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Vashon / Maury Island Water Resources Study

Submitted to the King County Department of Planning and Community Development, Planning Division

Prepared by J. R. Carr / Associates

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King County Executive
Randy Revelle

King County Council
Bruce Laing, Chairman, District 6
Audrey Gruger, District 1
Scott Blair, District 2
Bill Reams, District 3
Lois North, District 4
Ruby Chow, District 5
Paul Barden, District 7
Bob Greive, District 8
Gary Grant, District 9

Department of Planning and Community Development
Holly Miller, Director

Planning Division
Harold Robertson, Manager

VASHON WATER RESOURCES STUDY

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SUMMARY

This study was undertaken to generate information about the water resources of Vashon/Maury Island as a limit on population and land use. Four basic questions were addressed:

- Where does the Islands' water supply originate? Where is it located? What is its quality?
- How much water is available for human use on Vashon/Maury Island?
- What constraints does the water resource place on population density and land use?
- What must be done to protect and enhance the water resource for future generations?

CONCLUSIONS

The study team concludes that the water resource of Vashon/Maury Island will support a maximum population of approximately 11,000. (The 1980 census population was 7,377; the population is projected at 9,099 by 1990.)

The maximum densities to ensure adequate infiltration to the underground supply and to prevent accelerated deterioration of water quality are:

7.7 Acres/dwelling unit - in high recharge potential areas,

5.5 Acres/dwelling unit - in medium recharge potential areas,

4.6 Acres/dwelling unit - in low recharge potential areas,

(See Figure 6.13 in Chapter 6 for map distribution of these areas.)

FINDINGS

The major findings of the study are summarized below with references to chapters where a complete discussion can be found.

1. The Islands' water supply is obtained primarily from wells and springs. The Principal Aquifer is composed of fine to medium sand and is generally located above sea level at elevations between 0 and 400 feet. It yields moderate amounts of water to wells; about 95% of Island wells penetrate this aquifer. The Deep Aquifer lies at depths of about 100-300 feet below sea level; it has been penetrated by over a dozen wells. The Deep Aquifer is capable of yielding larger quantities of water, but its recharge is apparently more limited. (Chapter 4)

2. Local precipitation is the only source of water. There is no recharge of Island supplies from off-island sources. (Chapter 6)

3. Average annual precipitation (1945-1954) is about 40 inches per year. Limited data indicates decreasing precipitation from west to east across the Islands. (Chapter 2)

4. About half the annual precipitation evaporates, and the other half either runs off or infiltrates through the soil. In high recharge areas, an estimated 11 inches runs off, 7 inches infiltrates to the Principal Aquifer, and 2 inches recharges the Deep Aquifer. On an Island-wide basis, runoff is estimated to be 15 inches, with 4 inches infiltrating to the Principal Aquifer and 1 inch recharging the Deep Aquifer. (Chapter 5)

5. The direction of ground water flow in the Principal Aquifer is generally from west to east on Vashon Island and from a high near each end of Maury Island towards Quartermaster Harbor. (Chapter 5)

6. Ground water levels fluctuate in response to seasonal and long-term recharge variation as well as from tidal and barometric influences and pumping. Data from 61 Island wells show seasonal variations ranging from less than 1 foot to over 12 feet during the water year. The greatest fluctuations were observed in recharge areas, in wells completed in the Principal Aquifer. (Chapter 3)

7. The most important area of recharge to the Principal Aquifer is along a north-south corridor of west-central Vashon. Recharge to the Principal Aquifer ranges from 3 to 9 inches -- equivalent to a total recharge of about 9 million gallons per day (mgpd) or about 6,000 gallons per minute (gpm). (Chapter 6)

8. The major recharge for the Deep Aquifer may be west-central Vashon Island and its total recharge is probably less than 3 million gallons per day, or 2,000 gallons per minute. (Chapter 6)

9. Of the total recharge, an estimated 1.58 mgpd (1100 gpm) could theoretically be recovered from the Principal Aquifer when the factors of drought and capture ratio are taken into account. (Chapter 9)

10. Based on an estimated average water use of 120 gallons per person per day, the total current water use is approximately 1 million gallons per day or 365 million gallons per year. (Chapter 8)

11. Based on water quality considerations related to attenuation of septic tank effluent (Renovation Capacity), the

Island could support a population of about 11,000 people. (Equivalent to 1.31 million gallons per day or less than 1000 gpm of suitable quality water.) (Chapter 10)

12. In the Principal Aquifer the amount of ground water available for future population growth is about 0.27 million gallons/day (200 gpm) when water quality considerations, stream flow requirements and current water use are accounted for. This available water supply would allow the addition of about 2,300 new residents to the existing population. (Chapter 10).

13. The major sources of potential water supply contamination are septic tank effluent and animal waste (measured by the level of nitrate as nitrogen) and salt water intrusion (measured by chloride content and specific conductance). Relatively high nitrate as nitrogen levels are found toward the north and east of Vashon Island and the north and south ends of Maury Island. Nitrate as nitrogen concentrations have gradually increased over the last 15 years. The prime area of salt water intrusion is in near-shore wells at the north end of Vashon Island. Chloride levels have also increased in some deep wells over the past 15 years.

WATER RESOURCE MANAGEMENT OPTIONS

King County has three basic options for managing the Islands' water resources: no-action, passive management and active management.

Under the no-action option, no new management or planning actions would be taken. Existing land use plans and regulations would allow densities higher than the Islands' capacity to attenuate septic tank effluent. Water quality would continue to deteriorate. Uncontrolled well development and withdrawals would create local overdrafts and salt water intrusion into wells around the margins of the Islands.

Under the passive management option, strict regulatory or legislative controls would be adopted to restrict use of the resource and recharge areas to prevent contamination and overdraft. Water quality and quantity would remain at or near present levels.

Under the active management option, broad uses of the resource and recharge areas would be allowed; a management agency would be responsible for monitoring water use and taking action when contamination or overdraft was detected. Water quality would be maintained or improved; control of well development and withdrawals would prevent and possibly reverse salt water intrusion and local overdraft. Potentially, a larger population could be supported by an adequate supply of good quality water.

Both the passive and active management options would require development and implementation of a water resource management plan. The basic objectives of such a plan, under either the passive or active management option, would be to protect and if possible enhance water quality and water supply.

To implement one or more of these objectives, a range of economic, legislative, regulatory and educational strategies are possible.

RECOMMENDATIONS

PRIMARY RECOMMENDATIONS

1. Create or designate a specific agency with responsibility for managing the Islands' water resources.

2. Integrate the findings of this report into the Vashon Community Plan and produce a comprehensive water management plan.

3. Implement the water management plan as soon as possible. Because implementation of the primary recommendations may require considerable time, specific measures are provided to protect the resources in the interim.

INTERIM MEASURES

1. Limit the Islands' total population to a maximum of 11,000 people.

2. Adopt zoning to limit density to 10 acres per dwelling unit in high recharge potential areas not served by a sewer system.

3. Preserve high recharge potential areas as parks or recreational space.

4. Adopt zoning to limit density to 4 to 5 acres/dwelling unit in low and medium recharge areas not served by a sewer system.

5. Protect sensitive landslide areas.

6. Compare Recharge Potential Level areas to current zoning for all upland areas on the Islands. For areas that are unsewered and far above the housing densities recommended here, enact building moratoria to reduce or stabilize ground water degradation by septic systems.

7. Refine subdivision and building codes to maintain and enhance recharge capability and water quality.

8. Review local codes and regulations on transportation, storage and disposal of potentially hazardous wastes.

9. Provide sewage collection, treatment and disposal off-island for all high population density areas.

10. Make improvements to the sewage treatment plant to exclude infiltration of storm water and shallow ground water.

11. Monitor solid waste disposal on the Islands.

12. Continue collecting water inventory data to verify and amplify the findings of this report.

13. Remove or regulate intense agricultural activities from recharge areas.

14. Plan and implement a program of public education and cooperation for conservation and protection of the water resource.

STUDY LIMITATIONS

Limited available data pertaining to precipitation, ground water levels, stream discharge, water quality, geologic characteristics, and water use have necessitated certain assumptions and estimates. These have then been used to estimate water surplus, recharge areas and recharge amounts. Additional assumptions of drought, recoverable ground water, characteristics of septic tank effluent and a renovation factor have been applied to estimate the resource related planning capacity for the Islands. To protect and achieve optimum use of the water resources, these estimates and identified problems need verification through further monitoring and investigation.

PART I

FOREWORD

CHAPTER 1

INTRODUCTION

In the Puget Sound area, it is easy to take water for granted. Residents endure long periods of rain which appear to provide an endless supply of water. Despite this apparent abundance, the resource is finite. The limits of ground water supply are especially difficult to appreciate because they are always out of sight and usually out of mind. The importance of ground water is also easily overlooked because its development requires no impressive dams and water treatment facilities. However, prudent leaders are now coming to realize that these resources must be protected and carefully managed for the survival of their communities.

Over the last few years, ground water has been increasingly in the news, with reports of important aquifers becoming unproductive from over-pumping and unusable from neglect and abusive waste disposal practices. Many parts of the country are already up against this harsh reality. The dire predictions of 20 years ago are coming true.

- In the arid Southwest, water levels are declining from overdraft. Drastic measures have been proposed to prevent the complete exhaustion of the water supply.

- In the heavily urbanized Northeast, residential and industrial development of recharge areas is polluting the water supply. In New Jersey, the waste plume from a solid waste disposal site is within one or two years of entering the well field serving Atlantic City.

- In Florida, saltwater intrusion is threatening the water supply of residential communities because recharge areas were drained to make way for development.

Closer to home, all these problems are appearing:

- In some irrigated areas of eastern Washington, where there is little recharge, water levels are declining rapidly.

- In King and Pierce Counties, effluent from septic tank and solid waste disposal sites has contaminated some local water supplies.

- In nearby coastal areas such as Whidbey Island, salt water has invaded the aquifers because withdrawals exceed recharge rates.

Islands like Vashon/Maury present a rare opportunity to illustrate clearly the reality of water as a finite resource, and to develop a management strategy to protect and enhance the water supply for future generations.

Vashon/Maury Island is an isolated hydrologic system. The only water entering the system comes from direct precipitation. Rain infiltrates the ground to the aquifers and is drawn from wells and springs for people's use. Any pollutants that infiltrate the ground will eventually affect water quality. There is only so much water, and only so many people can be supported by the water resource.

Because the limits of the water resource on Vashon/Maury Island are finite, the necessity and the opportunity for managing the resource are more obvious.

STUDY PURPOSE

For several years, King County and Vashon/Maury Island residents have been planning the future land use of the Islands. There has been a general understanding among many people that the size and nature of the Islands' water resource impose a limit on the ultimate population and type of land use that the Islands can support. Others have believed that the Islands' water supply originates on the mainland, and therefore is not a factor in determining desirable population density. However, there has been a lack of sufficiently detailed information to resolve questions about the water resource as a possible constraint to land use planning.

This study was undertaken to gather such information and to present it for use in planning the Islands' future.

This study has focused on four basic questions:

- Where does the Islands' water supply originate? Where is it located? What is its quality?
- How much water is available for human use on Vashon/Maury Island?
- What constraints does the water resource place on population density and land use?
- What must be done to protect and enhance the water resource for future generations?

STUDY APPROACH

To address these questions, King County Planning Division engaged the consulting firm of J.R. Carr/Associates. The consulting team has approached the study in three phases:

The first phase was to carefully describe the Islands' geological framework, inventory the ground water and surface water resources, examine water quality, and define patterns of precipitation, evaporation, infiltration and runoff.

The second phase was to analyze the data to determine how much water infiltrates to the water supply, how much water is needed for human use, and finally, how many people can be supported by the water resource.

The third phase was to examine what water resource management efforts and land use controls are needed to maintain and enhance the water supply for future generations.

REPORT ORGANIZATION

This report attempts to present complex technical information and sophisticated analytical concepts in a form that will be useful to the general public, local officials, water supply managers and others who will be involved in making the decisions necessary to protect and enhance the Islands' water resources.

Part I sets the stage with this chapter on the context of the water resource problem and the purpose of the study on Vashon/Maury Island.

Part II reports the findings of this first comprehensive inventory of the Islands' water resource, with chapters on climate, hydrology, geology and aquifer characteristics, water budget, recharge, water quality, and water use and supply.

Part III identifies the limits on population imposed by the water resource. One chapter defines the maximum population based on the amount of ground water that can theoretically be recovered for use. Another chapter defines the maximum population based on the amount of available water, taking water quality considerations into account.

Part IV presents guidelines for managing the water resources. One chapter describes the three basic management options and lists a range of possible economic, regulatory and educational strategies. Another chapter offers specific recommendations of actions that should be taken. The final chapter defines how data limitations affect the findings and conclusions of the study, and suggests actions needed to obtain improved data.

Extensive water resource data is presented in Tables throughout the text. Numerous Figures depict the important relationships discussed. Many conventional and new technical terms used in this report are defined in a comprehensive glossary. Selected references are listed.

In describing the study area, the terms **Vashon/Maury Island** or **Islands** are used to describe features of both. Characteristics which are found on one of the two are referred to as **Island** characteristics. Thus, the **Islands'** precipitation falls on **Vashon and Maury,** and the **Island's** surface water bodies include Bank Road Pond, located on **Vashon Island.**

WATER RESOURCES INVENTORY

PART II

CHAPTER 2

CLIMATE

This chapter examines the record of precipitation on Vashon/ Maury. Local precipitation is the source of all surface and ground water on Vashon/Maury Island (see Chapter 6). Establishing an understanding of the amounts and patterns of precipitation is the first step in developing the Islands' water resource inventory.

SUMMARY

The average annual precipitation at Vashon's Cove Weather Bureau Station for the period from 1945-54 was 46.29 inches per year. During the same period, the average annual precipitation at Sea-Tac Airport was 39.07 inches per year. Thus the Vashon Station received about 18% more rainfall than Sea-Tac during this 10 year period. During the period from 1974-82, precipitation at Krimmel's on the south end of Vashon averaged 26% more than at Sea-Tac.

Precipitation data collected as a part of this study shows a decrease in precipitation from west to east across Vashon and Maury Islands. During the 1981-82 water year, rainfall on the west side of the Island was 53.5 inches and only 35.5 inches at Point Robinson. This study uses an average precipitation of 40 inches per year for Vashon/Maury Island.

BACKGROUND

HISTORICAL CLIMATIC DATA

Historical climatic data is available from the U.S. Weather Bureau. Nearly all official weather bureau stations report precipitation and daily maximum and minimum temperatures. More sophisticated stations include maximum, minimum, and average daily temperature, precipitation, wind speed, hours of sunshine, barometric pressure, rain intensity analysis, and some statistical data analyses. The Sea-Tac Airport Station, located six miles east of Vashon Island at an elevation of 400 feet, has complete records beginning in 1945. The weather patterns at this station parallel those on Vashon, and much of this chapter is based on Sea-Tac Weather Bureau data.

For many years, the Weather Bureau supported an official station on Vashon. Beginning in 1887, those records were kept by Mrs. C.B. Carpenter. The station was moved a number of times until the effort was terminated in February of 1955. The last station was maintained by O.E. Ramquist near Cove (T23N, R2E, Section 26H). The climatological summary at this Vashon-Cove station for the period 1931 to 1954 is shown in Table 2.1.

U.S. DEPARTMENT OF COMMERCE, WEATHER BUREAU IN COOPERATION WITH
THE WASHINGTON STATE DEPARTMENT OF COMMERCE AND ECONOMIC DEVELOPMENT
CLIMATOGRAPHY OF THE UNITED STATES 20-45

TABLE 2.1

LATITUDE 47° 26'
LONGITUDE 122° 30'
ELEV. (GROUND) 231 ft.

CLIMATOLOGICAL SUMMARY

STATION: VASHON ISLAND, WASH.

MEANS AND EXTREMES FOR PERIOD 1931-1954

Month	Temperature (°F)							** #	Precipitation Totals (Inches)								Mean number of days					Month
	Means			Extremes								Snow, Sleet						Temperatures				
																		Max.		Min.		
	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year	Mean degree days	Mean	Greatest daily	Year	Mean	Maximum monthly	Year	Greatest daily	Year	Precip. .10 inch or more	90° and above	32° and below	32° and below	0° and below	
(a)	24	24	24	24		24		24	24	24		24	24		24		24	24	24	24	24	
JAN	43.5	33.3	38.4	66	1935	8	1943	825	6.74	3.24	1935	4.6	19.5	1935	14.0	1943	12	0	2	12	0	JAN
FEB	47.6	35.0	41.3	68	1941+	11	1950+	665	5.58	3.90	1951	1.3	8.0	1936	4.0	1949+	11	0	1	9	0	FEB
MAR	52.5	36.6	44.6	74	1934	25	1936	630	4.56	2.63	1950	.8	11.3	1951	5.3	1951	11	0	0	6	0	MAR
APR	59.5	40.3	49.9	82	1940+	25	1935	455	2.75	1.55	1937	T	T	1954+	T	1954+	7	0	0	2	0	APR
MAY	65.5	44.2	54.9	88	1953	29	1954	315	1.94	1.33	1941						6	0	0	*	0	MAY
JUN	70.5	48.3	59.4	95	1942	36	1944	170	1.69	1.20	1931						5	*	0	0	0	JUN
JUL	75.2	50.7	63.0	96	1942	40	1939	80	.82	1.09	1934						3	*	0	0	0	JUL
AUG	74.1	51.7	62.9	95	1952+	42	1935	80	.95	1.06	1936						3	*	0	0	0	AUG
SEP	68.4	49.3	58.9	91	1944	35	1934+	185	2.21	2.02	1953						5	*	0	0	0	SEP
OCT	59.3	44.7	52.0	81	1934	21	1935	405	4.52	2.14	1934						9	0	*	*	0	OCT
NOV	50.7	39.6	45.2	70	1949	19	1935	595	6.61	2.16	1942	.4	7.5	1946	6.0	1946	12	0	0	4	0	NOV
DEC	46.0	36.5	41.3	64	1939	13	1941+	735	8.16	3.22	1937	.8	7.7	1948	3.0	1948	14	0	*	8	0	DEC
Year	59.4	42.5	51.0	96	JUL 1942	8	JAN 1943	5140	46.53	3.90	FEB 1951	7.9	19.5	JAN 1935	14.0	JAN 1943	98	*	3	41	0	Year

(a) Average length of record, years.

T Trace, an amount too small to measure.

** Base 65°F

\+ Also on earlier dates, months, or years.

* Less than one half.

\# Estimated

The official narrative summary of Vashon's climate, prepared in 1962 by Earl L. Phillips, U.S. Weather Bureau State Climatologist, is as follows:

> Vashon Island, located in Puget Sound, southwest of Seattle and north of Tacoma, covers an area 12 miles long and 4 miles wide. State-owned ferries provide regular service to the Island from Seattle, Tacoma on the mainland and Southwick (sic) on the Kitsap Peninsula. There are numerous small harbors and coves along the Island's 50-mile shoreline. The terrain is rolling with hills rising 300 to 500 feet above sea level.
>
> In a northwesterly direction and within a distance of 40 miles, the Olympic Mountains rise to elevations of 4000 to 7000 feet. This range is very effective in protecting the Island from the more intense winter storms moving inland from over the Ocean. In an easterly direction and within 50 miles, the Cascade Mountains reach elevations of 5000 to 7000 feet with snowcapped peaks in excess of 10,000 feet. The Cascades shield the Puget Sound area from the higher summer and lower winter temperatures observed in eastern Washington.
>
> The climate is predominantly a mid-latitude, west-coast marine type with cool dry summers, mild but rather rainy winters and a small range in temperature. During the spring and summer, a clockwise circulation of air around the large high pressure area over the north Pacific brings a flow of comparatively dry and cool air from a northwesterly direction into western Washington. As the air moves inland, it becomes warmer and drier, resulting in a dry season beginning in the late spring and reaching a peak in mid-summer. During July and August, it is not unusual for 2 to 4 weeks to pass with only a trace of precipitation. Afternoon temperatures in the warmest months are in the 70's and nighttime readings are in the 50's. Maximum temperatures reach 80° or 85° on a few afternoons, however, 90° is unusual. The hottest days occur when hot dry air from east of the Cascades reaches this area. The humidity is low under these conditions and the warmest afternoons are not especially uncomfortable. Following one or two hot days, cooler air from over the Ocean moves inland and temperatures return to the 70's. Fog or low clouds sometimes form during the early morning hours and disappear before noon.
>
> During the fall and winter seasons, the low pressure area near the Aleutian Islands intensifies and the high pressure area over the north Pacific becomes smaller and moves southward. A circulation

of air around these two pressure centers brings a prevailing flow of warm moist air from a south-westerly direction into the State. This results in mild winter temperatures and a rainy season beginning in October, reaching a peak in mid-winter and gradually decreasing in the spring. Snowfall is light and seldom remains on the ground longer than a few days. Average afternoon temperatures in the coldest months are in the 40's and the nighttime readings are in the 30's. The coldest weather occurs when cold dry air from Canada or east of the Cascades reaches the Puget Sound area. The sky is generally clear under these conditions and minimum temperatures may range 12 to 20 degrees and maximum temperatures remain near freezing for a few days.

Cloudiness, sunshine, relative humidity and wind data recorded at Seattle are representative of conditions on the Island. The number of clear or only partly cloudy days each month increases from about 8 in mid-winter to more than 20 in mid-summer. The percentage of possible sunshine ranges from 24% in December to 62% in July. The average relative humidity in mid-afternoon ranges from 45% in July to 77% in December. During the late night and early morning hours, the relative humidity ranges from 75% to 90% most of the year. The prevailing direction of the wind is north in mid-summer and south or southwest the remainder of the year.

For the period 1945 to 1954, precipitation data was collected both at Vashon and Sea-Tac. This period of official record allows correlation between the two stations and estimation of the relative amounts of rainfall received at each station. Statistical comparison of the data between these two stations shows a perfect 100% correlation for this period. Thus the relative amounts of precipitation at each station are consistent.

This ten-year period of record also shows the relationship between the amount of precipitation received at Sea-Tac and the amount at the Vashon-Cove station. The ten-year average precipitation is 39.07 inches per year at Sea-Tac, and 46.29 inches per year at Vashon. This data indicates that this Vashon station received about 18% more precipitation than did Sea-Tac.

Precipitation data is also available from Krimmel's (Well 12) records for 1974-1982. As shown in Figure 2.1, this station, near the south end of Vashon, has consistently higher precipitation than Sea-Tac. For this nine-year period precipitation averaged 26% more than Sea-Tac.

DATA COLLECTION

To better understand the pattern of precipitation on Vashon, several stations were established as a part of this study. Garretson resumed collection of daily precipitation records at the Ramquist station. Official precipitation gages were installed at Water District 19 offices (T23N, R3E, Section 31A) and at Point Robinson Coast Guard Station (T22N, R3E, Section 23A).

Precipitation records were also obtained from other Island residents who have been keeping this data for their own interest. These records were available from Krimmel, Elmer, Blomgren, Henrickson, and Baxter. The location and period of record of these stations is shown in Figure 2.2.

Rainfall data collected at these stations have been used to construct an isohyetal map as shown in Figure 2.3 for the water year October 1981 through September, 1982. The precipitation record from Sea-Tac Airport is also included in this map.

INTERPRETATION

As shown on the isohyetal map (Figure 2.3) rainfall was greatest along the west side of Vashon and decreased toward Point Robinson. The difference between the west side of Vashon and Point Robinson is a very significant 18 inches of total precipitation over the year. In other words, the west side of Vashon, during this period, received about 50% more rain than the east end of Maury Island. As shown, Sea-Tac received about 4 inches more than that recorded at Point Robinson.

During the wetter months of October, 1981 through February, 1982, the pattern is similar to that of the full water year. The dryer months of March through September, 1982 show a more uniform distribution across Vashon and Maury with slight variations, probably reflecting the influence of localized showers.

The very large difference in rainfall recorded from west to east across the Islands during 1981-82 water year is probably unusual, since the ten-year and nine-year comparison discussed above show a difference of only 18% and 26% respectively between Sea-Tac and the Vashon-Cove station. The longer period of record is considered much more reliable and a better indication of the actual precipitation differences than the record for the single 1981-82 water year.

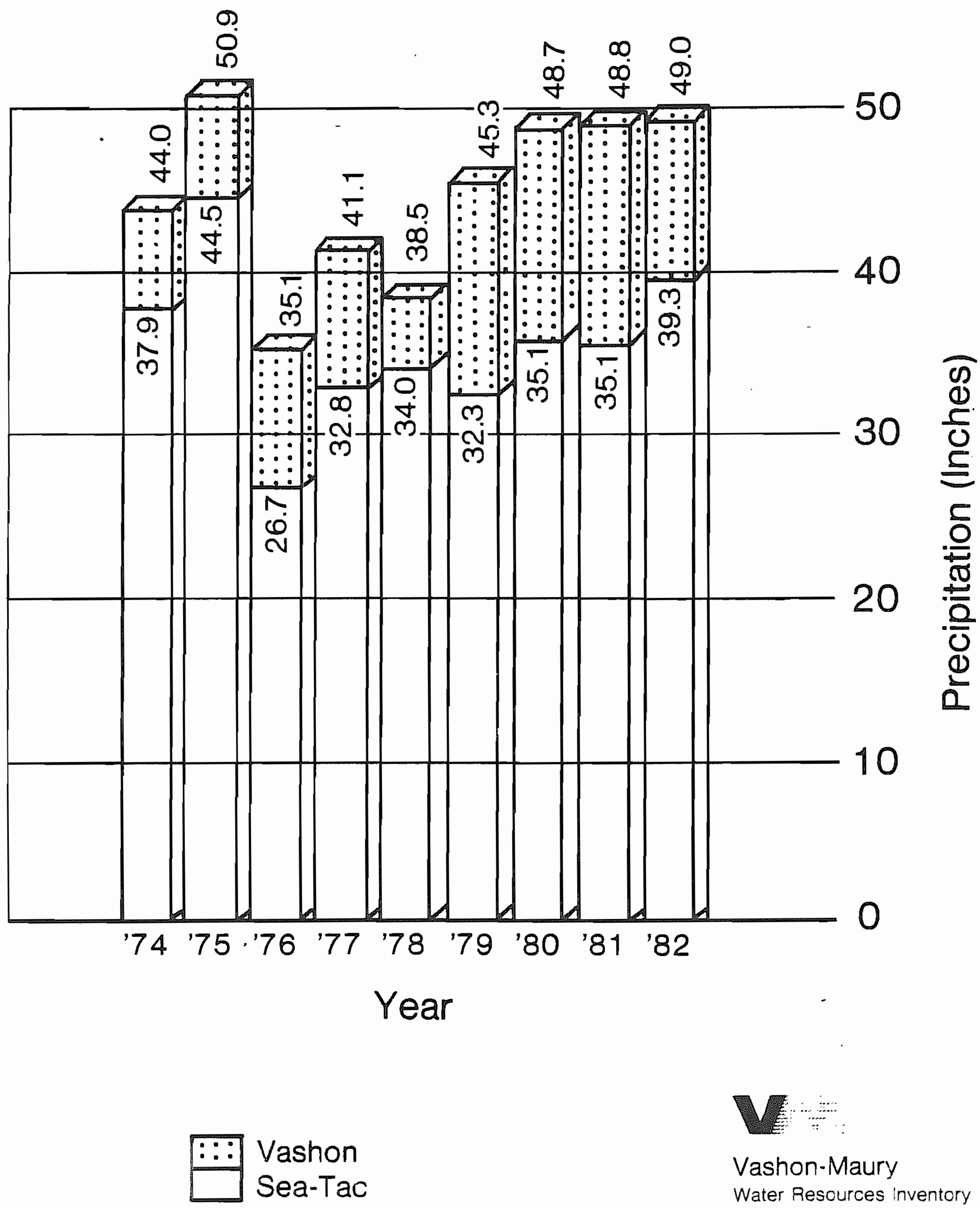
Data on air temperature and movement have not been collected as a part of this study. While there is probably considerable variation within the study area, these differences are not significant in evaluation and determination of evaporation. In Chapter 5, the analysis of evaporation uses the official recorded temperature at Sea-Tac, where the average temperatures are representative of Island conditions.

Figure 2.1

Precipitation Comparison

Vashon (Krimmel)/Sea-Tac

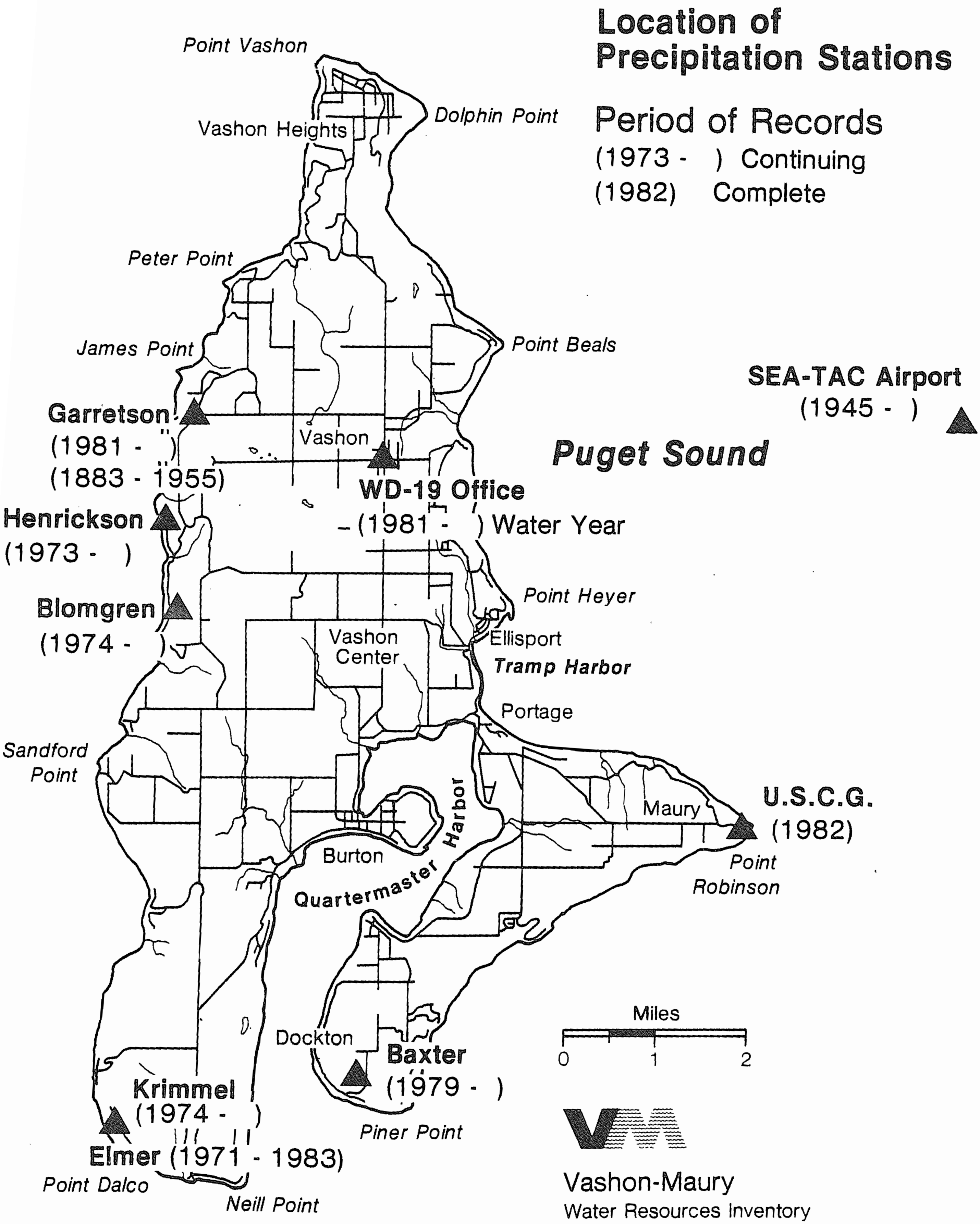
1974 - 1982



Vashon-Maury

Water Resources Inventory

Figure 2.2

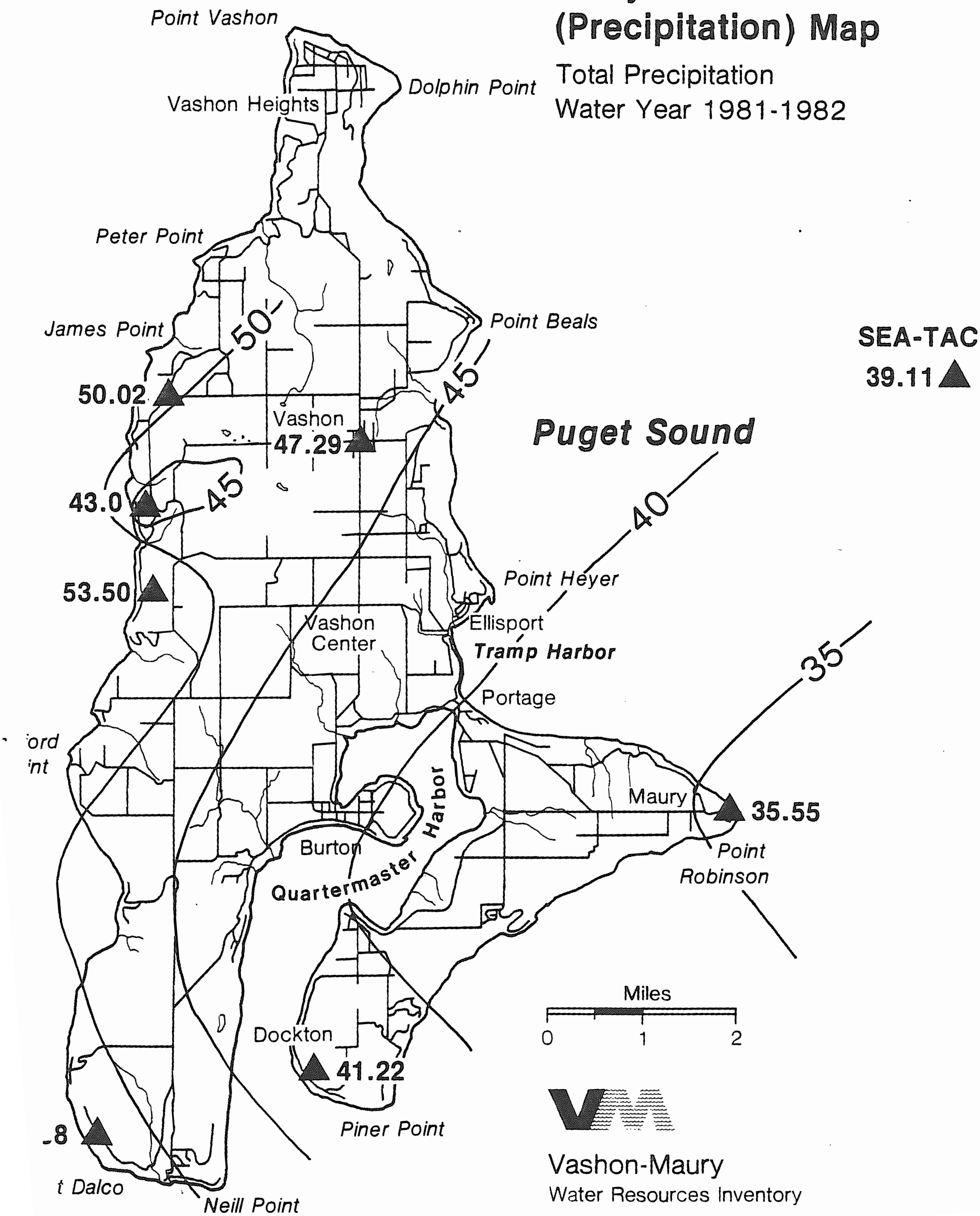


Vashon-Maury
Water Resources Inventory

Figure 2.3

Isohyetal (Precipitation) Map

Total Precipitation
Water Year 1981-1982



Vashon-Maury
Water Resources Inventory

CHAPTER 3

HYDROLOGY

This chapter presents the basic concepts of hydrology, and describes the movement of surface and ground water over and through the Islands. Drainage basins are defined and the relationship between surface and ground water is examined. Long-term hydrologic data can be used to evaluate the effects of drought, overdraft, and development on the water resource.

SUMMARY

Of the Islands' 27 drainage basins, Judd and Needle Creeks have the Islands' largest drainage areas and stream discharges. Many smaller streams with small catchment areas are dry through the summer months, while others maintain baseflow by interception of ground water from the Principal Aquifer. (See Chapter 4).

The levels of upland ponds and small lakes fluctuate in response to precipitation and evapotranspiration, and from infiltration of minor amounts of water.

Measurement of ground water levels in 61 island wells shows seasonal variations ranging from less than 1 foot to over 12 feet during the water year. The greatest fluctuations occurred in recharge areas, in wells completed in the Principal Aquifer; much lower fluctuations were recorded in wells completed in the Deep Aquifer. The direction of ground water flow in the Principal Aquifer is generally from west to east on Vashon and from a high near each end of Maury Island toward Quartermaster Harbor.

Around the margins of the Islands and in the stream valleys, springs discharge at numerous locations where the topography intersects the Principal Aquifer. Spring discharges vary seasonally (lower during the summer months).

Ground water levels fluctuate in response to seasonal and long-term recharge variation as well as from tidal and barometric influences and pumping. Most wells completed in the Principal Aquifer achieve high water levels within one or two months after the peak water surplus. The long-term water level record from one well suggests that the Islands' ground water levels may still be depressed from the effects of the 1976-1978 drought.

Continued monitoring of water levels and stream flows is needed to evaluate the long-term response and capacity of the water resources.

BACKGROUND

THE HYDROLOGIC CYCLE

Water is constantly in motion. Even when it seems to be standing still, as in a snow bank or pond, it is actually moving. A snow bank may be melting underneath and seeping into the ground, while its surface sublimates moisture directly into the air. Pond water also evaporates into the air, and infiltrates into the ground. Some ground water is taken up by plant roots and transpired through the leaves to the air. Some water is pulled by gravity through the soil and subsurface and discharged to lower elevation as streams and lakes, or onto the land surface as springs. These changes through the liquid, vapor and solid states, and movement of water over and through the earth is called the hydrologic cycle. Driven by gravity and the continuous energy of the sun, water moves in a constant unending process.

Water vapor evaporated from rivers, lakes, land surfaces, and the ocean moves with the wind to higher elevations where it cools and condenses to form clouds, gathers into droplets, and falls as rain or snow. Sometimes precipitation evaporates again before it even hits the ground. Most, however, falls on vegetation or bare earth. From there it either evaporates to the air, runs off to rills, streams, rivers, and the sea, or infiltrates the soil to join the ground water segment of the cycle.

Water infiltrating below the ground to an aquifer is known as recharge; water returning to the surface or withdrawn from wells is called discharge. Corresponding terms entirely within either the surface water or ground water regime are called inflow and outflow. The movement of ground water through the subsurface is called underflow.

Water that infiltrates the soil may be taken up by plant roots and evaporated or transpired back to the atmosphere (evapotranspiration) or it may bypass plant roots and trickle downward in response to gravity. Eventually it reaches a zone where all of the pore spaces in the subsurface materials are full of water. This is the zone of saturation or water table. In many kinds of materials, capillary attraction produces a zone of near saturation that extends a few feet above the true water table. These relationships are illustrated in Figure 3.1.

Earth materials like sand or gravel which are saturated with water and which are permeable enough to allow the water to discharge into a well or to the surface are known as aquifers. Sometimes aquifers are bounded above and below by less permeable materials such as clay which retards the vertical migration of the water. If recharge into such an aquifer takes place at a higher elevation, then water will rise up the well bore and may discharge or flow at the surface. Such a well is called a flowing artesian well.

SEASONAL VARIATIONS

On the Islands, precipitation is scant from early summer through fall, and evaporation and transpiration exceed rainfall. The soil is dry and stream flows are maintained by ground water discharge. Ground water levels in near surface aquifers are at their lowest levels.

As the winter rainy season begins, precipitation is collected and stored in the soil and intercepted by the vegetation. Stream flows increase slightly but are maintained primarily by ground water discharge. Ground water levels remain at the low level.

Continued precipitation through the winter restores the moisture-holding capacity of the soil and vegetation. Stream flows increase dramatically. The available moisture exceeds the evapotranspiration and water infiltrates to the ground water table, causing a water level rise in shallow wells. In somewhat deeper wells, water levels continue to rise for one or two months after the peak water surplus.

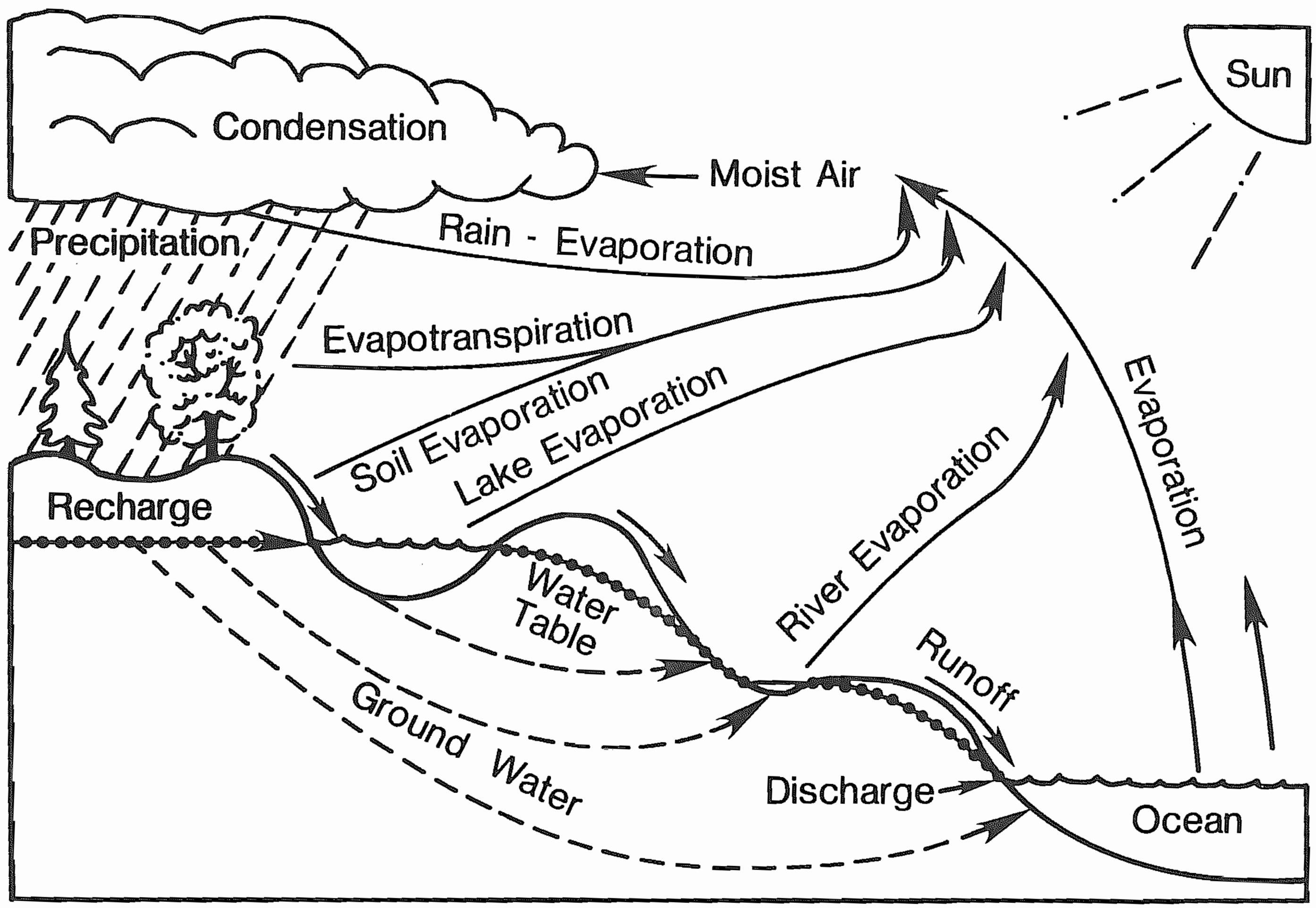
As the rainy season comes to an end, evapotranspiration increases and stream flows decline gradually to a rate maintained by ground water discharge from the basin. Soils lose their moisture content through evaporation and transpiration from plants, and ground water levels in shallow wells begin to decline.

DATA COLLECTION

EXISTING HYDROLOGIC DATA

Some hydrologic data of Vashon/Maury Island has been reported in previous studies. **Water Supply Bulletin 18** identifies 17 drainage basins on the Islands and presents minimum stream flow and drainage area for those basins. The named-stream data are summarized in Table 3.1. The Bulletin also presents the drainage area and 1961 low flow record for an additional 88 unnamed streams on the Islands.

The Hydrologic Cycle



Vashon-Maury
Water Resources Inventory

Figure 3.1

TABLE 3.1

Low-Flow Discharge Measurements

For 11 Island Streams
(From Water Supply Bulletin 18)

Stream	Location	Drainage* Acres	Low Flow GPM	Date
Beal Cr.	NE 1/4 SE 1/4 S-29,T23N,R3E	307	54	8-4-61
		147**	135	8-21-61
Ellis Cr.	NE 1/4 NE 1/4 S8,T22n,R3E	576	237	8-4-61
	"	576	45	8-21-61
Mileta Cr.	SE 1/4 SW 1/4 S16,T22N,R3E	339	18	8-4-61
	"	339	9	8-21-61
Back Bay Cr.	SE 1/4 SW 1/4 S8,T22n,R3E	275	45	8-4-61
	"	275	13	8-21-61
Judd Cr.	NW 1/4 NE 1/4 S18,T22N,R3E	3226	941	7-3-61
	"	3315**	224	8-21-61
Fisher Cr.	SW 1/4 NW 1/4 S19,T22N,R3E	1248	394	8-4-61
	"	1248	180	8-21-61
Tahlequah Cr.	SE 1/4 SE 1/4 S2,T21N,R2E	749	139	8-4-61
	"	749	67	8-21-61
Jod Cr.	NW 1/4 NW 1/4 S14,T22N,R2E	493	349	8-4-61
	"	493	135	8-21-61
Green Valley Cr.	SW 1/4 NE 1/4 S11,T22N,R2E	269	394	8-4-61
	"	288**	67	8-21-61
Needle Cr.	SW 1/4 SW 1/4 S18,T23N,R3E	1811	103	8-4-61
	"	1875**	673	8-21-61
Cedarhurst Cr.		154	45	8-21-61

* Reported in Water Supply Bulletin 18.

** Drainage areas as reported in W.S.B. 18 show these differences.

The U.S. Geological Survey **Open File Report 76-704** identified 13 streams on Vashon/Maury Island and observed no flow or dry conditions in all streams except Judd Creek. Between 1968 and 1974, the U.S.G.S. operated a continuous recording gaging station on Judd Creek. Those data are presented and considered in more detail in Chapter 5 of this report.

The Vashon/Maury Island **Physical Characteristics and Shoreline Inventory** (1975) identified seven island drainage systems and estimated the mean annual surface flow at 32,000 acre feet of water. That report also presented a suggested map of "sub-surface water horizons" or water level contour map based on limited well water level records. **Water Supply Bulletin 18** presented water level elevations in 35 drilled and dug wells on the Islands.

King County Planning Department's **Wet-Lands Inventory,** to be published in 1983, contains additional hydrologic information. This report indicates Vashon/Maury Island has 2,062 acres of wetlands of which 95% are salt water marshes and estuaries. The study indicates the total area of fresh water lakes and ponds to be about 120 acres.

NEW HYDROLOGIC DATA

Between September, 1981 and October, 1982 new hydrologic information was collected as a part of this study. Precipitation data collected by volunteers from seven island stations are presented in Chapter 2. Volunteers also collected spring flow data, and periodic staff gage heights on three ponds and six streams. J.R. Carr/Associates' staff measured water levels in 61 wells, made periodic checks of pond and stream staff gages, measured stream velocity for flow determination in six streams, and directed the efforts of the volunteers.

Drainage Basins

As a first step in organizing the hydrologic data, the Islands were divided into 27 drainage basins. These divisions are illustrated and described in Figure 3.2. These divisions coincide with the principal stream drainages.

The largest drainage basins on Vashon Island are the Needle Creek basin (1,996 acres) and the Judd Creek basin (3,149 acres). The streams discharging from these two drainage basins are the largest streams on Vashon Island. On Maury Island, the principal surface water drainage is identified as Mileta (1,546 acres). Most of the remaining drainage basins on the Islands are relatively small. The streams of these small basins are correspondingly small and many have measurable flow only during the rainy season.

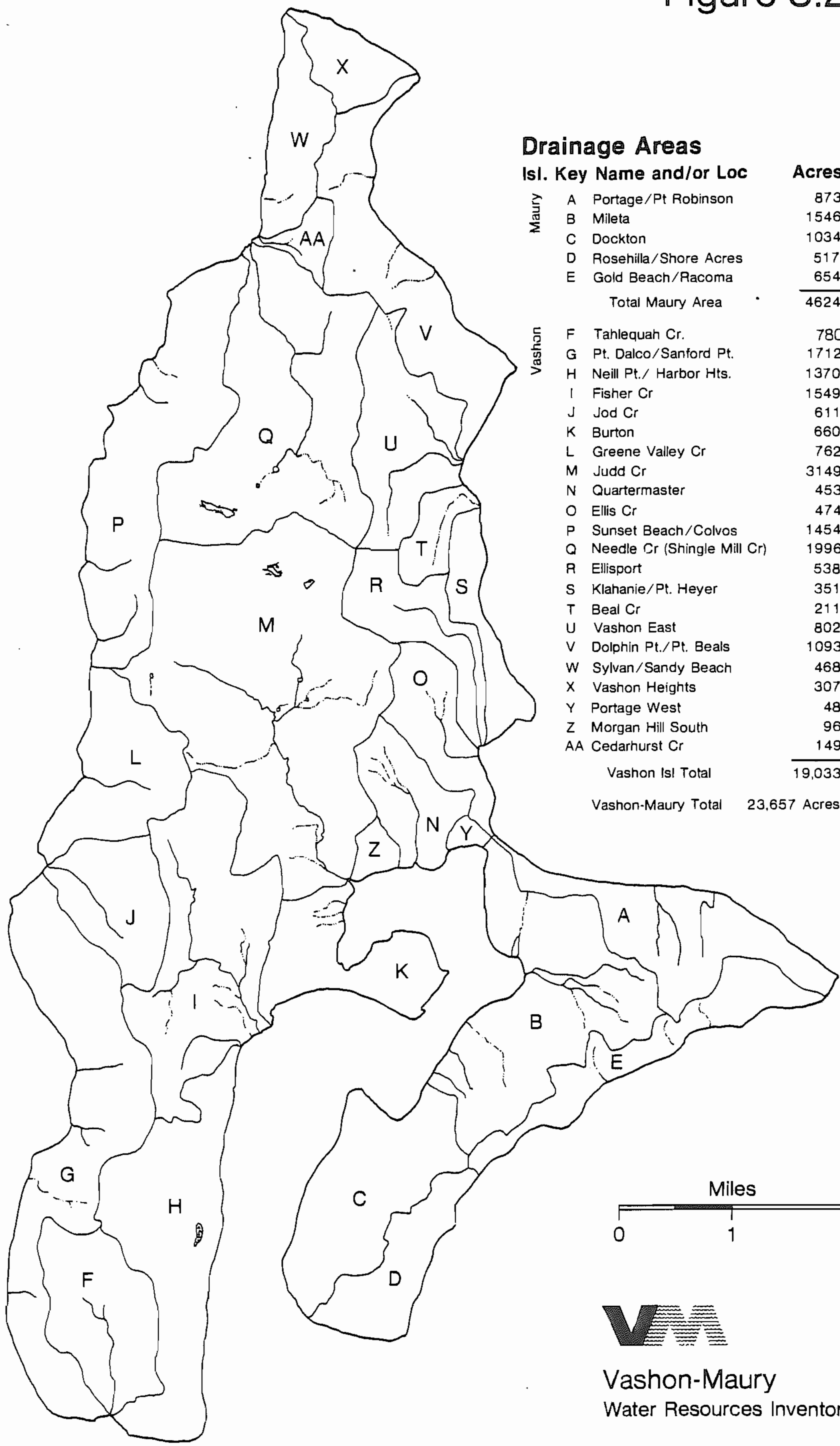
Stream Flow

To establish stream flow response and assist in determining the stream discharge, staff gages were installed in six Island streams. Four of these gages were read at least weekly by project volunteers. Periodically the project staff calibrated gage height to flow using a current velocity meter. These hydrographs, from Tahlequah, Back Bay (Quartermaster), Cedarhurst, and Needle Creeks are shown in Figure 3.3.

The hydrographs show peak flows during the winter months in response to increased precipitation on the drainage basins. Peak flows in these streams appear to occur within hours after major precipitation events.

Low flows of the streams occur through the summer months. Summer low flow or base flow is quite uniform from late May through August. This base flow is supported by ground water discharge from the Principal Aquifer.

Figure 3.2



Drainage Areas

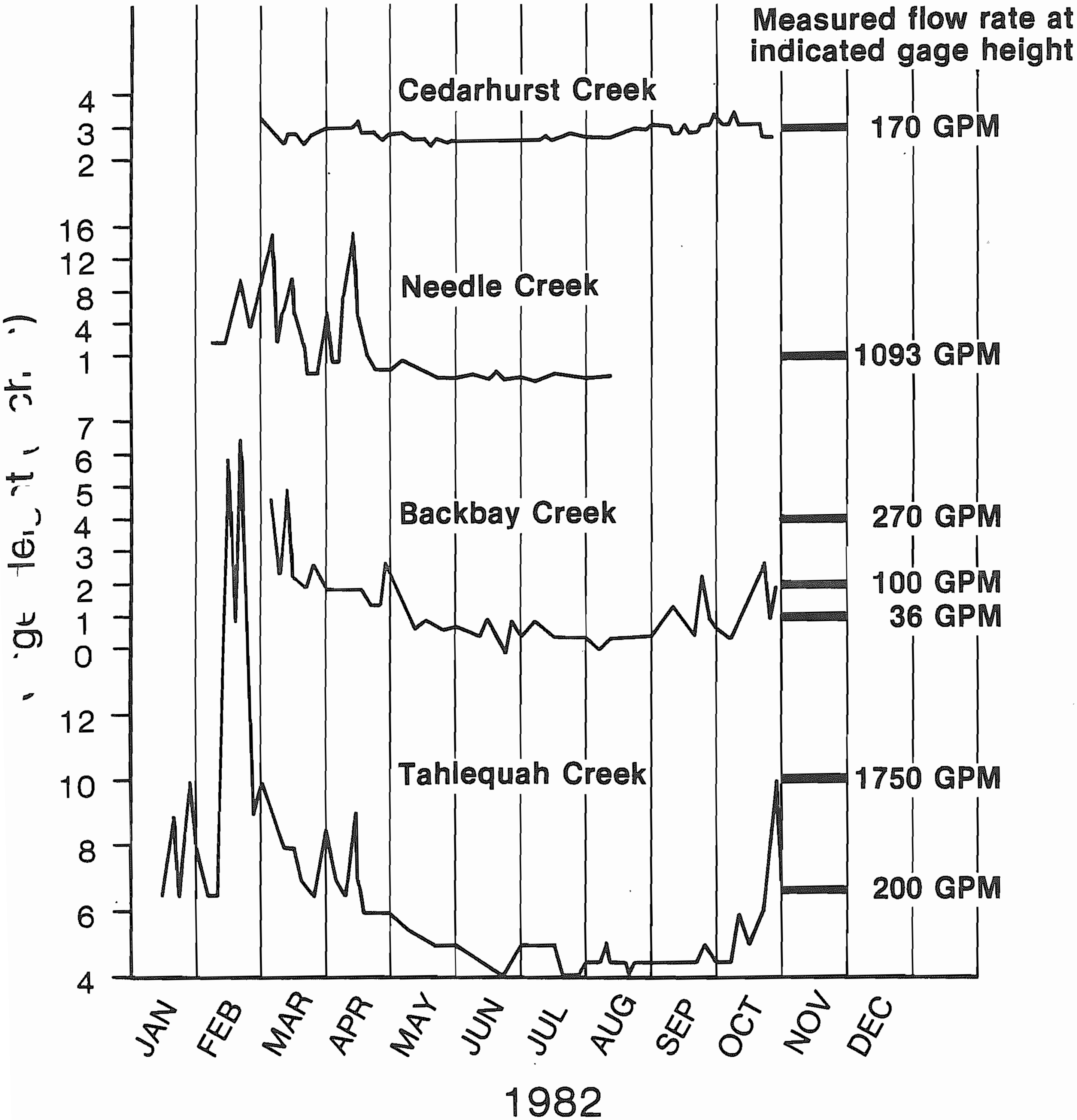
Isl.	Key	Name and/or Loc	Acres
Maury	A	Portage/Pt Robinson	873
	B	Mileta	1546
	C	Dockton	1034
	D	Rosehilla/Shore Acres	517
	E	Gold Beach/Racoma	654
		Total Maury Area	4624
Vashon	F	Tahlequah Cr.	780
	G	Pt. Dalco/Sanford Pt.	1712
	H	Neill Pt./ Harbor Hts.	1370
	I	Fisher Cr	1549
	J	Jod Cr	611
	K	Burton	660
	L	Greene Valley Cr	762
	M	Judd Cr	3149
	N	Quartermaster	453
	O	Ellis Cr	474
	P	Sunset Beach/Colvos	1454
	Q	Needle Cr (Shingle Mill Cr)	1996
	R	Ellisport	538
	S	Klahanie/Pt. Heyer	351
	T	Beal Cr	211
	U	Vashon East	802
	V	Dolphin Pt./Pt. Beals	1093
	W	Sylvan/Sandy Beach	468
	X	Vashon Heights	307
	Y	Portage West	48
	Z	Morgan Hill South	96
	AA	Cedarhurst Cr	149
		Vashon Isl Total	19,033
		Vashon-Maury Total	23,657 Acres

Vashon-Maury
Water Resources Inventory

Figure 3.3

Hydrographs

Four Streams



Vashon-Maury
Water Resources Inventory

Analysis of base flow relationship (gpm) to drainage basin size (acres) shows highly variable results: 0.2 gpm per acre in Tahlequah Creek, 0.3 gpm per acre in Judd Creek, and 0.5 gpm per acre in Needle Creek. The extremes range from less than 0.1 gpm per acre in Back Bay Creek to over 1.0 gpm per acre in Cedarhurst Creek. The ratio is apparently affected by the degree of capture of infiltration of the Principal Aquifer in the drainage basin.

Pond and Lake Levels

Staff gages were set in three Island ponds and lakes to examine the water level response. Project volunteers made weekly readings of the gages. Bank Road Pond (Banks Lake) was selected for measurement because of its relatively large size and ease of access to the gage. (Access proved equally easy for vandals on two occasions.) Peck's Pond was measured in an isolated location, and provided daily exercise for the volunteer measurer. Lost Lake, situated in a distinctly different geologic environment than the other two ponds, was measured to evaluate the potential effect of that difference on the water levels.

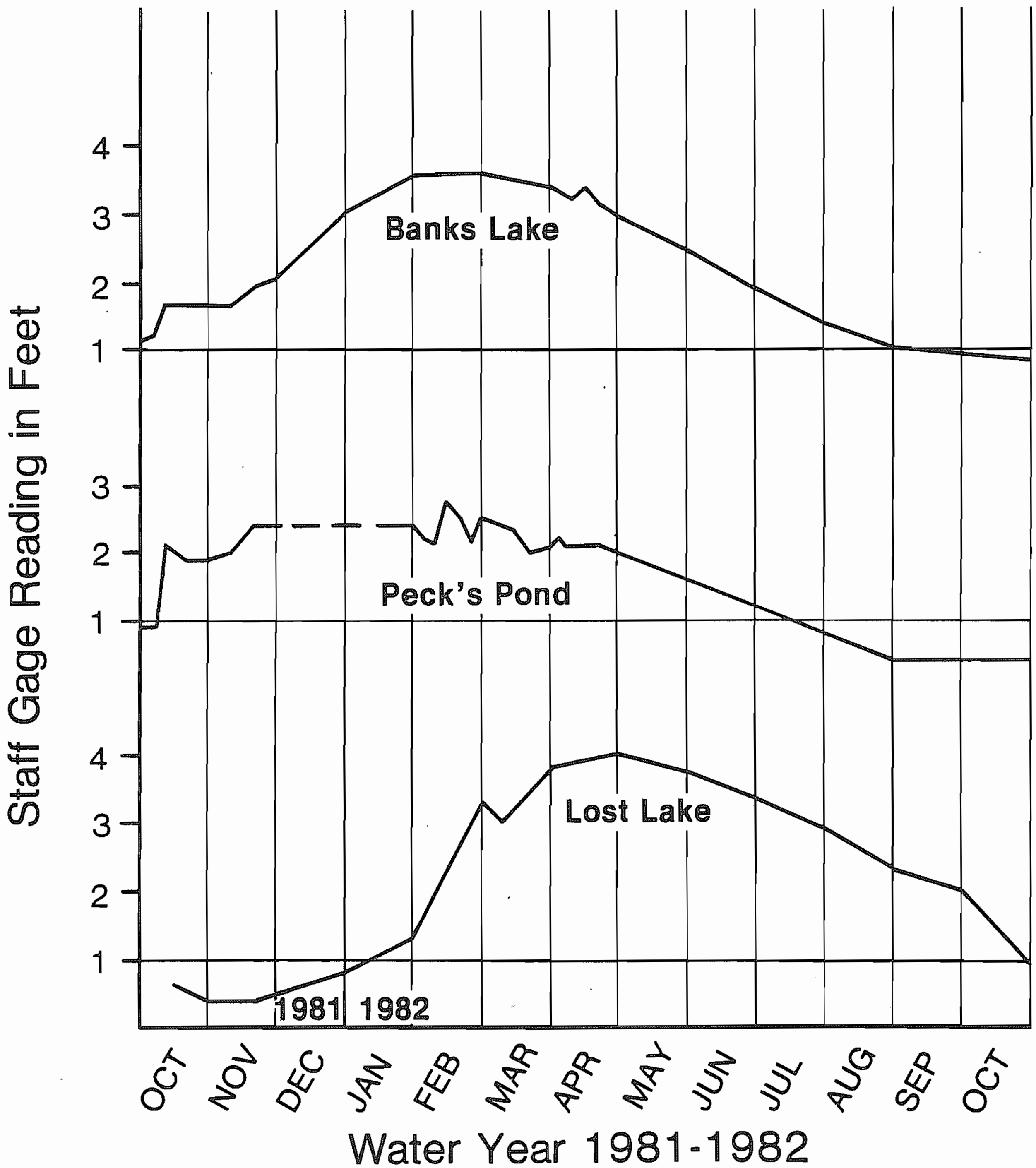
Staff gage readings in these three ponds are illustrated in Figure 3.4, and data is summarized below:

- Banks Lake is located on the uplands in the north-central part of the Island at an elevation of about 350 feet. The lake encompasses about 14.7 acres, and has rather dense growth of aquatic plants around its margins. As shown in Figure 3.4, the amplitude of lake level fluctuation was about 2.8 feet during the period of study. The lake level on October 1, 1982, was slightly below that measured on October 1, 1981. The lake overflows above an elevation of about 350 feet and is tributary to Needle Creek.

Figure 3.4

Hydrographs

Three Island Lakes



Vashon-Maury
Water Resources Inventory

- Peck's Pond is also located on the upland at an elevation of about 340 feet. The pond is reportedly man-made with a small island near its north end. The pond has an area of about 2.5 acres and overflows at an elevation of 345 feet into Judd Creek. During the 1981-82 water year, the pond fluctuated 2.4 feet and was about 6 inches lower on October 1, 1982, than on the previous year.

- Lost Lake is located on the backslope of a massive land slide in the southeast of Vashon Island. The lake is nearly full of aquatic vegetation and has an area of about 5 1/2 acres. During the 1981-82 water year, the lake level fluctuated 3.6 feet and was slightly higher in October, 1982 than in October, 1981. The lake lies at an elevation of 120 feet, in a long, narrow trough of a slump block; at an elevation of 140 feet, the lake would overflow into outer Quartermaster Harbor.

Close examination of Figure 3.4 shows a rather parallel response of water level in Banks Lake and Peck's Pond with each reaching the high water level in February of 1982. Lost Lake, on the other hand, reaches its peak near the end of April or two months after the peak in the upland lakes. This difference in response probably results from a difference in its source of water. All three lakes received water from direct precipitation and runoff in their catchment areas. In addition to this, Lost Lake apparently receives water from springs out of the Principal Aquifer.

Ground Water Levels

To observe the change in ground water levels, water level measurements were made in 61 wells on the Islands. Continuous water level recorders were maintained on two wells. Water level measurements were made weekly in seven wells and monthly in 24 additional wells. Water levels in 17 wells were taken three times (fall 1981, spring 1982, and fall 1982). Eleven additional wells were measured once during the study.

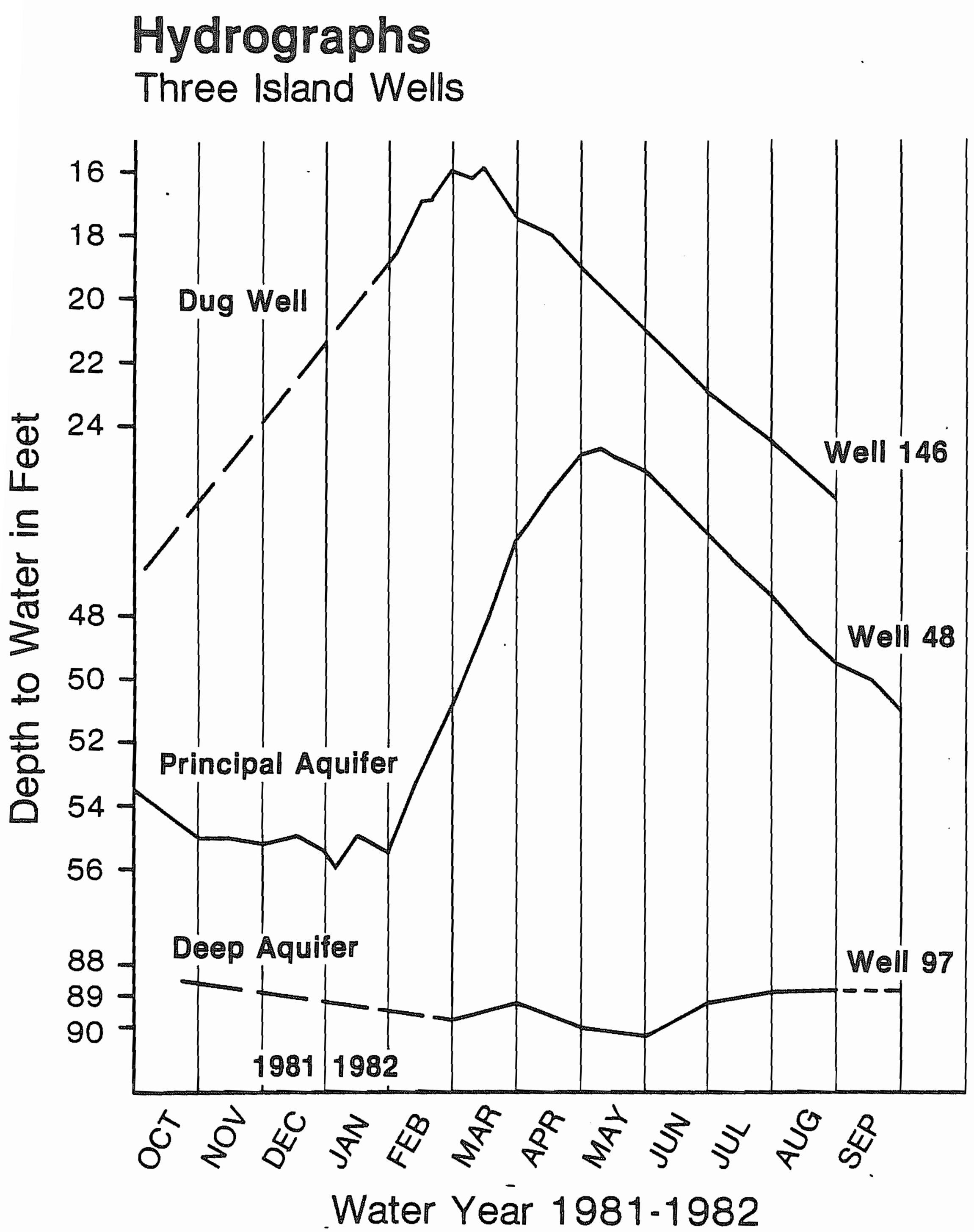
Analysis of the water level response revealed distinctly different patterns between wells completed in the Principal Aquifer and those in the Deep Aquifer. As illustrated in Figure 3.5, water levels in wells penetrating the Principal Aquifer (well 48) and a perched aquifer (well 146) had water level changes of about 13 feet. Water levels in wells completed in the Deep Aquifer (well 97) showed a fluctuation of less than 2 feet.

To accommodate this difference in response, wells were categorized to distinguish the aquifer of completion so that water level data could be used to construct a water level contour map. Well location, elevation and measured water levels from wells completed in the Principal Aquifer were processed using the STAMPEDE computer program which then plotted and contoured the water level elevations.

A drafted computer plot of the fall 1982 water level elevations in the Principal Aquifer is shown in Figure 3.6. These maps are characterized by generally higher water levels along the west side of Vashon and numerous local water level highs or mounds. On Maury Island, water level mounds appear near each end of the Island. This map also indicates the general direction of ground water flow in that water is traveling from the higher to the lower elevations.

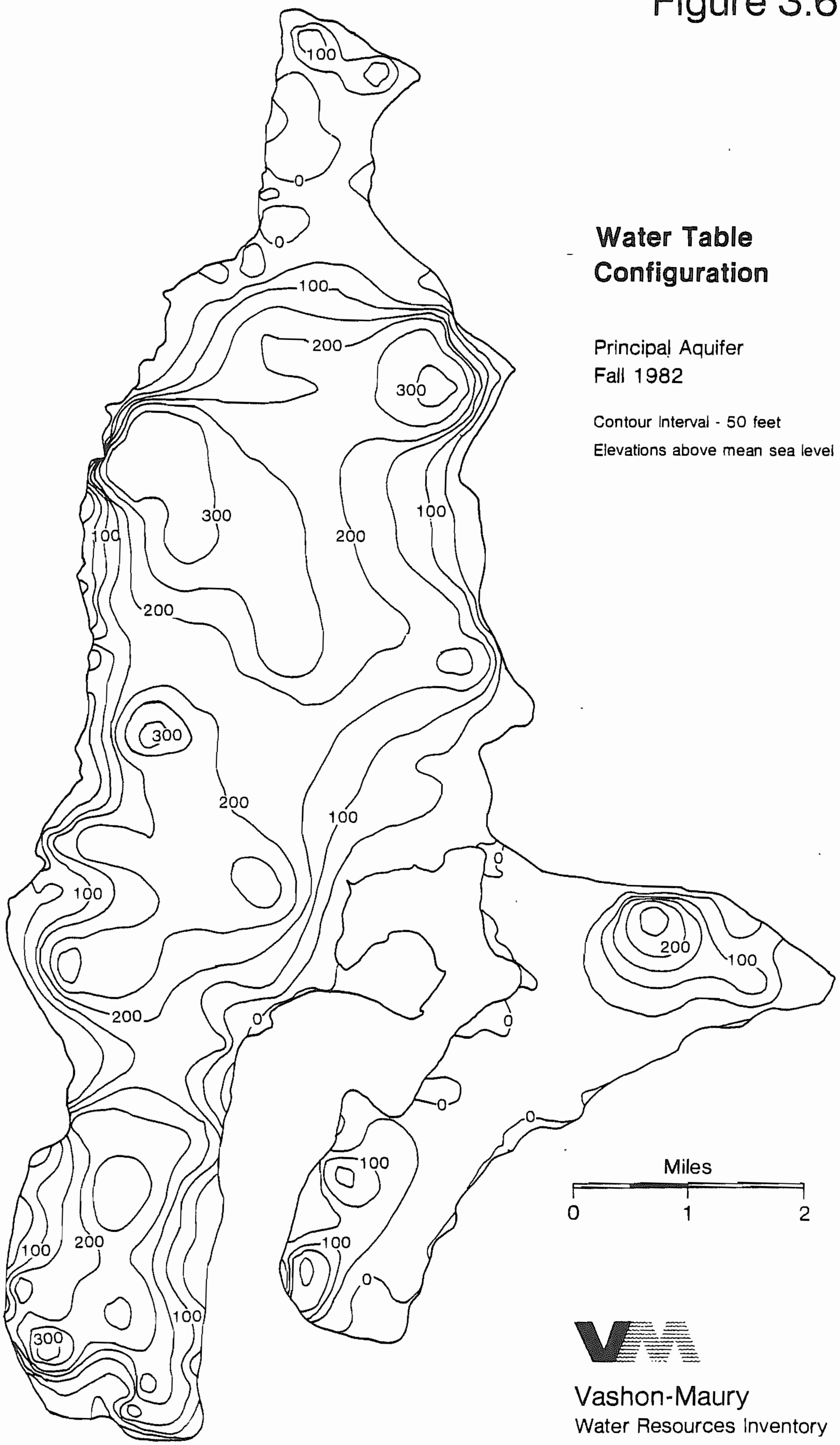
Because of the limited number of wells in the Deep Aquifer, data on water level elevations are very sparse. A water level (piezometric) map of the Deep Aquifer system is presented in Chapter 6.

Figure 3.5



Vashon-Maury
Water Resources Inventory

Figure 3.6



Water Table Configuration

Principal Aquifer
Fall 1982

Contour Interval - 50 feet
Elevations above mean sea level

Vashon-Maury
Water Resources Inventory

Spring Flows

There are hundreds of springs on Vashon/Maury Island, ranging in size from major flows to mere trickles. Springs occur around the margins of the Islands and in stream valleys where the topography intersects the water level of the Principal Aquifer. The discharge of these springs erodes the underlying sediments and, aided by runoff from precipitation, has carved impressive canyons on the flanks of the Islands.

The location of some of these springs is shown in Figure 3.7. A few spring areas where well points or other shallow ground water collection devices have been constructed are included as wells on Fig. 4.2 (Chapter 4). Springs are used as water supply sources by many Island residents. On Maury Island the Dockton and Maury Mutual Water systems are supplied exclusively by springs. Until 1980, the sole source of water for King County Water District 19 was spring 15 on Beal Creek and spring 13 on Ellis Creek.

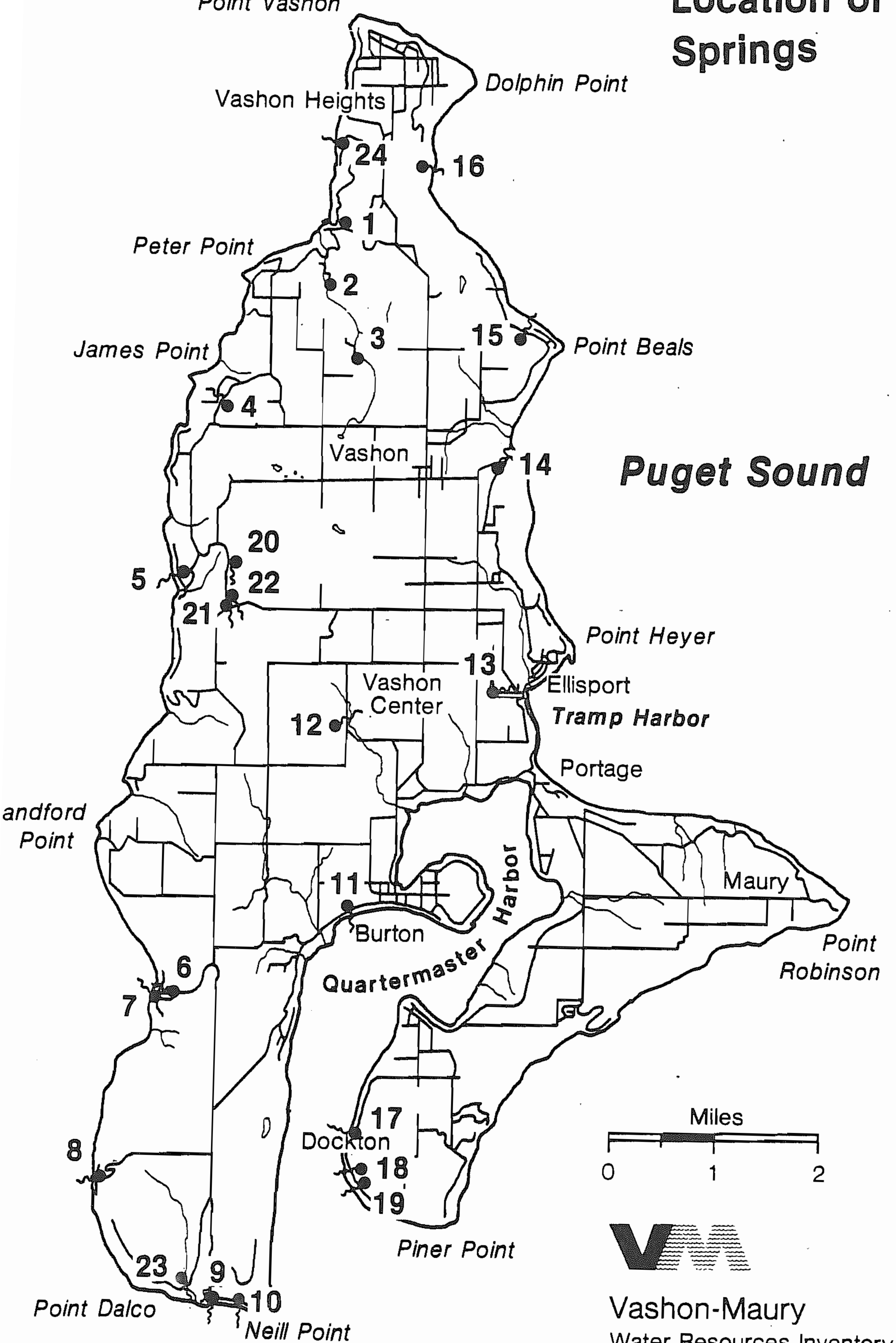
Characteristically, spring discharge on the Islands does not occur at a single point, but rather emerges from dispersed wet areas in valleys or on the hillsides. These conditions make spring discharge difficult to quantify, but significant seasonal variation has been observed. Figure 3.8 shows the variation of spring discharge at Corbin Beach (spring 24).

INTERPRETATION

Stream flow records show peak flows through the winter months, and close correlation between high runoff and major precipitation events. The summer stream base flow is maintained by springs and natural ground water discharge from the drainage basin. The base flow to drainage area ratio is variable and may be controlled by the water-bearing characteristics of the section incised by the stream.

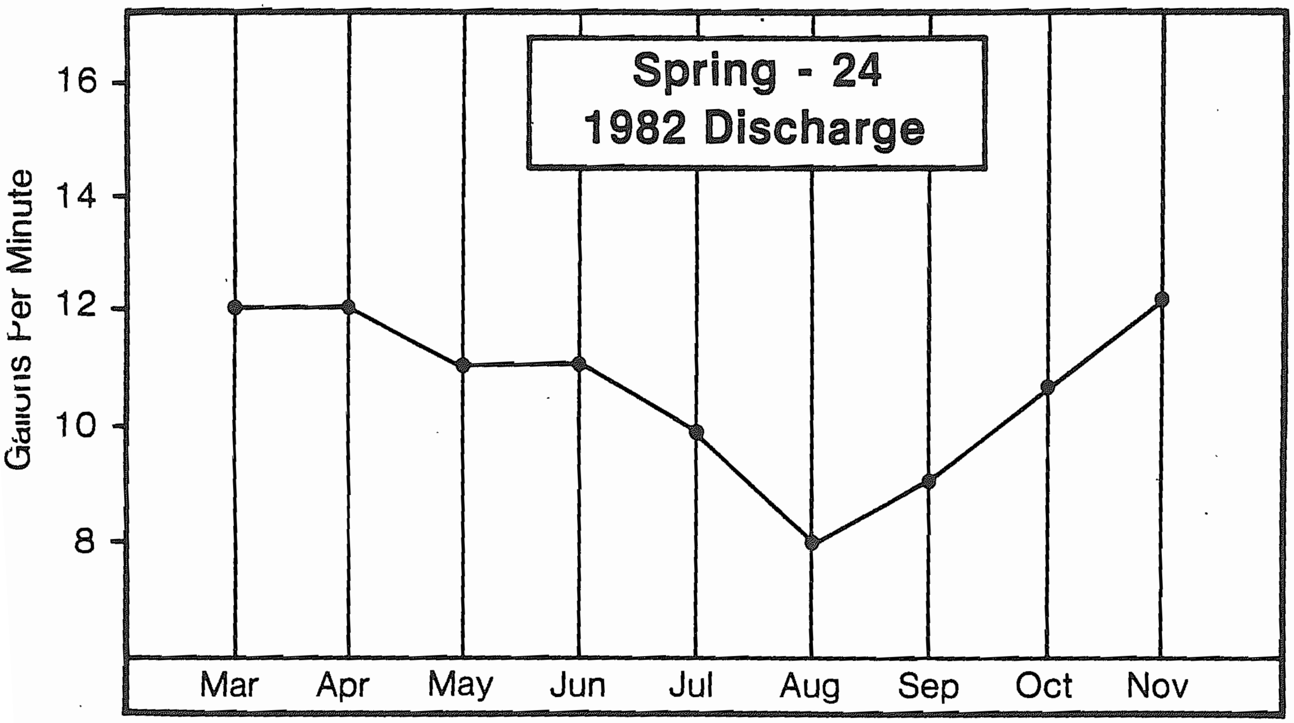
Figure 3.7

Location of Selected Springs



Vashon-Maury
Water Resources Inventory

Figure 3.8



Vashon-Maury
Water Resources Inventory

Interpretation of water levels in lakes and ponds indicates limited infiltration of water from these sources. Most of these ponds on the upland are in rather impermeable till or till-like sediments and have accumulated fine sediments and a bottom organic mat which retards infiltration. Figure 3.9 compares the water level in Banks Lake and Peck's Pond to the precipitation minus evapotranspiration through the 1982 summer months. The amount of water lost from the lakes exceeds precipitation-minus-evaporation by 2 to 3 inches per month. Thus some infiltration out of the ponds may be occurring.

Interpretation of fluctuations of the Islands' ground water levels indicates response to:

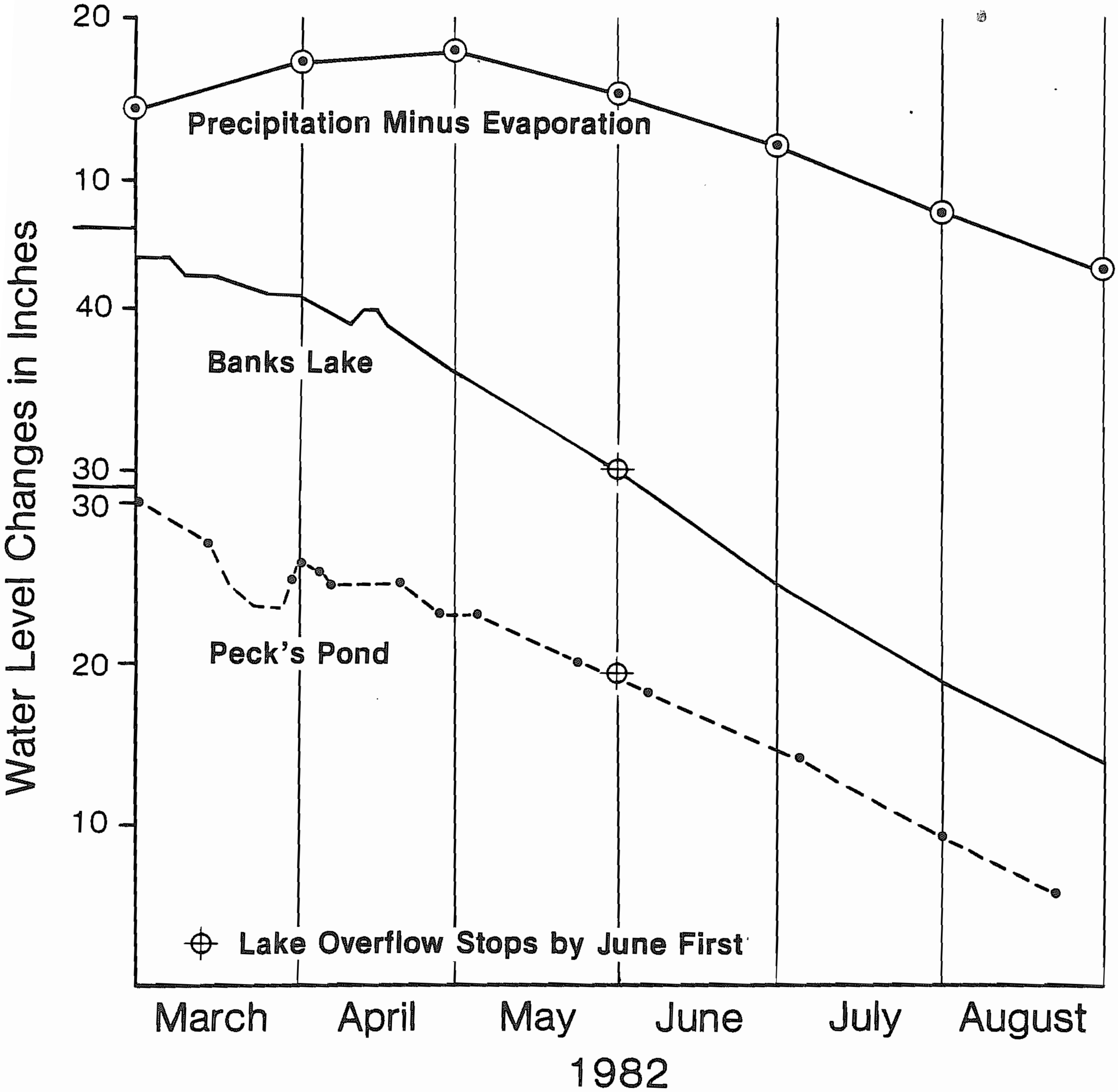
- Seasonal and long-term variation in recharge
- Changes due to pumping and interference from other wells
- Response to tidal influence
- Response to barometric influence

As shown in Figure 3.5, the seasonal change of ground water levels during this study period range from less than 1 foot to over 12 feet. In general, shallower wells had greater fluctuation of water levels than deeper wells. Water level response in deeper wells is later than in shallow wells. Figure 3.10 compares the lag time (between the peak water surplus in early February 1982 and the peak ground water level) to well depth. Based on the available data, this lag time appears to increase about three months per 50 foot of well depth.

Analysis of the long-term water level record available from well 3 shows a probable delay of about six months. These data (Figure 3.11), show a rapid decline of water level from 1977 through 1979, and a slow rise in water level from 1979 to 1982. This 7 foot drop in water level may be in response to the regional drought conditions suffered in 1976-78.

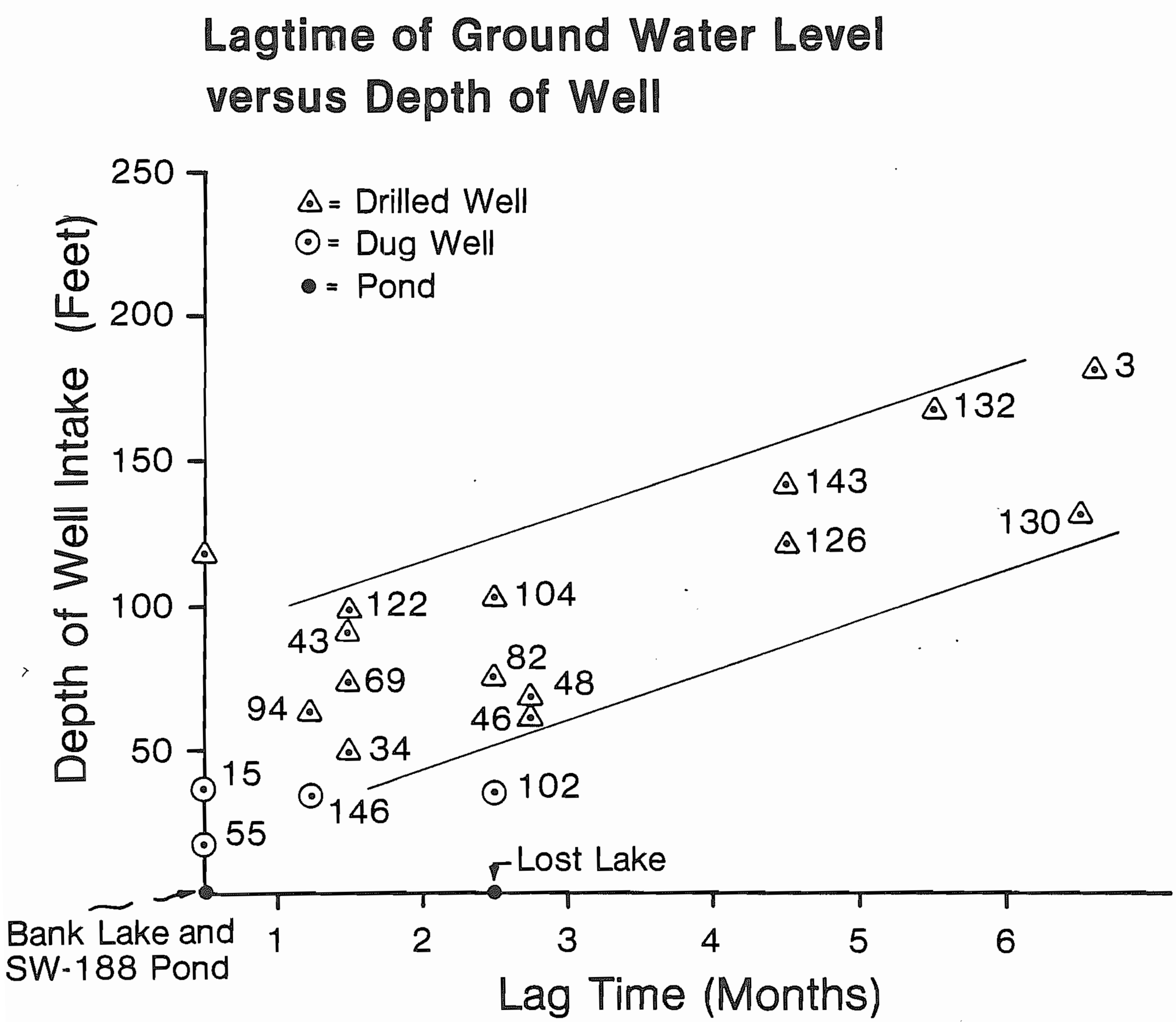
Figure 3.9

Precipitation Minus Evaporation and Water Levels In Two Lakes



Vashon-Maury
Water Resources Inventory

Figure 3.10

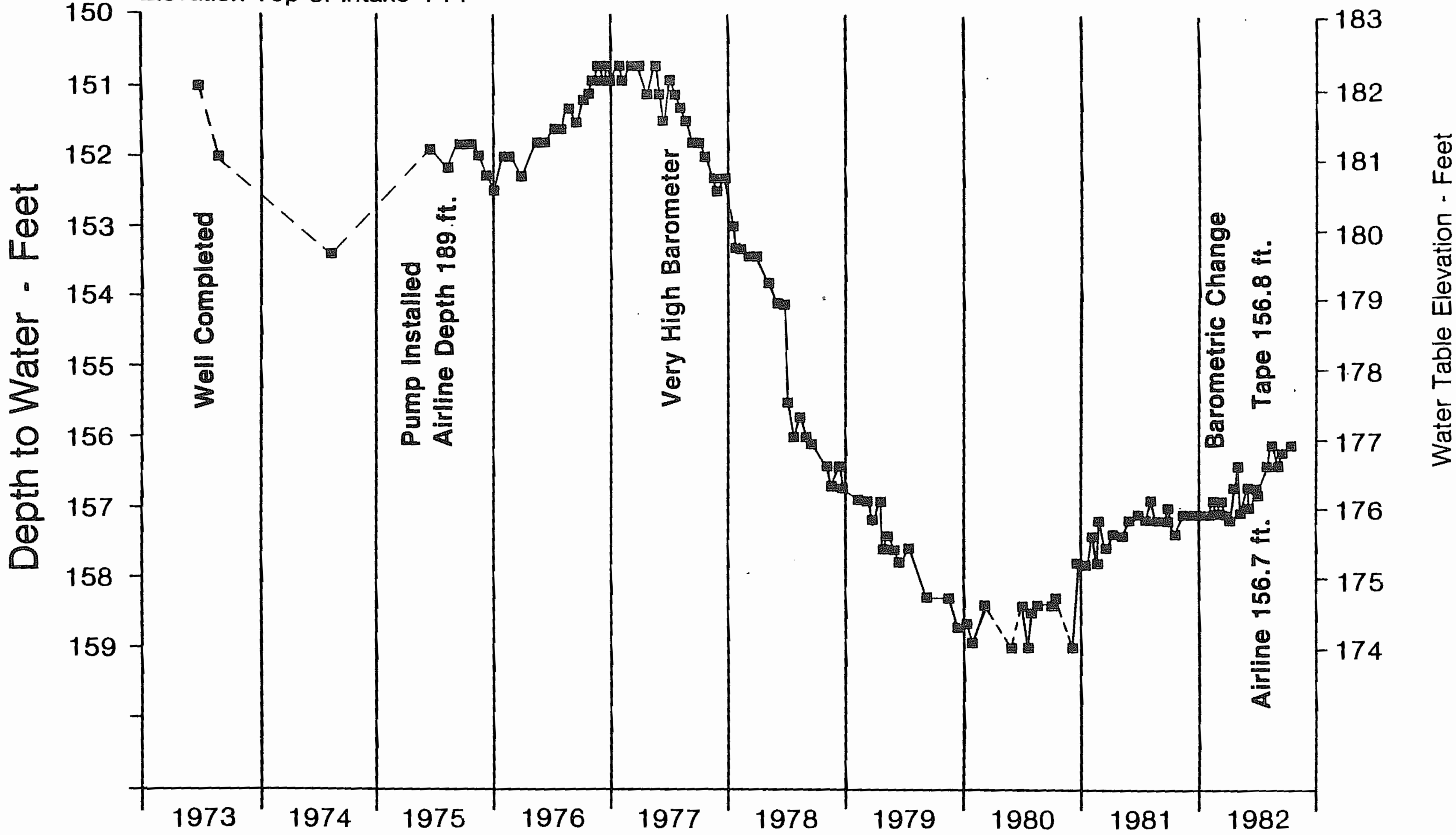


Vashon-Maury
Water Resources Inventory

Well No. 3 Kellum

T21N, R2E, SEC. 1 F3

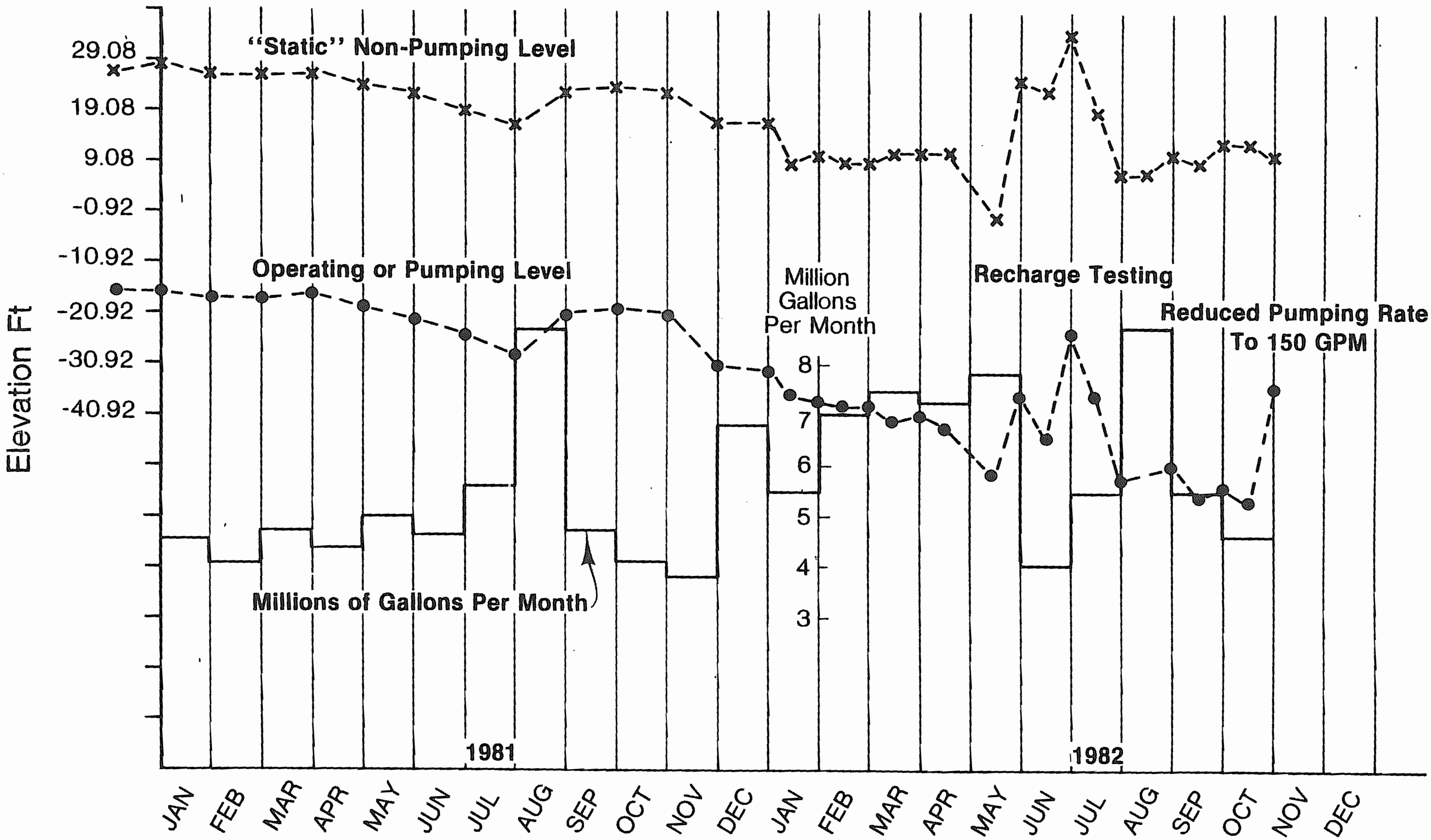
Surface Elevation 333'
Bottom Elevation 124'
Elevation Top of Intake 144'



Vashon-Maury
Water Resources Inventory

Figure 3.11

King County Water District 19
Deep Production Well



Vashon-Maury
Water Resources Inventory

Figure 3.12

The effects of pumping on water level are demonstrated in analysis of operational data for King County Water District's deep well (Figure 3.12). In May and June of 1982, this well was pumped much less frequently. During this time, the well's non-pumping water level record recovered to above its original static level. Resumption of pumping in August, 1982 then caused immediate return to a depressed static water level about 10 feet above sea level.

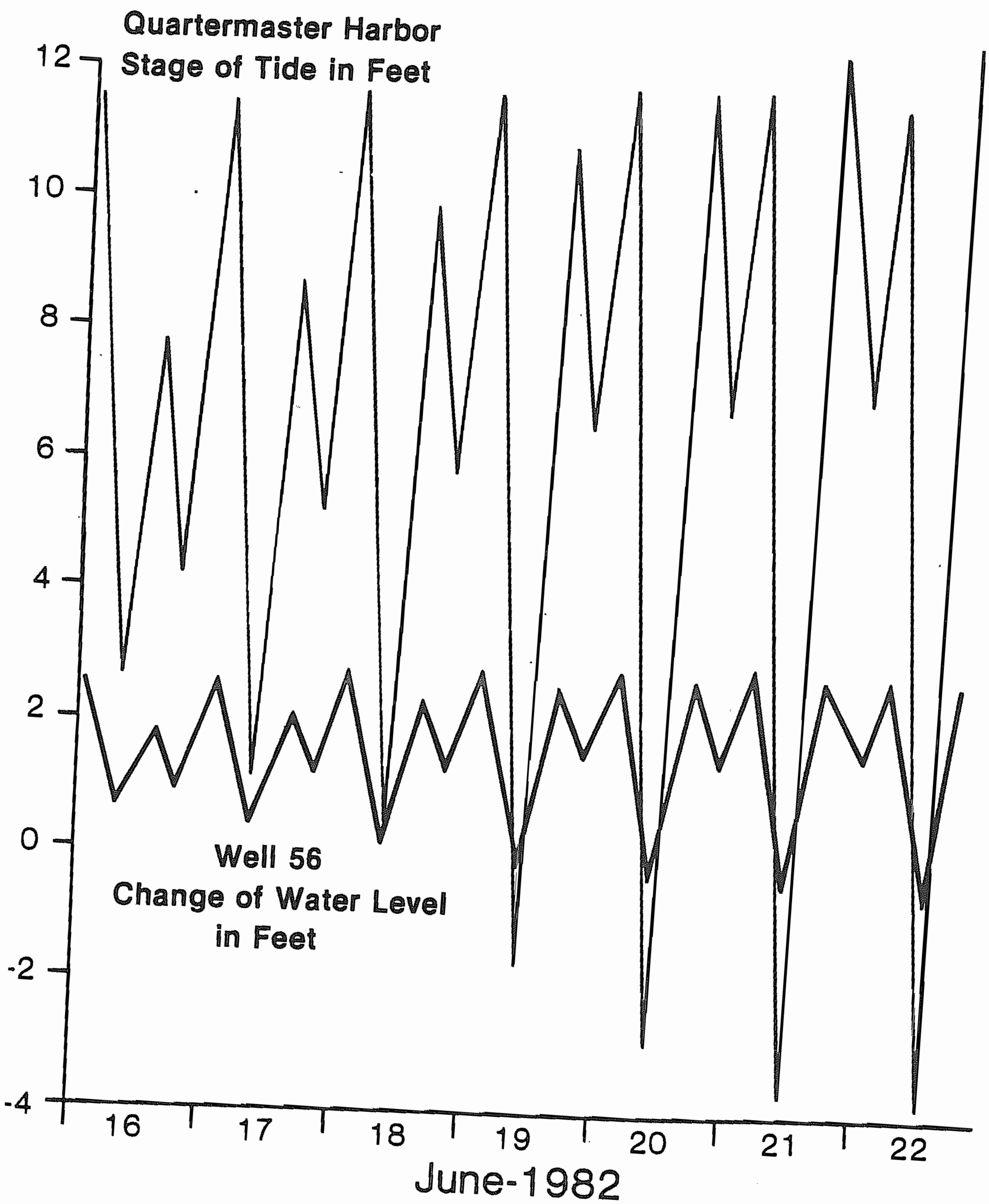
Water levels on a few of the Islands' wells have been observed to fluctuate in response to tidal changes. These wells are located near the shoreline and completed in aquifers at or below sea level. The continuous water level record from well 56 is compared to tidal fluctuations at Seattle (Quartermaster Harbor, Cf.) in Figure 3.13. This illustration shows very little, if any, time delay or lag between tide and water level in the well, and shows the change in water levels in the well to be about one quarter of the tidal amplitude.

Changes in atmospheric or barometric pressure can affect the water level in wells which penetrate confined aquifers. Water levels in some of the Islands' wells completed in the deep Aquifer exhibit slight (less than 1 foot) response to barometric changes.

Figure 3.13

Hydrographs

Island Well and Tide



Vashon-Maury
Water Resources Inventory

CHAPTER 4

GEOLOGY AND AQUIFER CHARACTERISTICS

This chapter describes the Islands' geology and characteristics of the aquifers. These considerations affect the movement of water into and through the ground and determine where, how, and how much water can be developed.

SUMMARY

Vashon/Maury Island is composed of glacially derived sediments. Generally, the deposits above sea level are derived from the latest glaciation known as the Vashon stade of the Fraser glaciation which ended about 11,000 years ago. This study has identified three generalized geologic units exposed on Vashon/Maury Island, which have significance for the water resource:

- UNIT I - Glacial drift, principally till.
- UNIT II - Sand, and sand and gravel.
- UNIT III - Silt and clay with sandy zones.

Similar geologic units have been identified on the Kitsap Peninsula as well as on the mainland. On Vashon/Maury Island, unlike surrounding areas, the sediments below sea level are primarily silts and clays of Unit III (to depths of nearly 600 feet below sea level). In the surrounding areas, at least four separate glaciations have been identified by till and related drift deposits. Such evidence of earlier glaciations on the Islands is not identified in this study.

The Principal Aquifer (Unit II) on Vashon/Maury Island is characterized by its complexity. It is extremely heterogeneous from site to site and varies widely in thickness and productivity as an aquifer. Sandier sections of Unit II are often uniformly fine-grained, dense and silty, and yield low amounts of water to wells. Sand and gravel sections of the aquifer are characteristically more permeable and yield moderate amounts of water to wells. Around the perimeter of the Islands where ground surface intersects the water table, hundreds of springs and seeps emerge from the Principal Aquifer (Unit II).

A Deep Aquifer lies within Unit III at depths of about 100 to 300 feet below sea level. It has been penetrated by over a dozen wells on the Islands, and is described as a fine to medium sand, dark in color with minor amounts of gravel. This aquifer provides more available drawdown than Unit II, and therefore is usually capable of yielding larger quantities of water to properly designed and constructed wells. However, the total recoverable resource of the deep aquifer is more restricted because of the limited recharge it receives (see Chapter 6).

BACKGROUND

Vashon/Maury Island is located in Central Puget Sound, surrounded by Colvos Passage on the west, East Passage on the east and north, and Dalco Passage on the south.

A narrow isthmus at Portage connects the north end of Maury Island to east central Vashon Island. The two islands are separated by Quartermaster Harbor. Vashon Island trends generally north-south and is about 12 miles long and about 3 1/2 miles wide at its widest point in the east-west direction. Maury Island trends north-east, south-west and is about 5 miles long and about 1 mile wide over most of this length.

Vashon Island is characterized by steep, high banks around most of its shoreline. Its upland rises to an elevation of slightly over 400 feet and is gently undulating. The Island is transected by numerous streams, the largest of which are Judd Creek, which flows toward the southeast and discharges into Quartermaster Harbor; and Needle Creek, which flows to the northwest and discharges into Colvos Passage.

Maury Island has steep, high banks along its southeast side and rises to an elevation of nearly 500 feet. Its land surface then slopes more gently from this high ridge toward Quartermaster Harbor along the northwest side of the Island.

Except for a few surface water sources, all of the Islands' water supplies come from wells and springs which tap the underlying aquifers.

DATA COLLECTION

Geologic data was obtained in three ways:

- Review of information from previous studies of the Islands and neighboring areas.
- Observation and measurement of exposures on the Islands.
- Survey and evaluation of existing wells and well log data.

PREVIOUS STUDIES

Geologic studies of the glaciated Puget Lowland began with those of Willis (1898) and Bretz (1913), which were modified and extended by Crandell and others (1958), Armstrong and others (1965), and Easterbrook and others (1967, 1981). More specific information on the Islands' geology is presented in: Fulmer's **Vashon and Maury Islands Physical Characteristics**

and Shoreline Inventory; A Geologic Map of Vashon and Maury Islands by Othberg, DNR (unpublished); and the **Shoreline Inventory Coastal Zone Atlas of King County.**

Additional understanding came from a review of geologic and water resource studies in surrounding areas of similar geology, including: **Water Supply Bulletin 22, Ground Water of Central Pierce County; Water Supply Bulletin 28, Geology and Ground Water Resources of Southwest King County;** and **U.S.G.S. Water Supply Paper 1852, Water Resources of King County, Washington;** and most usefully, **Water Supply Bulletin 18, Water Resources and Geology of Kitsap Peninsula and Certain Adjacent Islands.**

As indicated by these studies, the Puget Sound Lowland underwent extensive glaciation ending about 11,000 to 13,000 years ago. There were at least four separate glacial advances, each with a typical sequence of glacially deposited sediments.

Characteristically, meltwater streams from ice of each glaciation moved down the Puget Trough, depositing coarse sediments called advance sands and gravels. These outwash deposits in turn were eroded and overridden by ice. Sediment directly deposited from the ice is termed glacial till, which typically consists of a dense mixture of silt, sand and gravel. As the ice retreated, meltwater streams eroded the till and deposited recessional sand and gravel, often in irregular and discontinuous channels. During periods when the ice was absent, silt and clayey sediments were deposited in vast lakes and deep fjords covering much of the area.

Geologists usually name identifiable stratigraphic units after localities where exposures of such units are prominent. Vashon has given its name to sediments of the last glaciation. These are collectively called Vashon drift, including Vashon till, which mantles much of the surface of the Puget Lowland. Likewise, the name Colvos has been assigned to a sand unit which underlies the till, because it is exposed on the west side of the island along Colvos Passage. More recent studies following Easterbrook have adopted the name Esperance for this sand.

Prior studies also identify other geologic units which are in part distinguishable on Vashon. Because of the environment of their deposition, the character and relationships of glacially derived sediments are very complex. The different stratigraphic relationships and names assigned by various investigators are summarized in Table 4.1.

As indicated in the table, there is considerble difference in professional interpretation of the stratigraphy of the area. In addition, a recent report by Easterbrook (1981) assigned an age of about 800,000 years to the Salmon Springs deposits, previously dated between 70,000 and 85,000 years old. Thus, the Salmon Springs designation of earlier studies may be inappropriate.

FIELD OBSERVATION

Additional data was obtained by examining dozens of exposures on the Islands. The sediments in the most prominent exposures were identified and carefully measured to assist in developing the geologic framework. The locations of these measured sections are presented in Figure 4.1.

WELL DATA

Finally, all available Island well logs were collected from DOE (Redmond). Of these, 150 were selected for the data base and field-checked to accurately determine locations and well-head elevations. A matrix of well data is presented in Table 4.2, and a map showing well locations in Figure 4.2. In the well log descriptions, drillers use many terms which may not be technically precise but which are often descriptive. Glacial till is most often described as "hardpan" and silt is

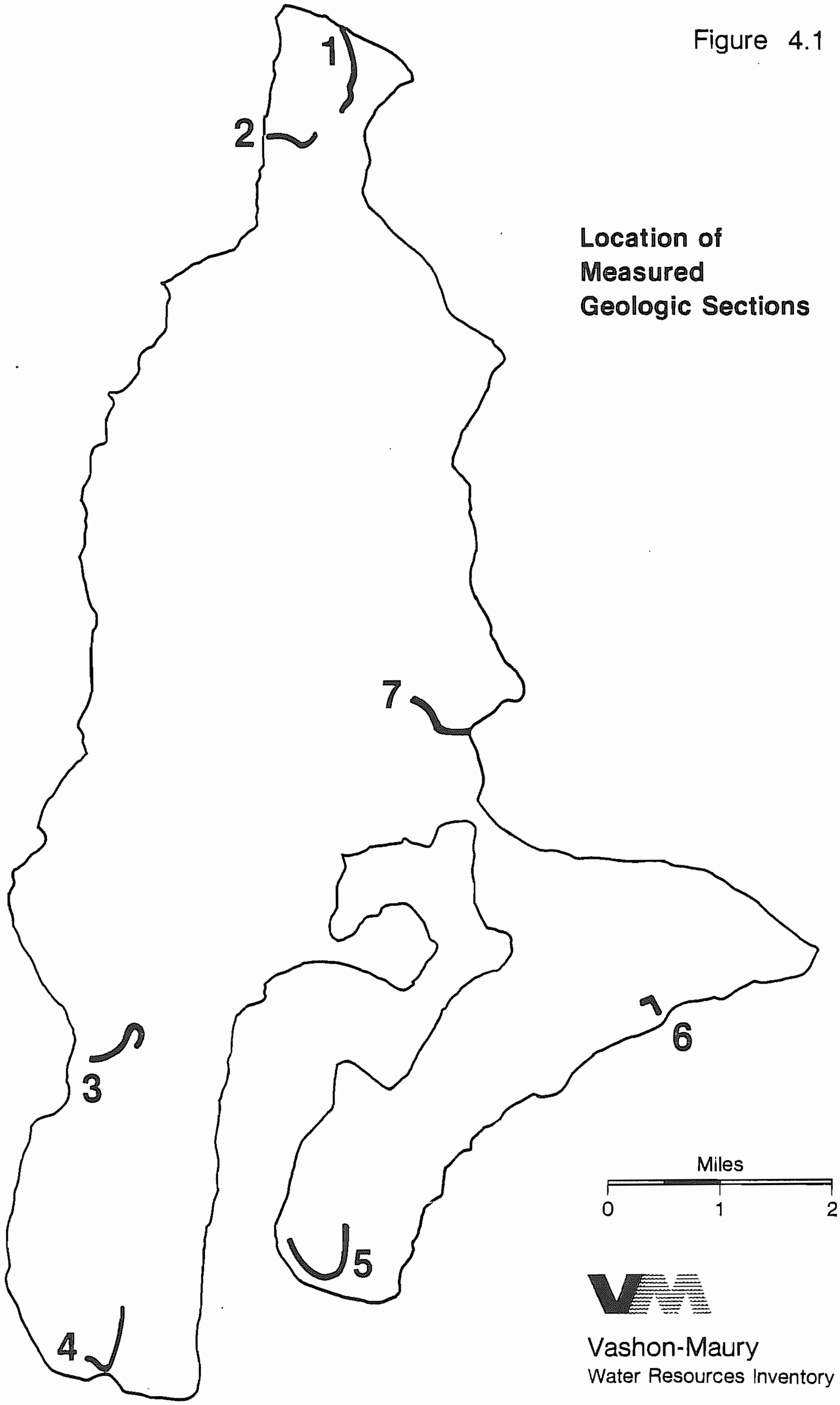
VASHON WATER RESOURCES STUDY
SIMPLIFIED STRATIGRAPHIC CORRELATION
PUGET SOUND AREA

Approx. Time Years	Climatic Event	Kitsap (SCEVA 1957)	Pierce Co. (Walters, 1967)	Kitsap Co. & Islands (Molenaar 1970)	Island Co. (Easterbrook 1968)	Vashon Study Units
5,000		Alluvium	Electron & Osceola Mudflows Alluvium	Alluvium	Alluvium	
11,000	Sumas Stade				Sumas Drift	Mapped as I or II Based on Lithology
13,000		Gorst Creek Outwash	Steilacoom Gravels Recessional Outwash	Recessional Outwash	Recessional Outwash	
15,000	Vashon Stade	Till	Vashon Till	Vashon Till	Till	I
		Advance Outwash	Advance Gravel	Advance Outwash	Advance Outwash	II
23,000		Puyallup	Colvos Sand	Colvos Sand	Esperance Sand	II
	Olympia	Kitsap Clay	Kitsap Formation	Kitsap Formation (silt & clay)	Quadra Formation (silt, sand)	
50,000	Interglacial Period					III
70-85,000			Salmon Springs	Salmon Springs	Possession Drift (Double Bluff)	
		Admiralty Drift	Puyallup Formation	Pre-Salmon Springs Deposits		III
110,000						Deeper Aquifers
			Stuck Drift			
125,000	Earlier Glaciations					
			Alderton Drift			
180,000						
			Orting Drift			
200,000						

TABLE 4.1

Figure 4.1

Location of Measured Geologic Sections



Vashon-Maury
Water Resources Inventory

frequently called "clay, sticky or mastic." These descriptions are important but require considerable interpretation because of differences in terminology between individual drilling machine operator's knowledge, experience and geologic training.

INTERPRETATION

This study has provided an opportunity to examine the geology of the Islands in more detail than possible in earlier regional studies. Close examination of exposures and well logs revealed widespread variability and extreme complexity of previously mapped units. For example, in some places the glacial (Vashon) drift (Unit I) occurs as extremely dense and impermeable till, and elsewhere as less dense and even stratified, grading laterally into moderately permeable deposits of silty sand and gravel. Perhaps the greatest amount of variation is in the sands and sands and gravels of the Vashon drift. These deposits are found in some areas to be clean (unsilty) and permeable and in other areas to grade vertically and laterally into a dirty (silty) sediment of low permeability. Deposits resembling till were also found within the sand and sand/gravel units previously described as outwash and Colvos Sand. These relationships are natural and expected in light of the origin of these sediments.

The glacial till on the Islands was deposited either as a lodgement till directly beneath moving ice, or as ablation till from wasting ice. The former left a dense, nearly impermeable concrete-like deposit, and the latter left a less consolidated, more permeable sediment.

Sands and gravels were deposited by ice marginal, meltwater streams. These streams sorted the sediments. Coarse deposits were left near the ice margins and finer sediments were carried further from the source.

Till-like layers found within the sands and gravels on Vashon/Maury Island appear to have been deposited by minor retreat

Project Number	U.S.G.S. Number	Owner's Name	Ground Surface Elevation (ft.)	Well Depth (ft.)	Well Log Available	Well Type Dr=Drilled CT=Cable Tool Dg=Dug R=Rotary WP=Well Point Spr=Spring	Water Level: Fall '82 DTW - Feet	1981-82 Chemical Analyses
1	21/02 1F1	Young	331	180		Dr/CT	160.43	Yes
2	21/02 1F2	Wright	342	197	Yes	Dr/CT	-	Yes
3	21/02 1F3	Kellum	333	209	Yes	Dr/R	156.1	Yes
4	21/02 1F4	Krell	336	185	Yes	Dr/CT	163.42	
5	21/02 1L1	Miller	323	180	Yes	Dr/CT	-	Yes
6	21/02 1M1	McIntyre	306	183	Yes	Dr/CT	133.63	Yes
7	21/02 1M2	McIntyre	288	93	Yes	DR/CT	60.80	Yes
8	21/02 1N1	Galford	192	18	Yes	Dg	8.92	Yes
9	21/02 1N2	Mish	216	49	Yes	Dr/R	30.32	Yes
10	21/02 1N3	Rotter	240	37	Yes	Dr/CT	-	Yes
11	21/02 1P	Sterling	68	96	Yes	Dr/CT	Dry	
12	21/02 2D	Krimmel	279	132	Yes	Dr/?	107.15	Yes
13	21/02 2E1	Gates	281	140	Yes	Dr/R	-	
14	21/02 2E2	Elmer	229	125	Yes	Dr/R	102.27	Yes
15	21/02 2E3	Person	336	38		Dg	34.77	Yes
16	21/02 2E4	Reagon	300	82	Yes	Dr/CT	-	
17	21/02 2H	Gateman	184	145	Yes	Dr/R	122.58	Yes
18	21/02 2J	Davis	267	273	Yes	Dr/CT	245.0	Yes
19	21/02 2K	Alton	8	50	Yes	Dr/CT		Yes
20	22/02 1D1	85 Acre Wtr. Sys.	270	145		Dr/?	87.73	Yes
21	22/02 1D2	Gerrior	207	?		Dr/?	-	Yes
22	22/02 1H	Mann	208	58	Yes	Dr/CT	-	Yes
23	22/02 1N1	Nelson	401	210	Yes	Dr/CT	191.06	Yes
24	22/02 1N2	Nelson	395	10		Dg	6.95	
25	22/02 1N3	Betts	415	223		Dg	-	
26	22/02 1P	Whittaker	420	253	Yes	Dr/CT	-	
27	22/02 1R	Steward	315	60	Yes	Dr/Ct	-	
28	22/02 11B	Madrona-West	60	110	Yes	Dr/CT	47.94	Yes
29	22/02 11J1	Wilkens	400	224	Yes	Dr/CT	-	
30	22/02 11J2	Shackleton	395	85	Yes	Dr/CT	-	

WELL DATA

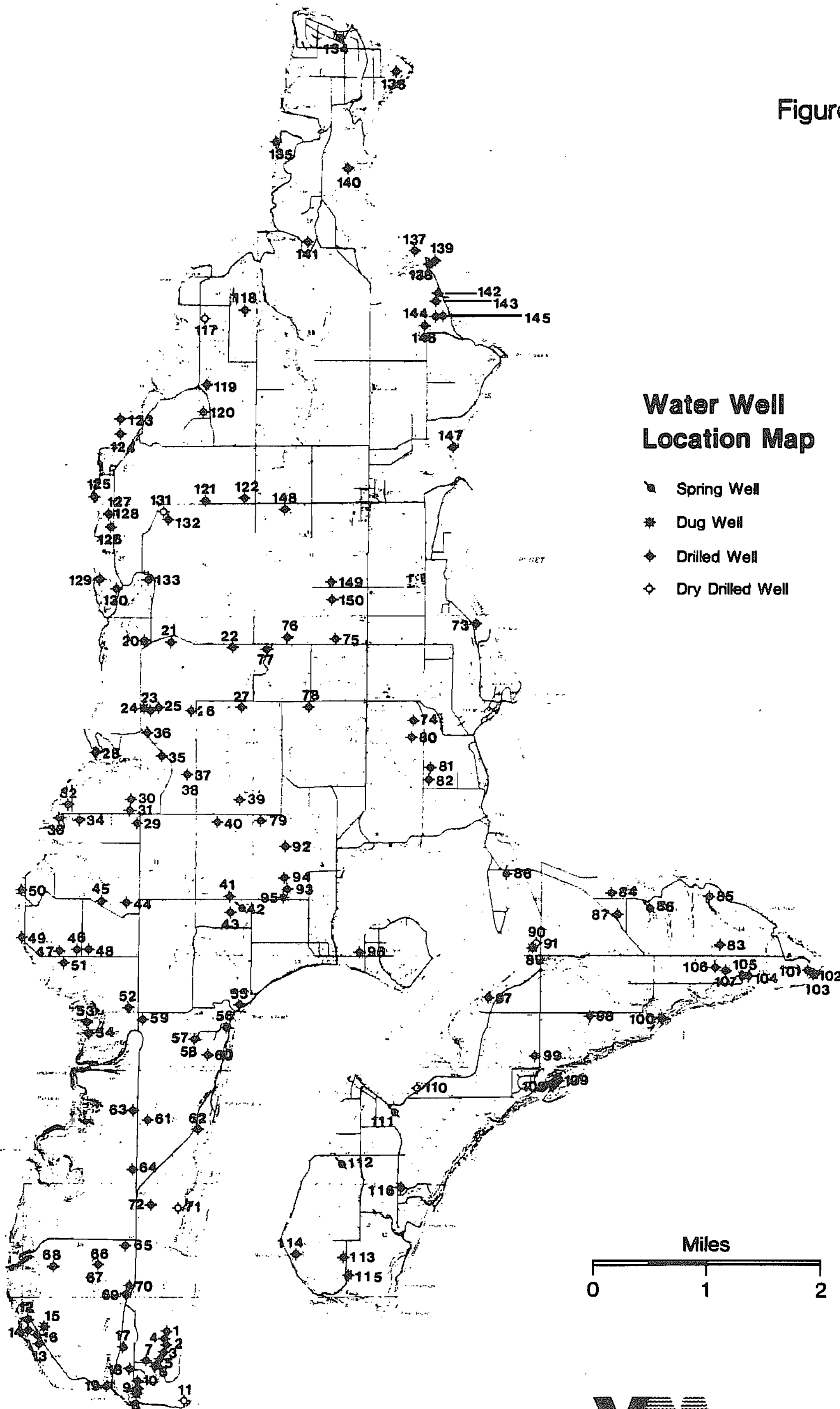
Project Number	U.S.G.S. Number	Owner's Name	Ground Surface Elevation (ft.)	Well Depth (ft.)	Well Log Available	Well Type Dr=Drilled CT=Cable Tool Dg=Dug R=Rotary WP=Well Point Spr=Spring	Water Level: Fall '82 DTW - Feet	1981-82 Chemical Analyses
31	22/02 11J3	Shackleton	395	157	Yes	Dr/CT	-	
32	22/02 11L	Hutzler	180	50	Yes	Dr/CT	-	
33	22/02 11P1	Cooley	161	20		Dg	10.6	Yes
34	22/02 11P2	Beaumont	210	56	Yes	Dr/CT	12.06	Yes
35	22/02 12D1	Hoffman	383	198	Yes	Dr/CT	171.26	Yes
36	22/02 12D2	Wilson	390	204	Yes	Dr/CT	-	
37	22/02 12F1	Von Neida	401	174	Yes	Dr/CT	-	Yes
38	22/02 12F2	Von Neida	401	14		Dg	-	
39	22/02 12J	Nike Launch Site	390	161		Dr/?	-	
40	22/02 12Q	Stewart	345	596	Yes	Dr/R	-	
41	22/02 13H	Veltman	350	63	Yes	Dr/R	-	
42	22/02 13J2	Burton Wtr. Co.	258	20		Dg/wp		Yes
43	22/02 13J	Hansen	264	98	Yes	Dr/CT	64.38	Yes
44	22/02 14H	Parsons	285	107	Yes	Dr/CT	-	
45	22/02 14K	New Well	295	?		Dr	-	
46	22/02 14P1	Baker	289	62	Yes	Dr/CT	23.82	Yes
47	22/02 14P2	Kueker	261	257	Yes	Dr/R	-	Yes
48	22/02 14Q	Baker	291	68		Dr	51.27	
49	22/02 15R	Ruggenberg	100	151	Yes	Dr/CT	-	
50	22/02 15H	Miller	72	256	Yes	Dr/CT	-	
51	22/02 23C	Brown	235	214	Yes	Dr/CT	-	Yes
52	22/02 23H	Blakemore	385	300	Yes	Dr/CT	-	Yes
53	22/02 23K1	Vashon Wtr. & Rds.	86	230	Yes	Dr/CT	54.44	Yes
54	22/02 23K2	Vashon So.	48	205	Yes	Dr/CT	-	Yes
55	22/02 24H	Rasmusen	44	40		Dg	8.88	Yes
56	22/02 24J	Gordon	168	308	Yes	Dr/CT	156	
57	22/02 24K	Boyd	310	193	Yes	Dr/CT	-	
58	22/02 24D	Scott	300	81	Yes	Dr/CT	-	
59	22/02 24M	Harris	385	214	Yes	Dr/CT		
60	22/02 24Q	Wesleyan Church	302	307	Yes	Dr/CT	-	Yes

Project Number	U.S.G.S. Number	Owner's Name	Ground Surface Elevation (ft.)	Well Depth (ft.)	Well Log Available	Well Type Dr=Drilled CT=Cable Tool Dg=Dug R=Rotary WP=Well Point Spr=Spring	Water Level: Fall '82 DTW - Feet	1981-82 Chemical Analyses
61	22/02 25E	Chase	405	123	Yes	Dr/CT	-	
62	22/02 25K	Roberts	360	225	Yes	Dr/CT	-	
63	22/02 26H	Vashon Isl. Dev.	410	233		Dr/?	-	Yes
64	22/02 26R	Hall	386	108	Yes	Dr/CT	89.37	Yes
65	22/02 35J	Ofdenkamp	360	148	Yes	Dr/CT	-	
66	22/02 35K	Hall	298	116	Yes	Dr/CT	77.89	Yes
67	22/02 35E	Roberts	335	330	Yes	Dr/CT	-	
68	22/02 35M	Goetz	350	223	Yes	Dr/CT	189.91	
69	22/02 35R1	Carlson	314	79	Yes	Dr/CT	57.1	Yes
70	22/02 35R2	Holst	320	101	Yes	Dr/CT	62.62	Yes
71	22/02 36C	Mitchell	378	115	Yes	Dr/CT	Dry	
72	22/02 36D	Fredrickson	360	144	Yes	Dr/CT	-	
73	22/03 5A	Gregg	290	405	Yes	Dr/?	-	
74	22/03 5P	Golemac	266	283	Yes	Dr/R	-	
75	22/03 6B	Johns	380	61	Yes	Dr/R	-	
76	22/03 6C	Gaetaniello	293	300		Dr/?	-	Yes
77	22/03 6E	Vashon Cem.	298	210	Yes	Dr/CT	36.08	Yes
78	22/03 6P	Kermes	225	172	Yes	Dr/CT	-	
79	22/03 7N	Lamoureux	300	210	Yes	Dr/CT	-	
80	22/03 8C	Robinson	239	227	Yes	Dr/CT	183.57	
81	22/03 8G1	Seligman	137	126	Yes	Dr/CT	-	
82	22/03 8G2	Hammett	120	88	Yes	Dr/CT	61.97	
83	22/03 14N	Skyridge	413	365		Dr/CT	-	Yes
84	22/03 15E	Schmidt	205	160	Yes	Dr/CT	-	
85	22/03 15H	Luena Beach	119	79	Yes	Dr/CT	-	Yes
86	22/03 15H	Maury Mutual	211	3		WP	-	Yes
87	22/03 15M	Flynn	280	190	Yes	Dr/CT	-	
88	22/03 16F	KIRO Radio	56	462	Yes	Dr/CT	-	
89	22/03 16P1	Knutson	25	20		Dg	8.75	Yes
90	22/03 16P2	Ebb Tide	62	105	Yes	Dr/CT	aban'd	

Project Number	U.S.G.S. Number	Owner's Name	Ground Surface Elevation (ft.)	Well Depth (ft.)	Well Log Available	Well Type Dr=Drilled CT=Cable Tool R=Rotary Dg=Dug WP=Well Point Spr=Spring	Water Level: Fall '82 DTW - Feet	1981-82 Chemical Analyses
91	22/02 16P3	Ebb Tide	62	60	Yes	Dr/CT	aban'd	
92	22/03 18C	Dawdy	280	140	Yes	Dr/R	-	
93	22/03 18F1	Nelson	300	80	Yes	Dr/CT	-	
94	22/03 18F2	Farris	311	70		Dr	48.01	
95	22/03 18F3	Nelson	304	75	Yes	Dr/CT	-	
96	22/03 18R1	Hastings	40	38		Dg	-	
97	22/03 21E	Reuter	108	473	Yes	Dr/CT	89.0	Yes
98	22/03 21J	Vashon S. & G.	382	518	Yes	Dr/CT	-	
99	22/03 21P	Iliad	390	520	Yes	Dr/R	372.95	
100	22/03 22K	Williamette West	213	435	Yes	Dr/CT	-	Yes
101	22/03 23A1	King Co. Park	91	149	Yes	Dr/CT	76.7	Yes
102	22/03 23A2	USCG	59	35		Dg	12.48	Yes
103	22/03 23A3	USCG	59	9		Dg	Dry	
104	22/03 23C1	Chobot	143	108	Yes	Dr/CT	93.62	Yes
105	22/03 23C2	Chobot	148	11		Dg	7.60	Yes
106	22/03 23D1	White	399	375	Yes	Dr/R	-	Yes
107	22/03 23D2	Matsumuto	337	388		Dr/CT	-	Yes
108	22/03 28B1	Gold Beach	100	113	Yes	Dr/CT	-	
109	22/03 28B2	Gold Beach	100	118	Yes	Dr/CT	-	
110	22/03 29C	Hegedorn	74	175	Yes	Dr/CT	Dry	
111	22/02 29F	Dockton & Harborvw.	80	?		Spr/WP	-	Yes
112	22/03 30R	Dockton Sp.	180	?		Spr/WP	-	Yes
113	22/03 31J	Hillcrest	360	493	Yes	Dr/CT	357.29	Yes
114	22/03 31L	Manzanita Beach	150	?		Dr/?	-	Yes
115	22/03 31R	Harbor Vista	248	306	Yes	Dr/CT	248.6	
116	22/03 32C	Shore Acres	310	423	Yes	Dr/CT	-	
117	22/02 24G	Starr	214	290	Yes	Dr/CT	aban'd	
118	23/02 24H	Copperburg	300	133	Yes	Dr/CT	-	
119	23/02 24Q	Marsh	280	186	Yes	Dr/CT	-	
120	23/02 25B	Johnson	380	122	Yes	Dr/R	-	

Project Number	U.S.G.S. Number	Owner's Name	Ground Surface Elevation (ft.)	Well Depth (ft.)	Well Log Available	Well Type Dr=Drilled CT=Cable Tool Dg=Dug R=Rotary WP=Well Point Spr=Spring	Water Level: Fall '82 DTW - Feet	1981-82 Chemical Analyses
121	23/02 25Q	Fisher	373	469	Yes	Dr/R	319.7	
122	23/02 25R	Fisher	367	98		Dr/?	75.06	
123	23/02 26A	Eastley	88	92	Yes	Dr/CT	-	
124	23/02 26H	Schroeder	134	52	Yes	Dr/R	-	
125	23/02 26Q	McReynolds	100	175	Yes	Dr/CT	-	
126	23/02 35B1	Hamilton	201	118	Yes	Dr/CT	74.37	Yes
127	23/02 35B2	Janke	200	167		Dr/CT	-	Yes
128	23/02 35B3	Janke	200	?		Dg	-	
129	23/02 35K	Henrikson	218	314	Yes	Dr/CT	205.62	Yes
130	23/02 35R	Paquetts	236	132	Yes	Dr/CT	98.58	Yes
131	23/02 36D1	DeFrang	462	440	Yes	Dr/CT	aban'd	
132	23/02 36D2	DeFrang	442	175	Yes	Dr/CT	141.49	Yes
133	23/02 36M	Lotus	380	109	Yes	Dr/CT	-	
134	23/03 6Q	North Vashon	81	-		Spr.	-	Yes
135	23/03 7N	Sandy Beach	14	130		Dr/CT	-	Yes
136	23/03 8D	Philips	270	94	Yes	Dr/CT	-	
137	23/03 17P	Noel	166	188	Yes	Dr/CT	-	
138	23/03 17Q1	Mallman	70	96	Yes	Dr/CT	68.57	Yes
139	23/03 17Q2	Kirschner	25	50		Dr/?	23.32	Yes
140	23/03 18A	Heights Water	207	177		Dr/CT	-	
141	23/03 18L	Needle Creek	300	192	Yes	Dr/CT	-	
142	23/03 20B1	Hillside	103	121	Yes	Dr/CT	103.85	Yes
143	23/03 20B2	Glen Acres	131	142	Yes	Dr/CT	-	
144	23/03 20F	Sauer	270	293	Yes	Dr/CT	-	
145	23/03 20G1	Stevens	260	123	Yes	Dr/CT	-	Yes
146	23/03 20G2	Stevens	260	34		Dg	29.71	Yes
147	23/03 29J	Tweedie	15	143	Yes	Dr/CT	-	
148	23/03 31D	Parker	393	173	Yes	Dr/CT	-	Yes
149	23/03 31E	Magee	390	160	Yes	Dr/CT	-	
150	23/03 31Q	King Co. Dist. 19	411	1005	Yes	Dr/R	398.0	Yes

Figure 4.2



Water Well Location Map

- Spring Well
- Dug Well
- Drilled Well
- Dry Drilled Well

Miles

0 1 2

Vashon-Maury

Water Resources Inventory

and readvance of glacial ice.

The most consistent and uniform deposit found in exposures and well logs is the silt and clay which lies below the Colvos Sand. This dense, thinly stratified and often varved fine-grained sediment is exposed near or above sea level around much of the perimeter of the Islands, and is penetrated by wells on the upland with adequate depth to reach sea level.

GENERAL GEOLOGICAL DESCRIPTION

For geologic mapping and cross sectional description purposes of this study, a system of identification with three generalized geologic units was used. Their identification and description is based on composite data of lithology, stratigraphic position and hydrologic impact. This model of geologic units and their probable relationship to units of previous studies of the area is shown in Table 4.1. A detailed description of each unit follows.

Unit I

This uppermost unit of glacial drift is predominantly lodgement till, usually blue-gray in color and resembling concrete in exposures. Exposures show very little weathering and stand nearly vertical without significant erosion. Unit I also includes deposits of ablation till and deposits of recessional sand and gravel. The unit mantles much of the upland of Vashon Island with thickness ranging from less than 1 foot to over 50 feet. The till is often found draped over pre-existing topography and masks the underlying sediments.

The till has very poor water-bearing characteristics, but sandy layers provide limited water to shallow dug wells. These sand and till contacts may form springs where exposed. Many of the Islands' drainfields are situated in Unit I, which usually has sufficient permeability to meet "perc" rate standards.

Unit II

This unit consists of relatively uniformly-graded deposits of sand, and sand and gravels. Sand layers in exposed sections are usually compact, often stratified and occasionally cross-bedded. Their degree of sorting and compaction vary from well-graded, loose alluvial gravels; to a uniformly-graded, dense silica sand. Sands and gravels generally occur as discontinuous layers within the sands. The sands of these layers are coarser and less uniform. Also contained are rounded gravels of pebble size (up to 2"), composed of crystalline rocks. The sand portion of the unit is typically light in color but shows iron staining at various locations. The sand grains are predominantly quartz and feldspar and are characteristically uniform in size. The unit is typically 50 to 100 feet thick, but exposures several hundred feet thick are found along the southeastern shore of Maury Island. Where saturated, this unit acts as an aquifer, providing water to most of the Islands' wells and virtually all of the major springs. Unit II is referred to as the Principal Aquifer.

Unit III

This unit is predominantly a homogenous blue to brown varved silt or clay, which may grade vertically into a silty clay with sand zones (more common toward the south end of Vashon Island). Coal-like peaty layers are exposed within the clay at several locations such as those near Dalco Point. Peaty layers have also been noted in several deep drill holes at elevations near sea level.

Unit III is commonly exposed near sea level around the periphery of the Islands and was mined for brick production in the early 1900's.

Toward the north end of Vashon Island, Unit III thickens, forming the cliff at Cove which is nearly 200 feet high.

Here a predominantly silty upper section overlies older and more dense clay. These deeper clay sections, which may correlate with exposures at Point Defiance, show considerable deformation near Burton and at Neil Point.

Unit III acts as an aquitard, slowing the infiltration of water out of Unit II, and forms springs where the two units are exposed around the perimeter of the Islands.

Sandwiched within Unit III, at about 100 to 300 feet below sea level, deep wells have penetrated a fine to medium grained water-bearing sand. This zone is designated as the Deep Aquifer. Thirteen widely spaced wells on the Islands have penetrated this Deep Aquifer. However, variations in aquifer depth, thickness and character make definitive correlation questionable. The Deep Aquifer may not be continuous under all of Vashon/Maury Island.

GEOLOGIC MAPS AND CROSS-SECTIONS

These three units have been used in construction of the geologic map (Figure 4.3) and cross-sections (Figure 4.4). Except for some minor differences, these maps are in agreement with those of prior studies. Prior mappings have included some deposits from the Salmon Springs glaciation.

Careful analysis of the available data indicates no significant hydrologic impact for deposits of this earlier glaciation.

Additional elements of the geologic map and cross sections not described above include landslides and the Deep Aquifer. Major segments of the perimeter of Vashon Island show massive landslide features. These are particularly prominent along the west side of Quartermaster Harbor and north of Ellisport. These massive block failures are triggered by water in sediments overlying the silts and clays of Unit III.

INTERPRETIVE MAPS

The thickness and altitude or configuration of these units forms a pattern which can be used to better understand the distribution of the water resource. Several maps have been prepared to facilitate such interpretation. Figures 4.5 and 4.6 show the thickness of Unit I, and the thickness of the Principal Aquifer Unit II.

The thickness of Unit I varies from less than 1 foot to over 50 feet. Where it is least permeable, Unit I shields the sands and gravels of Unit II from recharge because it transmits water poorly. Its depositional pattern, caused by direct glacial overriding of the Islands, reflects the chance distribution of materials in the ice when it melted.

The thickness of the Principal Aquifer (Unit II) is more interesting. It shows several centers of deposition, most of which are near or at the present Island margins. They apparently reflect the cascade of meltwater from glaciers which occupied the channels on either side of Vashon/Maury Island. Outwash sand and gravel carried by the meltwater was deposited in great alluvial aprons at the edge of the ice. There are several examples of these deposits on the Islands but the best examples are on Maury (See Figure 4.6). Here, three alluvial fans or depositional centers were formed and merged to form an apron which has been truncated on the southeast side of Maury Island. The source of the material, a tongue of glacial ice, occupied what is now the open channel of East Passage.

Because of its ability to transmit water, the thickness distribution of Unit II is a very important factor in recharge and storage of ground water on the Islands.

Figure 4.3

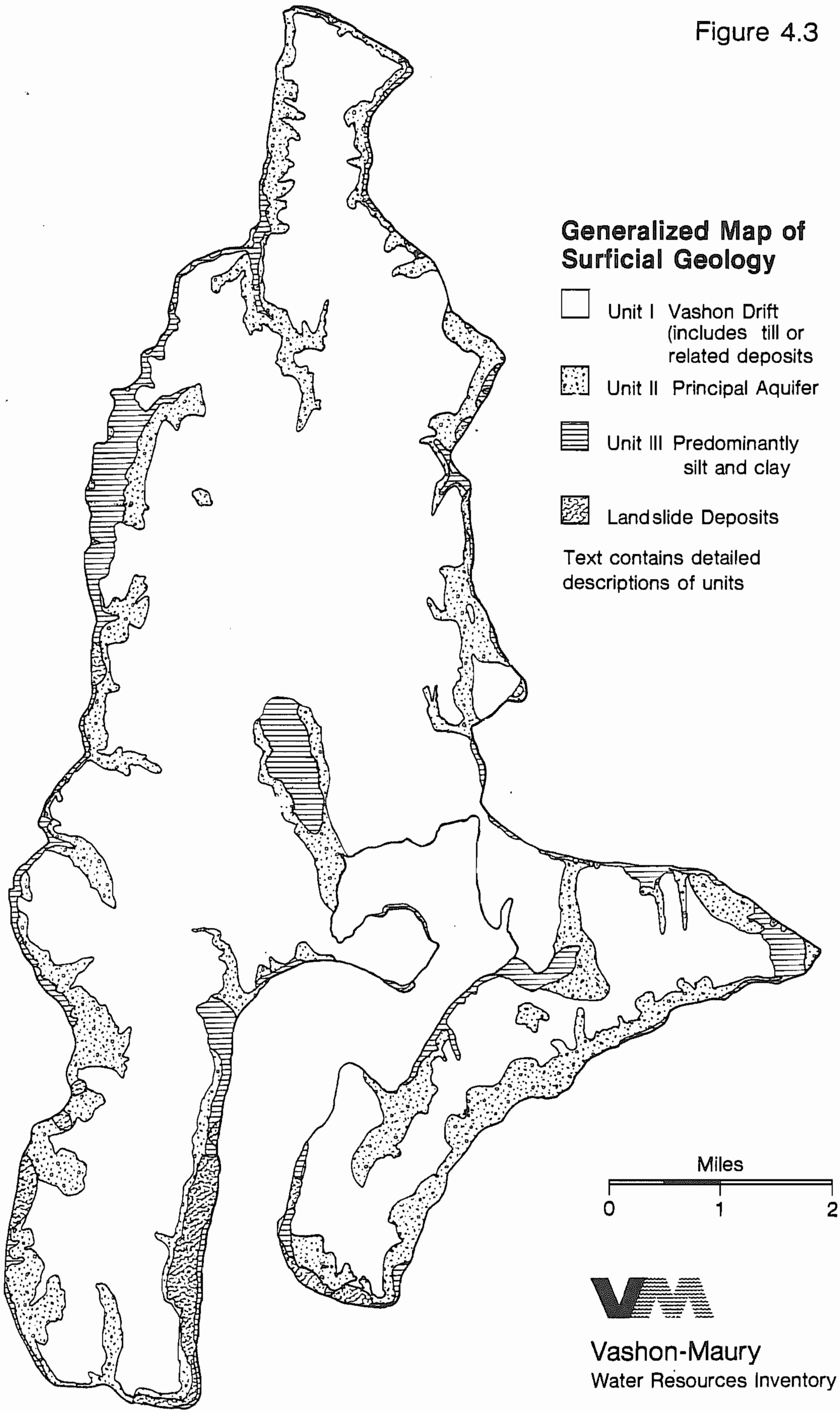

Generalized Map of Surficial Geology
Unit I Vashon Drift (includes till or related deposits
Unit II Principal Aquifer
Unit III Predominantly silt and clay
Landslide Deposits
Text contains detailed descriptions of units
Miles
0
1
2
Vashon-Maury
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Figure 4.4

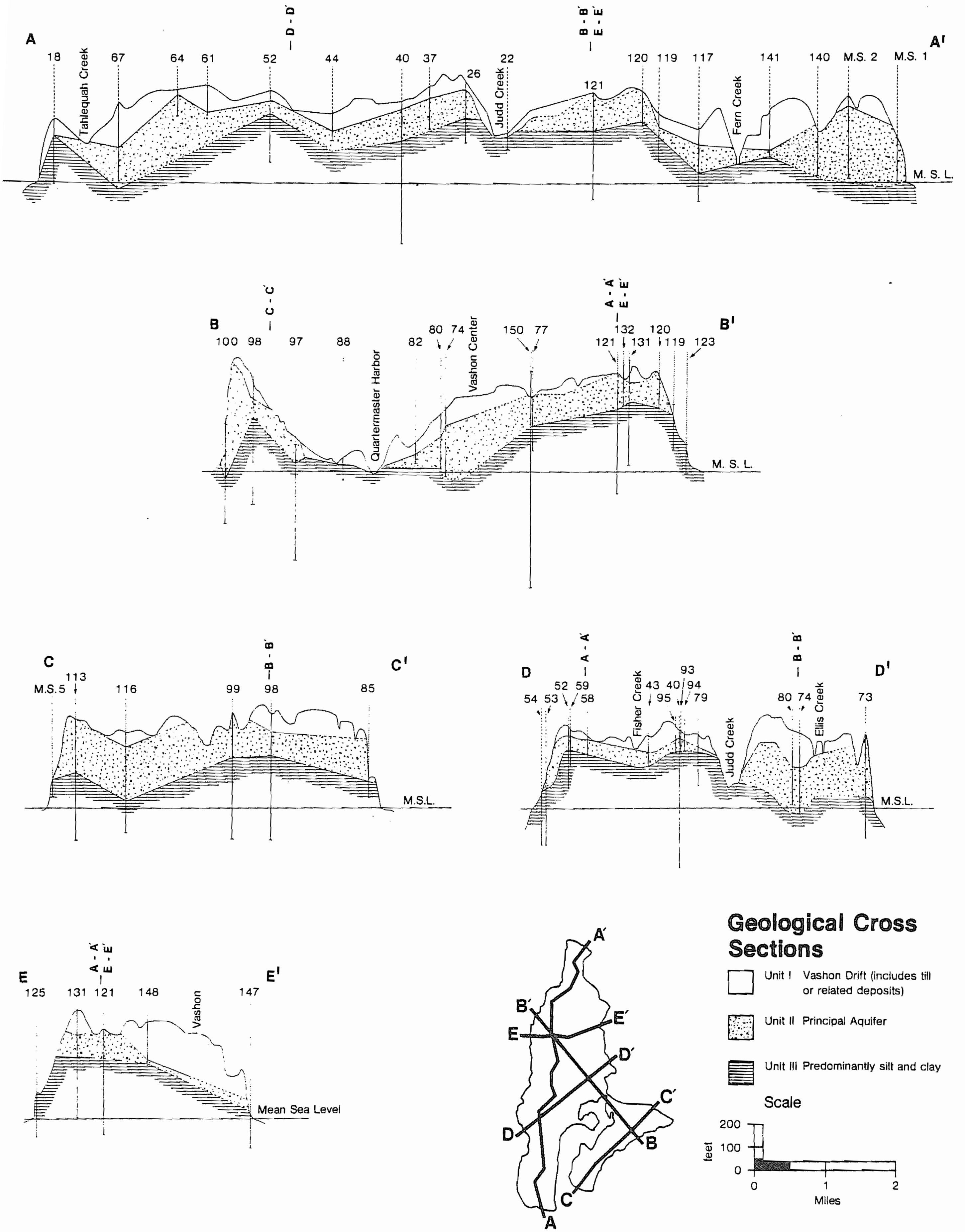
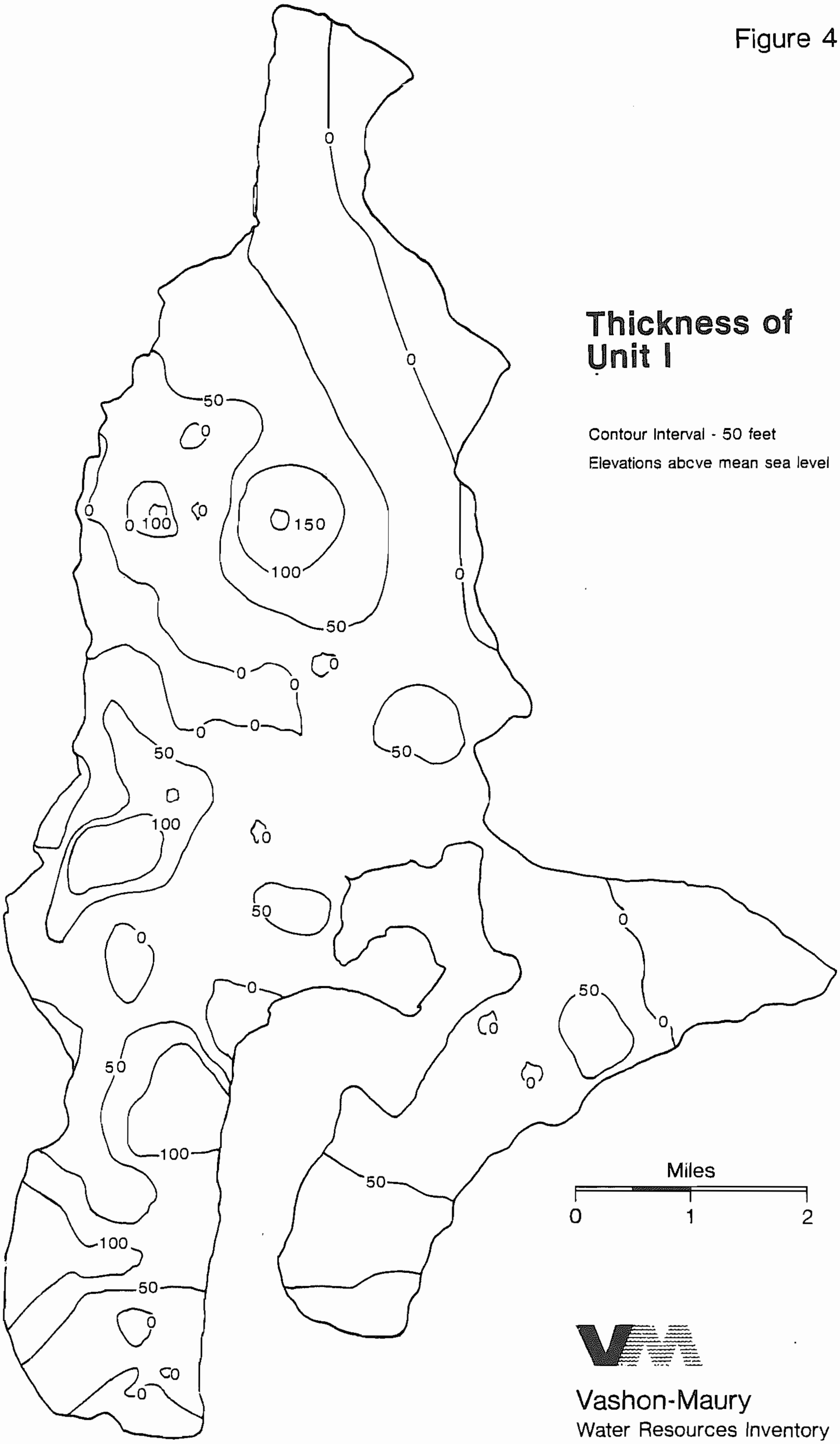

A
A'
D - D'
B - B'
E - E'
18 67 64 61 52 44 40 37 26 22 121 120 119 117 141 140 M.S. 2 M.S. 1
Tahlequah Creek
Judd Creek
Fern Creek
M. S. L.
B
B'
C - C'
A - A'
E - E'
100 98 97 88 82 80 74 150 77 121 132 131 120 119 123
Quartermaster Harbor
Vashon Center
M. S. L.
C
C'
M.S. 5 113 116 99 98 85
B - B'
M.S.L.
D
D'
A - A'
B - B'
54 53 52 59 58 43 93 40 94 95 79 80 74 73
Fisher Creek
Judd Creek
Ellis Creek
M.S.L.
E
E'
A - A'
E - E'
125 131 121 148 147
Vashon
Mean Sea Level
A'
B'
E
E'
D'
C'
D
B
C
A
Geological Cross Sections
Unit I Vashon Drift (includes till or related deposits)
Unit II Principal Aquifer
Unit III Predominantly silt and clay
Scale
200
100
0
feet
0 1 2
Miles

Figure 4.5

Thickness of Unit I

Contour Interval - 50 feet

Elevations abcve mean sea level



Vashon-Maury

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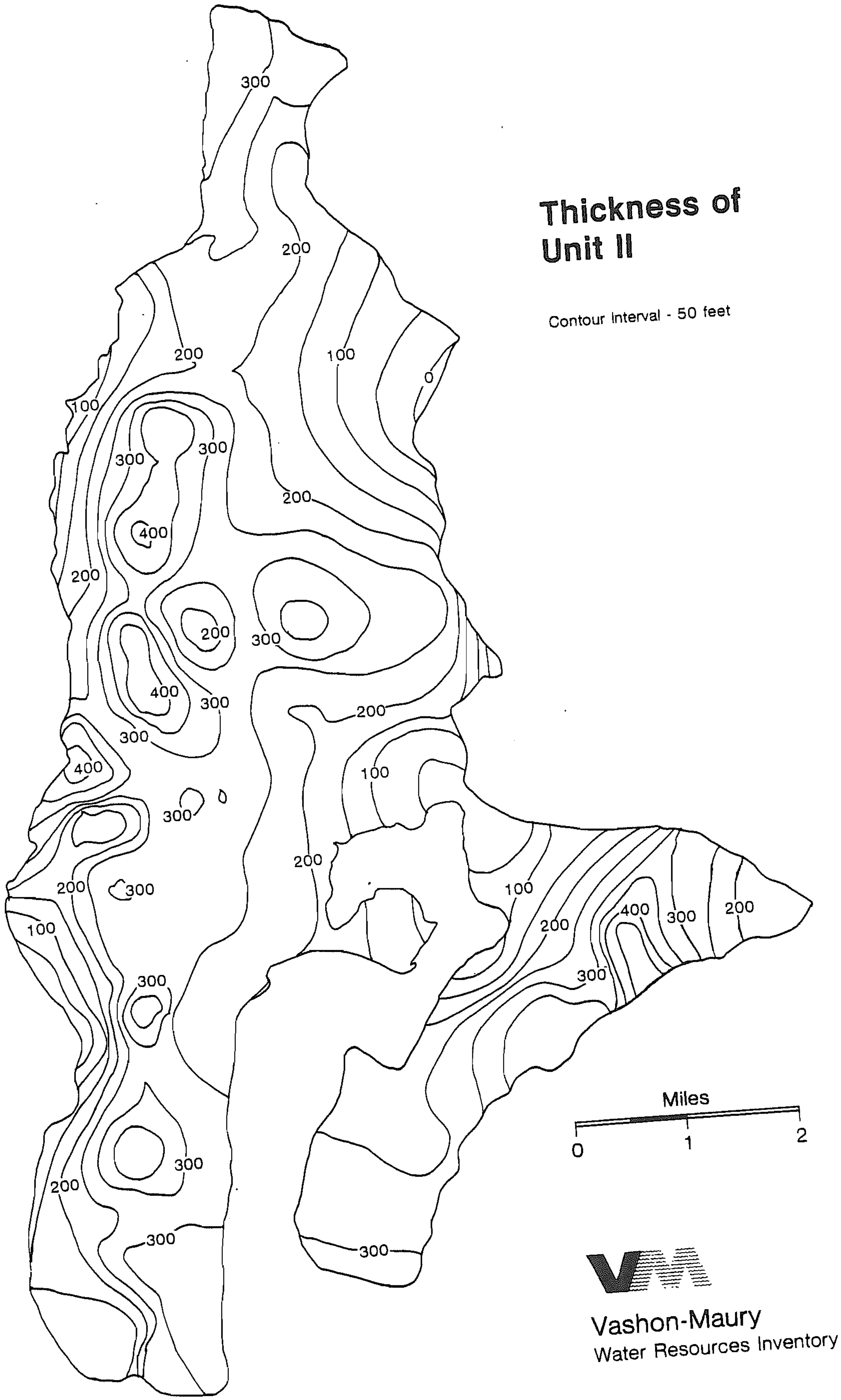
Figure 4.6


Thickness of Unit II
Contour Interval - 50 feet
300
200
100
0
400
Miles
0
1
2
Vashon-Maury
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CHAPTER 5

WATER BUDGET

All precipitation which falls on the Islands follows one of these paths:

- Runoff (in streams and overland flow)
- Evaporation (from air, surface waters and soil)
- Transpiration (from plants)
- Infiltration (into and through the soil)

This chapter presents calculation of the Islands' water budget, showing how much of the precipitation is discharged through evaporation, and transpiration. From the water budget, the water surplus can be estimated. Water surplus is defined as that portion of precipitation which infiltrates or runs off. The amount of infiltration is then used to calculate the recharge to the aquifers (see Chapter 6).

SUMMARY

Of the 40 inches of average annual precipitation on Vashon/ Maury Island, roughly half evaporates. The remaining 20 inches of rainfall either runs off or infiltrates through the soil.

In areas of high recharge potential (such as west-central Vashon) about 7 inches infiltrates to the Principal Aquifer while 11 inches are direct runoff. The remaining 2 inches may be available to recharge the Deep Aquifer system.

On an island-wide basis, runoff is estimated to be 15 inches. An estimated 4 inches of the surplus infiltrates to the Principal Aquifer and 1 inch recharges the Deep Aquifer.

METHOD

CALCULATION OF SURPLUS

Of the methods that have been devised to calculate water surplus, the best known are the Blaney-Criddle Method and the Thornthwaite Method. The Blaney-Criddle Method has application primarily in irrigation and agriculture. The Thornthwaite Method has broader application for hydrologic studies and has proven very applicable to the conditions of the Puget Sound area.

Thornthwaite Method

The Thornthwaite Method can be stated as:

Surplus (at a selected soil moisture capacity) = Precipitation - Actual Evapotranspiration

where each factor is in inches and described as:

Precipitation: the atmospheric water which falls to the land surface measured in rain gages.

Actual Evapotranspiration: the amount of water discharged to the atmosphere from soil, surface waters, and vegetation. The calculation of actual evapotranspiration uses an empirically derived relationship for potential evapotranspiration to account for solar radiation based on the local temperature and latitude.

Soil Moisture Capacity: the equivalent inches of water held in the soil profile for discharge as evaporation or infiltration. (Sandy soils have lower moisture capacities than silty or clayey soils.) For Vashon/Maury Island, a 4-inch soil moisture capacity provides the most reasonable result. In the graphic model (Figure 5.1), soil moisture capacity over time is shown as "soil moisture utilization."

Analysis

Two sets of data are available for analysis:

SET I. Precipitation: using 1941-70* Sea-Tac 30-year monthly rainfall averages

Evapotranspiration: using 1941-70* Sea-Tac 30-year monthly average temperature

Soil Moisture Capacity: using 4-inch profile

Using this data the calculated surplus is:

Surplus = 38.79 - 18.54 = 20.25 inches

SET II. Precipitation: using 1982 monthly totals from Water District 19 offices

Evapotranspiration: using 1982 Sea-Tac monthly average temperatures

Soil Moisture Capacity: using 4-inch profile

Using this data the calculated surplus is:

Surplus = 47.83 - 15.42 = 32.41 inches

Interpretation

The 1982 Vashon/Maury Island precipitation data produce a surplus of about 12 inches more than the 30-year average at Sea-Tac Airport. The longer period of record is more meaningful because the short term irregularities of precipita-

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* 1941-70 average applied because 1951-80 not available at time of calculation.

tion are averaged. The 30 year average of 20 inches is then a more correct, albeit conservative, estimate of water surplus.

A graphical representation of the relationships between precipitation, evapotranspiration and soil moisture capacity (as soil moisture utilization) is shown in Figure 5.1. Here, using the 30-year Sea-Tac average monthly values, January begins with a water surplus which continues until evaporation exceeds precipitation in May when a water deficit is created and continues through early October. However, water surplus does not reoccur until the soil moisture is replenished in mid-November.

CALCULATION OF RUNOFF

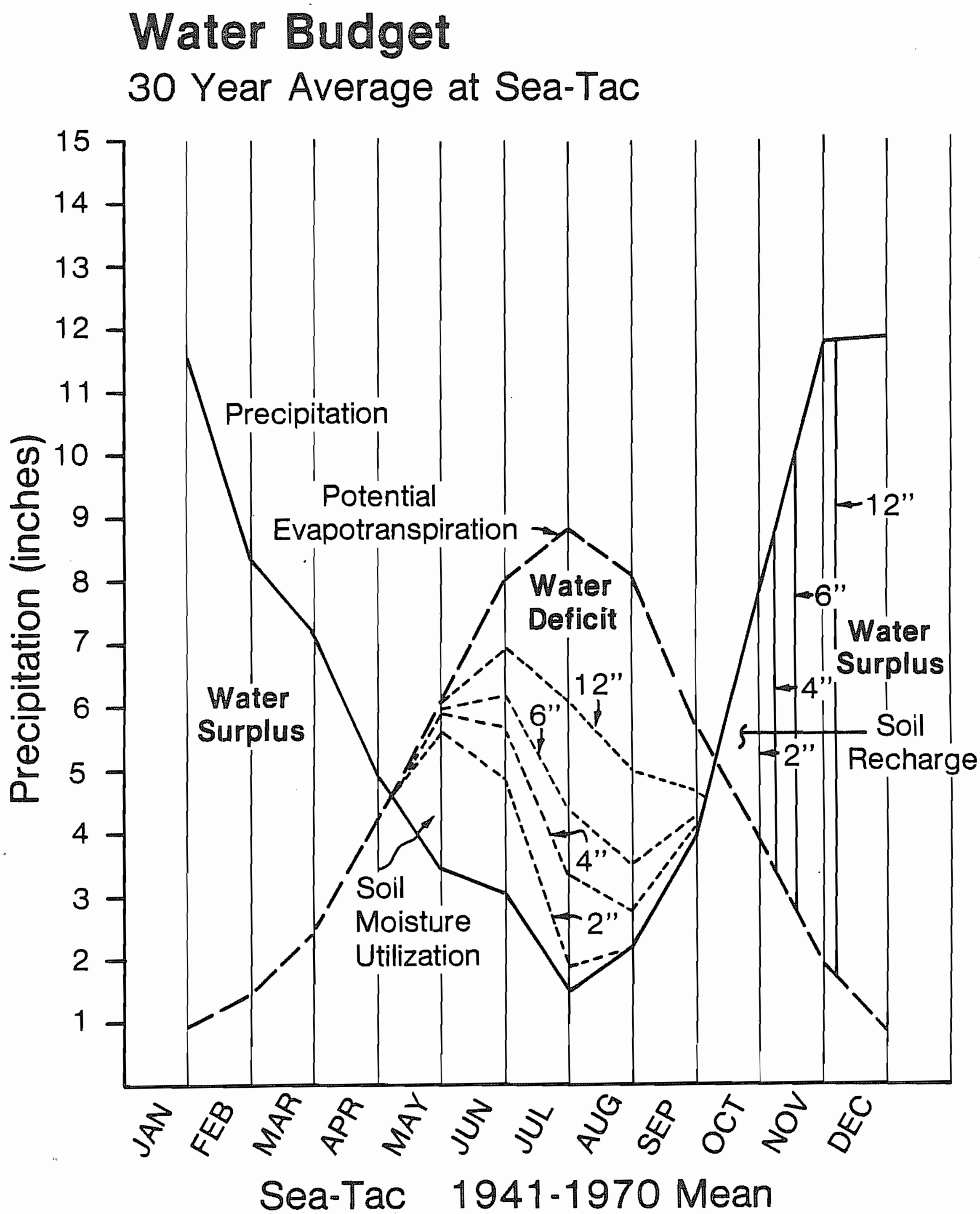
As discussed above, the water surplus estimate includes both runoff and infiltration. To determine the amount of water available as ground water resources, the relationship between runoff and infiltration must be distinguished.

Analysis of stream runoff requires accurate, long-term records of stream flow and precipitation. The only known long-term runoff records for Vashon/Maury Island are those by the USGS on Judd Creek from 1968-1975. Precipitation data from Sea-Tac for the same period are used in this analysis.

Monthly runoff and precipitation records for the 1968-75 period are compared to the 30 year average precipitation in Figure 5.2. Average precipitation for this 8-year period was about 1 inch greater than the 30-year average. The water surplus reaches a maximum in January and falls to zero from May through October.

Runoff in Judd Creek was at its maximum during January and reached its base flow during July and August. The runoff data are presented here in equivalent inches of water using

Figure 5.1



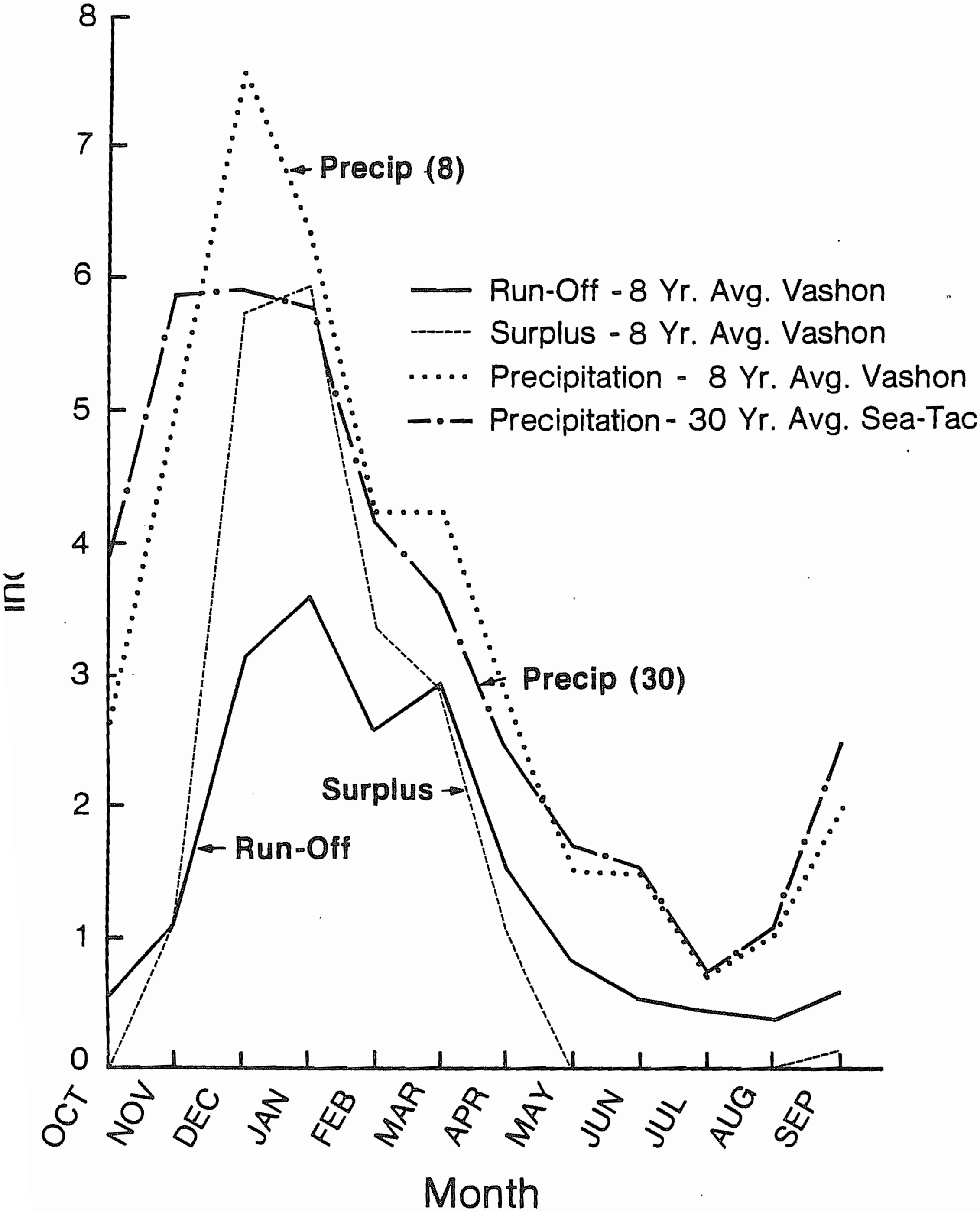
(For Vashon/Maury - 4-inch soil moisture capacity provides the most reasonable result.)

Vashon-Maury
Water Resources Inventory

Figure 5.2

Judd Creek Run-Off Analysis 1968-1975

Using Sea-Tac Precipitation As Indicated



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Water Resources Inventory

the 4.41 square mile area (USGS computerized data)* of the Judd Creek drainage basin.

For the 1968-1975 period the records show the following:

Average Precipitation = 39.87 inches
Average Water Surplus = 20.41 inches
Average Runoff = 18.38 inches

The runoff in Judd Creek consists of both direct runoff and ground water intercepted by the creek which has infiltrated through the soil and sediments overlying the clayey aquitard (Unit III). The difference between average surplus (20 inches) and average runoff (18 inches) represents an estimate of the amount of precipitation which escapes interception by Judd Creek and is available for recharge to deeper underlying aquifers. Thus, in the area of Judd Creek, about 2 inches of the precipitation may be available to recharge the Deep Aquifer system.

CALCULATION OF INFILTRATION

To estimate the amount of surplus which infiltrates to the Principal Aquifer, we have examined the amount of water taken into and released from storage in a recharge area in the west central part of Vashon Island. This area, (Figure 5.3) around well 48, shows that a bell-shaped mound was formed between fall of 1981 and spring of 1982 and that the mound dissipated between spring of 1982 and fall of 1982.

Computations show that about 14,000 acre-feet of water infiltrated into the mound between the fall of 1981 and spring of 1982. Dividing this volume by the area over which the mound occurs, and adjusting for the estimated porosity (15%), shows the total volume of infiltrated water to be about 45% of the surplus and 23% of the 1981-82 precipitation at Sea-Tac.

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* USGS estimate is lower than that presented in Chapter 2 of this report, and in <u>Water Supply Bulletin 18</u>.

Because the precipitation at this location is probably greater than at Sea-Tac, the actual infiltration percentage is probably slightly less than 23%. Soil characteristics and other natural conditions make this location one of the primary recharge areas for the Island.

For the west-central recharge area of Vashon, the relationship between water surplus, runoff and infiltration can be summarized as shown in Table 5.1.

TABLE 5.1

WEST-CENTRAL VASHON

Item	Inches	% of Precipitation	% of Surplus
Precipitation	40	100	xx
Water Surplus	20	50	100
Direct Runoff	11	27.5	55
Infiltrated Runoff (captured from Principal Aquifer by stream)	7	17.5	35
Infiltration to Deep Aquifer System	2	5	10

However, average infiltration over most of the Islands probably does not exceed 12.5% of the precipitation. The Island-wide relationships are summarized in Table 5.2.

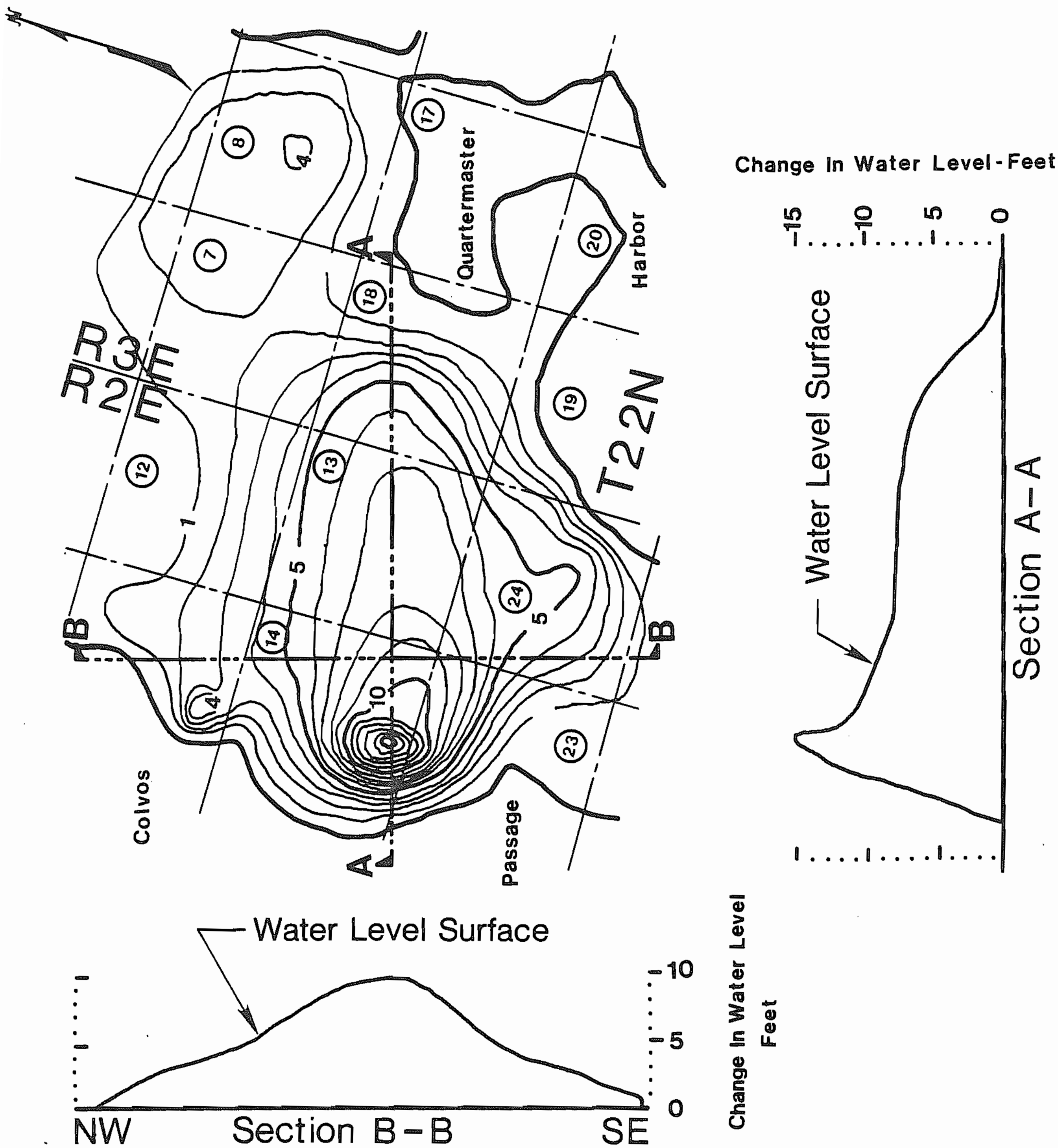
TABLE 5.2

ISLAND WIDE

Item	Inches	% of Precipitation	% of Surplus
Precipitation	40	100	xx
Water Surplus	20	50	100
Direct Runoff	15	37.5	75
Infiltrated Runoff (captured from Principal Aquifer by stream)	4	10	20
Infiltration to Deep Aquifer System	1	2.5	5

An Island-wide distribution of precipitation is shown graphically in Figure 5.4.

Figure 5.3



RECHARGE MOUND

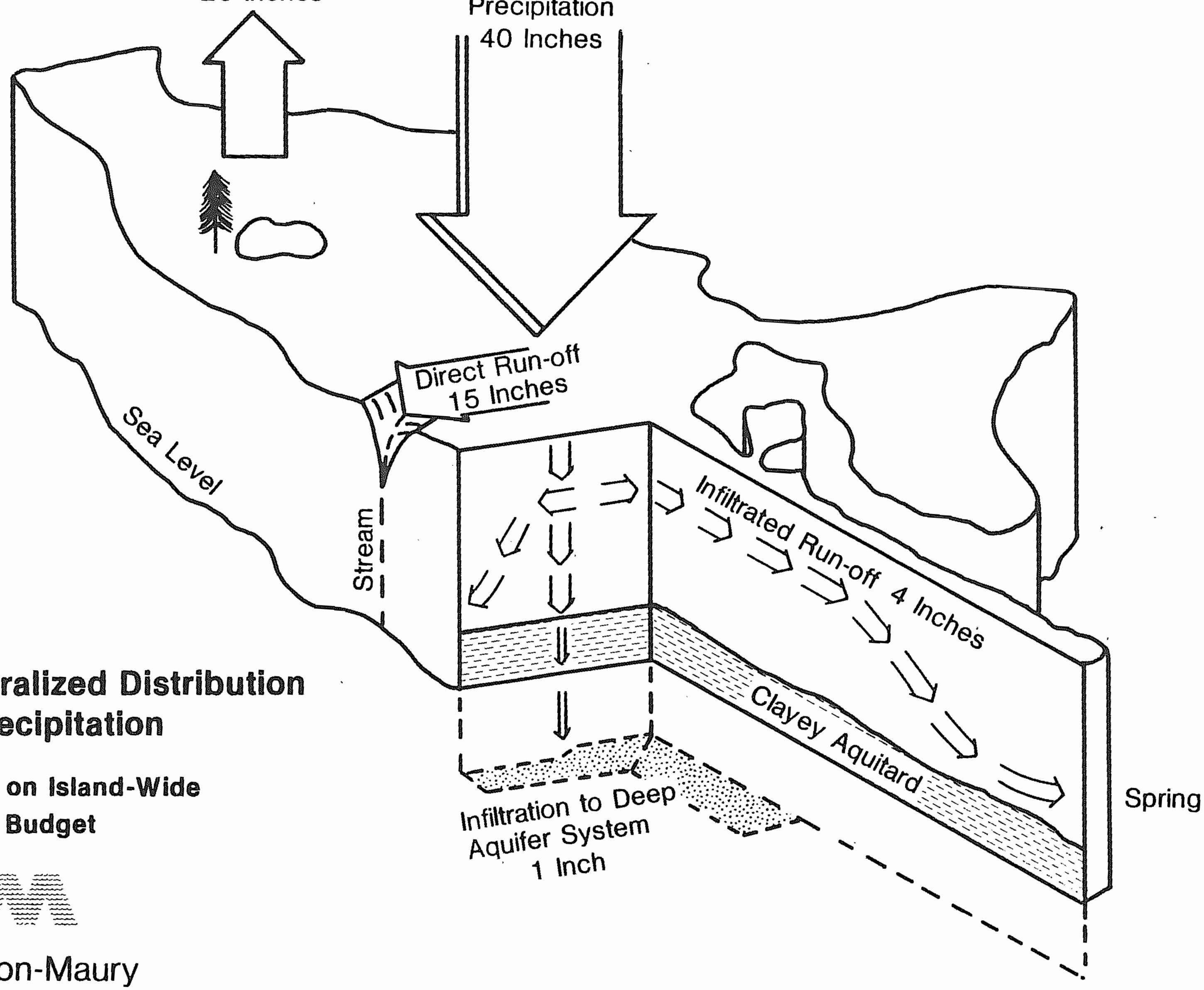
Contour Interval = 1'

Scale: Horizontal 1" = 4,000'

Vertical 1" = 10'

Vashon-Maury

Water Resources Inventory



Generalized Distribution of Precipitation

Based on Island-Wide Water Budget

Vashon-Maury
Water Resources Inventory

Figure 5.4

CHAPTER 6

RECHARGE

Water which infiltrates through the Islands' soil and substrata and replenishes the ground water is termed recharge. This chapter compares the relative amounts of recharge occurring in various parts of the Islands, and estimates the inches of recharge in each. This evaluation can be used to protect and enhance areas of optimum recharge and to estimate the total amount of water which replenishes the ground water system.

SUMMARY

All of the glacial sediments which compose Vashon/Maury Island are permeable to some degree. As a consequence, recharge takes place everywhere on the Islands. The recharge potential map presented in this chapter delineates areas of high, medium, and low recharge. The most important area of recharge to the Principal Aquifer is along a north-south corridor of west-central Vashon Island. Recharge to the Principal Aquifer is estimated at 9 inches in the high recharge potential level, and at 5 inches and 3 inches in the medium and low recharge potential levels. These amounts are equivalent to a total recharge of about 9 million gallons per day (mgpd), or about 6,000 gallons per minute (gpm). (Only a portion of this amount is recoverable - see Chapter 9.) Because there is very little data on the Deep Aquifer, estimates of its recharge are necessarily sketchy. The major recharge area for the Deep Aquifer may be west-central Vashon Island, and its total amount of recharge is probably less than 3 mgpd (2,000 gpm). This investigation has found no basis for off-island sources of recharge to the known Island aquifers.

BACKGROUND

OFF-ISLAND SOURCES OR RECHARGE

A popular concept among some Island residents is that the Islands' water comes from off-island sources such as the Olympic Mountains, Mt. Rainier or Mt. Baker. Many residents of the San Juan Islands also believe that their water supply originates on Mt. Baker. This concept was discussed and displayed pictorially in **Water Supply Bulletin 46, Geology and Water Resources of the San Juan Islands.**

While the idea of an endless supply of high quality water may give residents a certain amount of comfort, this investigation has found no basis for off-island sources of any of the currently known water resources of Vashon/Maury Island. For the Islands' water supplies to be derived from off-island sources would require:

- Recharge areas at very high elevations to force the water through the aquifers to the Island.

- Continuity of aquifers from the Island to the mainland or the peninsula, presumably through structural down warps under East Passage and Colvos Passage.

- Significant artesian pressure in wells completed at depth.

Elevation of Aquifers

Data produced by this study contradict all of the above requirements. First, as shown in the cross-sections of Vashon/Maury Island presented in Chapter 4, the aquifers and intervening aquitards, are all rather flat and show no structural deformation or downwarping that would carry them beneath Puget Sound. The Principal Aquifer is above sea level throughout nearly the entire study area.

Continuity of Aquifers

Secondly, the deepest portions of the Deep Aquifer are about 300 feet below sea level on Maury Island (wells 88 and 97). Most of the Deep Aquifer lies at an elevation of between 100 and 200 feet below sea level. Vashon/Maury Island is surrounded by deep bodies of salt water. East Passage, which lies between the Islands and the mainland, is over 600 feet deep (600 feet below sea level) along its entire reach from north of Vashon Island to Dalco Passage on the south. Colvos, or West Passage, has depths of at least 300 feet all along the west side of Vashon Island. The depth of the waters surrounding Vashon/Maury Island is illustrated in a perimeter bathymetry map in Figure 6.1.

Between the north end of Vashon Island and Blake Island, the depth of the salt water decreases to less than 100 feet, allowing for possible undersea connection of deep aquifers between those two islands. Between Blake Island and the south end of Bainbridge Island (Beans Point and Restoration Point) a connection at a depth of less than 200 feet is possible. However, highly impermeable bedrock is exposed at the south end of Bainbridge Island. This bedrock forms the Bainbridge reef and Orchard Rocks between Blake and Bainbridge Islands, precluding the likelihood of recharge from that area.

The shallowest part of the salt water surrounding Vashon/Maury Island lies between the south end of Vashon Island and Gig Harbor (see Figure 6.1). This area, shown as Y-Y' on Figure 6.1 was examined in detail. Cross-section Y-Y' in Figure 6.2 shows Colvos Passage having two channels which extend about 200 feet below sea level, separated by a rather wide mound which is about 120 feet below sea level. Because no wells of record have been drilled into the Deep Aquifer near the location of this cross-section on Vashon Island, there is no certainty that the aquifer is present in that

Figure 6.1

Perimeter Bathymetry

Depths in Feet Below Sea Level

Vashon-Maury
Water Resources Inventory

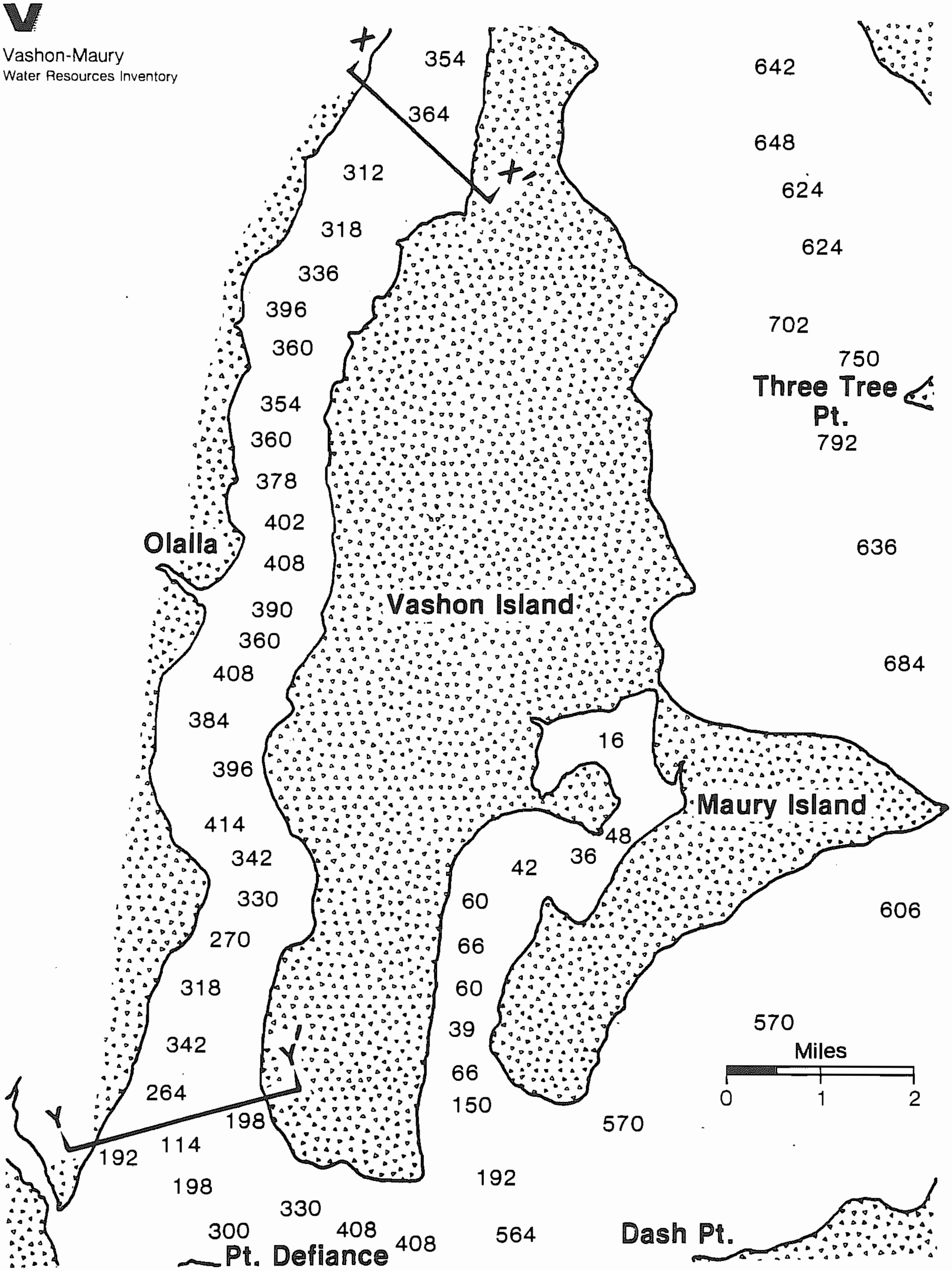
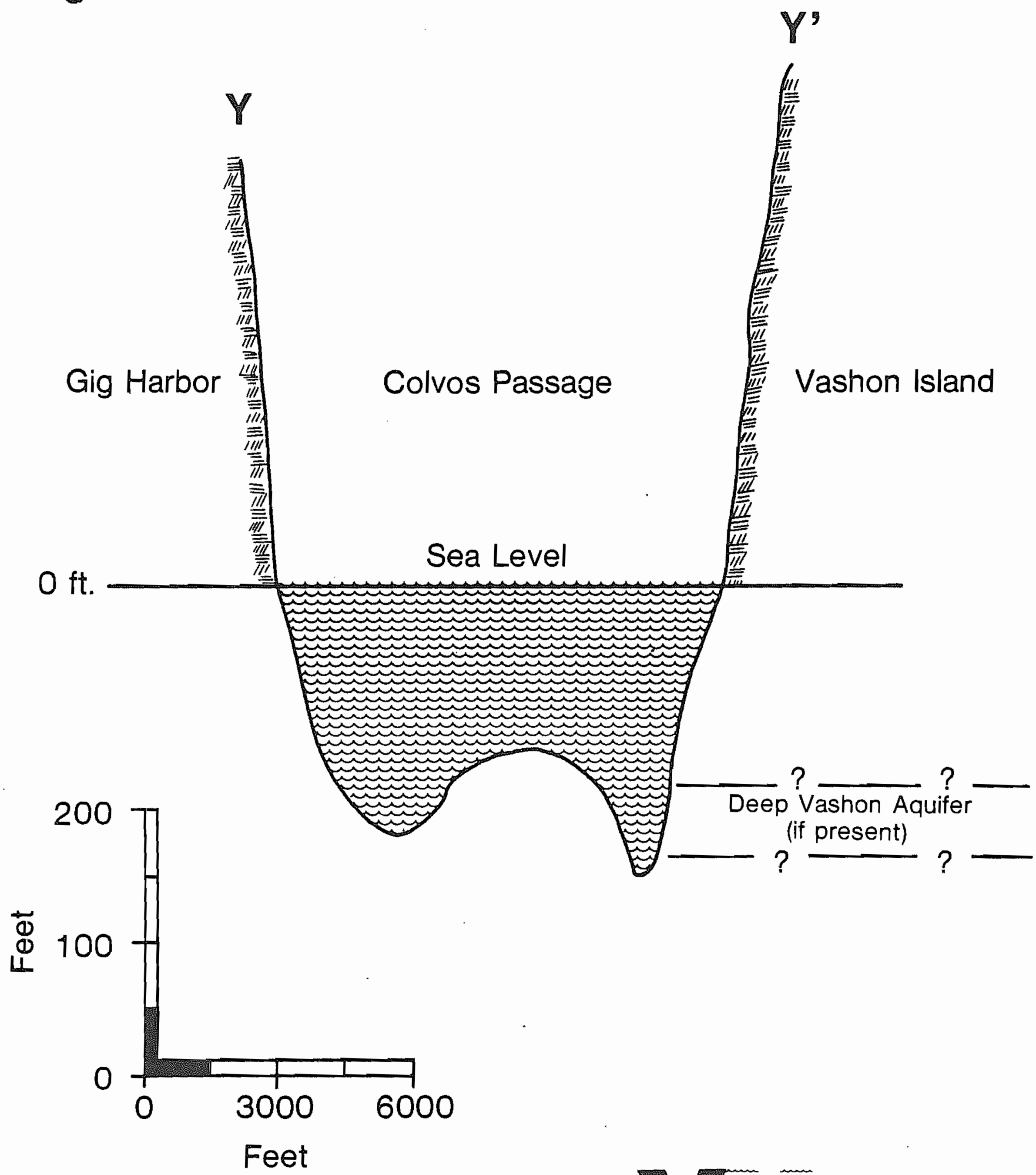


Figure 6.2

Cross Section Y-Y'
Gig Harbor-Vashon Island



- 500 ft.—— ? ——— ?
Deep Aquifer Serving Gig Harbor
(Below Elev. -500 ft. ±)

Vashon-Maury
Water Resources Inventory

area. However, as shown in all the cross-sections, the deepest part of the aquifer would probably still be above the lowest part of Colvos Passage, eliminating a potential for cross-sound connection to the Gig Harbor Peninsula. On the Gig Harbor side of Colvos Passage, a deep aquifer was penetrated at about 500 feet below sea level in a well completed in 1977 by the Town of Gig Harbor. Drilling to an elevation of nearly 600 feet below sea level in well 150, King County Water District 19 encountered the Deep Aquifer from 150 feet to 250 feet below sea level and only silt and clay below that depth. Thus the deep "Gig Harbor aquifer," which could conceivably have a narrow connection to Vashon Island, has not been encountered by drilling on the island.

A possible connection to the Southworth area beneath Colvos Passage has also been examined through the construction of the cross-section X-X' in Figure 6.3. As shown, Colvos Passage in that area has a depth of over 300 feet below sea level, which is over 100 feet below the position of the known Deep Aquifer on Vashon Island. In the Southworth-Manchester area, there are no known significant deep productive aquifers.

Artesian Pressure

Finally, any aquifers recharged from areas of high elevation off the Islands would be expected to produce artesian head in Island wells. In this scenario, Vashon/Maury Island would be the discharge area for the aquifer system being recharged by these off-island sources. Aquifer discharge areas are characterized by progressively higher head from successively deeper aquifers. In other words, the water levels in successively deeper aquifers would be higher and higher. Just the opposite has been found on Vashon/Maury Island. That is, water levels in wells on the Islands drop with the depth of the well and the depth of the aquifer in which they are completed.

Figure 6.4 is a map of selected wells with variable depths. The relationship between their water levels and depth is shown in Figure 6.5. The graph indicates that, without exception, the elevation of the water level decreases in deeper aquifers. Thus, water from the shallow aquifers is infiltrating to the underlying deeper aquifers through the intervening sediments.

It is also interesting to note that the slope of these lines connecting wells in an area is remarkably uniform. As shown, this downwardly vertical gradient is about 50 feet per 100 feet of well depth over much of the study area.

The relationships shown in Figure 6.5 could be used to predict water levels in Island wells. For example, an aquifer encountered at an elevation of about 100 feet below sea level in the central part of the Vashon Island (well group line 75, 77 and 150) would have an expected elevation of the static water level of about 120 feet above sea level. Other well group lines could be used to predict water levels in other areas of the Islands.

Conclusion

Considering all of the above information, there is no evidence of off-island recharge of the water resources of Vashon/Maury Island. Careful study of the data indicates that all of the water from both the Principal and Deep Aquifer, as well as lakes, ponds and streams, originates as precipitation on the Islands.

RECHARGE OF THE PRINCIPAL AQUIFER

METHODOLOGY

To identify the areas of optimum recharge and determine the Recharge Potential Level (high, medium, or low) of the Islands, three separate methods were used:

Figure 6.3

Cross Section X-X'
Southworth Area-Vashon Island

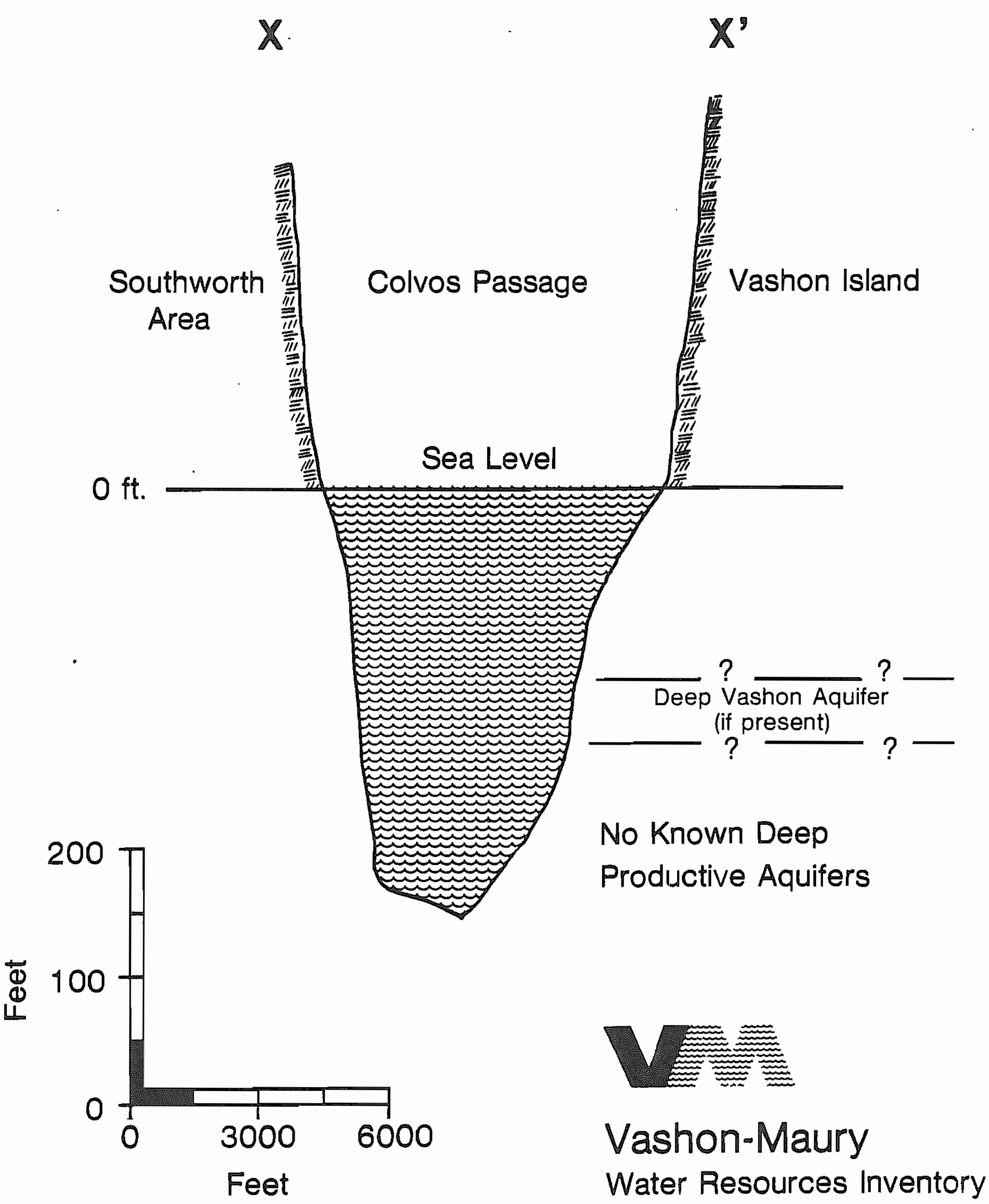
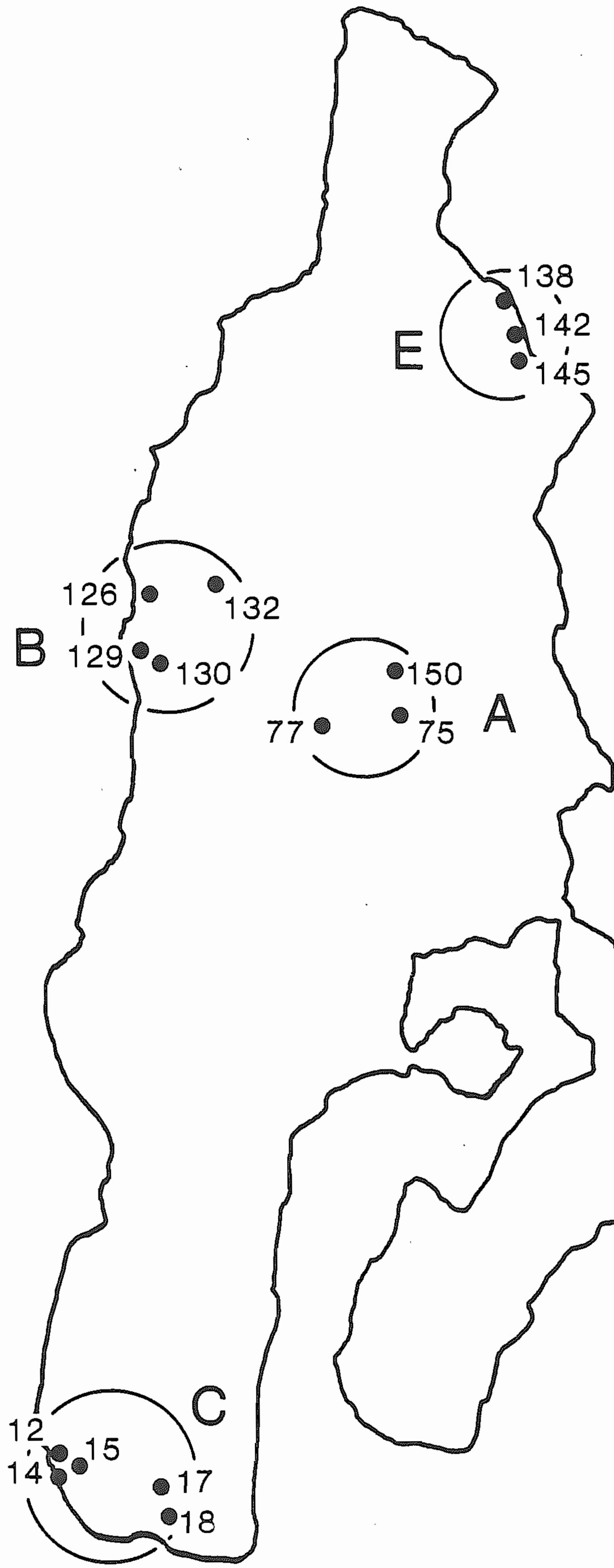


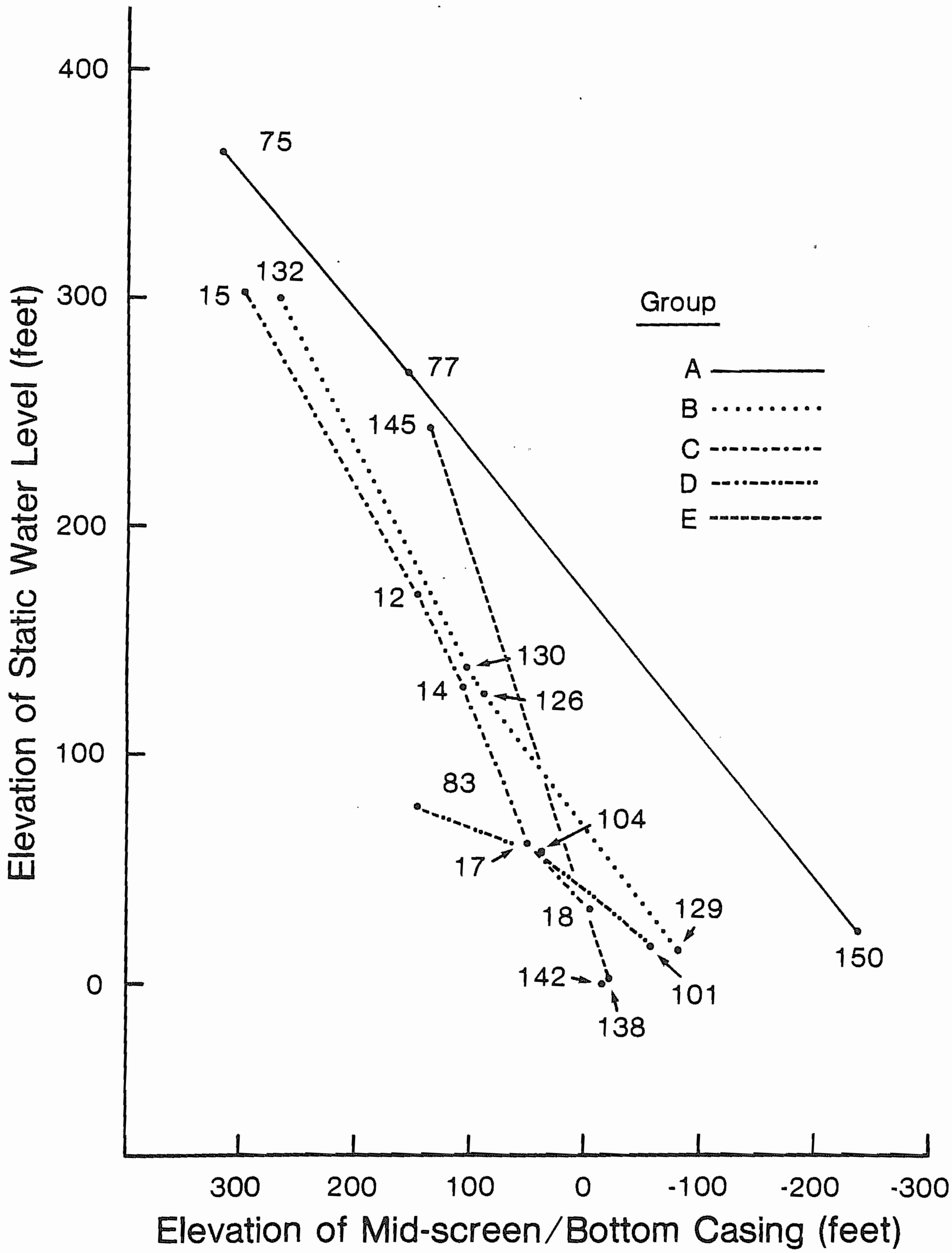
Figure 6.4

Location of Wells used in Figure 6.5



Vashon-Maury
Water Resources Inventory

Relationship of Aquifer Elevation to Elevation of Water Level



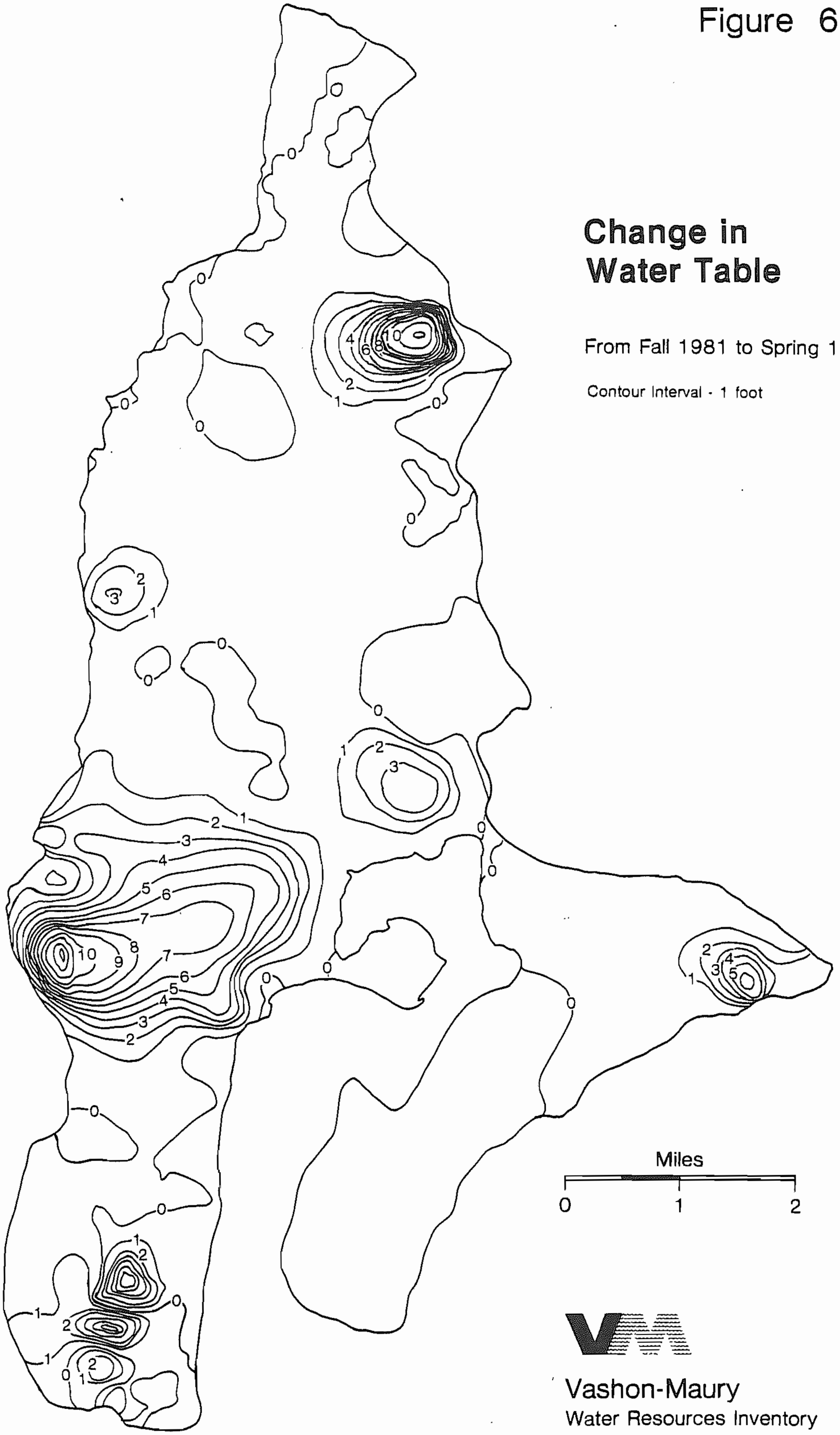
Vashon-Maury
Water Resources Inventory

Figure 6.6

Change in Water Table

From Fall 1981 to Spring 1982

Contour Interval - 1 foot



Miles

0 1 2

Vashon-Maury

Water Resources Inventory

- Water levels (elevation and amplitude of fluctuation)
- Physical characteristics (surface and subsurface)
- Time delay (water level response)

Water Levels (Elevation and Amplitude of Fluctuation)

Under uniform conditions, areas with the highest water table elevations will coincide with recharge areas. Areas which show marked change in elevation during the period of greatest recharge should coincide with or be close to the locus of recharge.

Water level elevations for wells in the Principal Aquifer were utilized to construct water table maps for fall, 1981, (Chapter 3, Figure 3.6), spring, 1982, and fall, 1982. Changes in water level from fall, 1981 to spring, 1982, which represent the time of principal annual recharge were also plotted and contoured as Figure 6.6. Changes which occurred from spring, 1982 to fall, 1982 were plotted as Figure 6.7. (These computer-assisted maps were prepared using the STAMPEDE program.)

Water Table maps (i.e. Figure 3.6) shows highest water levels along west-central Vashon Island, and mounds near Point Beals and the north end of Maury Island. The mound features are, in part, a result of higher water levels in perched aquifers. The amount of recharge from these perched aquifers is probably not as significant as that of west-central Vashon Island.

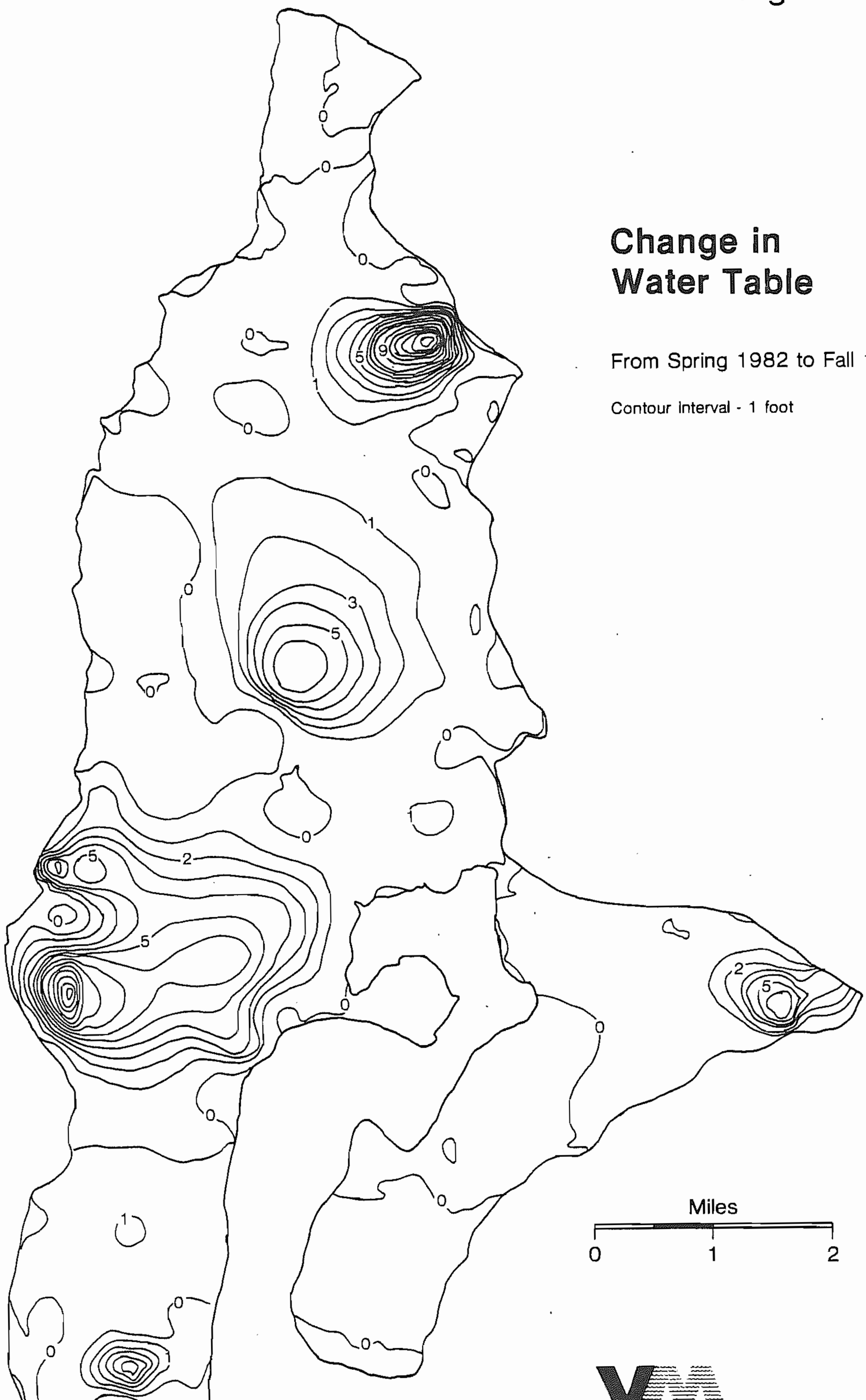
The water table fluctuation maps in Figures 6.6 and 6.7 show five areas of significant fluctuation. The largest and most important of these is a large area immediately west of Burton. Details of this recharge mound were illustrated earlier. (Chapter 5, Figure 5.3)

Figure 6.7

Change in Water Table

From Spring 1982 to Fall 1982

Contour Interval - 1 foot



Vashon-Maury
Water Resources Inventory

RECHARGE MATRIX

Recharge Potential Level	Soil * Types	Subsurface Geology (Permeability/Clastic Ratio)	Topography (slope)	Vegetation
Low	Alderwood Arent-Alderwood Bellingham Kitsap Seattle Shalkar Low Permeability	Clastic Ratio: less than 1	Steep greater than 30%	Urban Areas
Medium	Everett Norma Rogner Medium Permeability	Medium Permeability Clastic Ratio: about 1	Moderate 6-30%	Forest
High	Indianola Orcas High Permeability	High Permeability Clastic Ratio: greater than 1	Low 0-6%	Grassland brush and cultivated land

* Soil type classification by U.S. Soil Conservation Service, King County, Washington

TABLE 6.1
RECHARGE MATRIX

Physical Characteristics (Surface and Subsurface)

Evaluation of soils, subsurface geology, topography and vegetation provides a means to estimate relative recharge potential. These characteristics are presented in the recharge matrix found in Table 6.1 which defines low, medium and high Recharge Potential Levels.

Soil type uses the U.S. Soil Conservation Service designation and permeability results to define the three categories.

Evaluation of subsurface geology employs a ratio of coarse clastics (sand and gravel) to fine clastics (silt and clay) as described in the available well logs. Here, larger values of the calculated ratios represent greater permeability.

Slope, determined from topographic maps, established an inverse relationship where high, medium and low Recharge Potential Levels correspond to low, moderate and steep slopes respectively.

The effect of vegetation is designated as high, medium and low recharge potential levels for grasslands, forests, and urban areas respectively.

The geographical distribtution of these characteristics is shown as:

Soil Permeability	Figure 6.8
Subsurface Permeability	Figure 6.9
Slope	Figure 6.10
Vegetation	Figure 6.11

Each weighted characteristic can then be superimposed as shown in Figure 6.12. The resultant derivative map Figure 6.13 delineates the areas of high, medium and low Recharge Potential Levels (RPL) on the Islands.

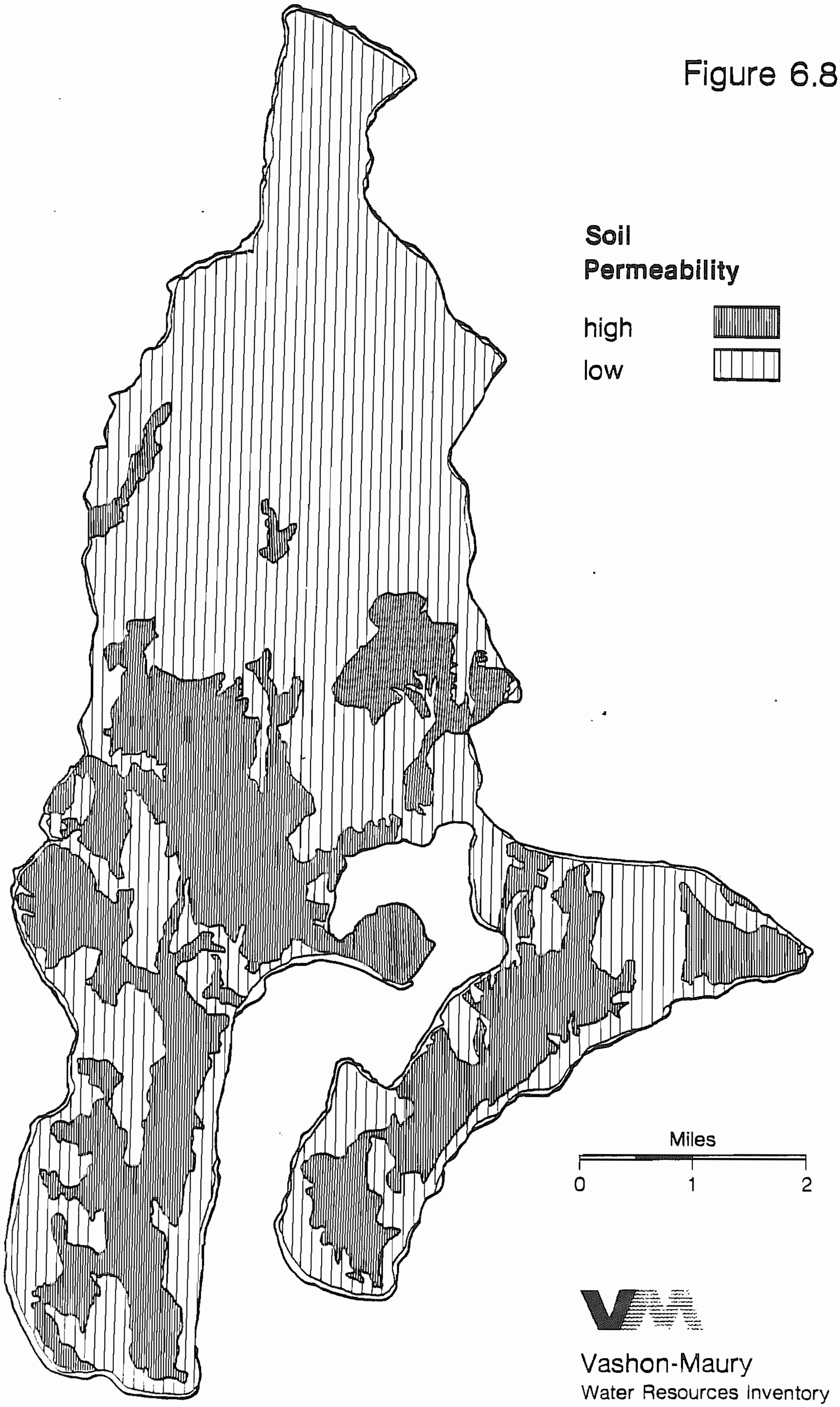
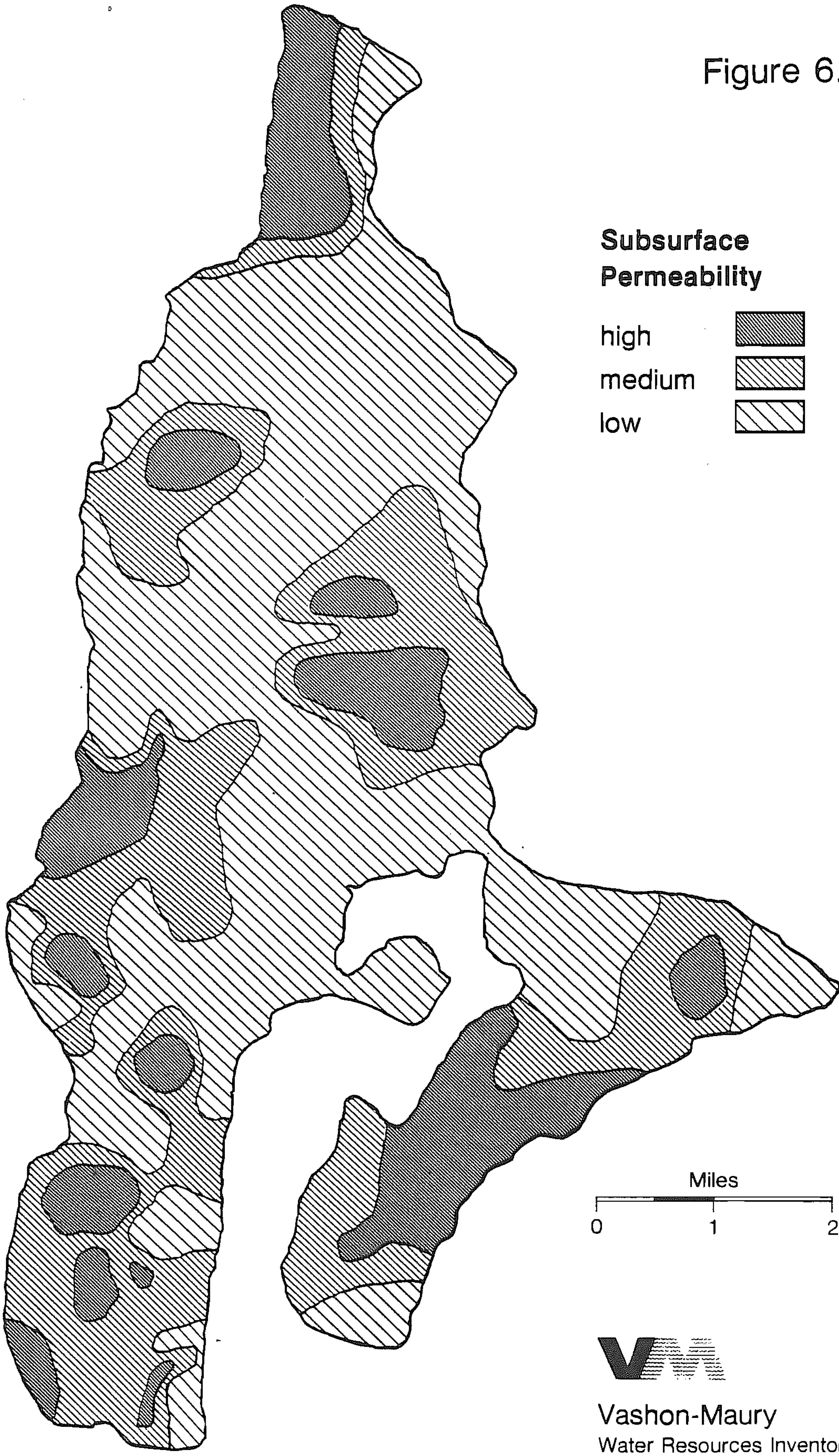


Figure 6.8
Soil
Permeability
high
low
Miles
0
1
2
Vashon-Maury
Water Resources Inventory

Figure 6.9



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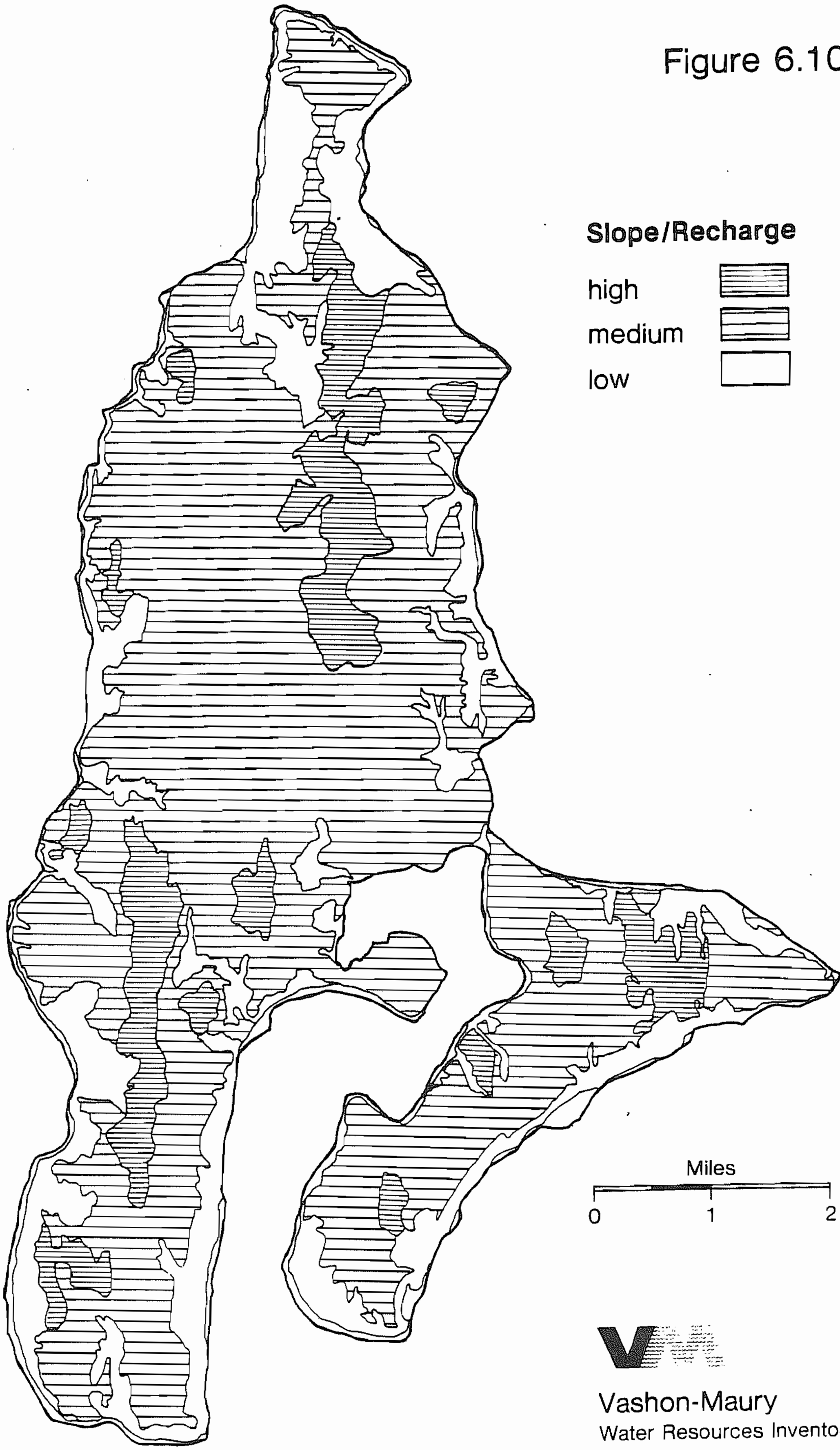
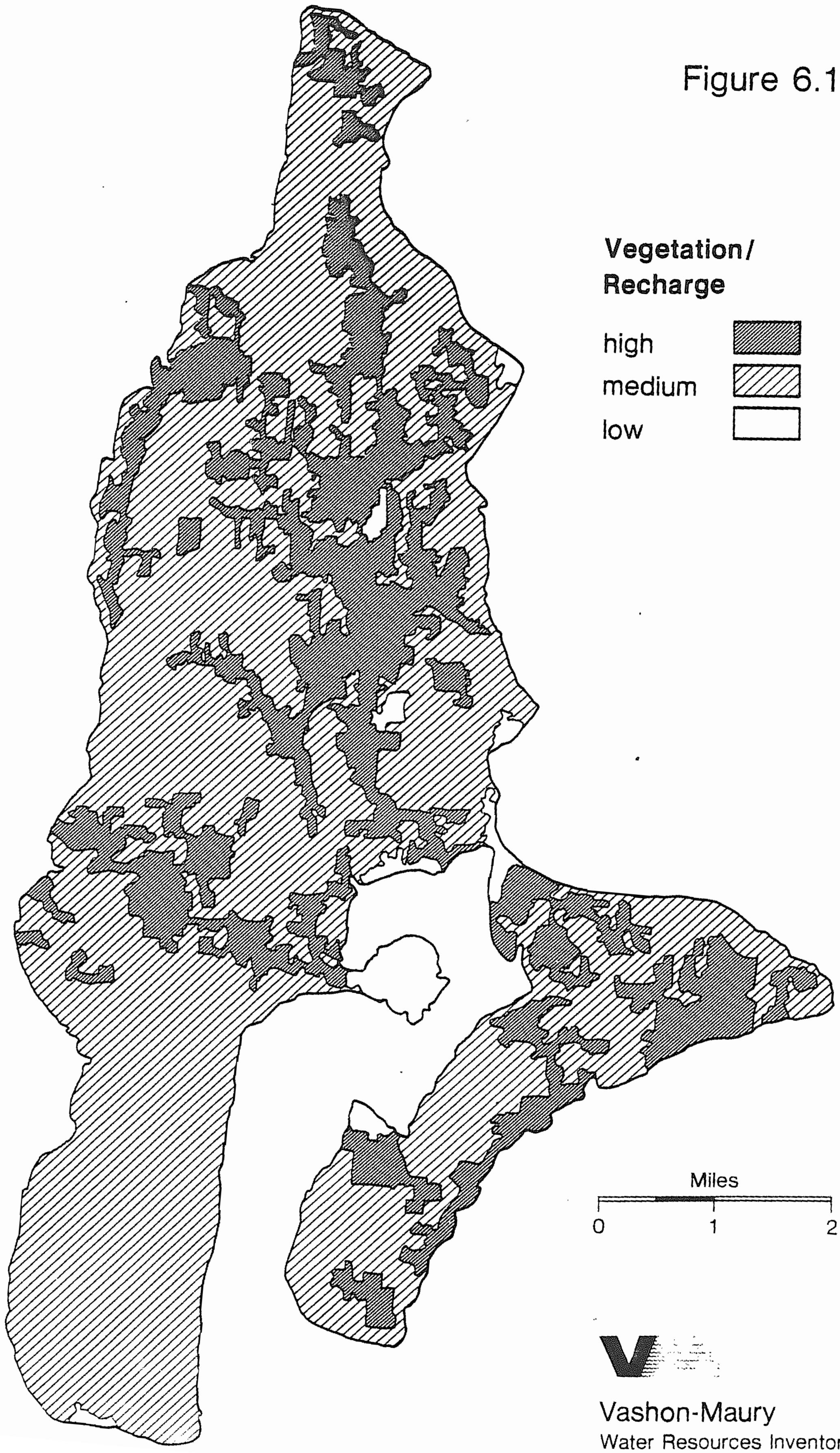
Water Resources Inventory

Figure 6.10



Vashon-Maury
Water Resources Inventory

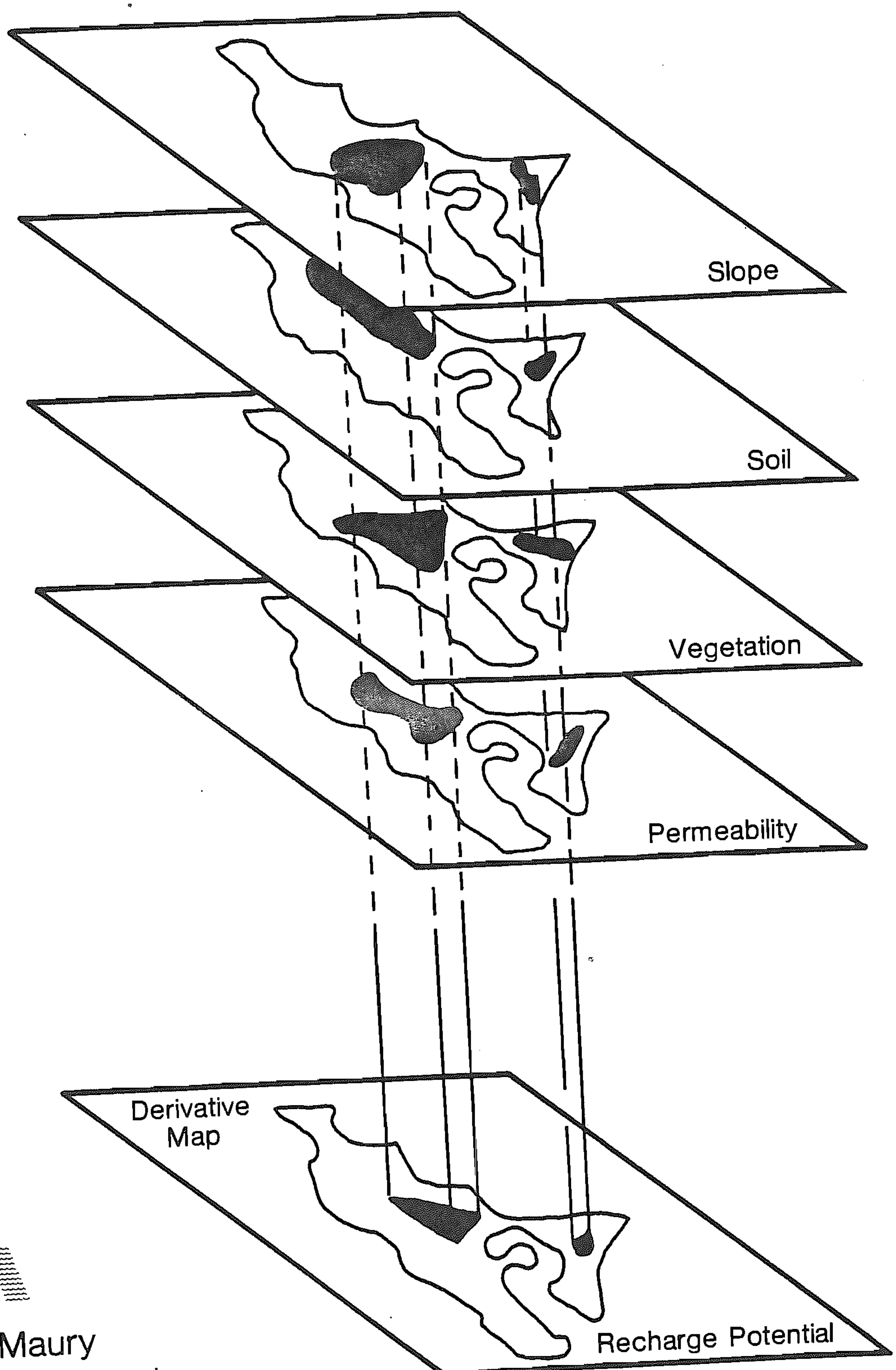
Figure 6.11



Vashon-Maury
Water Resources Inventory

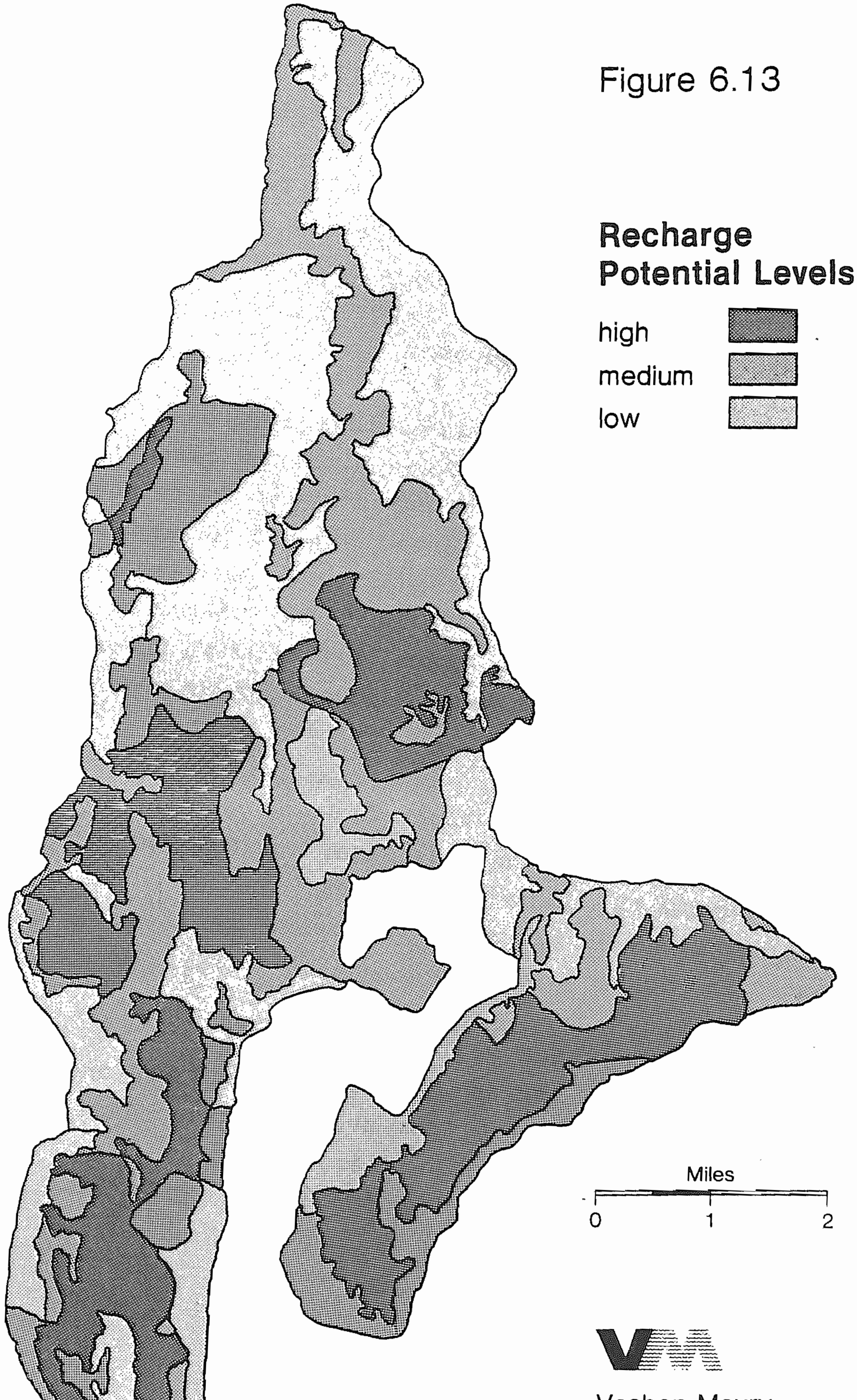
Figure 6.12

Recharge Derivative Map - Example



Vashon-Maury
Water Resources Inventory

Figure 6.13



Vashon-Maury
Water Resources Inventory

By applying physical characteristics method to the Principal Aquifer, the areas of highest Recharge Potential Level on Vashon Island are located along a north-south corridor on the upland of central and the south arm, and in the Vashon Center-Ellisport area. High Recharge Potential Levels on Maury Island are delineated at upper elevations, paralleling Maury's southwest-northeast axis.

Time Delay (Water Level Response)

Assuming relatively uniform conditions of gross permeability and system geometry, the time at which the changes in water level reach their peak in different areas is related to the distance from the recharge area. Water levels within or close to the recharge source will peak or respond earlier than those further away. As in runoff patterns of river systems, the variations of water level elevation are greater close to the recharge areas, and lower and more prolonged in discharge areas.

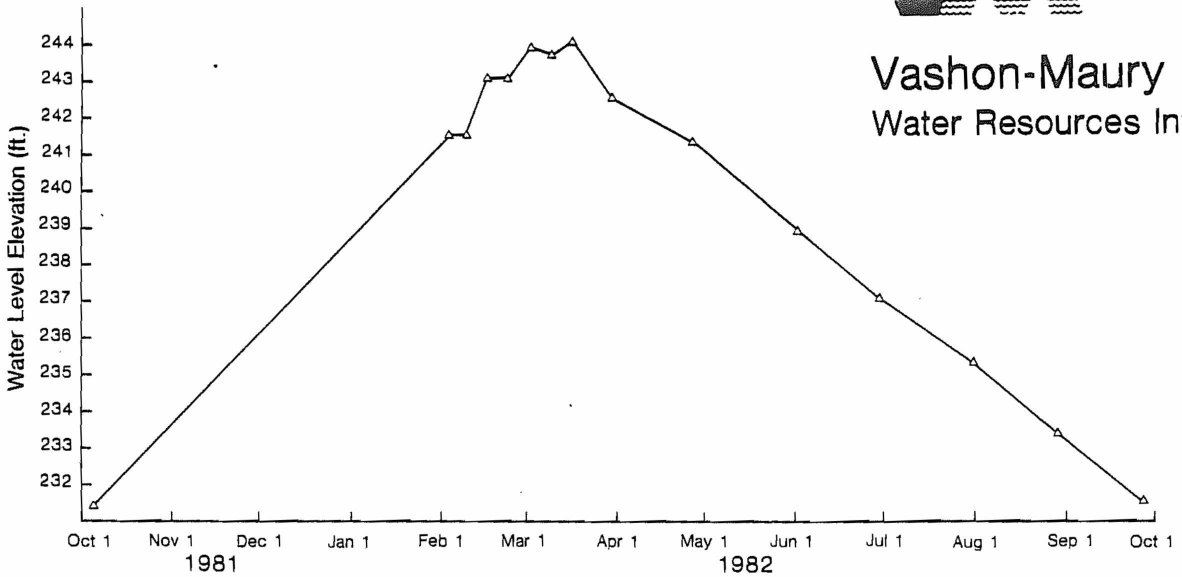
Such variations can be evaluated using a series of water level measurements. Using this data, aquifer hydrographs can be constructed to estimate recharge areas. Although not strictly a time-series model, a series of these graphs is presented in Figure 6.14.

These records show that wells 145, and 104 are located near sources of recharge and that wells 69, 34, 101 and 130 are progressively farther away from such sources. Time delay of water level response is also affected by the depth of the aquifer in which the well is completed. This relationship was discussed and illustrated in Chapter 3.

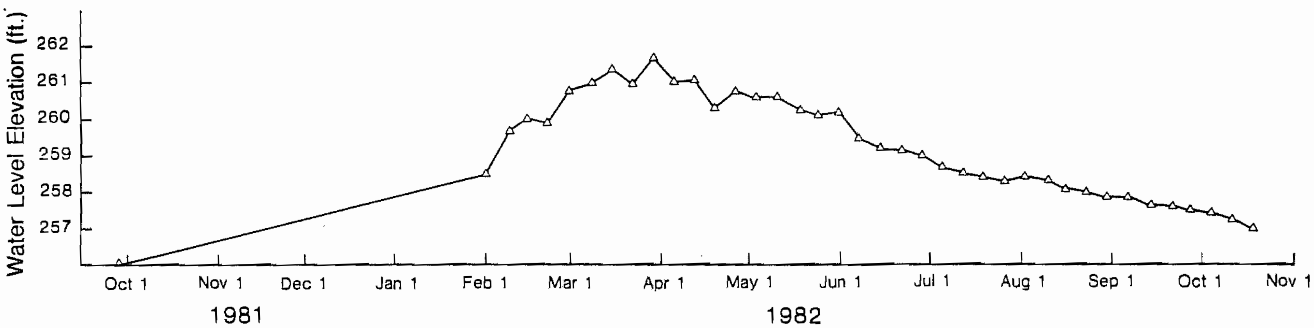
Figure 6.14A

Vashon-Maury
Water Resources Inventory

Water Level vs. Time - Well 145 (Stevens)



Water Level vs. Time - Well 69 (Carlson)



Water Level vs. Time - Well 104 (Chobot Drill)

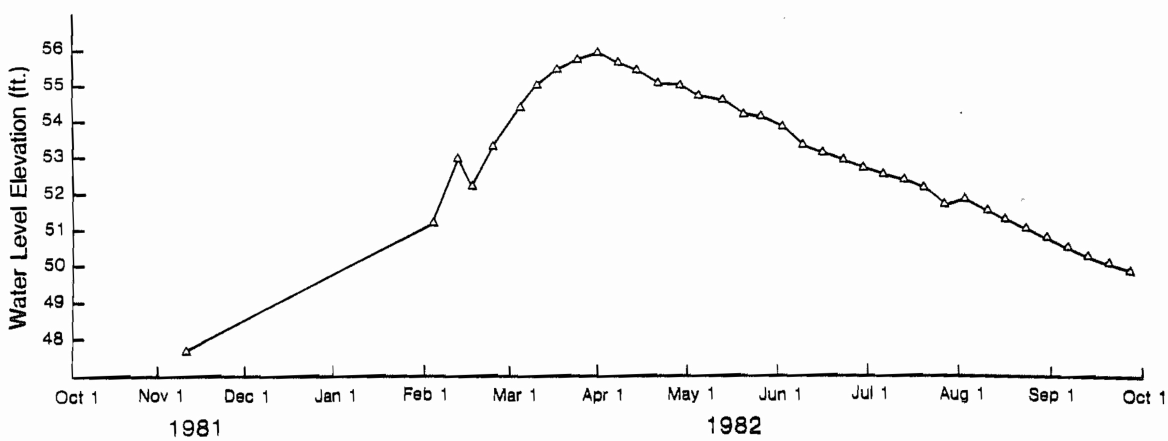
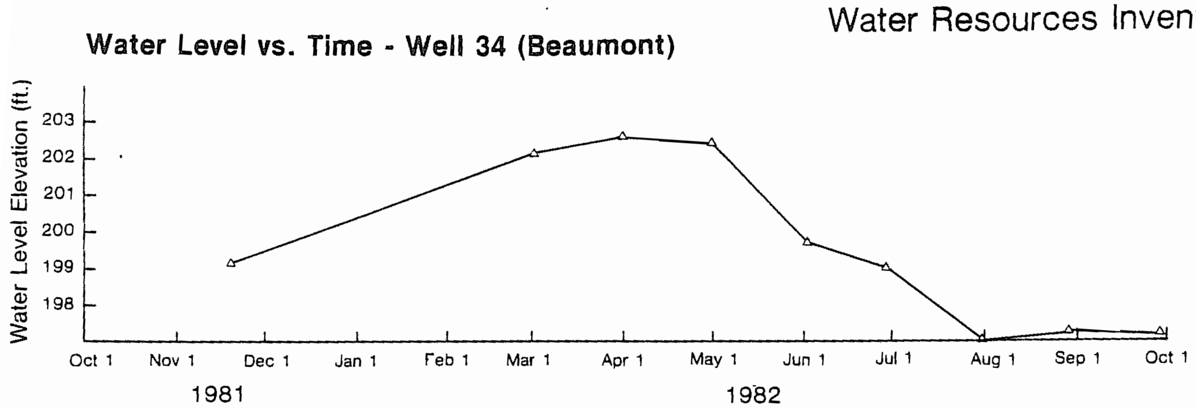
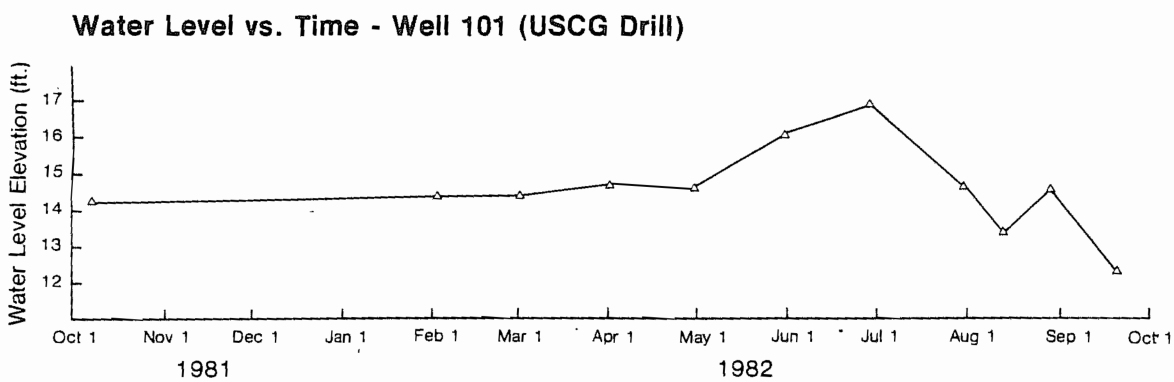
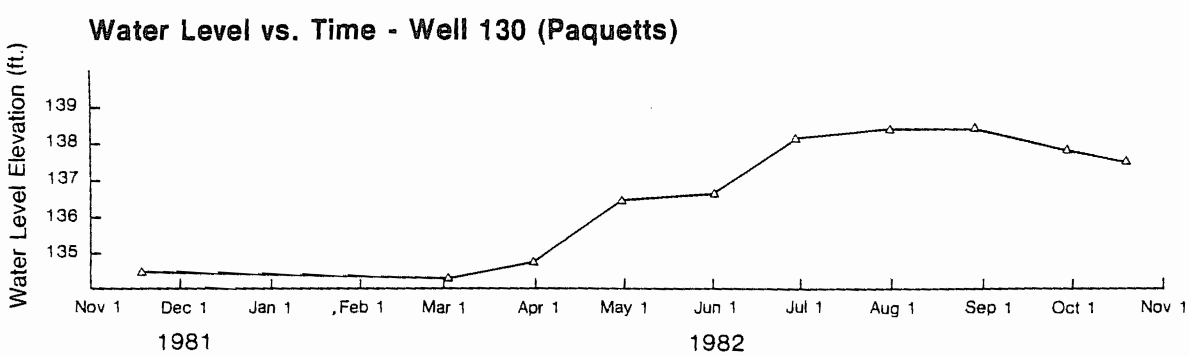


Figure 6.14B

Vashon-Maury
Water Resources Inventory







Agreement between the recharge potential levels as determined by the three distinct methods used is surprisingly close. On Vashon Island the results define the west-central corridor as an important recharge area for the Principal Aquifer. On Maury Island, a prime recharge area is located on the upland toward the north end of the island.

ESTIMATED QUANTITY OF RECHARGE (PRINCIPAL AQUIFER)

Chapter 5 provided an estimate of Island-wide infiltration of 4-inches to the Principal Aquifer and 1-inch to the Deep Aquifer. Areas of high, medium and low recharge potential have been identified using the above described methodology. To estimate the quantity of recharge in each area, the recharge rates described in Chapter 5 were multiplied by the estimated size of each recharge area, as shown in Table 6.2.

The total amount of recharge to the Principal Aquifer is estimated to be 8,900,000 gallons per day or about 6,000 gpm. Of this recharge nearly half (45%) occurs in the areas of high potential recharge which account for only 25% of the Islands' area.

As described in Chapter 9, the amount of recharge is not equivalent to the amount of retrievable water, which is believed to be substantially less.

RECHARGE TO THE DEEP AQUIFER SYSTEM

As defined in Chapter 4, the Deep Aquifer consists of saturated sands with some layers of sand and gravel that interrupt the rather continuous section of less permeable silt of Unit III. From the limited available well log information, it seems most likely that the permeable zones are discontinuous. It also seems likely that the part of the Deep Aquifer which is 100 feet or more below sea level could be continuous from Vashon to Maury Island beneath Quartermaster Harbor. The maximum depth of Quartermaster Harbor is about 60 feet below sea level, so that the aquifers could have inter-island connection.

METHODOLOGY

On Vashon/Maury Island there are at least 14 wells which penetrate the Deep Aquifer, at elevations of about 100 to 300 feet below sea level. There are also a number of wells which penetrate an aquifer which is near or immediately below sea level, such as those in the Glen Acres area.

None of the wells completed in the Deep Aquifer are ideally suited to monitoring because their deep pump settings make sounding difficult and because many are pumped rather heavily. An exploratory drilling and monitoring program is needed to provide better geologic and hydrologic data.

Since water level records are limited to the 14 wells which penetrate the deeper aquifer system, there are rather large data gaps for many parts of the Islands. As noted, it was not possible to accurately measure the water level in many of the wells. For some of these wells, reported water levels have been used in the data base.

Bearing these inadequacies in mind, a piezometric (water-level) map of the Deep Aquifer is shown in Figure 6.15.

INTERPRETATION

The map shows that the highest water levels in the Deep Aquifer occur near the central part of Vashon Island near well 40. From that high point, the gradient to the west toward Colvos Passage is rather steep. The slope of the water table in the northerly direction is flatter and there is an apparent higher water level mound extending beneath Quartermaster Harbor and Maury Island.

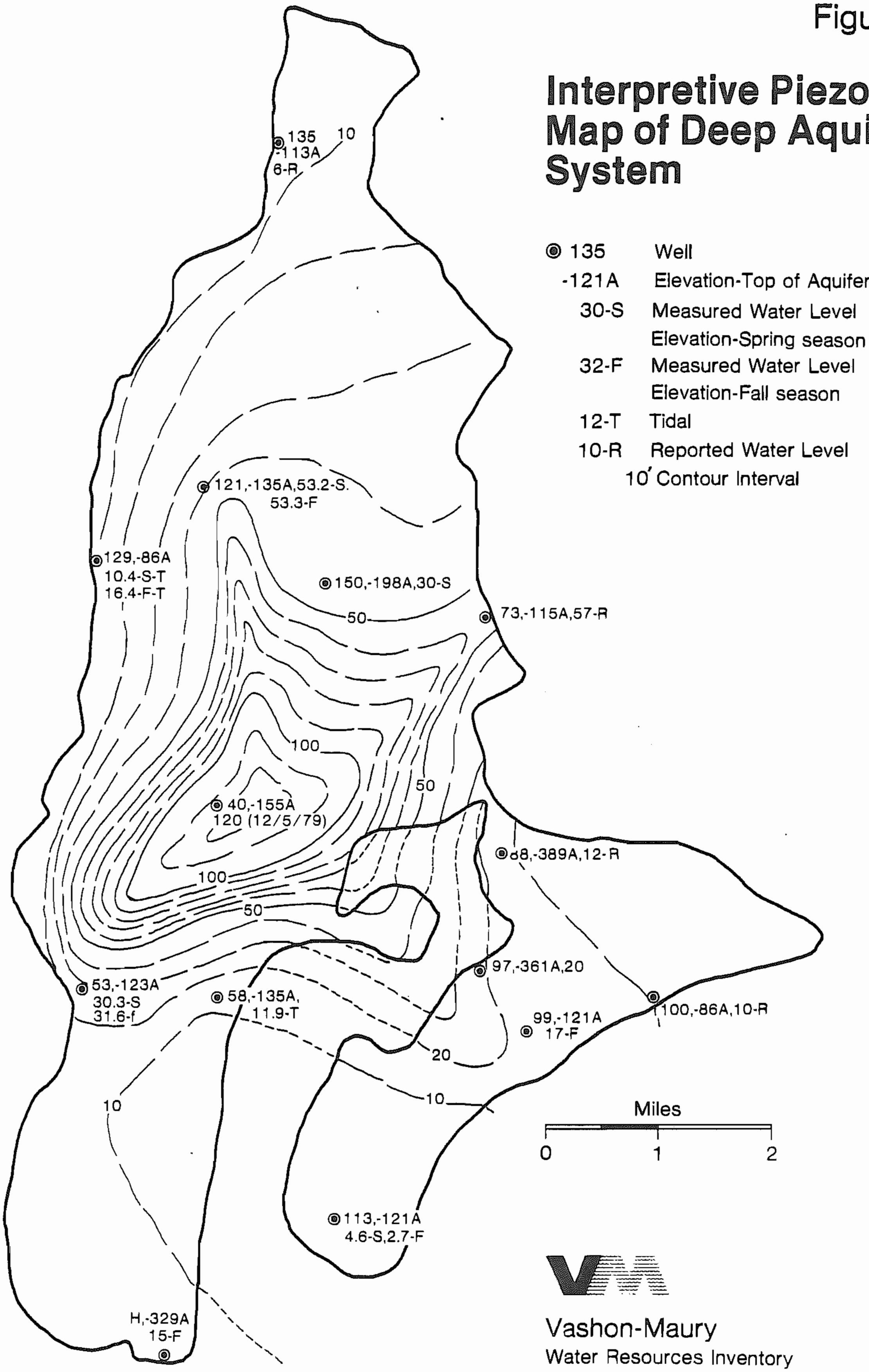
QUANTITIES OF RECHARGE

Recharge Potential Level	Recharge Value	Gallons/day an acre	Area (Acres)	Estimated Total Recharge		
				Gallons/Year	Gallons/Day	Gallons/Minute
High	9 inches/yr.	670	5,922	1,460,000,000	4,000,000	1760
Medium	5 inches/yr.	372	6,918	912,500,000	2,500,000	1780
Low	3 inches/yr.	223	10,817	876,000,000	2,400,000	1660
		Totals	23,657	3,248,500,000	8,900,000	6200

TABLE 6.2
QUANTITIES OF RECHARGE

Figure 6.15

Interpretive Piezometric Map of Deep Aquifer System



Vashon-Maury

Water Resources Inventory

The available data indicate that recharge to the Deep Aquifer occurs from infiltration of water from overlying sediments. This vertical gradient, illustrated in Figure 6.5, is relatively uniform at about 50 feet of water level drop per 100 feet of aquifer depth. This gradient persists over much of the Islands and throughout most of the section from the upland portion of the Islands to 200 or 300 feet below sea level.

The apparent high water level at well 40 may indicate an area of higher recharge. Similarly the relatively high water level in Well 97 on the east side of Quartermaster Harbor may indicate recharge to the Deep Aquifer from Maury Island.

ESTIMATED QUANTITY OF RECHARGE (DEEP AQUIFER)

Because of the limited data, the amount of recharge reaching the Deep Aquifer is extremely difficult to quantify. Many of the wells penetrating the aquifer were completed only within the last few years. From the limited water level records available, there is no clear trend of water levels.

In Chapter 5, the infiltration (recharge) to the Deep Aquifer was estimated at 1 to 2 inches/year. Assuming that this recharge occurs over most of the Islands' area, the total recharge can be calculated to be between 1200 and 2400 gpm. As in the Principal Aquifer, the amount of water believed to be retrievable from the Deep Aquifer is less than the amount recharged (see Chapter 9).

CHAPTER 7

WATER QUALITY

This chapter evaluates the chemistry of the Islands' water resources. Water quality characteristics are controlled by the quality of the precipitation and by the minerals and ions which are dissolved as water infiltrates to and moves through the aquifers. This evaluation of water quality is essential to establish the water's suitability for use and its protection for future development.

SUMMARY

Precipitation which falls on the Islands has very few dissolved ions, and a relatively low pH. As water travels through the hydrologic regime, it dissolves minerals and other materials along its path and its composition is changed. Where contaminants infiltrate to the zone of saturation, they can add their concentration to the ground water.

Specific conductance is an analytical determination which is directly related to the total dissolved solids content (mineralization) of water. Island wells completed in the Principal Aquifer have water with specific conductance generally between 100 and 150 umhos/cm. Island wells in the Deep Aquifer have specific conductance values of about 300 umhos/cm. Specific conductance in the Principal Aquifer has been found to increase about 30 umhos/cm per 100 feet of well depth. Some wells around the margins of the Island which are completed below sea level have specific conductance values over 500 umhos/cm. This finding, associated with salt water intrusion into the aquifer, is particularly evident at the north end of Vashon Island.

Analysis for chloride confirms the existence of incipient salt water intrusion in at least nine Island wells. These wells have chloride concentrations above the normal range of 3 to 5 mg/L in the Principal Aquifer and about 5 mg/L in the Deep Aquifer. Elevated concentrations of chloride can also occur as a result of contamination of the ground water from septic tank effluent.

Nitrate is the primary indicator of contamination from septic tank effluent. The natural background of nitrate as nitrogen on the Islands is near the limit of detection at 0.01 mg/L. The range of concentration of nitrate as nitrogen found in this study was from zero (not detected) to 5.3 mg/L. (One well had 27 mg/L.) The DSHS maximum contaminant level for nitrate as nitrogen is 10 mg/L. Other potential sources of nitrate on the Islands include fertilizers, animal wastes and decaying vegetation.

Ground water from 25 isolated Island wells had iron concentrations at or above the DSHS limit of 0.3 mg/L. These concentrations are presumed to result from natural conditions in the aquifer and are often associated with elevated concentrations of manganese. Concentrations of manganese in the Deep Aquifer are generally higher than in the Principal Aquifer.

Arsenic and cadmium analyses of samples from ten Island springs and streams showed no detectable amount present. Prior analyses of water from wells and other Island sources also had no indication of these contaminants.

Principal Aquifer wells along the west side of Vashon generally have water with lower specific conductance and lower concentrations of chloride and nitrate. This factor and the northward and eastward increase in these parameters substantiate the designation of west-central Vashon as a recharge area.

Comparison of analytical results of this study to prior analyses shows increasing specific conductance, chloride and nitrate in some areas. Water quality monitoring on the Islands should be continued to further define these problems and provide the tools for resource management.

BACKGROUND

CHEMICAL CHARACTERISTICS OF WATER

Water has been called the universal solvent, which means given time it can and will dissolve anything. The high concentrations of dissolved materials in sea water demonstrate the solute properties of water. Since all water eventually reaches the ocean, virtually every natural element can be found dissolved in salt water. The concentration of these elements ranges from a few parts per billion for less soluable elements such as gold, to thousands of parts per million for more soluble ions such as sodium and chloride.

The concentration and type of dissolved materials changes in each phase of the hydrologic cycle. The total concentration of dissolved materials in the ocean is about 30,000 parts per million or about 3%. Evaporation from the surface of the ocean is like distillation; the concentration of dissolved minerals in water vapor is reduced to less than 0.01%. This water vapor condenses and falls as precipitation. Part of the precipitation runs off to streams which dissolve some minerals from rocks along their path. Water which infiltrates into the ground is altered first by reactions in the soil. The relatively high organic content in many Island soils renders the water more acidic and more aggressive. As water infiltrates, more minerals are dissolved and exchanged in complex geochemical reactions. In recharge areas, the total mineralization of water increases with depth and residence time.

The total concentration of dissolved material is called dissolved solids. The dissolved solids concentration or the concentration of any specific element is expressed as parts per million (ppm) or in metric terms of milligrams per liter (mg/L). Most laboratories now report in mg/L, which indicate milligrams (weight) of the element or compound per liter (volume) of water. The analyses presented in the tables of this chapter are in mg/L, except for specific conductance and pH.

WATER QUALITY STANDARDS

Various government agencies have generated standards for maximum allowable concentrations for particular elements or groups of elements such as nitrogen and oxygen in nitrate (NO_3^-). The Maximum Contaminant Limits (MCL) imposed by the State of Washington, Department of Social and Health Services (DSHS) are included in Table 7.1.

Most of these standards relate to health hazards which occur if the limits are exceeded. A few of the standards such as those for iron and manganese are related to aesthetics and present no known health hazard. The standard for bacterial contamination, which is not presented in the table, is zero. Additional standards for exotic chemicals such as volatile organics and chlorinated phenols are available as EPA's 108 priority pollutants.

Various industries have other standards for water quality to optimize production of their products. Such industries as paper production, brewing and baking require low concentrations of iron and manganese. Water used in boilers and air conditioning systems requires low hardness and low dissolved solids.

TABLE 7.1

WATER QUALITY ANALYSES

WELLS AND SPRINGS

ANALYSES BY OTHERS, 1982 AND BEFORE

Symbol				As	Ba	Cd	Fe	Pb	Mn	Hg
Units				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
MCL (11)				0.05	1.0	0.01	0.3	0.05	0.05	0.002
Owner										
Beymer (Miller)	5	21/2-1L1	3/3/61(2)				0.48			
Beymer (Miller)	5	21/2-1L1	1966(10)				0.45			
McIntyre	6	21/2-1M1	1966				0.7			
McIntyre-Galford(Galford)	8	21/2-1N1	1966				0.1			
85 Acre System (Spano)	20	22/2-1D1	9/30/80	0.01	0.25	0.002	0.35	0.01	0.06	0.001
Madrona West	28	22/2-11B	1966				0.13			
Madrona West	28	22/2-11B	4/30/80	<0.01	<0.25	<0.002	0.08	<0.01	<0.01	<0.005
Hoffman	35	22/2-12D1	8/29/78				0.2			
Old Nike Site	39	22/2-12J	9/25/79				0.24		<0.03	
Stewart	40	22/2-12Q	2/20/80	0.005	0.03	0.001	0.12	0.001	0.053	0.003
Burton Water Company	42	22/2-13J2	9/13/66				0.16		0.007	
Burton Water Company	42	22/2-13J2	8/9/77	0.01	0.10	0.005	0.01	0.01	0.01	0.001
Maury Mutual	86	22/3-15H	1966							
Queen City B. KIRO Radio	88	22/3-16F	12/16/59				1.3			
KIRO (same well)	88	22/3-16F	7/5/60							
KIRO (same well)	88	22/3-16F	5/22/81	0.01	0.25	0.002	3.8	0.10	0.45	0.001

NOTES: N.D. = Not Detected

(1) Calculated from analyses for Nitrate

(2) From W.S.B. No. 24

(3) Converted from grains per gallon reported

(4) Minimum alkalinity

(5) USPHS - 1962

(6) World Health Org. 1963

(7) Applicable to surface water supplier

(8) Wells not assigned project number

(9) Probable lab error

(10) Most 1966 analyses are 9/13 or 9/16/66

(11) MCL: Maximum contaminant level

Symbol	Se	Ag	Na	H(t)	F^-	NO_3-N	Cl^-	$SO_4^=$	SiO_2	HCO_3^-
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
MCL	0.01	0.05	20	-	2.0	10	250	250		20(4)
<u>Owner</u>										
Beymer (Miller)			5.0		0.1	0.002(1)	2.8	11	38	42
Beymer (Miller)				40		N.D.				
McIntyre				55	0.3	N.D.	217.5(9)			
McIntyre-Galford(Galford)				70		2.2(1)				
85 Acre System (Spano)	0.005	0.01	10	65	0.2	0.2	10	10		
Madrona West				80		5.8(1)	10			80
Madrona West	0.005	<0.01		70	0.21	2.0				
Hoffman				47.6(3)						
Old Nike Site						0.2				
Stewart	0.001	0.001		70	0.2	0.1	1.0			
Burton Water Company				40		0.27(1)	2			30
Burton Water Company	0.005	0.01		40.3	0.04	0.044				
Maury Mutual				65		2.2	10			80
Queen City B. KIRO Radio			43	190	0.3	0.1(1)	8.8	3	41	346
KIRO (same well)				184						330
KIRO (same well)	0.005	0.01	43	191	0.2	0.2	26	10		

Symbol				PO_4	S.C.	TDS	TDS	pH		
Units				mg/L	umhos/cm	mg/L	mg/L		C.U.	N.T.U.
MCL						500(5)			75	1.0(7)
Owner										
Beymer (Miller)	5	21/2-1L1	3/3/61	0.18	104	91	90	7.4	5	
Beymer (Miller)	5	21/2-1L1	1966							0
McIntyre	6	21/2-1M1	1966					7.3		10
McIntyre-Galford(Galford)	8	21/2-1N11	1966					8.3		1
85 Acre System(Spano)	20	22/2-1D1	9/30/80		145				5	7
Madrona West	28	22/2-11B	1966					7.4		2.0
Madrona West	28	22/2-11B	4/30/80		170				<5	0.5
Hoffman	35	22/2-12D1	8/29/78			68(3)		7.6		
Old Nike Site	39	22/2-12J	9/25/79			100		7.4	10	
Stewart	40	22/2-12Q	2/20/80		190				0.2	0.4
Burton Water Company	42	22/2-13J2	9/13/66	0.28	80.6	48.8		6.5	4	0.02
Burton Water Company	42	22/2-13J2	8/9/77		80				4	0.5
Maury Mutual	86	22/3-15H	1966					7.3		5
Queen City B. KIRO Radio	88	22/3-16F	12/16/59	0.59	545	338	346	7.6	10.0	
KIRO (same well)	88	22/3-16F	7/5/60		511			7.8		
KIRO (same well)	88	22/3-16F	5/22/81		540				25	4.3

Symbol		Cr	Ca	Mg	NO_3	K
Units	°F		mg/L	mg/L	mg/L	mg/L
MCL		0.05	75(6)	50(6)	45	
Owner						
Beymer (Miller)	47		5.5	5.6	0.1	1.0
Beymer (Miller)			8		N.D.	
McIntyre			6		N.D.	
McIntyre-Galford(Galford)			10		10	
85 Acre System(Spano)		0.01				
Madrona West			12		26.3	
Madrona West		<0.01			2.0	
Hoffman						
Old Nike Site						
Stewart		0.001				
Burton Water Company			7.23	N.D.	1.24	1.13
Burton Water Company		0.01			0.20	
Maury Mutual			10		10	
Queen City B. KIRO Radio	54		45	19	0.5	7.4
KIRO (same well)	66					
KIRO (same well)		0.01				

Symbol				As	Ba	Cd	Fe	Pb	Mn	Hg
Units				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
MCL				0.05	1.0	0.01	0.3	0.05	0.05	0.002
Owner										
Pt. Robinson Pk King Cty	101	22/3-23A1	1966				0.57			
Pt. Robinson USCG	102	22/3-23A2	1966				0.03			
Gold Beach Well 2	109	22/3-28B2	9/23/76				0.2		0.2	
Gold Beach Well 2 (same)	109	22/3-28B2	5/21/82	<0.01	<0.25	<0.002	<0.05	<0.01	<0.01	<0.0005
Sandy Beach Comm.	135	23/3-7N	1966				0.01			
Morningside Comm. Water Assn. (Noel)	137	23/3-17P	1982				0.32		0.09	
Hillside Community	142	23/3-20B1	1966				0.04			
W.D. 19 - Well 1	150	23/3-31Q	10/25/79				0.05		0.039	
W.D. 19 Well 1	150	23/3-31Q	12/22/80	<0.01	<0.25	<.002	<0.05(9)	<0.01	<0.084	<.0005
Westside Water Co. (Cedarhurst Creek)	S3	23/3-19P	9/13/66				0.12		0.003	
Sunwater Beach	S6	23/3-23Q	1966							
W.D. 19 Plant 2 (Island Mutual)	S13	22/3-8B	9/13/66				0.16		0.017	
W.D. 19 Plant 2 Ellis Creek	S13	22/3-8B	12/22/80	<0.010	<0.25	<0.002	<0.10	<0.01	0.016	<0.0005
King Co. W.D. 19 Beal Creek	S14	23/3-32A	9/13/66				0.19		0.010	
W.D. 19 Plant 1 Beal Creek	S14	23/3-29Q	12/22/80	<0.010	<0.25	<0.002	<0.05	<0.01	<0.01	<0.0005
W.D. 19 Plant 1 Beal Creek	S14	23/3-29Q	12/22/82	<0.01	<0.25	<0.002	0.08	<0.01	0.013	<0.0005
Heights Water Corp. Spring	S16	23/3-18A	9/13/66				0.10		0.014	
U.S. Govt.	X(8)	22/3-7J	3/24/59				0.01			
U.S. Govt. (same well)	X(8)	22/3-7J	11/3/59				0.04			
North Cedarhurst (Well 300' from Puget Sound	X(8)	23/3-18D	1966				0.20			
Sandy Shores	X(8)	22/3-32C	1966				0.05			

Symbol	Se	Ag	Na	H(t)	F^-	NO_3-N	Cl^-	$SO_4^=$	SiO_2	HCO_3^-
MCL	0.01	0.05	20	-	2.0	10	250	250		20(4)
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
<u>Owner</u>										
Pt. Robinson Pk King Cty				230		N.D.	10			
Pt. Robinson USCG				110		2.2(1)	27.5			
Gold Beach Well 2			11	132		0.3	9	20	26	129
Gold Beach Well 2 (same)	<0.005	<0.01	10	130	0.2	0.8	5	-		
Sandy Beach Comm.				235		2.2(1)	67.5			
Morningside Comm. Water Assn. (Noel)						0.95	575	79		
Hillside Community				145		N.D.	7.5			
W.D. 19 - Well 1			50	79		<.05	4	1.3		165
W.D. 19 Well 1	<.005	<0.01	40	70	<0.2	<0.2				
Westside Water Co. (Cedarhurst Creek)			3.57	88	0.15	0.82(1)	4.5	19	15	64
Sunwater Beach				115		Trace	7.5			
W.D. 19 Plant 2 (Island Mutual)			3.34	58	0.13	0.3(1)	4.5	18.6	11.25	46
W.D. 19 Plant 2 Ellis Creek	<0.005	<0.01	<10	60	<0.2	0.9				
King Co. W.D. 19 Beal Creek			3.42	66	0.14	1.56(1)	4.5	17	14.5	46
W.D. 19 Plant 1 Beal Creek	<0.005	<0.01	10	90	<0.2	6.2				
W.D. 19 Plant 1 Beal Creek	<0.005	<0.01	5	70	<0.2	0.0	<5			
Heights Water Corp. Spring			3.19	88	0.1	1.3(1)	3	20	17	70
U.S. Govt.			5.3	52		0.04(1)	3.0	7.3	33	64
U.S. Govt. (same well)			5.2			0.0(1)	3.2	7.4	34	64
North Cedarhurst (Well 300' from Puget Sound				790		N.D.	660			
Sandy Shores				100		N.D.	15			

Symbol				PO_4	SC	TDS	TDS	pH		
Units				mg/L	umhos/cm	mg/L	mg/L		C.U.	N.T.U.
MCL						500(5)			75	1.0(7)
Owner										
Pt. Robinson Pk King Co.	101	22/3-23A1	1966					7.1		
Pt. Robinson USCG	102	22/3-23A2	1966					7.9		5
Gold Beach Well 2	109	22/3-28B2	9/23/76				220	6.3		1.5
Gold Beach Well 2 (same)	109	22/3-28B2	5/21/82		230				5	0.1
Sandy Beach Comm.	135	23/3-7N	1966					7.4		2
Morningside Comm. Water Assn. (Noel)	137	23/3-17P	1982		2200			7.2	5	
Hillside Community	142	23/3-20B1	1966					6.7		1.0
W.D. 19 Well 1	150	23/3-31Q	10/25/79		>300		240	7.6	10	1.4
					Calc					
W.D. 19 Well	150	23/3-31Q	12/22/80		300				5	0.4
Westside Water Co. (Cedarhurst Creek)	S3	23/3-19P	9/13/66	0.29	186		124.4	7.22	6	0.06
Sunwater Beach	S6	23/3-23Q	1966					7.6		0
W.D. 19 Plant 2 (Island Mutual)	S13	22/3-8B	9/13/66	0.32	134		90.8	6.95	7	0.18
W.D. 19 Plant 2 Ellis Creek	S13	22/3-8B	12/22/80		170					
King Co. W.D. 19 Beal Creek	S14	23/3-32A	9/13/66	0.48	154		100.5	7.5	4	0.015(9)
W.D. 19 Plant 1 Beal Creek	S14	23/3-29Q	12/22/80		230				5	0.4
W.D. 19 Plant 1 Beal Creek	S14	23/3-29Q	1/22/82		170				<5	0.2
Heights Water Corp. Spring	S16	23/3-18A	9/13/66	0.36	190		117	7.4	5	0.35

Symbol Units	°F	Cr mg/L	Ca mg/L	Mg mg/L	NO_3 mg/L	K mg/L
MCL		0.05	75(6)	50(6)	45	
Owner						
Pt. Robinson Pk King Co.			44		N.D.	
Pt. Robinson USCG			18		10	
Gold Beach Well 2		<0.01	22	19		
Gold Beach Well 2 (same)						
Sandy Beach Comm.			60		10	
Morningside Comm. Water Assn. (Noel)					4.3	
Hillside Community			24		N.D.	
W.D. 19 Well 1	49.5		21	5.5		6.6
W.D. 19 Well		<0.01				
Westside Water Co. (Cedarhurst Creek)			18.07	1.20	3.72	0.46
Sunwater Beach			12.5		Trace	
W.D. 19 Plant 2 (Island Mutual)			9.23	6.00	1.42	2.40
W.D. 19 Plant 2 Ellis Creek		<0.01				
King Co. W.D. 19 Beal Creek			12.85	3.20	7.08	2.54
W.D. 19 Plant 1 Beal Creek		<0.01				
W.D. 19 Plant 1 Beal Creek		<0.01				
Heights Water Corp. Spring			19.27	2.40	6.02	3.88

PRIOR STUDIES

Only limited information has been published on the quality of the Vashon/Maury Island water resources. **Water Supply Bulletin No. 18, Water Resources and Geology of the Kitsap Peninsula and Certain Adjacent Islands** includes an excellent chapter on water quality, with an analysis of 39 ground water sources including two from Vashon/Maury Island Water District 19's Plant 1 at Beal Creek, and the Queen City Broadcasting (KIRO) deep well at Portage (See Table 7.1). **Water Supply Bulletin No. 24, Ground Water in Washington, Its Chemical and Physical Characteristics** includes an analysis of these two wells and two others: U.S. Government Well 22/3-7J and the R.K. Beymer well 2/2-1L (See Table 7.1).

In 1966, the Seattle-King County Public Health Department produced a **Report of Improvements Made on Public Water Supplies Located on Vashon-Maury Islands.** This document, while primarily concerned with bacterial analyses, included some chemical evaluations. Chemical analyses of record have also been obtained from several island water companies. The most extensive of these are annual records beginning in 1967 from Water District 19's Plant 1 Beal Creek source.

All of these prior chemical analyses have been included in Table 7.1. It should be noted that analyses from several wells have been included that are not part of our 150 well network. These wells were not included in the network because their logs were not available and precise field locations could not be determined. However, their chemical record is included for completeness.

DATA COLLECTION

SAMPLE COLLECTION AND ANALYSES

During the course of this study, water samples were collected and submitted to Laucks Laboratory, Inc. for chemical analysis. Samples were taken from 72 well sources and analyzed for specific conductance, chloride, nitrate as nitrogen, and iron. At several locations, multiple samples were taken over the course of the one-year study to evaluate any seasonal change in water quality. As previously noted, such sources as Maury Mutual (Project No. 86) and Dockton-Harborview (111) have been included as wells even though they are shallow well points in spring discharge areas. The analyses of well samples collected primarily during the late fall, 1981, are listed in Table 7.2.

Samples were also collected from 23 other sources including springs, streams, and special sources of potential water contamination. These samples were analyzed in part by Laucks Laboratory and in part by J.R. Carr/Associates project personnel with Hach field test equipment. Analyses were made for specific conductance, chloride, nitrate as nitrogen, iron, hardness, alkalinity, arsenic, cadmium, and manganese. Some samples were also analyzed for pH and lead. These analyses, from samples collected primarily during the summer, 1982, are included in Table 7.3.

DATA CATEGORIES

The data presented in Tables 7.1, 7.2 and 7.3 can be divided into several categories of chemical characteristics. The dissolved compounds contained in water disassociate into positive and negative ions. The cations have a positive charge and include all of the metals. Anions are negative charged ions such as chloride (Cl^-) and fluoride (F^-) and combined elements which act as single anions such as nitrate (NO_3^-) and sulfate ($SO_4^=$).

Hardness and alkalinity are measures of groups of ions with specific properties. Hardness measures primarily calcium and magnesium concentration and is customarily reported as the equivalent mg/L of calcium carbonate ($CaCO_3$). Alkalinity in

Proj. No.	Surface Elev.	Depth of Intake	Elev. of Intake (Bottom)	Specific Conductance umhos/cm	Chloride mg/L	Nitrate as Nitrogen mg/L	Iron mg/L
1	331	180±	151(1)	128	2	N.D.	0.31
2	342	197	145	99	3	0.48	0.12
3	333	209	124	103	3	N.D.	0.05
5	323	180	143	94	3	N.D.	0.10
6	306	183	123	120	4	N.D.	3.7
7	288	93	195	121	4	N.D.	1.6
8	192	18	174	132	4	0.5	0.11
9	216	49	161	116	5	0.87	0.41
10	240	37	203	150	7	0.08	0.06
12	279	132	147	120	4	N.D.	4.7
14	229	125	104	110	3	N.D.	0.39
15	336	38	298	107	8	0.07	0.13
17	184	145	39	184	3	N.D.	0.25
18	267	273	-6	180	3	N.D.	0.20
19	8[illegible]	50	-42	180	6	N.D.	16.6
[illegible]	[illegible]	145	125	130	2	0.88	0.05
[illegible]	[illegible]	50±	151(1)	145	3	0.32	0.08
[illegible]	[illegible]	58	150	144	3	N.D.	0.19
[illegible]	[illegible]	210	191	124	2	0.4	0.04
[illegible]	[illegible]	110	-50	130	4	0.17	0.07
[illegible]	[illegible]	20	141	42(2)	2	N.D.	0.05
[illegible]	[illegible]	56	154	150	3	0.07	0.22
[illegible]	[illegible]	198	185	96	5	0.83	0.43
[illegible]	[illegible]	174	227	113	2	N.D.	0.07
[illegible]	[illegible]	20	238	76	3	0.13	0.029
[illegible]	[illegible]	98	166	126	3	0.3	0.03

Proj #	Surface Elev	Depth of Intake	Nitrate
Luena Beach 85	49	79	5.3
Maury Mutual 86 (11/5/81)		2	3.7
86 (8/24/82)		2	4.3
Coast guard 102		35	27
111 Beckton's Harborview Spring		2	1.9
112 Dockton spring		2	3.0
North Vashon Spring 134 10/30/81		2	2.8
134 8/24/82		2	3.8
520 Judd Creek			3.0

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1981-1982 WATER QUALITY DATA
WELLS

TABLE 7.2
Page One

Proj. No.	Surface Elev.	Depth of Intake	Elev. of Intake (Bottom)	Specific Conductance umhos/cm	Chloride mg/L	Nitrate as Nitrogen mg/L	Iron mg/L
46	289	62	227	162	8	N.D.	0.74
47	261	257	4	165	3	0.03	2.0
51	235	214	21	180	3	N.D.	0.12
52	385	300	85	140	5	<0.005	0.32
53	86	230	-144	150	2	N.D.	0.33
54	48	205	-151	125	2	N.D.	0.08
55	44	40	4	142	3	N.D.	0.37
60	302	307	-5	142	3	N.D.	0.44
63	410	233	177	97	2	N.D.	0.12
64	386	108	278	105	6	N.D.	0.07
66	298	116	182				
69	314	79	235	138	4	N.D.	0.4
70	320	101	219	93	3	N.D.	3.6
76	293	300±(1)	-7	210	3	0.3	0.16
77	298	210	88	138	3	0.48	0.44
83	413	305	108	142	5	0.52	0.02
85	119	79	40	156	5	5.3	0.007
86 (11/5/81)	211	2±(1)	209	141	6	3.7	0.13
86 (8/24/82)	211	2±(1)	209	280(4)	-(3)	4.3	-(3)
89	25	20	5	185	5	0.7	0.36
97	108	473	-365	250	4	<0.1	0.09
100	213	435	-222	315	24	<0.1	1.4
101	91	149	-58	430	10	0.43	0.14
102	59	35	24	520	18	27	0.034
104	143	108	35	142	10	N.D.	0.42

TABLE 7.2
Page Two

Proj. No.	Surface Elev.	Depth of Intake	Elev. of Intake (Bottom)	Specific Conductance umhos/cm	Chloride mg/L	Nitrate as Nitrogen mg/L	Iron mg/L
105	148	11	137	140	13	0.20	0.30
106	299	375	-76	155	5	N.D.	0.22
107	377	388	-11	160	4	0.22	0.57
111	80	2(1)	78	148	4	1.9	0.023
112	180	2(1)	178	164	5	3.0	0.028
113	360	493	-133	525	6	<0.1	0.15
114	150	447	-297	-	<0.2	-	-
123	88	92	-4	190	3	0.40	0.028
126	201	118	83	225	5	N.D.	9.2
127	200	167	33	200	5	N.D.	0.23
129	218	314	-96	120	3	N.D.	0.16
130	236	132	104	138	5	0.50	0.23
132	442	175	267	117	3	N.D.	0.12
134 (10/30/81)	81	2(1)	79	166	9	2.8	0.034
134 (8/24/82)	81	-	-	-	-	3.8	-
135	14	130	-116	720	177	N.D.	0.90
138	70	96	-26	490	74	<0.005	0.032
139	25	50	-25	280	9	0.9	0.017
142	103	121	-18	320	9	0.65	0.012
145	260	123	137	180	2	0.19	0.064
146	260	34	226	210	12	0.74	6.2
148	393	173	220	125	2	0.68	0.19
150 (11/30/81)	411	665	-254	320	5	<0.2	0.05

NOTES: (1) Depth of well - reported or estimated.
(2) Possible lab error.
(3) No analysis made.
(4) Field analysis of 7/27/82.

TABLE OF SPRINGS, STREAMS AND SPECIAL SAMPLES
WATER QUALITY ANALYSIS

Proj. No.	Specific Conduct umhos/cm	Chloride mg/L	Nitrate as Nitrogen mg/L	Iron mg/L	Hardness (Total) as CaCO mg/L	Alka-linity as CaCO mg/L	Arsenic mg/L	Cadmium mg/L	Manganese mg/L	Approx. Elev. of Sample Ft.	Remarks
S 1	118	4	1.6	0.10	-	-	-	-	-	120	Cedarhurst Creek
S 2	80	4	1.7	0.43	-	-	-	-	-	60	Needle Creek
S 3	-	-	-	-	-	-	-	-	-	200	Westside Water
S 4	90	10	N.D.	0.03	90	50	pH 6.4	-	-	220	Cove Sp. Box
S 5	-	-	-	-	-	-	-	-	-	60	Sunset Beach
S 6	-	-	-	-	-	-	-	-	-	200	Sunwater
S 7	275	10	N.D.	N.D.	-	120	-	-	-	30	Paradise Cove
S 8	108	15	N.D.	N.D.	-	50	-	-	-	200	Spring Beach
S 9	-	-	-	-	-	-	-	-	-	120	Bachelor Rd. E.
S 10	140	15	0.84	.03	100	50	<0.005	<0.002	pH 6.6	120	Bachelor Rd. W.
S 11	100	15	N.D.	0.01	100	-	<0.005	<0.002	-	30	Burton-Shawnee
S 12						Discharge Meas. Station				70	Judd Creek
S 13	160	5	0.62	0.07	70	-	<0.005	<0.002	-	80	Ellis Creek
S 14	170	<5	0.8	0.19	70	-	<0.01	<0.002	0.013	100	Beal Creek
S 15	340	15	N.D.	0.05	150	100	-	-	-	200	Dilworth Pt.
S 16	-	-	-	-	-	-	-	-	-	100	Heights Water
S 17	390	15	N.D.	0.01	230	180	-	-	-	100	Keller
S 18	350	10	<.02	0.09	200	pH 6.6	<0.005	<0.006	-	200	S.M.B.W.A.
S 19	150	15	N.D.	0.02	140	70	-	-	-	180	Carlson-Jensen
S 20	48	3	3.0	0.03	17	Pb<0.01	<0.005	<0.002	-	360	Judd- Above Land
S 21	53	3	2.7	0.43	24	Pb<0.01	<0.005	<0.002	-	320	Landfill-Bypass
S 22	370	14	<0.05	2.9	220	Pb<0.01	<0.005	<0.002	-	300	Landfill-Creek
S 23	120	3	.81	<0.05	54	45	<0.005	<0.002	-	10	Tahlequah Creek
S 24	-	-	-	-	-	-	-	-	-	30	Corbin Beach

NOTES: 1. pH is the negative logarithm of hydrogen ion concentration.
2. Pb is lead concentration in mg/L.

ground water is primarily caused by the bicarbonate ion (HCO_3^-) and is also reported as equivalent mg/L of $CaCO_3$.

The term pH designates the acidity of water, and is defined as the negative logarithm of hydrogen ion concentration. In other words, water with a pH of 6 is ten times more acid than water with a pH of 7.

As previously described, total dissolved solids measure the mineralization of the water. Specific conductance is another way of estimating dissolved solids content. The value of conductance is proportional to the dissolved solids content. Specific conductance (umhos/cm) on Vashon/Maury Island has been found to be about 1.5 times the dissolved solids content in mg/L.

Further discussion of the major water quality parameters and their occurrence on Vashon/Maury Island is presented below.

Specific Conductance

Samples from 72 wells collected during the course of this study indicate a range of specific conductance from 42 to 720 umhos/cm. A sample from well 137 (Morningside) collected and analyzed by others during 1982, showed a specific conductance of 2,200 umhos/cm. The specific conductance of 23 spring samples ranged from 48 to 390 umhos/cm.

Evaluation of this data reveals direct relationship between specific conductance and elevation of the aquifer. Figure 7.1 illustrates this relationship and shows specific conductance increasing in successively deeper wells. This analysis uses the lowest or deepest-part of the well which produces water.

A number of points in this illustration appear extraneous to the normal range of conductance. These points may be sources where salt water intrusion or contamination of the aquifer is occurring.

The majority of sources have conductance within three overlapping ranges. The lowest range of conductance (70 to 180 umhos/cm) corresponds to wells completed at elevations of 100 to 300 feet above sea level in the Principal Aquifer or in perched aquifers.

A medium range of conductance (120 to 210 umhos/cm) occurs in wells completed from about 40 feet above sea level to 150 feet below sea level. The highest range of conductance (190 to 320 umhos/cm) is found in wells completed from 220 to 350 feet below sea level.

Contours of specific conductance in the Principal Aquifer (Unit II) are shown on Figure 7.2. This shows the lowest conductance in south central part of Vashon/Maury Island west of Burton, and another area of low conductivity on Vashon Island's south arm. Conductance is generally lower along the west side of Vashon Island and increases gradually eastward. Observed conductance increases more rapidly toward the north end of Vashon Island and toward the south side of Maury Island.

Chloride

Chloride is normally a very soluble ion, but the natural soils and sub-strata of Vashon/Maury Island have very little natural chloride. Chloride analyses were included as a part of this study to examine the potential of salt water intrusion and other forms of contamination containing chloride.

The chloride content of water from wells on the Islands is generally very low. Of the 72 well samples collected, 62 had chloride concentrations between 2 and 8 mg/L; ten others, showing influence of salt spray, salt water intrusion or contamination, ranged from 10 mg/L to a high of 177 mg/L.

Relationship between Specific Conductance and Elevation of Well Bottom

1981 - 1982 Analyses

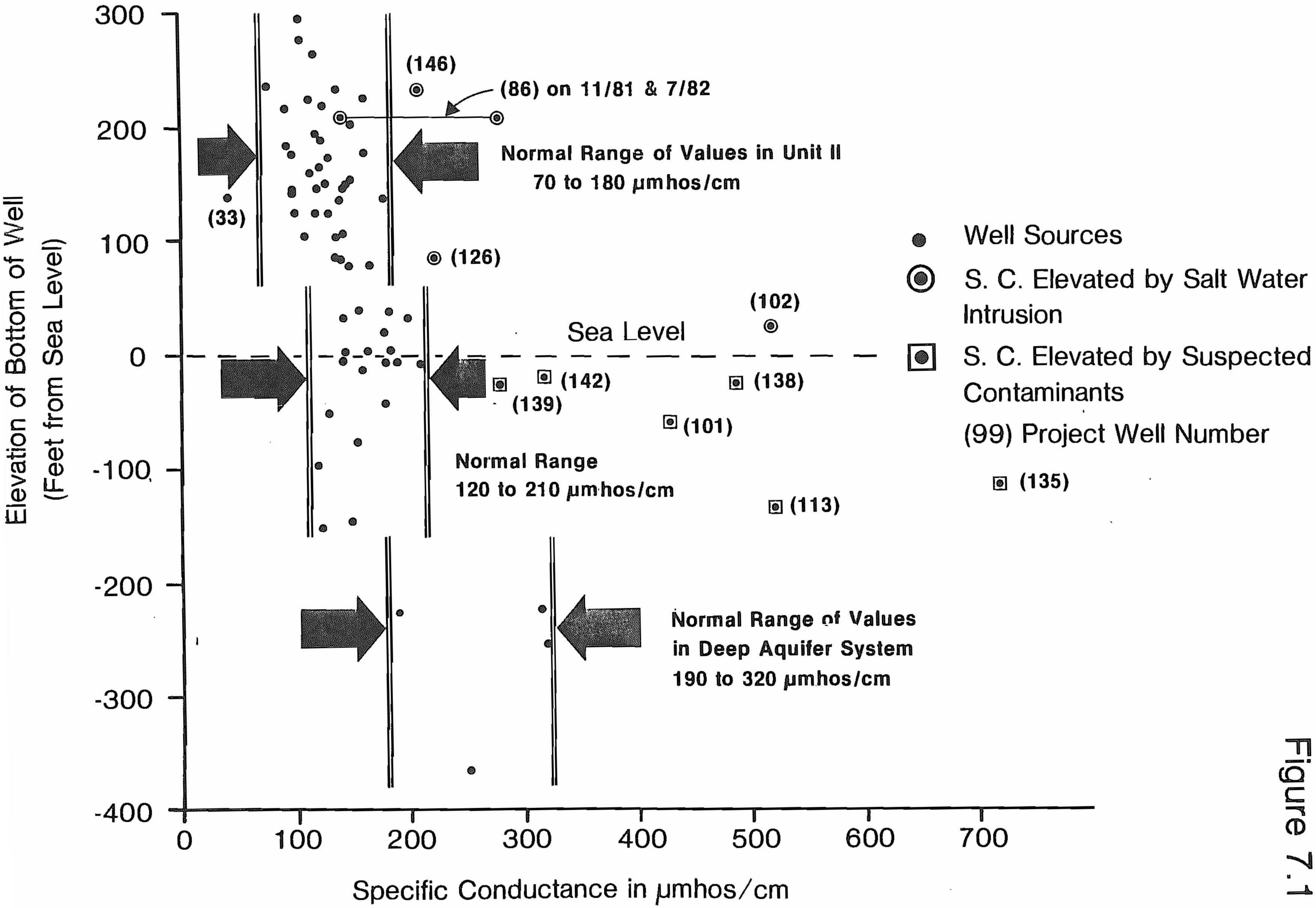


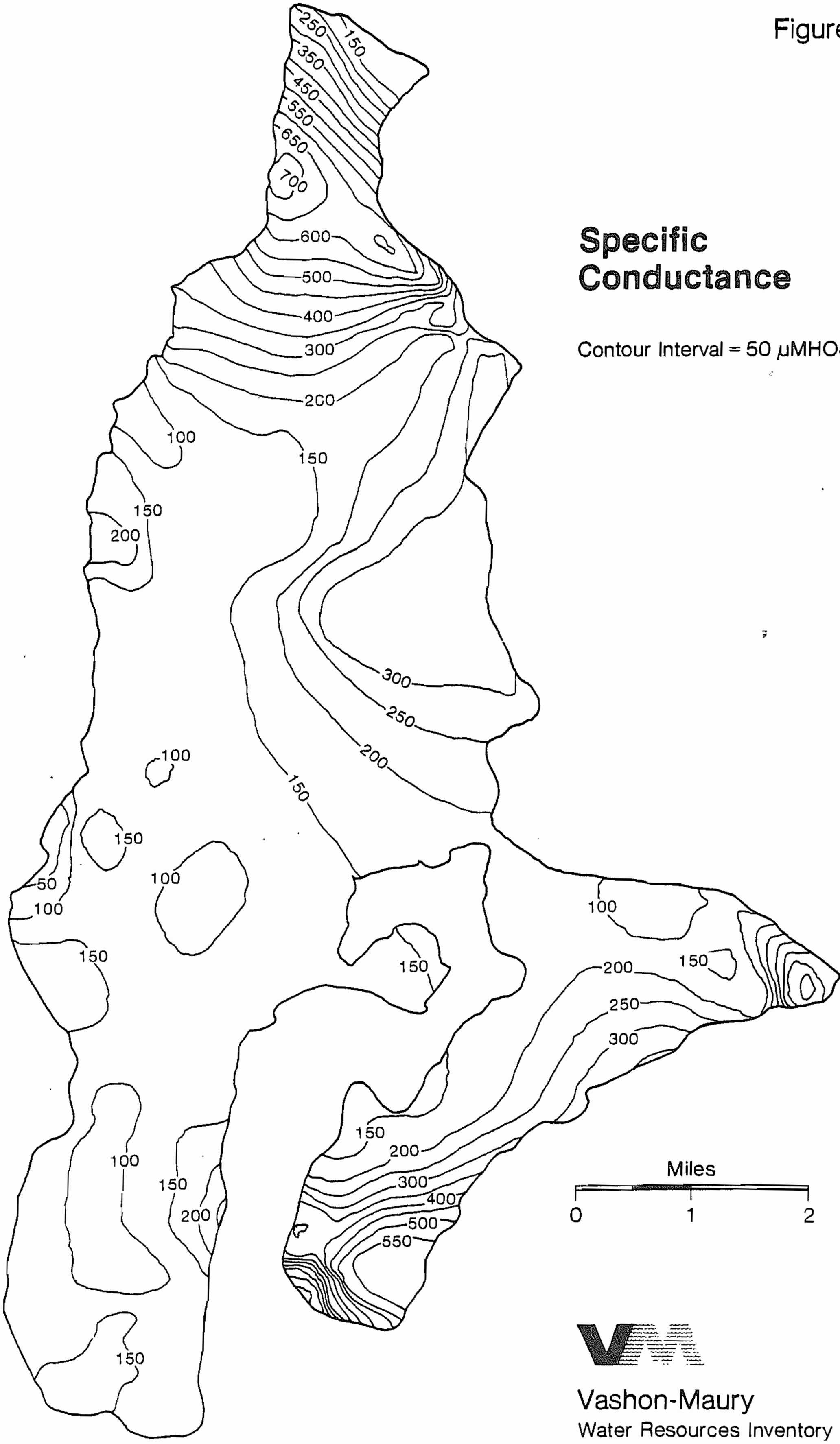
Figure 7.1

Vashon-Maury
Water Resources Inventory

Figure 7.2

Specific Conductance

Contour Interval = 50 μMHOS / CM



Vashon-Maury
Water Resources Inventory

Analysis of water from springs and stream sources showed somewhat higher chloride than the well sources. Sixteen such sources had chloride ranging from 3 to 15 mg/L. Chloride in eight springs was 10 to 15 mg/L, while seven of the eight stream analyses showed 3 to 5 mg/L. The stream immediately below the landfill showed the highest chloride of 14 mg/L. The generally higher chloride concentration found in the springs as compared to that in the wells may be a result of salt spray on the shoreline springs.

The analyses for chloride, shown in Table 7.1 for wells and springs from 1982 and before, reveals particularly high chloride in Morningside well 137 (575 mg/L), North Cedarhurst well (660 mg/L), and Sandy Beach Community well 135 (67.5 mg/L). The 1966 chloride analysis for well 6 (217.5 mg/L) was probably a laboratory error.

The pattern of chloride concentration is shown on the accompanying chloride isochemical map, Figure 7.3. Lowest chlorides are found along the west side of Vashon Island, and concentrations gradually increase towards the east and north margins of the Islands. Several areas of isolated higher chlorides are also present at a number of spring locations, particularly around the margins of Maury Island.

Nitrate as Nitrogen

Nitrate as nitrogen was selected for analysis because of its significance as an indicator of potential contamination. The DSHS standard is based on evidence that excess concentrations of nitrate causes methemoglobinemia or blue baby syndrome in infants. There are no known natural geologic sources of nitrate on the Islands, so measured concentrations are presumed to be generated from sources such as drainfields, drainfield effluent, fertilizer, animal wastes, and decaying vegetation.

Analyses of samples from 71 well sources showed nitrate to range from zero (not detected) to 5.3 mg/L. One source, Well

101 (Coast Guard well at Point Robinson) had a concentration of 27 mg/L which greatly exceeds the DSHS nitrate-nitrogen limit of 10 mg/L.

Analyses of water from 16 springs and streams showed a concentration range of zero (not detected) to 3.0 mg/L. Some of the springs had undetectable concentrations, whereas creek sources had higher concentrations, ranging from 0.8 to 3.0 mg/L. Again, it should be noted that wells 86, 111, 112, and 134 actually tap spring discharge areas. These sources had concentrations of 4.3, 1.9, 3.0 and 3.8 mg/L respectively. Historic water quality analyses as shown in Table 7.1 show several elevated concentrations of nitrate as nitrogen. These sources include S14 (Beal Creek on 12/22/80) at 6.2 mg/L, well 135 at 2.2 mg/L, and well 28 at 5.8 mg/L.

The accompanying isochemical map (Figure 7.4) shows the lowest area of nitrate concentration in the central part of Vashon Island. Higher concentrations of nitrate are noted near the margins of the island with particularly high zones of nitrate concentrations near the north and south ends of Maury Island.

Iron

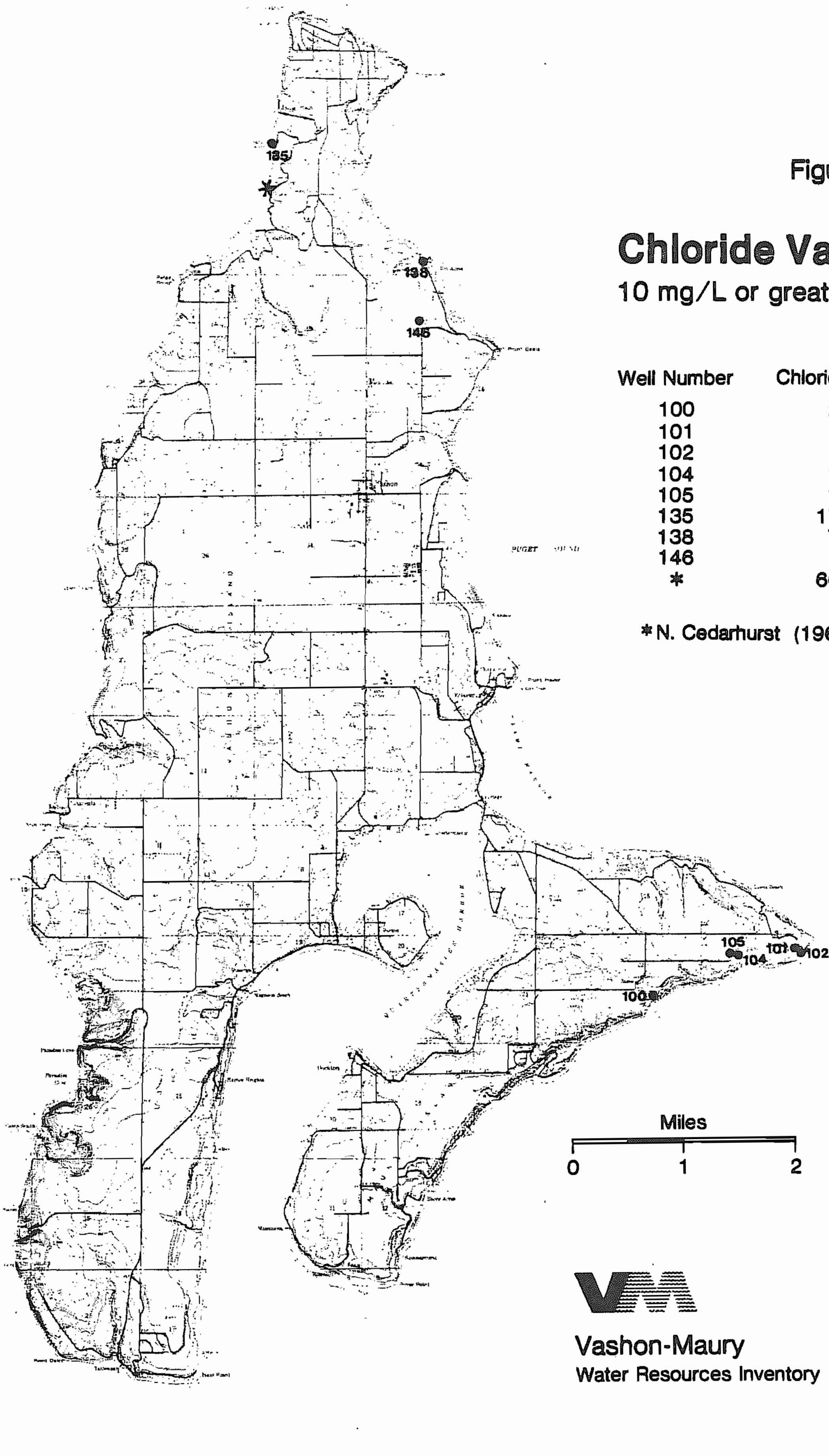
Analysis during 1981-82 for iron in 72 wells ranged from 0.1 to 16.6 mg/L. Iron concentration in 16 springs and streams ranges from zero (not detected) to 2.7 mg/L at the spring immediately below the landfill. The majority of wells in the sampling had iron concentration below the recommended limit of 0.3 mg/L. The springs generally appeared to have lower concentrations of iron than the wells.

The map of iron concentration, Figure 7.5, shows several areas of higher concentration of iron in the Principal Aquifer. The most notable of these are areas near Tahlequah and Glen Acres. These high concentrations of iron apparently occur as isolated pockets so that contouring of iron concentration is not appropriate.

Figure 7.3

Chloride Values

10 mg/L or greater



Well Number	Chloride mg/L
100	24
101	10
102	18
104	10
105	13
135	177
138	74
146	12
*	660

* N. Cedarhurst (1966)

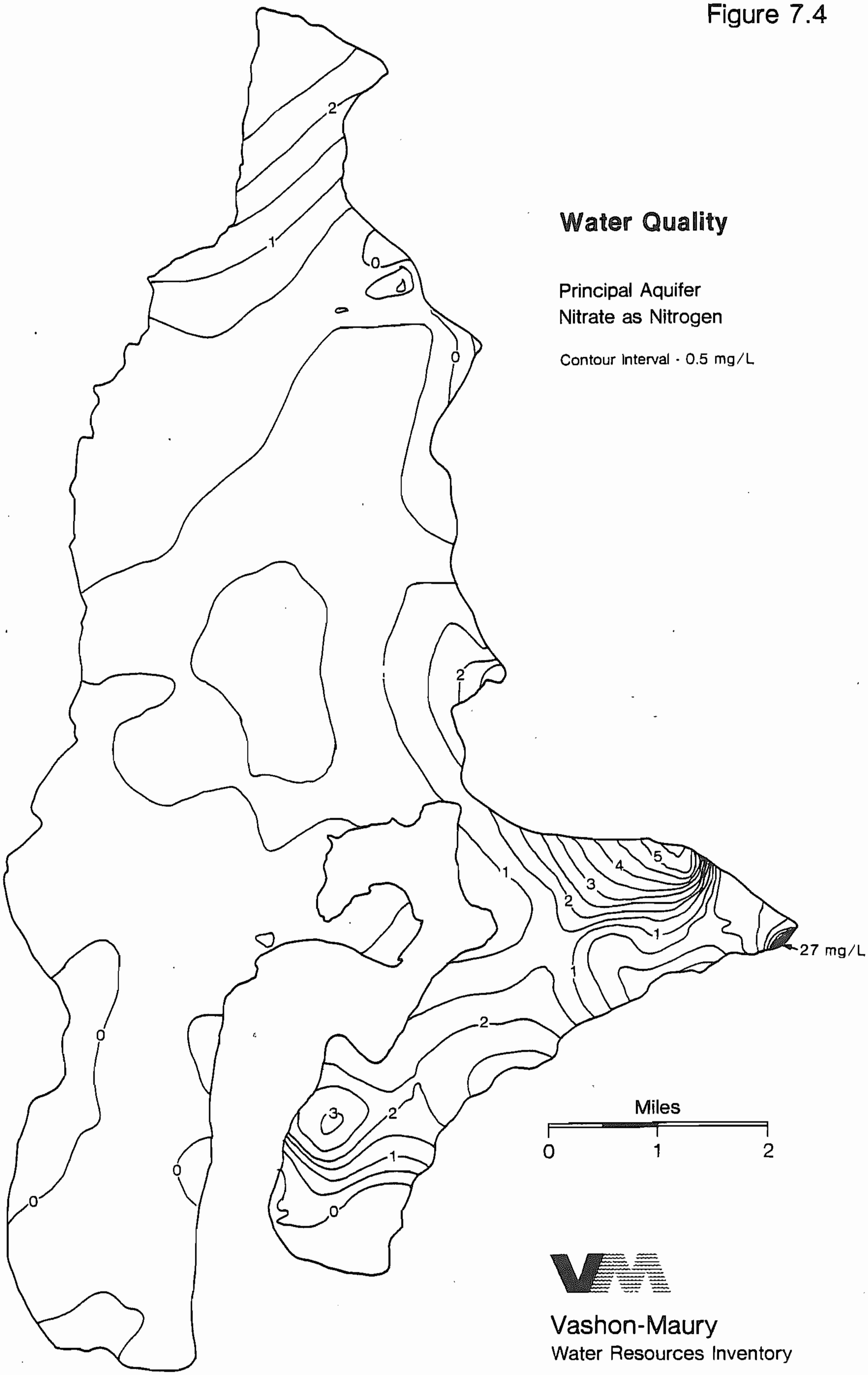
Vashon-Maury
Water Resources Inventory

Figure 7.4

Water Quality

Principal Aquifer
Nitrate as Nitrogen

Contour Interval - 0.5 mg/L



Vashon-Maury
Water Resources Inventory

From the sampling and analyses of our study and older data, it appears that the Deeper Aquifer system in Unit III generally has a slightly higher iron concentration than the Principal Aquifer.

Water with iron concentrations over 1 mg/L may be affected by the presence of iron bacteria. This bacteria thrives in anaerobic conditions such as those that exist below the water table where sources of iron are available. The bacteria pose no health hazard, but are very persistent and a great nuisance in wells and water distribution systems because they clog pipes, valves, and the openings in well screens.

Manganese is a metal which behaves very much like iron in water. Analysis for manganese was not routinely made on the samples collected as a part of this survey, but some other analyses are available. The Deep Aquifer appears to have greater manganese concentration than the Principal Aquifer. Manganese at Deep Aquifer wells 150, 40, 37, and 38 all have manganese concentrations above the recommended limit of 0.05 mg/L.

Acidity

As previously described, pH designates the acidity of the water. The neutral pH value for water is 7.0. Thus, a pH of 6 has hydrogen iron concentration 10 times greater than that of water with a pH of 7.

The routine analyses of this study did not include pH. However, some analyses for pH in several springs show average values of about 6.4. Analysis included in Table 7.1 show generally higher values for pH, most of which are above 7.2.

Most of the acidity in water on Vashon/Maury Island is caused by the presence of carbonic acid (H_2CO_3). This mild acid easily disassociates, producing the bicarbonate ion (HCO_3^-) and releasing CO_2. The analysis for pH is variable and often depends on the length of time between collection and analysis. A sample which is not analyzed immediately can release CO_2, reducing the quantity of H_2CO_3 present in the sample and thereby increasing the pH. Based on the information available, most of the ground water on Vashon/Maury Island has a pH value of less than 6.4.

Arsenic, Cadmium and Lead

During the course of this study, some public concern arose regarding the presence of arsenic and cadmium as found in soils of the Islands. According to the Vashon/Maury Island **Beachcomber** (Volume 25, No. 36, November 12, 1981) two residents of Pohl Road had soil analyses indicating cadmium levels of 0.75 and 1.39 ppm, compared to the natural background levels of 0.05 to 0.3 ppm. Fallout from the Tacoma ASARCO Smelter is the suspected source of these contaminants which apparently occur primarily toward the south end of Vashon Island and on Maury Island.

To determine the potential impact of these elements on the water resource, water samples were selected from ten springs and streams and analyzed for arsenic, cadmium and lead. As shown in Table 7.3, the results of these analyses and older analyses reported in Table 7.1 were all below these limits of detection:

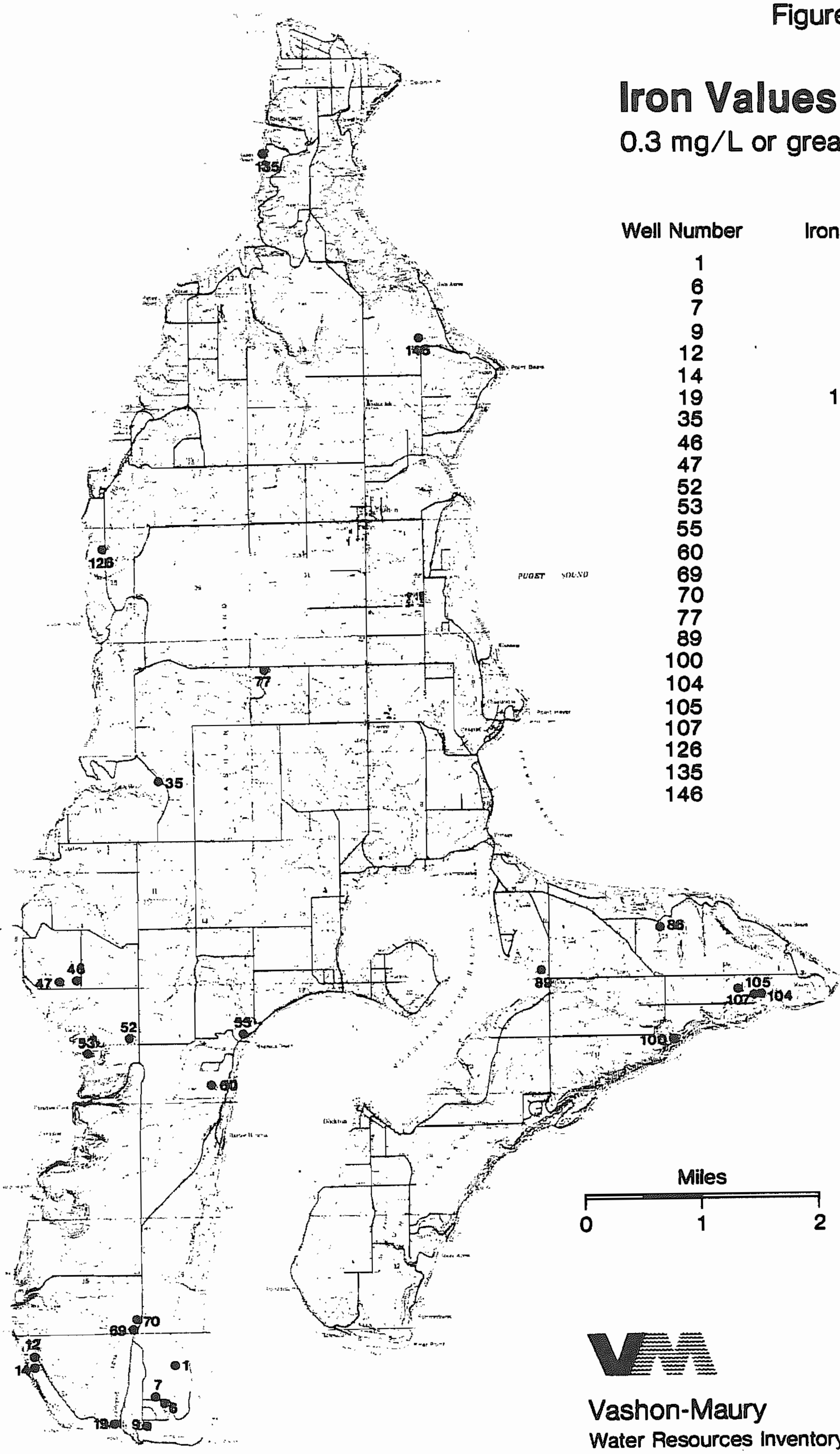
Arsenic	0.005 mg/L
Cadmium	0.002 mg/L
Lead	0.01 mg/L

Analysis of samples collected below the landfill (S-22) were also below the limits of detection. Thus, it is presumed that these cations have been taken up and retained in the soil profile and to date, have not infiltrated to the ground water.

Figure 7.5

Iron Values

0.3 mg/L or greater



Well Number	Iron mg/L
1	.31
6	3.7
7	1.6
9	.41
12	4.7
14	.39
19	16.6
35	.43
46	.74
47	2.0
52	.32
53	.33
55	.37
60	.44
69	.4
70	3.6
77	.44
89	.36
100	1.4
104	4.2
105	.30
107	.57
126	9.2
135	.90
146	6.2

Miles

0 1 2

Vashon-Maury

Water Resources Inventory

Temperature

Water temperature is an important consideration in many applications including food processing (berries), heating and air conditioning and fish propagation.

The insulating properties of the earth dampen atmospheric temperature fluctuations to produce nearly uniform year-round ground water temperatures. At a depth of 30-60 feet, ground water temperature generally exceeds the mean annual air temperature by two to three degrees Fahrenheit and fluctuates less than one degree Fahrenheit. Below this depth, ground water temperature generally increases in response to the geothermal gradient of the earth's crust.

While ground water temperatures are nearly constant, measurement of representative temperatures is more difficult. Temperatures from near surface springs can be affected by air temperature. Temperature of water from wells can be warmed by pumping and altered by the storage and distribution system.

On the Islands, ground water from wells penetrating the Principal Aquifer has been found to be generally less than 50 degrees Fahrenheit. Water from wells penetrating the Deeper Aquifer system has temperatures of 50 to 54 degrees Fahrenheit.

Temperatures of several Maury Island springs measured 46°F in November 1981, and 54°F in July 1982, showing the effect of ambient air temperature. The temperature of water from some dug wells and shallow drilled wells was observed to be about 44°F, reflecting winter recharge temperatures.

INTERPRETATION

CHEMISTRY OF PRECIPITATION

Rain and snow which falls on Vashon/Maury Island is condensed evaporation from the Pacific Ocean, Puget Sound and other sources. In the evaporative process, a few ions are transported and returned to earth with the precipitation.

The chemical composition of precipitation is quite variable from place to place, and even varies between storms at a specific location. For example, chemical analysis of two samples collected on Vashon during the course of our study are compared with two other sources in Table 7.4.

TABLE 7.4

CHEMICAL ANALYSES OF PRECIPITATION

	TDS mg/L	Cl^- mg/L	Mg mg/L	Na mg/L	pH	S.C. umhos/cm
Dist. 19 10/28/82	2.6	ND	0.013	0.18	5.45	3.9
Kellum Tahlequah 10/82	-	-	-	-	6.8	22
Menlo Pk, CA	12.4	3.75	-	2.24	5.9	-
Baltimore, MD	-	0.38	-	0.26	4.1	-

As shown in the table, the composition of precipitation is quite variable on the Islands and across the nation. The composition of the water and of the precipitation collected at Water District 19 offices shows very low dissolved solids and notably low pH. Analysis of precipitation collected at Kellum's near Tahlequah shows a higher conductivity and higher pH. The difference in these two analyses is probably a result of different sampling methods. These analyses of the Islands' water resources at their outset, show very low mineralization and low pH. As water travels through the hydrologic regime, its composition is changed and altered as it dissolves minerals and other materials along its flow path.

CHANGES IN SPECIFIC CONDUCTANCE

For the purposes of this investigation, specific conductance was selected for analysis because it is easily determined and because of its usefulness as an indicator of dissolved minerals. Wells with high chloride would have high dissolved solids and correspondingly high conductance.

Effect of depth.

The conductance and chloride as shown in the isochemical maps indicates generally lower conductance near the recharge areas. Presumably, greater volumes of water are infiltrated faster at these locations so that the water maintains a lower overall mineralization. The relationship is complete because conductance also increases with depth. From the uplands of Vashon/Maury Island down to sea level, this increase is approximately 30 umhos/cm per hundred feet of depth, or an equivalent increase in dissolved solids of about 45 mg/L per hundred feet of depth. Below sea level, the increase with depth is more rapid, being about 100 umhos/cm per hundred feet of depth, or 150 mg/L of dissolved solids per hundred feet of depth. The more rapid increase below sea level could be attributed to slower infiltration of the water through the more silty and clayey sediments of Unit III.

Seasonal change.

The limited data available also suggests some seasonal change in the chemical character of the water. The spring-well at Maury Mutual (well 86) increased from 141 to 280 uhmos/cm between late November, 1981 and August, 1982. Nitrate analysis taken at the same time showed a similar increase from late fall to the following summer with nitrate as nitrogen increasing from 3.7 mg/L to 4.3 mg/L. These relationships, if valid, could result from the dilution effect of higher winter recharge. Such an interpretation could also affect the water analysis from wells pumping more extensively during the summer season.

SALT WATER INTRUSION (CHLORIDE CONTAMINATION)

Chemical analyses for this and prior studies show a definite indication of salt water intrusion on the Islands. This is evidenced by high concentrations of chloride and high specific conductance in a number of wells. Wells where salt water intrusion exists or is incipient are shown in Table 7.5.

TABLE 7.5

WATER QUALITY IN WELLS WITH SUSPECTED SALT WATER INTRUSION

Well No.	Owner	Elevation of Bottom in Ft.	Specific Conductance umhos/cm	Chloride mg/L
100	Willamette Western	-222	315	24
101	US Coast Guard	- 58	430	10
113	Hillcrest	-133	525	6
135	Sandy Beach	-116	720	177
137	Morningside	- 22	2200	575
138	Mallman	- 26	490	74
139	Kirschner	- 25	280	9
142	Hillside	- 18	320	9
North	Cedarhurst*	?	790	660

*(1966 analysis)

As previously described, the normal range of specific conductance in the Principal Aquifer is from 70 to 180 umhos/cm. The normal range of chloride is about 3 to 5 mg/L in the Principal Aquifer and about 5 mg/L in the Deeper Aquifer.

In the wells with suspected salt water intrusion, there is a wide range of conductance, indicating varying impacts of salt water on water quality (See Table 7.5).

Except for a well at the Coast Guard station at Point Robinson and Willamette Western's gravel pit on Maury Island, all of these wells with salt water intrusion are located toward the north end of Vashon Island. It is also important to note that all of the wells are located near the shoreline and most are completed less than 100 feet below sea level. The Deeper Aquifer lying more than 100 feet below sea level does not generally show an indication of high chloride or conductance.

The north Vashon Island area of salt water intrusion is notably distant from the defined recharge mounds and probably receives limited natural fresh water underflow. In addition, the near sea level aquifer is not extensive around the rest of the islands and probably provides ready and open access to the salt water in nearby Puget Sound at the north end of the Island.

Unfortunately, there are very few historical analyses of conductivity or chloride from these wells. One well where chlorides were found in 1966 has shown a definite increase. Well 135 shows an increase in chloride from 67.5 mg/L in 1966 to 177 mg/L in 1982. It is also possible that the chloride concentration and conductivity may vary seasonally depending on the amount of underflow and usage. However, we have no data available to support this idea.

Water in some of these wells is above the recommended limit for chloride and dissolved minerals. Without management and corrective measures, it is possible and even likely that salt water intrusion will continue to increase. Besides imparting a salty taste to the water, these waters have rather high hardness and sodium concentration. High sodium concentration could be detrimental to people with cardiovascular problems.

NITRATE CONTAMINATION

Sources

Above the water table, organic nitrogen as ammonia from effluent, and animal and plant wastes undergo nitrification and decomposition, releasing ammonia and nitrate (NO_3^-). Some ammonium ions (NH_4^+) are absorbed by silt and clay in the soil and some are released as ammonia to the atmosphere. Ammonium and nitrate are also taken up by plant roots. Nitrate which escapes uptake then migrates as leachate to the water table.

Potential sources of nitrate are septic tank effluent, fertilizer and animal waste. Using the Beal Creek drainage basin as an example, it is apparent that all these sources of nitrate are present. The area lying east of 97th Avenue SW is unsewered, and septic tanks are used for domestic disposal. Nitrate fertilizers may originate from the Beal greenhouses in the southwest quarter of Section 32. Nitrate from animal wastes could originate from Smith's Chicken Farm located at an elevation of about 280 feet, one-quarter mile west of Plant 1. The chicken farm and greenhouses lie outside of the Beal Creek surface water drainage basin. However, ground water infiltration from these areas could discharge to the Beal Creek canyon as springs. Roy Wilkerson, Manager of Water District 19, reports that analyses of springs from the north side of Beal Creek Canyon have shown high nitrates. Thus, it seems possible that some of the increase in contaminants shown in the analysis of Plant 1 may originate from the vicinity of the chicken farm.

Concentrations

The concentration of nitrate as nitrogen in drainfield effluent has a range of about 25 to 80 mg/L and occurs primarily as ammonia. This concentration is attenuated by the above described reactions, and by direct infiltration of precipitation. The remaining leachate, which infiltrates to the ground water, is detected in various sources on Vashon/Maury Island. Sources with suspiciously high concentration include wells 85, 86, 102, 111, 112, and 134. All of these, except for 85 and 102, are very shallow wells or spring developments. Springs may be particularly susceptible to nitrate contamination from surface runoff entering the catchment. The very high concentration of 27 mg/L nitrate as nitrogen at well 27 may result from animal waste. The Coast Guard reportedly used horses at one time to remove boats from the water and kept these animals in the area of the well.

From the available data, it appears that the natural background concentration for nitrate on Vashon/Maury Island is near the limit of detection or 0.1 mg/L. Sources with concentrations above 0.5 mg/L are probably receiving recharge containing nitrate from organic sources (i.e. septic tank systems, fertilizers and animal wastes). Sources with concentration above 1.0 mg/L should be carefully monitored and studied to determine if corrective measures would improve the water quality.

WATER QUALITY TRENDS

An important consideration in the interpretation of water quality data is the change in quality with time. Unfortunately, very few historical analyses are available. Limited analyses from Water District 19's plants 1 and 2 on Beal Creek and Ellis Creek are shown in Figure 7.6. While the conductance has rather irregular values, particularly at Beal Creek, a general increase in conductance with time is apparent. Using this data, it appears that the increase has been about 5 umhos/cm per year. The maximum specific conductance of 250 umhos/cm is equivalent to a dissolved solids content of about 167 mg/L.

The U.S. Public Health Service recommends a total dissolved solids limited of 500 mg/L (1962), and the U.S. Environmental

Protection Agency recommends 250 mg/L in domestic water supplies (1976). Vashon waters are generally well below these limits. Thus, the important consideration is not the total concentration, but rather the trend of the water quality.

It is also apparent (see Figure 7.6) that the conductance at Beal Creek is higher than that at the Ellis Creek Plant 2. We can only speculate as to the cause of higher conductance at Beal Creek and the general increasing trend in conductance at both sites. The results are rather irregular, suggesting a relationship between concentration and runoff (precipitation). However, the highest value of 256 umhos/cm in 1975 corresponds to a year when precipitation was about 6 inches above normal and the water surplus (runoff) was about 7 inches above the 30-year average. Most of the samples were collected and analyzed during December of each year. However, several were collected during other months and may reflect some seasonal fluctuation in concentrations.

The analyses displayed in Figure 7.6 and 7.7 were performed by the DSHS lab in Seattle. Analyses were made to determine concentrations of nitrate, hardness, iron, (and an occasional chloride) as well as conductance values. Four analyses for chloride were made during the period and these show an average of about 5 mg/L. Figure 7.7 illustrates the relationship between conductance, hardness, and nitrate as nitrogen. These three values all show a similar increasing trend over the period and a close parallel between conductance and nitrate as nitrogen.

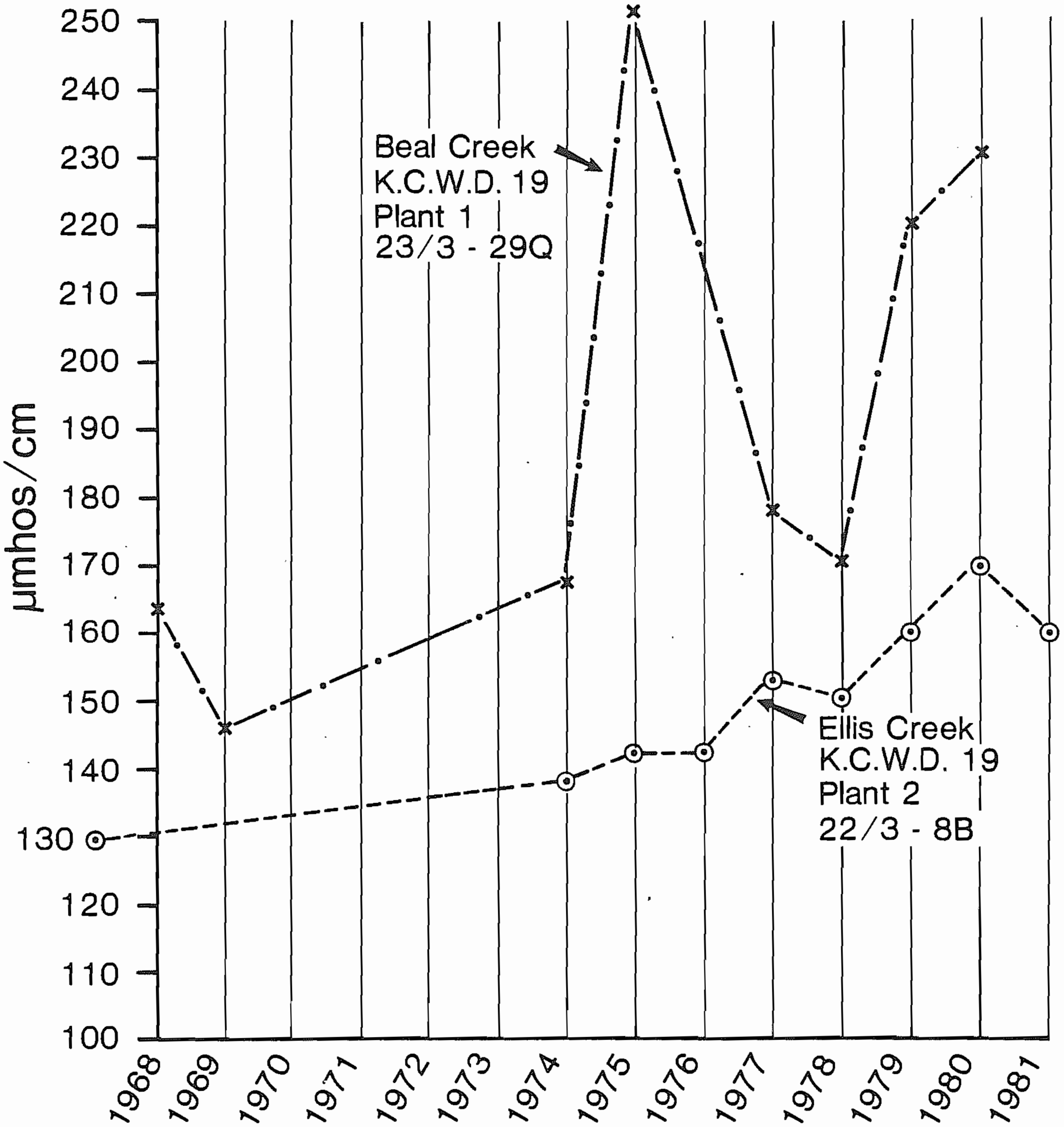
DSHS analysis for nitrate as nitrogen from 45 Vashon/Maury Island systems were originally examined by David Frank and Bob Gilliom. Their data from 28 water systems, when averaged together, show a generally increasing trend. The concentrations increase from less than 1 mg/L in 1967 to over 2 mg/L in 1981. Nitrate as nitrogen data from springs show concentrations increasing from about 1 mg/L in 1967 to about 2.5 mg/L in 1981.

Figure 7.6

Specific Conductance

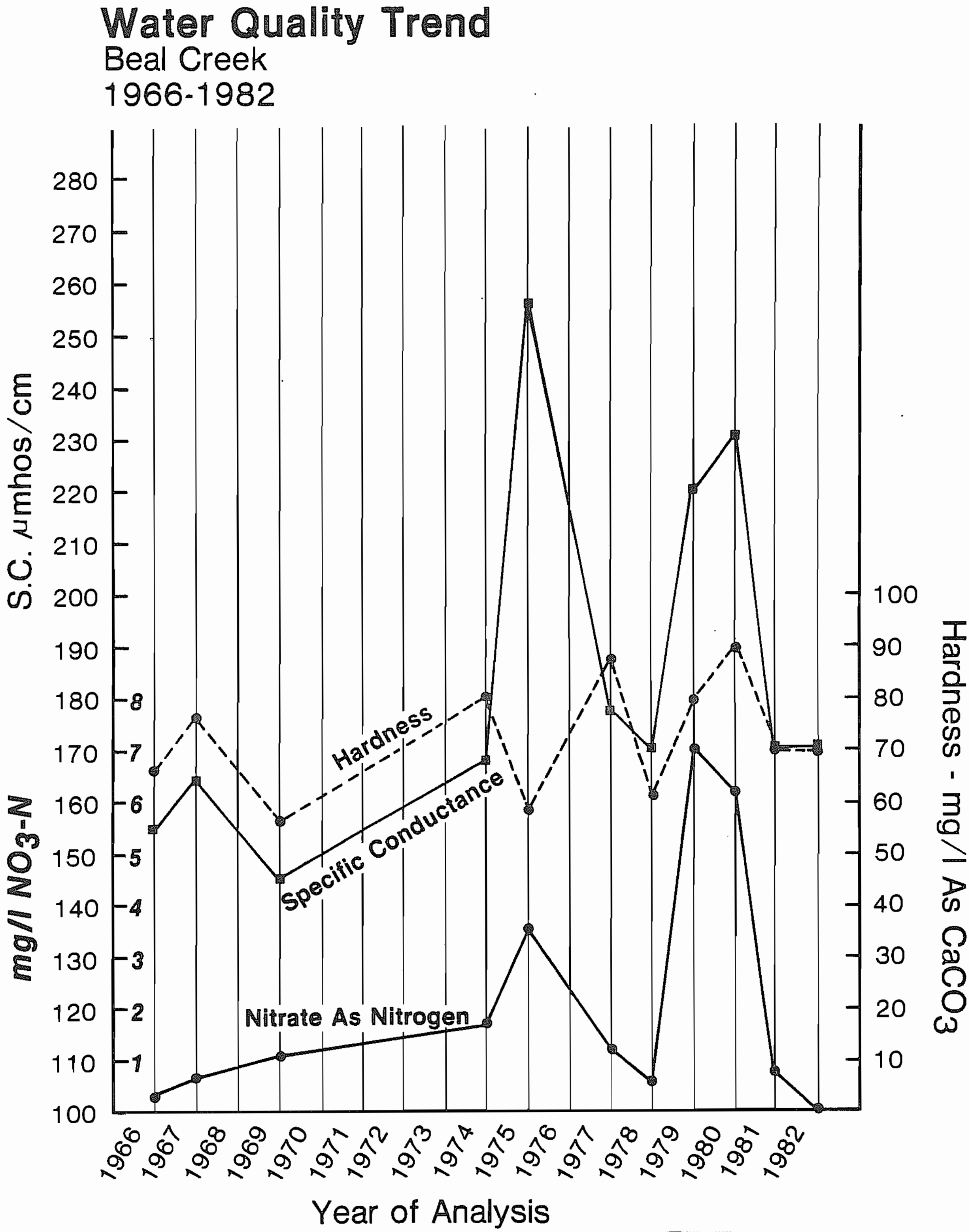
Change with Time

µmhos/cm



Vashon-Maury
Water Resources Inventory

Figure 7.7



Vashon-Maury
Water Resources Inventory

CHAPTER 8

WATER USE

This chapter provides an estimate of the amount of water currently used on Vashon/Maury Island, and projects future water demands based on the population forecast for 1990 and 2000. These estimates are needed to compare water use to the water available on the Islands.

SUMMARY

Private wells and springs and public water systems using both springs and wells provide water to the Islands' residents. The 1980 census recorded a population of 7,377 for the Islands. Based on water service connection data and the number of private wells, the Islands' population may actually be larger, particularly during summer months.

Based on an estimated average water use of 120 gallons per person per day, total water use on the Islands is estimated to be about 1 million gallons per day or 365 million gallons per year.

According to the Vashon Community Plan, Puget Sound Council of Governments (PSCOG) forecasts of the Islands' population show an increase of about 1,000 people by the year 1990. This would increase the total water use to about 1.1 million gallons per day or 400 million gallons per year. Any significant increase in water use must be met by coordinated efforts of the water utilities.

BACKGROUND

WATER SOURCES

Nearly all water used on Vashon is ground water from wells and springs. Most water is used for domestic purposes, with minor amounts supporting commercial and light industrial applications. A few wells are used to irrigate crops. There have also been some irrigation withdrawals from Judd and other Creeks.

The original settlers used springs and shallow dug wells for their water supplies (Eernisse 1978). In recent years, wells have been drilled using both cable tool and rotary methods. Of the 150 wells measured in this study, 80% were drilled by cable tool and 12% were drilled with rotary equipment. Dug wells accounted for 8% of the total. The total number of developed water sources on Vashon/Maury Island is probably over 500. In recent years, particularly during the 1977-78 drought, many shallow and dug wells have been replaced with deeper, drilled wells.

About 75% of the drilled wells are completed with 6-inch diameter casing. Cable tool wells in this sampling had an average depth of 186 feet, and the average depth of the rotary wells was 213 feet (not including three deep mud-rotary wells Nos. 40, 121 and 150).

Many spring sources have been developed by improving the spring capture or installing shallow well points. Directing runoff away from intake areas has improved protection from surface contaminants.

The development of water sources on the islands is sometimes stymied by natural conditions and construction problems. Water in the Principal Aquifer is often difficult to detect and develop. The fine-grained nature of this aquifer generally yields more water to properly designed, screened wells. Drilling to the Deeper Aquifer requires careful planning, so that adequate sized casing can be placed at the completion depth.

ADEQUACY OF WATER SUPPLY

The Principal Aquifer is generally capable of yielding sufficient quantities of water to supply single family residences. In some areas, this aquifer is capable of yielding adequate quantities to supply small water systems or providing the partial supply of larger system demands. Many of the Islands' systems have supplies which are only marginally adequate, and have no standby or surplus availability. Development and management of additional supply is essential to the future of such systems.

Wells completed in the deep aquifer are often capable of higher yields (100-300 gpm). Such wells are suited for supplying larger systems and irrigation needs.

WATER PURVEYORS

The State of Washington classifies all water systems according to the number of connections they serve, and regulates the quantity of supply required and frequency of water quality analysis. In general, the State requires water systems to have a peak capacity for peak day and fire flow of 800 gallons per day per connection, and estimates the average demand at 300 gallons per day per connection.

The Vashon Community Plan reported that the Islands' residents were served by 83 water companies. Since that report, at least one consolidation has been accomplished. It is likely that the Islands may have 10 or more additional unrecorded public water systems.

VASHON/MAURY ISLAND WATER SYSTEMS

	Total	Class 1 Over 99	Class 2 10 to 99 Services	Class 3 Transitory of 25 to 299	Class 4 2 to 9 Services
Number of systems	82	5	25	2	50
Number on Vashon	69	4	21	2	42
Number on Maury	13	1	4	0	8
Total connections	2575	1933	441	27	174
Number of wells	40	3	11	4	22
Number of springs	48	4	14	2	28
Estimated average gallons used per day from water systems	802,800	595,500	134,675	3,375	69,250
Estimated population on water systems	7,714	5560	1446	31	677
Estimated gallons used per person per day	103 (average)	107	93	109	102
Estimated gallons used per connection per day	311 (average)	308	305	125	398

(From data in Vashon Community Plan - Proposed 1980)
(Updated for consolidations and 1982 data from District 19)

TABLE 8.1

DATA

Vashon/Maury Island water system data is summarized in Table 8.1. As shown, the estimated water use for Class 1 and 2 systems is about 300 gallons per day. Class 4 water use is nearly 400 gallons per day per connection. Water use by Class 3 systems is much lower because this classification applies to transitory populations such as Camp Sealth. As shown in the table, 1,933 connections (75%) are served by Class 1 systems, and about 51% of these by Water District 19.

During 1982, Water District 19 supplied an average of over 300 gallons per day per connection. District 19 records show the peak month (usually June) use at 565 gallons per day per connection, and the peak day of the peak month at 785 gallons per day per connection. These measured water uses on Vashon are close to the State's standard for average and peak demand.

INTERPRETATION

CURRENT WATER USE

The 1980 census recorded the Vashon/Maury Island population as 7,377 persons. The average water use of 300 gallons per day (gpd) per connection is equivalent to 120 gpd per person (using 2.5 persons per household as reported in the **Vashon Community Plan Draft** - page 9). Thus for the Islands' population:

1980 average water use = 885,240 gallons per day (gpd)
or
323 million gallons/year (mgpyr)

The peak water requirement of 800 gpd per connection is equivalent to 320 gpd per person and peak day consumption of 2,360,640 gallons for the reported population.

Because of only limited growth on the Islands since 1980, the population probably has not increased significantly since the census date. However, as shown in Table 8.1, the estimated population served by the Islands' water systems was 7,714 in 1980. In addition there are at least 100 homes (connections) served by private wells, which when factored into population adds 250 people. Thus the population based on water system data and private wells may be at least 8,000 people. Therefore current water use is probably very close to 1 million gallons per day (average), and about 2.5 million gallons per day during peak demand.

FUTURE WATER DEMANDS

Preliminary PSCOG forecasts of Island population, issued in 1981, are: 8,238 for the year 1990 and 9099 for the year 2000. Using these forecasts, future water demand is estimated:

		AVERAGE USE IN MILLION GALLONS		PEAK DEMAND IN MILLION GALLONS
YEAR	POPULATION	PER DAY	PER YEAR	PER DAY
1990	8238	1 mgpd	365 mgpyr	2.6 mgpd
2000	9099	1.1 mgpd	390 mgpyr	2.9 mgpd

These estimates may be too low if, as discussed in the previous section, the present population is actually about 8,000. Since peak demand rates do not occur over an entire year, these factors are not appropriate for estimating future water use, and are not presented.

Accurate forecasting of water use is influenced by many intangible factors. These factors include consideration of: the land use plan; application and effectiveness of any water conservation measures; changes in the transportation system to the Islands; public desire to maintain the rural atmosphere; potential large uses of water by expanded or new industry; and the ability of existing or new water systems to meet the demands.

Many Island water purveyors are small and have limited revenues and financing capability to accomodate substantial new growth. Such expansion requires not only development and management of additional resources but also costly storage and distribution. Any significant development will require coordinated effort of the water utilities.

IMPACT

OF THE WATER RESOURCE

ON LAND USE PLANNING

PART III

CHAPTER 9

GROUND WATER PRODUCTIVE CAPACITY

This chapter identifies the population limit of Vashon/Maury Island based on the Islands' Ground Water Productive Capacity (GPC). Ground Water Productive Capacity is defined as the proportion of the ground water that theoretically can be recovered for use by conventional means (wells, springs). Since ground water is the Islands' most economical water source, a reliable means of estimating the Ground Water Productive Capacity is necessary to determine the maximum population that can be supported by the ground water resource and to make other land use decisions.

SUMMARY

The Ground Water Productive Capacity is calculated from the amount of recharge in each Recharge Potential Level by applying factors to account for drought (drought ratio) and the recoverable ground water (capture ratio). Ground Water Productive Capacity from wells in the Principal Aquifer is calculated to be 257 million gallons per year in areas of high Recharge Potential Level (RPL); 165 million gallons per year in medium RPL areas; and 156 million gallons per year in low RPL areas. Based on the Ground Water Productive Capacity, Vashon/Maury Island can support a population of about 13,000.

METHOD

The capacity of the Principal Aquifer to supply water is dependent upon the amount of recharge. As shown in Table 6.2, the amount of recharge is calculated from the Recharge Potential Level (RPL) (high, medium, and low) for each recharge area, applying the appropriate recharge rate (Rr) for each level. Two other important factors affecting productive capacity are the capture ratio (Cr) and drought ratio (Dr).

Capture ratio is the proportion of recharge that can be recovered from wells and springs. Its value varies with aquifer characteristics and is generally estimated to be 10% to 60% of the total recharge. The ratio is a product of aquifer retention and recovery factors. About 50% of water in an aquifer is retained by surface tension. In addition, recovery of more than 50% of an aquifer's water requires scientific selection of all well locations, depths, and discharge. Using these two factors, the capture ratio for Vashon/Maury Island is estimated to be 25% (50% x 50%).

The drought ratio is also an important part of the calculation, accounting for prolonged reduction in recharge. Brief periods of reduced recharge are unlikely to effect productive capacity because water in storage provides a buffer. However, prolonged drought reduces storage and hence, affects the Ground Water Productive Capacity. A multiplier of .70 has been used in the calculations to compensate for reduced capacity during drought.

A final assumption involved in these calculations relates to on-site disposal systems. Recycled water from septic tanks can infiltrate as recharge. However, that portion of recharge has not been included as a part of the recoverable resource because such contributions vary over different parts of the Islands and must be accounted for locally as a part of an active management program (see Chapter 11 and 12).

CALCULATION OF GROUND WATER PRODUCTIVE CAPACITY

The formula for calculating Ground Water Productive Capacity is:

$$\text{Ground Water Productive Capacity} = \text{Recharge Rate} \times \text{Capture Ratio} \times \text{Drought Ratio}$$

GPC (inches/yr/acre) = Rr (inches/yr/acre) X Cr (.25) X Dr (.70)

Using the above formula, the calculations of Ground Water Productive Capacity for each Recharge Potential Level are shown in Table 9.1.

TABLE 9.1

GROUND WATER PRODUCTIVE CAPACITY (INCHES PER YEAR PER ACRE)

Recharge Potential Level	Recharge Rate (in/yr/acre)	Drought Ratio %	Capture Ratio %	Ground Water Productive Capacity (in/yr/acre)
High	9	.70	.25	1.6
Medium	5	.70	.25	.88
Low	3	.70	.25	.53

The GPC for each Recharge Potential Level is converted to total Ground Water Production Capacity (GPC) expressed in millions of gallons per year in Table 9.2 using the following formula:

GPC (in/yr/acre) x 27150 (conversion factor) x Area (acres) = GPC (mg/yr

TABLE 9.2

GROUND WATER PRODUCTIVE CAPACITY

(GALLONS)

RECHARGE POTENTIAL LEVEL	GROUND WATER PRODUCTIVE CAPACITY	CONVERSION FACTOR	TOTAL ACRES	GROUND WATER PRODUCTIVE CAPACITY IN MILLIONS OF GALLONS PER YEAR
High	1.6	27150	5922	257
Medium	.88	27150	6918	165
Low	.53	27150	10817	156
TOTAL GROUND WATER PRODUCTIVE CAPACITY				578 mg/yr

In this report, values are calculated for the Principal Aquifer only. The Deep Aquifer is as yet insufficiently explored and tested to establish reasonable limits for water quantity and quality (including the potential for salt water intrusion). In addition, its recharge appears to be very limited, thus restricting production potential. Evaluation and possible addition of the Deep Aquifer as a supply source must await further information and establishment of an active management program (see Chapter 11 and 12).

CALCULATION OF RESOURCE RELATED PLANNING CAPACITY

The population which can be supported by the Ground Water Productive Capacity (GPC) is determined by dividing the GPC for a specific area by a usage factor. Water usage on Vashon/ Maury Island has been estimated at 300 gallons per day per connection (Chapter 8). According to the 1981 Vashon Community Plan, the number of occupants per dwelling unit is approximately 2.5 persons. Thus the per capita consumption of water is 300/2.5 = 120 gallons per day per person or 43,800 gallons per year per person.

For a given area, the supportable population can be computed from:

$$\text{Population} = \frac{\text{Ground Water Productive Capacity}}{\text{43,800 gallons per year per person}}$$

The computed supportable population based on the GPC (from Table 9.2) for each recharge potential level is shown in Table 9.3.

TABLE 9.3

ESTIMATED SUPPORTABLE POPULATION BASED ON GROUND WATER PRODUCTIVE CAPACITY

Recharge Potential Level (RPL)	Ground Water Productive Capacity (GPC) in million gal/yr	Estimated Supportable Population (persons)
High	257	5,868
Medium	165	3,767
Low	156	3,562
TOTALS	578	13,197

CONCLUSION

Considering ground water resource availability alone, Vashon/Maury Island will support a total population of approximately 13,000 persons.

CHAPTER 10

RENOVATION CAPACITY

This chapter identifies the population limit of Vashon/Maury Island based on the Islands' Renovation Capacity (RC). Renovation Capacity is defined as the maximum density of dwelling units, based on the reduction of contaminants to acceptable levels by attenuation.

SUMMARY

Renovation Capacity is derived from the following factors: the recharge rate adjusted for drought, the acceptable level of nitrate concentration, the proportion of nitrates reaching the water table, the quality and quantity of effluent discharge, and the average number of occupants per dwelling unit. For Vashon/Maury Island, the Renovation Capacity is calculated to be 468.6 gallons/day/acre for high recharge potential level areas, 260.3 for medium recharge potential level areas, and 156.2 for low recharge potential areas. Based on the Renovation Capacity, Vashon/Maury Island can support a population of about 11,000. The water available for future use considering Renovation Capacity and Instream Flow Requirements is estimated at 100 million gallons/year. This amount of water would allow the addition of about 2,300 new residents to the Islands' existing population.

METHOD

Renovation Capacity is dependent upon several factors, including soil composition, texture, slope, water table and vegetation. Several methods are available for calculating the Renovation Capacity for each Recharge Potential Level. For this study, the model used was based on the work of Trela and Douglas (1978), modified for the local geological and physical conditions.

This method relates several pertinent factors, listed below, in a formula which yields Renovation Capacity in terms of density (dwelling units per acre).

$$\text{Renovation Capacity (RC)} = \frac{\text{Net Infiltration (In)} \times \text{Pollutant Concentration Limit (L)}}{\text{Pollutant Renovation Factor (Rf)} \times \text{Concentration Septic Effluent (Ce)} \times \text{Quantity of Effluent (Qe)} \times \text{Occupants per Dwelling Unit (Oc)}}$$

or

$$RC = \frac{(In)(L)}{(Rf)(Ce)(Qe)(Oc)}$$

Where:

In = Net Infiltration in gallons/acre/day.

Recharge rate (Rr) from Chapter 5, adjusted for drought periods. In = 0.7 Rr

L = The concentration of nitrate as nitrogen (NO_3-N) in mg/L.

DSHS permits NO_3-N concentrations of 10 mg/L. It is unlikely that most communities would be willing to accept water systems, public or private, which consistently supplied water with NO_3-N concentrations at that level. In addition, arrival at this concentration would involve rates of increase which very likely would carry the concentration well above the limit before remedial measures could mitigate the problem. For these reasons, values of 2, 5 and 10 mg/L have been used in the calculations as reasonable acceptable estimated values for high, medium and low recharge potential level areas.

Rf = Pollutant Renovation Factor - a decimal fraction derived from the rate of denitrification.

Organic nitrogen and ammonia are typically nitrified in the anerobic-saturated zone near septic tank drainfields. This produces ammonium ions which are adsorbed by silt and clay particles in the soil. In the aerobic zone, further away from the field, organic nitrogen and ammonia are denitrified, producing nitrogen oxides and nitrogen which is then available for uptake and removal from the soil by plant roots. Any nitrogen products which escape treatment in the soil and mantle migrate toward the water table as recharge.

This process, called denitrification, has been investigated extensively and is now well known. Rates of denitrification in moderately to well--drained soils are quite low. Reasonable estimates of nitrate removal ratios for Vashon/Maury Island vary from 10% to 30%. An average of 20% is considered reasonable, leaving the balance of 80% (0.80) as the concentration level remaining in the water reaching the aquifer. This value is used as the pollutant renovation factor in calculating the renovation Capacity.

Ce = Concentration of Septic Effluent in mg/L.

The concentration of nitrate as nitrogen in septic effluent averages 43 mg/L. This average concentration has been established in numerous previous studies which have measured this factor.

Qe = Quantity of Effluent Discharge in gal/day/person.

Quantity of effluent is estimated to be 70% of the average water used per day per capita. The average usage per connection for permanent residences was calculated (Chapter 8) at slightly over 300 gallons per day. This is equivalent to 120 gallons per day per person (300 ÷ 2.5). The average effluent discharge is then about 84 gpd/person (120 x 0.7).

Oc = Occupants per Dwelling Unit
Occupants per dwelling unit, given 2.5 in the Vashon Community Plan Draft (p.9).

CALCULATION OF NET INFILTRATION

Net infiltration (In) is calculated from the Recharge Rate derived in Chapter 5 according to the following formula:

In = Rr X Dr X CF X CF

Where:

RPL = Recharge Potential Level (From Chapter 5)
Rr = Recharge Rate (From Chapter 5)
Dr = Drought Ratio - Correction for low yield cycles
CF = Conversion Factor (inches/acre to gals/acre)
CF = Conversion Factor (Annual to Daily Rates)

TABLE 10.1

NET INFILTRATION

RPL	Rr		Dr		CF		CF		In (gallons/ day/acre)
High	9"	X	.70	X	27,150	÷	365	=	468.6
Medium	5"	X	.70	X	27,150	÷	365	=	260.3
Low	3"	X	.70	X	27,150	÷	365	=	156.2

CALCULATION OF RENOVATION CAPACITY

Having computed the Net Infiltration for each Recharge Potential Level, the Renovation Capacity can then be calculated by applying the factors (Rf), (Ce) and (Q) and the appropriate concentration Limit (L) of 2 mg/L for high, 5 mg/L for medium, and 10 mg/L for low RPL areas.

Where: $$RC = \frac{In \times L}{Rf \times Ce \times Qe \times Oc}$$

for High recharge Areas of In = 468.6 gpd/acre and L = 2 mg/L (NO3-N)

$$RC = \frac{(468.6)(2)}{(.8)(43)(84)(2.5)} = 0.130 \text{ Dwelling Units/Acre}$$

for Medium Recharge Areas of In = 260.3 gpd/Acre and L = 5 mg/L (NO3-N)

$$RC = \frac{(260.3)(5)}{(.8)(43)(84)(2.5)} = 0.180 \text{ Dwelling Units/Acre}$$

for Low recharge Areas of In = 156.2 gpd/Acre and L = 10 mg/L (NO3-N)

$$RC = \frac{(156.2)10}{(.8)(43)(84)(2.5)} = 0.216 \text{ Dwelling Units/Acre}$$

These calculated Renovation Capacities are summarized in Table 10.2 with their reciprocal values of acres/dwelling unit.

TABLE 10.2
RENOVATION CAPACITY (RC)

RPL	In	RC (DU/ACRE)	$\frac{1}{RC}$ (ACRE/DU)
High	468.6	0.130	7.7
Medium	260.3	0.180	5.5
Low	156.2	0.217	4.6

RPL = Recharge Potential Level

In = Net Infiltration (gals/day/acre) (Table 10.1)

RC = Renovation Capacity (Dwelling Units/Acre)

$\frac{1}{RC}$ = Reciprocal of RC to convert to Acre/Dwelling Unit

CALCULATION OF RESOURCE RELATED PLANNING CAPACITY

The population which can be supported by the Renovation Capacity is calculated by multiplying the area in each Recharge Potential Level Area by the Renovation Capacity and the occupants per dwelling unit.

Calculations of the estimated resource related planning capacity are shown in Table 10.3, using data from Tables 6.2, 10.2 and the estimated 2.5 occupants per dwelling unit. Thus, consideration of the renovation capacity provides a maximum population of about 11,000 people on the Islands.

TABLE 10.3

RESOURCE RELATED PLANNING CAPACITY

Recharge Potential Level (RPL)	Area in Acres	X	Renovation Capacity (RC) Acre/Du	X	Persons Per Dwelling Unit (Oc)	=	Population
High	5,922		0.13		2.5		1,924
Medium	6,918		0.18		2.5		3,113
Low	10,817		0.217		2.5		5,868
TOTAL							10,905

WATER AVAILABLE FOR FUTURE USE

The amount of water available for future use can also be estimated by deducting the current use from the available water resource.

As shown in Chapter 5, the Islands' have an estimated water surplus of 20 inches. About 15 inches of this surplus is direct run off to streams and 5 inches recharges the ground water resources. This recharge supports ground water withdrawal, and the ground water fed summer base flow of Island streams.

The State of Washington, Department of Ecology, acting under **WAC 173-515** (July 24, 1981) provides that the Islands' major streams (Judd Creek, Jod Creek, Needle Creek, and Fisher Creek) and their tributaries were closed to any further consumptive appropriation of water. This protection was provided for preservation and protection of anadromous fish, aesthetics, water quality and recreation. Minimum discharge amounts are not provided in the code. In addition, WAC 173-515-050 **Groundwater,** provides that future ground water withdrawals which impact the protected surface waters are similarly restricted.

The average Ground Water Productive Capacity (GPC) (Table 9.1) for the high, medium and low Recharge Potential Level areas is about 1 inch. Deducting this from the average recharge of 5 inches leaves 4 inches for minimum stream flow. Four inches of base flow on an Island-wide average is equivalent to a total average minimum discharge of 2600 million gallons/year or $7x10^6$ mgpd (4888 gpm).

The estimated average retrievable amount of ground water (GPC) on an Island-wide basis of one inch is equivalent to about 640 million gallons per year. Withdrawals exceeding this average amount would by definition require sophisticated interception measures such as dams, and would impact the protected instream resources.

Since the Islands' current water use is about 350 million gallons per year (120 gpd/person x 365 days x 8000 people), the difference between GPC (640 mgpyr) and current use (350 mgpyr) or 290 million gallons per year is an approximation of the amount of water available for future use. Because this estimate uses an averaged Ground Water Productive Capacity of 1 inch (640 mgpyr), the determination is not as meaningful as the GPC of 578 mgpy shown in Table 9.2 using the appropriate GPC's and corresponding areas for high, medium and low recharge areas. The estimated 290 mgpyr of water available for future use also assumes that the Ground Water Productive Capacity could be fully developed without interrupting minimum stream flow requirements. Since these discharge amounts have not been quantified by the Department of Ecology, the potential impact of full development of the GPC cannot be determined.

WATER RESOURCES

MANAGEMENT GUIDELINES

PART IV

CHAPTER 11

WATER RESOURCE MANAGEMENT OPTIONS

This chapter presents an overview of options for managing the ground water resources of Vashon/Maury Island. Strategies for protecting and enhancing both water quality and water supply are presented.

SUMMARY

King County has three basic options for managing the Islands' water resources: no-action, passive management and active management.

Under the no-action option, no new management or planning actions would be taken. Existing land use plans and regulations would allow densities higher than the Renovation Capacity. Water quality would continue to deteriorate. Uncontrolled well development and withdrawals would create local overdrafts and allow salt water intrusion into wells around the margins of the Islands.

Under the passive management option, strict regulatory or legislative controls would be adopted to restrict use of the resource and recharge areas to prevent contamination and overdraft. Water quality and quantity would remain at or near present levels.

Under the active management options, broad uses of the resource and recharge areas would be allowed. A management agency would be responsible for monitoring water use and taking action when contamination or overdraft was detected. Water quality would be maintained or improved. Control of well development and withdrawals would prevent local overdraft and possibly reverse salt water intrusion. Active management of the resource could be expected to provide a greater supply of good quality water than would passive management.

Both the passive and active management options would require development and implementation of a water resource management plan. The basic objectives of such a plan, under either the passive or active management option, would be to protect and if possible enhance water quality and water supply.

To implement one or more of these objectives, a range of economic, regulatory and educational strategies are discussed:

Economic	Regulatory	Educational
Tax on Water Use	Zoning Designations	Conservation Practices
Purchase of Water Shed	Subdivision Regutions	Development Practices
Condemnation of Property	Building Codes	Construction Practices
	Performance Standards	Agricultural Practices
	Cluster Zoning	Logging Practices
	Transfer of Development Rights	
	Planned Unit Development	
	Phased Capitol Improvements	
	Conservation Easements	
	Reservation of Water Rights	
	Reduce or Capture Exfiltration	
	Increase Infiltration	

BACKGROUND

FACTORS AFFECTING WATER QUALITY

Vashon/Maury Island is an independent water regime entirely bounded by Puget Sound with no freshwater underflow from off-island sources (see Chapter 6). Therefore, the quality of ground water is affected only by factors related to regional air quality and local land use.

Regional Factors

Gaseous and particulate matter is discharged from air pollution sources, distributed widely downwind, and carried into ground water via infiltration of the precipitation. Protection of ground water is usually dependent on state, regional or national standards and regulatory action. Local action by King County government and Island residents would need to be directed through state, regional and national channels to mitigate any demonstrated problems.

Local Factors

On-Site Effluent

On-site effluent waste disposal is a potential source of serious contamination, particularly by various nitrogenous compounds. Domestic waste rarely contains organic chemicals, heavy metals or other chemically hazardous materials. Pathogens are generally thought not to be carried beyond the leach field area. Population density control or provision of sewage collection, treatment and disposal are the principal solutions to this problem.

Agricultural Practices

Agricultural practices provide a potential for both positive and negative effects on ground water quality. Contaminants in accumulated animal wastes, fertilizers, herbicides and pesticides can be infiltrated and carried into water supply systems. Although moderate amounts of these contaminants are removed by adsorption with fine-grained soil materials, under certain conditions they are carried into the water table. Proper agricultural management practices reduce runoff and erosion and maintain low turbidity in streams.

Solid Waste Disposal

Solid waste disposal facilities must be carefully located and operated to ensure protection of ground water supplies. Even well-located and well-designed facilities have been found unsatisfactory from a public health perspective. Appropriate measures to monitor and, if necessary, control the migration of pollutants may be required for existing solid waste storage and disposal facilities. The location and design of facilities must be carefully evaluated if land disposal is planned. Ultimate protection would be provided by a reclamation strategy.

Transportation

Transportation-induced contamination usually involves dispersion of lead compounds from motor fuels, or spills from transport of liquids by bulk carriers. The former is a somewhat nebulous risk which is being reduced by the phase-out of lead-containing fuels. The latter is a risk which is seldom addressed.

FACTORS AFFECTING WATER SUPPLY

Although human activities have an important impact on ground water resource availability, protection of the quantity of water supply has only recently been considered. Any activities that increase runoff (and thereby decrease infiltration) effect recharge. Agricultural/logging practices also effect the evapotranspiration-infiltration-runoff relationship, thus effecting the ground water supply. Various measures have been proposed and attempted to overcome negative effects to maintain natural levels of recharge, and to increase supplies available. These have been evaluated in terms of their applicability to Vashon/Maury and have been classified in terms of active and passive management options.

WATER RESOURCE MANAGEMENT OPTIONS

King County has three basic options for managing the Islands' water resources:

- No-action - continue management by multiple organizations and individuals - maintain land use plans and regulations that allow densities higher than the Renovation Capacity.

- Passive management - adopt regulatory or legislative controls to prevent or restrict use of the resource and recharge areas to prevent contamination and overdraft.

- Active management - allow broad use of the resource and recharge areas while monitoring carefully for potential contamination and overdraft.

Both the passive and active management approach would require development and implementation of a water resource management plan. The active approach would require designation of an agency responsible for monitoring water use and taking action when contamination or overdraft was detected.

The active management approach would permit the greatest use of the resource by accepting risk of misuse, and would be designed to correct undesirable consequences. However, it would require a higher commitment of financial and human resources. The passive approach would avoid such commitment but would require adoption of more conservative limits on the use of the resource.

The basic objectives of the passive and active approaches would be to protect and if possible enhance water supply and water quality.

EVALUATION OF MANAGEMENT OPTIONS

No-Action

Under the "no-action" alternative, no new management or planning actions would be taken. The population would continue to grow at recent or accelerated rates up to the existing zoning code of 2.5 acres per dwelling unit (1 person per acre). In this scenario, water quality could be expected to deteriorate, particularly in known problem areas, followed by generally increasing contamination of nitrate and other pollutants in other parts of the Islands' Principal Aquifer. Uncontrolled well development and withdrawal would create local overdrafts and salt water intrusion into wells located around the margins of the Islands. Most of the water available would be acceptable for all purposes, except human consumption.

Passive Management

The passive management alternative would develop planning criteria based on existing information without the benefit of monitoring feedback. Thus, to achieve adequate protection, passive management requires a conservative approach and strict limits to total population and densities. Public pressure to relax these strict limits would be extreme.

Active Management

Under the active management approach, a management agency would monitor the water resource and guide development. Measured impacts of development would be used to determine the acceptability of increased density. Water quality would be maintained or improved through protection and enhancement actions. Control of well development and withdrawals would prevent and possibly reverse salt water intrusion and local overdraft. In contrast to passive management, an active management alternative allows growth to be guided by feedback from monitoring of the water resource as well as other strategies. The monitoring program must be carefully planned and implemented to provide reliable input to planning needs. Ultimately a population larger than under passive management could enjoy Island life, supported by an adequate supply of good quality water. While this approach probably would have the highest operating costs, the drawbacks of the other alternatives would make it more acceptable to the public.

STRATEGIES FOR PROTECTING AND ENHANCING WATER QUALITY AND SUPPLY

To protect and enhance water quality and supply, a water resource management plan would be developed, including a combination of economic, legislative/regulatory and educational strategies such as those discussed below. Most of these strategies are aimed directly or indirectly at protecting the recharge areas, which is necessary for both water quality and water supply objectives.

ECONOMIC STRATEGIES

Economic strategies described here involve providing economic incentives for private actions to improve water resources quality or availability, and using public funds to achieve protection or enhancement objectives.

Tax on Water Use

Taxation can provide conservation incentives, funds for implementation of a water resource management plan and a sinking fund for purchase of conservation easements in recharge areas for preservation in perpetuity. Tax benefits extended to property owners in recharge or otherwise critical areas might make voluntary natural preservation attractive to some property owners.

Purchase of Watershed

Purchase of property in recharge areas in fee simple or through conservation easement is a viable means of protecting the watershed recharge area by preventing property development. Purchase of water rights alone would not protect the property from other use. If a property aquisition program were combined with a parks and recreational facilities development program multiple objectives may be met.

Condemnation of Property

Condemnation or the exercise of the right of eminent domain, is a special and extreme step, with many political and psychological drawbacks. However, it may be justified in certain instances where early protection from imminent activity is required.

REGULATORY STRATEGIES

Zoning, subdivision regulations and building codes are the basic tools for achieving compliance with objectives determined to be beneficial to the community as a whole. A number of newer methods which have recently emerged could be used to protect water resources are also discussed.

Zoning Designations

Zoning is perhaps the most widely utilized tool for protecting water resources. Its use in this connection is well known and has been employed on Vashon already. Newer zoning categories involving designation of critical areas have been tested through litigation and have generally been upheld, at least where there is sufficient objective information to support the designation for specific sites.

Subdivision Regulations

Subdivision regulations are not often used for this purpose, but offer promise especially in support of zoning. For example appropriate "natural" drainage standards may be substituted for the curb, gutter and storm sewer requirements in suburban settings. Use of a swale concept as a design criterion permits increased (or at least maintained) infiltration ratios, reduces runoff and offers other environmental advantages. Since implementation of the concept is usually of economic advantage to the developer, it is readily accepted and quickly applied. Its availability as an option in the regulations may even permit negotiation of other concessions from the developer which have resource protection benefits (e.g. installation of dry wells or sand drains from roof drains). Permeable asphalt might be specified for all roadway surfaces to maintain infiltration ratio.

Building Codes

Building codes may also contribute significantly to ground water resource availability. Grading standards, drainage requirements, well construction and septic tank installation standards can be coordinated in such a way as to have a significant positive impact on quantity of recharge and/or water quality. Because implementation of these requirements has generally not been coordinated, advantages seen in one area are largely offset elsewhere. Specific examples include:

- Prohibit unnecessary disturbance of existing grade; require retention of natural soil profile and vegetation.
- Where grading is necessary, require design slopes to be low and stepped to create swales and increase retention time.
- Where drainage is required, require consideration of sand drains, swales or other design concepts.

- To decrease surface drainage requirements and to compensate for infiltration lost by installation of hard surfaces, require consideration of dry-wells, sand drains, cisterns or other similar devices.
- Encourage or require use of permeable asphalt design for driveways, aprons, patios and other surfaces.

Performance Standards

Performance standards may be employed to modify zoning and codes or subdivision regulations to achieve the desired goal. Performance standards generally do not specify the means or mechanisms, but rather define the desired outcome.

An example is the requirement that post-development rate of runoff from a site shall not exceed that which existed before development.

Performance standards give the developer the flexibility to choose the most effective techniques and to balance effectiveness and economics for the specific situation. Performance standards are not affected by changing technology so it is not necessary to continuously update codes and regulations.

Cluster Zoning

Cluster zoning allows developers to subdivide lots smaller than the zoned minimum in exchange for preserving areas of open space. This trade-off is flexible and desirable to the developer and is more likely to achieve the overall objective of protection than some other methods. Because clustering allows for more efficient use of land and reduced cost of installing access and utility infrastructure, there is considerable motivation for developers to use this option. Where housing is clustered on land with lower recharge potential and appropriate higher recharge potential land is preserved as natural area, enhanced recharge may be achieved.

Transfer of Development Rights

Transfer of development rights (TDR) expands the concept of cluster zoning. Clustering applies to the increase in zoned density through the creation of open space on adjacent land. Under TDR, clustering is permitted between locations which are not necessarily continuous or even contiguous. TDR permits different land owners to transfer zoning density from one tract to another. Their motivation to do so involves more efficient use of the land and decreased development costs. The community goal is to preserve recharge or protect other critical areas. TDR has been implemented in Connecticut, Florida and Vermont.

Planned Unit Development

Planned unit development applies generally to large development projects and is based on the premise that development of new housing on a large scale is really the birth of a new community. The concept gives the developer the same kind of trade-off described under cluster zoning and TDR and achieves the same kind of benefits to both the developer and the community. Clustering of buildings and mixing of housing types are permitted and even encouraged in exchange for preservation of natural feature, recharge areas, or other community objectives. This mechanism can be very effective in maintaining or enhancing recharge to benefit water supply.

Phased Capital Improvements

Phasing in capital improvements permits orderly provision of utility and other improvements and reduces the strain on community resources caused by rapid, uncontrolled development. A carefully prepared and implemented plan for water resource management could include requirements for phased aquisition and preservation of recharge areas and water supply source sites. This general concept has been tested and upheld in both Ramapo, New York and Petaluma, California, and is now well-established as a valid mechanism for balancing community and private interests.

Conservation Easements

Conservation easements involve purchase or trade of development rights in perpetuity. A property owner agrees to sell to an appropriate jurisdiction the right to develop housing (or certain other permitted uses) in exchange for a cash payment or other consideration. The relinquishment of such right is protected by appropriate covenant on the deed for the property and is binding on heirs or successors. A variation of this concept involves community purchase of the property on the open market and resale to private owners with the retention of development rights.

Reservation of Water Rights

Reservation of water for future public water supply is an important strategy for possible use in an active water resource management plan. Under auspices of a management agency, the Water Resource Act, RCW 90.54; WAC 173-590, provides for reservation of water rights for future use. This mechanism could be utilized to guarantee the availability of ground water resources for future public use.

Regulations to Reduce or Capture Exfiltration

Reducing exfiltration, the amount of water lost through outflow or underflow, results in increased storage, enhancing the potential supply. Most measures for reducing exfiltration involve engineered structures such as grout curtains. Where exfiltration takes place above sea level, indirect effects might include reduced landslide potential. Where outflow is below sea level, reducing exfiltration too much might result in salt water intrusion. Where outflow occurs at major springs, attempts to reduce outflow at the spring site might produce diversion to other sites with little net gain in storage. A more feasible alternative is to capture the natural flow and transport it to points of use. Various means can be utilized to increase flow rates and protect the area above the outlet. Reduction in both surface and subsurface outflow is automatically achieved as water is withdrawn from the aquifer.

Regulations to Increase Infiltration

Measures to stimulate higher rates of recharge by artificially increasing infiltration at the surface have been widely used to increase supply. A very wide range of measures are used, including:

Surface impoundment - This practice offers the potential for both increased infiltration and direct use of surface supplies. Disadvantages include high capital cost, high operating cost, and inflexibility in operation.

Water spreading - This practice of spreading water on prepared land surfaces at appropriate times to increase infiltration can be effective but requires appropriate hydrogeological conditions, considerable land surface and careful management.

Well injection - This practice involves injecting surface water directly into an aquifer. It requires modest initial investment but is subject to high maintenance costs because well screens tend to clog and encrust.

EDUCATIONAL AND COOPERATIVE STRATEGIES

In the long run, strategies to educate the public and stimulate cooperative efforts may be the most effective ways to protect and enhance water quality and supply. Most citizens are not only interested in protecting the general welfare, but will actively participate when informed of what needs to be done. Furthermore, public participation in selection of the appropriate economic and regulatory strategies will increase their effectiveness.

Public education should be aimed at influencing the following practices:

Conservation Practices

The simplest and most direct way to increase available water is to reduce usage. Conservation leaves more water available for all uses without significant cost. Attitude or awareness changes in domestic users can result in savings of 10 to 20%. Simple physical devices can be attached to showers and toilets to reduce use. Similar reduction in usage may be achieved in commercial or light industrial settings where ground water is used for cooling purposes. Installation of recirculation equipment or air-to-air cooling may achieve further savings. Many cost effective conservation techniques are available, combinations of which can reduce water use by up to 30%.

Development Practices

Pavement, roofs and other hard surfaces increase runoff and thereby reduce infiltration. Areas receiving the discharge may not be capable of increased infiltration to compensate. As much as 20-25% increase in runoff may result from current suburban development practices. Modified practices such as porous pavement and improved drainage design can preserve or restore natural ratios.

Construction Practices

Disturbance of the natural soil profile decreases permeability and increases runoff and erosion. Topographic changes resulting from regrading natural landforms often result in locally steeper slopes and hence increased runoff. Requirements for curb, gutter and storm sewer have the same effect. Such construction practices can temporarily and permanently increase runoff and decrease infiltration. Careful management and modification of design specification and construction practices has a beneficial effect on the infiltration/runoff ratio. Examples include use of swales instead of curb, gutter and storm sewer; French or sand drains for perched water tables instead of tiled fields; and permeable asphalt.

Agricultural and Logging Practices

Infiltration rate as well as water quality are affected by logging, soil tilling and cultivation techniques, drainage practices, irrigation and even the choice of crops planted. Changes in these practices can protect or enhance ground water supply and quality. For example, modified plowing geometry, and no-till farming may reduce erosion and increase infiltration.

Selective logging, in lieu of clear cutting, reduces erosion and maintains low turbidity in surface runoff. Some Island logging practices have caused increased turbidity in adjacent streams.

CHAPTER 12

WATER RESOURCE MANAGEMENT

RECOMMENDATIONS AND GUIDELINES

This chapter presents a series of recommendations and guidelines which are most essential for protecting and enhancing the water resources of Vashon/Maury Island.

SUMMARY

The most important recommendation is for King County to adopt an active management approach and create or designate an agency responsible for managing the Islands' water resources. In the interim before such an agency can be designated and a management plan implemented, King County should take a passive management approach toward management of the Islands' water resources.

Four steps are involved in both the active and passive approach to water resource management planning:

- Evaluate the water resources
- Establish guidelines and management criteria
- Design a management plan
- Implement the plan

An initial inventory of water resources has been reported in Chapters 2-10. Chapter 11 outlines the basic options of a no-action, passive or active management approach, and presents a range of potential strategies. This chapter sets forth criteria and guidelines for the additional steps needed to develop and implement a management plan.

Interim guidelines include a population limit of 11,000, housing density limits (10, 5 and 4 dwelling units per acre), preservation of high recharge areas as undeveloped land, and protection of landslide areas. Recommended changes in land

use regulations include: housing moratoria for most highly impacted areas, revisions of building and subdivision codes, and regulations to maintain recharge. Also recommended are sewage facility additions and improvements, changes in agricultural and logging practices and a major program of education and cooperation to further water management objectives.

RECOMMENDATIONS/GUIDELINES

PRIMARY RECOMMENDATIONS

1. Create or designate a specific agency with responsibility for managing the Islands' water resources.

   Currently, no agency has this specific responsibility. An active management program and responsible agency is essential if maximum resource utilization is to be achieved safely. Agency responsibilities should include monitoring and regulating ground water recharge and use to achieve protection of water quality and enhancement of supply. The means to fulfill these objectives might include well permitting, testing, monitoring, and data processing. Regulation of withdrawal, use and disposal to protect the resource should also be evaluated. The agency could have responsibility for defining those areas where optimum benefits could be derived by water or sewer systems. Such agencies have been effective in other parts of the country with critical water resource problems.

2. Integrate the findings of this report into the Vashon Community Plan and produce a comprehensive water management plan.

   Initially, the plan should have passive components, leading to an active management program within an appropriate population, time, and/or economic framework. The need for such a plan should be clear from the fact that much of the Island area is currently zoned too high for the resource related planning capacities derived in this study.

3. Implement the water management plan as soon as possible.

Because there is a significant gap between currently planned housing density and the findings of this report, there is a need for prompt action to mitigate the impact of the recommendations on the Island residents. Active management will provide a basis for modifying and clarifying local variations in the general restrictions imposed by the results of this study.

Interim measures recommended below, if adopted, will serve to provide temporary protection of the water resource until they are superceded by an appropriate management program.

INTERIM MEASURES

Designating a responsible agency and implementing a water resource management plan to allow active management of the water resource is likely to take months or even years to accomplish. Given the existing problems of both water quality and water supply, a passive management approach is recommended for the interim. Recommended actions and guidelines for such an approach are listed below.

Land Use Planning

1. Limit the Islands' total population to a maximum of 11,000 people.

The water resource related planning capacity for the Islands, based on current methods of wastewater disposal, has been estimated at 11,000 (see Chapter 10). That number should be officially adopted for planning purposes until more information permits calculation of a better estimate.

Under a resource management plan, a responsible agency can and should be able to adjust the resource related planning capacity to accommodate local or site variations in geologic, hydrologic or use conditions which become clearer as more information is gathered. In general, these changes are liable to be in the direction of more flexible uses and higher local population densities.

2. Adopt zoning to limit density to 10 acres per dwelling unit in high recharge potential areas not served by a sewer system.

Special effort should be taken to ensure protection of areas designated "high" on the Recharge Potential Level map (Figure 6.13). All such areas should be zoned with an appropriate zoning classification, tentatively titled Resource Related Sensitive Area, with a maximum density of 10 acres per dwelling unit. This density is based on limits outlined in Chapter 10, with allowance for other factors.

3. Preserve high recharge potential areas as parks or recreational space.

Undeveloped land zoned as Resource Related Sensitive Areas should be considered for purchase as parks or recreation space to preserve its capacity as a recharge area. Mechanisms described for conservation easements might also be explored for the same purpose. Development limits for these areas should include exclusion of residential, commercial and industrial development activities appropriate to recreational use. These areas should be considered for water-related recreational facilities to encourage enhanced recharge, wherever feasible.

4. Adopt zoning to limit density to 4 to 5 acres/dwelling unit in low and medium recharge areas not served by a sewer system.

   Areas designated "medium" and "low" on the Recharge Potential Level map (Figure 6.13) have a significant impact on both the quantity and quality of recharge. The protection of these areas should be assured principally through zoning and subdivision regulation.

   In all parts of the Islands where a sewage collection and treatment system is not available or planned, medium Recharge Potential Level areas should be zoned at a density of 5 acres/dwelling unit, and low Recharge Potential Level areas should be zoned at 4 acres/unit.

5. Protect sensitive landslide areas.

   Areas designated as landslide and potential landslide areas on the steep outer slopes of the Islands are particularly sensitive to increased soil moisture and runoff. The instability of these areas represents a real and present danger to all property owners in the vicinity. On-site disposal facilities in these areas should be either discouraged or designed very carefully to preserve slope stability. Unregulated development above these areas will increase runoff and decrease slope stability.

Land Use Regulation

1. Compare Recharge Potential Level areas to current zoning for all upland areas on the Islands. For areas that are are unsewered and far above the housing densities recom-

mended here, enact building moratoria to reduce or stabilize ground water degradation by septic systems.

In some areas that already exceed Renovation Capacity, the existing contaminant load overwhelms the capacity and even a moratorium will not prevent further degradation of the ground water.

2. Refine subdivision and building codes to maintain and enhance recharge capability and water quality. Measures described above related to construction practices and development standards should be carefully reviewed and incorporated in codes and regulations as appropriate. Of particular value might be those measures which directly retard runoff and increase infiltration such as swales, dry wells, sand drains, and porous pavement. Most of those specific options listed in this category in Chapter 11 are applicable here.

3. Review local codes and regulations on transportation, storage and disposal of potentially hazardous wastes.

   Where feasible, these can be modified to reduce the potential for contamination from spills by restricting certain materials or requiring movement by certain routes.

Sewer Facility Improvements

1. Provide sewage collection, treatment and disposal off-island for all high population density areas.

   The total population of Vashon/Maury Island is limited by both the capacity of the soil to cleanse wastewater effluent (Chapter 10) and by the ground water available for use (Chapter 9). Permitting higher population density around the town of Vashon or elsewhere where sewers are constructed will also permit denser population in unsewered areas. Up to 2,000 additional population could be accommodated on sewered connections if facilities are provided. Higher development densities in unsewered areas might be "traded off" against construction of sewer facilities or conservation easements.

2. Improvements to the sewage treatment plant to exclude infiltration of storm water and shallow ground water.

The existing sewer system allows storm water and shallow ground water to overload the treatment plant. These problems should be corrected to maintain capacity and efficiency of the system and perhaps permit an increase in housing served.

Solid Waste Practices

1. Monitor solid waste disposal on the Islands.

The existing operating facility has had no apparent impact on private wells in the area. However, these wells are some distance from the disposal site and may not clearly reflect existing contamination. A program of installing observation wells and monitoring water quality should be implemented promptly. Currently, the site does not accept industrial waste, but such wastes may have been disposed of there in the past. Household and garden chemicals, commonly disposed of in such facilities, could contribute to water quality degradation. Constituents such as nitrates, chlorides, iron and methane are likely to be present in the ground water around this site.

No appropriate material exists in sufficient quantity near the upland surface in suitable hydrogeologic setting for a new landfill. Consequently, long range planning should include either waste reclamation facilities or off-island disposal.

Water Resource Management

1. Continue collecting water inventory data to verify and amplify the findings of this report.

   As a first step in developing the water management plan, the collection of water level, precipitation and chemical data should be continued at periodic intervals. This action will provide longitudinal data to aid development of the plan. Also, Recharge Potential Level areas that have been generally located in this report should be delineated more specifically, and if necessary, additional levels should be defined.

2. Remove or regulate intense agricultural activities from recharge areas.

   All of the upland surface of the Islands is a recharge area and has limited Renovation Capacity. It is therefore susceptible to contamination by animal wastes, herbicides, insecticides, fungicides and fertilizers. Use of these substances should be strictly regulated throughout the Islands. Animal feed lots or other commercial stock operations should be removed from water shed areas and high Recharge Potential Level areas. Regulations also should be adopted to collect and properly dispose or use the waste products.

Education

1. Plan and implement a program of public education and cooperation for conservation and protection of the water resource.

The thrust of such a program should be threefold:

a. Inter-agency information exchange and cooperative effort for regulatory review and implementation of report findings.

b. Advice and information exchange with political leaders and their staffs to develop understanding and support for recommended measures.

c. Public information, cooperation and support for personal action to reduce consumption and protect water quality.

CHAPTER 13

STUDY LIMITATIONS AND RECOMMENDATIONS

This chapter discusses the data limitations of the study and the viability of the findings. Within the budgetary and time constraints of this project, it has not been possible to measure and evaluate every aspect of the water resource of the Islands. To overcome these limitations and determine long term trends of the water resource characteristics, a monitoring program and continued investigation is recommended.

SUMMARY

Limited available data pertaining to precipitation, ground water levels, stream discharge, water quality, geologic characteristics, and water use have necessitated certain assumptions and estimates. These have then been used to estimate water surplus, recharge areas and recharge amounts. Additional assumptions of drought, recoverable ground water, characteristics of septic tank effluent and a renovation factor have been applied to estimate the resource related planning capacity for the Islands. To protect and achieve optimum use of the water resources, these estimates and identified problems need verification through further monitoring and investigation. Recommended activities in order of their importance are:

1. Monitor ground water levels - 20 wells - monthly.

2. Sample and analyze water from 20 wells and six springs - quarterly.

3. Collect precipitation data from nine stations - daily.

4. Install and operate stream measuring stations at three locations - continuously.

5. Monitor spring discharge at six locations - monthly.

6. Drill and geologically log six to ten monitoring wells.

7. Monitor water levels in the new monitoring wells.

8. Meter all major water production.

9. Make new estimates of Island population for winter/ summer.

10. Perform site-specific evaluation of water quality problems.

11. Perform site-specific evaluation to delineate Recharge Potential Level area boundaries.

12. Investigate impact of drought on aquifer water levels.

13. Investigate the pollutant renovation factor (Rf) of each Recharge Potential Level area.

14. Prepare annual evaluation of collected water resource data.

DATA LIMITATIONS AND RECOMMENDATIONS

CLIMATE

Long term climatic data, particularly precipitation records, are required for meaningful analysis. As noted, the official U.S. Weather Bureau Station on Vashon was abandoned in 1954, providing only a ten-year overlap of record with Sea-Tac. Other historic and current precipitation records have been obtained from Island residents. The local data has been assumed to be generally accurate, although some inaccuracies may have resulted from using different types of rain gages, and possible errors in measurement.

To provide long term accurate records of precipitation, standardized rain gages have been left in place and are being monitored at:

- Water District 19 office.
- Garretson (location of 1931 to 1955 record).

Continued collection of precipitation data using standard gages should be encouraged by Island residents including:

- Krimmel (1971 to present)
- Blomgren (1974 to present)
- Henrickson (1973 to present)
- Baxter (1979 to present)

Three new precipitation stations using standardized equipment should be added at:

- North Central Vashon
- Portage
- North End of Maury Island

HYDROLOGY

Hydrologic data collected as part of this study has included measurement of stream flow, pond and lake fluctuations, spring discharge, and ground water levels. Continuous long-term records are available only from Judd Creek (1968-1975) and from well 3 (1973-present). In addition, most of the ground water levels measured were from wells that are currently in use, so that some water level measurements may have been influenced by recent pumping.

The hydrology evaluation is based primarily on data for one water year (October 1981 through September 1982). The dynamics of the hydrologic system are controlled by variable climatic events, so that this one year of record amounts to a snapshot summary of an epic documentary film. While the findings based on the available data appear reasonable, continued monitoring of the hydrologic variables will provide data for continuing analysis.

Hydrologic monitoring should include:

1. Monthly water level measurements in a network of 20 key wells.

2. Monthly measurement of spring discharge in six to ten key springs.

3. Installation of stilling wells and recorders to determine stream discharge on Judd, Needle and Beale Creeks.

4. Monitoring of water levels in unused wells and test wells to be drilled.

GEOLOGY AND AQUIFER CHARACTERISTICS

In contrast to the dynamics of the hydrologic system, the geological framework is fixed. However, because most of the important features are buried, the complex relationships of various geologic units are necessarily interpretative.

The geologic and aquifer characteristics have been defined by examination of exposures and by description provided in the available well logs. Geologic exposures on the Islands are usually masked by vegetation or complicated by weathering, erosion and alteration of the outcrop. Well log data is limited by location and depths (relevant to the well owner's needs) and by frequently ambiguous descriptions provided by drill operators who are often unaware of the relevance of certain information.

To improve the interpretation of the Islands' geology and better define important relationships, a series of test wells should be drilled and carefully logged by an experienced geologist. These test holes should be completed as monitoring wells and used in the water level measuring network. Test drilling should be planned to explore both the Principal Aquifer and the overlying sediments and the Deep Aquifer and intervening sediments.

Exploration of the Principal Aquifer should concentrate on the west central part of Vashon. Initial drilling should include four to six wells drilled to a depth of about 300 feet. Wells should be located to provide optimum geologic data and spaced on about one mile centers depending on the availability of public or other suitable property.

Exploration of the Deep Aquifer should be begun with a program of about five wells. These wells should be located on the south end of Vashon, on the west central part of Vashon (near well 40), on the north end of Vashon near or in Heights Water Company's "dry hole", at Vashon Elementary, and on Maury near the northeast quarter of Section 29. Some of the deeper wells could be completed with multiple piezometers isolated in the Principal and Deep Aquifers or other intervening water bearing zones.

WATER BUDGET

Determination of the water surplus uses climatic data. During the 1981-82 water year, the variation in the amount of precipitation across the Islands was dramatic. Long term average precipitation data may show less variation in precipitation. However, assuming the 1981-82 water year was generally representative, 40 inches of precipitation is about the average for both Islands. However, this average could result in a slightly larger water surplus on Vashon and a slightly lower surplus on Maury. This difference could make the water surplus on Vashon about 10% greater than has been estimated.

Continued measurement of precipitation and stream runoff is essential to determine long term average water surplus.

RECHARGE

The existing data are sufficient to show clearly that there is no off-Island recharge to any known aquifer on Vashon/ Maury Island.

Delineation of recharge is dependent on evaluation of the physical characteristics (slope, soils, vegetation, permeability) and the accuracy of those determinations. Assigned boundaries of high, medium and low Recharge Potential Levels are interpretive and will require a closer definition at a larger scale for site specific problem. Continuing investigation could define additional intermediate recharge levels, or delineate important recharge areas not identified in this study.

Where suitable data is available, definition of areas as high, medium and low by the physical characteristics is in good agreement with the evaluation techniques using amplitude of water level change and time delay of water level response. This consistency is an indication of the general validity of the data and the methods.

Calculation of the amounts of recharge is dependent on accuracy of the climatological data, stream flow runoff, and measured changes in ground water levels. While the bulk of this data uses only one water year, the results appear very reasonable. Long term monitoring would permit further refinement of the estimated recharge amounts.

The estimate of the amount and areas of recharge of the Deep Aquifer is less precise. Additional monitoring is needed in the existing wells and at new monitoring wells to determine water level response. Suggested locations for Deep Aquifer monitoring wells have been presented above.

WATER QUALITY

The most important limitation of the water quality data is the lack of historical analyses. Except for a few isolated cases, the oldest analyses are from 1966 and there are only a few sources where regular analyses have been performed. Thus, evaluation of the long term water quality trend is very restricted.

Older analyses of some of the important ions such as nitrate also require interpretation. Until 1970, commercial laboratories reported nitrate as nitrate rather than the current practice of reporting nitrate as nitrogen. Comparisons of older data must make this conversion to similar units.

Possible laboratory error must also be considered as a limitation. In samples collected as a part of this study, any irregularities were rechecked or duplicate samples were submitted. A few obvious errors in older analyses have been noted.

It is also possible, if not likely, that the wells sampled for this study are sources where water quality is above average. The well data base used wells of record with the DOE. These wells for the most part are either water system wells or wells drilled since 1971. Since that date, DOE has required installation of a surface seal for protection from potential surface contaminants. Thus a more complete sample which included all the shallow dug wells and older wells could be expected to show higher concentration of potential contaminants, and the overall water quality on the Islands could be somewhat worse than the available data indicates. In addition, bacterial analysis has not been performed in this study because it is generally not indicative of ground water characteristics. However, based on observations of some systems, it is probable that they may have bacterial contamination due to poor facility maintenance.

To determine the long term trend and identify potential problems not noticed in this sampling, water quality monitoring must be continued. An active water resource management agency could direct regular sampling and analysis of the key network wells and springs, and focus specific efforts on problem areas. Such analysis should be performed at least quarterly to establish seasonal variation and should include testing for arsenic and cadmium (in case they should begin to appear), as well as chloride, nitrate, total dissolved solids, specific conductance, hardness, and alkalinity. Samples should also be collected regularly from monitoring wells located near the landfill for analysis of solvents, volatile organics and other potential contaminants.

WATER USE

The average water use of 120 gpd/person fits very well with the data available from the Islands' major water purveyors. As is discussed in Chapter 8, the 1980 census population may be low, particularly for the summer population. This would indicate that the forecasted consumption could approach total water available sooner than anticipated. On the other hand, since many residents work off-Island, the actual use may be slightly lower than estimated.

Regulations requiring metering of all water produced by the Islands' water companies would provide a better estimate of current use and improve the forecast of future water use. Measurements of withdrawals from private (domestic, irrigation, and industrial sources) will be more difficult to accomplish even with the encompassing power of an active water management agency. Such private metering would probably meet considerable public resistance.

GROUND WATER PRODUCTIVE CAPACITY

Calculations of the Ground Water Productive Capacity has applied an estimated capture ratio (Cr) and drought ratio

(Dr) to the estimated amount of recharge in each recharge potential level. The accuracy of the estimated amounts of recharge has been discussed above. The capture ratio estimate of 25% is based on surface tension and optimum well spacing and withdrawal in the Principal Aquifer. These factors vary with the character of the aquifer and the manner in which ground water is developed. The capture ratio for the Islands could be above or below the estimated 25%.

Drought reduces water surplus and recharge. While drought impact on the ground water resource is less than that on surface water, long term drought will reduce the available ground water. A 70% factor has been applied to include this potential impact of drought. Long-term Island precipitation records, when correlated with long term ground water levels, could alter this estimate.

Adjusting the amount of recharge by capture and drought ratios produces relatively conservative estimates of Ground Water Productive Capacity. Evaluation of long term records may provide the basis for less conservative estimates.

On the other hand, additional reduction of the Ground Water Productive Capacity could be appropriate because of the need to maintain Instream Flow Requirements for anadromous fish in the Islands' streams.

RENOVATION CAPACITY

Calculation of Renovation Capacity uses estimates of net infiltration, pollutant concentration limit, renovation factor, concentration of septic effluent, quantity of effluent, and occupants per dwelling unit. The reliability of the net infiltration (recharge) estimate and occupants per dwelling unit (population) have been discussed above.

Effluent discharge is estimated at 70% of water consumption to account for water lost as evaporation or used for non-household purposes. This estimate is in close agreement with the ratio between the average water used and the average effluent returned to the Vashon sewage treatment plant. In applying the effluent discharge estimate to the Renovation Capacity, this ratio is presumed to have similar application to the unsewered areas of the Islands.

Assigning pollutant concentration limits of 2, 5 and 10 mg/L nitrate as nitrogen to the high, medium and low Recharge Potential Levels is directed toward preserving water quality by recharging the highest quality water. Different limits could be selected based on different community criteria for nitrate or other contaminants.

The pollutant renovation factor of 80%, and the character and quantity of septic effluent on the Islands, could be investigated in future studies as directed by a water resource management agency. These studies should address potential differences in the renovation factor in the high, medium and low Recharge Potential Level areas.

The densities resulting from application of the above factors are probably conservative. That is, the application of less conservative values could produce densities 10 to 20% higher than those presented here. However, without an active water management agency, the more conservative estimate is appropriate.

In addition, the calculation assumes that pollutant concentration in the water used starts at zero. However, as pollutants are added to the water, concentrations will increase gradually, and on reuse, continue to increase. Thus, an even more conservative approach might be appropriate.

It is interesting to recall that while many of the Islands' water supplies have very low concentrations of nitrate as nitrogen, a gradual increase has been noted in some of these supplies.

The existing situation where the population of about 8,000 (3200 estimated dwelling units) occupies the Islands' 23,657 acres is equivalent to an average density of 7.4 acres per dwelling unit. Thus the existing average density is roughly equivalent to the most conservative density proposed for preservation of water quality in the high recharge areas. Because certain areas on the Islands have shown apparent degradation of water quality, specific site problems obviously will require more restrictive criteria.

LIMITS OF POPULATION AND DENSITY

Calculations of the population limits (13,000 people using the Ground Water Productive Capacity and 11,000 people using the Renovation Capacity) are extensions of previously estimated values. Insofar as the previously described estimates are valid, then the population limits are appropriate. The relatively close population limits using two separate resource control factors lends credence to their viability. However, application of the most restrictive densities could limit the population further. If the minimum population limit for each evaluation system and each Recharge Potential Level is used, the population that can be supported by the resource is only 8,572 people or only slightly more than the apparent present population.

MANAGEMENT GUIDELINES

While the limitations of this study prevent assignment of absolute limits of population density, it is obvious that the water resources of the Islands are finite and vulnerable to contamination. Still, any and all density restrictions must also consider the broader range of planning factors of which water resources are only a part. The effectiveness of such restriction will be greatly aided by public understanding of the problem, and the possible consequences of the various management options.

The recommended guidelines are based on probable water resource characteristics over the foreseeable future meaning about 20 years. Beyond 20 years, technological advances may occur which could change the definition of the problem and the remedies. For example, innovations in disposal of household effluent and development of water treatment systems could offer new answers and approaches. Also, land use pressures by the year 2000 could make consideration of off-Island sources of water imperative. Finally, comparisons of estimated costs of the alternatives and actions beyond 20 years would be unreliable.

GLOSSARY

FOR

VASHON/MAURY ISLAND

WATER RESOURCES STUDY

Ablation Till — A poorly consolidated glacial till deposited by wasting ice.

Active Resource Management — Continuing actions undertaken to manage the water resource using input from monitoring activities.

Adsorption — The attraction and adhesion of a layer of ions from an aqueous solution to the solid mineral surfaces which it contacts.

Advance Outwash — See Outwash Deposits.

Alkalinity — The capacity of a water to accept protons, i.e. hydrogen ions. It is usually expressed as milliequivalents/liter of calcium carbonate.

Alluvium — The general term for all detrital deposits resulting from the operations of rivers.

Aquifer — A saturated formation or part of a formation with sufficient permeability to yield significant quantities of water to wells or springs.

Aquitard — A formation or part of a formation with low permeability permitting only limited water flow or movement.

Artesian Well — A well in which water under pressure rises above the top of the aquifer.

Attenuate — To weaken in force, intensity, quantity, or value: used in the sense of diminishing an original amount of substance by any means including, but not exclusively limited to, dilution.

Base Flow — That quantity of stream flow sustained by interception of ground water, occuring in some streams on Vashon/Maury during summer months.

Basin Closure — An extensive low area into which the adjacent land drains and which has no surface outlet.

Bathymetry Map — A topographic map of the floor of a body of water such as Puget Sound.

Bed Rock — The solid rock which underlies unconsolidated sediments or is exposed at the surface of the earth.

Bituminous — Soft coal containing about 80% carbon and 10% oxygen.

Cable Tool — A method of drilling where percussion movement of tools cuts a cylindrical hole in unconsolidated sediments or rock.

Capillary Zone — A zone overlying the zone of saturation in which the pressure is less than atmospheric. Some or all of the pore spaces may be filled with water.

Capillarity — The force which allows water to be lifted against gravity by surface tension.

Capture Ratio (Cr) — The estimated factor (0.25) which when applied to Recharge Rate (RR) yields the amount of water recoverable for human use under natural conditions.

Casing — The permanent liner of a well.

Cistern — A vessel used to store water, often used to collect water from roof drains.

Chloride — An ion of the element chlorine. Where found in sufficient concentration in water, it indicates potential contamination from salt water, septic tank effluent, or other sources. The DSHS maximum contaminant level for chloride is 250 mg/L.

Clastics — Fragments of rock that have been moved individually from their places of origin.

Concentration of Septic Tank Effluent — Average concentration of nitrate as nitrogen occurring in septic tank effluent; 43 mg/L.

Cross-Section — A profile portraying an interpretation of a vertical section of the earth.

Darcy's Law — A derived formula for the flow of fluids.

Deep Aquifer — The Vashon/Maury water-bearing sand found within Unit III at depths of 100 to 300 feet below sea-level.

Desalination — Salt removal from sea water or brackish water.

Discharge — Rate of flow at a given instant in terms of volume per unit of time.

The flow of water which occurs naturally as in a stream or from a spring, as well as the pumped flow from a well; usually reported as volume per unit time.

Distillation — The removal of impurities from liquids by boiling or evaporation.

Downwarping — A structural depression of geologic units.

Drainage Basin — Area from which a given stream and its tributaries receive water.

Drainfield — A disposal area for effluent from a septic tank.

Drift — All glacial deposits consisting of such materials as till, gravel, sand, silt and clay.

Drilled Well — A tubular vertical structure constructed with a drill, i.e. cable tool or rotary.

Drought Ratio (Dr) — The ratio of the dryest years precipitation (infiltration) to the average year; (0.70).

Dry Well — An excavation used to store and transfer water into and through low permeability soils. Also a well, drilled to supply water, in which inadequate water was encountered.

Dug Well — A vertical structure built by manual digging; usually shallow and of large diameter.

Evaporation — The discharge of water to the atmosphere from the soil and surface water bodies.

Evapotranspiration — The sum of evaporation and transpiration.

Exfiltration — The natural outflow of ground water through springs and seeps.

Glacial Till — Unstratified, unsorted glacial drift deposited directly by glacial ice.

Glaciation — The covering of a land area by glacial ice.

Ground Water — Any water beneath the surface of the ground which has freedom of movement through the Islands' sediments. (This is a more general definition than in common scientific use.)

Ground Water Productive Capacity (GPC) — The volume or amount of the ground water resource recoverable for use under natural conditions. Usually expressed as gallons/yr/area.

Hardness — A measure of the amount of calcium and magnesium dissolved in water.

Hard Pan — A non-technical descriptive term used by drillers to describe hard layers encountered in unconsolidated sediments; often interpreted to mean glacial till.

Hydrograph — A graph showing the variability of water levels as a function of time.

Hydrology — The science that relates to water of the earth.

Hydrologic Cycle — The system of water movement by evaporation from sea to atmosphere; precipitation onto land, and return to the sea under the influence of gravity.

Infiltration — The flow or movement of water into the ground and through the soil profile.

Injection Well — A well used for introducing fluids into the substrata.

Iron — An element occuring in water primarily as the simple ion Fe++ or as the complexed ion FeOH+. The DSHS maximum contaminant level for iron is 0.3 mg/L.

Iron Bacteria — Anerobic, iron feeding bacteria which are believed to be pathogenically harmless, but can cause clogging of a water system.

Isochemical Map — A map portraying lines of equal chemical concentration of a particular constituent.

Isohyetal Map — A map portraying lines of equal rainfall.

Isthmus — A narrow strip of land bordered on both sides by water, that connects two larger bodies of land.

Lodgement Till — A dense glacial till deposited beneath a moving glacier.

Mineralization — The process of water dissolving the ions from the rocks and minerals through which it passes.

Net Infiltration (In)	The amount of recharge available for use under drought conditions; (0.70 R); reported in inches or gallons/day/acre.
Nitrate	An ion of nitrogen at its highest oxidation level. Where found in significant concentration it can be an indicator of the contamination of water from septic tank effluent, animal waste, decayed vegetation, or other sources. Reported as "nitrate as nitrogen" (NO_3-N) where the ratio of nitrate to nitrogen is approximately 4.5 to 1. The DSHS maximum contaminant level for NO_3-N is 10 mg/L.
No-Till Farming	Agriculture procedure whereby the soil is not broken by plowing or cultivating.
Occupants Per Dwelling Unit (Oc)	For Vashon/Maury 2.5 persons per household derived from the Vashon Community Plan draft (p.9).
On-Site Effluent	The liquid waste discharge of the septic tank system.
Open-Bottom Casing	A well completion method which uses no well screen and no perforations.
Outcrop	A surface exposure of a formation or part of a formation.
Outwash Deposits	Alluvial material transported and deposited by meltwater from advancing or retreating glaciers.
Overdraft-Mining of Ground Water	The situation where the pumping rate of water from an aquifer exceeds the recharge rate to the aquifer.
pH	A number representing the negative logarithm of hydrogen ion concentration which describes the acidic or basic characteristics of liquid, for example: pH 1 acidic — pH 7 neutral — pH 14 basic
Passive Resource Management	A management system where controls are established to protect the water resource without input from monitoring. Usually requires more restrictive land use than active resource management.
Perched Aquifer	Local permeable zones of saturation where water levels are held above those in the Principal Aquifer by intervening saturated or unsaturated sediments of low permeability.

Permeability	The ability of unconsolidated sediments to transmit water.
Permeable Asphalt	A paving surface designed to transmit water from the surface to the subgrade.
Piezometric Surface	The surface defined by water levels in wells tapping an artesian aquifer.
Pollutant Concentration Limit (L)	The maximum concentration of nitrate as nitrogen in ground water which is deemed to be acceptable by community standards. Expressed in milligrams per liter (mg/L).
Pollutant Renovation Factor (Rf)	A factor equivalent to that percentage of nitrate as nitrogen remaining after denitrification of septic tank effluent; (0.80).
Porosity	The property of unconsolidated materials describing the open space between grains (usually expressed as a percentage of pore volume to total volume).
Precipitation	Atmospheric water which falls to the land surface.
Principal Aquifer	The Vashon/Maury aquifer which supplies water to most of the Islands' wells, consisting of sand and usually occurring above sea-level.
Quantity of Effluent Discharge (Qe)	Amount of septic tank effluent discharged per day per capita (generally estimated at 70% of water use or 84 gpd/person for Vashon/Maury).
Recessional Outwash	See Outwash Deposits.
Recharge Area	An area where the physical characteristics of the surface and subsurface permit infiltration of water through the soil and sediments toward an aquifer; characterized by progressively lower head in successively deeper aquifers.
Recharge Potential Level (RPL)	The designation of relative recharge capability; as High (9 inches), Medium (5 inches), Low (3 inches).
Recharge	The process by which water moves to an aquifer.
Recharge Rate (Rr)	Infiltration rate for each designated recharge potential level as 9, 5, and 3 inches/year.

Resource Related Planning Capacity — An estimated population limit based on water resource considerations.

Rotary — A drilling method using a rotating column of drill pipe and an attached drilling bit while circulating air or fluid through the pipe.

Runoff — That portion of precipitation (or irrigation water) that drains from an area as surface flow.

Salt Water Intrusion — The movement of saline water into that part of an aquifer formerly occupied by fresh water.

Sand Drain — A tube constructed and filled with porous media to improve vertical percolation; sometimes called a French Drain.

Septic Tank — An underground tank that receives waste water directly from the point of use.

Specific Conductance — A measure of water's ability to transmit electrical current. The value is directly related to the concentration and charge of ions present in the water. Expressed as micro mhos per centimeter (u mhos/cm).

Spring — A continuous or intermittent flow of water from underground to the earth's surface, which occur where water table and ground surface intersect.

Storage — The amount of water held in an aquifer or ground water system.

Stratigraphy — The branch of geology which treats the sequence and correlation of stratified rocks.

Structural Deformation — The changing of form, volume and relative position of the earth's strata.

Sublimate — The transformation from a solid to a vapor state without forming a liquid; as occurs when water vapor escapes from snow or ice.

Surface Water — Water located on the surface of the earth; generally indicating fresh water in streams, rivers, ponds or lakes.

Swale — A slight, often linear depression in otherwise level terrain.

Thornthwaite Method — A commonly accepted method for evaluating evapotranspiration and calculating the water budget.

Till — A nonsorted, nonstratified sediment deposited by a glacier.

Transpiration — The process by which water vapor discharges from living plants and enters the atmosphere.

Underflow — The movement of ground water through permeable subsurface stratum.

Varve — A pair of thin sedimentary layers, one coarse, one fine; representing a one year depositional cycle.

Water — A compound which in its pure state consists of hydrogen and oxygen (H_2O).

Water Available for Future Use — The amount of ground water available beyond that currently used, taking into account recoverability, water quality, and Instream Flow Requirements.

Water Budget — A description of the balance between the income of water from precipitation and the outflow of water by evapotranspiration, runoff and infiltration to the ground water body.

Water Quality — A description of chemical, biological, and physical properties of water.

Water Surplus — That portion of precipitation which is available for runoff and infiltration.

Water Table — The surface of an unconfined ground water body where the pressure is atmospheric and which defines the top of the saturated zone.

Water Table Aquifer — An aquifer containing water under atmospheric conditions.

Well Point — A small-diameter tubular device used to extract shallow ground water.

Zone of Saturation — A sub-surface zone in which all the openings are filled with water; water within the zone of saturation is called ground water.

ABBREVIATIONS

USED IN

VASHON/MAURY ISLAND

WATER RESOURCES STUDY

Ce	concentration of septic effluent
CF	conversion factor
cf.	compare
Cr	capture ratio
cr	creek
cu	color units
DNR	(State of Washington) Department of Natural Resources
DOE	(State of Washington) Department of Ecology
Dr	Drought ratio
DSHS	(State of Washington) Department of Social and Health Services
DU/acre	dwelling units per acre
e.g.	for example
elev.	elevation
EPA	(United States) Environmental Protection Agency

°F	degrees Fahrenheit
ft.	feet
gal/yr	gallons per year
GPC	Ground Water Productive Capacity
gpd	gallons per day; also gallons/day
gpd/person	gallons per day per person
gpm	gallons per minute; also gallons/minute
i.e.	that is
in/yr/acre	inches per year per acre
In	Net Infiltration
Isl.	Island
King Co.	King County
L	Pollution Concentration Limit (a number)
Lab.	Laboratory
Loc.	Location

MCL	Maximum Contaminant Level Allowed
mgpd; mill.gal./day	million gallons per day
mgpyr; mg/yr;mill.gal./yr.	million gallons per year
mg/L	milligrams per liter
µmho/cm	micro mhos per centimeter
N.D.	not detected (as in a chemical analysis)
NE 1/4, SE 1/4, S29, T23N, R3E (WM)	A grid system of geographic location by Section, Township, and Range; the example would be read as: northeast quarter of the southeast quarter of Section 29, Township 23 north, Range 3 east (of Willamette Meridian).
Oc	occupants per dwelling unit
perc.	percolation
persons/DU	persons per dwelling unit
ppm	parts per million
precip.	precipitation
proj. no.	project number
PSCOG	Puget Sound Council of Governments
Pt.	point as in "Point Robinson"

Qe	quantity of effluent
RC	Renovation Capacity
1/RC	reciprocal of RC
RCW 90.54	Revised Code of Washington
Rds.	roads
Rf	Pollutant Renovation Factor
Rr	Recharge rate
RPL	Recharge Potential Level
Sea-Tac	Seattle-Tacoma as in Seattle-Tacoma Airport
S.C.	specific conductance
S. & G.	sand and gravel
(sic)	used to indicate a verbatum quotation
Sp.	spring
TDR	Transfer of Development Rights
TDS	Total Dissolved Solids
u mhos/cm	micro mhos per centimeter
USCG	United States Coast Guard
USGS	United States Geological Survey
USPHS	United States Public Health Service

WAC 173-590	Washington Administrative Code
Wash.	Washington
W.D. 19; KCWD 19	King County Water District 19
Well No.	Well number
W.S.B.	Water Supply Bulletin
wtr. sys.	water system
X	multiplication
Note: use of n/nn	as: "per" (as in gallons/minute) as: "and" (as in Vashon/Maury)

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Planning Division
Harold Robertson, Manager
Lois Schwennesen, Community Planning Section Chief
Ruth Dight, Vashon Community Planner