger Group, Inc. He is a candidate for the degree of Master of Science in Bio-Resource Engineering from the University of Maine in May 2001.