Bustins Island
Ground Water Study

to

Bustins Island Village Corporation
Freeport, Maine

by

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July 2, 1991

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1.0 INTRODUCTION AND PURPOSE

The purpose of this report is to summarize the work that Robert G. Gerber, Inc. (RGGI), has performed since last year's presentation at the BIVC 1990 4th-of-July informational meeting. Last year's report and informational meeting provided a basic overview of ground water movement on Bustins Island. Using literature sources plus a well survey taken on the island, RGGI interpreted the well data in light of the basic geology and hydrology of this island. The information in that report is not repeated here.

At last year's annual meeting, the BIVC voted to fund additional studies by RGGI. The purpose of these studies was to develop more detailed information on ground water flow and contaminant movement within ground water on Bustins Island. Some field mapping, aerial photo interpretation, and computerized ground water modeling were used to develop additional information. As a result of additional study, RGGI has recommended a ground water level monitoring program which began in spring 1991. A series of progress reports were issued by RGGI on their work throughout the winter and spring of 1991. This report summarizes that work in one report, and provides recommendations for managing the ground water resource on Bustins Island.

2.0 METHODS

2.1 FIELD WORK

In the late summer of 1990, Robert Gerber spent a day on Bustins Island walking the island and making observations on the geology and hydrology of the island. Specifically, he:

a) mapped the locations of bedrock outcrop and thin soil;
b) measured the dip and strike of bedrock foliation and joint planes;
c) made general observations on the joint density and aperture width;
d) examined and mapped various soil types;
e) mapped ponds and areas where ground water is close to ground surface;
f) mapped surface water features.

This information was utilized in compiling some of the maps in this report. It was also used in defining the RGGI ground water model boundary conditions and specifying parameter values or relationships among parameters.

2.2 GROUND WATER FLOW MODEL DEVELOPMENT AND CALIBRATION

The three-dimensional ground water flow model MODFLOW (McDonald and Harbaugh, 1988) was used. The numerical model was horizontally discretized into 36 rows and 65 columns as shown in Figure 1. The dimensions of the cells ranged from 50 to 100 feet. A fine discretization was used where there is a greater density of residences on the island.

Six layers were used in the vertical discretization. The model simulates a vertical thickness of 300 feet.

The bedrock located in the center of the island, which is more massive and less fractured, was treated as having a lower hydraulic conductivity than the remaining bedrock. Figure 2 displays the two bedrock zones divided according to transmissivity (hydraulic conductivity times aquifer thickness). The conductivity of the bedrock was treated as horizontally anisotropic, with the anisotropy assumed equal to 10 to 1. The anisotropy represents the fracture pattern of the bedrock, which allows for greater flow in the southwest to northeast direction than in a perpendicular direction.

For modeling purposes, the ground water elevation was fixed along the perimeter of the island at mean sea level. Locations of ground water discharges were incorporated as shown in Figure 3. Figure 3 also shows the location of soil zones, which represent areas where a significant thickness of soil is present. The recharge to the soil zones is assumed to be 15% of the average annual precipitation, which is 43 inches per year. The recharge to the remainder of the island is assumed to be 5% of the annual average precipitation.

The average annual ground water conditions were analyzed by calibrating the steady state model using ground water potential (elevation to which ground water would rise in a well open at a specific depth of interest in the aquifer) where it has been measured at wells. The location of the wells is displayed in Figure 5, and Table 1 contains the data concerning the wells used for calibration. The hydraulic conductivity was varied with the goal of reducing the mean residual, the difference between the simulated and observed ground water potentials, to zero, as well as to reduce the root mean square error (RMSE). The RMSE is equivalent to the standard deviation. The results of the calibration are presented in Table 2. The residual at each well, in addition to various statistical parameters, is reported.

2.3 TRANSPORT MODEL DEVELOPMENT AND CALIBRATION

Analysis of the ground water quality was accomplished by first modeling the ground water flow with a flow model. The results from the flow model are used in conjunction with a transport model to simulate the transport of contaminants by the ground water. Both the flow and transport models were transient, with conditions changing throughout the year. We used the calibrated transmissivities from the steady state flow model for this study.

RGGI used the three-dimensional ground water transport model MT3D (Zheng, 1990), which is based on MODFLOW as the underlying flow model. The recharge distribution to the soil and exposed bedrock zones was the same as for the steady state model, with the thicker soil zones receiving 15% of the annual precipitation as recharge, and the shallow-to-bedrock zones receiving 5%. The recharge rate varied monthly as shown in Figure 6 for the soil zones and in Figure 7 for the bedrock zones. The recharge rate is influenced by a combination of precipitation, evapotranspiration, and whether the ground is frozen. For each month, the soil recharge rate is equal to three times the recharge rate on bedrock.

The pumping of ground water also varies seasonally, with ground water withdrawal during the months of June, July, and August. Table 1 lists the pumping wells used for the analysis in addition to the rates of withdrawal. The locations of the wells are shown in Figure 3. The water is pumped from the appropriate layer of the model depending on the depth of the well. The waste water returned to the ground water by septic systems and out-houses is also included in the simulation. We estimate that 90% of the pumped water is returned to the ground water as waste water. The waste water was added to the top layer of the model downgradient (down hill) from the pumping well.

3.0 RESULTS OF FIELD WORK

Although the bedrock of Bustins Island is all part of one basic rock formation, the Cushing Formation, field mapping separated a migmatized, more massive portion of the rock from the more obviously layered rock. The migmatized zone has granitic inclusions and only relict foliation features and a lower density of fractures than in the other rock zone. This heavily migmatized zone is shown on Figure 2 as the "Lower K Bedrock Zone".

The rock has a layering called "foliation". The planes of the foliation have more or less uniform features across the island, except where these features are destroyed or altered by the presence of igneous dikes or migmatization. The line formed by the intersection of the plane of the foliation with a horizontal plane is called the "strike". The strike averages about 41 degrees east of true north but ranges from 25 to 60 degrees east of true north. The angle that the foliation plane makes with the horizontal in the downward direction perpendicular to strike is called the "dip". The dip of the foliation planes ranges from 51 to 90 degrees downward to the southeast from the horizontal, but is typically about 60 degrees to the southeast. The major axis of the computer model finite difference grid is located parallel to the strike of the bedrock foliation.

Field observations indicate that the foliation planes are much more predominant than other cross-cutting fractures in allowing movement of ground water in the bedrock. The computer model therefore assumes that the rock permeability along the plane of foliation is significantly greater than across the plane of foliation.

Field mapping of bedrock outcrop and soil helped to define the pattern of "thick" soil on the island. Figure 4 shows thick soil zones based on field mapping and aerial photo interpretation. The shaded zones on Figure 4 generally represent portions of the island where soils are 5 or more feet thick and thus capable of capturing and storing precipitation for later release to the underlying bedrock. The unshaded portion of Figure 4 are those areas having exposed bedrock or thin soils with a limited capability for moisture storage. Soil mapping showed the southeast half of the island to have a sand-silt-gravel and cobble mixture which was originally glacial till. This glacial till was partially sorted locally by wave action during a period of elevated sea level between 10,000 and 13,000 years ago. The northwest half of the island contains some dense fine sand and interbedded "marine clay" deposits.

4.0 RESULTS OF GROUND WATER MODELING

4.1 GROUND WATER RECHARGE AND FLOW PATTERN

The surface area of Bustins Island is approximately $5.6*10^6$ square feet. The calculated recharge rate is $1.65*10^6$ cubic feet per year, which is equal to 23.5 gallons per minute. Of course only a fraction of the recharge represents potentially usable water. The amount of "usable" ground water is a function of the locations and pumping rates of wells used to capture the water. Excessive pumping in some locations could induce saltwater intrusion. Additional computer simulations as originally contemplated under Tasks 5a and 5b (which were not authorized for 1990-1991) would need to be made in order to approach a quantitative estimate of the amount of "usable" water on Bustins Island. Furthermore, to maximize the amount of usable water, a redistribution of ground water withdrawal would have to be made. Since this is unrealistic and because there are many possible other combinations of well locations and withdrawal rates that could be hypothetically created, an easier way to approach the problem is to use the model to evaluate annual collective requests for additional well drilling. The incremental impact of additional well withdrawals can then be evaluated on a site-specific basis. A well drilling permit could be chared to cover the cost of the computer simulation.

Dug wells are subject to depletion from seasonal declines in water tables which may drop below the bottom of the well pump intake. Drilled wells are subject to seasonal water level decline, but usually do not go dry unless pumped at a rate that exceeds the well recharge rate. For those lots that have adequate water depth in their wells at end of summer, current lot sizes are adequate to recharge those wells with hand pumps. On a theoretical basis, lots using pressurized water systems and about 250 gallons per day would need about 1 acre of land to preserve adequate recharge capability. Of course, since the distribution of demand is not uniform throughout the island, there does not appear to be an adverse impact yet from smaller lots using 250 gallons per day. As we discussed above, the incremental effect of adding more pressurized water systems could be evaluated on a yearly basis.

Figure 9 displays the ground water potential in both the top and bottom layers of the model. The water table, represented by the potential of the top layer, roughly follows the shape of the ground surface. The flow paths may be estimated from the potential contours by starting at a source of interest, and tracing a line perpendicular to the contours. A better estimate of the flow paths within the bedrock would need to include the effect of the anisotropy of the hydraulic conductivity. The vertical flow may also be interpreted from the contour map. In the center of the island, the potential is greater at the surface than at depth, and there is recharge with the flow downward. The opposite is true near the perimeter of the island, where the flow is in the upward direction. The contours of the top layer are indented in the vicinity of the discharge areas, where the vertical flow also may reverse and be in the upward direction.

4.2 DEPTH TO SALTWATER INTERFACE

The depth to the saltwater interface was calculated using the Ghyben-Herzberg method. This method assumes hydrostatic conditions and a sharp interface between the fresh and saltwater. With these assumptions, the location of the interface is determined solely by the density difference between salt and fresh water, and the depth to the interface below sea level at any point is equal to 40 times the height of the water table above sea level. The annual average depth to the saltwater interface is shown in Figure 10. The location of the interface will be affected by ground water pumping, and a transition zone will exist between the salt and fresh water.

A more accurate depiction of the position of the saltwater interface could be derived through a computer simulation as originally proposed in Task 5b, which was not funded in 1990-91. Using the model, RGGI could simulate the conditions in each layer of the model at the end of the summer, using the ocean as a source of contamination and tracking its landward movement during the summer months.

Currently, there do not appear to be any areas where dug or drilled wells are in danger of being subject to saltwater intrusion. However, based on the model results, Figure 11 shows the portion of the island with the greatest likelihood of drilled wells encountering saltwater intrusion in the future.

4.3 POTENTIAL CONTAMINATION EFFECTS OF SEASONAL COTTAGE USE

We used numerical models to evaluate the potential long term impact on ground water quality from the present water use and disposal patterns. Because the water use on Bustins Island is very seasonal, we included the effect of the seasonal variability of both recharge and ground water pumping in the analysis. Since the dwellings on the island are clustered, the ground water in a large portion of the island should not be degraded. However in a number of localized areas, the ground water quality may be affected.

Figures 12 and 13 display contours of the ground water potential for the top and bottom of the model for June 1 and September 1 respectively. There are two principal differences between the two time periods. First, the water table drops over the summer due to pumping and the lack of significant recharge. Secondly, in some areas the direction of vertical movement changes, where pumping causes the ground water to flow downward at the end of the summer at locations where it was flowing upward in the spring. An example is located near the northeast shore of the island.

Ground water transport was analyzed with the three-dimensional model MT3D (Zheng, 1990). The discretization used was the same as for the flow model. The waste water was assigned a source strength of 100, and was treated as a conservative tracer. In other words, it is assumed for the purposes of this simulation that the contaminants in the waste water do not degrade over time or become bound to the soil.

The initial condition for the transport simulations was a concentration of zero over the entire island. The model was run for a simulated period of eight years, which allowed the predicted concentrations to equilibrate to a repeating annual pattern. Figure 20 is a plot of the percentage of source strength from applied sewage as simulated in the top four model layers at the cell located at row 25, column 26. This cell is located near the southern shore of the island. On average, the maximum annual concentration would be expected at the end of the summer, but as shown in Figure 20 the pattern is more complicated because of the combined influence of upgradient sources.

A significant result of this work is that contaminant concentrations in the ground water do not drop to zero between the end of one summer and the beginning of another. Figure 20 shows that although there are seasonal declines, a significant contaminant residual remains. For the area of the model represented by Figure 20, it took on the order of 7 years for an annual repeating pattern to be established. This implies that any incremental additions of seasonally-applied contaminants will only be fully felt on the order of 7 years later. In the first 3 or 4 years after a new source has been added, concentrations only increase to 1/3 of their ultimate incremental value. Because of this significant lag time in realizing the impacts of new septic systems, it will not be easy to monitor and verify the effects of a new source in one season. Caution is needed since after 7 years it may be too late to reverse a poor siting decision. This also implies that it will take on the order of 7 or more years to cleanse an area of contaminants, once it has been contaminated.

Figures 14 through 19 display contours of the waste water contaminant concentrations for each of the six model layers at the end of the summer season, September 1, when the concentrations in the soil are at their annual maximum values. Contours for the values of 1%, 5% and 10% are drawn. The lightly shaded regions represent areas where the concentration is greater than 5% of the source strength. The heavily shaded regions represent areas where the concentration is greater than 10% of initial source strength. The areas having the highest concentrations are those using pressurized water systems. A few pressurized water systems with water closets have a much more dramatic impact than a high density of cottages using only handpumps and privies.

Although rather arbitrary, we conclude that dug wells within areas presently having greater than 5% of initial source concentration as shown on Figure 14 have the potential to be contaminated by coliform bacteria, viruses, or nitrate-nitrogen. Similarly, the drilled wells located within areas presently having a concentration greater than 5% of source strength on Figure 17 have the potential to be contaminated by bacteria, viruses, or nitrate-nitrogen. This is not to say that other areas of the island are immune from contamination, or that wells within these defined problem areas will definitely have contamination. Rather, the present concentrations in these areas suggest a more likely problem than in other areas.

5.0 WATER QUALITY ANALYSIS

Table 4 summarizes what few water quality data have been given to RGGI. These 10 sample sets are really too few for purposes of performing statistical analysis. Therefore, any qualitative judgments made based upon the results of these few analyses should be viewed cautiously. The data suggest, however, that dug wells may be more susceptible to contamination than drilled wells on the island. RGGI has found this to be the case with other islands and coastal peninsulas. Dug wells are much more influenced by surface and near-surface water than are the drilled wells. Based on the reported coliform bacteria and nitrate concentrations, it appears that some human or pet-generated waste is affecting at least shallow ground water quality. Nitrate concentrations in 5 out of 9 wells tested showed concentrations greater than 1 mg/l. Uncontaminated ground water usually averages 0.25 mg/l as nitrate-nitrogen.

Saltwater intrusion is not a problem in the wells tested and the water is relatively "soft". Chloride, sodium and hardness are all low. However, only 2 bedrock wells have been tested.

Iron and manganese concentrations vary widely. This is a function of local soil and bedrock conditions. Four out of nine wells exceed the secondary drinking water standard for iron. This is not an unusual percentage for this area. Typically between 25% and 50% of wells in the Freeport to Harpswell area have excessive iron or manganese. Fortunately this is of no health consequence but it is annoying because of the staining of plumbing fixtures and laundry.

6.0 RECOMMENDATIONS FOR GROUND WATER MANAGEMENT

The BIVC should develop its own ground water management plan. The Maine Dept. of Environmental Protection (DEP) regulates the ground water impacts of only large developments. The State Subdivision Statute gives a Town the right to control ground water impacts in developments covered by the statute, but no guidance is given to Planning Boards in making the determination as to whether a development "will not, alone or in conjunction with existing activities, adversely affect the quality or quantity of ground water". Neither the DEP nor the State Subdivision Statute is likely to be operative in further development on Bustins Island. The State Planning Office administers the Comprehensive Planning process currently underway in Maine. The State growth management goal number 5 is: To protect the quality and manage the quantity of the State's water resources, including lakes, aquifers, great ponds, estuaries, rivers and coastal areas. Again, there is little guidance as to how to do this. On the level of individual land ownership, Maine uses the common law concept of "absolute ownership" in dealing with ground water, which essentially gives any land owner the right to remove as much ground water from under his property as he wishes, regardless of the effects on adjacent landowners. Maine is one of the few remaining states to hold to this arcane common law concept. It is clear that in the vacuum created by other possible regulatory processes, the BIVC is in the best position to manage the ground water resource.

We recommend the following two goals for the ground water management plan:

> I. PRESERVE QUANTITY--Preserve the recharge rate to the island aquifers to the extent practical such that ground water tables are not significantly lowered and saltwater intrusion does not occur to either existing or future well sites.
>
> II. PRESERVE QUALITY--Protect ground water quality so that it will at least meet the State of Maine Primary Drinking Water Standards. Where the quality is presently inferior to those Standards, the goal is to restore the ground water to a quality equal to or better than the Safe Drinking Water Standards.

It is important to note that these goals coincide with both State and Federal policies with respect to ground water management.

Under each goal, we have described a series of objectives that describe how each goal should be met. For each of these objectives, we describe an implementation plan. This implementation plan may not include all possible ways to meet the objectives, but it should give the BIVC a start in the right direction.

Some highlights of the objectives are given below.

I. PRESERVE QUANTITY

Minimize loss of recharge and augment, if possible. This should not be a major problem on the island until and unless there is some type of commercial development or recreational facility that will create a lot of runoff. Restrict the maximum percent of lot coverage with impervious surface (not just buildings) to be 25%.

Reduce excessive and progressive lowering of the ground water table. This must be accomplished through control of the type and density of wells. There has been a recent increase in the rate of changeover from dug to drilled wells. With the model that we have now developed of the island ground water, we can predict the incremental effect of adding more wells to the island. A perhaps more significant change than just the switch from dug to drilled wells is the switch from handpumps to pressurized water systems. Water usage may increase from 5 gallons per day to 250 gallons per day. Although much of this increased water demand may be returned to the island ground water, it is distributed in a different manner and may not offset a tendency toward saltwater intrusion in the bedrock aquifer. As described in Section 4.2, we recommend that our model be used each year to evaluate the incremental impacts of new wells and change overs to pressurized water systems.

Do not exceed the safe yield of the aquifers. The recharge to the bedrock aquifer is limited--it will supply only enough water to support an average island density of about 1 dwelling unit per acre for those lots using pressurized water systems. For lots using hand pumps and privies, present lot sizes are adequate to support recharge for the small amount of water use. (As discussed in the next section, water quality impacts are probably more limiting than water demand.) Water conservation should be encouraged with all existing uses and possibly forced upon all new uses involving pressurized water systems. To minimize the chances of saltwater intrusion, we recommend that new drilled wells should not be drilled closer than 200 feet from the high water mark. This is particularly important in light of the prediction that sea level is likely to rise 3 feet in the next hundred years. In some parts of the island, this could cause the saltwater interface to rise 120 feet in the bedrock aquifer.

Develop a long-term monitoring program that will continue to collect well data and will monitor long-term trends in ground water elevations. A monitoring program is essential to the success of any management program. It appears that the best monitoring plan on the island would be to use existing drilled and dug wells and volunteers to collect the data. Figure 8 divides the island into discrete zones within which it would be desirable to collect water level and quality data on a regular basis from at least one well within each zone. Data should be gathered from both dug and drilled wells, if possible.

Provide education to island residents and island visitors concerning the need to conserve water, reduce demand, and preserve and enhance recharge. We envision that a pamphlet would be produced for distribution to the island property owners.

II. PRESERVE QUALITY

Prevent ground water degradation to the extent possible by setting appropriate building permit policy that will reduce the risk of ground water contamination. Except where grandfather provisions make this impossible, it appears that minimum lot sizes should be different depending upon whether a pressurized water system and septic system is used versus handpumps, sink drain and privy. The results of our modeling show the pressurized systems to have a much greater impact in both area and intensity. As a general rule of thumb, unless denitrification systems are used, single family residential lot sizes on pressurized water systems and septic systems should be about 2 acres per dwelling unit to avoid future problems. Because there is much resource protection and other common land on the island, the model could be used to develop very specific density recommendations for various areas of the island. The most sensitive area is that shown as Section A on the Zoning Map. Because of a number of hydrologic factors, combined with current land use considerations, this area of the island is most likely to show decreased ground water quality as a result of further development. Our model could be used annually to evaluate the incremental impacts of proposed additions to waste water disposal systems on the island.

The Plumbing Code presently requires septic systems to be located at least 100 feet from wells. In the type of hydrogeologic environment present on Bustins, we recommend that any wells located downgradient of privies, sink drains, or septic systems to be a minimum of 200 feet to minimize disease transmission by microbes (based on the average rate of travel in the aquifer and the survival time of pathogens in ground water). Wells located on the same contour, or upgradient of disposal systems can be located only 100 feet away, and possibly closer in particular cases.

Proper functioning of sink drains, privies, and septic systems--not only hydraulically, but also in terms of efficiency of treatment--is a function of proper design, construction and maintenance. There are many grandfathered systems on Bustins that would not meet today's Plumbing Code. Because there is essentially no source of fill on the island to construct systems that would comply with today's Plumbing Code, upgrading systems is very expensive and usually requires barging fill materials to the island. Nonetheless, prevention of water-borne illnesses is greatly enhanced if septic systems and privies are located above the water table that is likely to occur during the period of occupation. Although we have no particular recommendations as to how the island accomplishes it, we feel that it is important to upgrade existing systems as well as insure that new systems are built properly. We see no particular problem with properly built privies and conclude that they have much less impact on ground water quality than septic systems connected to water closets.

Control the storage and disposal of materials that can affect ground water quality by generally restricting them to areas where existing or potential future wells will not be adversely affected. Our model of the island can be used to evaluate sites for the disposal, for example, of septic tank and privy wastes.

Underground storage tanks holding hydrocarbons or other chemicals should not be permitted. Fortunately, the island relies largely on propane as a fuel source. However, any gasoline, diesel, or kerosene tanks should be inspected periodically for leaks. The island should develop a SPCC (Spill Prevention, Control and Countermeasures) plan to deal with potential leaks of fuels or dangerous liquid chemicals. Part of an emergency response plan for reacting to accidental chemical or petroleum spills involves training key island residents and giving them the equipment and mainland support necessary to react properly. At a minimum, skimmers, booms, storage tanks, and absorbent pads should be available in sufficient quantity to control the largest conceivable spill on the island.

Any herbicides or pesticides used on the island should have a maximum half-life in unsaturated soil of 20 days. Pesticides we would consider acceptable, based on this criterion alone, are: 2,4-D; 2,4,5-T; Dicamba; Dalapon; Methyl Parathion; Malathion; Captan; and Carbaryl. Unacceptable pesticides include: Atrazine; Simazine; Terbacil; Linuron; TCA; Glyphosate; Parathion; Diazinon; Fonofos; Phorate; Carbofuran; Aldrin; Dialdrin; Endrin; Heptachlor; PCP; Trifluralin; Bromacil; Picloram; Paraquat; DDT; Chlordane; and Lindane.

Develop a long-term ground water quality monitoring plan. As with the "PRESERVE QUANTITY" monitoring objective, it will be important to monitor ground water quality trends over the long-term to measure progress on the plan. There is presently an inadequate data base on the island ground water quality. Recall that the full impact of new contamination sources will not be felt for about 7 years.

Develop a public education plan. We envision that information on how the property owner can affect ground water quality be part of the suggested brochure we discussed under the "PRESERVE QUANTITY" objective.

7.0 LIST OF REFERENCES

Zheng, C. 1990. A modular three-dimensional transport model for simulation of advection, dispersion and chemical reactions of contaminants in groundwater systems. Prepared for the U.S. Environmental Protection Agency Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma, by S.S Papadopulos & Associates, Inc. Rockville, MD.

McDonald J.M. and A.W. Harbaugh. 1988. A modular three-dimensional finite-difference ground-water flow model. Techniques of Water Resources Investigations of the U.S. Geological Survey, Book 6. 586 pp.

Pollock, D.P. 1989. Documentation of computer programs to compute and display pathlines using results from the U.S. Geological modular three-dimensional finite-difference ground-water flow model. U.S. Geological Survey Open File Report 89-381. 188 pp.

Table 1 - Well Data used for Flow Model Calibration

Bustins Island Ground Water Evaluation
File #843well.wkz
data entered by: ECR/ECB
filename: 843well.wkz
revised 2/21/90

Well #	Section and Lot number where well is located		Cottage Occupant	Drilled Well Depth [feet]	Drilled Well Yield [gpm]	Static Water Level depth [feet]	Year Drilled Well Installed	coordinates east [ft]	north [ft]	Land Elevation from topo [ft msl]	Ground water Potential [ft msl]
1	B	13	Harris, S.	100	10	1	1988	5113.4	1481.9	42.9	41.9
3	C	9	Ewing, R.	245	8	0	1988	4053.9	928.3	19.9	19.9
7	E	19	Kirkland, H.	120	3	4	1988	4252.7	2345.1	16.0	12.0
9	C	12 & 13	Nickerson, B.	90	5	8	1988	3925.8	944.6	19.5	11.5
11	E	51	Kitchen, C.	180	5	18	1988	5437.8	1705.8	47.7	29.7
13	B	25 A	Cooper, W.	147	2.5	5	1981	4721.4	1495.5	50.0	45.0
14	CA		Davis, J.	280	1.5	5	1988	3912.9	1444.0	28.8	23.8
15	A	18	Richardson, C.	100	3.5	12	1988	6045.8	2329.5	43.8	31.8
35	C	6	Gempel, R.	100	3.5	6	1981	4181.5	1045.8	31.9	25.9
41	A	40	Richardson, G.	100		10	1988	6038.6	2458.7	46.0	36.0
44	D	18	Mellecker, J.	100	2	15	1988	3594.1	1462.4	19.3	4.3
45	D	33	Whiting, N.	135	5.5	11	1981	3796.6	1491.7	20.5	9.5
53	D	4	Koleda, M.	100	3	10	1988	3398.6	1167.1	17.0	7.0
55	A	20	Thomas, C.	120	3	16	1988	6098.8	2431.9	39.3	23.3
61	E END		Perry, W.	118	0.25	5	1973	6234.1	3704.6	20.8	15.8
62	C	30	Shields, K.	160	1	12	1988	4241.1	1252.1	40.0	28.0
63	E	13	Larrabee, L.	115	15	2	1981	5015.9	3265.1	10.3	8.3
68	A	55	Carr, B.	120	20	8	1988	6257.7	3081.4	20.0	12.0
69	B	15	Richardson, G.	260	0.75	14	1988	5037.8	1410.6	37.9	23.9
70			BIVC Store	120	3	7	1988	4660.2	1125.9	30.4	23.4
71	B	12	Taisey, R.	170	1.5	5	1988	4977.3	1739.1	60.0	55.0
74	CG		Leland, R.	200	2	8	1988	4094.0	1182.0	30.1	22.1
75	CC		Petrie, K.	240	0.75	10	1988	3904.1	1358.6	24.6	14.6
76	D	24	Hughs, W.	200	1	5	1988	3675.4	1060.6	10.0	5.0
77	D	33 0	Baker, W.	180	3	9	1988	3959.4	1596.9	28.6	19.6
79	E	52 A	Tozier, R.	110	5	10	1988	5589.5	1800.2	46.2	36.2
80	E	52 A	Tozier, R.	100	1	19	1988	5623.8	1810.4	48.5	29.5
81	E	60	Kirkland, S.	160	2	3	1988	4457.6	2442.5	22.0	19.0
82	E	1	Sweatt, R.	120	5	7	1988	4488.8	2729.2	12.8	5.8

To convert from local coordinates to Maine state coordinate system add N 350,000 ft and E 520,000 ft.

Table 2 - Model Calibration Statistics

Well	Flow model row	Flow model column	Flow model layer	Observed head [ft]	Simulated head [ft]	Head residual [ft]
1	27	37	4	41.85	34.71	-7.14
3	20	14	6	19.88	17.11	-2.77
7	8	37	5	11.99	14.71	2.72
9	19	13	4	11.52	14.56	3.04
11	28	42	5	29.73	32.86	3.13
13	21	32	5	45.00	41.91	-3.09
14	15	20	6	23.84	20.96	-2.88
15	28	50	5	31.83	25.76	-6.07
35	20	18	4	25.94	21.72	-4.22
41	26	51	4	35.96	31.53	-4.43
44	11	15	4	4.28	7.98	3.70
45	14	19	5	9.53	15.46	5.93
53	13	8	4	7.00	7.16	0.16
55	27	52	5	23.34	25.25	1.91
61	16	61	4	15.77	12.55	-3.22
62	19	22	5	28.00	29.36	1.36
63	6	50	4	8.29	11.50	3.21
68	20	57	5	12.00	20.64	8.64
69	27	35	6	23.92	29.08	5.16
70	25	26	5	23.38	21.71	-1.67
71	21	39	5	55.00	49.53	-5.47
74	18	19	5	22.06	25.03	2.97
75	16	18	6	14.56	21.41	6.85
76	16	11	5	5.00	13.54	8.54
77	15	23	5	19.63	20.12	0.49
79	29	43	5	36.17	30.11	-6.06
80	29	44	4	29.52	31.45	1.93
81	10	40	5	18.98	22.52	3.54
82	6	42	5	5.81	13.47	7.66

```
Sum....(residuals):        29.7557
Mean...(residuals):         0.9919
Median.(residuals):         1.9235    R|lq:      -3.0931    R|uq:       3.6974
Sum....|residuals|:       123.8057
Mean...|residuals|:         4.1269
Median.|residuals|:         3.3787   |R|lq:       2.7729   |R|uq:       5.9281
Sum....(residuals^2):     661.0138
RMSE:...............        4.6940
Cv :................        4.7326 (|Cv|> 1, not Normal)
Sum....(residuals^3):  0.1585E+04
Csk :...............       -0.1153  (= 0, Normal)
```

File #843
data entered by: ECB
filename: 843PUMP
revised 6/10/91

Table 3 - Water Use Data

Well #	Section and Lot number where well is located		Cottage Occupant	Ownership O=Own CO=Co-o T=Tenant P=Public	Dug Well Depth [feet]	Drilled Well Depth [feet]	Drilled Well Yield [gpm]	Year Drilled Well Installed	Shared Well 1=YES 2=NO	Shared with whom	Hand Pump 1=inside 2=outside	Pressure System 1=YES	Use Public Wells 1=YES	Public Well Location I=Indian sp M=Muni bld P=Ice Pond	Public Well Use [gpd]	Note	Rain Barrel Total Capacity [gallons]	Well Water Use [gpd]	Well Water Use [days/year]	Rain Barrel Use [gpd]	Rain Barrel Use [days/year]	Q out [gpd]	Q in [gpd]	Well depth
2	B	33	Wall, C.	O					2		1		1		70		200	15	90	15	90	0	27	
4	AA		Barrows, W.	CO					1	Public			1	I	83		250	1.5	28	2.5	28	0	4	
8	E	21 C	Barnett, C.	O					2		1			P	84		300	2	75	10	75	0	11	
19	E	5 & 6	Jellis, D.						1	Jellis, W.	2				38			20	70			0	18	
20	A	46	Hancock, J.	O					1	Public			1	I	83		650	3.5	60	7.5	60	0	10	
24	A	28	Spalding, S.	O					1	Public			1	I	83		360	2	30	6	30	0	7	
25	B	27 A	Grece, P.	O					1	Public			1	M	70		210	5	38	5	38	0	9	
27	B	32 A	Brueck - Hatch	CO					1	Public			1	M	70		375	5	50	12.5	50	0	16	
36	A	52	Clark, W.	O					1	Public			1	I	83			30	17			0	27	
10	E	53 C	Eckel, J.	O	25				2			1						15	67			15	14	25
12	E	10	Spike, W.	O	8				1	Spike, R.	both							40	65			40	36	8
16	B	22 A	Nielsen, R.	O	12				1	2 cottages		1						40	65			40	36	12
23	C	4	Spalding, E.	O	10				1	Public			1	M			280	2	70	6	70	2	7	10
28	E	21 A	Reynolds, H.	O	15				2		1							10	30			10	9	15
29	E	1 - 1	Hunziger-Garfiel	CO	10					Baker, W.		1						250	60			250	225	10
30	EX		LaFleur, M.	O	8				1	Tozier								45	30			45	41	8
33	E	22 - 26	Norris, D.	O	14				2		2							5	60			5	5	14
38	E	124	Jellis, W.	O	15				1	Jellis, D.	both							175	90			175	158	15
47	C	29	Roberts, K.	O	10				1	*8 houses	1		1				150	5	20			5	5	10
52	E	68	Fournier, S.	O	20				2		both							12.5	50			12.5	11	20
57	B	31	Gerry, G.	O	8				1	Public	1		1	M			500	30	120	20	120	30	45	8
58	E	7 , 8 & 9	Pepin, P.	O	11						both							5	60			5	5	11
67	B	1	Taisey, R.	O	12				1	Taisey								200	30			200	180	12
83	shore reserve		Indian Spring		13													47	9			47	9	13
84			Ice Pond		13													24.5	20.25			25	20	13
1	B	13	Harris, S.	O	14	100	10	1988	2			1					500	20	120	40	120	20	54	100
3	C	9	Ewing, R.	O		245	8	1988	2		1	1					200	30	120	15	120	30	41	245
6	A	13	Baker, W.	O	16	125		1981	1	Hunziger		1						8	30			8	7	125
7	E	19	Kirkland, H.	O		120	3	1988	2		1	1						240	90			240	216	120
9	C	12 & 13	Nickerson, B.	O		90	5	1988	1	*8 houses	both		1				300	50	180			50	45	90
11	E	51	Kitchen, C.	O	14	180	5	1988	1		both						1200	10	200	6	150	10	14	180
13	B	25 A	Cooper, W.	O		147	2.5	1981	2		2	1					500	40	90	4	90	40	40	147
14	CA		Davis, J.	O		280	1.5	1988	2		2						300	20	30	20	30	20	36	280
15	A	18	Richardson, C.	O		100	3.5	1988	1	2 cottage	2						300	40	30	10	30	40	45	100
17	B	25	Pease, R.	O		120	1	1988		Pease, F.	2		1	M			500	14	45	20	45	14	31	120
26	E	20	Kirkland, H.	O	dug				2		1	1						240	90			240	216	
32	E	53	Pease, D.	O	dug				2		1							60	100			60	54	
35	C	6	Gempel, R.	O		100	3.5	1981	2		2							50	40			50	45	100
39	B	27 B	Pease, F.	O		120	2	1973	1	Pease, R.	2		1					200	100			200	180	120
41	A	40	Richardson, G.	O	5	100		1988	1	Public	2		1	M				30	70			30	27	100
44	D	18	Mellecker, J.	O		100	2	1988	1	Public	2		1	P			350	5	35	3	35	5	7	100
45	D	33	Whiting, N.	O		135	5.5	1981	2		2						350	5	40	10	40	5	14	135
46	A	53	Petrie, T.	O		120	15	1988	1	Public			1	M			150	4	30	4	30	4	7	120
48	D	10	Monzeglio, C.	O		135		1981	2									60	30			60	54	135
51	D	8	Rudolph, J.	O					1	Public			1	P		84	200	2.5	60	5	60	0	7	
53	D	4	Koleda, M.	O		100	3	1988	1	Public			1	P			350	10	65	5	65	10	14	100
55	A	20	Thomas, C.	O		120	3	1988	1	Public			1	I			365	5	70	25	70	5	27	120
61	E	END	Perry, W.	O		118	0.25	1973	1									60	100			60	54	118
62	C	30	Shields, K.	O		160	1	1988	2		2						470	3	32	10	32	3	12	160
63	E	13	Larrabee, L.	O		115	15	1981	2		both							8	50			8	7	115
64	C	28	MacDonald	O					1	Roberts	1		1	P		47		7	45			0	6	
68	A	55	Carr, B.			120	20	1988								a		48				48	43	120
69	B	15	Richardson, G.			260	0.75	1988								a		48				48	43	260
70			BIVC Store			120	3	1988										41.5	19.35			41.5	19.35	120
71	B	12	Taisey, R.			170	1.5	1988								a		48				48	43	170
72	B	22 B	Gerry, J., Shields, B.			113	2.25	1973								a		48				48	43	113
73	B	18	Harris, S.			105	3.5	1973								a		48				48	43	105
74	CG		Leland, R.			200	2	1988								a		48				48	43	200
75	CC		Petrie, K.			240	0.75	1988								a		48				48	43	240
76	D	24	Hughs, W.			200	1	1988								a		48				48	43	200
77	D	33 D	Baker, W.			180	3	1988								a		48				48	43	180
78	D	13	Larrabee, L.			110	10	1981								a		48				48	43	110
79	E	52 A	Tozier, R.			110	5	1988								a		48				48	43	110
80	E	52 A	Tozier, R.			100	1	1988								a		48				48	43	100
81	E	60	Kirkland, S.			160	2	1988								a		48				48	43	160
82	E	1	Sweatt, R.			120	5	1988								a		48				48	43	120
5	?		Knight, F.	O					1	Public	rain barr.		1	I	83	c	400	6	75	20	75			
21	?		Leyden, B.	O					1	Public			1	I	83	c	300	4	27	4	27			
34	?		Shephard, P.	O					1	Public			1	M	70	c	100	6.5	30	17.5	30			
40	?		Smith, D.	T					1	Public			1	M	70	c	350	5	30	20	30			
50	?		Ledin, P.	O					1	Public			1	P	84	c		20	40					
65	?		Mulry, Stager, Silv	O					2		2		1	P	84	c	1000	2.5	60	14	60			
66	?		Hutch, Gardiner	CO					1	Public			1	M	70	c		10	30	25	30			
37	see well #23		Drew, P.	CO					1	Public			1	M		b	200	4	20	6	20			
43	see well #29		Hunziger-Garfiel	CO						Baker, W.						b		180	22					
42	?		Paddock, R.	O					1	Tozier	2					b	500	8	80	15	80			
18	see well #4		Barrows, J.	CO					1	Public			1	I		b		3	14	8	14			
22	?		Knight-Rank	CO					1	Public	rain barr.		1	I		b	500	5	14	9	14			
60	?		Malloy, N.	O					1	Boon	1		1	P		b	55	10	40	3	40			
56	E	10	Spike, R.	O					1		2					b		50	100					
9			Derrah, R.	O												b								
49	see well #23		Drew - Hohn	CO					1	Public	1		1	M		b	500	5	60					
59	?		Tozier, R.	T	15				1	LaFleur						b		30	100					
31	?		Tozier, R.	O	20				1	Boon						b		100	90					
85			Tozier, R.		dug																			
86			Taisey		dug																			
87			Municipal		dug																			

2.5

notes:
a use average drilled well withdrawal
b disregard cottage
c add withdrawal and waste to public well

Table 4 - Water Quality Results

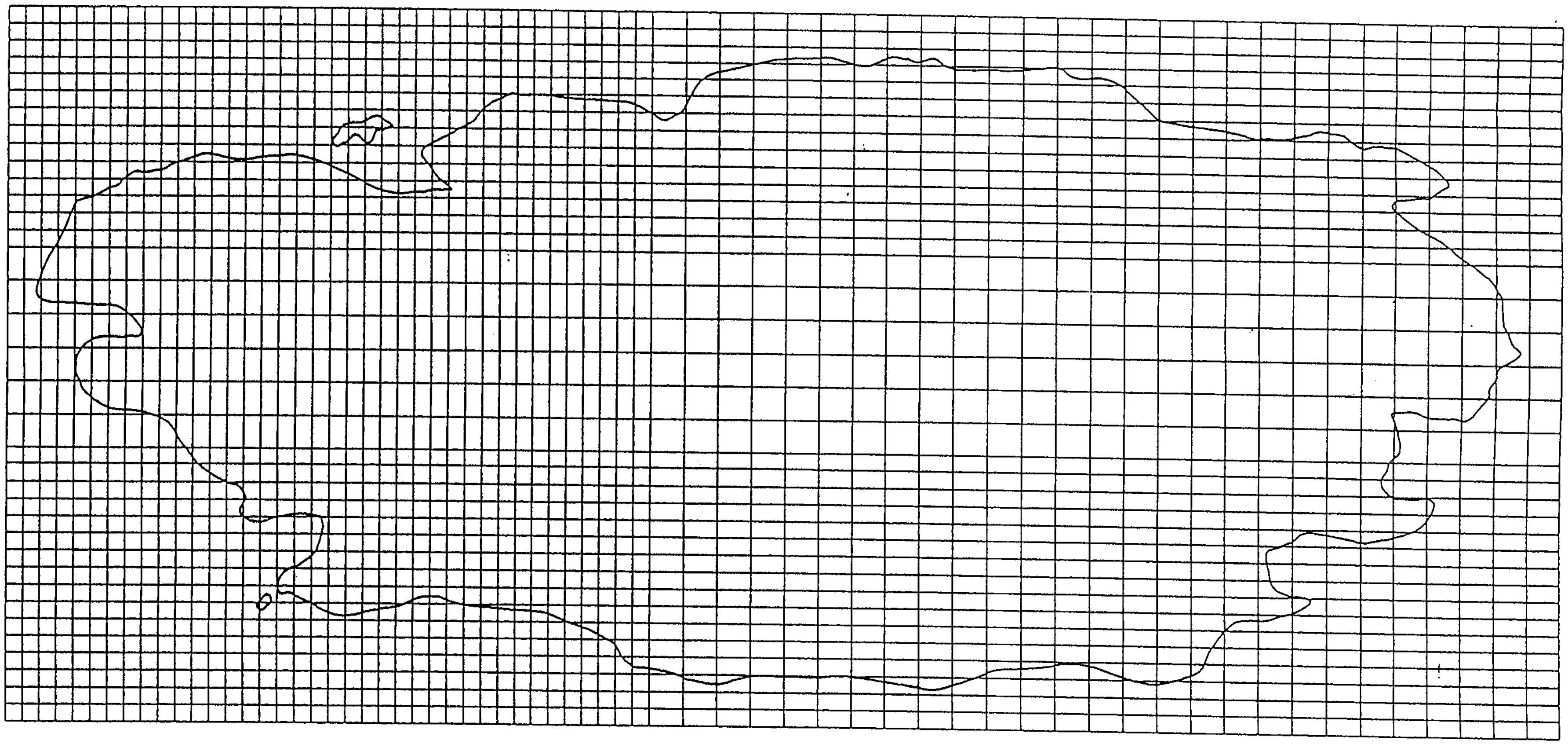
Job: 843
By: ECB
Date: 11 June 91
File: 843WATQ.WQ!

Bustins Island
Water Quality Data

Date	Owner	pH	Cl [mg/l]	Hardness [mg/l]	Nitrite N [mg/l]	Nitrate N [mg/l]	Cu [mg/l]	Fe [mg/l]	Mangenese [mg/l]	Coliform [count/100ml]	Na [mg/l]	Well Type	Depth [ft]
08/30/90	Clarence Wall	6.4	16	26	ND	ND	ND	0.36	0.07	TNTC	11.6	Spring	-
09/07/90	Dan Jellis	7.7	4	17	ND	2.1	ND	ND	ND	-	6	Dug	15
07/18/89	Robert Ewing	7.5	10	66	ND	ND	ND	0.32	ND	0	-	Drilled	245
10/16/90	G. Richardson	6.4	15	25	ND	1.7	ND	ND	ND	2	11	Dug	10
10/16/90	Guppy	6.5	6	29	ND	1.4	ND	3.4	0.88	25	7	Dug	8
10/16/90	Indian Spring	6.2	8	12	ND	ND	ND	ND	ND	15	6	Spring	
10/16/90	Folly	7	6	46	ND	4	ND	0.49	0.08	200	7	Dug	10
10/16/90	K. Roberts	6.9	8	75	ND	3.8	ND	ND	ND	4	8	Dug	10
10/11/90	R.B. Leland	6.5	11	39	ND	ND	1.2	ND	ND	0	-	Drilled	200
08/23/90	Charles Thomas	-	-	-	-	-	-	-	-	0	-	Drilled	120
Detection limit					0.05	0.5	0.05	0.05	0.05				

NOTES:
Folly well: analysis for "other" bacteria
ND: below detection limit
-: analysis not performed
TNTC: to numerous to count

Ground Water Model Grid

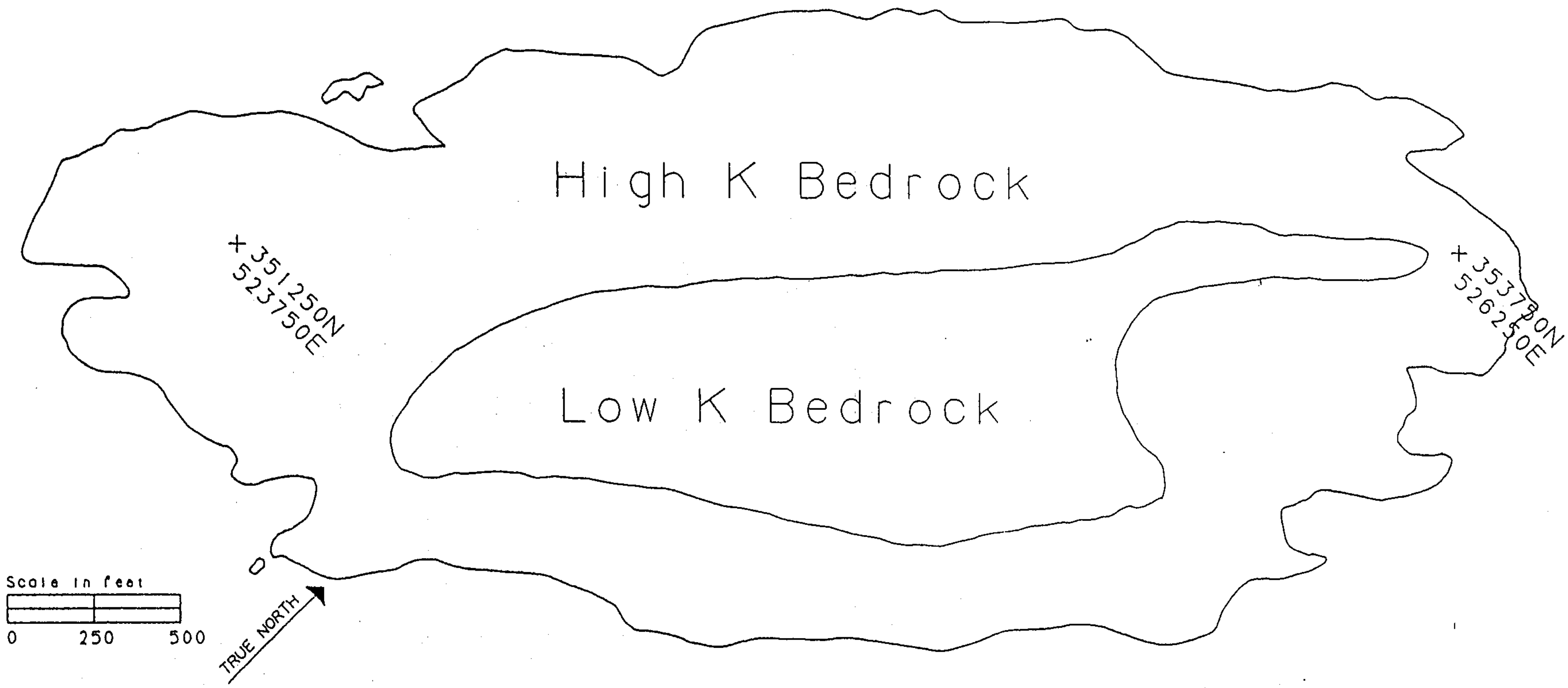


Job 843
Bustins Island Water Supply
21 February 1991

Robert G Gerber, Inc.
Freeport, Maine

Figure 1

Hydraulic conductivity zones

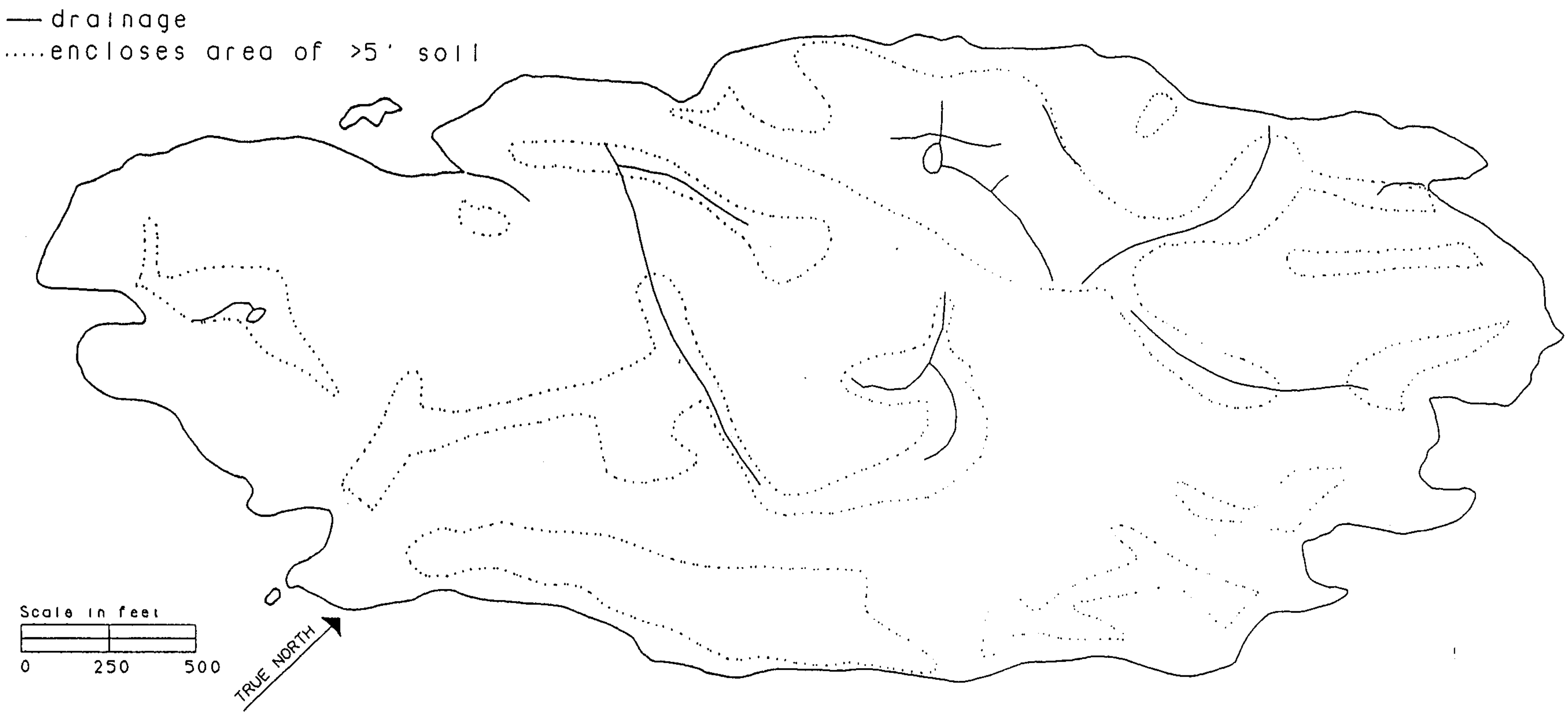


Job 843
Bustins Island Water Supply
21 February 1991

Robert G. Gerber Inc.
Freeport, Maine

Figure 2

Soil zones and drainage locations

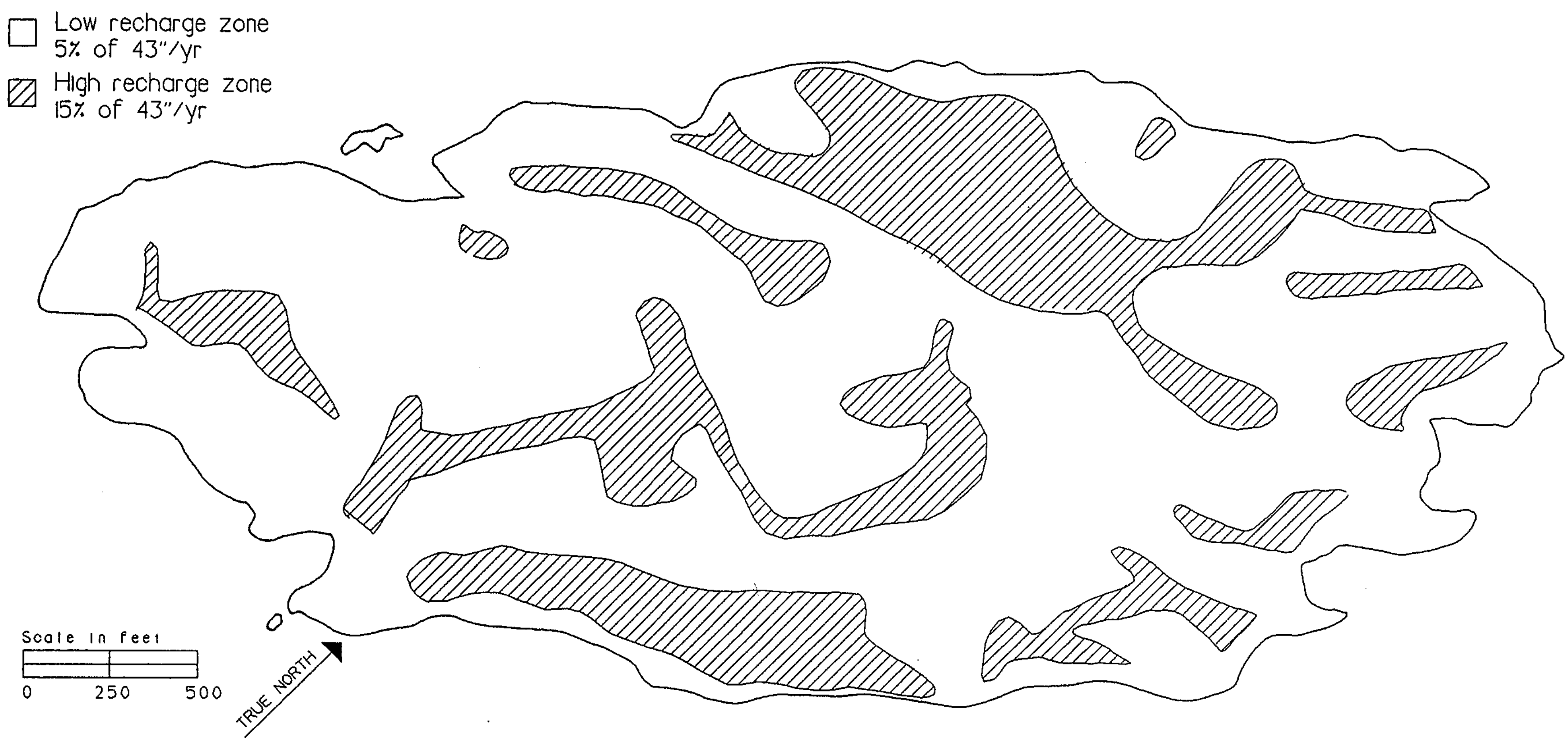


Job 843
Bustins Island Water Supply
21 February 1991

Robert G. Gerber, Inc.
Freeport, Maine

Figure 3

Recharge Zones

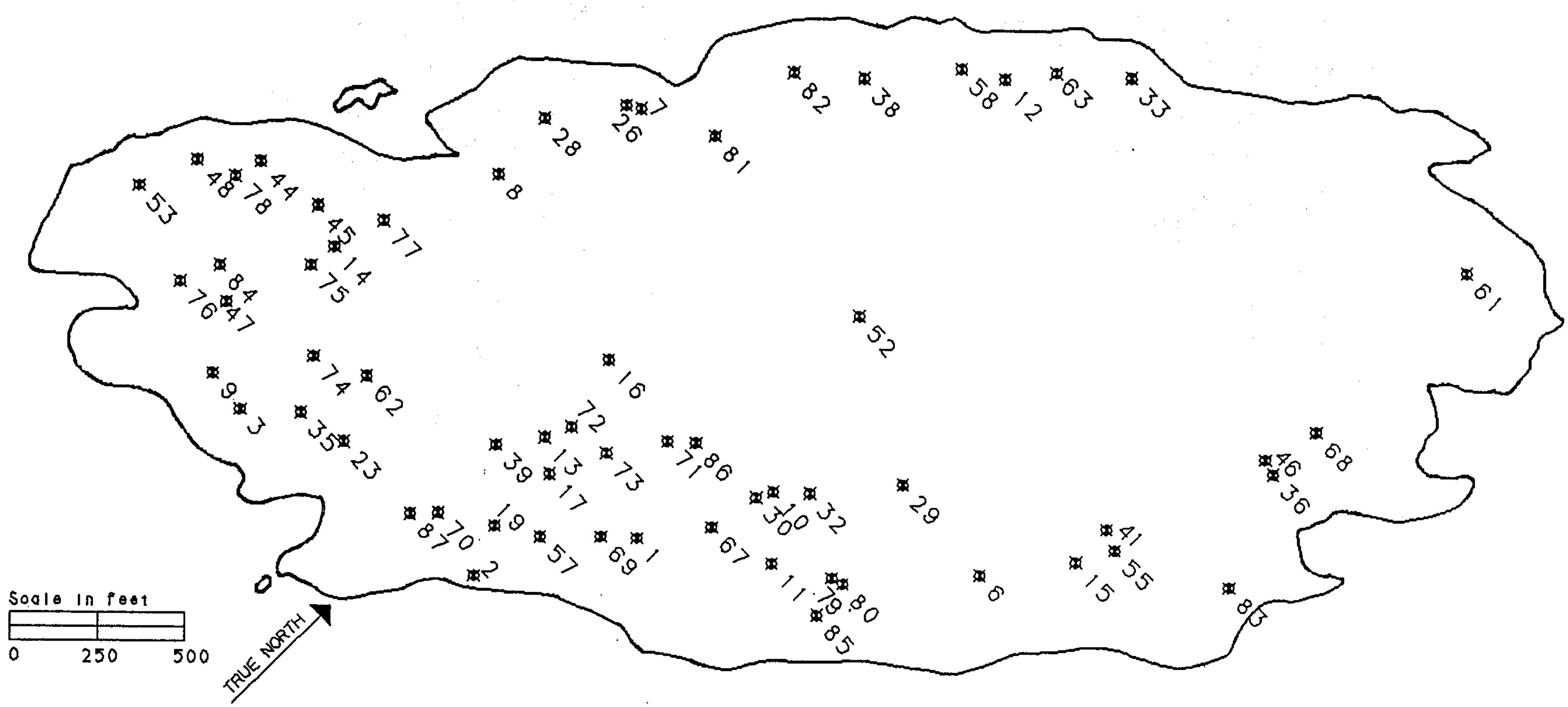


Job 843
Bustins Island Water Supply
6 June 1991

Robert G. Gerber, Inc.
Freeport, Maine

Figure 4

Location of Wells



Job 843
Bustins Island Water Supply
26 April 1991

Robert G. Gerber, Inc.
Freeport, Maine

Figure 5

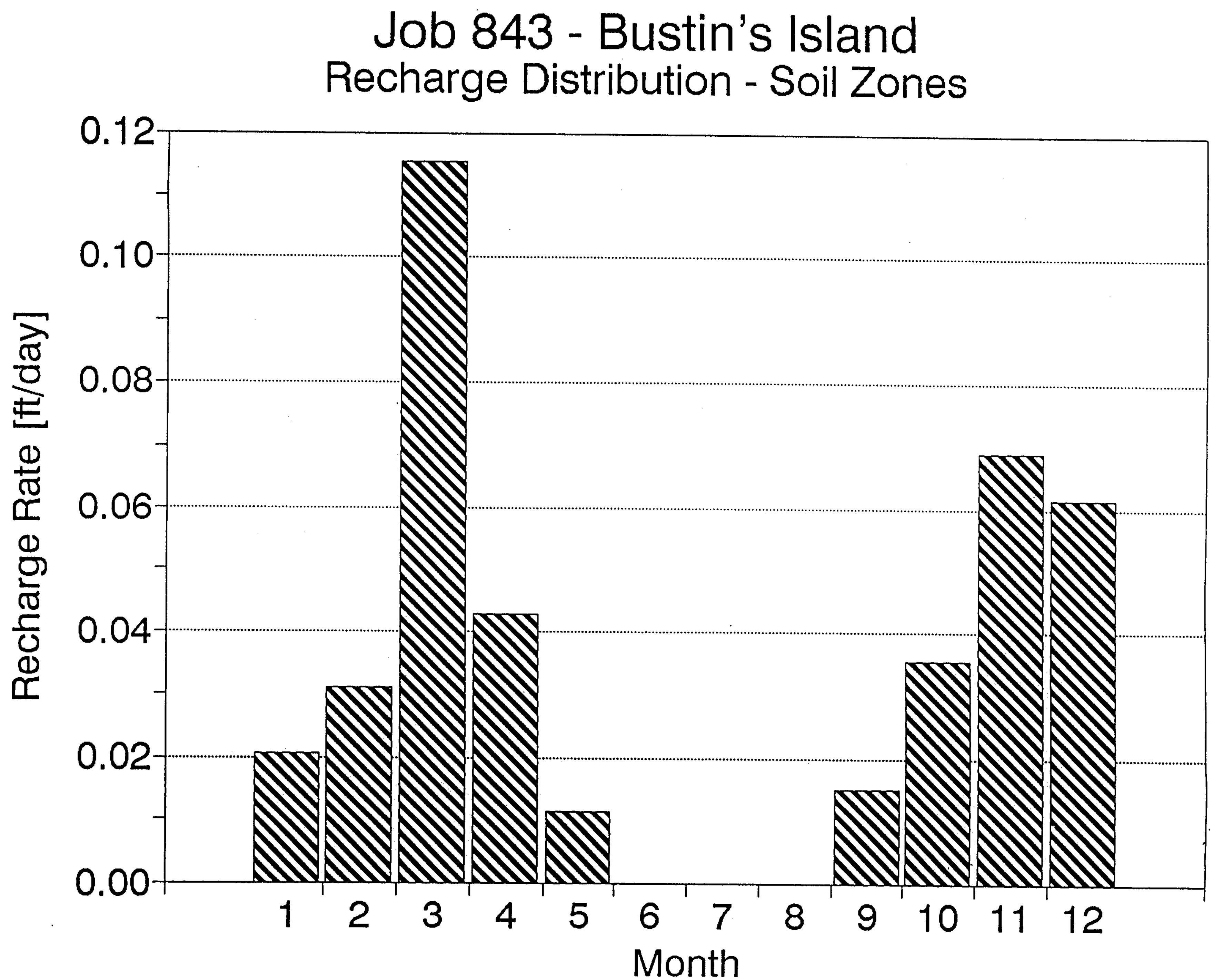

Job 843 - Bustin's Island
Recharge Distribution - Soil Zones
Recharge Rate [ft/day]
0.12
0.10
0.08
0.06
0.04
0.02
0.00
1
2
3
4
5
6
7
8
9
10
11
12
Month

Figure 6

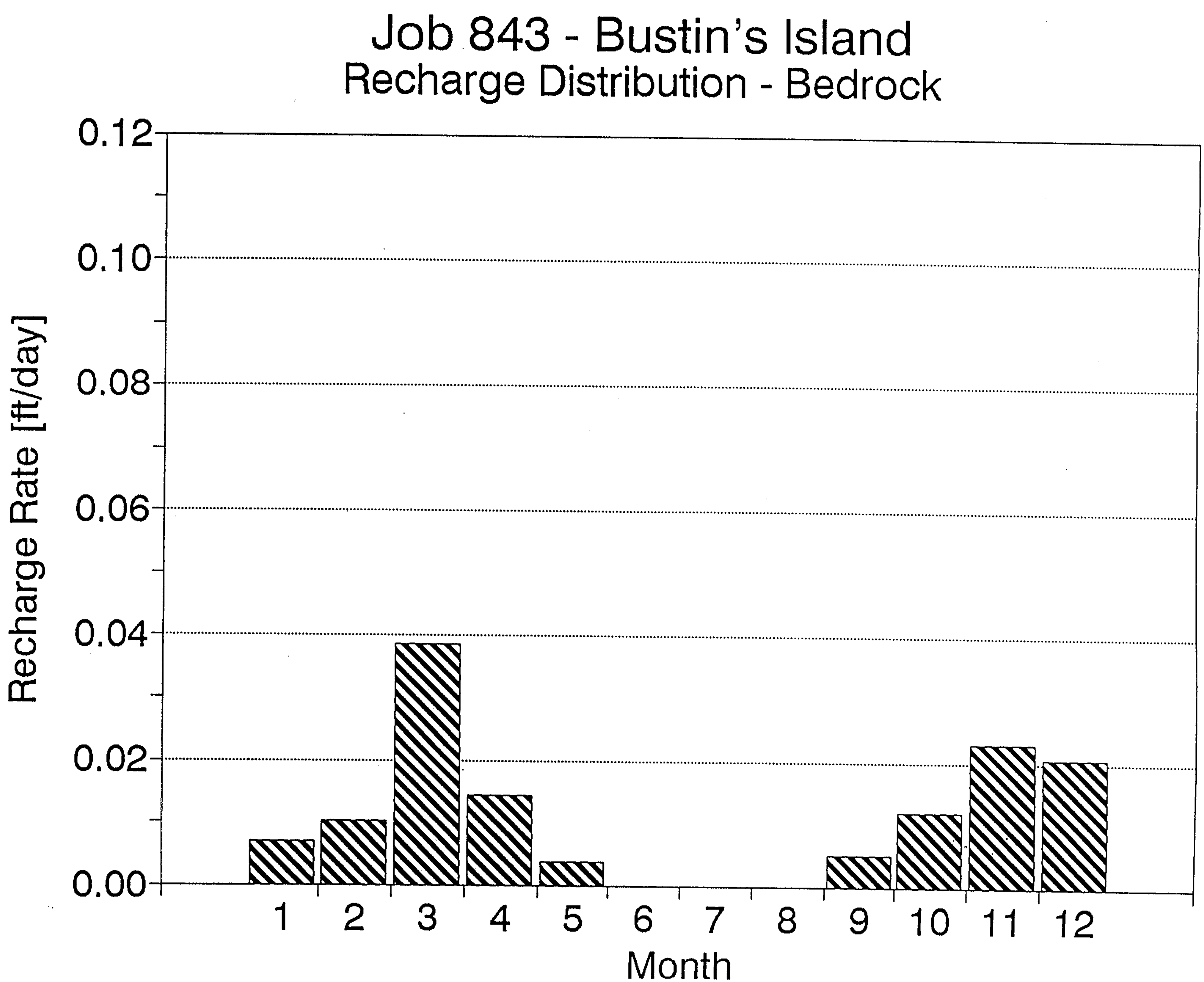
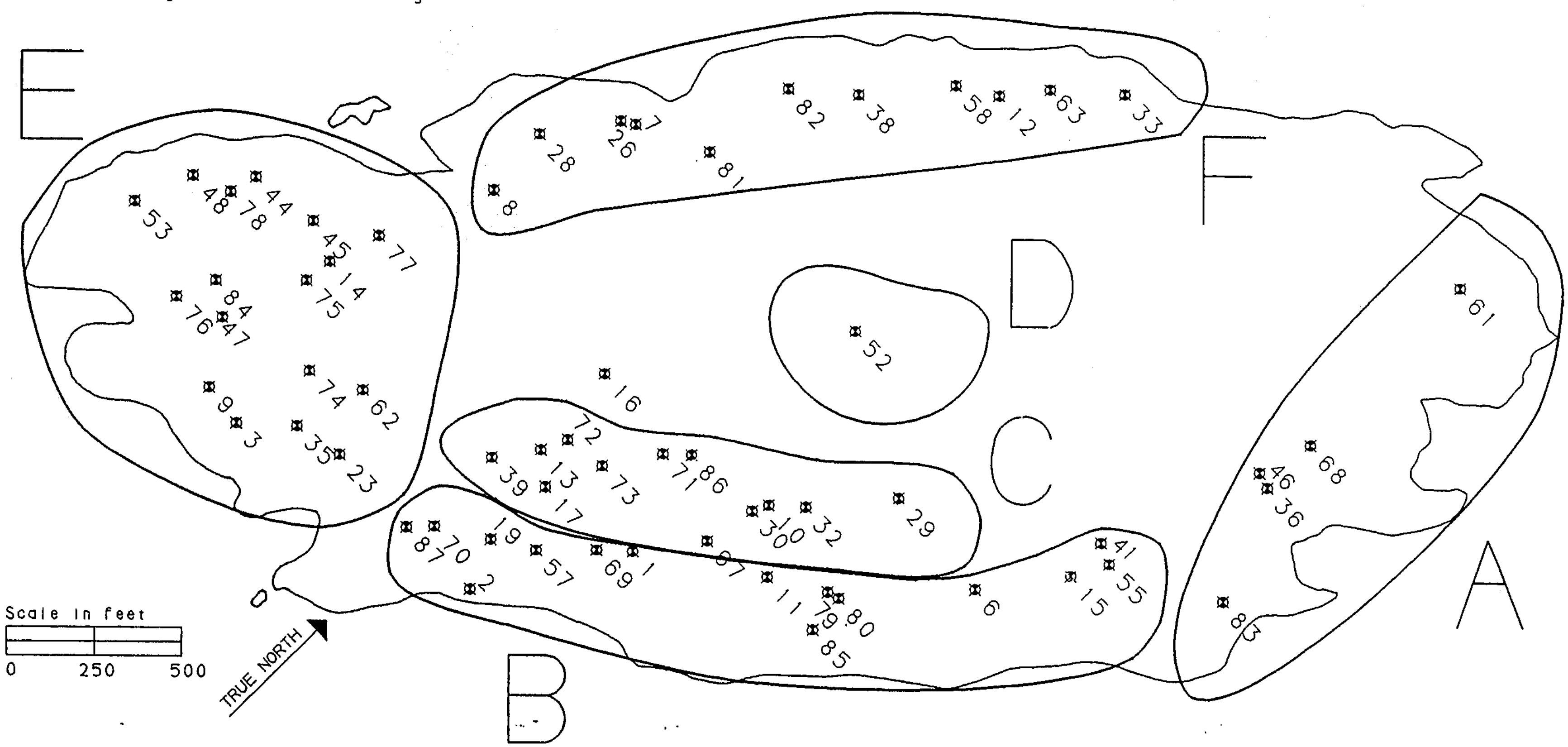

Job 843 - Bustin's Island
Recharge Distribution - Bedrock
Recharge Rate [ft/day]
0.12
0.10
0.08
0.06
0.04
0.02
0.00
1
2
3
4
5
6
7
8
9
10
11
12
Month

Figure 7

Ground Water Monitoring Zones



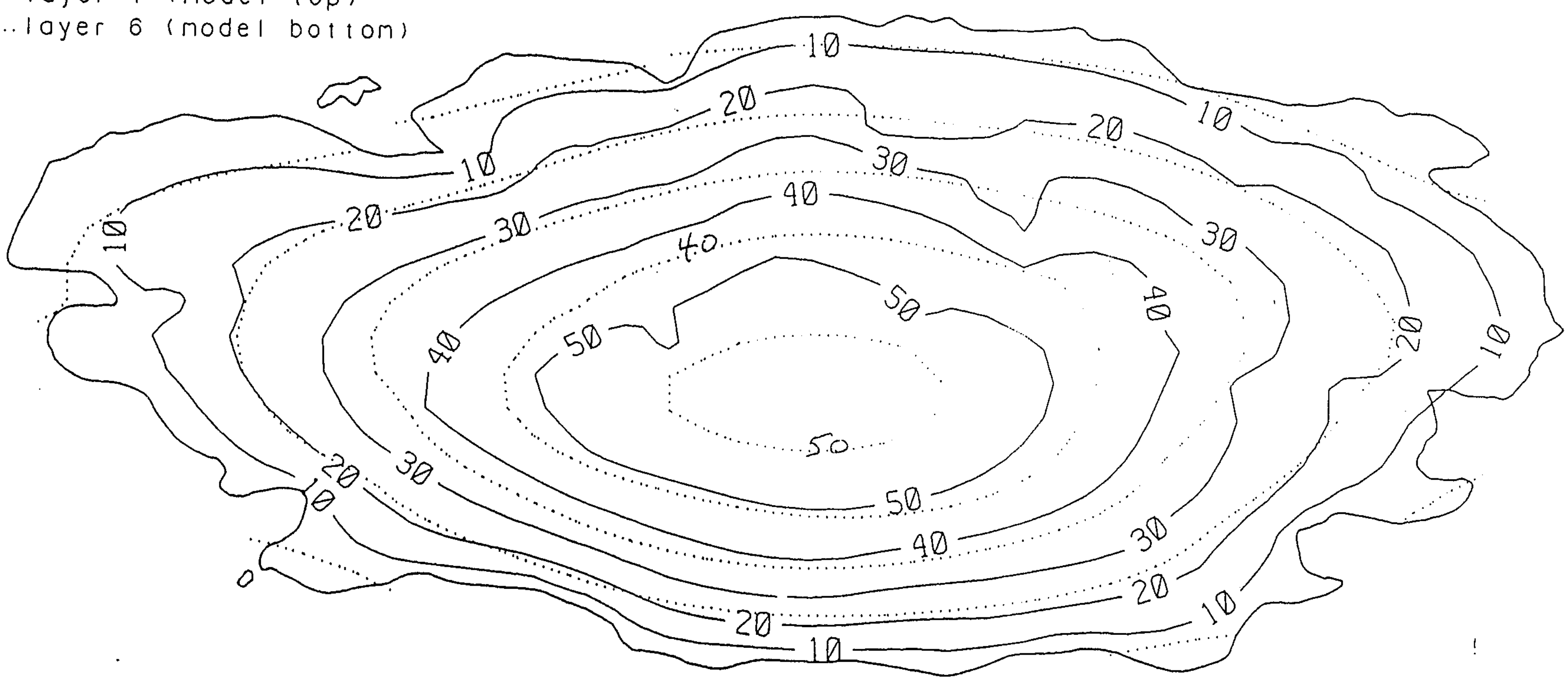
Job 843
Bustins Island Water Supply
26 June 1991

Robert G. Gerber, Inc.
Freeport, Maine

Figure 8

Simulated Ground Water Potential - Steady State

— layer 1 (model top)
.... layer 6 (model bottom)

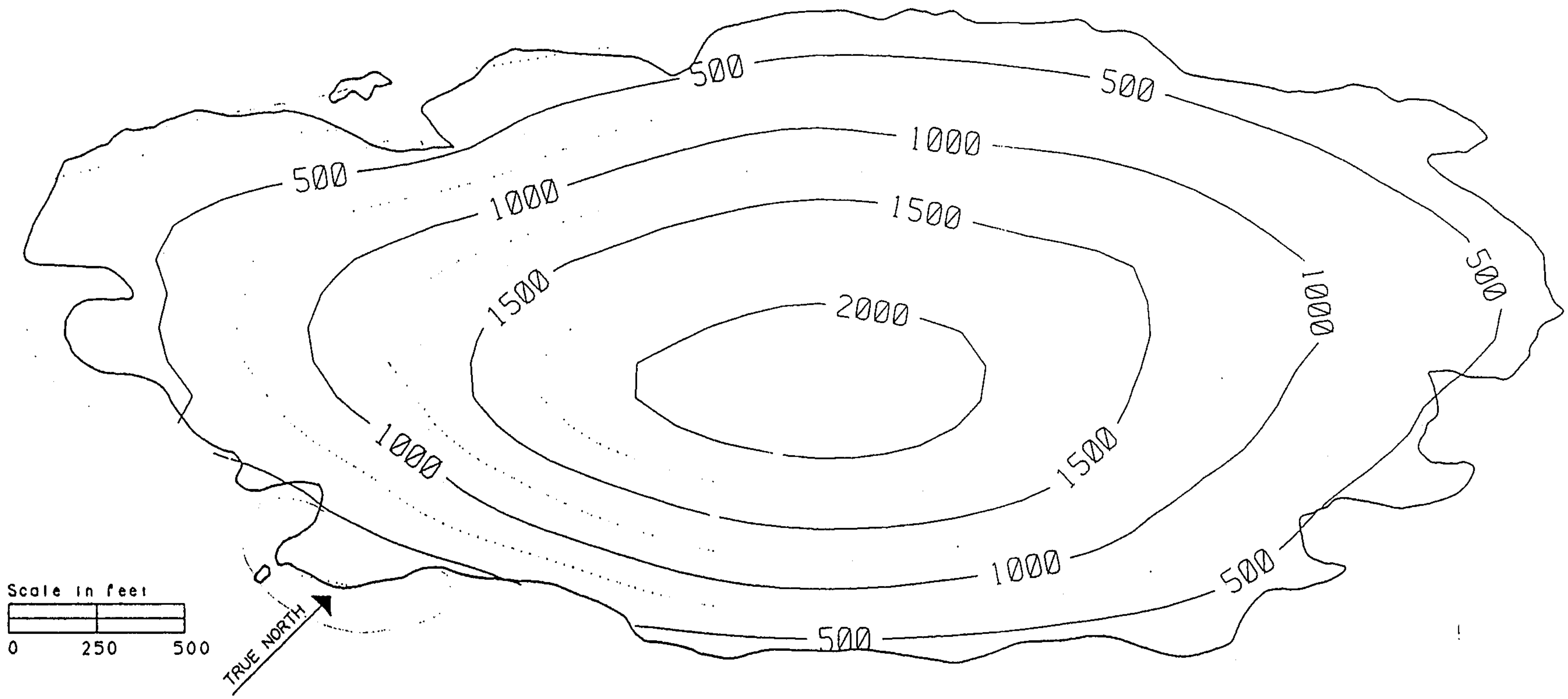


Job 843
Bustins Island Water Supply
21 February 1991

Robert G. Gerber, Inc.
Freeport, Maine

Figure 9

Depth to saltwater interface (feet below msl)
Average annual conditions without pumping

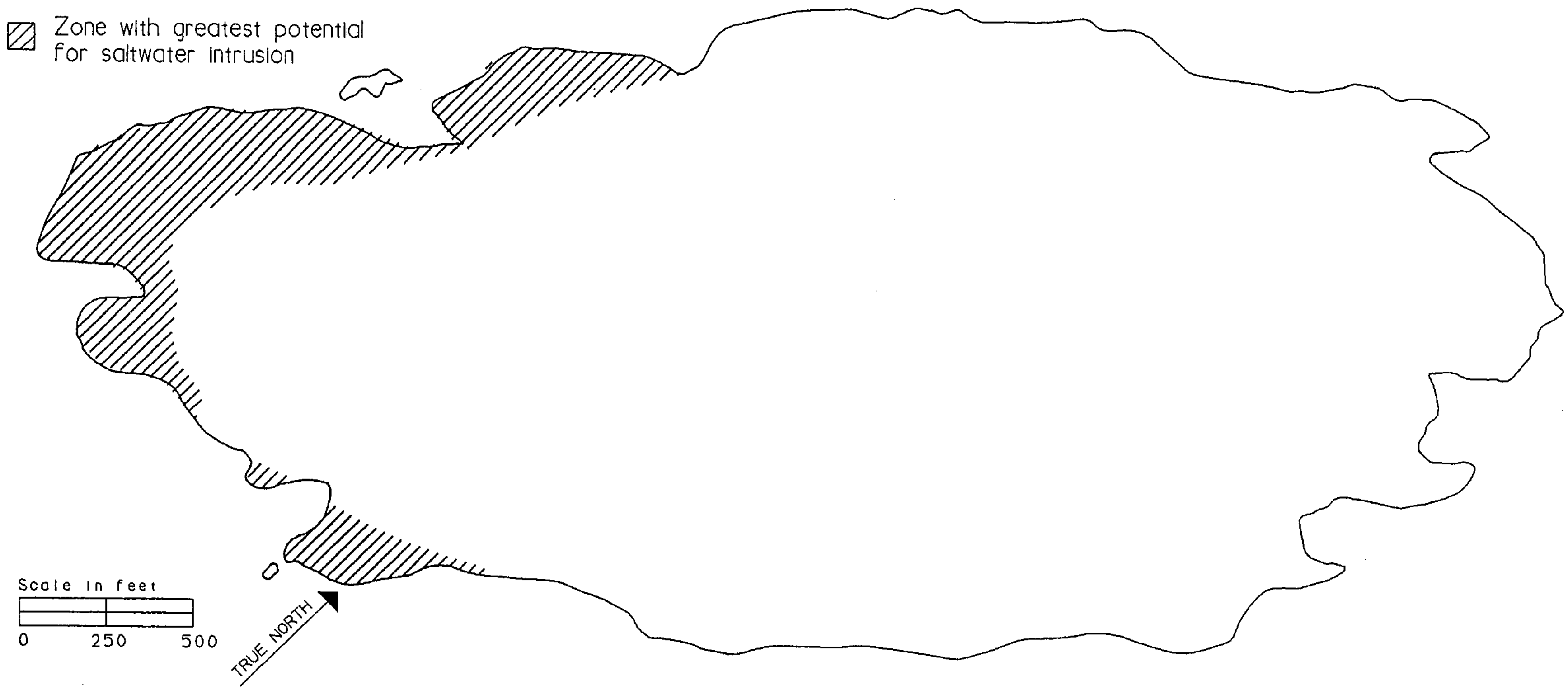


Job 843
Bustins Island Water Supply
21 February 1991

Robert G. Gerber, Inc.
Freeport, Maine

Figure 10

Zone with greatest potential for saltwater intrusion

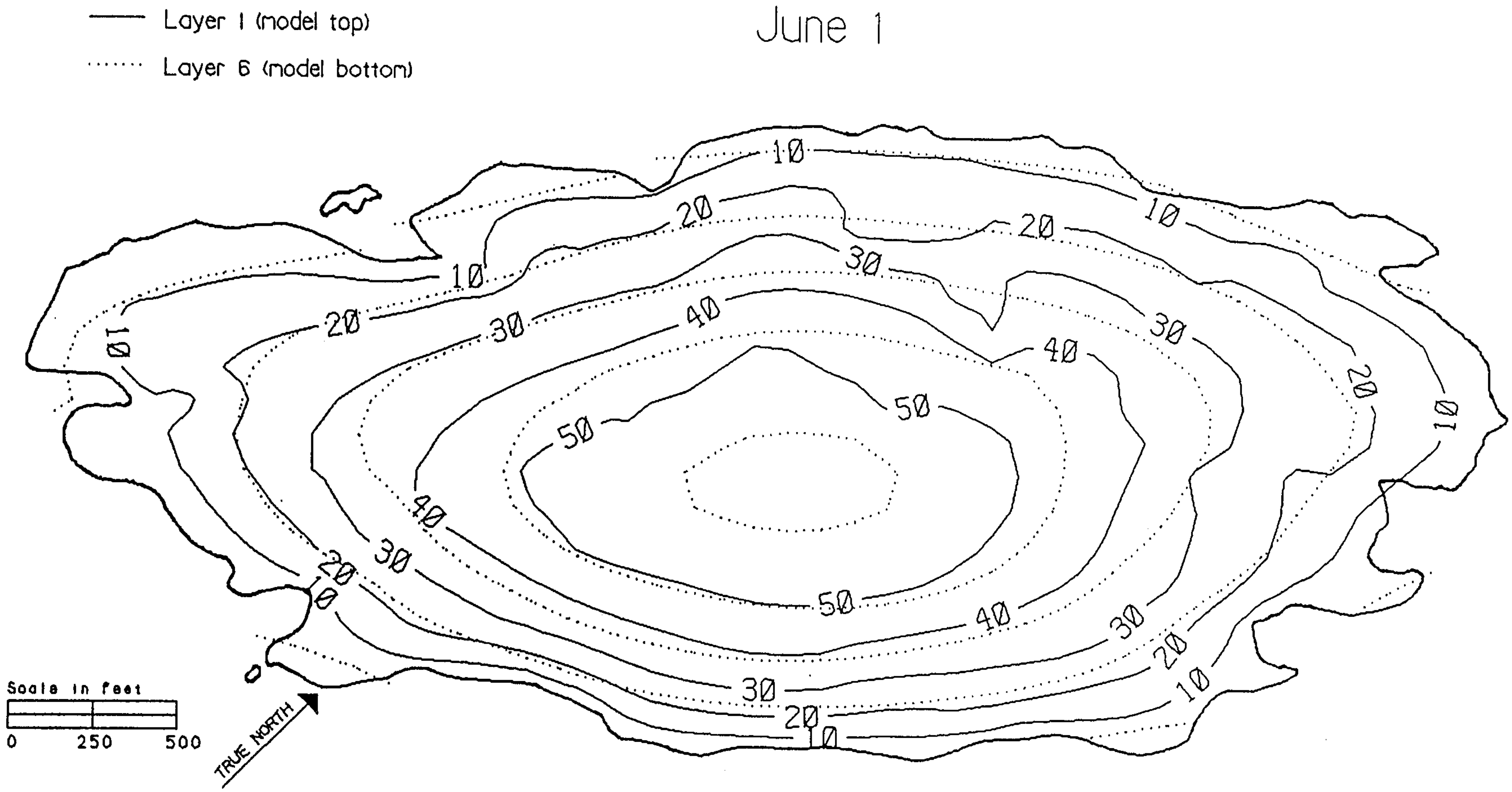


Job 843
Bustins Island Water Supply
6 June 1991

Robert G. Gerber, Inc.
Freeport, Maine

Figure 11

Simulated Transient Groundwater Potential
June 1

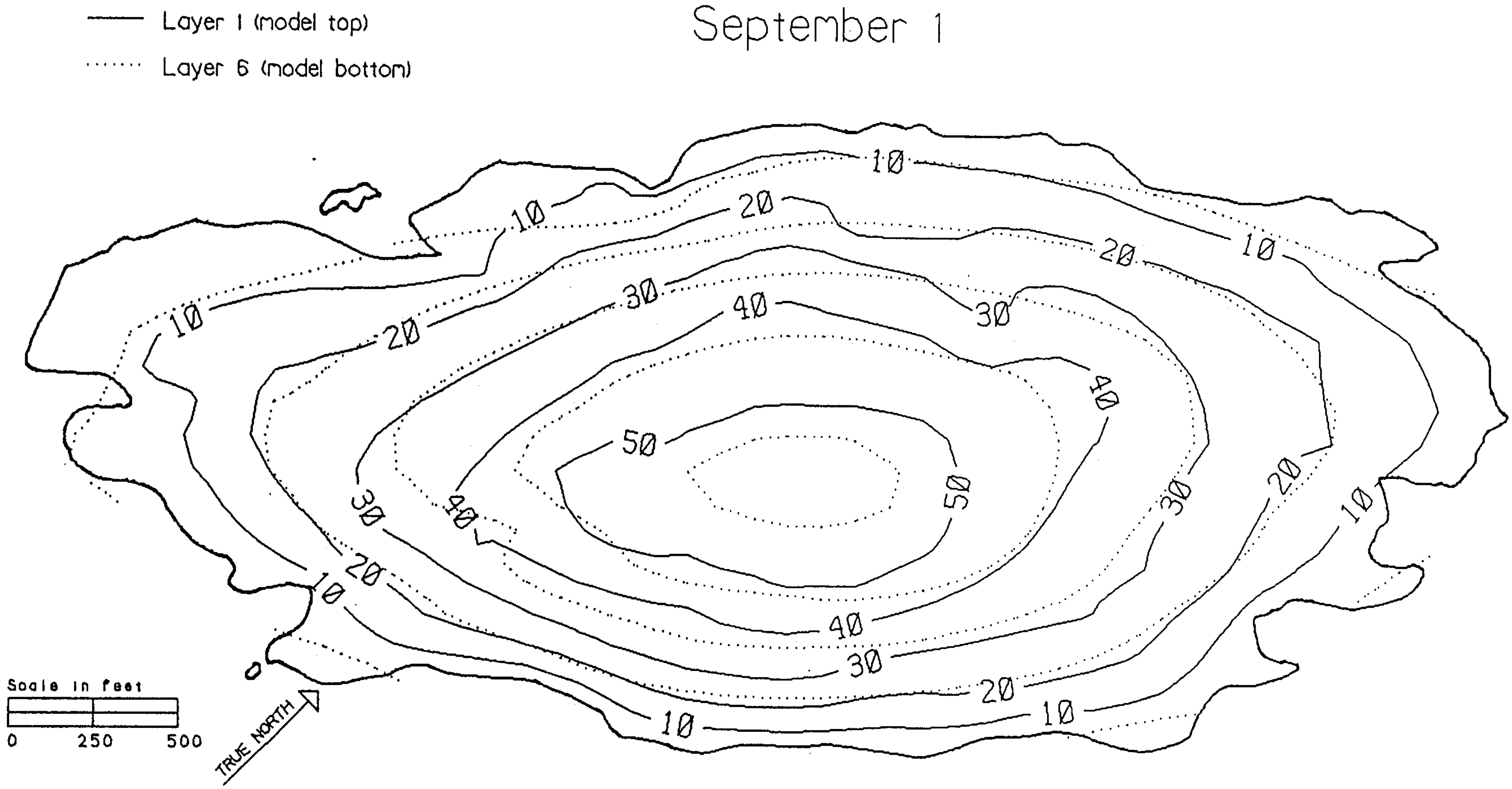


Job 843
Bustins Island Water Supply
1 April 1991

Robert G. Gerber, Inc.
Freeport, Maine

Figure 12

Simulated Transient Groundwater Potential
September 1

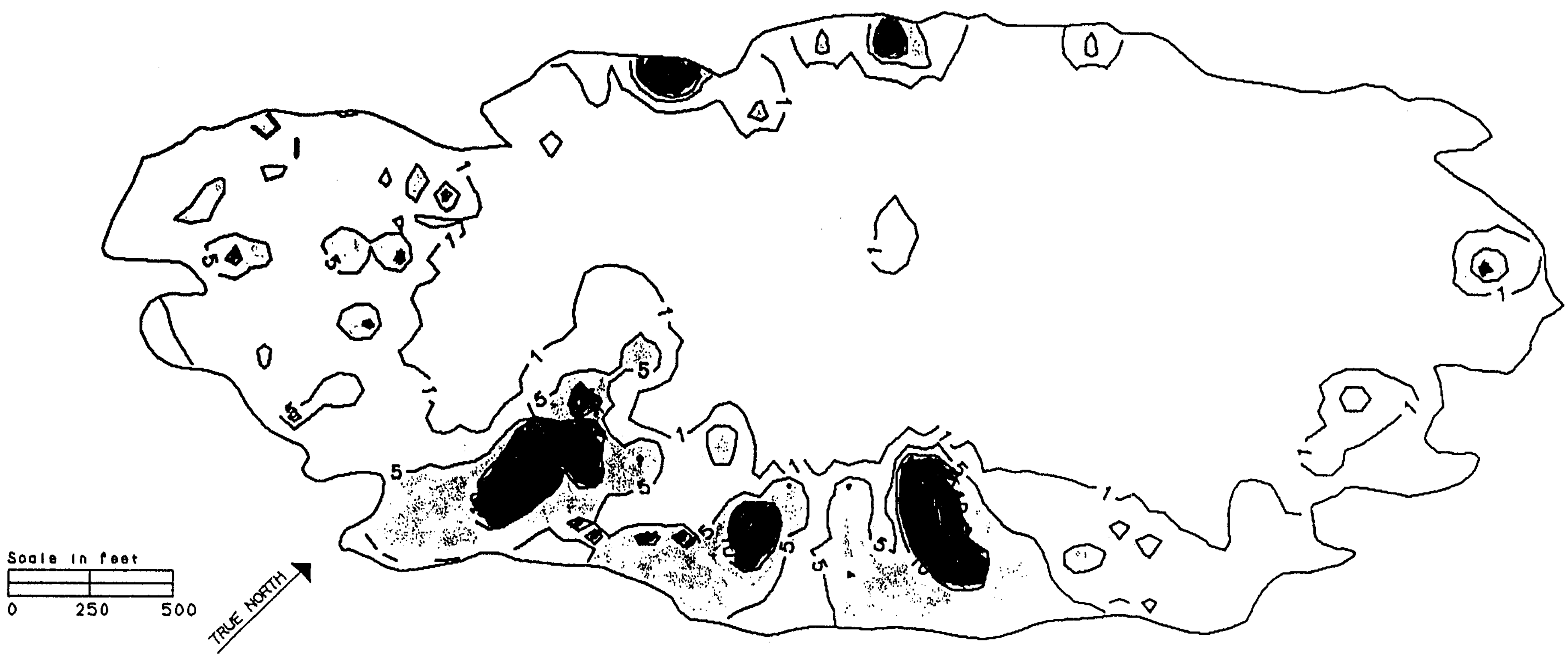


Job 843
Bustins Island Water Supply
1 April 1991

Robert G. Gerber, Inc.
Freeport, Maine

Figure 13

Job 843 - Transport - Sept 1 - Layer 1



Percentage of source strength from applied sewage

Concentration > 5% of source strength

Concentration > 10% of source strength

Bustins Island Water Supply
1 April 1991

Robert G. Gerber, Inc.
Freeport, Maine

Figure 14

Job 843 – Transport – Sept 1 – Layer 2

Percentage of source strength from applied sewage

Concentration > 5% of source strength

Concentration > 10% of source strength

Bustins Island Water Supply
1 April 1991

Robert G. Gerber, Inc.
Freeport, Maine

Figure 15

Job 843 - Transport - Sept 1 - Layer 3

Percentage of source strength from applied sewage

Concentration > 5% of source strength

Concentration > 10% of source strength

Bustins Island Water Supply
1 April 1991

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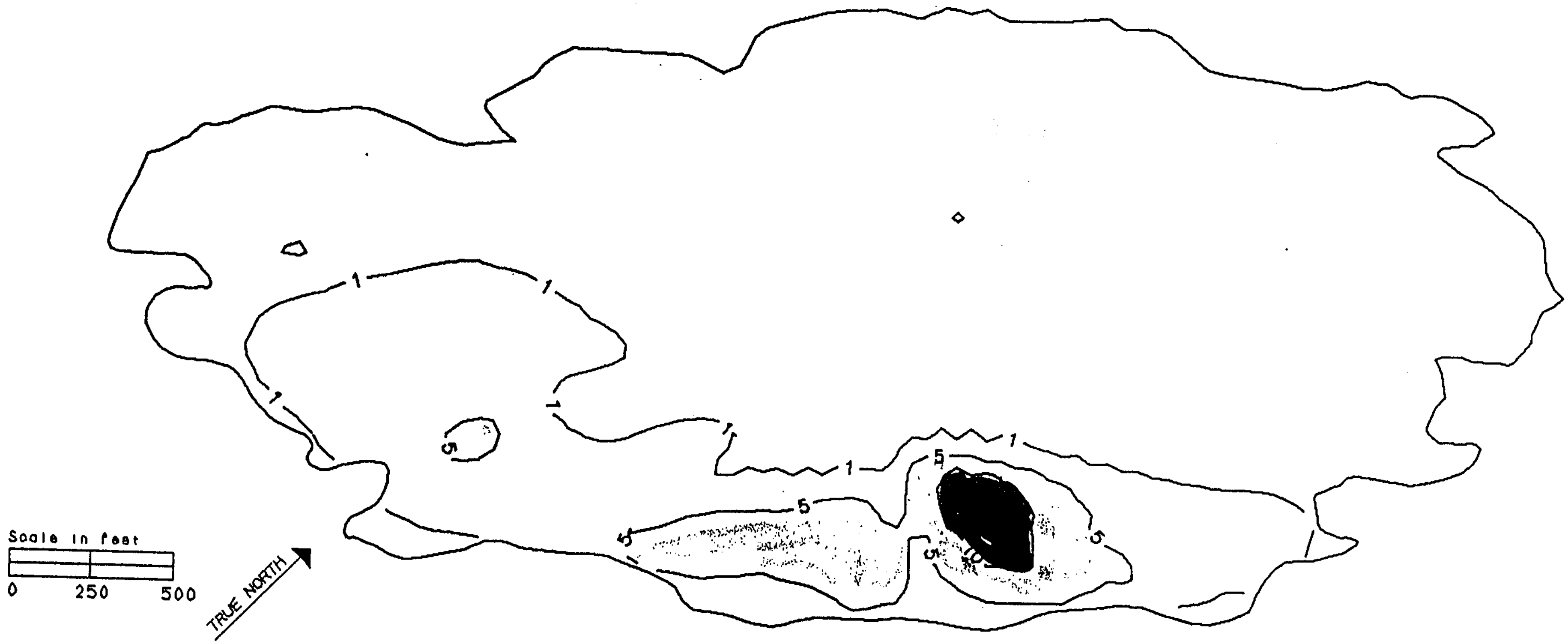
Freeport, Maine

Figure 16

Job 843 – Transport – Sept 1 – Layer 4



Percentage of source strength from applied sewage

Concentration > 5% of source strength

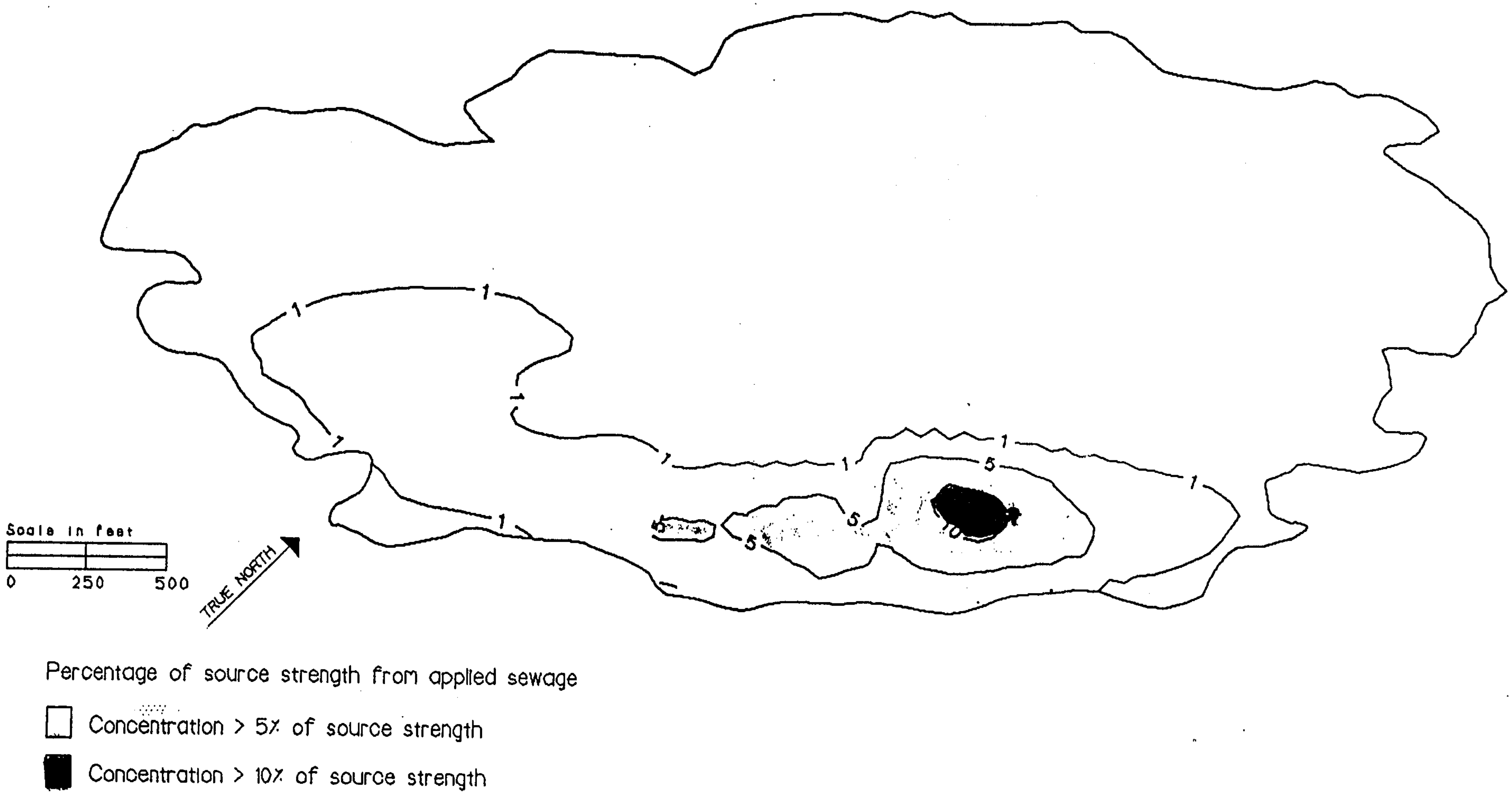
Concentration > 10% of source strength

Bustins Island Water Supply
1 April 1991

Robert G. Gerber, Inc.
Freeport, Maine

Figure 17

Job 843 – Transport – Sept 1 – Layer 5



Bustins Island Water Supply
1 April 1991

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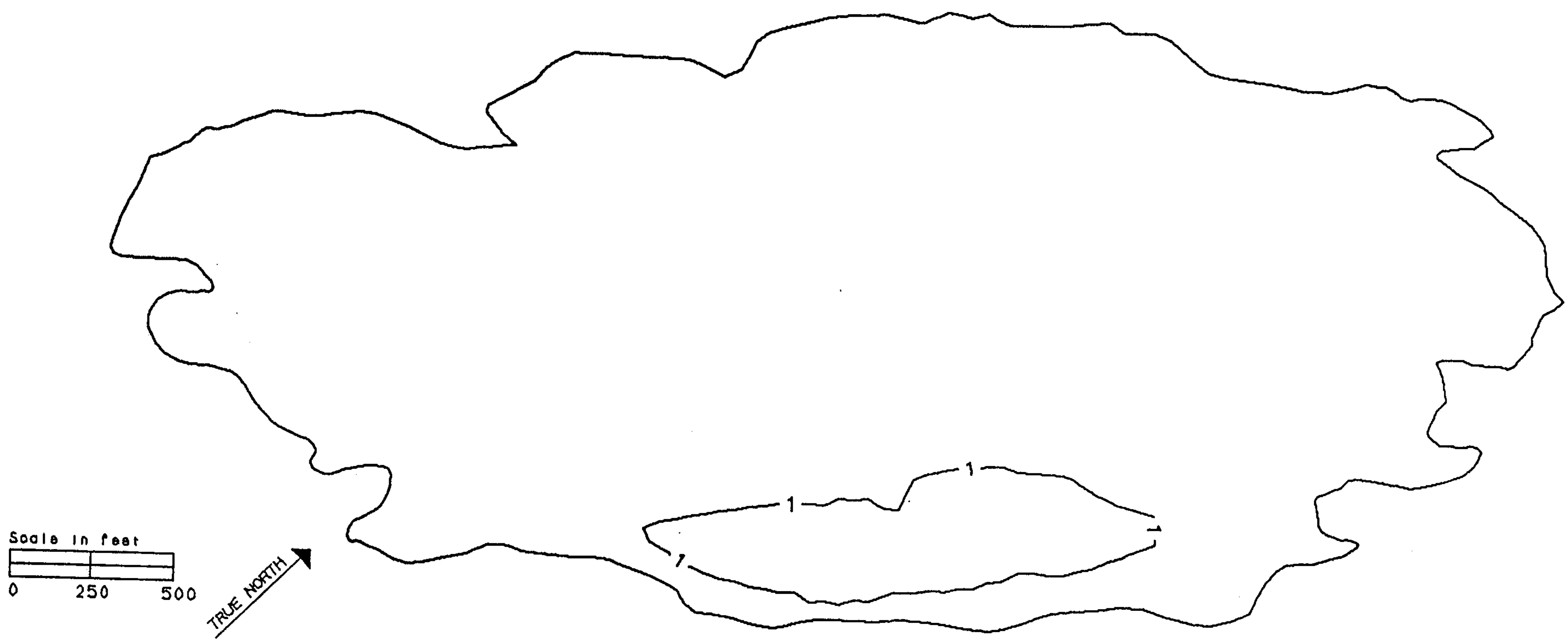
Freeport, Maine

Figure 18

Job 843 - Transport - Sept 1 - Layer 6



Percentage of source strength from applied sewage

Concentration > 5% of source strength

Concentration > 10% of source strength

Bustins Island Water Supply
1 April 1991

Robert G. Gerber, Inc.
Freeport, Maine

Figure 19

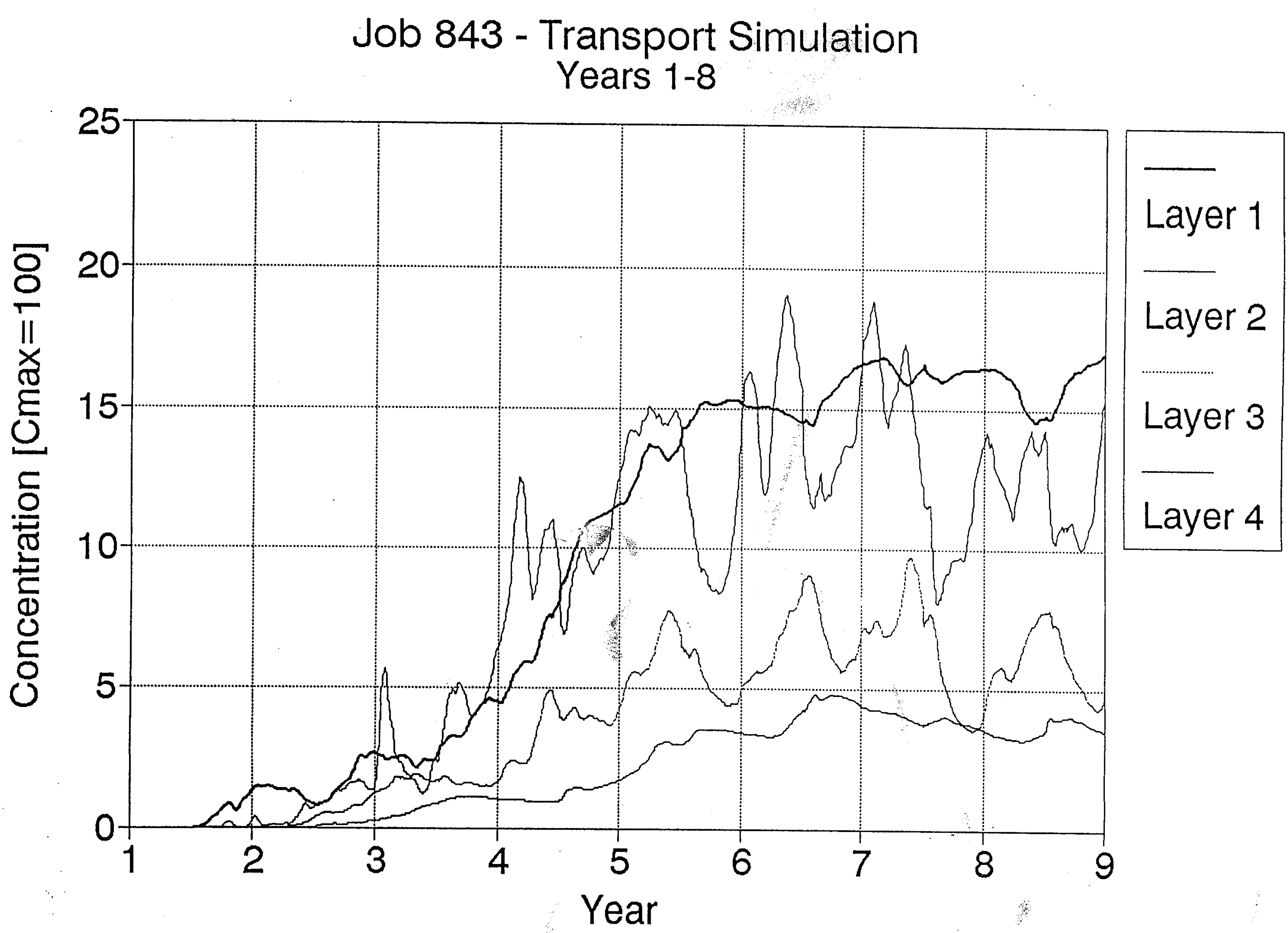


Figure 20 Percentage of Source Strength from Applied Sewage