ORIGINAL

SPOKANE AQUIFER
CAUSE AND EFFECT REPORT

DECEMBER 1978

WITH
1983 UPDATE

'208' WATER QUALITY MANAGEMENT PROGRAM

SPOKANE COUNTY OFFICE OF COUNTY ENGINEER

208 CAUSE AND EFFECT REPORT

1983 UPDATE

by

DR. LARRY A. ESVELT, P.E.
Consultant

MR. STAN A. MILLER
Program Manager

SUPPLEMENT NO. 1

to

SPOKANE AQUIFER CAUSE AND EFFECT REPORT

SUMMARY REPORT OF '208' WATER QUALITY RESULTS
AND CAUSE AND EFFECT RELATIONSHIPS FOR WATER
QUALITY IN THE SPOKANE-RATHDRUM AQUIFER

JUNE 1983

Spokane County, Washington '208' Program
County Engineers Office
North 811 Jefferson Streeet
Spokane, Washington 99260

I. INTRODUCTION

The Spokane County Water Quality Management Program (208 program) conducted a comprehensive investigation of the Spokane Rathdrum Prairie Aquifer in Washington from May, 1977 through June, 1978. A report on the findings, which contained conclusions regarding the cause and effect relationships between man's activities on the ground surface and water quality in the aquifer, was published in December, 1978.

The 208 program published, in 1979, a Water Quality Management Plan which called for continuing monitoring of many of the points sampled during the 208 studies. The Spokane County Health District has monitored a number of the points since that time, and the US EPA has analyzed many of the samples for organic constituents. Also the US Geological Survey has continued some of its studies initiated during the 208 program, including completion of its aquifer flow model report and data collection from monitoring wells designed to determine the effects of septic tank and drainfield on-site sewage disposal systems in the Spokane Valley.

This "Update" report summarizes the results of data made available since publication of the Cause and Effect Report and contains discussion relating these results to the conclusions presented earlier.

The WQMP includes a large number of recommended actions developed to protect the aquifer from further degradation. Many of these actions have been integrated into local government regulations and policies. Of the three major potential aquifer contamination sources discussed in the plan, domestic waste disposal, storm water runoff and chemical spills, only in the area of storm water runoff have actions been taken that will actually reduce the contaminant load to the aquifer. And even here, the actions apply only to new developments. The actions now being undertaken to reduce the number of homes and businesses discharging waste water to the ground over the aquifer and to control chemical spills which might reach the aquifer will need to be completed in order to arrest the observed trends. The fact that aquifer quality continues to degrade should not be construed to mean the plan will not work. Rather, it should cause us to redouble our efforts to see that all the recommended actions are put in place as soon as possible.

II. SUMMARY

The information presented in this supplement to the Spokane Aquifer 208 Cause and Effect Report substantiates and verifies many of the conclusions drawn in that document. Those conclusions and the source of information supporting them are as follows:

1. The ground water in the Spokane-Rathdrum Auifer is currently suitable for domestic, municipal, commercial, agricultural and industrial uses. This is verified by its continued satisfactory application to these uses even though several incidents indicate that the conclusion is not true in all locations all of the time.

2. The alluvium overlying the aquifer is extremely permeable making the aquifer susceptible to contamination. This is verified by the chlorinated organics contamination, incidents of bacteriological and chemical contamination, the USGS model and onsite disposal studies and by the continued degradation in water quality with time at various locations where data is available for valid comparison.

3. There is percolation (or recharge) of water from the ground surface to the aquifer and transport of constituents from the ground surface to the aquifer. Verification includes information in the USGS model, data from historical water quality comparisons, documentation of incidents of pollution and from the USGS studies of onsite sewage disposal.

4. Travel time for pollutants through the alluvium overlying the aquifer is comparatively fast. This is illustrated by the USGS tracer study in connection with their study of onsite sewage disposal.

5. Low flow rates near the aquifer periphery result in a greater accumulation and higher concentration of dissolved solids and other constituents than in higher flows in the aquifer main stem. The USGS model, which indicates that flows are lower near the periphery, and water quality changes with time, when compared between areas, verify this conclusion.

6. Industrial development and activities over the aquifer have resulted in water quality deterioration. Verification that this conclusion continues to be valid is contained ~~data~~ in data regarding chlorinated organics contamination, and in the documented incidents of aquifer contamination.

7. Solid waste disposal activities over the aquifer have caused groundwater quality deterioration. Chlorinated organics concentrations in the vicinity of a solid waste disposal site further verifies this conclusion.

8. A substantial portion of aquifer dissolved solids increase has resulted from man's activities over and adjacent to the aquifer. Increase in these activities accompanying population growth (urbanization) over the aquifer and on lands tributary will result in increasing deterioration of aquifer water quality. Further data relating water quality changes with time verify the validity of this conclusion.

9. There is a risk of bacteriological degradation of the aquifer which accompanies current and future development over and adjacent to the aquifer. This is verified by the bacteriological contamination and removal from service of municipal water supply wells.

10. The risk of serious contamination of the aquifer by hazardous or toxic substances, including pathogens, appears to be the same in the central portion of the aquifer and in the aquifer peripheral areas. Verification of this conclusion is contained in this supplement with documentation of further aquifer degradation with time, and with the documentation of incidents of bacteriological and chemical contamination causing wells to become unsuitable for use.

13. Surface waters enter the aquifer from the Spokane River in two major reaches, from the State Line downstream to Greenacres and in the vicinity of Upriver Dam. There is also interchange in reaches where the net flow is from the aquifer to the river. Surface waters from many tributary drainage basins also enter the aquifer. Publication of the USGS flow model for the aquifer now makes available to the public information upon which this conclusion was partially based in the Cause and Effect Report.

16. The level of some toxicants is sufficient to warrant continued monitoring. This conclusion is still valid as shown by the chlorinated organics data.

It appears that, though many actions to protect the aquifer have been taken, their effects on water quality are not yet apparent. As the WQMP was developed, it was expected that there would be a delay before any water quality improvement was noted. The efforts to control domestic waste discharges and chemical spils now being pursued need to continue. If, after implementation of these measures, continued monitoring does not show at least some signs that the downward trend in water quality has been reduced, a new look at the recommended actions may be needed.

III. RESULTS AND DISCUSSION

USGS FLOW MODEL

The USGS, as a portion of their responsibilities as a cooperative agency in the 208 project, developed a hydrologic model of the aquifer (Bolke, E.L., and Vaccaro, J.J., 1981 "Digital-model simulation of the hydrologic flow system, with emphasis on ground water, in Spokane Valley, Washington and Idaho," U.S. Geological Survey Water Resources Investigations Open File Report 80-1300). The model was calibrated with data from the 1977-1978 208 project period.

The USGS flow model calibration reflected a net recharge from precipitation within the Spokane Valley of 0.41 inches per month. This value was developed using the "Blaney and Criddle" method of evapotranspiration estimation. The USGS estimated an average evapotranspiration of 1.31 inches per month as opposed to an average precipitation of 1.72 inches per month.

Earlier the 208 staff had estimted that the average net precipitation excess over evapotranspiration during the period from 1969 through 1977 was 5.22 inches per year with a standard deviation of 1.93 inches per year (Memo to file from Stan Miller, 1978). This estimate was used to verify estimates of the Spokane region water resources study that excess precipitation does occur which leads to percolation of surface water to the aquifer (Todd, D.K., "The Effect of Applied Surface Waters on Ground Water Quality in the Spokane Valley." Water Resources of the Metropolitan Spokane Region, Department of the Army, Corps of Engineers, 1975).

The USGS flow model confirmation of a net precipitation excess for percolation to the ground water verifies earlier calculations by Todd and the 208 program and verifies the 208 Cause and Effect Report conclusion that there is percolation of water from the ground surface to the aquifer. The flow model also shows that there is less aquifer depth and lower permeabilities at the peripheries which results in lower transmissivity and less aquifer flow at these locations, confirming Cause and Effect conclusions in this regard. It also further defined areas of Spokane River-aquifer interchange.

ON-GOING MONITORING

Since the completion if the 208 water quality monitoring program, aquifer quality has been assessed on a semi-annual or quarterly basis. In 1979, two sets of samples were taken by program staff and analyses were performed by the U.S. Environmental Protection Agency laboratory in Seattle. Since 1979, the Spokane County Health District has monitored several water purveyor wells on a regular basis. Table S1-1 contains a summary of data collected during this on-going monitoring program.

INCREASE IN CONTAMINANTS WITH TIME

The Spokane County Health District has been monitoring several wells for which earlier data is available from both the 208 study and an earlier one year sampling program conducted by the Health District in 1971-72. During 1981, 1982 and 1983, samples were collected on these wells throughout the year without a seasonal bias which makes the results comparable to data from the 1971-72 survey and the 208 study.

Figure S1-1 shows nitrate concentration means and standard deviation ranges for 5 wells during each of the four years of year-round comparable data. Figure S1-2 shows conductivity (specific conductance) in the 5 wells during the same sampling periods. The data presented in these two figures shows that contaminant concentrations are continuing to increase.

The Vera 4 wells is in the south peripheral portion of the aquifer (see Plate 1 in the Cause and Effect Report) where exchange is slow and in an area where urban development has been extremely rapid in the last decade. The near linear increase in both total salts concentration (conductivity times 0.6 approximately equals total dissolved solids in mg/l), and in nitrate nitrogen shows that the urbanization is affecting the aquifer water quality in that area.

The WWP 1-5A well is also along the south periphery but farther west. It too shows the affect that urbanization has on water quality. The Orchard #1 and the Modern #1 wells are near the center of the aquifer where aquifer flow and exchange with the river is the greatest. Even here the water quality is deteriorating with time. The CID 11 well is at the Idaho state line in a part of the aquifer described by the Panhandle Health District as being influenced by onsite sewage discharges from the Post Falls area (Jones, F.O. and K.W. Lustig, "Ground Water Quality Monitoring Rathdrum Prairie Aquifer," Panhandle Health District No. 1, 1977) and is also seeing continued deterioration in quality.

The mean values plotted on Figures S1-1 and S1-2 were compared for each time period. Increases were significant at the 90% confidence level or greater using the Students' t test in fourteen of twenty comparisons. Three others shows increases that are significant at the 80% level or greater. Three remaining were not significantly greater (Modern 1 nitrate 1978-1981; WWP 1-5 nitrate 1978-1981; and CID 11 conductivity 1978-1981). Comparing mean values from the 1971-72 to the 1981 data collection period shows all 1981 means to be greater at the 90% significance level or greater except one (Modern 1 nitrate).

This data confirms the Cause and Effect Report conclusion that a substantial portion of aquifer dissolved solids increase has resulted form man's activities over and adjacent to the aquifer. Also, further verified are the conclusions that there is percolation of water (and contaminants) from the ground surface to the aquifer and that lower flow rates near the aquifer periphery result in higher concentrations of dissolved salts.

CHLORINATED ORGANICS

The EPA region 10 water quality office has been sampling wells in the Spokane area for chlorinated organics since 1978. Initial results showing low levels of 1,1,1 Trichloroethane and Tetrachloroethylene, both solvents, in some well water samples were reported in the 208 Cause and Effect Report. Since that time, over 70 wells have been sampled. Several where detectable levels of chlorinated organics have been found have been sampled several times.

A total of more than 70 wells were sampled from May, 1978 through October, 1982 by the EPA or the Health District, with all analyses performed by the EPA laboratory. About 240 samples were analyzed. About 160 had concentrtions less than 1 microgram per liter (ug/l, same as parts per billion, ppb) for all of the substances tested for. Over 70 samples contained one or more of the chlorinated organic compounds at a concentration of 1 ug/l or greater. Most results 1 ug/l or greater were 1,1,1 Trichloroethane. Data for wells where the chemical was detected (1 ug/l or greater) is shown on Table S1-2.

Chlorinated organics concentrations were less than 1 ug/l in most samples taken from wells east of about Sullivan Road. Exceptions were the Jeffers well and the CID 2 and 3 wells. The Jeffers well, which is in close proximity to an abandoned solid waste disposal site west of Liberty Lake, was sampled 7 times and the mean concentration of organics was as follows:

1,1,1 Trichloroethane	2.0 ug/l	
Tetrachloroethene	26 ug/l	
Trichloroethene	8 ug/l	
1,2 Dichloroethane	14 ug/l	(3 tests)
Dichloroethene (trans)	185 ug/l	(3 tests)
Methylene chloride	68 ug/l	(1 test)

The CID 2 and 3 wells, west of the Jeffers well, contained 1,1,1 Trichloroethane at 2.3 and 1.1 ug/l, respectively, on one sampling but had concentrations less than 1 ug/l during 5 and 4 respective additional tests.

Other wells along the south periphery of the aquifer had occasional tests showing greater than 1 ug/l of 1,1,1 Trichloroethane (5 of 35 tests), all of which were less than 4 ug/l. Positive results occurred in Vera 4, Model 1, East Spokane 2, and Spokane Ray wells. Vera 2, Modern 7, WWP 2-5, Modern 4, Dishman, WWP 1-5, 1 and 2 (21 tests) all showed less than 1 ug/l of the chlorinated organics tested for.

In the north Valley area, most wells tested showed the presence of 1,1,1 Trichloroethane during a portion of the samplings. The data is shown on Table S1-2.

The Kaiser Trentwood well was sampled 7 times and contained an average of 22 ug/l of 1,1,1 Trichloroethane (1,1,1 TCE) concentration but less than 1 ug/l of all other chlorinated organics tested for. Conversely, wells east of the Kaiser well, the Industrial Park wells, the CID 5, CID 6 and CID 4 wells contained concentrations of less than 1 ug/l (1 of 4 tests of Industrial Park showed 2.5 ug/l of 1,1,1 TCE). North and south of Kaiser, the Trentwood wells had only 1 of 4 tests over 1 ug/l of 1,1,1 TCE. To the west, however, downstream in the aquifer, a number of wells showed 1,1,1 TCE concentrations greater than the 1 ug/l detection limit (Irvin, Millwood, Orchard 1 and 2, Spokane Parkwater and Spokane Electric). The Spokane Electric well averaged 6 ug/l in 7 tests. Some tests of wells in the Pasadena Park area (2 of 13) also contained detectable concentrations of 1,1,1 TCE.

The 1,1,1 TCE in the Kaiser Trentwood well and wells to the west definitely indicates that a source of discharge, disposal or spillage of the substance is present either in the Spokane Industrial Park, the solid waste disposal site between the Industrial Park and the Kaiser well, or in the vicinity. Firms are operating in the Industrial Park that use 1,1,1 TCE in their manufacturing processes.

In the aquifer north of the Spokane River through the Hillyard trough to the Little Spokane River a total of twenty-two wells were tested. Testing of these wells frequently showed 1,1,1 TCE to be present in detectable concentrations, but not the other organics tested for. Of particular note, the Spokane Nevada well has averaged 5 u/l in 7 tests, and the adjacent Spokane Grace well had an average of 4.4 ug/l in 2 tests. The Spokane Hoffman well had detectable concentrations of 1 and 1.2 ug/l in 3 tests. Of the nineteen remaining wells in the Hillyard trough which were tested, 15 tests out of a total of 57 for 1,1,1 TCE were from 1 to 2.3 ug/l. The others were less than 1 ug/l. All other organics tested for were less than 1 ug/l except in WWP 3-6 where one test showed 1,2 Dichloroethane at 3.7 ug/l and Carbontetrachloride at 1.4 ug/l.

Data collected in monitoring for chlorinated organics confirms several conclusions in the Cause and Effect Report. These include that: the aquifer is extremely susceptible to contamination by certain types of substances spilled or placed on the ground or in the immediate drainage area; industrial development and activities over the aquifer have resulted in water quality deterioration; solid waste activities over the aquifer have caused groundwater quality deterioration; and the level of some toxicants is sufficient to warrant continued monitoring.

AQUIFER WATER POLLUTION INCIDENTS

There have been documented water pollution occurrences in the Spokane aquifer which illustrate tht its vulnerability to actions on the above ground surface can indeed lead to the water quality degradation to a point where the water is unsuitable for use, and that health and property can be threatened.

During the 208 sampling program in 1977, bacteriological analysis of water from the Spokane County-owned well at Edgecliff indicated it did not meet drinking water standards. The well was taken out of service and its water supply function replaced with service from a water district.

Two municipal wells located in S. 18, T. 25 N., R. 44, one belonging to Model Irrigation District between Modern 9 and WWP 2-4, and the other belonging to Washington Water Power about 1/2 mile south of Modern 9, on Plate 1, were found to be bacteriologically contaminated. Both were placed in service with satisfactory water quality. Each was taken out of service due to bacteriological contamination after the area surrounding it was developed for urban density housing, all served by onsite sewage disposal and drywell runoff disposal. The Model well has never been returned to service. The WWP well was placed back in service after installation of a chlorination system.

In 1980, the Town of Millwood was forced to take its "Hedman" well out of service due to bacteriological contamination. It is located just east of Orchard 2 (see Plate 1). Investigation indicated that the contaminated water was entering the well from the uppermost portion of the aquifer. The contamination source was not identified but concluded to be wastes from urban density housing in the vicinity, all of which disposes of wastewater through onsite sewage systems and drywells for runoff. The Town has constructed a new well deeper into the aquifer at the City Park.

Beginning in 1978, an investigation of water quality in the vicinity of the Kaiser Mead aluminum reduction plant revealed that cyanides were present in groundwaters beneath and northward from the plant. A number of contaminated private wells were taken out of service and the residences served with water from a municipal source or provided with new wells deeper into the aquifer. The cyanide apparently originated from pot linings disposed of at the plant site. Remedial action to halt the continuing travel of the contaminant to the aquifer has been attempted but the results are as yet uncertain due to the long travel time for such constituents through the alluvium (about 150 feet thick) overlying the aquifer at this location.

Petroleum spills have threatened the aquifer within recent years. A diesel spill at a railroad yard was investigated in 1977. The material was traced to the groundwater but no ensueing inconvenience was apparent. In late 1982, a gasoline spill was recorded near a junior high school in Millwood. The fumes entered the school causing its closure for an extended period of time until an air blower was installed to draw fumes from the soil immediately above the aquifer adjacent to the school building. This reduced the fume problem in the school so it could be reopened. The gasoline is apparently remaining on top of the aquifer in the immediate vicinity and not dispersing downstream so the long-term consequences are still unknown.

The contamination incidents discussed in this section verify several other conclusions drawn in the Cause and Effect Report. The nature and location of these problems indicates that industrial activities over the aquifer have resulted in water quality deterioration, that there is a risk of bacteriological contamination of the aquifer that is associated with population growth and that the risk of aquifer contamination is the same in the central portions of the aquifer as it is in the peripheral areas.

USGS ONSITE DISPOSAL STUDY

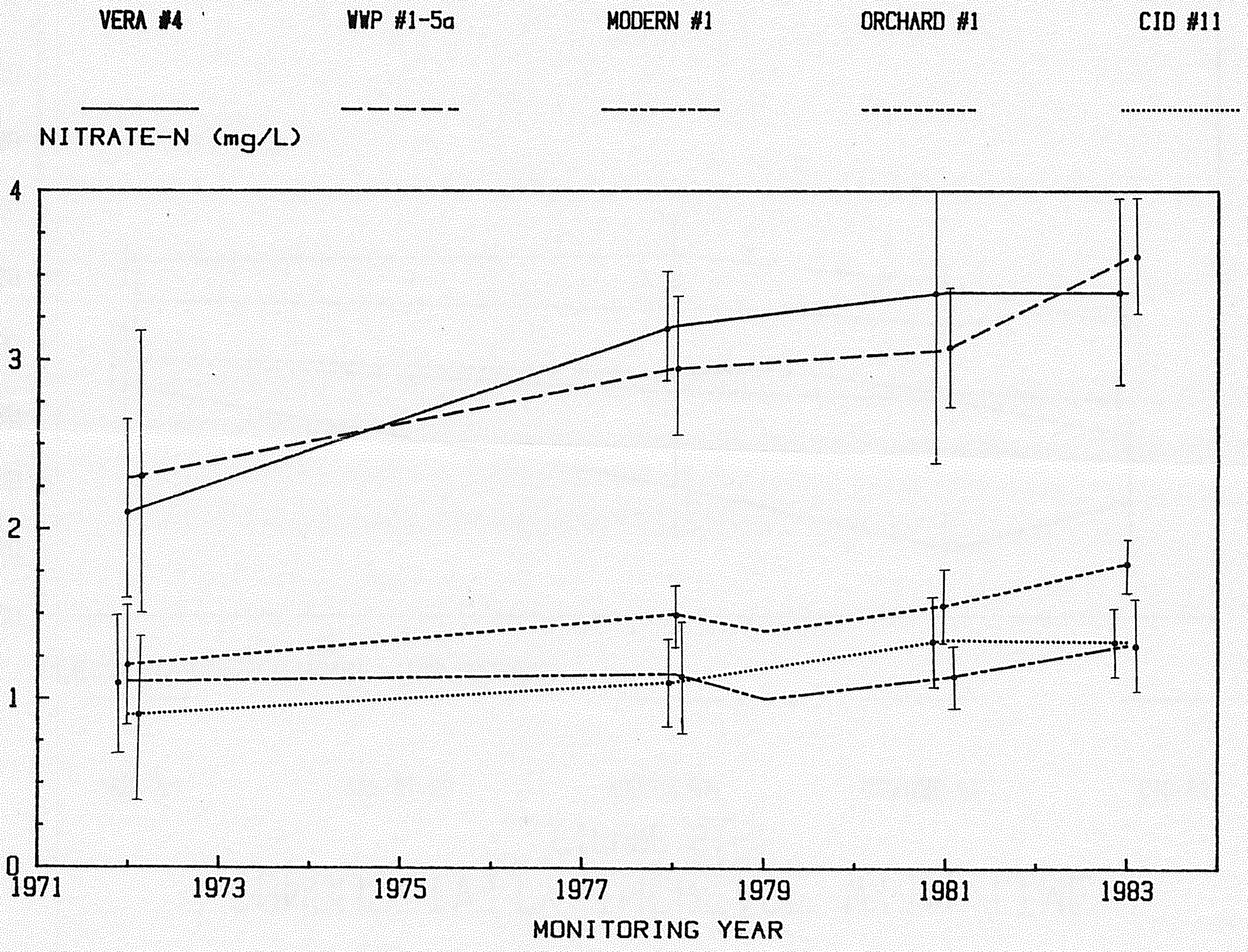
In 1978, the U.S. Geological Survey began a study of the fate of pollutants introduced to the ground through onsite sewage disposal. They had several monitoring wells constructed upstream (in the aquifer) and downstream of a new multi-family housing development with onsite sewage disposal, located near Millwood. Sampling has been conducted from about 1980 to the present. Final results have not yet been reported by the USGS but initial review of data indicates that chlorides and nitrates are increased in the downstream wells.

Additional data was collected from a short-term test where bromide was introduced into the sewage disposal system of one of the dwellings. Bromide, while not of health concern, is normally not present in the aquifer water in detectable concentrations. Bromide is very soluble and is chemically similar to chloride. It was detected in measurable concentrations in a downstream test well only about 9 days following its introduction into the sewage system.

The studies by the USGS verify the Cause and Effect report conclusions: that there is percolation of water from the ground surface to the aquifer which transport constituents from the ground surface to the aquifer; and that travel time for pollutants through the alluvium overlying the aquifer is comparatively fast (i.e. weeks or less).

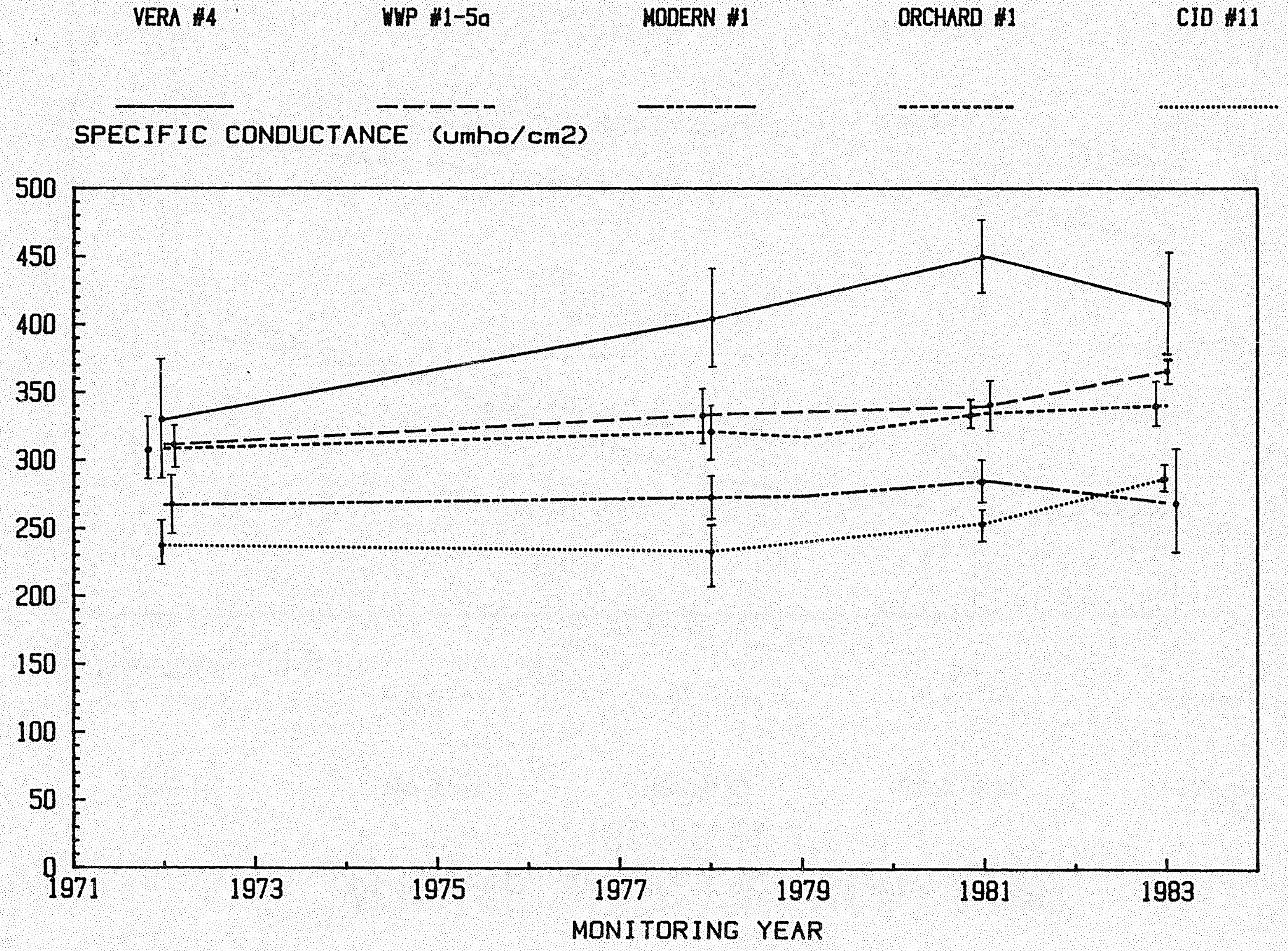
NITRATE INCREASE WITH TIME

FIGURE S1-1



CONDUCTIVITY INCREASE WITH TIME

FIGURE S1-2



BLE ON- WATE ITY RING

WELL	DATE	CONDUCTIVITY, umho/cm					NITRATE-N, mg/l					CHLORIDE, mg/l				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		1979		80-81	1981	82-83	1979		80-81	1981	82-83	1979		80-81	1981	82-83
Name	I.D.#	EPA	208	DSHS	DSHS	DSHS/IHW	EPA	208	DSHS	DSHS	DSHS/IHW	EPA	208	DSHS	DSHS	DSHS/IHW
CID 11	6631N	-	-	248 ±21(6)	260 ±0(2)	180 ±8(4)	-	-	1.3 ±0.2(6)	1.05 ±0.21(2)	1.34 ±0.18(4)	-	-	2.12 ±1.4(6)	1.5 ±0.7(2)	1.58 ±0.4(4)
CID 2	5518R	-	-	170 ±14(4)	285 ±78(2)	125 ±8(2)	-	-	0.88 ±0.15(4)	0.80 ±0(2)	1.3 ±0.3(4)	-	-	1.93 ±1.3(4)	2.0 ±0(2)	2.0 ±0.7(4)
Kaiser East	5402Q	652 ±201(2)	568 ±187(2)	638 ±231(4)	405 ±64(2)	330 ±76(4)	6.3 ±2.1(2)	7.0 ±4.0(2)	6.3 ±3.0(4)	3.05 ±0.70(2)	2.7 ±2.7(4)	94 ±50(2)	91.5 ±52(2)	88 ±53(4)	15 ±13(2)	18 ±28(4)
Modern 1	5415M	274 ±7(2)	205 ±7(2)	285 ±17(4)	-	190 ±19(4)	1.0 ±0.14(2)	.95 ±0.07(2)	1.13 ±0.15(4)	-	1.35 ±0.3(4)	<1 (2)	1.2 ±0.1(2)	5.1 ±4.2(4)	-	2.3 ±1.2(4)
Vera 4	5426L	417 ±19(2)	228 ±3(2)	450 ±26(2)	440 ±14(2)	310 ±37(4)	3.55 ±0.07(2)	3.2 ±0.4(2)	3.43 ±1.06(4)	3.40 ±0.14(2)	3.4 ±0.54(4)	2.5 ±0.7(2)	4.2 ±0.1(2)	6.20 ±2.14(4)	5.0 ±0 (2)	6.0 ±0.7(4)
WWP 2-4	5429A	-	-	385 ±7(2)	-	295 ±22(3)	-	-	4.25 ±0.64(2)	-	4.82 ±1.03(3)	-	-	13.0 ±1.4(2)	-	14.6 ±2.8(3)
Orchard 1	5312H	317 ±15(2)	245 ±7(2)	335 ±10(4)	340 ±28(2)	235 ±15(4)	1.4 ±0(2)	1.4 ±0.3(2)	1.55 ±0.19(2)	1.9 ±0.85(2)	1.8 ±0.13(4)	2.0 ±0.0(2)	3.0 ±0.14(2)	6.63 ±2.1(4)	3.5 ±3.5(2)	4 ±1(4)
WWP 1-5A	5323A	195 ±7(2)	270 ±11(2)	340 ±18(4)	350 ±19(2)	260 ±11(4)	0.75 ±0.21(2)	0.6 ±0.28(2)	3.06 ±0.33(4)	2.85 ±0.21(2)	3.60 ±0.34(4)	1.5 ±0.7(2)	2.5 ±0 (2)	8.3 ±2.4(4)	7.5 ±3.5(2)	7.8 ±0.8(4)
WWP 1-5B	5323A	-	-	342 ±13(4)	350 ±1 (2)	260 ±14(4)	-	-	3.1 ±0.4(4)	3.05 ±0.70(2)	3.5 ±0.33(4)	-	-	8.8 ±26.5(4)	7.5 ±3.5(2)	7.6 ±1.2(4)
E. Spo. 1&2	5424J&L	-	-	474 ±19(7)	440 ±0 (1)	293 ±52	-	-	4.8 ±0.4(7)	4.4 ±0 (1)	4.82 ±0.8(4)	-	-	14.2 ±12.7(7)	13.0 ±0 (1)	10.7 ±5.0(4)
Spokane-Ray	5322F	-	-	360 ±92(3)	430 ±28(2)	314 ±47(4)	-	-	4.37 ±0.40(3)	4.05 ±0.35	4.4 ±0.2(4)	-	-	13.4 ±3.9(3)	8.0 ±8.5(2)	12.1 ±0.9(4)
Spokane Nevada	5308A	-	-	267 ±15(3)	275 ±7(2)	183 ±13(4)	-	-	1.4 ±0(3)	1.4 ±0(2)	1.68 ±0.3(4)	-	-	8.4 ±7.3(3)	3.0 ±1.4(2)	3.8 ±1.0(4)
WWP 3-1	6330R	260 ±5(2)	200 ±0 (2)	263 ±11 (3)	275 ±7 (2)	182 ±12(4)	1.35 ±0.07(2)	1.40 ±0.28(2)	1.47 ±0.29(3)	1.15 ±0.7 (2)	1.48 ±0.4(4)	1.5 ±0.7(2)	2.8 ±0.07(2)	7.0 ±5.6(3)	1.0 ±0 (2)	2.9 ±1.0(4)
N Spokane 4	6327E	-	-	258 ±10(4)	255 ±7(2)	167 ±16(4)	-	-	1.05 ±0.13(4)	1.1 ±0 (2)	1.06 ±0.5(4)	-	-	7.9 ±2.2(4)	2.0 ±1.4(2)	3.2 ±1.2(4)
WWP 3-5	6308B	412 ±27(2)	370 ±28(2)	455 ±142(4)	430 ±14(2)	301 ±17(4)	1.6 ±0 (2)	1.90 ±0.42(2)	1.75 ±0.19(4)	1.8 ±0.42(2)	1.75 ±0.3(4)	10.5 ±0.7(2)	12.0 ±1.3(2)	13.0 ±3.5(4)	8.0 ±2.8(2)	7.0 ±4.4(4)
WWP 3-7	6303N	-	-	430 ±175(4)	495 ±205	420 ±42(2)	-	-	3.43 ±3.72	5.85 ±5.59(2)	8.8 ±1.9(2)	-	-	14.8 ±8.6(4)	20.0 ±19.8(2)	24.5 ±6.5(2)
Whitworth 3B	6307P	-	-	333 ±45(3)	350 ±0 (1)	208 ±24(4)	-	-	1.87 ±0.64(3)	1.6 ±0 (1)	1.48 ±0.4(4)	-	-	5.7 ±4.0(3)	6.0 ±0 (1)	3.1 ±1.1(4)
Whitworth 3A	6307K	-	-	330 ±37(4)	335 ±7 (2)	-	-	-	2.28 ±1.02(4)	1.6 ±0.14	-	-	-	9.2 ±3.3(4)	5.0 ±1.4(2)	-

Notes:

1. Conductivity readings for 1982-83 were performed in the field by Spokane County Health District personnel. The instrument used to perform these tests is known to have a different calibration than the instrument used by DSHS in prior years. The relationship between these two sets of data is:

   COND(DSHS) = 0.97 COND(SCHD) + 113.5

2. The calcium and magnesium concentrations for 1979 were calculated from calcium hardness and the difference between total hardness and calcium hardness respectively.

TABLE SI-1 ON-GOING WATER QUALITY MONITORING DATA

WELL	DATE	CALCIUM, mg/l					MAGNESIUM, mg/l				
		16	17	18	19	20	21	22	23	24	25
		1979		80-81	1981	82-83	1979		80-81	1981	82-83
Name	I.D.#	EPA	208	DSHS	DSHS	DSHS/IHW	EPA	208	DSHS	DSHS	DSHS/IHW
CID 11	6631N	-	-	25.8 ±4.7(6)	19.5 ±13 (2)	28.0 ±1.6(4)	-	-	20.0 ±7.3(6)	14 ±1.4 (2)	12.5 ±0.8(4)
CID 2	5518R	-	-	22.8 ±4.6(4)	16.5 ±7.8(2)	22.5 ±1.3(4)	-	-	6.7 ±1.8(4)	11 ±8.5(2)	5.7 ±0.2(4)
Kaiser East	5402Q	-	53.2 ±1.7(2)	56.3 ±26.8(4)	29.5 ±27.6(2)	39.0 ±7.5(4)	-	32.5 ±7.4(2)	23.1 ±11.7(4)	13.5 ±0.7(2)	13.2 ±0.7(4)
Modern 1	5415M	-	32.8 ±1.1(2)	29 ±4.5(4)	-	30.0 ±9.8(4)	-	26.1 ±3.3(2)	20.9 ±7.7(4)	-	12.6 ±0.6(4)
Vera 4	5426L	-	55.6 ±0.6(2)	47.8 ±14.7(4)	53.5 ±16.3(2)	54.6 ±2.6(4)	-	25.8 ±1.2(2)	22.5 ±8.2(4)	17.0 ±1.4(2)	15.3 ±0.7(4)
WWP 2-4	5429A	-	-	45.0 ±19.8(2)	-	50 ±3.3(3)	-	-	21.0 ±8.5(2)	-	16.9 ±1.6(3)
Orchard 1	5312H	-	39.2 ±2.3(2)	29.7 ±7.7(4)	24 ±20(2)	36.0 ±2.8(4)	-	28.7 ±2.1(2)	22.5 ±0.5(4)	15.0 ±1.4(2)	15.6 ±0.3(4)
WWP 1-5A	5323A	-	34.8 ±0.6(2)	34.3 ±9.4(4)	27.5 ±23.3(2)	41.3 ±3.4(4)	-	23.8 ±7.4(2)	19.8 ±6.8(4)	15.0 ±1.4(2)	14.4 ±0.9(4)
WWP 1-5B	5323A	-	-	30.6 ±8.9(4)	28.5 ±23.3(2)	42.9 ±2.1(4)	-	-	19.9 ±7.1(4)	14 ±0 (2)	14.3 ±0.7(4)
E. Spo. 1&2	5424J&L	-	-	49.4 ±10.3(7)	12 ±0 (1)	43.3 ±14.6(4)	-	-	28.9 ±10.9(7)	20 ±0 (1)	16.3 ±3.3(4)
Spokane-Ray	5322F	-	-	43.0 ±13.5(3)	36.0 ±22.6(2)	49.0 ±2(4)	-	-	17.1 ±6.5(3)	14.0 ±2.8 (2)	15.4 ±1(4)
Spokane Nevada	5308A	-	-	26.3 ±7.6(3)	23.0 ±12.7(2)	32.3 ±1.4(4)	-	-	11.6 ±3.8(3)	10.5 ±0.7(2)	11.4 ±0.9(4)
WWP 3-1	6330R	-	31.6 ±2.8(2)	30 ±0 (3)	23 ±8.5(2)	26.9 ±1.6(4)	-	20.3 ±3.3(2)	15.7 ±2.1(3)	11.5 ±3.5(2)	13.7 ±0.5(3)
N Spokane 4	6327E	-	-	24.0 ±3.4(4)	20.5 ±10.6(2)	26.9 ±3.8(4)	-	-	14.1 ±5.2(4)	10.5 ±2.0(2)	10.8 ±0.5(4)
WWP 3-5	6308B	-	40.0 ±11.3(2)	38.9 ±6.1(4)	33.0 ±6.1(2)	36.9 ±3.5(4)	-	27.6 ±6.2(2)	20.3 ±2.5(4)	15.5 ±7.8(2)	19.8 ±1.0(4)
WWP 3-7	6303N	-	-	44.3 ±12.3	37.0 ±5.7	55.8 ±2.6(2)	-	-	15.5 ±3.4(4)	13.5 ±2.1(2)	31.3 ±5.8(2)
Whitworth 3B	6307P	-	-	34.7 ±2.1(3)	34 ±0 (1)	30.3 ±1.3(4)	-	-	19.7 ±4.7(3)	18 ±0 (1)	16.6 ±0.4(4)
Itwo 3A	63	[illegible]	[illegible]	5 ±3.0(4)	26. ±9.2(2)	-	[illegible]	-	21 ±2.9(4)	±6.4(2)	[illegible]

TABLE SI-1 ON-GOING WATER QUALITY MONITORING DATA

WELL	DATE	SULFATE, mg/l					SODIUM, mg/l				
		26	27	28	29	30	31	32	33	34	35
		1979		80-81	1981	82-83	1979		80-81	1981	82-83
Name	I.D.#	EPA	208	DSHS	DSHS	DSHS/IHW	EPA	208	DSHS	DSHS	DSHS/IHW
CID 11	6631N	-	-	14.8 ±8.3(6)	13 ±0 (2)	13.3 ±3.3(4)	-	-	3.8 ±0.8(6)	3.0 ±0(2)	2.5 ±0.1(4)
CID 2	5518R	-	-	15.9 ±7.3(4)	12.5 ±3.5(2)	11.4 ±1.1(4)	-	-	3.1 ±1.0(4)	2.5 ±0.7(2)	2.2 ±0.1(4)
Kaiser East	5402Q	15.0 ±4.2(2)	-	18.8 ±9.8(4)	13.0 ±1.4(2)	12.7 ±2.2(4)	24.2 ±17.0(2)	-	26.6 ±11.2(4)	11.0 ±5.7(2)	10.9 ±14.3(4)
Modern 1	5415M	14.0 ±0.0(2)	-	24.6 ±2.5(4)	-	13.6 ±3.3(4)	2.9 ±0.1(2)	-	4.28 ±1.5(4)	5.5 ±4.9(2)	3.1 ±0.6(4)
Vera 4	5426L	14.5 ±0.7(2)	-	27.5 ±4.1(4)	16.5 ±0.7(2)	17.9 ±3.7(4)	6.6 ±1.0(2)	-	7.0 ±1.2(4)	7.5 ±0.7(2)	6.5 ±0.2(4)
WWP 2-4	5429A	-	-	22.5 ±0.7(2)	-	11.2 ±2.9(3)	4.2 ±0.3(2)	-	4.6 ±2.2(4)	-	7.4 ±0.7(3)
Orchard 1	5312H	14.5 ±0.7(2)	-	8.6 ±13.0(4)	14.0 ±2.8(2)	15.5 ±3.3(4)	4.2 ±0.3(2)	-	9.0 ±0 (2)	-	4.4 ±0.2(4)
WWP 1-5A	5323A	14.5 ±0.7(2)	-	20.3 ±10.8(4)	14.0 ±1.4(2)	15.0 ±5(4)	3.7 ±0.3(2)	-	6.3 ±0.9(4)	5.5 ±0.7(2)	5.9 ±0.4(4)
WWP 1-5B	5323A	-	-	20.9 ±8.7(4)	14.5 ±0.7(2)	15.1 ±5.3(4)	-	-	6.5 ±1.3(4)	5.0 ±0 (2)	5.9 ±0.4(4)
E. Spo. 1&2	5424J&L	-	-	20.6 ±11.2(7)	17 ±0 (1)	17.3 ±3.4(4)	-	-	9.7 ±1.0(7)	10.0 ±0 (1)	10.0 ±1.4(4)
Spokane-Ray	5322F	-	-	29.7 ±2.1(3)	17.0 ±0 (2)	16.4 ±1.9(4)	-	-	8.8 ±0.4(3)	8.0 ±1.4(2)	8.2 ±0.8(4)
Spokane-Nevada	5308A	-	-	22.2 ±3.9(3)	14.5 ±0.7(2)	14.3 ±5.0(4)	-	-	4.4 ±1.0(3)	5.5 ±2.1(2)	3.3 ±0.2(4)
WWP 3-1	6330R	14.5 ±0.7(2)	-	21.8 ±8.6(3)	16.5 ±0.7(2)	14.7 ±4.8(4)	3.1 ±0.1(2)	-	4.4 ±101(3)	3.0 ±0 (2)	2.9 ±0.1(4)
N Spokane 4	6327E	-	-	17.6 ±8.8(4)	13.5 ±0.7(2)	13.3 ±5.7(4)	-	-	5.6 ±1.7(4)	5.0 ±0 (2)	3.2 ±0.3(4)
WWP 3-5	6308B	59.5 ±12.0(2)	-	50.0 ±34.5(4)	52.5 ±10.6(2)	65.4 ±7.2(4)	15.0 ±4.7(2)	-	12.7 ±5.6(4)	16.5 ±0.7(2)	15.2 ±1.1(4)
WWP 3-7	6303N	-	-	47.4 ±23.0(4)	23.0 ±2.8(2)	31.7 ±8.1(2)	-	-	9.5 ±5.7(4)	10.0 ±8.5(2)	14.4 ±3.3(2)
Whitworth 3B	6307P	-	-	30.3 ±7.1(3)	18 ±0 (1)	13.7 ±3.1(4)	-	-	5.7 ±1.1(3)	6.0 ±0 (1)	3.2 ±0.2(4)
Whitworth 3A	6307K	-	-	28.1 ±5.5(4)	15.5 ±3.5	-	-	-	6.4 ±1.4(4)	6.0 ±0 (2)	-

TABLE S1-2 1,1,1-TRICHLOROETHANE DATA SUMMARY FOR SELECTED WELLS

All concentrations are ug/l

	DATE								
WELL NAME	3/78	9/80	1/81	5/81	7/81	10/81	7/82	10/82	1/83
CID 11	0.11	<1	<1	<1	<1	<1	1.M	1.M	<1
Jeffers	-	1.2	<1	2.1	6.5	<1	4.0	<1	<1
Vera 4	-	<1	<1	<1	<1	<1	2.6	1.5	1.4
Model 5	<0.3	1.6	<1	-	<1	<1	-	-	-
East Spokane 2	-	3.8	-	-	<1	-	<1	<1	<1
Spokane Ray	-	1.9	-	<1	<1	<1	<1	<1	<1
Vera 2	<0.3	<1	<1	-	<1	-	<1	<1	<1
Modern 7	-			<1	<1	<	<1	1.M	<1
WWP 2-5	-	1.5	-	<1	<1	<1	-	-	-
Modern 4	-	-	-	-	<1	<1	-	-	-
Dishman	-	-	-	<1	<1	<1	-	-	-
WWP 1-5a	-	<1	<1	<1	<1	<1	<1	<1	<1
Kaiser Trentwood	-	62	31	13	31	8.1	4.5	2.9	2.3
Spokane Ind. Pk 4	-	-	-	-	2.5	-	-	-	-
Spokane Ind. Pk 1	-	-	-	<1	<1	<1	-	-	-
CID 4	-	<1	-	<1	<1	<1	-	-	-
CID 5	-	-	-	<1	<1	<1	<1	<1	<1
CID 6	-	-	-	-	<1	-	<1	<1	<1
Irvin 1	0.46	1.2	2.4	1.4	2.3	<1	2.6	2.4	1.0
Millwood	-	-	-	<1	1.9	<1	-	-	-
Orchard 1	2.5	9.3	4.6	2.7	3.7	<1	2.3	1.M	1.M
Orchard 2	2.9	8.3	-	-	2.3	-	-	-	-
Spokane Parkwater	5.8	10	2.1	<1	<1	<1	-	-	-
Spokane Electric	13	7.7	10.0	3.5	9.8	1.3	-	-	-
Spokane Nevada	4.4	5.8	-	4.2	-	4.9	3.4	4.9	1.2
Spokane Grace	-	-	-	3.2	5.5	-	-	-	-
Spokane Hoffman	-	-	-	1.0	-	<1	-	-	-
WWP 3-4	0.17	1.2	<1	<1	<1	<1			
WWP 3-5	0.48	1.5	<1	<1	<1	<1	2.1	1.M	1.M
Livengood	-	5.7	<1	2.5	<1	<1	2.3	1.M	1.2

-	No analysis performed
1.M	Detected but less than 1 ug/l
<1	Not detectable

SPOKANE AQUIFER CAUSE AND EFFECT REPORT

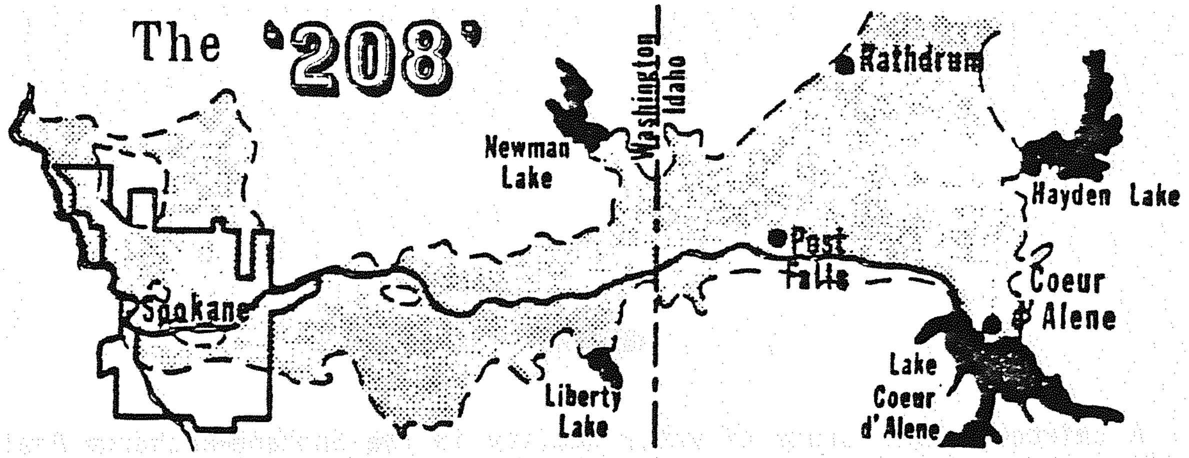
SUMMARY REPORT OF '208' WATER QUALITY RESULTS AND CAUSE AND EFFECT RELATIONSHIPS FOR WATER QUALITY IN THE SPOKANE-RATHDRUM AQUIFER

by

DR. LARRY A. ESVELT, P.E.

DECEMBER 1978

Spokane County, Washington '208' Program
County Engineers Office
North 811 Jefferson Street
Spokane, Washington 99260



Spokane Aquifer Study

FOREWORD

This report is an output of the Spokane County '208' Water Quality Management Program (Ground Disposal). Protection of the water quality in the Spokane-Rathdrum Aquifer in Washington is the principal objective of this program. The aquifer has been designated by the Environmental Protection Agency as the sole source of domestic water supply for the Spokane metropolitan area and its preservation as a resource is essential to the health and welfare of Spokane area residents.

A draft of this report has been reviewed and commented on by members of the Technical Advisory Committee and the Citizen Representatives Core Committee of the Spokane County '208' Study, the Washington State Department of Ecology, the Environmental Protection Agency, the U.S. Geological Survey, and Battelle Northwest Laboratories. Their comments have been taken into account in production of this final report. The findings presented in this report will be used in development of a Water Quality Management Program for the Spokane-Rathdrum Aquifer in Washington.

Ray Card,
Program Manager
Spokane County '208' Study

ABSTRACT

A thirteen month study of water quality in the Spokane-Rathdrum Prairie Aquifer, in Washington State, was conducted by Spokane County as part of the Aquifer Water Quality Management Program. Results of the study indicate that the aquifer water quality is well within the Federal Drinking Water Regulations. However, activities, including increased urbanization, on the land surface above the aquifer have affected the water quality. Water quality degredation from salts and bacteria has occurred even though the unconfined aquifer, which has been designated a Sole Source Aquifer by the Environmental Protection Agency, lies from 40 to 150 feet below ground surface.

Data collected during the study and other data included in historical files and collected by other entities was analyzed. The study concluded that the aquifer is extremely vulnerable to contamination by activities on the overlying land surface. Control measures are recommended for various types of land uses and waste disposal practices.

CONTENTS

I. INTRODUCTION

The Spokane County Water Quality Management Program (Ground Disposal) has been assigned the responsibility of developing water quality management procedures for the Spokane-Rathdrum Aquifer in the State of Washington. This responsibility was delegated to Spokane County by the Washington State Department of Ecology under the '208' Statewide Water Quality Management Program.

The Water Quality Management Program included a one year study of the aquifer to determine whether groundwater quality was being altered as it flows through the area and if so, the extent and causes for the alteration. Tasks 2.20 through 2.26 of the detailed Work Plan for the Water Quality Management Program describe the aquifer water quality monitoring studies[1]. A progress report was published in June, 1977 which described the sampling network, existng wells used for sampling, new wells which were constructed to allow depth selective sampling, and the sampling and analytical procedures and schedules[2].

This report contains a summarization of the results of the water quality monitoring program and attempts to determine cause and effect relationships for water quality variations in the Spokane-Rathdrum Aquifer within the State of Washington. The summarization of data does not include a complete data presentation. This information is on file in computer printout form at the Spokane County Engineers Office.

The preparation of this report was funded in part by: The U.S. Environmental Protection Agency under Public Law 92-500, Section 208; and, the Washington State Department of Ecology under State Referendum 26.

↳ Clean Water Act
[FWPCA]

II. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This report presents an analysis of water quality data for the Spokane-Rathdrum Aquifer in Washington. Data was primarily derived from a one year monitoring study conducted by the Spokane County '208' Water Quality Management Program. Additional data from a number of sources was considered.

SUMMARY

The following findings are presented in this report:

1. With the exception of one well which was taken out of service, none of the aquifer samples from points monitored during the study contained any of the contaminants covered by the Drinking Water Regulations in concentrations consistently exceeding the established limits.

2. Overall average dissolved solids concentrations were found to increase in the aquifer downstream from the State Line to the City of Spokane and Little Spokane River.

3. Dissolved solids concentrations were found to be higher along the aquifer periphery than in the center of the aquifer.

4. In depth selectively sampled wells chloride, nitrate-nitrogen and total dissolved solids concentrations were statistically significantly higher in samples taken near the aquifer water surface than in samples taken from deeper in the aquifer.

5. Bacteriological testing of operating water supply well samples resulted in positive coliform findings in 10 of 117 one hundred milliliter samples taken from over the aquifer study area. Comparable frequency of positive coliform results were found by the Panhandle Health District in samples from the Idaho portion of the aquifer and by the Spokane County Health District. Total aerobic bacteriological content tests resulted in 57% showing 500 or more organisms per milliliter and a log mean concentration of 626 per millilliter. One well was found to be contaminated according to coliform and fecal coliform test results and taken out of service. That was the only location exceeding drinking water limitations.

6. Water quality variations in the aquifer peripheral area south of Opportunity were plotted. Dissolved solids concentrations were greater beneath the populated area than immediately adjacent to the aquifer edge. Seasonal shifts of the high concentration zone occurred.

7. Historical records of aquifer water quality confirm the current water quality differences between the aquifer peripheral areas and its main stem in the Spokane Valley and show that dissolved solids concentration have been increasing in these areas over the period of record. This has occurred during the period when population has been increasing in the same area.

8. Some changes in aquifer water quality were observed following the onset of increased precipitation. This principally consisted of salt concentration increases at some locations.

9. Aquifer water quality in the vicinity of ground surface solid waste disposal sites was observed to vary from that found at other locations and salt concentrations were higher. Water quality in a well downstream of one abandoned solid waste disposal site increased in dissolved salts following the onset of seasonal precipitation. *

10. Cyanide has been found in the aquifer downstream of a major industrial site. Concentration apparently exceeds recommended levels although no regulation limitation exists.

11. Organochlorides have been found at low concentrations in various aquifer locations. The EPA has not determined them to hazardous at these concentrations.

12. The heavy metals chromium and mercury have been found in detectable concentrations. Some mercury concentrations approached drinking water standards. Samples in which this occurred were not frequent.

13. Water quality variations occurred along the Spokane River through the Spokane Valley. Greatest variations were observed in the State Line to Greenacres vicinity and downstream (west) of the Upriver Dam. Variations also occurred near river reaches where the USGS has indicated net flow to be from the aquifer to the river.

14. Concentration gradients of dissolved solids away from the landfill area northwest of Spokane were nearly equal in both the upstream and downstream directions and water in the Nine Mile area appeared to be stagnant. ✓

15. Groundwater quality in the Mead area showed higher levels of total dissolved solids, chloride, nitrates and other salts than was contained in "main stem" aquifer water.

16. Water quality downstream of aquifer penetrations for gravel extraction did not differ from that elsewhere in the central portion of the aquifer, except that quality variations with depth below the aquifer surface were reduced.

CONCLUSIONS

The following conclusions are based on the Spokane-Rathdrum Aquifer water quality findings presented in this report and summarized above:

1. The groundwater quality of the Spokane-Rathdrum Aquifer is currently suitable for domestic, municipal, commercial, agricultural and industrial uses.

2. The glacial outwash deposited alluvium overlying the aquifer is extremely permeable making the aquifer susceptible to contamination by certain types of substances spilled or placed on the ground or in the immediate drainage area.

3. There is percolation (or recharge) of water from the ground surface to the aquifer. Water from precipitation, irrigation, waste disposal and runoff all contribute to recharge and transport constituents from at or near the ground surface to the aquifer. The addition of constituents from these sources results in the variation in groundwater quality with depth and an increase in the concentrations along the aquifer.

4. Travel time for pollutants through the alluvium overlying the aquifer is comparatively fast (ie. weeks) considering the depth of the water table below ground surface, although it undoubtedly varies with moisture availability, soil type, quantity and distribution of the pollutant and the nature of the constituent.

5. Low flow rates near the aquifer periphery result in a greater accumulation and higher concentration of dissolved solids and other constituents than in higher flows in the aquifer main stem (nearest the center).

6. Industrial development and activities over the aquifer have resulted in water quality deterioration. Future unregulated industrial and related activities could further jeopardize aquifer water quality.

7. Solid waste disposal activities over the aquifer have caused groundwater quality deterioration.

8. A substantial portion of aquifer dissolved solids increase has resulted from man's activities over and adjacent to the aquifer. Increase in these activities accompanying population growth (urbanization) over the aquifer and on lands tributary will result in increasing deterioration of aquifer water quality.

9. There is a risk of bacteriological degredation of the aquifer which accompanies current and future development over and adjacent to the aquifer. The risk of contamination will increase with additional population growth.

10. The risk of serious contamination of the aquifer by hazardous or toxic substances, including pathogens, appears to be the same in the central portion of the aquifer and in the aquifer peripheral areas. Dilution is greater in

the central portion of the aquifer but greater permeability of the overlying alluvium would transport hazardous substances to the groundwater more rapidly than through finer soils near the periphery.

11. Agricultural practices were not shown to directly affect water quality as much as man's activities in more urbanized settings but mismanagement of wastes, fertilizer or chemical applications, materials storage and other activities has the same potential for groundwater contamination as if the activities were of urban origin.

12. Gravel mining and extraction, as currently practiced, is apparently not degrading water quality but such activities do increase the susceptibility to contamination by improving accessability to the aquifer.

13. Surface waters enter the aquifer from the Spokane River in two major reaches, from the State Line downstream to Greenacres and in the vicinity of Upriver Dam. There is also interchange in reaches where the net flow is from the aquifer to the river. Surface waters from many tributary drainage basins also enter the aquifer (et. Newman Lake, Liberty Lake, Plouf Creek).

14. Groundwater along the Spokane River valley where it runs northerly, west and northwest of Spokane may not be a continuous part of the Spokane-Rathdrum Aquifer.

15. There is a tributary aquifer entering the main aquifer in the Mead area. This aquifer originates from the Peone Prairie area and affects water quality in several water supply wells.

16. The level of some toxicants such as mercury, organochlorides and cyanide is sufficient to warrant continued monitoring.

RECOMMENDATIONS

Based on the effects of surface activities above the aquifer on water quality the following recommendations are made for consideration during development of the Water Quality Management Program for the Spokane-Rathdrum Aquifer, in Spokane County, Washington to preserve and enhance the current water quality.

1. All sources of potential spills of toxic or hazardous materials should be considered and placed under a program of surveillance and control. Spill control plans should be developed for each significant source. The immediate effect of a spill on the aqufier water quality would depend somewhat on the material spilled. Highly viscous materials would not reach the aquifer immediately and water qualilty effects could be mitigated by a fast-acting cleanup procedure. Non-viscous materials have been shown to progress rapidly to the aquifer and spill prevention is essential for these types of materials. Controls and mitigating procedures should be placed on both mobile and fixed potential sources.

2. All industrial discharges to the land over the aquifer should be placed under control of a permit which addresses the particular type of waste and the handling or storage procedure for the material to be disposed of. Disposal of hazardous or toxic materials should not be allowed in areas where they could enter the aquifer. Storage of hazardous or toxic raw materials or wastes should be allowed only in areas where complete containment is assured.

3. Solid or liquid waste disposal, even when wastes which are toxic or hazardous are excluded, should be controlled and even discouraged to assure that they do not promote aquifer water quality degradation. Strong measures should be enforced to prevent unauthorized materials from being placed in these sites to prevent the aquifer water quality from being jeopardized.

4. Land use controls and mitigating measures to offset water quality changes which accompany urban and suburban land uses should be initiated. In other words, further land development should be curtailed or corrective or mitigative measures for wastewater disposal, runoff and percolation initiated to hold pollutant load to the aquifer at or below its present level.

5. Runoff from suburban, urban, commercial and industrial developments should be managed to preserve or improve current water quality.

6. Wastewater disposal from domestic and commercial developments should be managed to preserve or improve current water quality.

7. Public education regarding aquifer vulnerability to pollution due to overlying land use activities and placement or discharges of materials on the ground surface should be intensified. This is especially pertinent with regard to public use of toxic or hazardous substances, even in small amounts, and use of fertilizers, herbicides, pesticides or chemicals.

8. Existing control procedures for operation of aquifer penetrations for gravel pit extraction should be maintained, and future controls planned to prevent these excavations from becoming a means for aquifer contamination either intentionally or inadvertently

9. Surface waters in the area where they can recharge the aquifer should be maintained at an acceptable quality to prevent their adversely affecting the aquifer.

10. A continuing water quality monitoring program should be established to assure the effectiveness of the water quality management procedures established for aquifer protection.

III. BACKGROUND

The Spokane-Rathdrum Aquifer is virtually the sole source of water supply for domestic use in the Spokane metropolitan area. It's quality is of vital concern to residents of the area and especially to officials responsible for supplying the aquifer water for domestic consumption.

The Spokane-Rathdrum Aquifer in Washington lies under the Spokane Valley from the Washington-Idaho State Line to the City of Spokane and beneath the City and Hillyard Trough north of the City to the Little Spokane River. It flows westerly from the Idaho State Line at a rate approaching 1000 cubic feet per second (cfs) and lies 40 to 150 feet below the ground surface in a glacial or glacial outwash deposited alluvium of coarse sand to large gravel.

Washington State University conducted investigations to determine whether ground surface activities, especially on-site wastewater disposal practices, were affecting the groundwater in the Spokane-Rathdrum Aquifer. The results were reported by Crosby, et.al[3]. These studies were performed primarily in the unsaturated alluvium overlying the aquifer in the Spokane Valley east of Spokane and consisted of test hole drilling and sampling of the extracted soils for analysis. The WSU studies found that "chemical laden moisture fronts are advancing to, or have in the past advanced to, the lower parts of the test holes, either by gravity or capillary mechanisms". "The analyses for NO_3^- clearly indicate a downward ionic migration of NO_3^-, which in places has exceeded 50 feet from the leach bed", and that coliform organisms were in soil samples taken from depths 11 to 26 feet below the bottom of some leach beds. They found low moisture content (about 3%) in soils at depth, however, and therefore concluded that "moisture is returned to the atmosphere at essentially the same rate that wastewaters are applied". Even though the latter conclusion was qualified it was taken by local groups at face value.

The Army Corps of Engineers conducted the Metropolitan Spokane Water Resources Study. A theoretical analysis of moisture relationship (moisture balance) was performed by Dr. David Todd[4] and he concluded "that aquifer recharge was occurring from moisture percolating from the overlying ground surface and that a significant proportion of the leachate from septic tank drainfields is available for percolation to the water table of the groundwater." He stated that "the entire dissolved solids content of the septic tank effluents should be reaching the groundwater, except for minor dissolved constituents such as phosphates". Dr. Todd hypothesized a resulting "distinctive graduation of dissolved solids concentration" near the surface of the aquifer water table and "accumulation along a groundwater flow line".

Obviously, a disparity in interpretation if not in meaning existed between the conclusion of the two principal investigations preceding this '208' effort. Dr. Todd maintained that the WSU results corroborated his hypothesis but some people disagreed. They pointed to the lack of data from the aquifer itself as sufficient reason to discount the affect of ground surface activities on groundwater quality.

The final report of the Corps of Engineers study recommended that a groundwater quality monitoring program should be undertaken to verify the conclusion of Dr. Todd.

The '208' Study aquifer monitoring program was designed to determine if surface "recharge" is occurring to carry ground surface pollutants to the aquifer, and if so, the affect of such a phenomena.

Such information would be used as basic background data for the development of a aquifer water quality protection program.

IV. CONDUCT OF STUDY

Water quality monitoring was initiated in May, 1977 and continued into June, 1978. The Spokane County '208' program collected samples from about 80 locations in the Spokane area, 20 of which were specially constructed depth selective sampling wells, and the remainder were water purveyor wells and privately owned wells. Plate 1 shows the sampling point locations and names. The wells drilled for depth selective sampling were constructed and cased to allow sample withdrawal from measured depths below the aquifer water surface with specially designed equipment (depth selective sampling). A total of about 1400 samples were collected by the '208' field sampling crew and some 21,000 individual tests were run. Analyses were conducted by the '208' staff, the Idaho Health and Welfare Laboratory, Coeur d'Alene, Idaho, and the laboratories of the Environmental Engineering Section of the Department of Civil and Environmental Engineering at Washington State University, Pullman, Washington. Analyses conducted, their frequency, and analytical procedures are contained in the June 1977 Progress Report[2].

In a concurrent cooperative program, the U.S. Geological Survey collected samples from about 150 locations three times over the one year period. Their samplings occurred in May and October of 1977, and May of 1978. Most of the sampling points used by the '208' program were also sampled under the U.S. Geological Survey program. The remainder were distributed over the aquifer area to get a more thorough areal coverage. The Geological Survey participation in the program was intended to provide simulation techniques for groundwater quality variations. In other words, the Geological Survey undertook the task of developing a groundwater quality and transport mathematical model for computer application. The model to be developed was an extension of a groundwater flow model, which was already under development by the U.S. Geological Survey when this '208' program began. Both were intended for use in aquifer water quality and quantity management but were not available for use during preparation of this report.

SAMPLING NETWORK

Plate 1 shows the geographic location of the aquifer, the aquifer boundary and the location of the '208' program sampling points. Each sampling point is indicated by name according to location, or owner of the well in the case of purveyor or privately owned wells. The wells drilled for depth selective sampling are indicated by separate symbol on the map and the names are preceeded by '208'. Each sampling point was sampled from four to twelve times over the thirteen month monitoring period. The general program was to sample monthly, but some sites were added during the sampling program, which resulted in their being sampled fewer times. Equipment malfunctions prevented sampling at some sites for a portion of the sampling periods and in some cases severe weather during the winter months also prevented sampling at some sites.

Testing

Analyses run on each of the samples collected varied according to the sampling plan. These are presented in the Progress Report[2]. Some deviations from the plan were necessary due to the addition or deletion of some of the sampling sites, but the overall number of analyses were maintained at approximately the level planned at the beginning of the project in order to maintain budget control.

'Field tests' were performed by the '208' sampling crew at the time of sampling or on the same day in a laboratory facility at the County Engineers office. Field tests included temperature, pH, conductivity (specific conductance), hardness, chloride, and nitrate-nitrogen. The pH, conductivity, hardness and chloride were performed by accepted standard methods of procedures, except that the hardness and chloride titrants were at modified normalities and titrated with a Hach Digital Titrator. Nitrate-nitrogen analyses were performed using a Specific Ion Electrode with the Orion pH and Specific Ion Meter. Blanks and standards were run for the tests daily. A number of the tests performed by the field crew were also performed on duplicate samples by the Idaho Health and Welfare or Washington State University laboratories in order to confirm testing validity and accuracy.

The Idaho Health and Welfare Laboratory performed tests for conductivity, chloride, hardness, total dissolved solids, alkalinity, calcium, magnesium, sodium, potassium and the heavy metals (arsenic, barium, cadmium, chromium, copper, iron and lead). They also performed total and fecal coliform analyses and total plate count bacteriological analyses on samples from purveyor wells and performed a scan for pesticides on about 80 samples from 40 wells. The frequency of the various tests were as presented in the sampling report[2].

Washington State University Environmental Engineering Laboratory performed tests for nitrite plus nitrate-nitrogen, nitrate-nitrogen, ortho phosphate, ammonia nitrogen, sulfate, detergent (MBAS), chemical oxygen demand (COD), total organic carbon, total kjeldahl nitrogen and total phosphorus. Testing at Washington State University was predominantly by auto analyzer.

Sampling

Samples from purveyor wells and other wells with permanently installed pumps were collected at the tap nearest the pump head. Samples were shipped preserved and unpreserved, according to the particular test, via bus to Washington State University and were transported daily to the Idaho Health and Welfare Laboratory by the sampling crew. Sampling from the '208' depth selective sampling wells was done with a specially designed sampler mounted in a sampling van. The sampler consisted of a submersible turbine pump with inflatable packers mounted at each end which could seal the 6 inch casing above and below the pump for sampling from a particular depth below the surface of the aquifer. The pump was lowered into and retrieved from the well via a cable and a winch arrangement. The electrical connection, the discharge hose and the air hose for inflating the packers were wound on a live hose reel in the van and lowered into the hole parallel to the pump suspension cable. The pump was powered by an electrical generator mounted in the van which also housed an air compressor for supplying air to inflate the packers. The lift winch was driven by the sampling van electrical system which contained a heavy duty alternator and extra storage batteries.

Depth selective sampling was conducted according to consistent procedures where the water was pumped from the particular sampling level following packer closure for at least 15 minutes and up to 30 minutes prior to sampling. A majority of the time samples were collected at the uppermost or surface level first and subsequently at respectively lower depths. However, a portion of the time samples were collected in reverse order from the lowest depths first and subsequently at lesser depths up to the water surface to ensure that the order in which samples were collected did not skew the analytical results. Dye testing confirmed that the packers effectively sealed the cased well and confirmed that sample withdrawal was from the desired level.

The '208' personnel performing sampling and field analyses were given procedural instructions by qualified professionals. Each of the laboratories doing analytical work maintained strict quality control procedures to assure the accuracy and reproducibility of the results. Check samples were sent to the laboratories with known concentration additions of various constituents to obtain an estimate of the accuracy of the testing done. The sampling analysis and quality control procedures and results are contained in an Appendix to the Spokane County '208' final project report.

V. RESULTS AND DISCUSSION

The summarized results of the one year program of aquifer water quality monitoring are shown on Table 1. These results are presented as the means and standard deviation of the entire set of results collected over the monitoring period for each sampling point.

The Table 1 contents and their significance are as follows:

- Column 1 contains the sampling point by name. The numbers shown for the depth selective wells are the mean and standard deviation of depth below the ground surface of the water table over the sampling period.
- The well number (No.) is as assigned by USGS giving the last figure from Township and Range, the Section number and the sixteenth by letter (ie. 6630D is in the NW 1/4, NW 1/4, Section 30, Township 26N, Range 46 EWM).
- Conductivity is a measure of electrical conductance of the water. It relates directly to the amount of solids dissolved in the water. A total dissolved solids (TDS) maximum of 500 milligrams per liter has been recommended[5], which translates to a conductivity of about 800 micromhos/cm. Source of TDS can be minerals dissolved from rocks or pollutants introduced to the aquifer.
- Nitrate-nitrogen is the concentration of nitrogen in the nitrate form (as opposed to ammonia or organic form). The drinking water standard maximum concentration limitation (MCL) is 10 milligrams per liter[6]. Nitrates in the aquifer are from surface runoff, wastes or fertilizers.
- Chloride concentrations are recommended not to exceed 250 milligrams per liter for esthetic reasons (taste)[5]. Chlorides are rare in local rocks and, therefore, any found in the aquifer are from ground surface sources such as disposed or stored salts or sewage.
- Hardness is a measure of the concentration of multivalent cations (calcium and magnesium) expressed as calcium carbonate ($CaCO_3$). It occurs naturally in groundwater as it is dissolved from the rocks although it can also be introduced in wastes. No limitations have been established or recommended although soap usage and scaling problems are less with soft waters. Hardness concentrations of 0 to 75 milligrams per liter have been described as soft, 75 to 150

milligrams per liter as moderately hard, 150 to 300 milligrams per liter as hard and over 300 milligrams per liter as very hard[7].

- Alkalinity (Alk) is a measure of buffering capacity of a water against pH variations. It consists primarily of carbonate and bicarbonate ions which are dissolved from natural rocks in this aquifer area. Human health would not be impaired by drinking water concentrations below 400 milligrams per liter[7].

- Sulfates naturally occur in some geological formations in the Spokane-Rathdrum Aquifer area. A maximum sulfate concentration of 250 milligrams per liter has been recommended[5] as higher concentrations have been reported to cause laxative effects on some persons. It can be introduced from wastewater.

- Sodium and potassium are at a low availability in rocks of the area. They can cause taste problems at high concentrations. High sodium in relation to calcium and magnesium makes water undesirable for irrigation. Sodium is present in wastewater.

- Zinc is indigenous to some geological formations in this area and mined commercially in the Coeur d'Alene district of Idaho. There is no MCL but a recommended limit is 5 milligrams per liter (5,000 micrograms/liter)[5].

- pH is a measure of acid or alkaline tendency of a water. Neutral is 7. Commonly groundwaters are acidic with some at pH less than 6.

- Temperature of groundwaters is usually very stable and cool (near 10^{o}).

The Table 1 results are separated according to the agency performing the analysis. The means and standard deviation are based on the data as reported by the laboratories except for the nitrate-nitrogen from the '208' testing with the specific ion electrode. The nitrate-nitrogen '208' values are the mean and standard deviation of corrected readings. Corrections were made using coefficients obtained by linear regression of '208' electrode values to the values reported from duplicate samples by the WSU lab. The linear relationship between the WSU nitrate-nitrogen values and those obtained using the '208' procedures was developed separately for the period from project initiation through November 14, 1977, for the period November 15 through December 6, 1977, and for the period December 12, 1977 through the end of the project. Each of the periods was the use duration of one electrode. This method of relating nitrate-nitrogen concentration using the specific ion electrode and standard procedures for analysis was shown to be valid by Shuval and Gruener[8]. In their investigations in Israel they found the linear relationship of 0.99 times phenol disulfonic acid method nitrate-nitrogen plus 0.96 equal to the electrode value. The linear relationship they described had a correlation coefficient (r) of 0.98. The relationships found during this investigation are as follows:

- from project initiation through November 14, 1977 - Electrode NO_3-N = 0.302 + 1.071 x auto analyzer NO_3-N, r = 0.997;
- for the period from November 15 through December 6, 1977 - Electrode NO_3-N = 0.397 + 1.325 x auto analyzer NO_3-N, r = 0.983; and
- for the period December 12, 1977 through the end of the project - Electrode NO_3-N = 0.033 + 1.044 x auto analyzer NO_3-N, r = .971.

The linear relationship between field electrode NO_3-N concentrations and those found using the auto analyzer indicated that the electrode measurements during this program had a higher degree of accuracy than those experienced by Shuval and Gruener. The correlation coefficient for the three periods, which coincided with periods of separate electrode usage during the field measurement equalled or exceeded the correlation found by Shuval and Gruener in all cases. There was no significant change in the coefficients during the period of continuous useage of any of the three electrodes, only differences between them.

The '208' electrode NO_3-N readings obtained during this study were corrected according to the above linear equations prior to averaging the data for Table 1. It can be seen in Table 1 that the average values correspond very closely between the corrected '208' electrode readings and those obtained from WSU auto analyzer and those obtained from the Geological Survey for like sampling points.

From Table 1 it can also be seen that the results of other field analytical work performed by the '208' correlated very closely to that performed by the other laboratories. The chloride analyses performed by the Idaho Health and Welfare laboratories for a three to four month period at the start of the project were done using a strength of titrant more applicable to chloride concentrations above 10 milligrams per liter, and therefore the concentrations found in the aquifer water were unsuitable for this technique. Thus, the averages found using the Idaho Health and Welfare data are not as accurate as the '208' or USGS results. The results during that period of testing were consistently too high. Following discovery of this error in application, the procedure was changed and from that time forward Idaho Health and Welfare Laboratory chloride results correlated very closely with those performed by the '208' staff. The overall average chloride from the '208' analytical work are more representative of actual aquifer chloride content and should be used as the most accurate concentrations found during this study. Chloride run by the USGS correspond very closely with the '208' chloride analytical results.

Conductivity results were run on duplicate samples by the '208' and the Idaho Health and Welfare Laboratory. The ratio of the conductivity by the Health and Welfare lab to those experienced by the '208' staff was approximately 0.98 on an overall average basis with a standard deviation of 0.10.

Conductivity, or specific conductance, is a measure of the total concentration of ions in the water. For a specific water with a particular ratio of the various ionic species, the conductivity is indicative of the total dissolved solids concentration (or total salts in solution). Total dissolved solids tests were performed on numerous samples by the Idaho Health and Welfare Laboratory. The ratio of conductivity to total dissolved solids (TDS) for 242 samples averaged 1.67 with a standard deviation of 0.20. To estimate the concentration of total dissolved solids in aquifer water samples, the conductivity should be divided by 1.67 (or multiplied by 0.60).

The other comparative tests performed by the field procedure and the Idaho Health and Welfare Laboratory was hardness, or the combined equivalent concentration of calcium and magnesium expressed as calcium carbonate ($CaCO_3$). Comparative values on duplicate samples correlated very closely between the '208' and Idaho Health and Welfare tests. The procedures were comparable except for the Normality (strength) of the titrant used in the test procedure.

WATER QUALITY VARIATIONS BY AQUIFER CROSS SECTION

Water in the Spokane-Rathdrum Aquifer flows from the Idaho-Washington State Line westward underneath the Spokane Valley, the City of Spokane, and emerges as springs along the Spokane and Little Spokane Rivers[9,10]. The aquifer flows through glacial outwash deposited alluvium from its source in North Idaho to its outlet in the Spokane vicinity (a thorough discussion on Geology is contained in the '208' final report).

During planning of the water quality monitoring program, sampling wells constructed by the '208' program for depth selective sampling were located in "cross sections" of the aquifer so the water quality in the aquifer could be tested as the water progressed downstream from the Idaho State Line to the outlet springs along the Spokane and Little Spokane Rivers and input of constituents from the ground surface over and tributary to the aquifer could be determined. Cross sections, as indicated on Plate 1, were located at the State Line, at Greenacres, at Dishman, at Parkwater (East Spokane city limits), at the North Spokane City Limits and at the outlet springs along the Little Spokane River.

State Line Cross Section

Three wells were located at the State Line cross section, as shown on Plate 1, along Idaho Road from Trent Road (SR 290) south to the Consolidated

Irrigation District property north of Wellesley Avenue. The mean level of conductivity, hardness and sulfate (SO_4) in these wells is plotted on Figure 1. Mean values for nitrate-nitrogen, chloride and sodium are plotted on Figure 2. USGS data from a well near the State Highway Department entry station south of the Spokane River, is also plotted on Figures 1 and 2. The USGS monitored only for conductivity, chloride and nitrate-nitrogen during this '208' program. In addition, the chloride, hardness, nitrate-nitrogen and conductivity found in the Spokane River during this monitoring program are included and plotted at the geographic location relative to the aquifer cross section. Figure 1 shows a possible influence of the river on aquifer conductivity at this cross section. The river discharges into the aquifer through a partially sealed bed in the stretch from Lake Coeur d'Alene downstream where the river elevation is above the aquifer surface elevation[9]. Figure 2 shows that the chloride and nitrate-nitrogen are lower south of the river than at the '208' Idaho CID well to the north. The river course from Lake Coeur d'Alene to this cross section follows near the south boundary of the aquifer. The Idaho Panhandle Health District in a '208' related water quality study of the Spokane-Rathdrum Aquifer in Idaho concluded that the Coeur d'Alene and Post Falls urban/suburban area was having an affect on the water quality through the Post Falls region[11]. This affect could be the cause for higher levels of constituents in the '208' CID well.

Greenacres Cross Section

Figures 3 and 4 show the average water quality concentrations at the Greenacres cross section. The '208' drilled depth selective wells sampled were the Campbell-Mission, Campbell-Euclid, and Gunderson (modified) wells. The CID (Consolidated Irrigation District) 3 and Holiday Hills wells are purveyor owned wells located near the south aquifer boundary. The Holiday Hills well is located immediately downstream from the Liberty Lake arm, or recharge area, of the aquifer. The river at this point has moved toward the center of the aquifer. Water quality at this cross section shows higher conductivity, nitrate-nitrogen, and chloride at the Holiday Hills well than at the wells farther into the aquifer main stem (center of the valley). In the south portion of the aquifer the influence of the river has resulted in lower concentrations of conductivity and other constituents. Along the far north portion of the aquifer slightly lower conductivity, hardness and sulfate may be the result of inflowing water from the Newman Lake and Hauser Lake drainage basins.

The elevated concentrations in the Holiday Hills well is notable at this point as it is the first instance of peripheral aquifer sampling points exhibiting higher readings than main stream aquifer locations. The slower moving and probably shallower aquifer water at the periphery apparently accumulates constituents to higher concentrations due to its longer residence time and lower dilution capability. The constituents apparently result from adjacent hillside slope runoff and water percolating from the ground surface.

The Liberty Lake arm or recharge area currently has a population of over 3,000 utilizing ground disposal of wastewater, most of which is discharged from a small treatment plant to a ditch leading towards the Holiday Hills well along the south aquifer periphery. The predominant use of land between the State Line cross section and the Greenacres cross section is agricultural with about 13,000 acres in this land use class, but the population is increasing with more and more suburban type residential development occurring. The current population between the State Line and Greenacres cross sections is about 7,000 persons. About 900 acres are occupied by residential land use while commercial and industrial uses occupy about 1,700 acres.

Dishman Cross Section

The Dishman cross section includes the Balfour Park, Valley Mission Park, and Irvin depth selective sampling wells. Figures 5 and 6 show the water quality average from these wells as well as from purveyor wells owned by the Dishman Water District, Pasadena Park Irrigation District and the Pleasant Prairie Water District. Data for the Pasadena Park #2 well is from the U.S. Geological Survey monitoring data. At this cross section wells along the aquifer periphery show striking increases in salt content, as reflected by conductivity and the tracer constituents, nitrate-nitrogen, chloride and sodium. At this point the river is near the north side of the aquifer and its diluting effect is not as apparent, compared to the Greenacres cross section.

A principal land use activity between the Greenacres and Dishman cross sections is housing at urban and suburban residential densities. The population of this area is about 32,000. About 4,000 acres is used as residential, while agriculture occupies about 8,600 acres. There are also substantial industrial activities at the Spokane Industrial Park and the Kaiser-Trentwood facilities to the north and a rapidly developing residential and commercial area over the southern portion of the aquifer in the Opportunity and Dishman vicinities. Existing industrial and commercial uses occupy about 4,200 acres.

Water quality in a number of purveyor wells near the Dishman cross section are shown on Figure 7. Conductivity, chloride and nitrate-nitrogen are shown for these sampling points. Ten were sampled by the '208' field crew, while data for other wells is from the U.S. Geological Survey monitoring results. The plotting of data from these wells confirms the distribution of water quality found in the '208' cross section wells and along the aquifer north and south boundaries in this vicinity.

Parkwater Cross Section

Figures 8 and 9 show the water quality results at sampling points for the Parkwater cross section. The '208' depth selective cross section wells are the Milwaukee, CPM (Central Pre-Mix), SCC (Spokane Community College), and WWP Substation. These figures show the high concentration of salts along the south aquifer periphery and the increase in salts toward the north edge of the aquifer at the SCC well. However, the WWP Substation well and the USGS monitored well called "Old Dairy" well, located approximately one half mile further north and at the north edge of the aquifer, indicate that there has been substantial dilution of the aquifer with river water immediately upstream at this point. The Upriver Dam impounds the river and raises the water surface elevation for approximately two miles in a stretch where it flows along the north edge of the aquifer east (upstream) of this cross section. The water quality along the north edge of the aquifer reflects that there is substantial river water entering the aquifer in this reach.

The existing land uses between the Dishman and Parkwater cross sections are about 2700 acres devoted to residential, 4300 acres of commercial and industrial, and 2500 acres of agricultural. The population in the area is about 35,000.

North Spokane Cross Section

The sampling points forming the North Spokane cross section consist primarily of purveyor and private wells, although the Arlington well is a '208' depth selective sampling point. The Ray/Bennett well is a combination of the water quality from two proximate privately owned wells. Figures 10 and 11 show the average water quality for wells at this cross section. Salts concentration at the west edge of the aquifer is higher than farther east. The aquifer between the Parkwater cross section and this cross section, according to Geological Survey publications[4], flows westerly and discharges to the Spokane River as well as flowing northerly through the Hillyard Trough. A substantial portion of the aquifer has been lost to the Spokane River before flowing northerly or westerly.

Due to the aquifer turning northerly under the City the aquifer water from along the south periphery at the Parkwater cross section would flow in a westerly direction to be discharged into the Spokane River. The aquifer water from along the northerly periphery at Parkwater would flow northward along the east side of the aquifer to the North Spokane cross section. The concentrations of constituents shown on Figures 10 and 11 when compared to Figures 8 and 9 seem to confirm this separation of the water diverted northerly from Parkwater.

The higher chloride shown for the North Spokane Water District on Figure 11 may be related to aluminum recovery tailings placed in an abandoned gravel pit one and a half to two miles south of this location in the 1950's. This will be discussed later in this report. Only one analysis for sulfate was performed on each of the WWP 3-1 and Spokane Central wells so little reliance can be placed on the sulfate concentration profile at this cross section.

Existing land use between the Parkwater and North Spokane cross sections is about 2500 acres urban residential and 3000 acres commercial north of a line from about Sprague and Havana to Shadle Park.

Outlet Cross Section

Water quality at two cross sections within the outlet area of the aquifer near the Little Spokane River are plotted on Figures 12 through 15. Figure 12 and 13 show the water quality in purveyor wells near the outlet springs. These figures show higher salt concentrations along the west aquifer boundary adjacent to the Five Mile Prairie at this cross section, and also show substantially higher salt content toward the easterly portion of the aquifer. Water quality variations in the Mead area are sufficiently drastic to indicate that water is flowing in from the Peone Prairie area east of Mead with much higher salt concentrations than the main portion of the aquifer. The water quality plotted on Figures 14 and 15 indicates, however, that the majority of the aquifer water in the Griffith Springs, Waikiki Springs, and Wandermere Springs reflect the quality of the Spokane Aquifer more closely than the quality of samples taken in the Mead area. The quantity of flow from the Peone Prairie area into the aquifer at this point is apparently relatively small. The water quality in the WWP 3-4 well appears to be representative of the quality of water entering the aquifer from the east. Constituent buildup under the suburban, industrial and commercial development in the Mead area may contribute to the high readings obtained although the aquifer water entering from the Peone Prairie is undoubtedly higher in salts than the main aquifer.

Figure 16 shows the water quality in four wells in the Mead area: WWP 3-4, WWP 3-6, WWP 3-5 and Whitworth 2A. The Whitworth 2A well is in the center of the aquifer and shows very consistent water quality. WWP 3-4 is a low yield well (400 gpm or less running against system head) and reflects the quality of water entering the aquifer from groundwaters in the Mead area. WWP-3-6, although it lies nearly straight north of WWP 3-4 shows a fluctuating water quality. During the summer months of 1977 when the well, which has a considerably higher pumping rate than WWP 3-4 (1000 to 1200 gpm), was operating it apparently drew central aquifer water into the area. Its discharge water quality was similar to that found in the central portion of the aquifer. However, upon shutdown of WWP 3-6 at the end of the heavy use season of 1977 the water quality in the well became very nearly that found in WWP 3-4 indicating displacement of the central aquifer water by water of a quality more indigenous to the area.

The water quality in WWP 3-5, also plotted on Figure 16, shows the same relationship between pumping and water quality as WWP 3-6. However, the normal water quality appears to be a mixture of the two aquifer waters and the quality was somewhere between that of the central aquifer illustrated by Whitworth 2A and the Mead area, illustrated by WWP 3-4, even when the well was pumping regularly.

Overall Aquifer Quality Changes Downstream from the State Line

The concentration of the three principal constituents used as tracers of land surface activities, conductivity, nitrate-nitrogen and chloride, increased in the aquifer from the State Line to the Outlet Springs. Table 2 shows a calculated average concentration of these constituents and a total dissolved solids concentration calculated from the conductivity for each of the cross sections. The averages were obtained using the proportions of the various sampling point average concentrations indicated in the footnotes to Table 2. The proportions were derived by estimating the percentage of the aquifer reflected by the particular sampling point and weighted by the knowledge that flow in the aquifer is much less along the aquifer periphery than in the center of the aquifer. Reduced flow in peripheral areas is due to decreased depth, or saturated thickness, and due to the finer materials which were undoubtedly deposited towards the edge of the aquifer during accumulation of the alluvial deposits. The aquifer depth was sounded at two locations in Seismic Surveys by the U.S. Geological Survey, near the State Line and in the Hillyard Trough. These investigations gave an indication of the saturated thickness of the coarse alluvium lying above the lower clay or volcanic ash stratas. Virtually all of the water flowing in the aquifer travels through the coarse alluvium [12]. The U.S. Geological Survey flow model currently under development indicates that the flow near the edge of the aquifer would be much lower than in the center under the same hydraulic gradient but was not available to assist in the calculations described above.

Table 2 shows an increase in total dissolved solids, nitrate-nitrogen and chloride from the State Line to the Parkwater cross section. A separate calculation of average water quality is for the portion of the water at the Parkwater cross section, which appears to flow northward underneath the City of Spokane to the North Spokane cross section. Samples from the southern periphery of the aquifer are eliminated from this estimate and northerly samples are weighted more heavily in order to exclude the influence of the south periphery higher concentration water which is assumed to exit westerly underneath the City of Spokane into the Spokane River. Using this estimate and concentrations from the North Spokane cross section and Outlet Springs it is possible to estimate the constituent concentration increases under the City and through the North Spokane area. The flow model may have provided assistance in obtaining a more accurate estimate if it were available.

For comparison and to assure that the Table 2 values were not unduly skewed by peripheral sampling point concentrations at the Spokane Valley cross sections average values for the center area of the aquifer were calculated. At the Idaho State Line cross section samples from the three '208' wells (Idaho Trent, Idaho Beck and Idaho CID) averaged as follows: conductivity = 276 micro mho/cm; nitrate-nitrogen = 0.92 milligrams per liter; chloride = 0.80 milligrams per liter. Dishman purveyor wells (Modern 6, Orchard 1, Orchard 2, WWP 1-3, WWP 1-4) water quality averages were as follows: conductivity = 286; nitrate-nitrogen = 1.37; chloride = 1.82.

WATER QUALITY VARIATIONS WITH DEPTH

Water quality was monitored by depth below the aquifer surface at 20 sampling points during this study program. There were three depth selective sampling wells at the State Line cross section, three at the Greenacres cross section, three at the Dishman cross section, four at the Parkwater cross section, one at the North Spokane cross section, and one at the outlet springs. A sampling point in the Nine Mile area and one near the City of Spokane northwest landfill west of Five Mile Prairie were also monitored throughout the year. Two depth selective sampling wells were drilled by the State Highway Department about one quarter of a mile apart adjacent to Highway 395 in the outlet section very late in the year, and were sampled twice. A depth selective sampling well was drilled at the Central Pre-Mix Sullivan Road pit site which was monitored for about half of the year.

Figures 17, 18 and 19 show the depth below the water surface of selected concentration levels according to time over the sampling period in the Balfour Park well, the '208' Arlington well and the Whitworth test well.

Table 3 contains an analysis of concentration variations in the depth selective sampling wells by presenting the mean and standard deviation of the aquifer surface concentration of conductivity, chloride and nitrate-nitrogen ratio to the concentration at the lowest sampling depth or to 50 feet below the water surface. The number of comparative samples and the level of significance at which the mean ratio is greater than 1.0 (Student's t test) is also shown. This statistical test gives the level of confidence that the ratio would not be obtained by chance from waters which are actually of the same quality. A high level of confidence of the ratio being greater than 1.0 leads to a conclusion that concentrations near the aquifer water surface were significantly (ie. statistically significant) higher than the concentration deeper into the groundwater.

State Line Cross Section

At the State Line cross section all three of the depth selective wells showed aquifer surface concentrations to be greater than at depth at a high level of significance except for chlorides at the Idaho-Trent well. The 64% significance level recorded for the chlorides ratio greater than 1.0 at this well is probably adequate to conclude that the chloride concentration was higher near the aquifer surface when considered with the high level of significance for greater conductivity and nitrates. At the Idaho CID well there appeared to be an increase in the ratio of the surface concentration to the concentration at the -50 foot level from approximately March, 1978 through the termination of the sampling program as shown on Figure 20. Concentration increase at that time would be about three to four months following the initiation of the heavier precipitation in November following the long dry period. This delay could be interpreted as: 1) time required for the precipitation to reach the soil moisture capacity before the excess water began moving down to the aquifer, carrying salts with it to the aquifer surface; 2) the travel time for the water from the Post Falls suburban area to this sampling point since the initiation of the heavier precipitation carrying salts down to the aquifer; or 3) a combination of the two. Since there was a higher concentration of these constituents at the aquifer surface than at depth even before November and that approximately 11 inches of precipitation occurred between November 1977 and March 1978, it seems unlikely that the entire delay was due to the build-up of soil moisture to its' capacity. This sampling point is approximately four miles downstream of the nearest urbanized part of the Post Falls area and a travel time of approximately four months would result in approximately 180 feet of travel per day for the aquifer water. This is greater than the approximately 60-70 feet per day estimated for this area by the U.S. Geological Survey[9].

Greenacres Cross Section

The three depth selective sampling wells in the Greenacres cross section: Campbell-Euclid, Campbell-Mission and Gunderson all showed consistently greater conductivity levels at the surface than at the depth reference point which was significant at the 85% level of confidence or greater. The Campbell-Euclid and Campbell-Mission wells also showed nitrate-nitrogen to be significantly greater at the 90% level or higher. The Gunderson well showed nitrate-nitrogen differences at the 71% level of significance although the deepest point of sampling in this well was only 12 feet below the aquifer surface. The chloride surface to depth concentration ratio in the Campbell-Euclid and Gunderson wells was greater than 1.0 at the 80% level of significance but the Campbell-Mission well did not show a significant chloride difference, possibly because of the low-chloride river water influencing the aquifer at this location.

The well drilled by Central Pre-Mix west of the new Sullivan Road gravel pit showed significantly greater conductivity at the surface than at -50 feet. Chlorides were at significantly higher concentrations at the surface than at -12 feet but the concentration at about -40 feet was higher than at -12 feet or at the surface from the end of November 1977, when sampling began at this point, through the end of the sampling program. The storage of salted sand at the County gravel pit about 1 mile east of the CPM pit or CMP pit activities may have influenced this result.

Dishman Cross Section

The Balfour Park well conductivity, chloride and nitrate-nitrogen concentration variations with depth are shown on Figure 17. The ratios of aquifer surface to -50 feet concentrations are confirmed to be statistically significantly greater than 1.1 on Table 3. The Valley Mission Park well and the '208' Irvin Water District well ratios for the nitrate-nitrogen and chloride concentration ratios between the surface and the -50 feet level were significantly greater than 1.0 at a high level of significance. The conductivity ratios were greater than 1.0 but at lower levels of significance.

Parkwater Cross Section

There are four depth selective sampled wells in the Parkwater cross section. The '208' WWP Substation well concentration ratios between the surface and any depth were not significantly different than could have occurred from random sampling and analytical variations. Total concentration levels of constituents in this well indicate river water input to the aquifer immediately upstream (Upriver Dam area). The Spokane Community College (SCC) well conductivity, chloride and nitrate-nitrogen ratios were significantly greater than 1.0 between the surface and 50 feet below the aquifer surface.

The '208' Central Pre-Mix well did not consistently show surface to depth concentration ratios to be greater than 1.0 as measured by conductivity, chlorides or nitrate-nitrogen. This sampling point is immediately downstream of a rather deep gravel extraction penetration into the aquifer which, because of wind action and other mixing phenomena including extraction of the gravel itself, could have disturbed any concentration variations with depth present at this location.

The '208' Milwaukee well located in this cross section was not perforated completely to the surface of the aquifer when it was constructed and it was impossible to draw samples closer than about 12 feet from the aquifer surface until February 1978. The ratios on Table 3 covering the last five sampling periods from February through June, 1978 are significantly greater than 1.0

North Spokane Cross Section

There was only one well for depth selective sampling at the North Spokane cross section. The Arlington '208' well depth of a constant concentration value with time was shown on Figure 18. Table 3 confirms that the ratio of surface to depth concentration for conductivity, chloride and nitrate-nitrogen was greater than 1.0 at a high level of significance.

Outlet Cross Section

At the Outlet cross section the Whitworth Test well was converted for depth selective sampling. Its concentration change with depth is shown on Figure 19. Table 3 shows that the Whitworth Test well and the data from the Highway Department wells (combined) had surface to depth constituent ratios significantly greater than 1.0 at a high level of confidence. The Whitworth Test well showed lower concentrations near the surface following the beginning of heavier precipitation in the late fall. The ratio of surface to depth concentration didn't change, however, indicating the change was due to dilution of the entire water column. This indicates that precipitation rapidly diluted the constituents and that moisture travel time from the ground surface to the aquifer surface was relatively short (ie. days or weeks).

The '208' landfill well was sampled throughout the monitoring period. The ratio of conductivity, chloride and nitrate-nitrogen concentration at the aquifer surface and at -40 to -50 feet was greater than 1.0 at a high level of significance. Inspection of the data revealed that the concentrations were nearly constant from the surface down through -22 feet indicating that aquifer water flow throuth this area is very low.

Depth selective sampling at the Nine Mile '208' well showed variations in concentration with depth. Apparent stagnation of the water in this location (odors) and lack of consistency of the water quality variations were sufficient to conclude that aquifer water flow through the area is low to nonexistent.

Discussion of Depth Selective Sampling Results

Dr. Todd, in conjunction with the Spokane Metropolitan Water Resources Study[4] hypothesized that "stratification" of the aquifer should occur if there is recharge from the ground surface to the aquifer by moisture which transports with it salts and contaminants resulting from overlying land use activities. Stratification can be defined as consistent variation in salt concentration from the surface downward (i.e. different concentrations occur at different elevation levels or 'strata'). Only two sampling sites did not show significant stratification by this definition and each was undoubtedly influenced by activities immediately upstream. This data shows that constituents occurring at the ground surface over the aquifer or on adjacent side slopes have been carried to the aquifer by "recharging" surface moisture.

SEASONAL VARIATIONS IN WATER QUALITY

Seasonal variations in water quality at a portion of the sampling sites are shown on Figures 16 through 20 and were briefly discussed earlier. Variations in water quality of samples from the Mead area indicated the separate nature of groundwater quality between the main aquifer stem and that entering from the east (Peone Prairie). Seasonal quality variations were also noted at several of the depth selective sampling wells, including the Whitworth Test well in the Outlet cross section, the Arlington '208' well in the North Spokane cross section, the Idaho CID '208' well at the State Line cross section and the Balfour Park '208' well in the Dishman cross section (see Figures 17, 18, 19 and 20).

It was indicated in the earlier discussion that the seasonal variations in water quality variations with depth at the Balfour Park well may have been attributed to a phenomenon beyond the relationship between precipitation and recharge. Figures 21, 22, 23 and 24 show the conductivity concentration zones in the area south of Opportunity in May 1977, October 1977, May 1978 and again in August 1978. The data used to develop these plots was from sampling conducted by the U.S. Geological Survey at numerous sampling points in the area, from '208' sampling at some locations and from a special study conducted by the '208' staff in August of 1978. The sampling points are shown on the figures. The water quality information collected by the U.S. Geological Survey correlated with information collected by the '208' staff at coinciding sampling sites. The iso-concentration lines on these figures provide positive indications that water quality varies considerably over the area shown.

Figure 21 shows that a zone of high total solids lay under the southern portion of the Opportunity urbanized area in May, 1977. It also shows the intrusion of lower concentration water from the main portion of the aquifer from the northeast and apparent existence of higher concentration water to the west along the southern aquifer boundary (near Dishman).

Figure 22 shows the water quality in October 1977 to be somewhat different with the higher concentration area of total salts located farther north. Water with a lower salt concentration then occupied the southerly portion of the region where the high salt concentration was during the May sampling period. Water surface elevation contours indicate that there was not a great deal of elevation change in the aquifer between the two sampling times. The elevation contours indicate a southward gradient in the area which indicates that flow through this area of the aquifer was not great at the time.

Figure 23 shows the concentration zones in May, 1978. Between the October 1977 and May 1978 sampling periods, the high concentration region shifted southward to approximately the location it occupied in May, 1977. The water quality and the aquifer water levels shown on Figure 23 indicates a strong central aquifer influence and intrusion down into the Opportunity area. This is evidenced by lower concentration aquifer water forcing its way from the central portion of the aquifer to cause concentration changes in the northern portion of the areas shown.

Figure 24 shows a similar pattern to that shown on Figure 23 for water quality in the area, although the higher salt concentration water does not extend as far eastward.

The data shown on Figures 21 through 24 indicate that salts reach higher concentrations in slowly displaced water in the aquifer under the urbanized area. The zone of higher concentration water has shifted over the year of monitoring, first northerly then southerly again apparently as the central aquifer influence changed. This could partially explain the variation in concentration variations with depth at the Balfour Park well. The water quality in the Edgecliff and Dishman wells, and other wells west of this area and near the south aquifer periphery (E. Spokane, WWP 1-5, Spokane-Ray) stayed relatively constant through the year of sampling). Apparently water flow through this area of higher constituent accumulation, south of Opportunity and near the south periphery west of Dishman, did not vary a great deal during the year of sampling. Waters which accumulated higher salt concentrations beneath the urbanizing area was discharged along the southern aquifer periphery in a relatively narrow strip, which influenced water quality in the southerly wells shown on the cross sections in Figures 6, 7, 8 and 9. In addition, more salts accumulated from the South Opportunity area to the more westerly wells.

In the south Opportunity area the aquifer extends far enough from the main aquifer flow zone to allow observation of the variations in water quality both spacially and on a seasonal basis. Apparently, the water flow rate through this entire area is relatively low, similar to a much narrower band along the remainder of the aquifer periphery. The low flow, slow movement and less dilution allow a build-up of salts. Urbanization was likely a major contributing factor at all locations.

Seasonal variation in water quality also occurred in the Kaiser-Eastgate well. Figures 25 and 26 show the water quality with time in the Industrial Park 3 and 4 wells and in the Kaiser-Eastgate well, located west of the Industrial Park, for 1977-78. [The water quality in the Industrial Park 2 well (not available for sampling during the '208' program) and the Kaiser-Eastgate well in 1973-74 as well as 1977-78 is also shown on Figures 25 and 26. During each of the years precipitation was very low from June through approximately November, with increasing precipitation in December and a fairly wet following winter.] Conductivity and chloride increased strikingly, with more modest increases in hardness and nitrate-nitrogen following the onset of high precipitation. A specific cause is attributable to this increase in concentration in the Kaiser-Eastgate well as compared with that in the Industrial Park wells in the same vicinity. In the early 1960's an aluminum recovery operation dumped aluminum tailing wastes into a former gravel pit directly east of the Kaiser-Eastgate well and west of the Industrial Park wells. Wash water disposal from an adjacent gravel pit into the abandoned pit allegedly caused chloride contamination of the Kaiser-Eastgate well in the 1960's so the practice was discontinued[14]. However, Figures 25 and 26 show that the wastes continue to be leached some 15 years later by precipitation moisture. The figures also show the immediacy of pollutant transport following the start of heavy natural precipitation on the overlying aquifer surface.

WATER QUALITY IN THE VICINITY OF WASTE DISPOSAL SITES

As shown above, the aluminum recovery waste disposal site east of the Kaiser-Eastgate well has resulted in and currently results in migration of pollutants to the aquifer during periods when moisture for recharge from the ground surface to the groundwater is available in the form of precipitation (see Figures 25 and 26). Aluminum recovery waste disposal practices apparently also resulted in pollutants migrating to the aquifer at a site in Hillyard which still influences the chloride concentration in the North Spokane W.D. well, over 20 years later (Figure 11). Waste disposal over the aquifer influences water quality and provides a store of materials that will be leached to the aquifer for many years following their placement.

The Jeffers well sampling point (see Plate 1) is in close proximity to an abandoned solid waste disposal site, west of Liberty Lake. The water quality in this well is considerably different from wells in the main part of the aquifer. There are no discernable seasonal fluctuations in the water quality in the Jeffers well, but the higher concentration of total salts and other constituents indicates a possible influence of the abandoned solid waste site (see Table 1).

In addition to the '208' sampling well, located north of Francis Avenue on the Nine Mile Road and near the Spokane City Landfill, there were several sampling points monitored by the U.S. Geological Survey in northwest Spokane and in close proximity to the Spokane River. Conductivity, chloride and nitrate concentrations decrease with distance both northwest and southeast from the landfill, as shown on Figures 27 and 28. Water quality in the wells shown on the Figures is plotted by equal concentration lines which are arbitrarily connected west and east of the line of wells. Three waste disposal sites are in the area: (1) the City of Spokane landfill; (2) an abandoned wastewater lagoon; and (3) a currently used wastewater lagoon. From Figures 27 and 28 it appears that waste disposal practices in this area are causing degredation of the groundwater quality. *

It was recently disclosed by Kaiser[15] that they have detected cyanide and fluoride residuals in aquifer waters northwest of their Mead plant site. They were apparently leached from a sludge lagoon by precipitation and/or discharge of treated domestic sewage plant effluent. This incident confirms observations made from the '208' monitoring results that the soils are extremely permeable and that wastes applied over the aquifer will be leached to the aquifer by surface applied moisture, including precipitation. The fact that the cyanide levels have, in some of the sampling points, been higher than those recommended for potable water supplies[5] emphasizes that special attention needs to be given to control of waste disposal practices.

BACTERIOLOGICAL WATER QUALITY

Samples from 44 water supply wells were collected over the period of study for bacteriological analyses. Total coliform analyses were run by the membrane filter method. Samples (100 milliliters) were filtered through an extremely fine filter media with pore openings small enough (0.45 micrometers) to retain bacteria. After filtration the membranes were incubated in a special growth medium to detect coliform bacteria growth. All positive results were confirmed to be coliform by standard procedures. Results from the Edgecliff well were negative for coliform in July, 1977 and February, 1978 but positive in 6 tests from April 17 through May, 1978. The Health District was notified and the well was removed from service.

There were 10 positive coliform results out of 117 samples from all sites except the Edgecliff well. There was no apparent correlation of positive results by geographical location or time and no sample point had more than one positive result. Wells which showed positive coliform readings were the Jeffers well (one positive out of four samples); the Dishman well (one of two); the Modern 9 well (one of five); Modern 6 well (one of four); the Modern 1 well (one of five); the WWP 2-4 well (one of four); the WWP 1-4 well (one of two); the WWP 1-5 well (one of three); the WWP 3-5 well (one of two); and the Spokane Baxter well (one of three). No positive results were found at: Industrial Park 3; Industrial Park 4; Vera 4; Vera 2; Moab Water District; East Spokane; Whitworth 1; Whitworth 2A; Whitworth 3A; Whitworth 4; Spokane Ray; Spokane Nevada; Spokane Central; Kaiser Mead; Pleasant Prairie; North Spokane; Ice House; Orchard 1; Orchard 2; CID 2; CID 3, CID 8, CID 10; CID 11, Trentwood; Hollywood Hills; WWP 3-2; WWP 3-1, WWP 3-4, WWP 3-6, WWP 3-7, WWP 1-3; and Hutton Settlement.

The positive coliform tests were wide spread over the aquifer. It can be assumed that all samples were taken from a single supply (the aquifer). Positive samples would then be obtained according to a probability distribution and the probability would be related to the actual density of organisms in the supply. With standard statistical procedures a probability of achieving a particular number of positive responses out of a given number of tests can be calculated for a range of organism densities and plotted. Figure 29 shows the probability of getting 10 positives in 117 samples of 100 ml ('208' results) versus numbers of organisms in each 100 ml (the density of organisms) of sample source. Also on Figure 29 are plots of the data collected by the Panhandle Health District (PHD) during their '208' studies in Idaho[11] and results of samples obtained from wells by the Spokane County Health District (SCHD) during the period from May 1977 to June 1978. The most probable number (MPN) of organisms in the sample source is the density where the maximum probability of achieving the particular results is obtained. Figure 29 shows no significant difference between the most probable density of coliform organisms from the 3 data sources.

The drinking water regulations[6] call for the coliform density by MPN to be 1/100 ml or less. The MPN of aquifer water based on the incidence of positive coliform results found during this and comparable studies (PHD, SCHD) is about one-tenth of the maximum drinking water contaminant level (MCL).

It has been reported that positive coliform results can be masked by high counts of total aerobic organisms in the samples[16]. Total plate count analyses were run on some 26 well samples. Seventy-four percent of the samples (54 samples in all) had total plate count values of 300 or more per one hundred milliliters and 57% had concentrations of 500 or more per one hundred milliliters. Eighty-one percent of the total plate count analyses were at 1000 per 100 ml or less, and 89% were 1500 per 100 ml or less. The log mean of total plate count results in 626 per 100 ml.

Extremely high plate counts were seen at Holiday Hills where counts of 7400 and 8700 were registered, but no positive coliform results were obtained during the two sampling periods. Ground disposal of treated wastewater and septic tank effluents is utilized by a population of 2000 in the Liberty Lake area.

At the Jeffers well, total plate counts from 27,000 to 65,000 organisms per one hundred milliliters were registered, and one postitive coliform count from four samples was obtained. A most probable number of multiple tube fermentation test for coliform was performed on the Jeffers well and was indicated to be less than three per one hundred ml at the time that the sample indicating 65,00 total plate count was obtained. Coliform development can be inhibited in fermentation tubes by high total plate counts as well as on membrane filters[16].

There was a positively established concentration of total aerobic organisms (total plate count) at all aquifer sampling points analyzed for total plate count. Aquifer dissolved oxygen is adequate for their survival at about 8 milligrams per liter. The only known source of these organisms is from the ground surface which confirms the aquifer vulnerability to contamination as shown above based on chemical data. It also implies rather rapid transport of water from the ground surface to the aquifer (for organisms to survive), in the range of weeks. The studies by Crosby et. al.[3] showed coliform penetration to 26 feet or more and these study results confirm the validity of their results.

A health hazard could exist due to increasing human population and wastewater disposal activities on the ground surface over and directly tributary to the aquifer. The risk occurs over the entire aquifer and doesn't appear ot be higher in any particular area.

HEAVY METALS

Analyses were performed for arsenic, barium cadmium, chromium, copper, lead, manganese, selenium, silver, zinc and mercury by the Idaho Health and Welfare laboratories. All of these heavy metals except copper, manganese and zinc have maximum concentration limitations in the 'Primary Interim Drinking Water Regulations'[6]. One hundred and sixty-five samples were analyzed for heavy metals. Samples were collected from 38 sampling points over the aquifer.

There were 24 total samples that exceeded the detectable limit for cadmium. One of those samples was indicated to be only 1 microgram per liter, well below the drinking water standard. There were 11 samples collected in the period from March 21 to March 30, 1978 from 11 separate locations that showed cadmium readings from 5 to 7 micrograms per liter. There were 12 samples from 12 separate locations collected during the period from May 1 through May 15 which ranged from 9 to 14 micrograms per liter of cadmium. The March and the May sample concentrations were within very close ranges and each set were probably analyzed at the same time indicating analytical procedures probably produced the positive results. Based on these results it cannot be concluded that there is widespread cadmium contamination of the aquifer.

The chromium MCL was exceeded in one sample and other samples above detectable limits occurred in the central Spokane Valley area. This indicates that chromium monitoring should be included in any ongoing monitoring program. The analytical results for mercury exceeded the detectable limits a total of 21 times out of the 165 samples that were analyzed. The drinking water regulations limitation of 2 micrograms per liter was exceeded five times with no particular time correlation evident. The mercury results above the detectable limits were widespread but more likely to occur in the western Valley area (Dishman to Parkwater) than elsewhere. This indicates that the type of development in the Valley (unsewered residential, commercial, industrial) may be conducive to mercury emission to the aquifer.

From the '208' analytical results only cadmium and mercury appear to be a potential water quality problem of the heavy metals with drinking water limits. The U.S. Geological Survey studied several wells in the Spokane area and analyzed for mercury and cadmium during 1977-1978 year. The maximum quantity for mercury found in their survey was 0.6 micrograms per liter at an Industrial Park well. Detectable amounts (0.1 microgram per liter) were noted at Wandermere Springs, the Livengood well, Ice House well, a well at Acme Concrete, and the Jeffers well, while .2 micrograms per liter was noted at the Kaiser-Eastgate well. Mercury may be of concern in the aquifer and continued monitoring should include this constituent. Only one sample, from Wandermere Springs, showed any detectable cadmium (2 micrograms per liter). This apparently confirms that the cadmium results of the '208' were not indicative of actual aquifer water quality. The fifteen sampling points sampled by the Geological Survey included Griffith Springs, a spring near the Spokane Country Club, Waikiki Springs, Wandermere Springs, the Livengood well, the Ice House well, the well at Acme Concrete, WWP 1-3, WWP 1-4, Edgecliff, Kaiser-Eastgate, Industrial Park 4, Jeffers, Holiday Hills, and CID 10.

There is no federal drinking water limit for copper, manganese, iron or zinc. Manganese is of concern because of its potential for causing taste and odor and for discoloring fixtures when it is present in domestic water supplies. The recommended limit for manganese in municipal water supplies is 50 micrograms per liter[5]. Thirty-four of the one hundred sixty-five samples taken exceeded the detectable limit for manganese. Five samples equalled or exceeded the recommended limit. Two of the samples were at Riverside Park where sampling crews had noted odor and color characteristics of the samples. The remaining positive samples were widespread and not time consistent. Iron was analyzed in several samples but extremely erratic results led to the conclusion it was resulting from well casing corrosion, especially in the depth selective sampling wells.

Zinc is an indigenous constituent in waters in the Spokane area due to its occurrence in geological formations in the area, especially in Idaho where zinc mining and refining takes place. A sample of the Spokane River collected during this program indicated approximately 200 micrograms per liter to be present. One hundred fifteen of the one hundred and sixty-five samples collected during this program contained zinc levels at or above the detectable limit of 1 microgram per liter. The mean zinc concentrations are included in Table 1 for those sampling points analyzed. The concentrations of zinc found during this program might lead to some observations regarding the influence of the Spokane River on aquifer water quality. At the State Line cross section the well closest to the river shows the highest zinc concentration. At the Greenacres cross section the zinc concentration in the Campbell-Mission well is substantially higher than that recorded for the Campbell-Euclid or Gunderson wells indicating a greater amount of river influence at the Campbell-Mission sampling point. At the Dishman cross section the '208' Irvin well also has a higher zinc concentration than the other two cross section wells, indicating more river influence and also indicating that there is river influence in the northern portion of the aquifer upstream of the Upriver Dam impoundment area. The river influence is most strikingly seen at the Parkwater cross section where the zinc concentration in the Washington Water Power substation well is substantially higher than in the other three wells in this cross section. River influence was shown by other chemical tests at this location also.

ORGANICS

The Idaho Health and Welfare Laboratory performed analyses for all organo-chlorine pesticides for which drinking water regulations have been promulgated[6] as well as poly chlorinated biphenyls (PCB's) and other organo-chlorine pesticides[1]. Detectable levels for the pesticides was 10 micrograms per liter and for the PCB's 100 micrograms per liter. None of these constituents were found at the detectable levels in the approximately 80 samples taken from the aquifer at 40 locations.

The Environmental Protection Agency has conducted a monitoring program for specific organic contaminants[18]. They disclosed the existence of low level contamination by 1, 1, 1 Trichloroethane and Tetrachloroethylene. The EPA has advised water purveyors that the levels found do not represent a health hazard. Maximum levels found were 16 and 8 micrograms per liter for the two constituents respectively. The majority of measurements were less than one microgram per liter. EPA estimates that the low levels found could result from very small spills occurring during industrial usage of these compounds. Alternately the use of some liquid drain cleaners in household amounts (a few pints a day) could contribute enough to reach the concentrations found. Although the levels of the organic contaminants found doesn't apparently present an imminent health hazard, EPA believes that action to control the storage, handling and disposal of such hazardous substances which may contaminate the aquifer, are appropriate.

HISTORICAL AQUIFER WATER QUALITY DATA

A summary of historical data on water quality in the Spokane-Rathdrum Aquifer from several sources is contained in Table 5. The data summaries contained in Table 5 are for selected locations in the aquifer where it appeared that the longest record of information was available. It must be remembered in reviewing this historical data, that standard testing procedures have changed for some of the constituents. Among the analyses least likely to be comparable over the period of time are nitrates. Sodium analysis methods have changed from flame ionization spectroscopy to atomic absorption spectroscopy, although the accuracy of the two methods should be comparable. Conductivity and hardness results should be comparable over the period of record as analytical procedures and equipment have not changed. Low level chloride analytical results can have considerable variation between technicians and individual laboratory procedures.

Historical data from the State Line and Greenacres vicinity appear to have increased slightly in conductivity and may have increased in nitrates over the period of record. This may confirm the findings of the Panhandle Health District that urbanization in the Coeur d'Alene-Post Falls corridor is altering aquifer water quality[11].

In the aquifer peripheral area south of Opportunity the Vera 4 well has a relatively long period of record. It would appear from the conductivity that there has been a substantial increase in salt contribution to the aquifer in this area over the period of record. The conductivity and hardness are plotted on Figure 30. In the Dishman and Parkwater south peripheral areas the aquifer historical quality is reflected by the Edgecliff, Dishman and Spokane-Ray wells, also shown on Figure 30. There appears to be a significant increase in dissolved salts (conductivity) in the Dishman and Edgecliff wells during the period of record. This correlates with the increase found in the Vera 4 well which would impact the south aquifer periphery areas downstream through the Edgecliff, Dishman, and even to the Spokane-Ray vicinity. The Spokane-Ray wells shows the same increase in salt content over the historical period of record. Population growth in the area south of Opportunity which apparently contributes to the water quality along the south aquifer periphery (see Seasonal Variations in Water Quality, above) has been from about 10,000 persons in 1960 to 20,000 in 1976. This growth rate closely corresponds with the rate of increase in conductivity over the same time period. This historical data confirms the effect of urbanization on aquifer water quality discussed earlier.

The Industrial Park vicinity wells appear to have increased slightly in salts as shown by the conductivity and the hardness since the earliest record in 1951. The Kaiser-Eastgate well just west of the Industrial Park has not increased in salinity since about 1971. However, the conductivity in the Kaiser-Eastgate well is substantially higher than is found in any of the Industrial Park wells which are located within a mile to the east. This shows the result of past waste disposal practices at the site east of the Kaiser-Eastgate well as was discussed earlier and where seasonal fluctuations were observed. Another incident is on record in this area where phenol contamination caused shutdown of an Industrial Park well in the mid 1970's. The source was minor spillage at a facility on the Industrial Park which illustrates the extreme hazard to the water supply from any use of hazardous substances on the overlying ground surface.

Water quality in the vicinity of the Spokane City Parkwater wells, the Orchard Prairie wells and adjacent areas also shows a long term increase in salt content as shown on Figure 31. There is a salts increase from the earliest data up through the present that appears to be consistent among all of the wells, as reflected by conductivity.

Areas north of the Spokane River also have relatively long periods of record, but do not have as much data in some cases. The Inland Empire Ice Company well seems to have increased in salt content including chlorides since the 1942 data were collected. The Spokane-Hoffman well seems to have also increased slightly in total salts.

The North Spokane Water District historical water quality indicates that there may be a slight increase in salt content although the increase was relatively modest. Variations in chloride content indicated in the data shows the probable affects of leaching of chloride from aluminum recovery tailings which were disposed of, in the 1950's, in an excavation in the Hillyard area. These tailings created a water quality problem in a well about a mile south of the North Spokane Water District well for a short period, at that time, until the operation was discontinued.

To summarize the information available from the historical water quality data, there are significant increases in salt content in the south peripheral area of the aquifer. Historically peripheral areas were apparently more comparable in quality to the central portion of the aquifer or aquifer main stem. Concentration increases were notable along the south edge of the aquifer and coincided with population growth in the area over and adjacent to the aquifer. Long term data also indicates salt concentrations increased in the central aquifer area, although to a lesser degree due to greater dilution. These increases also correspond in time with population growth and substantiate the affect of urban development on aquifer water quality.

AQUIFER FLOW

The Geological Survey has been developing an aquifer flow model which is nearing completion and should be ready for use in the near future. The aquifer flow model has been developed using estimates of recharge and discharge flow from the aquifer. The only published information available is contained in the "Sole Source" report[9]. That report indicates that groundwater flow at the State Line averages about 970 cubic feet per second (cfs). The estimated net flow inflow and outflow of the aquifer is as shown on Figure 32. Outflow from the aquifer occurs via springs along the Spokane and Little Spokane Rivers and pumping from wells. The aquifer gains water from the river, from side hill tributary area runoff (surface and subsurface), and water applied to the ground over the aquifer. Progress on the flow model since publication of the "Sole Source" report has continued and the flows may be lower than earlier anticipated[13].

Water level contours from data observed during 1977 and 1978 by the USGS are shown on Plate 2. The water surface elevation and its fluctuations observed in the '208' depth selective sampling wells is shown on Figure 33. River water entering the aquifer altered the aquifer water quality, especially from the State Line downstream to Greenacres, at Parkwater downstream of the Upriver Dam, and also along other river reaches where the net average annual water flow is from the aquifer to the river. The U.S.G.S. flow balance shown on Figure 32 doesn't show small scale "interchange" between river and aquifer in reaches where net flow is from the river to the aquifer.

Figure 32 shows overall withdrawals of water from the aquifer as estimated by the U.S.G.S.[9]. The Corps of Engineers[19] estimated withdrawals from the Spokane-Rathdrum Aquifer in Washington in 1976 at about 20 percent (180 cfs) of the aquifer flow. They estimated that the withdrawal rate during the summer irrigation season was nearly 40 percent. Projections to 2020 were made for nearly a 50 percent increase in average demand. Future withdrawals from the aquifer appear to be well within its overall capability for supply. However, the need for a flow predictive tool, such as the flow model being developed by the United States Geological Survey, for quality management, can be readily seen, since changes in withdrawals rate and withdrawal patterns may alter the aquifer-river water interchange and flow patterns in the aquifer. This could reduce the capability of the aquifer to maintain its water quality at current levels without improvements in management of potential pollutants. Recognition that aquifer flow relationships and withdrawal are important facets of water quality and that the aquifer is not limitless in quantity is essential for its protection as a useable and valuable resource for the Spokane metropolitan area.

The U.S.G.S. is developing transmissivity coefficients from their flow estimates and water surface elevation observations with the model. This may allow calculation of flow rate at any point in the aquifer and thus facilitate development of a materials balance for aquifer constituents, but to date the information is unrefined and a materials balance would be suspect.

Based on water quality observations during this study underground water flow from the Peone Prairie westerly into the aquifer does occur. The flow from this area has a higher salt content than Spokane-Rathdrum Aquifer water and contribute to increased salt concentrations in the aquifer outlet springs along the Little Spokane River.

The U.S.G.S. flow model assumes the aquifer to be continuous from the Spokane Valley east of Spokane through west Spokane and under the river valley northwesterly to Long Lake (Lake Spokane). It is assumed to extend through 2 gaps in the basalt between the Spokane River falls and Five Mile Prairie. A well drilled by the '208' program at Shadle Park (in the northerly gap) encountered rock before hitting groundwater, indicating little if any water flows westerly through that gap. Flow through the southerly gap apparently is the water source for the Downriver Springs sampled during this study (see Plate 1). They are above the river elevation. Thus, it would appear that the aquifer may not be continuous from east to west of the basalt rock ridge which runs from the Spokane River falls to Five Mile Prairie. Water quality data seems to indicate that the aquifer lying along the Spokane River west of this ridge may not be a portion of the Spokane-Rathdrum Aquifer. The aquifer water quality data from near the city landfill shows that the water in that area is moving very slowly, if at all, with dispersion in the "upstream" direction nearly equaling that "downstream". The water quality at the Nine Mile '208' well was odorous and stagnant, indicating little water movement in that area.

Figure 32 shows overall withdrawals of water from the aquifer as estimated by the USGS[9]. The Corps of Engineers[19] estimated withdrawals from the Spokane-Rathdrum Aquifer in Washington in 1976 at about 20 percent (180 cfs) of the aquifer flow. They estimated that the withdrawal rate during the summer irrigation season was nearly 40 percent. Projections to 2020 were made for nearly a 50 percent increase in average demand. Future withdrawals from the aquifer appear to be well within its overall capability for supply.

However, the need for a flow predictive tool, such as the flow model being developed by the USGS, for quality management, can be readily seen, since changes in withdrawals rate and withdrawal patterns may alter the aquifer-river water interchange and flow patterns in the aquifer. This could reduce the capability of the aquifer to maintain its water quality at current levels without improvements in management of potential pollutants. Recognition that aquifer flow relationships and withdrawals are important facets of water quality and that the aquifer is not limitless in quantity is essential for its protection as a useable and valuable resource for the Spokane Metropolitan Area.

REFERENCES

1. Spokane County Engineer's Office. Ground Disposal Workplan. No. 77-15. Washington State Department of Ecology. Spokane, Washington, October, 1976.

2. Spokane County '208' Study Staff. Progress Report on Water Quality Studies. Spokane, Washington, June 1977.

3. a. Crosby, J.W. 3d, et al., Migration of Pollutants in the Glacial Outwash Environment. Vol. 4, No. 5. Water Resources Research, 1968. pp. 1095-1114.

   b. Crosby, J.W. 3d, Johnstone, D.L., and Fenton, R.L. Migration of Pollutants in a Glacial Outwash Environment. Vol. 7, No 1. Water Reseources Research. 1971a. pp. 204-208.

   c. Crosby, J.W., 3d, Johnstone, D.L., and Fenton, R.L. Migration of Pollutants in a Glacial Outwash Environment. Vol. 7, No. 3. Water Resources Research. 1971b. pp. 713-720.

   d. Crosby, J.W., 3d, et al. Final Report, Investigations of Techniques to Provide Advance Warning of Groundwater Pollution Hazards with Special References to Aquifers in Glacial Outwash . OWWR Project No.: B-005-WASH. August, 1971.

4. Todd, D.K. The Effect of Applied Surface Waters on Ground Water Quality in the Spokane Valley. Prepared for Water Resources Study Metropolitan Spokane Region, Department of the Army, Corps of Engineers and Kennedy-Tudor Consulting Engineers. 1975.

5. Public Health Service. Drinking Water Standards, U.S. Department of Health, Education and Welfare. 1962.

6. U.S. Environmental Protection Agency. National Interim Primary Drinking Water Regulations. Federal Register, Vol. 40 No. 248, December 1975. Vol. 41 No. 133, July 6, 1976.

7. Quality Criteria for Water, EPA 440/9-76-023. U.S. Environmental Protection Agency. July 1976.

8. Shuval, H.I. & N. Gruener. Health Effects of Nitrates in Water. EPA 600/1-77-030. U.S. Environmental Protection Agency. June 1977.

9. Drost, B.W. and H.R. Seitz. Spokane Valley-Rathdrum Prairie Aquifer - Washington and Idaho. Open File Report 77-829. United States Geological Survey. 1978.

10. Department of the Army, Corps of Engineers and Kennedy-Tudor Consulting Engineers. Metropolitan Spokane Region Water Resources Study. Appendix B. January 1976.

11. Jones, E.O. and Lustig, K.W. GroundwaterQuality Monitoring Rathdrum Prairie Aquifer. Panhandle Health District No.1. March 30, 1977.

12. Newcomb, R.C., et al. Seismic Cross Sections across the Spokane Valley and the Hillyard Trough, Idaho and Washington. United States Geological Survey. 1953.

13. Bolke, Ed. PersonalCommunication (Flow Model). United States Geological Survey. 1978.

14. Public Health Relationship of the Minnehaha Sewer District and the Greater Spokane Community. Esvelt and Saxton Consulting Engineers. 1964.

15. News Release, Kaiser Aluminum and Chemical Corporation. August 30, 1978.

16. Goldreich, E.E., H.D. Nash, D.J. Reasoner, R.H. Taylor. The Necessity of Controlling Bacterial Population in Potable Waters: Community Water Supply. Journal AWWA.

17. Pickett, E.M. Memo, Spokane County Health District, October 26, 1978.

18. Burd, Robert S. Letter, Environmental ProtectionAgency, Region X, October 27, 1978.

19. Kennedy-Tudor Consulting Engineers. Technical Report, Metropolitan Spokane Region Water Resources Study. Department of the Army, Seattle District Corps of Engineers, January 1976.

FIGURES

Number

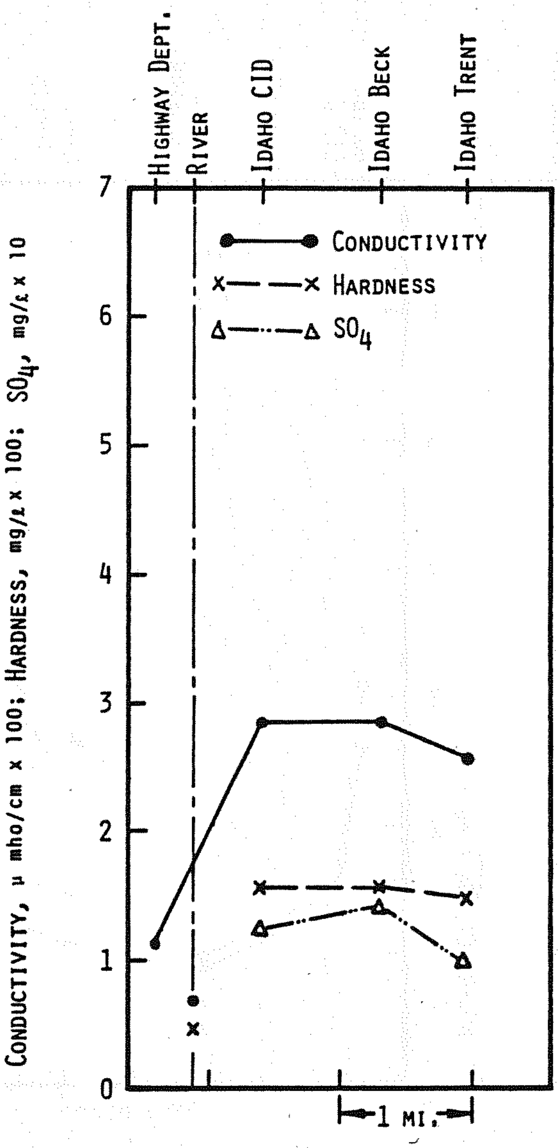


Figure 1. Conductivity, hardness and sulfate at the State Line Cross Section.

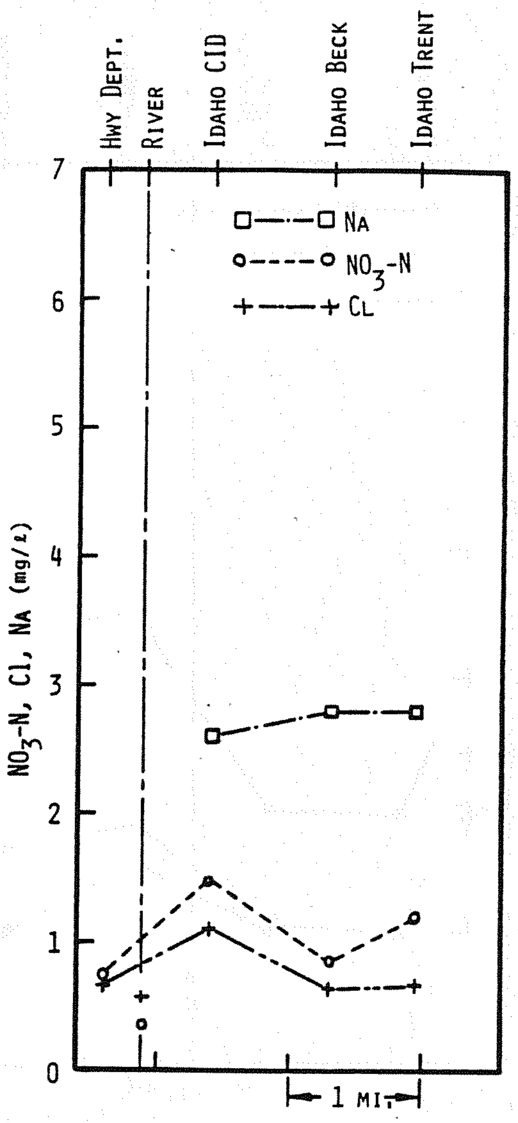


Figure 2. Nitrate-nitrogen, chloride and sodium at the State Line Cross Section.

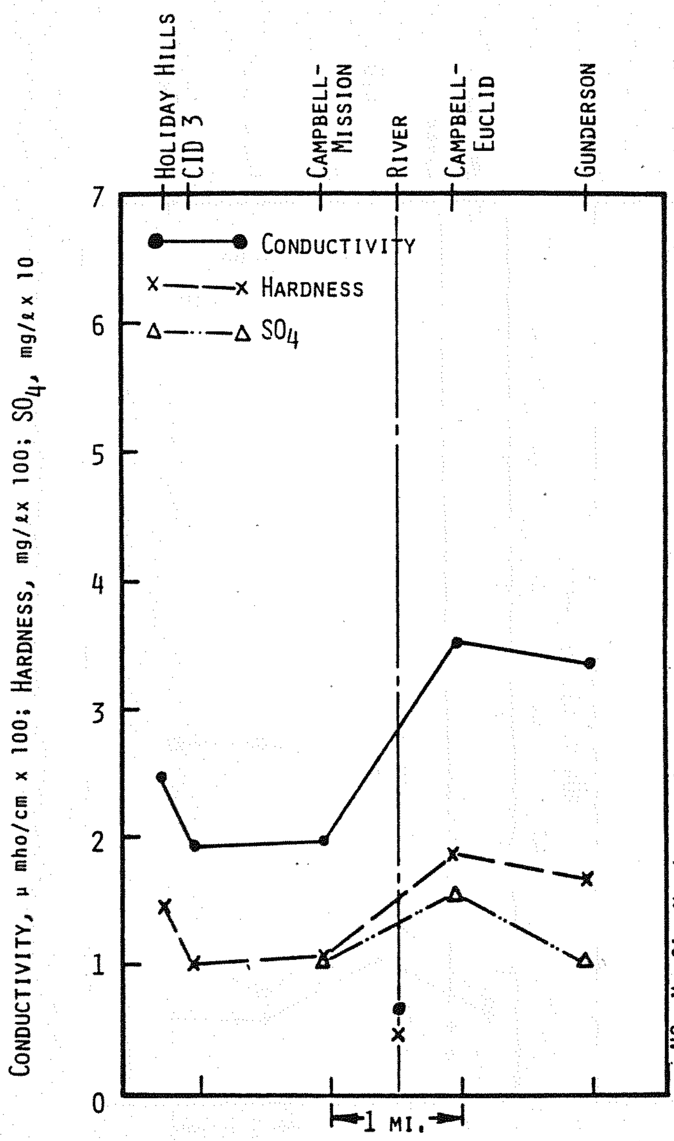


Figure 3. Conductivity, hardness and sulfate at the Greenacres Cross Section.

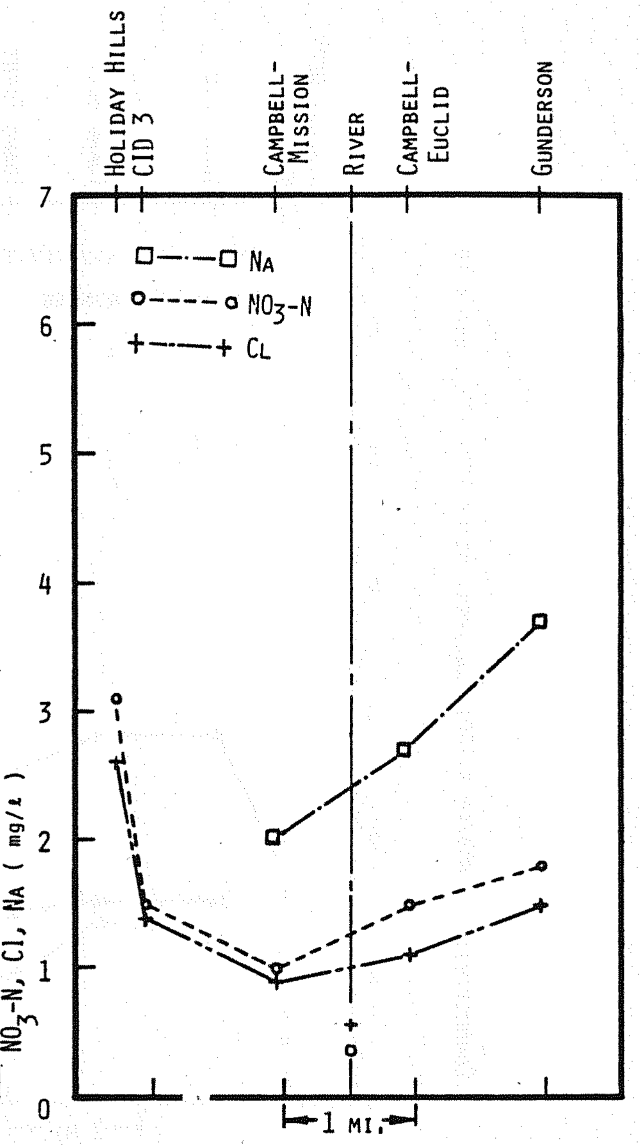


Figure 4. Nitrate-nitrogen, chloride and sodium at the Greenacres Cross Section.

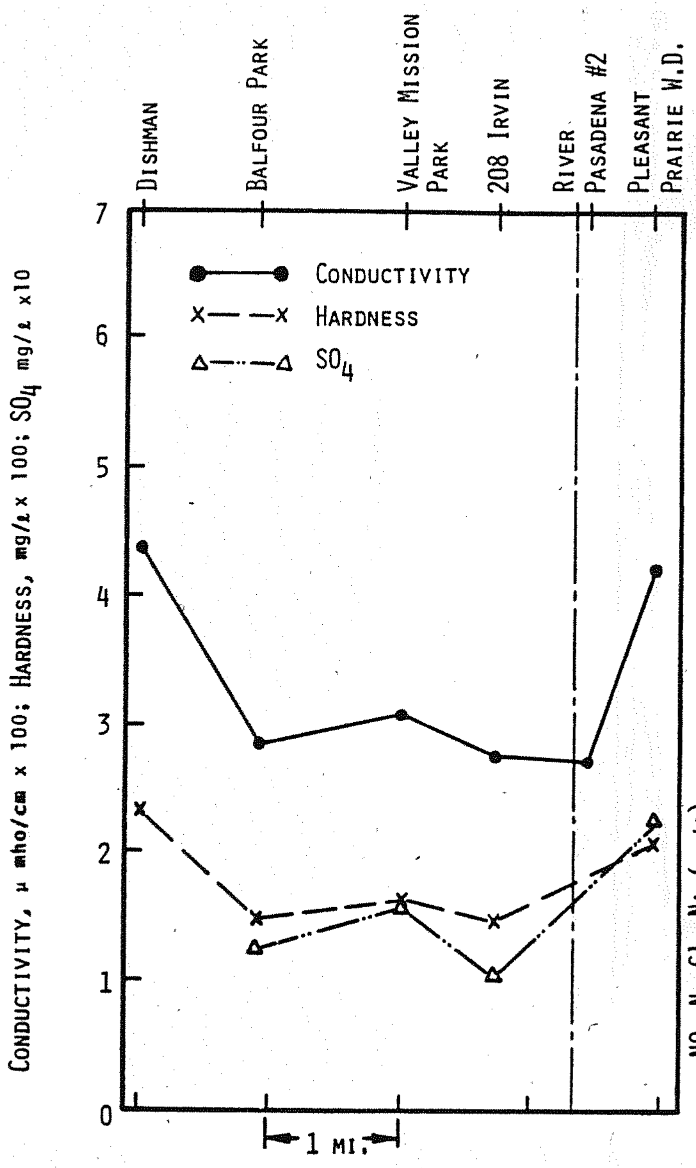


Figure 5. Conductivity, hardness and sulfate at the Dishman Cross Section.

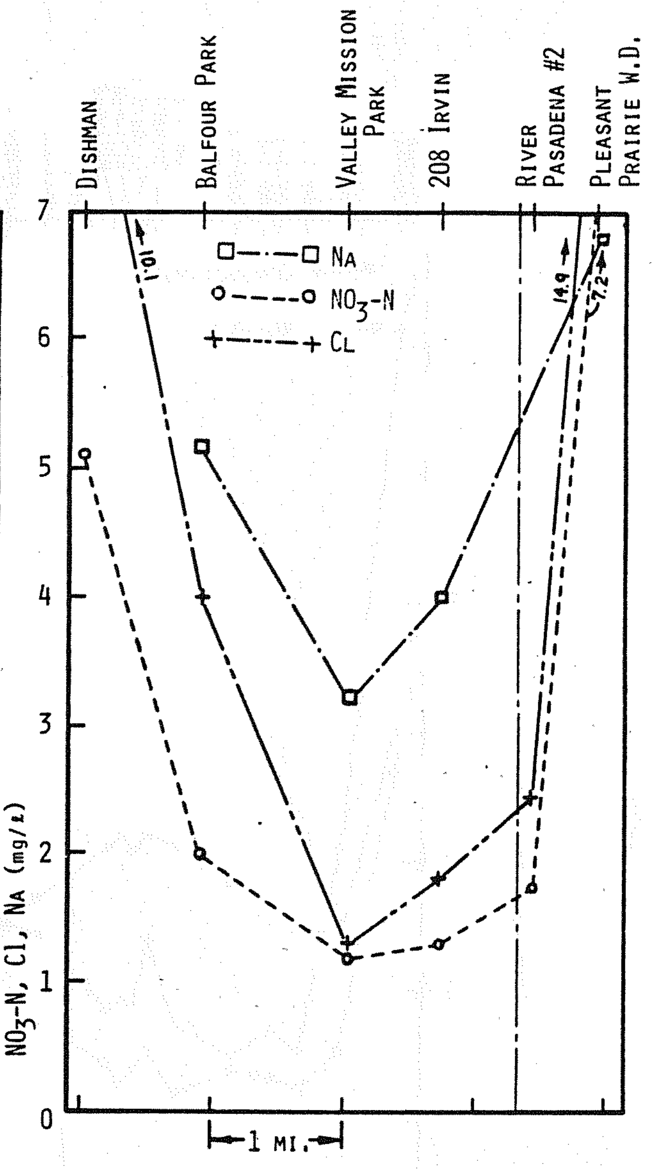


Figure 6. Nitrate-nitrogen, chloride and sodium at the Dishman Cross Section.

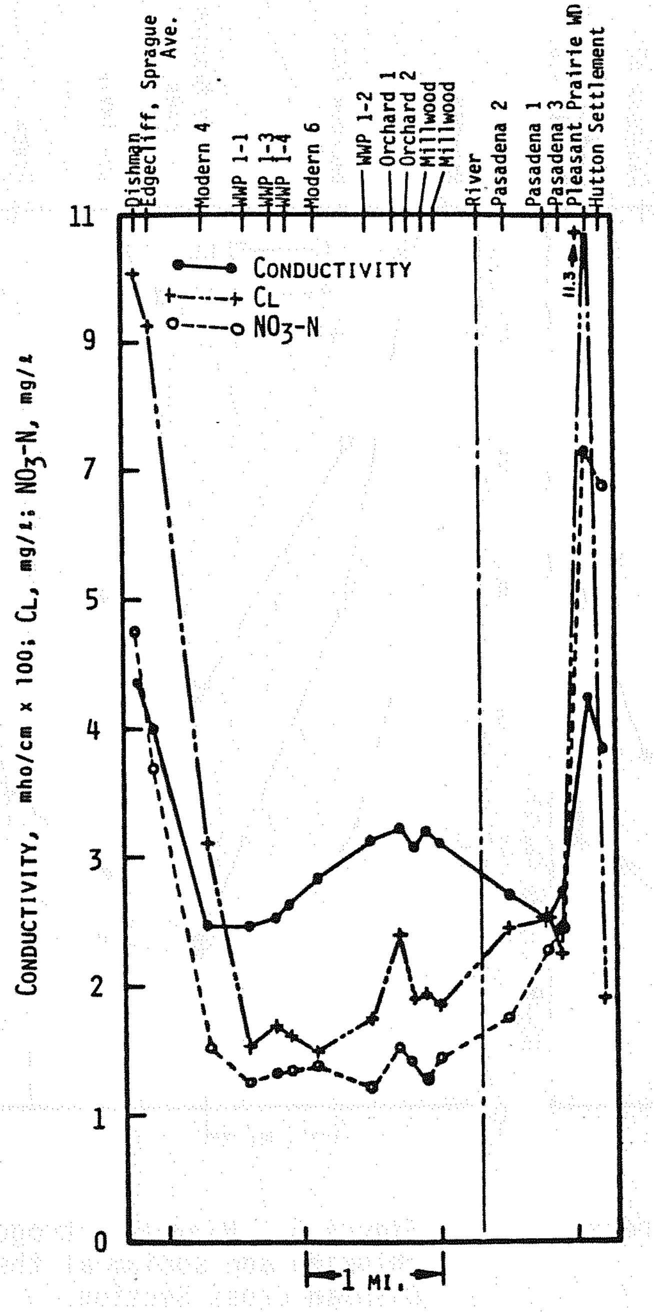


Figure 7. Conductivity, chloride and nitrate-nitrogen at purveyor wells in a Dishman Cross Section

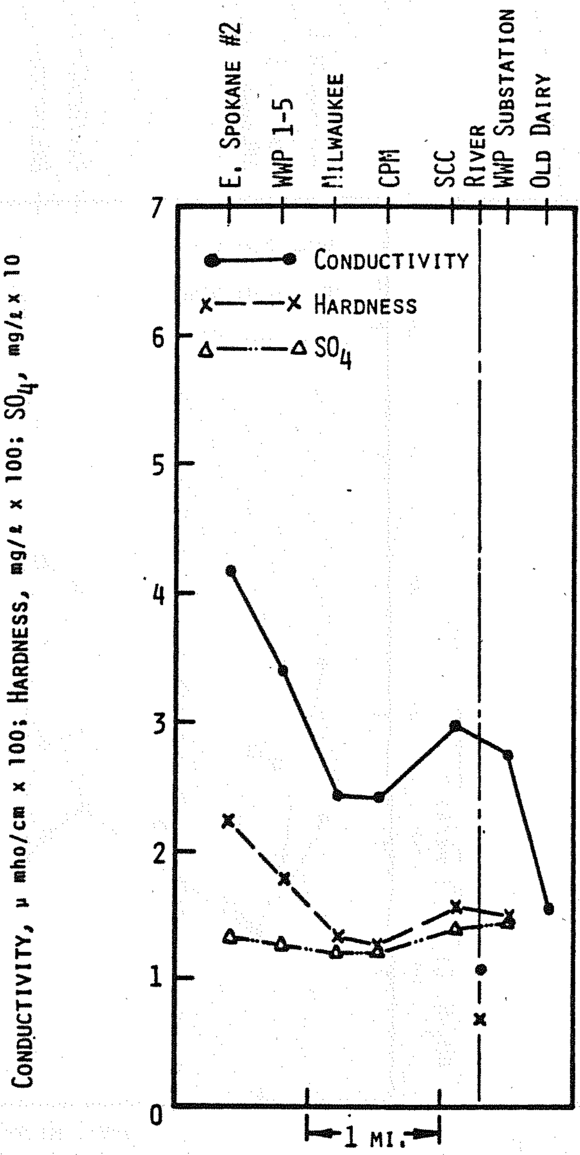


Figure 8. Conductivity, hardness and sulfate at the Parkwater Cross Section.

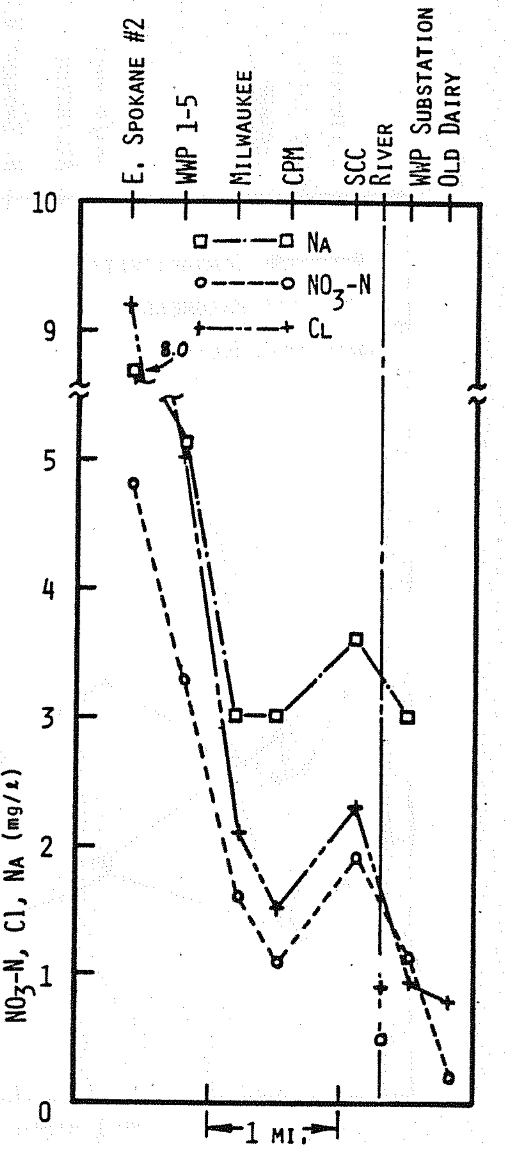


Figure 9. Nitrate-nitrogen, chloride and sodium at the Parkwater Cross Section.

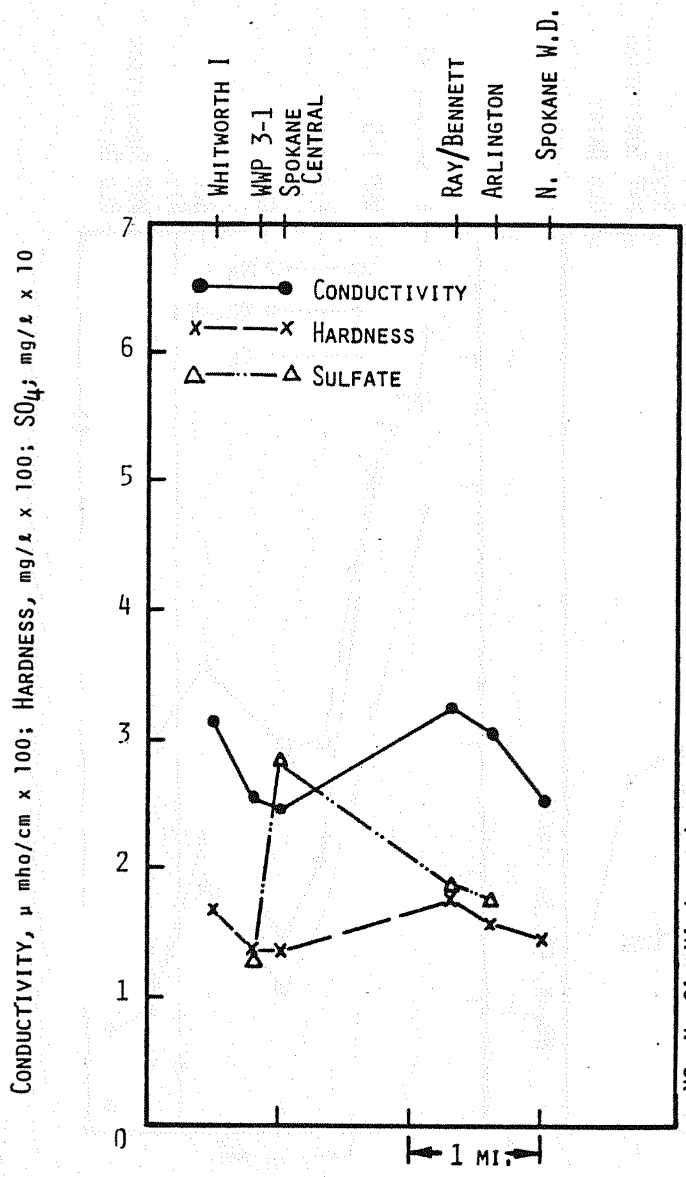


Figure 10. Conductivity, hardness and sulfate at the North Spokane Cross Section.

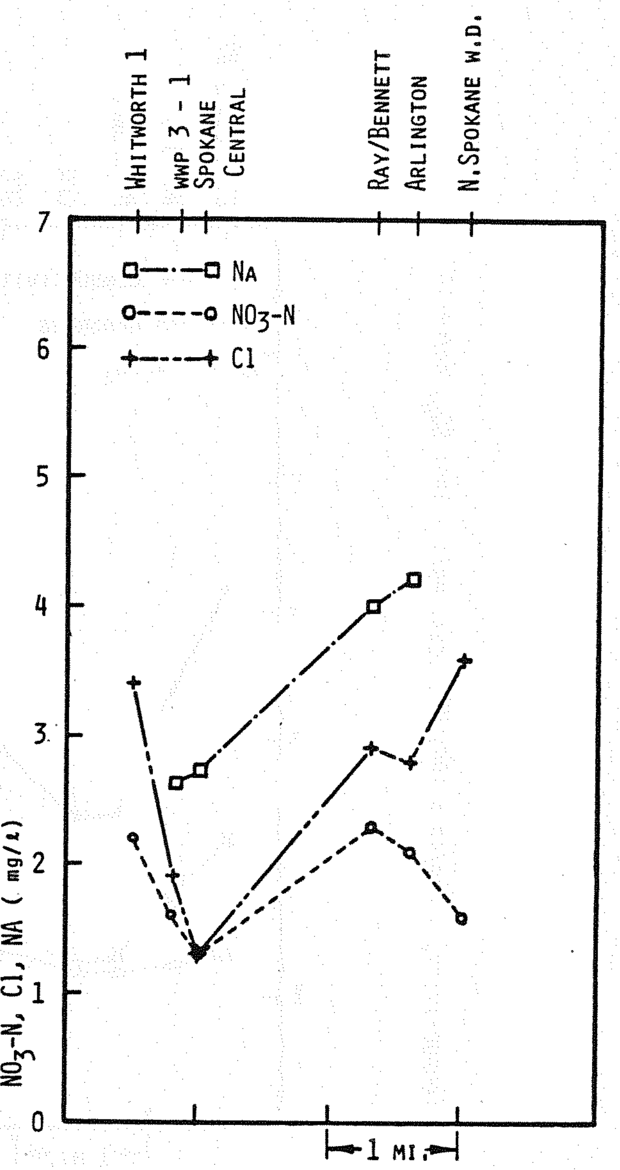


Figure 11. Nitrate-nitrogen, chloride and sodium at the North Spokane Cross Section.

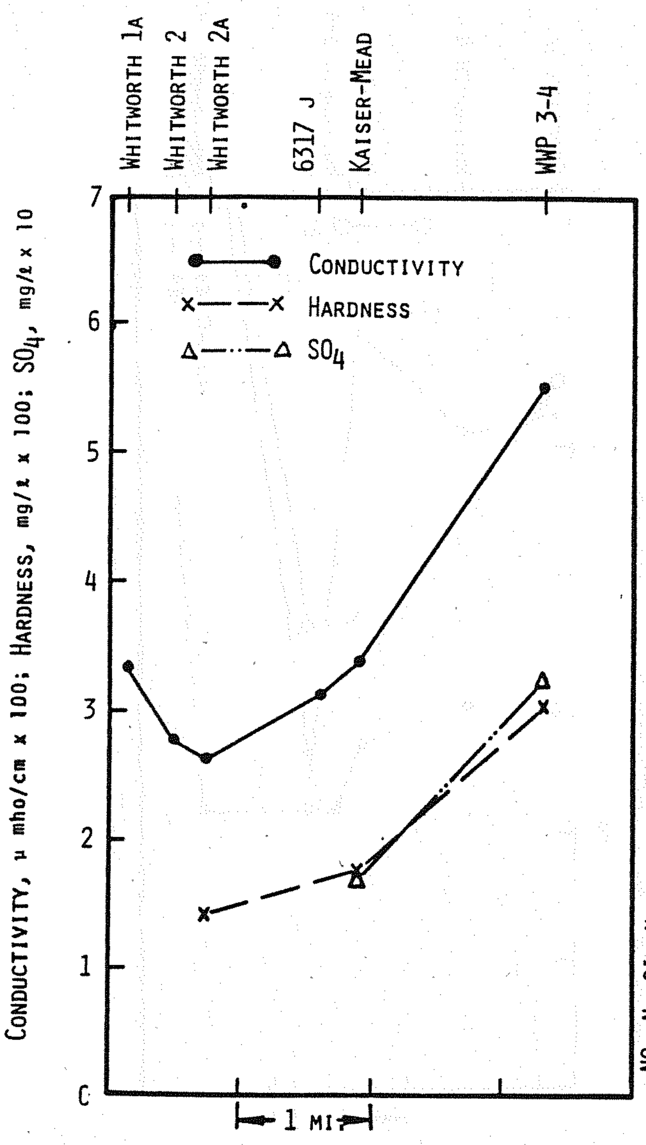


Figure 12. Conductivity, hardness and sulfate at the Whitworth-Mead Cross Section.

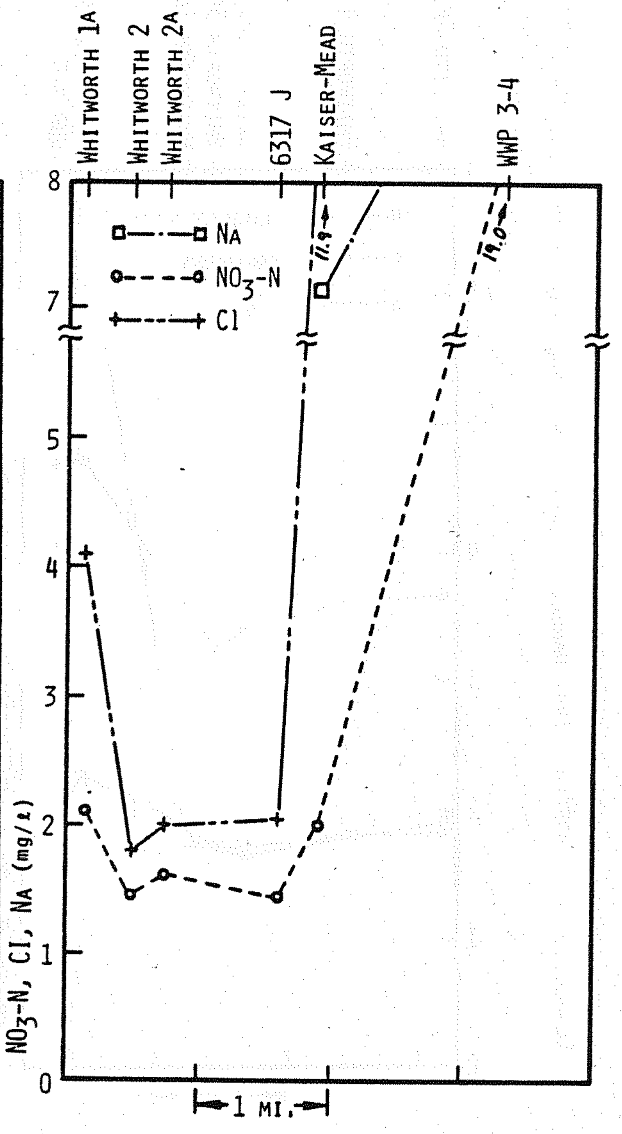


Figure 13. Nitrate-nitrogen, chloride and sodium at the Whitworth-Mead Cross Section.

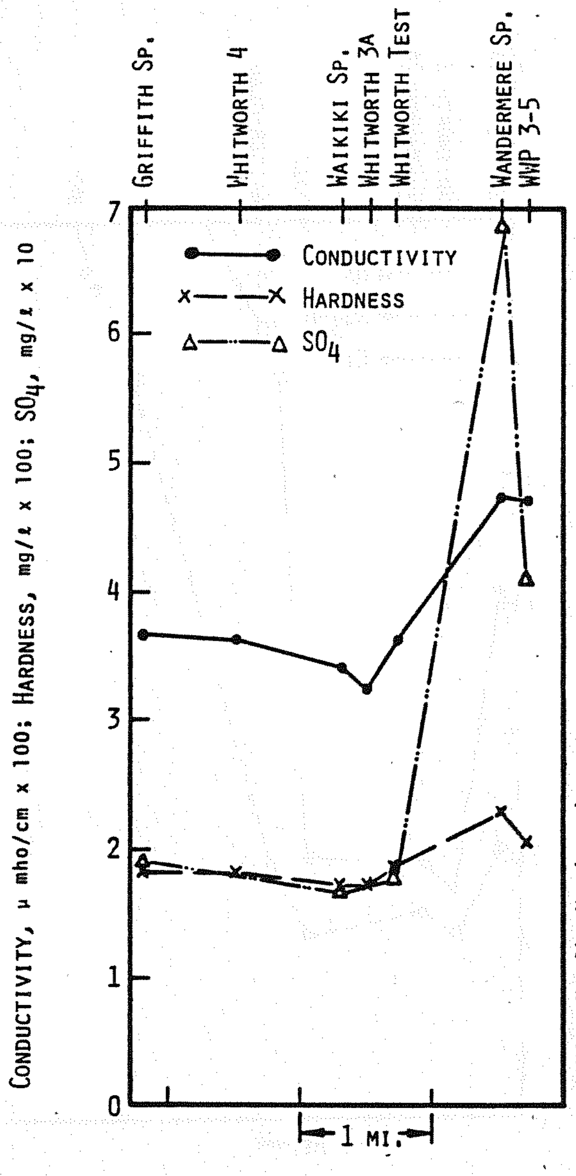


Figure 14. Conductivity, hardness and sulfate at the Outlet Cross Section.

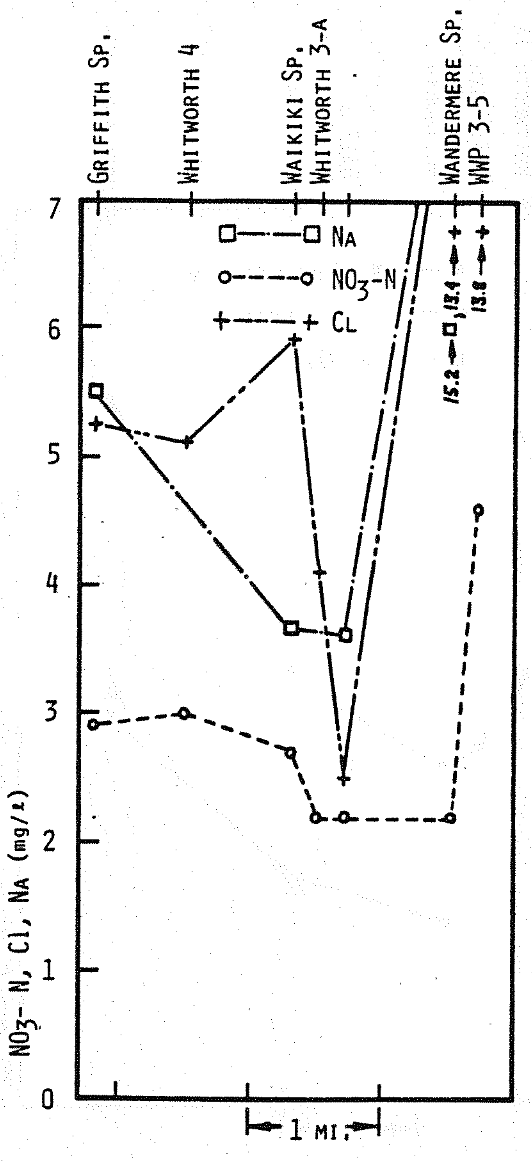


Figure 15. Nitrate-nitrogen, chloride and sodium at the Outlet Cross Section.

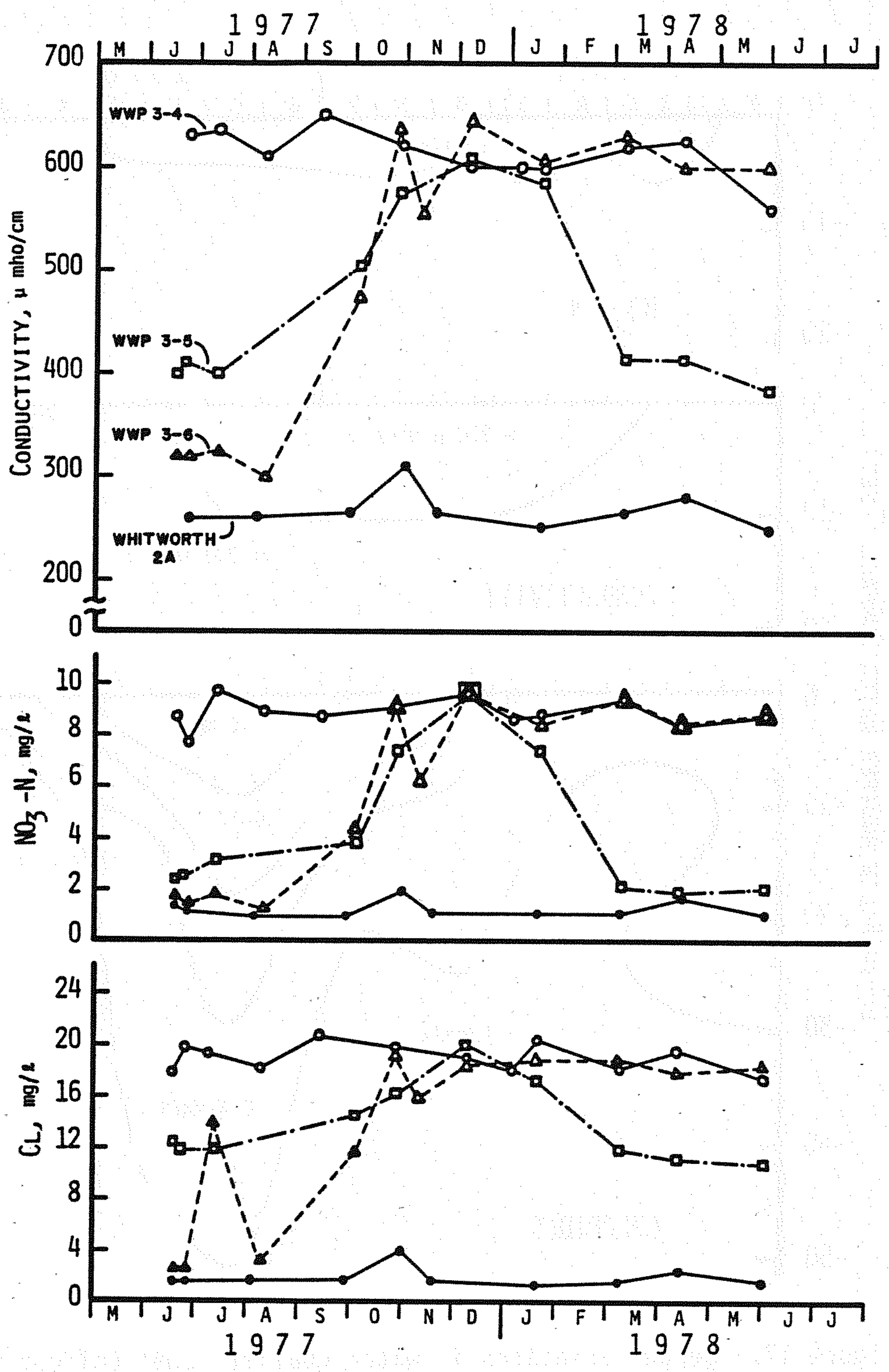


Figure 16. Mead area water quality variations.

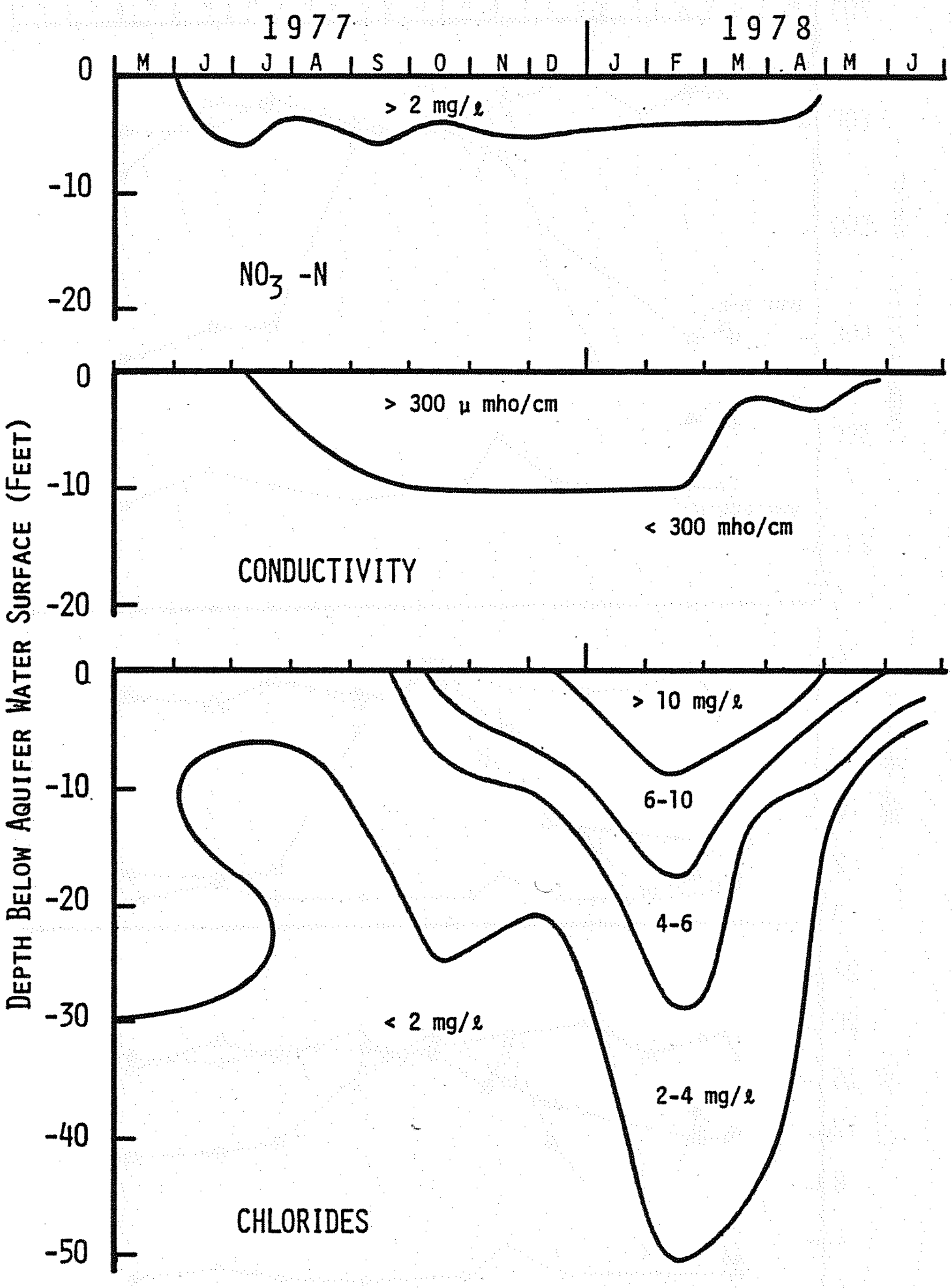


Figure 17. Depth variations in water quality '208' Balfour Park.

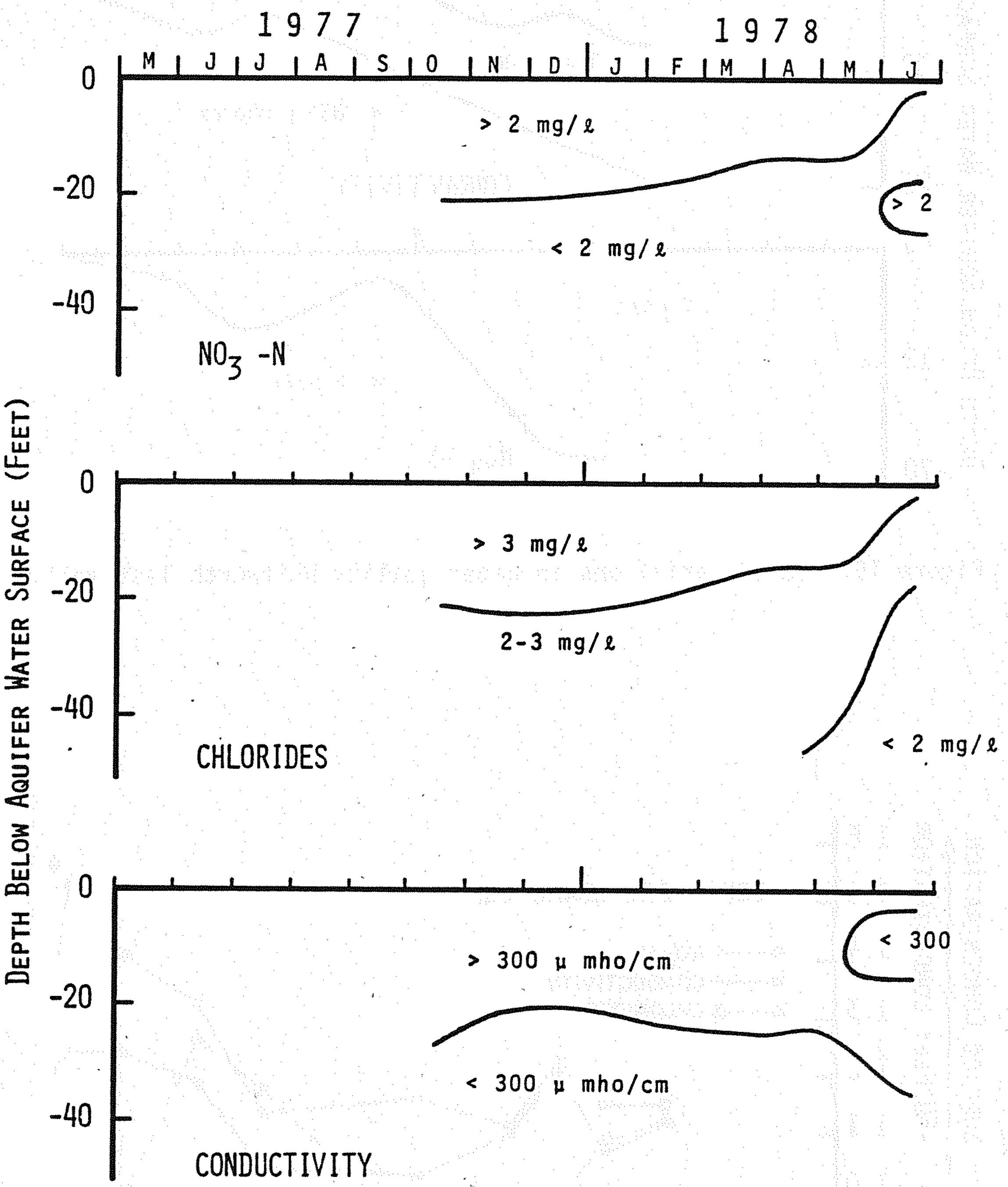


Figure 18. Depth variations in water quality '208' Arlington Well.

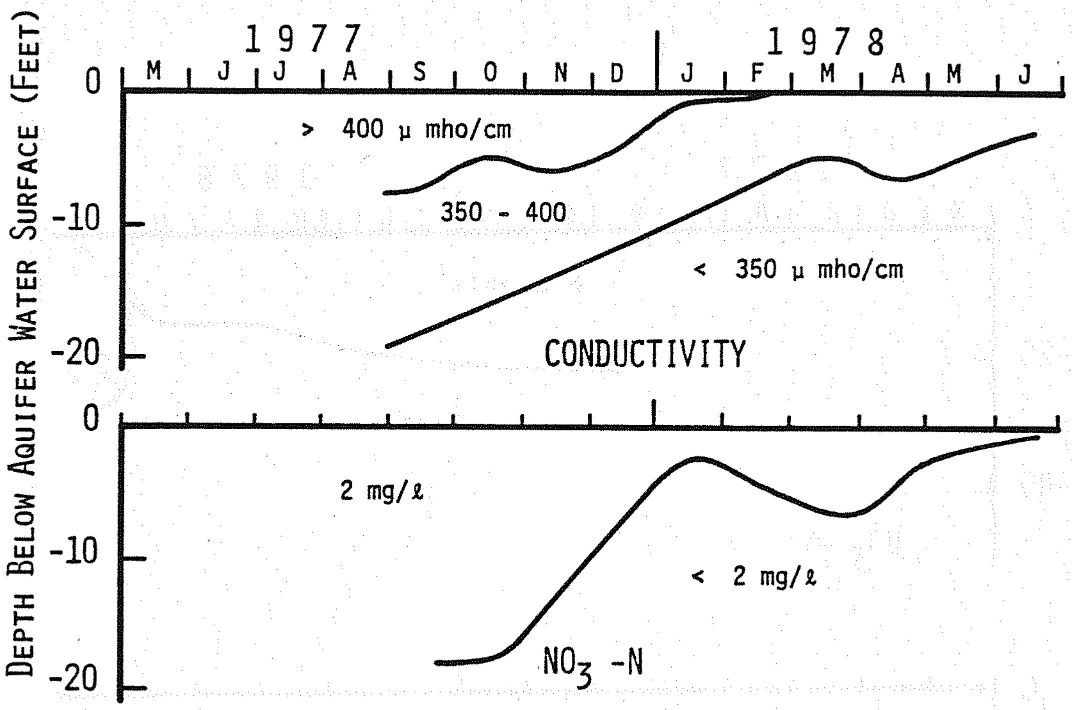


Figure 19. Depth variations in water quality Whitworth Test Well.

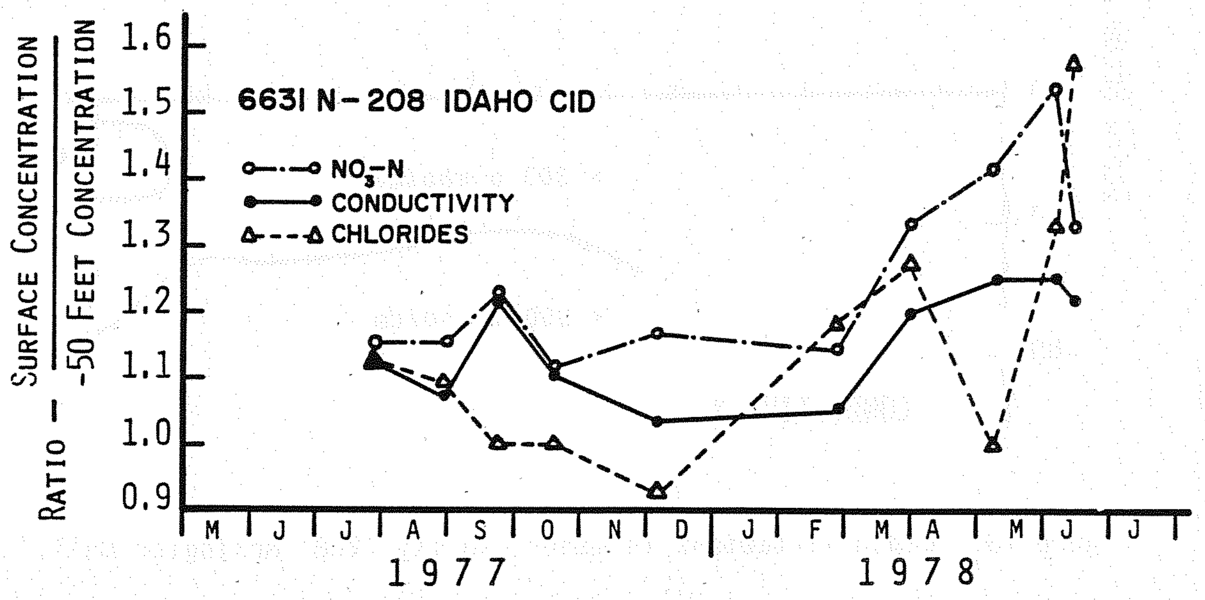


Figure 20. Ratio of surface to -50 feet salt concentrations in the aquifer at '208' Idaho CID sampling well.

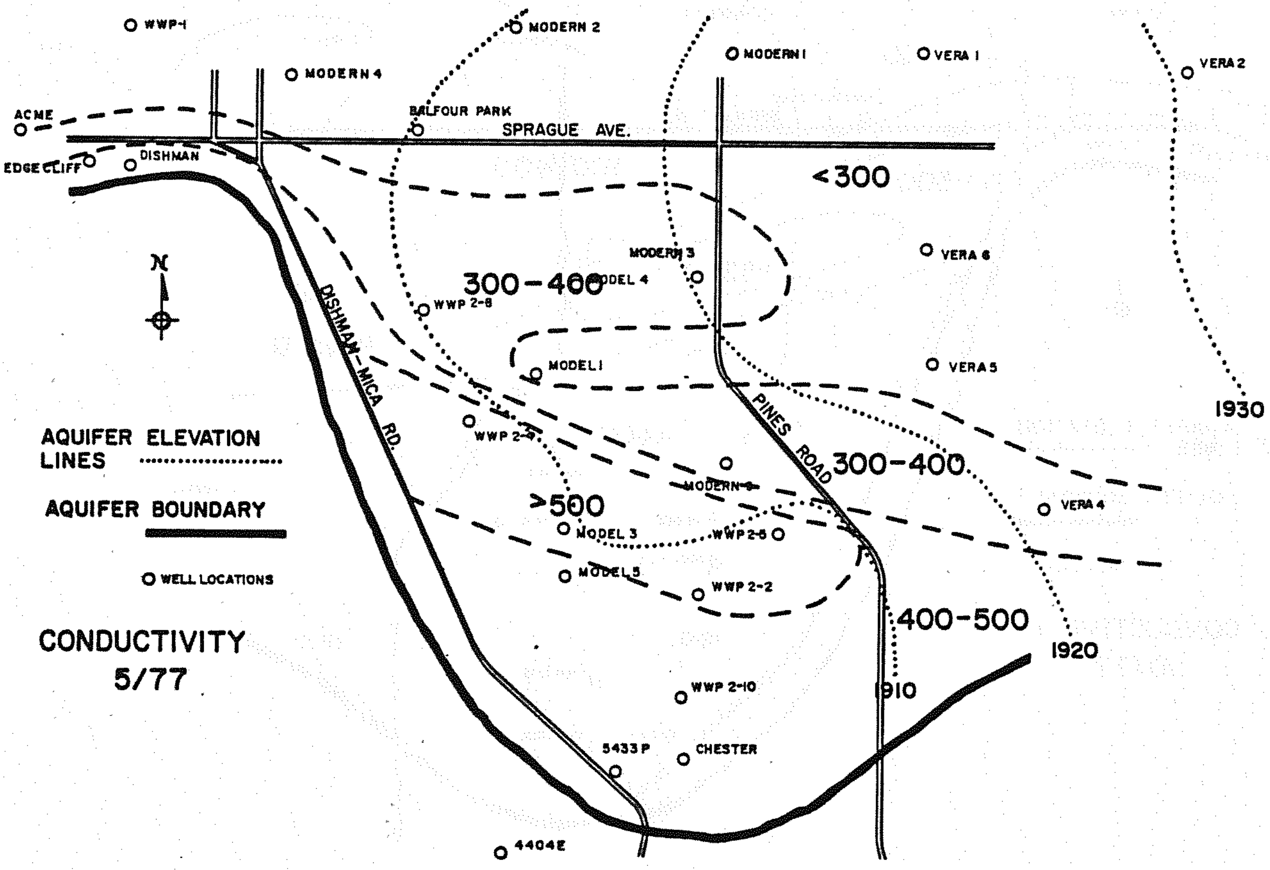


Figure 21. Aquifer water quality South Peripheral Area-Conductivity, May 1977.

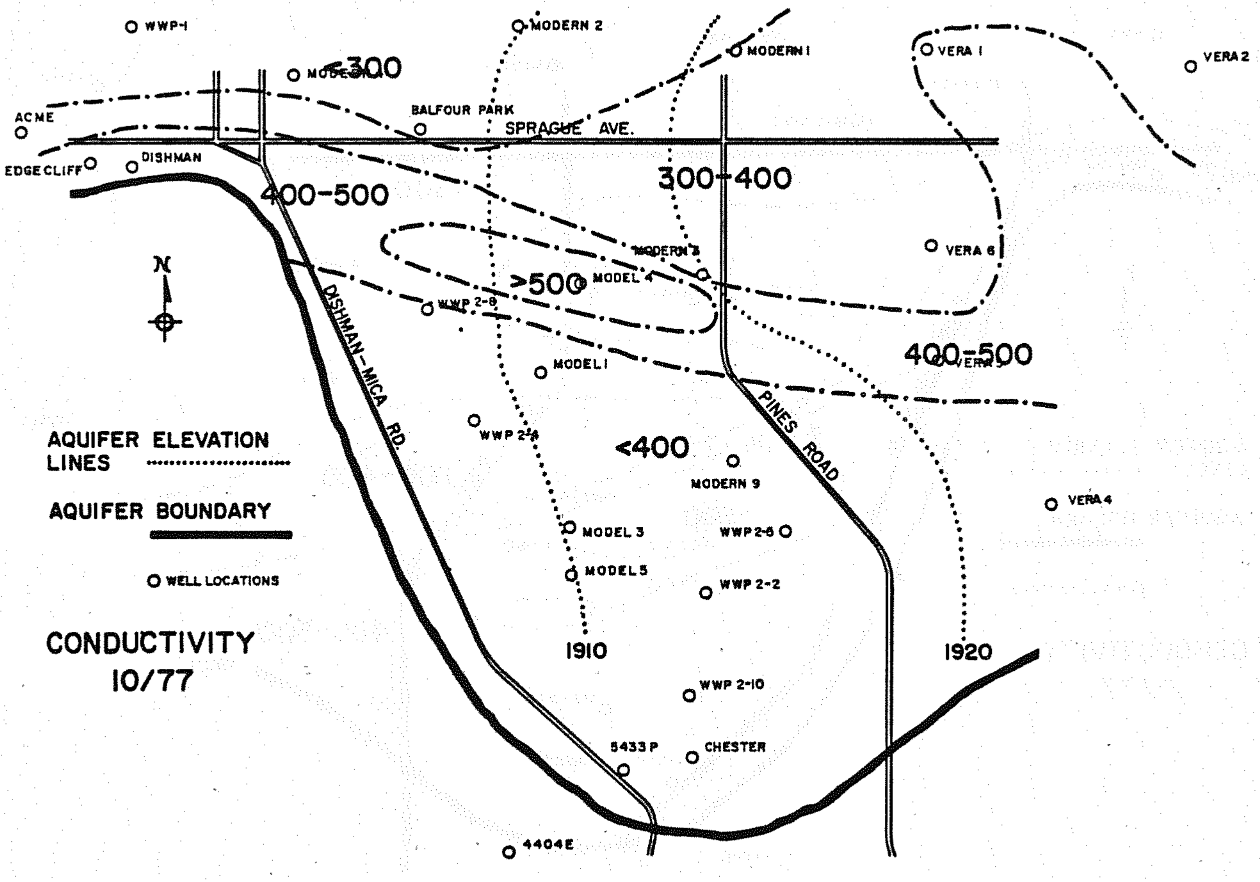


Figure 22. Aquifer water quality South Peripheral Area-Conductivity, October 1977.

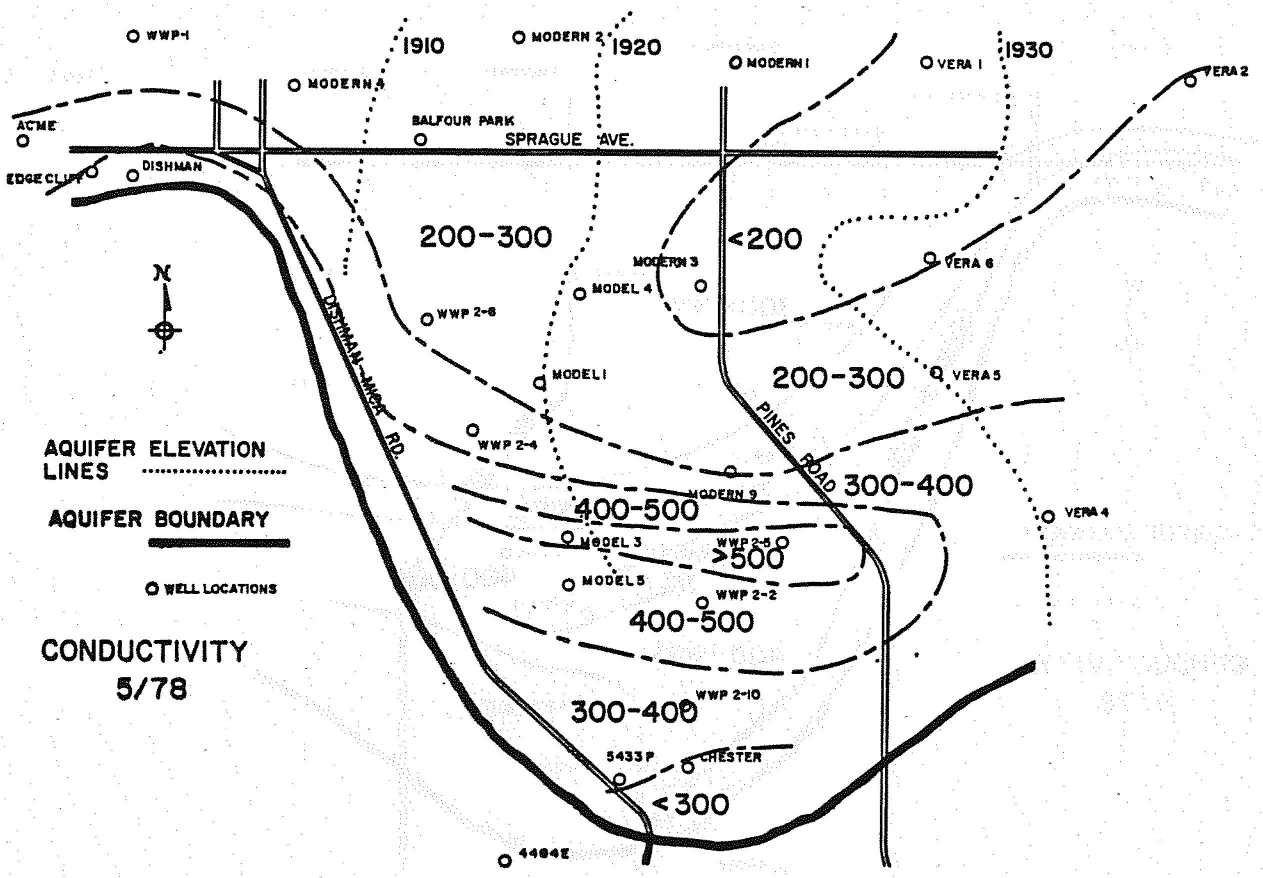


Figure 23. Aquifer water quality South Peripheral Area-Conductivity, May 1978.

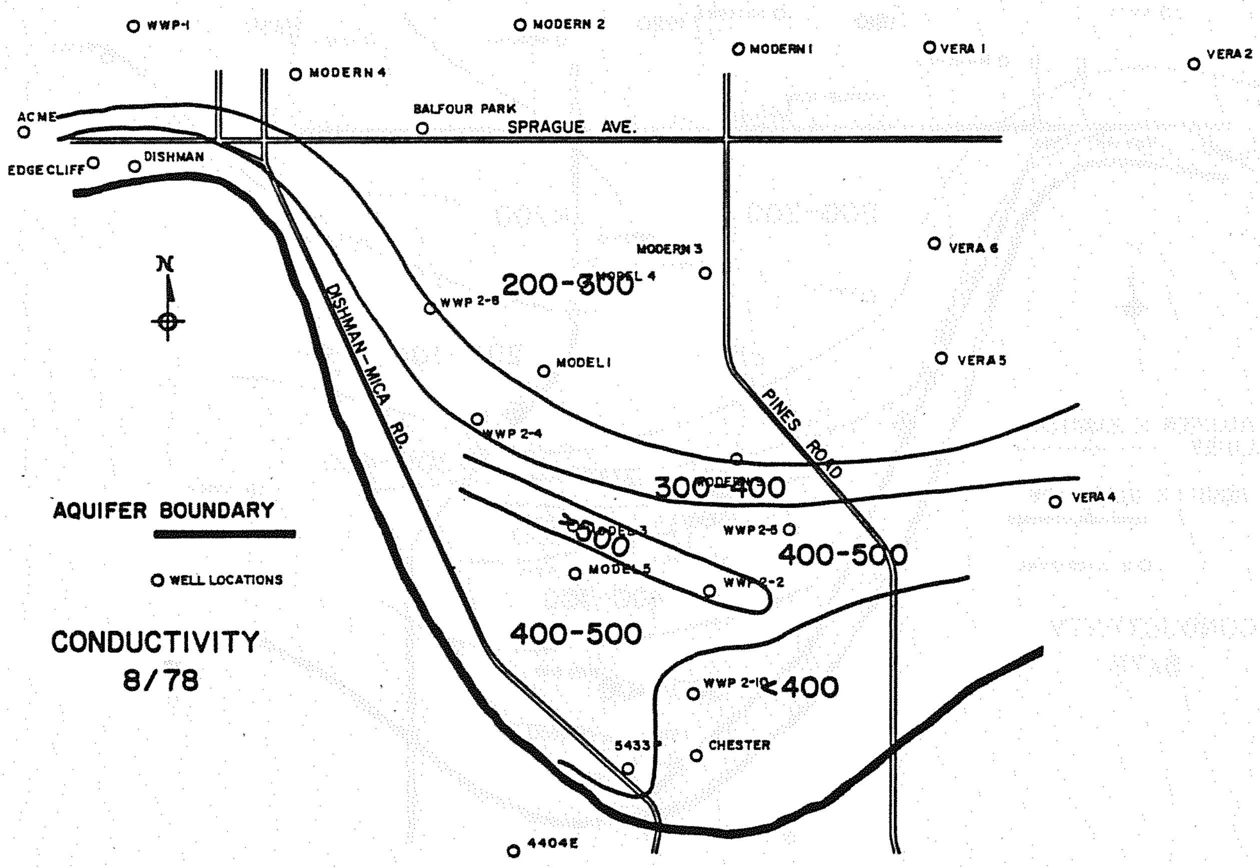


Figure 24. Aquifer water quality South Peripheral Area-Conductivity, August 1978.

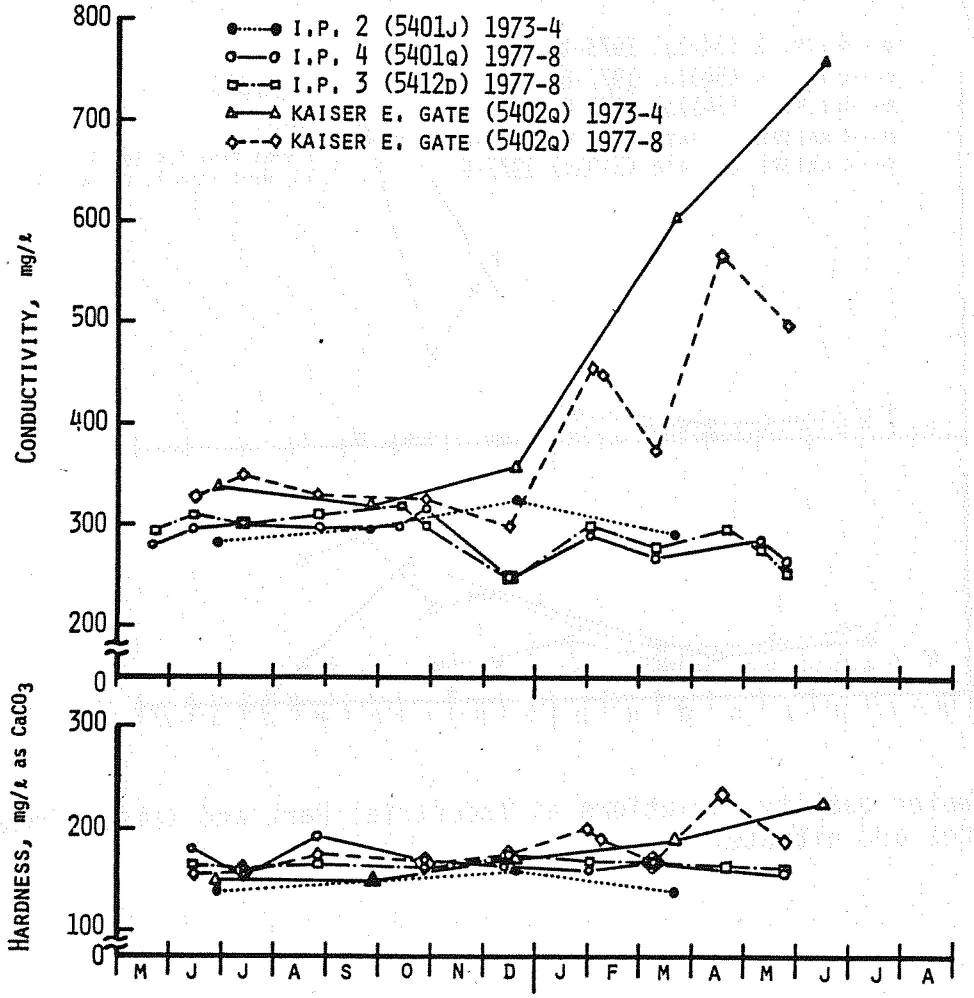


Figure 25. Water quality variations at Industrial Park and Kaiser Trentwood wells-Conductivity and hardness.

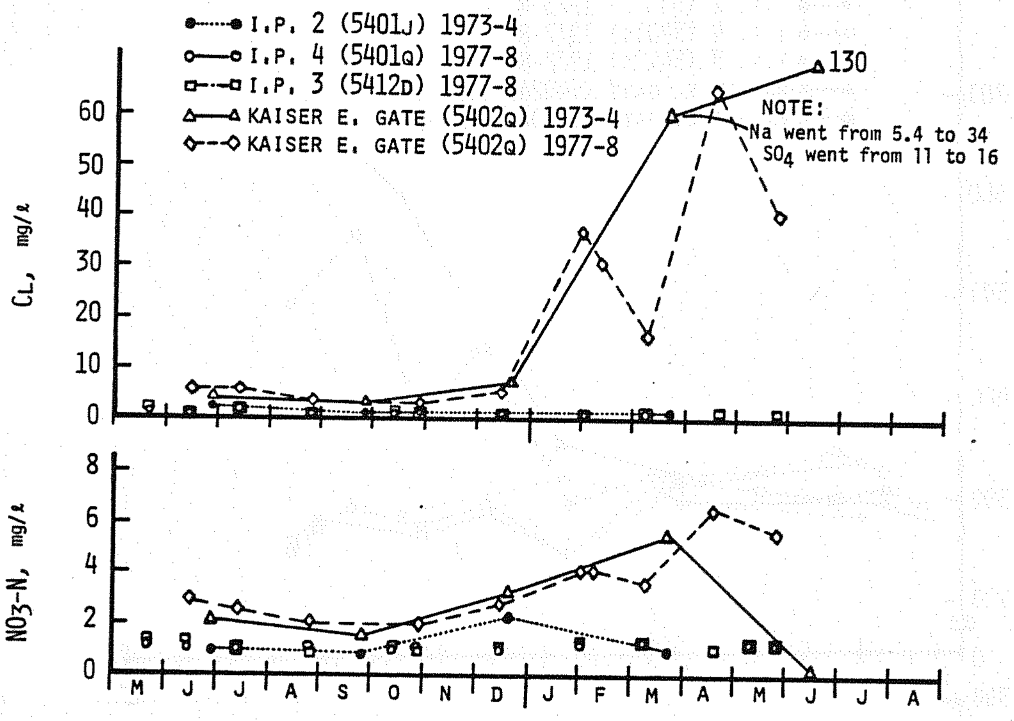


Figure 26. Water quality variations at Industrial Park and Kaiser Trentwood wells-Chlorides and nitrate.

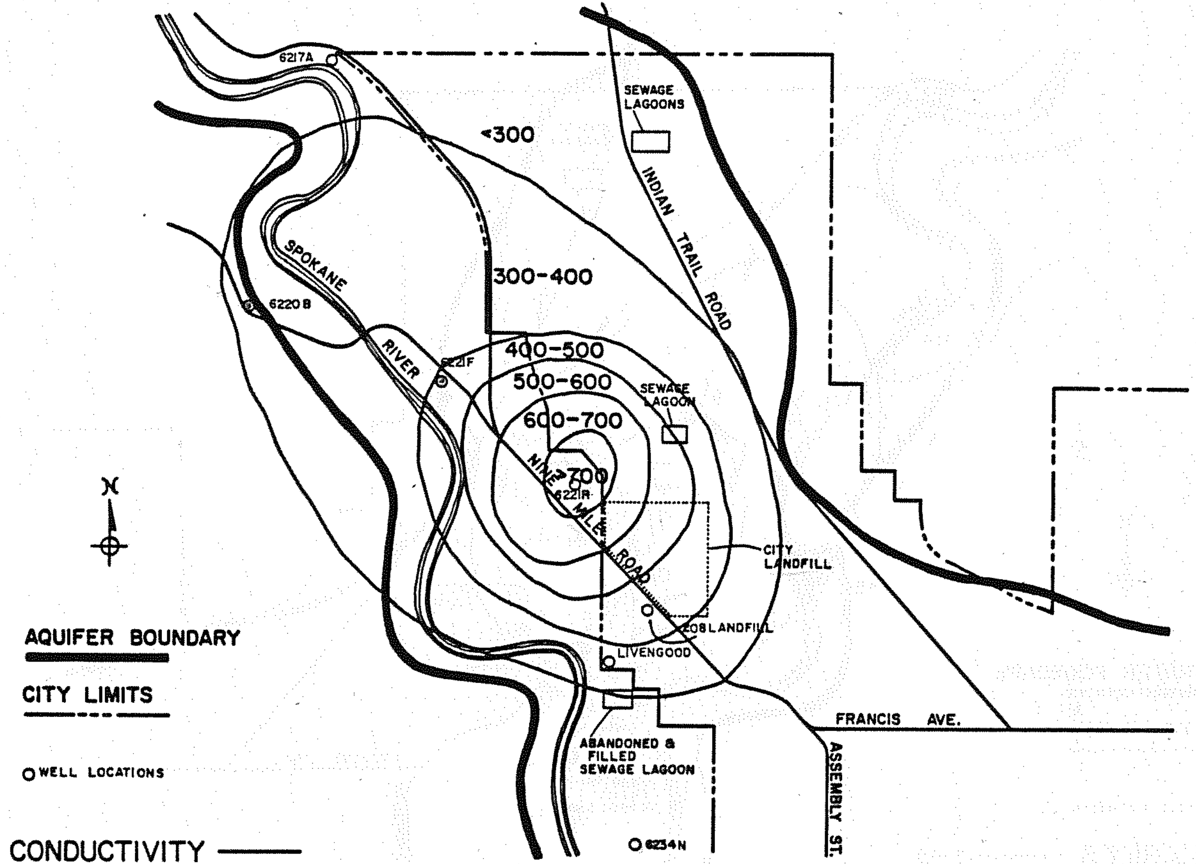


Figure 27. Water quality in the vicinity of waste disposal sites Northwest Spokane-Conductivity.

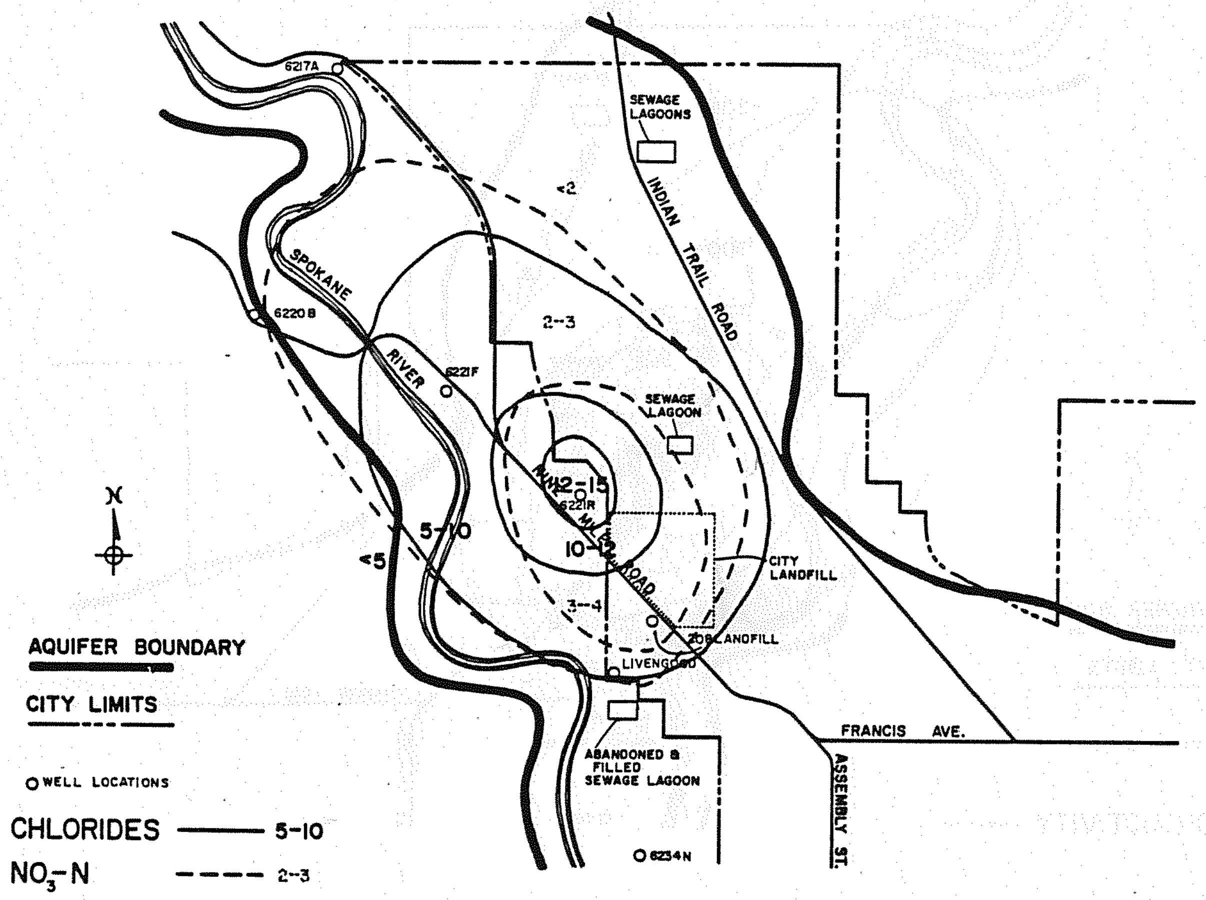


Figure 28. Water quality in the vicinity of waste disposal sites-Northwest Spokane-Chlorides and nitrate-nitrogen.

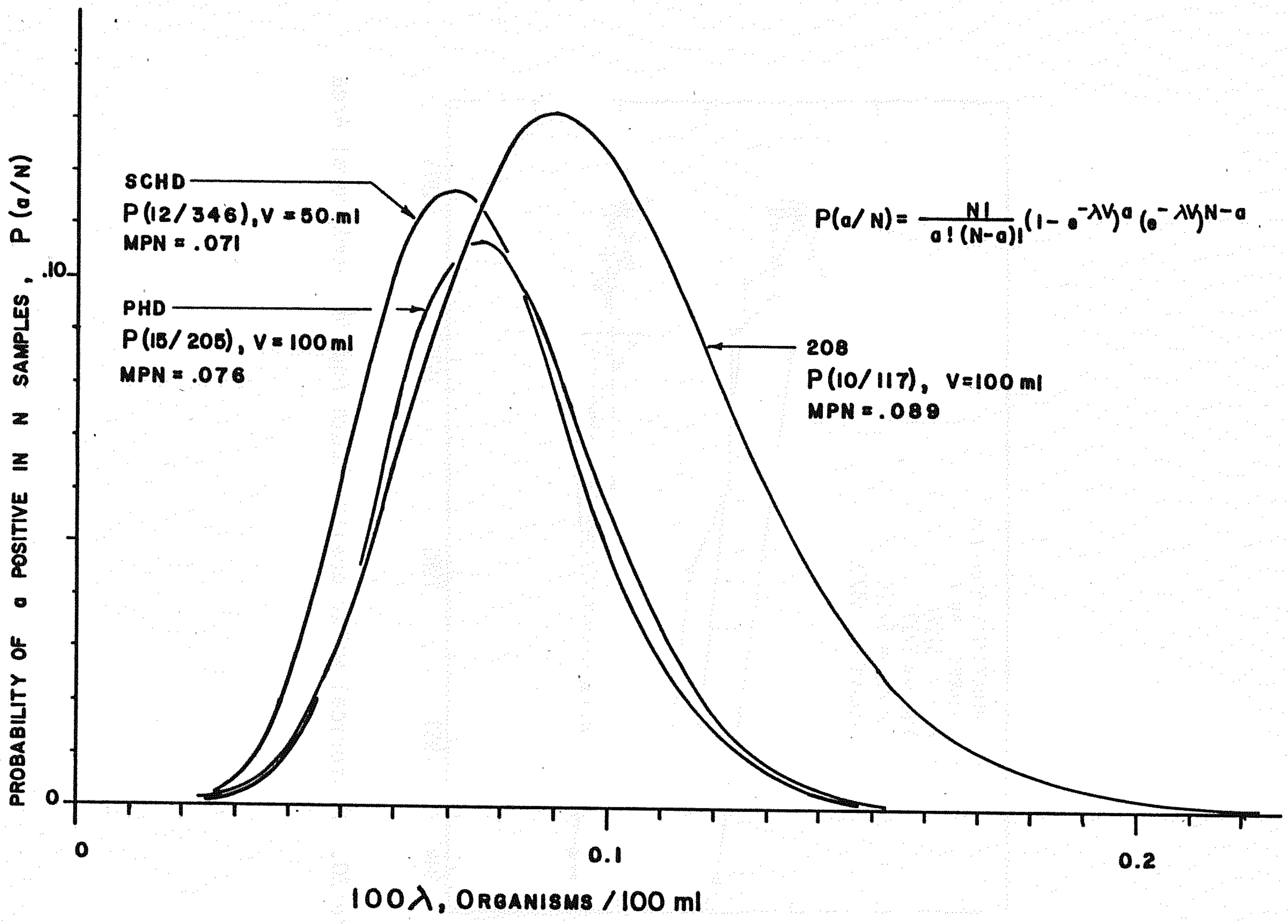


Figure 29. Coliform Density-Probablity Curves for '208', Panhandle Health District and Spokane County Health District Aquifer Sample Coliform Results.

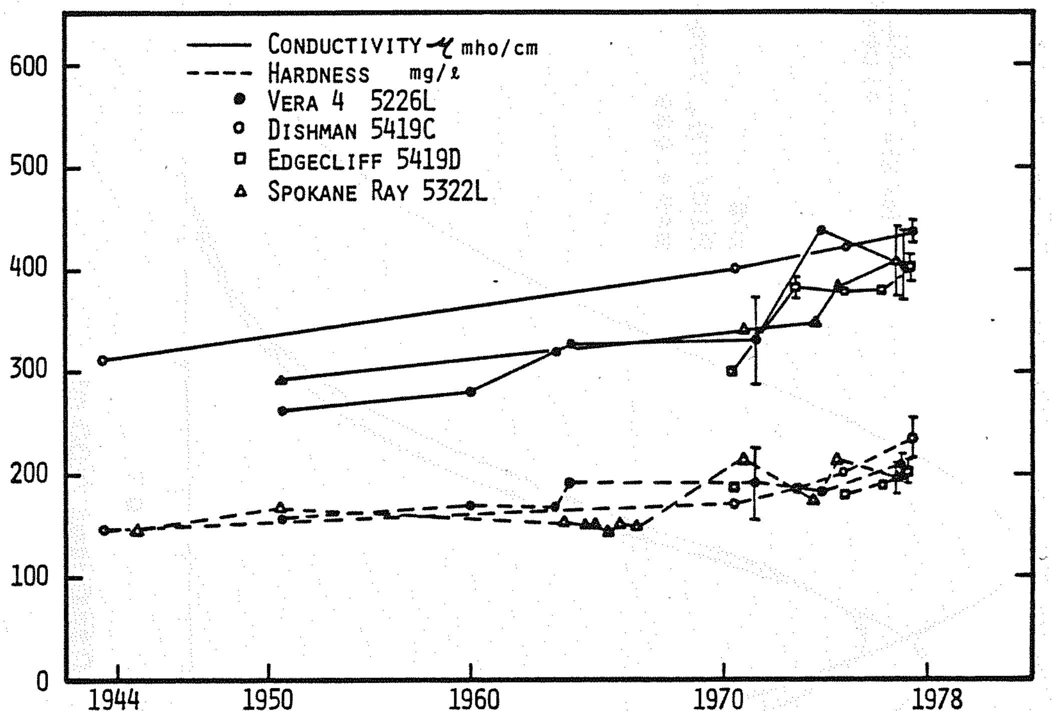


Figure 30. Historical water quality South Aquifer Peripheral Area.

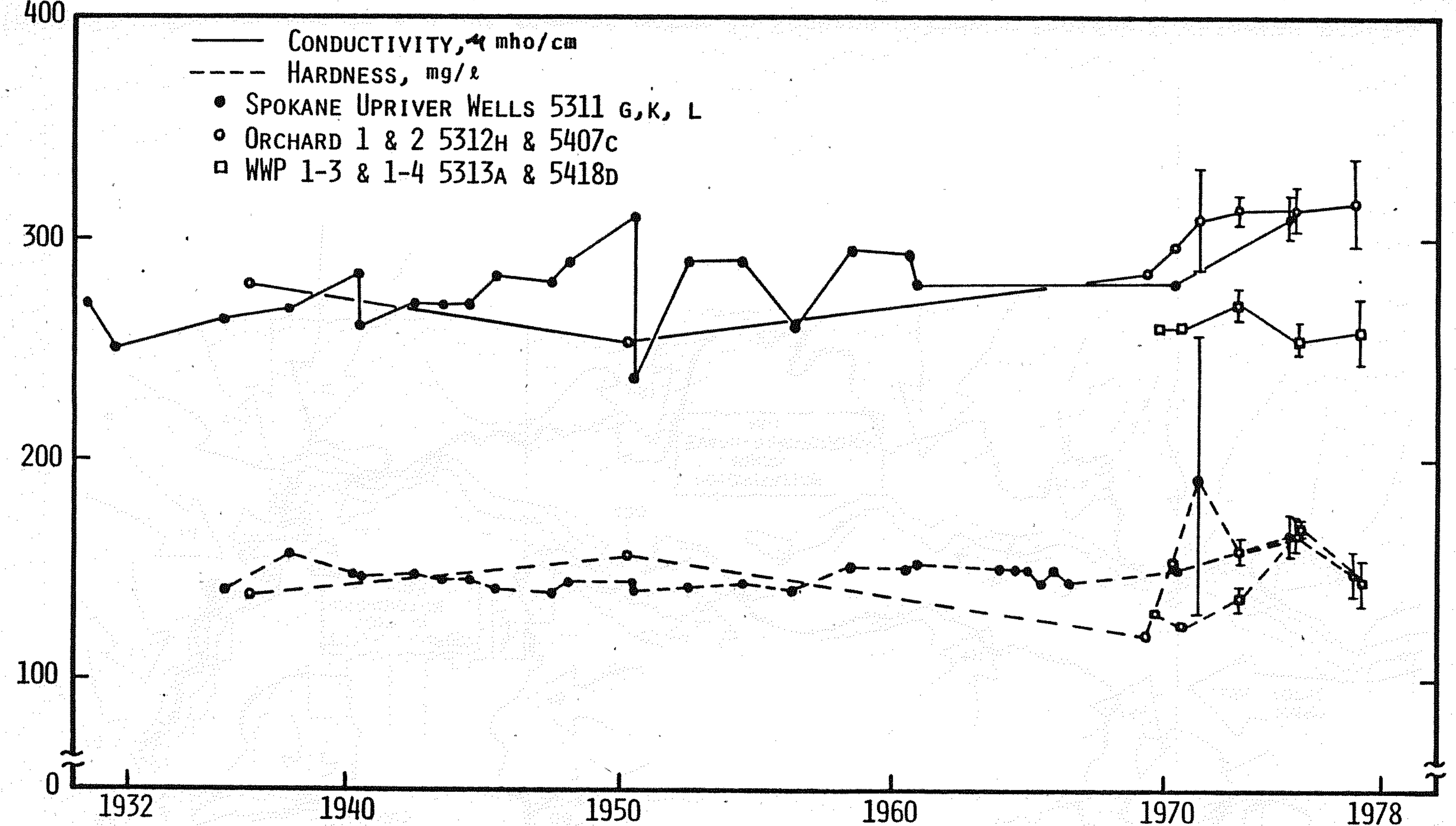


Figure 31. Historical water quality Central Aquifer Area at Dishman/Parkwater.

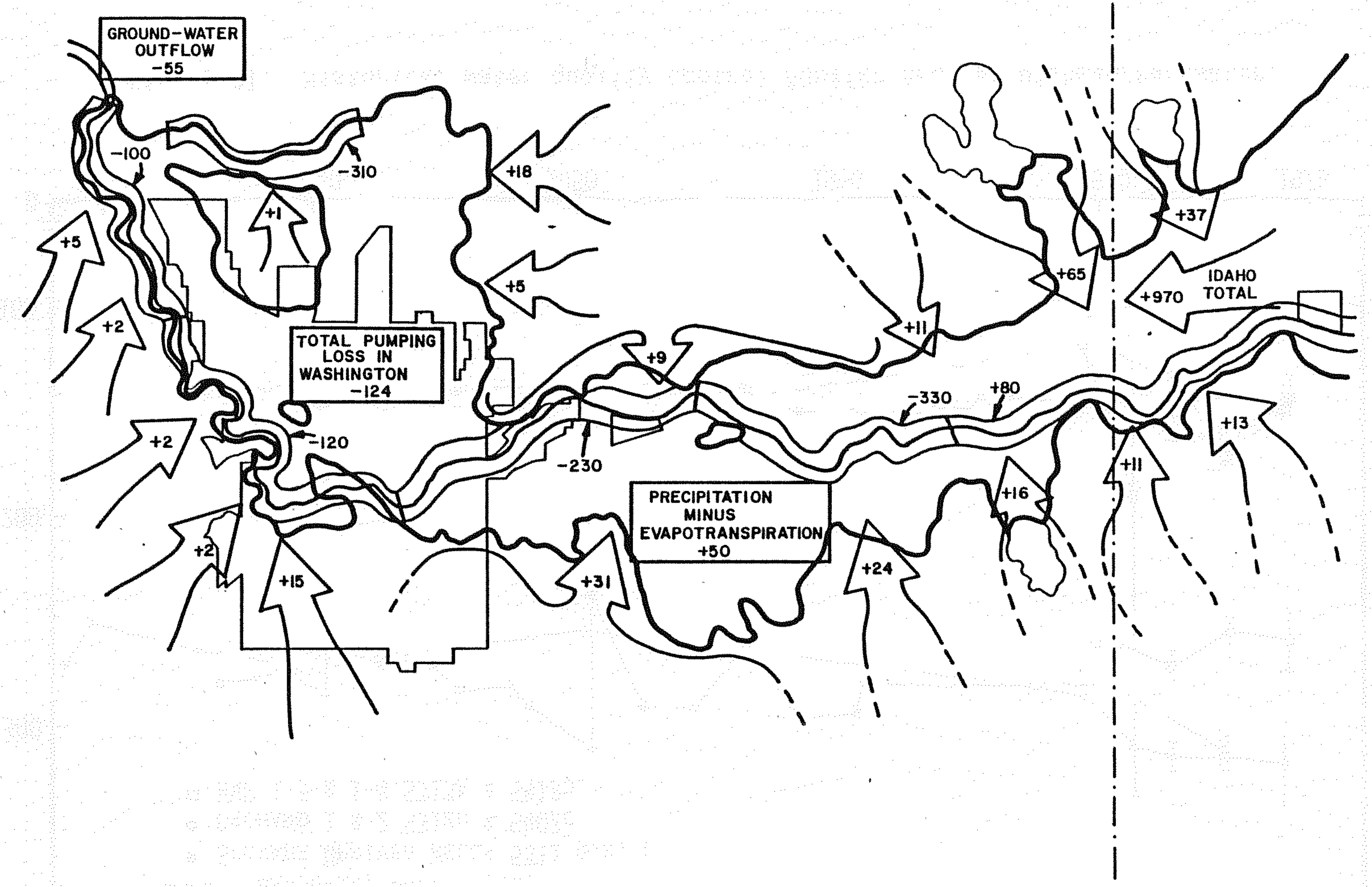


Figure 32. Average Net in and out flow of water in Spokane-Rathdrum Aquifer-Washington Portion. Flows in cfs, + is Net Addition to Aquifer, - is Net Removal from Aquifer. Source: U.S.G.S. Report to EPA for Sole Source Designation of Spokane-Rathdrum Aquifer. [9].

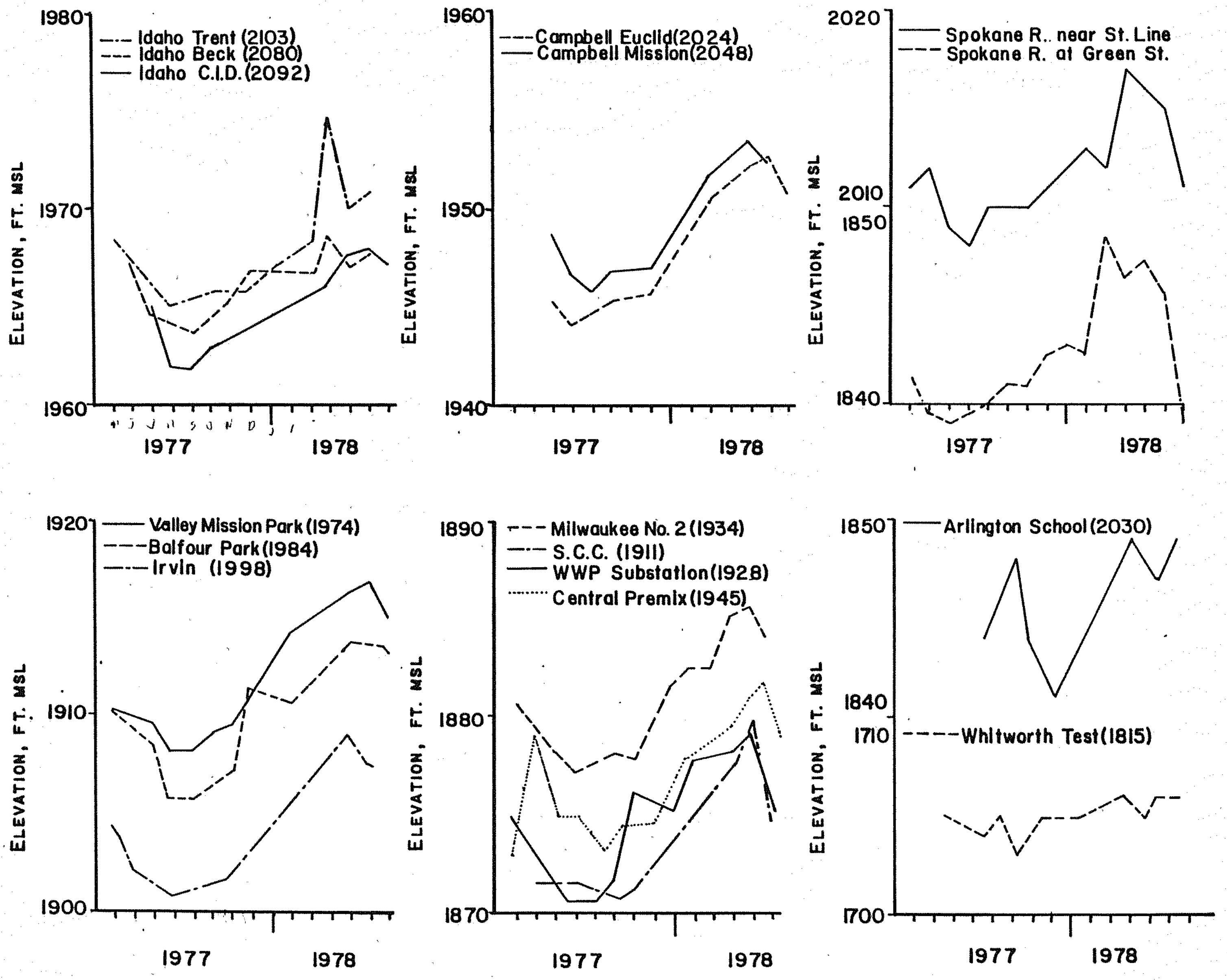


Figure 33. Water Surface Elevation in '208' Depth Selective Sampled Wells During 1977-1978 Aquifer Monitoring Program. Elevation of Ground Surface is Shown with Well Name ( ). River Elevation Changes as Shown for U.S.G. Gaging Stations.

TABLES

ERRATA

	Error	Correction
TABLE 1. Page 1		
Vera #4	Well Number	5426L
Sullivan Rd. Central Premix	Well Number	5412M
Industrial Park #4	Well Number	5401Q
Jeffers	208 Hardness	633±42 mg/l
TABLE 1. Page 2		
Irvin 208	Depth to Water	93.7'±3.6'
Valley Mission Park	Depth to Water	64.2'±4.1'
Balfour Park	Depth to Water	74.3'±3.1'
TABLE 5. Page 2		
5515D	Holiday Hills: 5/77, 5/78(2) Hard	No Data
	11/76 - 6/78(6) Hard	146±29
5426L	Well Name	Vera #4

TABLE 1. SUMMARY OF '208' AQUIFER MONITORING RESULTS - MAY 1977 THROUGH JUNE 1978

Sampling Point Depth to Water	No.	Conductivity, μ mho/cm			Nitrate - N, mg/ℓ			Chloride, mg/ℓ			Hardness as $CaCo_3$		ALK,mg/ℓ as $CaCO_3$	SO_4 mg/ℓ	Ca mg/ℓ	Mg mg/ℓ	Na mg/ℓ	K mg/ℓ	Zn mg/ℓ	Temp.	pH
		208	IHW	USGS	208	WSU	USGS	208	IHW	USGS	208	IHW									
IDAHO TRENT 136 ± 3.5'	6630D	255 ±12(35)	253 ±29(22)	262 ±14(16)	0.94 ±.14(35)	.97 ±.14(20)	.98 ±.12(16)	.68 ±.18(35)	1.5 ±1.0(22)	.94 ±.21(16)	145 ±86(35)	136 ±14.5(22)	117 ±5.5(9)	9.8 ±.65(8)	31.3 ±2.5(9)	12.4 ±.4(9)	2.8 ±.5(9)	1.8 ±.1(9)	22.9 ±46.0(7)	9.6 ±.35(35)	6.9 ±.30(35)
IDAHO BECK 114 ± 2.2'	6525J	288 ±14(48)	269 ±31(37)	289 ±21(15)	.60 ±.10(48)	.58 ±.04(34)	.62 ±.04(15)	.62 ±.26(48)	1.5 ±1.1(37)	.83 ±.13(15)	159 ±13(48)	149 ±7.9(37)	126 ±3.5(16)	14.0 ±1.29(15)	32.2 ±2.4(17)	15.7 ±.7(15)	2.8 ±.38(16)	2.0 ±.12(16)	17.8 ±14.6(10)	8.8 ±1.06(48)	6.8 ±.32(41)
IDAHO CID 128 ± 2'	6631N	284 ±24(47)	290 ±25(22)	308 ±23(10)	1.23 ±.22(47)	1.26 .24(21)	1.37 ±.23(10)	1.1 ±0.2(47)	2.0 ±1.0(21)	1.3 ±.3(10)	155 ±16(47)	154 ±37(22)	124 ±8.5(10)	12.2 ±1.3(7)	32.6 ±2.6(10)	15.1 ±1.1(10)	2.6 ±.33(10)	2.2 ±.13(10)	25.3 ±57.7(7)	11.2 ±.70(47)	6.9 ±.35(47)
MOAB W.D.	6525C	247 ±25(10)			.85 ±.23(10)			1.24 ±39(10)			142 ±22(10)									9.0 ±.71(9)	6.7 ±.21(10)
CID 10	6535F	264 ±11(8)		248 ±20(3)	.58 ±.09(8)		.62 ±.02(3)	.75 ±40(8)		.70 ±0(2)	148 ±6(8)									9.3 ±.89(8)	7.0 ±.52(8)
CID 9	5502G		249 ±12(3)				.94 ±.06(3)			.9 ±0(2)											
CID 8	6503F	288 ±25(4)			.75 ±.06(4)			1.6 ±1.4(4)			171 ±8(4)									8.9 ±.63(4)	6.9 ±.51(4)
HOLIDAY HILLS	5515D	250 ±6(6)		242 ±2(2)	2.85 ±.39(6)		2.0 ±.7(2)	2.6 ±.36(6)		2.2 (1)	146 ±29(6)									12.2 ±2.4(6)	6.8 ±.27(6)
JEFFERS	5516G	1095 ±70(11)	1070 (1)		1.0 ±.20(10)	.85 (1)		10.1 ±16.6(11)	.53 (1)		63.3 ±42(11)	612 (1)	523 (1)	11 (1)	195 (1)	48 (1)	11.7 (1)	3.7 (1)	5.8 (1)	13.5 ±6(11)	6.6 ±.23(11)
GUNDERSON 110 ± 1.3'	6533N	337 ±16(13)	323 ±23(11)	327 ±12(3)	1.7 ±.11(14)	1.7 ±.17(13)	1.5 ±.5(3)	1.5 ±.16(14)	2.1 ±.9(11)	2.1 ±.1(3)	168 ±10(14)	169 ±14(11)	150 ±3(9)	10.1 ±1.2(7)	37.8 ±3.6(9)	13.8 ±.4(9)	3.7 ±.10(9)	2.2 ±.13(9)	10.5 ±17.1(4)	9.5 ±.52(13)	6.8 ±.32(13)
CAMPBELL-EUCLID 77' ± 3'	5505R	352 ± 9(47)	328 ±43(21)	326 ±39(10)	1.19 ±.16(47)	1.3 ±.10(24)	1.3 ±.07(10)	1.1 ±.13(47)	2.2 ±1.0(21)	1.4 ±.23(10)	188 ± 8(47)	183 ±22(21)	152 ±24(12)	15.2 ±1.3(9)	39.7 ±5.4(12)	17.6 ±2.9(12)	2.7 ±.40(12)	2.2 ±.24(12)	6.5 ±2.5(4)	9.5 ±.5(47)	6.8 ±.25(47)
CAMPBELL MISSION 100 ± 8'	5508R	196 ±7(46)	189 ±13(28)	200 4(5)	.78 ±.10(45)	.86 ±.09(30)	.84 .10(5)	0.9 ±.2(45)	1.9 ±.9(28)	.86 .09(5)	103 ±11(45)	103 ±12(28)	80 ±4(13)	10.3 ±1.0 (11)	25.1 ±2.3(13)	8.2 ±.4(13)	2.0 ±.34(13)	1.6 ±.13(13)	20.7 ±45.6(7)	11.5 ±1.0(46)	6.7 ±.3(46)
CID 3	5517P	193 ±15(4)		182 18(3)	1.23 ±.25(4)		1.4 .10(3)	1.4 ±.32(4)		1.3 .14(2)	102 ±10(4)									10.9 .8(4)	7.1 .38(4)
CID 2	5518R	164 ±11(7)		147 ±25(3)	.89 ±.11(7)		.94 ±.056(3)	.96 ±.17(7)		.9 ±.14(2)	94 ±12(7)									10.3 ±.47(7)	6.7 ±.37(7)
VERA 2	5413M	234 ±13(7)	183 ±(1)	290 ±113(2)	1.21 ±.30(7)	1.07 ±.16(2)	1.8 ±1.1(2)	1.7 ±1.5(7)	1.1 ±(1)	2.4 ±1.9(2)	130 ±17(7)	108 ±(1)	92 (1)	9.5 ±.7(2)	28.8 (1)	8.6 (1)	2.6 (1)	1.7 (1)	2 (1)	11.4 ±1.4(7)	6.6 ±.23(6)
VERA 1				278 ±116(3)	1.35 ±.07(2)		1.7 ±.9(3)			2.7 ±1.5(2)											
MODERN 1	5415M	273 ±16(11)	273 ±(1)	267 ±42(3)	.77 ±.29(11)	.99 ±.02(2)	1.17 ±.06(3)	1.0 ±.32(11)	1.1 ±.78(2)	1.2 ±0(2)	160 ±11(11)	168 ±34(2)	128 ±1(2)	16 ±1.4(2)	35.2 ± .02(2)	15.7 ± .9(2)	2.5 ±.14(2)	1.8 ±.07(2)		9.2 ±.24(11)	6.7 ±.48(11)
VERA 4	3426L	404 ±34(11)	302 ±(1)	350 ±36(3)	2.9 ±.3(11)	2.7 ±.34(2)	2.7 ±.17(3)	3.3 ±.37(11)	3.8 ±.85(2)	3.5 ±.28(2)	207 ±13(11)	200 ±17(2)	168 ±13(2)	13 ±1.4(2)	23.6 ±5.7(2)	14 ±2.1(2)	6.0 ±.50(2)	2.8 ±.14(2)	23 (1)	9.7 ±.60(11)	6.7 ±.23(11)
MODERN 9	5427E	318 ±26(11)	276 ±4(2)	323 ±30(3)	2.5 ±.4(11)	2.3 ±31(3)	2.4 ±.26(3)	3.3 ±.78(11)	5.2 ±4.5(2)	4.1 ±.14(2)	164 ±12(11)	159 ±10(3)	126 ± 5(3)	12.3 ±1.16(3)	38.9 ±3.3(3)	12.6 ± .6(3)	4.3 ±.49(3)	1.9 ±.12(3)	2 (1)	10.9 ±.30(11)	6.7 ±.29(11)
WWP 2-4	5429H	358 ±19(10)	358 ±52(4)	418 ±100(3)	3.8 ±.5(10)	3.8 ±.22(4)	4.3 ±1.13(3)	6.4 ±.53(10)	7.5 ±1.6(4)	8.0 ±1.3(2)	187 ±12(10)	181 ±13(4)	149 ±6.0(3)	8.0 ±1.0(3)	50.3 ±4.0(3)	14.1 ± .9(3)	6.6 ±.15(3)	2.8 ±.12(3)	1 ±0(2)	8.8 ±.8(10)	6.8 ±.23(10)
SULLIVAN RD. CENT. PRE-MIX	3412M	292 ±12(26)	278 ±38(11)	293 ±10(5)	.79 ±.10(25)	.75 ±.06(11)	.79 ±.04(5)	5.5 ±3.7(26)	4.6 ±2.4(11)	7.6 ±3.2(5)	150 ±10(26)	161 ±23(11)	131 ± 8(5)	14.8 ± 1.9(5)	35.8 ±3.3(5)	15.9 ± .5(5)	3.7 ±.69(5)	2.0 ±.13(5)		9.3 ±.5(26)	7.0 ±.2(26)
IND PARK #3	5412D	290 ±23(9)		298 ±20(2)	1.04 ±.14(9)		1.1 ±10(3)	.9 ±.24(9)		1.2 ±0(2)	166 ± 5(9)									9.6 ±.7(9)	6.6 ±.2(9)
IND PARK #4	3401Q	288 ±23(8)		290 ±10(3)	1.00 ±.13(8)		1.0 ±.16(3)	.79 ±.22(8)		1.0 ±.1(2)	169 ±12(8)									9.4 ±.6(8)	6.5 ±.2(8)
KAISER EASTGATE	5402Q	399 ±91(10)	480 ±121(2)		3.5 ±1.5(10)			21.0 ±21.3(10)	42.7 ±36.7(2)		181 ±25(10)	198 ±48(2)								9.7 ±.5(10)	6.7 ±.2(10)
TRENTWOOD PROGRESS	5402B	337 ±46(5)		342 ±85(3)	2.4 ±.7(5)		2.7 ±.6(3)	2.3 ±1.0(5)		3.8 ±.6(2)	184 ±22(5)									11.4 ±1.3(5)	6.9 ±.06(5)
IRVIN #2	5459F	304 ±18(7)		267 ±18(3)	.80 ±.22(7)		1.1 ±.06(3)	.86 ±.20(7)		1.4 ±.2(2)	170 ± 8(7)									9.8 ±1.2(7)	6.7 ±.4(6)

TABLE 1. (continued, 2/3)

Sampling Point Depth to Water	No.	Conductivity, μ mho/cm			Nitrate - N, mg/ℓ			Chloride, mg/ℓ			Hardness as CaCo$_3$		ALK, mg/ℓ as CaCO$_3$	SO$_4$ mg/ℓ	Ca mg/ℓ	Mg mg/ℓ	Na mg/ℓ	K mg/ℓ	Zn mg/ℓ	Temp.	pH
		208	IHW	USGS	208	WSU	USGS	208	IHW	USGS	208	IHW									
208 IRVIN	5409C	277 ±17(47)	271 ±24(22)	275 ±21(16)	1.07 ±.13(46)	1.1 ±.09(23)	1.1 ±.06(16)	1.8 ±.5(46)	2.6 ±1.0(22)	1.9 ±.5(16)	149 ±10(46)	144 ±10(22)	124 ±2.5(11)	10.4 ± .8(10)	34.0 ±1.4(11)	12.6 ± .35(11)	4.0 ±.76(11)	2.0 ±.16(11)	11.2 ±6.8(6)	10.1 ± .4(47)	6.8 ±.3(47)
VALLEY MISS PK	5409P	308 ±10(49)	293 ±26(26)	303 ±10(16)	.90 ±.17(50)	.96 ±.11(36)	.93 .06(15)	1.3 ±.23(51)	2.7 ±1.16(26)	1.7 .9(16)	167 ±12(51)	159 ±14(26)	137 ±4(12)	15.6 ± .9(12)	35.7 ±4.4(12)	16.4 ± .6(12)	3.2 ±.43	2.1 ±.13(12)	8.1 ±8.8(10)	9.4 ±.4(49)	6.8 ±.2(49)
BALFOUR PARK	5419R	283 ±45(52)	267 ±52(29)	269 ±42(16)	1.67 ±.38(53)	1.7 ±.40(34)	1.6 ±.3(16)	4.0 ±3.6(53)	6.0 ±4.7(29)	3.2 ±1.8(16)	149 ±22(53)	149 ±33(29)	120 ±19(13)	12.4 ±1.0(12)	38.5 ±5.9(13)	11.0 ±1.2(13)	5.2 ±2.5(13)	2.0 ±.18(13)	5.9 ±5.4(7)	11.2 ±.5(52)	6.7 ±.3(51)
HUTTON SETTLEMENT	6432R	382 ±23(11)	356 ±30(2)		6.7 ±.5(11)	6.7 ±.14(2)		1.9 ±.25(11)	4.6 ±3.5(2)		190 ±10(11)	188 ±11(2)	141 (1)	14.0 (1)	41.6 (1)	17.8 (1)	6.5 (1)	3.3 (1)	13.7 11.4(2)	13.0 ±1.3(11)	6.7 ±.5(10)
PLEASANT PRAIRIE W.D.	5432Q	421 ±20(8)	459 ± 0(2)		7.4 ±.8(8)	7.2 ± 0(2)		11.3 ±.14(8)	14.9 ±0(2)		210 ± 3(8)	216 ±11(2)	142 ± 3(2)	22.6 ± .1(2)	36.8 ±0(2)	24.7 ± .1(2)	7.2 ±.07(2)	4.3 ±.07(2)			6.9 ±.3(7)
PASADENA #1/4	5406A	252 ±19(6)		228 (1)	2.3 ±.4(6)		1.8 (1)	2.5 ±.16(6)			138 ±11(6)									11.3 ±.8(6)	6.6 ±0.1(6)
MODERN 6	5408N	283 ±23(8)		270 ±44(3)	1.4 ±.24(8)		1.23 ±.32(3)	1.5 ±.39(8)		1.1 ±.2(2)	163 ±15(8)									9.7 ±1.6(8)	6.7 ±.3(8)
ORCHARD 2	5407C	307 ±14(9)			1.3 ±.15(9)			1.9 ±.44			172 ±13(9)									9.9 ±.9(9)	6.8 ±.3(8)
ORCHARD 1	5312H	321 ±21(8)	347 ±(1)	333 ±21(3)	1.5 ±.19(8)	1.3 ±(1)	1.3 ±.25(3)	2.4 ±.54(8)	2.6 ±(1)	2.0 ±.2(2)	174 ±10(8)	172 (1)	140 (1)	14.5 (1)	28.8 (1)	16.2 (1)	3.8 (1)	2.2 (1)		9.7 ±.7(8)	6.7 ±.3(7)
WWP 1-4	5418D	264 ±14(10)	250 (1)	266 ±10(3)	1.33 ±.23(10)	94 (1)	1.4 ±.06(3)	1.6 .18(10)	1.6 (1)	1.7 ±0(2)	148 ±11(10)	120 (1)									6.7 ±.3(10)
WWP 1-3	5313A	255 ±12(11)		244 ±24(3)	1.31 ±.21(11)		1.2 ±.2(3)	1.7 ±.27(11)		1.8 ±.6(2)	141 ± 7(11)										6.7 ±.30(11)
DISHMAN	5419C	437 ±11(4)			4.8 ±.36(4)			10.1 ±.41(4)			235 ±20(4)									10.5 ±1.3(4)	6.7 ±.3(4)
EDGECLIFF	5419C	401 ±12(10)			3.7 ±.4(10)			9.3 ±1.7(10)			199 ± 8(10)									11.6 ±.5(10)	6.7 ±.15(10)
EAST SPOKANE 2	5324L	419 ±38(12)	424 (1)		4.4 ±.5(12)	4.5 (1)		9.3 ±.2(11)	10.0 (1)		223 ±10(12)	208 ±(1)	167 (1)	13.0 (1)	52.8 (1)	18.6 (1)	8.0 (1)	3.3 (1)	11 (1)	11.3 ±.8(12)	6.7 ±.17(12)
WWP 1-5A	5323A	334 ±19(10)	330 ±33(4)	318 ±42(3)	3.0 ±.4(10)	2.9 ±.07(4)	2.8 ±0(3)	5.0 ±.39(10)	5.7 ±1.5(4)	4.9 .1(2)	179 ± 9(10)	169 ±12(4)	136 ± 6(3)	12.5 ± .5(3)	35.7 ±5.1(3)	14.2 ±.3(3)	3.2 ±.47(3)	2.4 ±.27(3)		11.6 ±.8(10)	6.7 ±.23(10)
SPOKANE RAY	5322L	406 ±33(10)	351 (1)	370 ±24(3)	4.0 ±.3(9)	4.4 ±.13(3)	4.0 ±.3(2)	8.0 ±1.1(10)	2.1 (1)	8.2 ±.8(2)	195 ±15(10)	196 (1)			17.5 (1)					11.3 ±.6(10)	6.7 ±.22(10)
MILWAUKEE NO.2 55 ± 31'	5314P	242 ±18(47)	237 ±22(22)	243 ±16(14)	1.36 ±.11(46)	1.4 ±.21(27)	1.4 ±.7(14)	2.1 ±.40(48)	2.4 ±1.0(22)	2.1 ±.5(14)	132 ±16(48)	124 ±15(22)	101 ±4(10)	11.8 ±1.2(10)	20.3 ±2.8(10)	9.8 ±.2(10)	3.0 ±.25(10)	1.8 ±.11(10)	8.8 ±9.6(4)	11.2 ±.7(47)	6.8 ±.3(47)
CENTRAL PREMIX 72 ± 4.7'	5314E	240 ±17(54)	228 ±25(41)	238 10(16)	1.19 ±.10(51)	1.15 ±.17(46)	1.2 .07(16)	1.5 ±.36(51)	2.6 ±1.2(41)	1.8 .4(16)	125 ±11(51)	121 ±10(42)	101 ±7(17)	11.9 ±1.3(18)	28.9 ±1.3(17)	9.9 ±2.3(17)	3.0 ±.38(17)	1.7 ±.26(17)	3.6 ±5.3(9)	11.0 ±.4(54)	6.8 ±.3(54)
SPOKANE COMM COL 38 ± 2.4'	5310Q	298 ±28(47)	282 ±41(31)	286 ±27(14)	1.6 ±.4(45)	1.6 ±.35(30)	1.6 ±.28(14)	2.3 ±.74(44)	3.1 ±1.4(30)	2.5 ±.9(14)	158 ±15(44)	157 ±24(31)	130 ± 8(14)	13.9 ±2.7(13)	39.0 ±4.1(14)	13.4 ±1.2(14)	3.6 ±.43(14)	2.1 ±.14(14)	2.7 ±30(9)	10.9 ±.5(47)	6.8 ±.3(47)
WWP SUBSTATION 54.5 ± 2.7'	5311M	273 ±14(54)	265 ±21(25)	268 ±11(16)	.86 ±.15(49)	.89 ±.06(26)	.89 ±.05(16)	.95 ±.17(49)	2.2 ±1.5(25)	1.1 ±.09(16)	149 ±12(49)	144 ±22(25)	121 ±4(10)	14.6 ± 3.7(12)	31.6 ±2.4(10)	14.2 ±1.4(12)	3.0 ±.82(12)	2.0 ±.13(12)	18.7 ±30.1(9)	9.8 ±.5(54)	6.8 ±.3(54)
SPOKANE NEVADA	5308B	257 ±19(10)		243 ±13(2)	1.42 ±.21(9)	1.2 (1)	1.4 ±0(2)	1.9 ±.28(10)		1.6 (1)	145 ±13(10)									10.9 ±.7(10)	6.8 ±.3(10)
SPOKANE HOFFMAN	5304A	292 ±26(10)	290 ±31(2)	372 (1)	1.35 ±.38(9)	1.2 ±.16(4)	2.1 (1)	2.3 ±.66(10)	5.3 ±3.0(2)	4.8 (1)	154 ±16(10)	156 ± 6(2)		13 (1)						10.5 ±.5(10)	6.8 ±.3(10)
ICEHOUSE	5213B	331 ±31(10)		354 40(3)	2.1 ±.3(9)		2.2 .17(3)	14.3 ±6.1(10)			165 ±10.2(10)									12.3 ±.9(10)	6.6 ±.3(9)
DOWNRIVER SPRINGS	5212S	300 ±16(8)			2.1 ±.3(8)			5.4 ±.99(10)			160 ±11(10)									11.8 ±.9(8)	6.9 ±.2(10)
SPOKANE CENTRAL	6331A	247 ±16(7)	238 ±30(2)	225 ±17(3)	1.08 ±.10(6)	1.1 ±.02(3)	1.1 ±.06(3)	1.3 ±.16(7)	6.2 ±1.3(2)	1.6 ±0(2)	136 ±10(7)	128 ± 6(2)	105 (1)	27 (1)	28.8 (1)	13.0 (1)	2.7 (1)	1.8 (1)	16 (1)	11.1 ±.8(7)	6.9 ±.3(7)
WWP 3-1	6330R	252 ±12(9)	256 ±31(4)	246 ±15(3)	1.34 ±.19(9)	1.3 ±.09(3)	1.4 ±.1(3)	1.9 ±.13(9)	2.2 ±.76(4)	2.0 ±0(2)	139 ±11(9)	135 ± 7(4)	107 (1)	12.8 (1)	27.2 (1)	13.2 (1)	2.6 (1)	1.8 (1)		10.4 ±1.6(9)	6.7 ±.2(9)

TABLE 1. (continued, 3/3)

Sampling Point Depth to Water	No.	Conductivity, μ mho/cm			Nitrate - N, mg/ℓ			Chloride, mg/ℓ			Hardness as CaCo$_3$		ALK, mg/ℓ as CaCO$_3$	SO$_4$ mg/ℓ	Ca mg/ℓ	Mg mg/ℓ	Na mg/ℓ	K mg/	Zn mg/ℓ	Temp.	pH
		208	IHW	USGS	208	WSU	USGS	208	IHW	USGS	208	IHW									
WHITWORTH 1	6330F	312 ±19(7)	293 ±(1)	312 ±4(3)	1.9 ±.2(7)		2.1 ±.3(3)	3.4 ±.40(7)	2.2 ±(1)	4.5 ±.2(2)	168 ± 6(7)	164 ±(1)								10.7 ±1.3(7)	6.7 ±.3(7)
ARLINGTON SCHOOL 185±3.3'	6328Q	305 ±36(28)	309 ±34(14)	308 ±27(10)	1.8 ±.6(28)	1.7 ±.72(16)	1.7 ±.5(10)	2.8 ±.70(28)	2.7 ±1.06(12)	3.1 ±.7(10)	156 ±15(28)	157 ±22(14)	123 ±13(7)	17.6 ±2.1(8)	28.4 ±4.2(7)	17.7 ±3.2(6)	4.2 ±.52(6)	2.4 ±.14(6)		11.2 ±.6(28)	7.1 ±.3(28)
BENNETT & RAY	6328 P/M	328 ±32(11)	340 ± 7(2)		2.1 ±.5(11)	2.1 ±.53(4)		2.9 ±.95(11)	7.1 ±.8(2)		177 ±13(11)	152 ±28(2)	136 ± 1(2)	18.5 ±7(2)	35.2 ±4.5(2)	21.3 ±1.0(2)	4.0 ±.21(2)	2.6 ±.14(2)	6 ±4.2(2)	10.9 ±1.3(11)	6.9 ±.3(11)
NORTH SPOKANE	6327E	253 ±28(9)	259 (1)	285 ±25(3)	1.33 ±.31(9)	1.1 (1)	1.1 ±.29(3)	3.6 ±1.5(9)	3.2 (1)	4.7 ±1.7(2)	145 ±18(9)	128 (1)								10.8 ±1.0(9)	6.8 ±.2(9)
WWP 3-2	6320N	260 ±13(8)	281 ±11(2)	260 ±11(3)	1.3 ±.20(8)	1.3 ±.04(2)	1.4 ±.06(3)	2.0 ±.32(8)	4.4 ±.4(2)	2.2 ±.14(2)	145 ±11(8)	138 ± 3(2)	111 ± 5(2)	14.4 ± .5(2)	29.6 ±1.3(2)	13.7 ± .6(2)	2.9 ±.35(2)	1.9 ±.07(2)		11.0 ±.5(8)	6.8 ±.3(8)
WHITWORTH 2A	6320D	263 ±27(10)		332 ±10(3)	1.30 ±.33(10)		2.1 ±.2(3)	2.0 ±.78(10)		4.1 ±.3(2)	141 ±15(10)									11.0 ±.7(10)	6.7 ±.3(10)
KAISER MEAD	6316D	338 ±19(9)	365 (1)	334 ±20(3)	1.7 ±.21(9)	1.8 (1)	2.3 ±.52(3)	11.9 ±.95(9)	15.5 (1)	17.5 ±.03(2)	176 ±23(9)	220 (1)	140 (1)	17 (1)	48 (1)	19.5 (1)	7.3 (1)	2.7 (1)		11.1 ±.7(9)	6.8 ±.2(9)
WWP 3-4	6310K	605 ±39(12)	562 ±58(5)	599 ±45(3)	8.9 ±.6(12)	8.7 ±.20(5)	8.6 ±.2(3)	19.0 ±1.0(12)	21.9 ±2.37(5)	19 ±0(2)	305 ±9(12)	306 ±18(5)	219 ± 3(3)	32.3 ±1.8(4)	64.1 ±6.9(3)	34.4 ±1.8(3)	13.0 ±..60(3)	5.5 ±.21(3)	1.3 ±1.5(3)	11.4 ±.6(12)	6.8 ±.2(12)
WWP 3-6	6303P	501 ±143(12)	622 (1)	480 ±175(3)	5.9 ±3.5(12)	4.2 ±4.1(2)	5.5 ±3.5(3)	13.6 ±6.8(12)	17.6 (1)	12.9 ±12.9(2)	252 ±71(12)	260 (1)	202 (1)	22.2 8.8(2)	56 (1)	30.7 (1)	10.8 (1)	5.0 (1)	4.0 (1)	11.4 ±1.2(12)	6.8 ±.2(12)
WWP 3-7	6303N	541 ±84(4)	565 (1)	442 ±176(3)	6.7 ±2.2(4)	7.1 (1)	4.1 ±3.7(3)	17.0 ±2.1(4)	17.4 (1)	12.0 ±11.4(2)	268 ±60(4)	256 (1)								11.3 ±2.1(4)	7.0 ±.4(4)
WWP 3-5	6308B	470 ±88(10)		444 ±170(3)	4.2 ±2.8(10)	2.0 (1)	4.0 ±3.8(3)	13.8 ±3.1(10)		12.7 ±11.8(2)	208 ±60(10)			41						11.9 ±2.2(10)	6.7 ±.35(10)
HIGHWAY DEPT N & S 50±.15' 50±.6'	6305L/P	383 ±64(16)	411 ±73(3)		2.5 ±.6(16)	2.3 ±.73(8)		13.6 ±1.9(16)	14.5 ±2.6(8)		174 ±20(16)	171 ±21(8)	131 ±15(8)	33.3 ±21.4(6)	35.6 ±3.9(8)	18.5 ±3.0(8)	16.1 ±8.3(8)	3.5 ±.6(8)		11.8 ±.3(16)	7.4 ±.1(16)
WANDERMERE SPR.	6305S	474 64(10)	450 77(10)		1.9 ±.14(10)	1.8		13.4 .06(10)	14.1 4.1(10)		229 37(10)	219 38(10)	125 ± 2(3)	67.3 ±2.5(3)	43.0 ±4.9(4)	19.9 ±1.7(3)	15.2 ± .64(3)	3.5 ±.06(3)		11.7 ±.5(10)	6.7 ±.3(10)
OLD CORRAL	6305N	458 11(2)	452 (1)		2.9 ±.1(2)	3.7 .21(2)		18 0(2)	24.6 (1)		185 4(2)	180 (1)								13 ±0(2)	7.4 ±.1(2)
WHITWORTH 3A	6307K	323 ±24(7)	320 (1)	303 ±36(3)	1.9 ±.2(8)	1.8 ±.14(2)	1.8 ±.35(3)	13.4 ±.28(8)	14.1 (1)	3.9 ±1.0(2)	173 ±11(8)	152 (1)								10.8 ±.7(7)	6.7 ±.3(7)
WHITWORTH TEST 110 ± .86'	6307G	362 ±43(26)	344 ±45(21)	371 ±37(7)	2.0 ±.4(24)	2.0 ±.39(21)	2.1 ±.40(7)	2.5 ±.60(24)	3.6 ±1.2(21)	3.1 ±.35(7)	188 ±28(24)	194 ±40(21)	143 ±18(11)	17.5 ±3.2(10)	34.2 ±6.9(11)	19.3 ±2.0(11)	3.6 ±.46(11)	2.6 ±.16(11)		10.4 ±1.1(26)	6.8 ±.3(26)
WAIKIKI SPR	6306S	344 ±27(10)	309 ±31(10)		2.2 ±.4(9)	2.3 ±.37(11)		6.8 ±2.2(9)	8.0 ±2.3(10)		171 ±12(10)	168 ±20(10)	129 ± 3(4)	16.9 ±2.2(5)	32.6 ±1.7(4)	18.1 ± .2(4)	5.0 ±2.67(-)	2.5 ±.29(4)		10.3 ±.7(10)	6.9 ±.2(10)
WHITWORTH 4	6212L	361 ±19(10)		336 ±17(3)	2.6 ±.3(10)		2.5 ±.15(3)	5.2 ±.3(10)		5.6 ±.3(2)	181 ± 4(9)									10.6 ±1.2(10)	6.7 ±.3(10)
GRIFFITH SPR	6211S	366 ±22(11)	335 ±30(10)	340 ±23(3)	2.5 ±.2(11)	2.5 ±.13(10)	2.4 ±.3(3)	5.5 ±.34(11)	7.2 ±2.(10)		182 ± 9(11)	183 ±10(10)	142 ± 5(4)	18.8 ± .9(4)	41.1 ±4.7(4)	18.4 ±1.0(4)	5.3 ±.44(4)	2.6 ±.13(4)		10.4 ±.5(11)	6.8 ±.3(11)
SPOKANE BAXTER	5203H	294 ±31(10)	291 ±42(2)	273 ±25(3)	1.6 ±.2(9)	1.6 ±.08(4)	1.4 ±.25(3)	4.2 ±.42(10)	5.3 ±3.0(2)	3.0 ±.5(2)	152 ±16(10)	156 ± 6(2)								10.9 ±.7(10)	6.7 ±.3(10)
LIVENGOOD	6227N	295 ±22(6)		292 ±8(3)	1.7 ±.2(6)		1.7 ±.06(3)	4.0 ±.14(6)		4.0 ±.2(2)	150 ± 7(6)									11.8 ±1.4(6)	6.8 ±.3(5)
LANDFILL 74 ± 1.0'	6227E	490 ±32(48)	474 ±26(24)	420 ±109(16)	4.0 ±.6(45)	4.0 ±.38(25)	4.0 ±.38(16)	6.5 ±.8(45)	7.6 ±1.5(24)	7.2 ±.6(16)	250 ±22(45)	245 ±13(24)	199 ± 4(9)	27.3 ±2.5(9)	47.5 ±4.8(9)	29.8 ±1.0(10)	7.2 ±1.04(10)	4.7 ±.20(10)	8.6 ±2.0(5)	13.3 ±.4(48)	6.8 ±.3(48)
RIVERSIDE PARK 17 ± .8'	6206H	435 ±50(48)	420 ±40(28)	420 ±55(15)	1.0 ±.4(44)	1.0 ±.45(21)	1.1 ±.58(15)	3.8 ±4.2(44)	6.5 ±6.5(23)	2.5 ±.8(15)	224 ±35(44)	228 ±19(23)	196 ±19(10)	15.5 ±4.2(9)	47.5 ±6.3(10)	25.6 ±2.8(11)	5.5 ±.76(11)	4.2 ±.32(11)	10.6 ±6.4(5)	10.9 ±.8(48)	6.7 ±.3(48)

TABLE 2. CROSS SECTION WATER QUALITY AVERAGES

Cross Section	Conductivity μ mho/cm	TDS[1] mg/ℓ	NO -N mg/ℓ	Cl mg/ℓ
State Line [2]	259	155	0.92	0.79
Greenacres [3]	268	161	1.18	1.11
Dishman [4]	302	184	1.68	3.16
Parkwater [5]	287	173	1.81	2.98
Parkwater-North [6]	260	156	1.17	1.63
North Spokane [7]	282	169	1.59	2.59
Outlet [8]	361	217	2.23	7.20

[1] TDS (total dissolved solids) = 0.60 x conductivity.

[2] State Line concentration = 0.3 x Idaho Trent + 0.3 x Idaho Beck + 0.3 Idaho CID + 0.1 x Highway Dept.

[3] Greenacres concentrations = 0.15 x CID 2/3 + 0.35 x Campbell-Mission + 0.3 x Campbell-Euclid + 0.2 x Gunderson.

[4] Dishman concentration = 0.05 x Edgecliff + 0.3 x Balfour Park + 0.3 x Valley Mission Park + 0.3 x 208 Irvin + 0.05 x Pleasant Prairie.

[5] Parkwater concentration = 0.1 x E. Spokane W.D. + 0.15 x WWP 1-5 + 0.15 x Milwaukee + 0.15 x CPM + 0.25 x SCC + 0.15 x WWP Substation + 0.05 x Old Dairy.

[6] Parkwater - North is an estimate of water quality at Parkwater which flows north under the City to the North Spokane Cross Section. Concentration = 0.1 x Milwaukee + 0.2 x CPM + 0.35 x SCC + 0.25 x WWP Substation + 0.1 x Old Dairy

[7] North Spokane concentration = 0.15 x Whitworth 1 + 0.15 x WWP 3-1 + 0.2 x Spokane Central + 0.15 x Ray/Bennett + 0.2 x Arlington + 0.15 x North Spokane W.D.

[8] Outlet concentration = 0.2 x Griffith Springs + 0.7 x Waikiki Springs + 0.1 x Wandermere Springs.

TABLE 3. CONCENTRATION VARIATIONS WITH DEPTH BELOW THE AQUIFER SURFACE

Sampling Point	Ratio of surface and Depth Readings and Significance of Ratio being > 1.0.		
	Conductivity	Chloride	Nitrate - N
208 Idaho-Trent 6630D	1.041±.046[1] (8), 98% [2]	1.024±.172 (8), 64%	1.127±.162 (8), 97%
208 Idaho-Beck 6525J	1.024±.039 (9), 95%	1.775±1.306 (9), 94%	1.144±.043 (9), 99.99%
208 Idaho-CID 6631N	1.154±.084 (10), 99.99%	1.150±.197 (10), 98%	1.259±.143 (10), 99.99%
Gunderson 6533N	1.021±.026 (5), 93%	1.160±.188 (5), 94%	1.019±.071 (5), 71%
Campbell-Euclid 5505R	1.017±.034 (10), 93%	1.047±.150 (10), 83%	1.049±.048 (10), 99.4%
Campbell-Mission 5508R	1.021±.056 (10), 87%	1.019±.207 (10), 61%	1.090±.167 (10), 94%
CPM-Sullivan Road 5412M	1.057±.083 (5), 90%	1.571±.352[3] (5), 98.9%	.993±.067 (5), <50%
208 Irvin 5409C	1.002±.056 (11), 55%	1.379±.393 (11), 99.5%	1.099±.085 (11,) 99.8%
Valley Mission Park 5409P	1.065±.026 (10), 77%	1.176±.240 (10), 98%	1.130±.043 (10), 99.99%
Balfour Park 5417R	1.265±.148 (10), 99.98%	3.614±2.447 (10), 99.6%	1.437±.275 (10), 99.96%
208 WWP Substation 5311M	Not Significantly Different than 1.0		

TABLE 3. (continued 2/2)

Sampling	Ratio of surface and depth readings and significance of ratio being > 1.0.		
	Conductivity	Chloride	Nitrate - N
208 SCC 5310Q	1.049±.041[4] (11), 99.9%	1.156±.302 (10), 93%	1.043±.057[4] (9), 97%
208 CPM 5314E	Not Significantly Different than 1.0		
Milwaukee [5] 5314K	1.065±.073 (5), 94%	1.080±.081 (5), 95%	1.027±.038 (5), 91%
208 Arlington 6328Q	1.264±.127 (5), 99.5%	1.744±.447 (5), 99.0%	1.849±.223 (5), 99.95%
Whitworth Test Well 6307G	1.209±.052 (8), 99.99%	1.353±.400 (7), 97%	1.241±.190 (8), 99.6%
Highway Dept. Wells 6305L & P	1.440±.181 (4), 99.2%	1.292±.291 (4), 93%	1.767±.448 (4), 98%
208 Landfill 6227E	1.138±.042 (10), 99.99%	1.223±.107 (11), 99.99%	1.174±.106 (11), 99.98%

[1] Mean ± standard deviation of ratio of surface (or near surface) concentration to concentration at 40 to 50 ft. below surface (or deepest point for shallow wells).

[2] Number of samples and statistical (t test) significance level at which mean ratio is greater than 1.0.

[3] Ratio between surface and -12 ft. Ratio between -12 ft. and -40 ft. was 0.34±.10 which is significantly less than 1.0 at the 99.99% level.

[4] Ratio between surface and -22 ft. Ratios between -22 ft. and -50 ft. showed a continued gradient with Conductivity = 1.106±.070 and Nitrate N = 1.125±.102. The ratios are significantly greater than 1.0 at the 99.95% and 99.8% levels respectively.

[5] The Milwaukee well perforations did not extend up to the aquifer water surface until it was reperforated in February 1978.

TABLE 4. HEAVY METALS CONCENTRATIONS IN AQUIFER WATERS

Heavy Metal	Drinking Water Regulation [6]		Detectable Limit		Comments
	µg/ℓ	No. Equal or Exceeding	µg/ℓ	No. Equal or Exceeding	
Arsenic (As)	50	0	10	1	Riverside Park (10 µg/ℓ 7 N.D.)
Barium (Ba)	1000	0	100	2	Jeffers (100 µg/ℓ, Riverside Park (100 µg/ℓ, 7 N.D.)
Cadmium (Cd)	10	10	1	24	See Note 1
Chromium (Cr)	50	1	10	5	See Note 2
Copper (Cu)			10	8	WWP Substation (60 µg/ℓ, 6 N.D.) WWP 3-2 (80 µg/ℓ, 1 N.D.); 6 samples ≤ 30 µg/ℓ.
Lead (Pb)	50	0	10	1	Hutton Settlement (10 µg/ℓ, 1 N.D.)
Manganese (Mn)			10	34	5 samples from WWP Substation, Balfour Park, Campbell-Mission, Riverside Park (2) exceeded 50 µg/ℓ.
Mercury (Hg)	2	5	0.5	21	See Note 3
Selenium (Se)	10	3	10	3	Valley Mission Park (10 µg/ℓ, 9 N.D.) Campbell-Euclid (20 µg/ℓ, 6 N.D.), 208 Landfill (10 µg/ℓ, 6 N.D.)
Silver (Ag)	50	0	1	1	Valley Mission Park (1 µg/ℓ, 9 N.D.)
Zinc (Zn)			1	115	See Table 1.

Notes

1. Cadmium positive readings were all obtained during 2 sampling periods except one sample. Eleven samples ranged from 5 to 7 µg/ℓ - all were collected from 3/21 to 3/30, 1978. Twelve samples ranged from 9 to 14 µg/ℓ - all were collected from 5/1 to 5/15, 1978. These results appear to indicate faulty analytical procedure. One sample (E. Spo. W. D.) was 1 µg/ℓ on 12/12/77.

2. Balfour Park - 70 µg/ℓ (8/77), 6 samples not detectable (N.D.) (5, 7/77 & 3, 5/78); Campbell-Mission - 1 @ 10 µg/ℓ, 1 @ 20 µg/ℓ (8, 9/77), 6 N.D. (7, 12/77 & 2, 3, 5/78); Milwaukee and Riverside Park - 1 ea @ 10 µg/ℓ (3 and 7 N.D. respectively).

3. Mercury results exceeding drinking water limits occured at: SCC (4.9 µg/ℓ, 1 @ 1.9 µg/ℓ, 1 @ 0.5 µg/ℓ, 6 N.D.); Jeffers (4 µg/ℓ); WWP 3-2 (4, 2 µg/ℓ, 1 N.D.); Hutton Settlement (2.5 µg/ℓ, 1 N.D.); Riverside Park (3 µg/ℓ, 1 @ 5 µg/ℓ, 6 N.D.). Results exceeding detectable limits but not drinking water limits occured at: WWP Substation (1 of 7); Orchard 1 (1 of 1); E. Spo. W. D. (1 of 1); 208 Irvin (1 of 7); Valley Mission Park (3 of 7); CPM Sullivan (1 of 4); Balfour Park (1 of 7); Campbell-Euclid (1 of 7); Campbell-Mission (1 of 8); Idaho-Beck (1 of 11); Gunderson (1 of 4).

TABLE 5. HISTORICAL WATER QUALITY SUMMARY - SPOKANE-RATHDRUM AQUIFER

WELL LOCATION	DATE	COND.	NO_3-N	CL	HARD.	SO_4	NA	REF.
6536E	5/42	271	.4	1	153	15	3.1	(2)
6631M (CID 11)	10/64	253	.43	.2	166	10.5		(3)
East Farms	11/64		1.6	2.0	142	10.7		(10)
	6/65		2.0	3.5	14.2	12.6		(10)
	12/65		2.1	2.0	144	9.6		(10)
	5/66		1.8	2.5	144	10.8		(10)
	11/66		1.5	2.0	144	9.6		(10)
	5/70	232	.37	2.5	100	14	2.8	(3)
	10/71-9/72(12)	240 ±11	.82 ±.48	2.6 ±1.4	138 ±22	18.6 ±6.0	3.2 ±.67	(3)
6536N & A	6,9, 12/73	288 ±14(6)	.87 ±.15(6)	1.5 ±.5(6)	147 ±8(6)	12.7 ±1.0(6)	2.9 ±1.2(6)	(4)
6631M (CID 11)	3/75	215	1.0	1.5	116	11	2.8	(3)
6631N (208 ID.CID)	6/77-6/78	284 24(47)	1.26 .24(21)	1.1 .2(42)	155 16(47)	12.2 1.3(7)	2.6 .33(10)	(8)
<u>Gunderson & CID 7 & 8 Area</u>								
5504A (Otis Orch)	6/51	297	1.2	1	153	16	3.0	(2)
5505H	1/55	272	.7	.7	124	8.2	3.2	(3)
6534L (CID 7)	4/71	240	.3	.25	124	26	3.4	(3)
5504C (CID 6)	4/71	240	.2	.75	152	27.8	2.9	(3)
5503F (CID 8)	4/71	296	.3	.75	152	22.5	3.1	(3)
6535F (CID 10)	6,9/73(2)	277 ±1	.45 ±.02	1 ±0	140 ±0	13.5 ±.7	2.7 ±.4	(4)
5504D (CID 6)	6/74	259	< .5	1.1	140			(9)
5504C (CID 6)	6/75	242	.2		130	11.4	3.2	(3)
5503 (CID 8)	6/75	289	.2	.1	160	16.4	3.1	(3)
6534L (CID 7)	8/75	236	.2	0	130	10	3.1	(3)
6535F (CID 10)	3,10/77(2)	263 ±11	.66 ±.05	.7 ±0	140 ± 0	13 ±1	2.3 ±.6	(3)
6533N (Gunderson)	2-6/78	337 ±16	1.7 ±.2	1.3 ±.2	168 ±10	10.1 ±1.2	3.7 ±.1	(8)
5505R (Campbell-Euclid)	7/77-6/78	352 ± 9	1.3 ±.1	1.1 ±.1	188 ± 8	15.2 ±1.3	2.7 ±.4	(8)
<u>Holiday Hills Area</u>								
5515D (Holiday Hills)	7/71-9/72(16)	238 ±24	1.9 ±.8	4.1 ±2.2	139 ±28	14.2 ±6.0	5.5 ±.8	(3)
	6/73-3/74(4)	258 ±11	1.9 ±.7	2.4 ±.15	120 ± 0	10.5 ±1.7	4.3 ±.3	(4)
	7/75	243	2.0	2.5	128	9.5	3.4	(3)
	3/77	230	3.3	3.1	130	14	4.3	(5)

TABLE 5. (continued 2/7)

WELL LOCATION	DATE	COND.	NO_3-N	CL	HARD.	SO_4	NA	REF.
	5/77, 5/78(2)	242 ±2	2.0 ±.7	2.2	146			(7)
	11/77-6/78(6)	250 ±6	2.8 ±.4	2.6 ±.4	29			(8)
5518R (CID 2)	5/70	150	.76	0	60	7	2.4	(6)
	9/71-9/72(13)	171	1.0	3.5	99	16.0	2.7	(3)
	6/74	170	1.2	.5	88	7.3	2.5	(3)
	3/75	170	1.5	1.5	84	8.8	2.9	(3)
	6/77-3/78(7)	164 ±11	.89 ±.11	.9 ±.2	94 ±12			(8)
	5,10/77, 5,78(3)	147 ±24	.94 ±.06	.9 ±.1				(7)
CID 4 - Campbell-Mission								
5518A (Rest.)	5/41	172	.5	1	94	10	2.2	(2)
5517D (CID 4)	10/70	180	.2	.3	94	12.3	2.1	(3)
5518A	4/71	188	1.4	.5	100	14	2.8	(3)
5517D	3/75	186	.1	3	92	17	1.8	(7)
	5,10/77, 5,78(3)	171 ±16	.8 ±.01	1.0 ± 0				(7)
5508R (Camp. Miss.)	7/77-6/78	196 ±7(46)	.86 ±.09(30)	.9 ±.2(45)	103 ±11(45)	10.3 ±1.0(11)	2.0 ±.3(13)	(8)
5426L	6/51	261		3.4	159			(6)
	11/60	280	.1		170	6		(3)
	3/64	320	5.1	3.0	166	12	12	(6)
	10/64	326	9.6	2.2	192	12		(3)
	11/70		3.7	3.0		18	6.2	(3)
	8/71-9/72(14)	331 ±43	2.8 ±2.4	4.5 ±2.9	191 ±35	21.3 ±5.2	6.3 ±1.0	(3)
	9/74	438	2.0	6.4	180	32	4.0	(3)
	5,10/77, 5,78(3)	350 ±36	2.7 ±.2	3.5 ±.3				(7)
	6/77-5/78	404 ±34	2.9 ±.3	3.3 ±.4	207 ±13	13 ±1.4	6.0 ±0.5	(8)
Modern 1								
5415M	5/70	249	.99	0	108	12	2.2	(3)
	9/71-9/72(12)	269 ±36	1.12 ±.60	4.9 ±3.5	148 ±17	20.1 ±4.6	3.3 ±.7	(3)
	3-7/75(3)	268 ± 7	1.8 ±1.7	2.5 ±1.0	147 ±17	15.2 ± .7	1.9 ±.6	(3)
	6/77-5/78	273 ±16(11)	1.2 ±.2(11)	1.0 ±.3(11)	160 ±11(11)	16 ±1.4(2)	2.5 ±.1(2)	(8)

TABLE 5. (continued 3/7)

WELL LOCATION	DATE	COND.	NO_3-N	CL	HARD.	SO_4	NA	REF.
	5,10/77, 5/78(3)	267 ±42	1.2 ±.1	1.2				(7)
Industrial Park								
5401J (Ind.Pk. 2)	Prior to 1951	271		.5	136	27		(2)
5401M (Ind.Pk. 1)	Prior to 1951	296		.5	146	19		(2)
5401J	6/51	227		3.3				(11) (11)
5401M	6/51	222		2.8				(11)
5401J	1/55	278	.44	.4	128	8.2	4.6	(3)
5401J&M	10/60(2)	245 ±5	.3 ±0	.5 ±0	147 ± 2	7.2 ±.2		(3)
5401J&M	11/70(2)	264 ±23	.6 ±.3	.5	149 ± 1	5.3 ±.2	3.3 ± 0	(3)
5401M	6/11/71(2)	265	1.4	3.8	148	8.7	4	(3)
5401J	5/73-3/74(4)	300 ±18	1.1 ±.7	1.3 ±.5	148 ±10	10.8 ± .5	3.5 ±.4	(5)
5401J,M,Q	5/75(3)	303 ±18	1.3 ±.7	3.3 ±.5	173 ±36	19.7 ±4.7	2.6 ±.4	(3)
5401Q (Ind. Pk. 4)	3,10/77(2)	296 ± 2	.9 ±.02	.9 ±.06	150 ± 0	13.5 ±2.1	2.6 ±.5	(5)
5401Q	6/77-5/78(8)	288 ±23	1.00 ±.13	.8 ±.2	169 ±12			(8)
5401Q	5,10/77,5/78(3)	290 ±10	1.0 ±.2	1.0 ±.1				(7)
5412D(Ind. Pk. 3)	6/77-5/78(9)	290 ±28	1.04 ±.14	.9 ±.2	166 ± 5			(8)
5412D	5,10/77,5/78(3)	298 ±20	1.1 ±.1	1.2 ± 0				(7)
Kaiser Eastgate								
5402Q	6/34			177				(3)
	4/71	380	4.7	23	156	17.6	14.2	(3)
	6/73-3/74(4)	401 ±127	3.0 ±1.8	18.5 ±27.7	165 ±19	12.5 ±2.4	12.4 ±14.4	(4)
	6/74	767	.01	130	228			(9)
	3,10/77	310	1.1	2.0	145	13	3.3	(5)
	6/77-5/78(10)	399 ±91	3.5 ±1.5	21 ±21	181 ±25			(8)
Orchard Ave. City Parkwater Area								
Spokane Upriver	1931	270		2.4		16.6	7.0	(10)
Spokane Upriver	1932	250						(10)
Spokane Wells	1936	263	1.3	5	140	12.7	4	(1)
Orchard Ave. Irr. Dist.	1937	279	4.0	2	138	12	6	(1)
5311G Spo Parkwater	12/38	269	0.7	2.6	157	13	2.5	(2)
Spokane Upriver	1941	260		3.5	146	122		(10)

TABLE 5. (continued 4/7)

WELL LOCATION	DATE	COND.	NO_3-N	CL	HARD.	SO_4	NA	REF.
Parkwater	1941	284		10	144	15		(1)
Spokane Upriver	1943	270		2.5	147	16.6		(10)
Spokane Upriver	1944	270		2.8	145	18.4	8.2	(10)
Spokane Upriver	1945	270		2.1	144	10.9	4.8	(10)
Spokane Composite	1946	283		10	144	15		(1)
Spokane Upriver	1948	280		3.2	139	17.9	12.7	(10)
5311G Spo Parkwater	1/49	290	0.1	3.5	142	8.4	6.7	(2)
5312H (Orchard 1)	6/51	253		2.9	156			(6)
Spokane Upriver	6/51	236		3.0	140			(11)
Spokane Upriver	1951	310		2.0	143	12.6	4.1	(10)
Spokane Upriver	1953	290		2.1	142	12.0	4.2	(10)
Spokane Upriver	1955	290		2.4	144	13.2		(10)
5311 Spo Parkwater	5/57	260	0.6	1.2	140	12.3	3.8	(10)
5311 Spo Parkwater	6/59	320	0.5	2.5	150	13	4.9	(10)
Spokane Upriver	7/61	293	1.0	1.8	150	14.5	2.9	(11)
Spokane Upriver	11/61	279		1.5	152	9.9	2.3	(11)
5311 Spo Parkwater	11/64		.8	2.5	150	10.9		(10)
5311 Spo Parkwater	6/65		2.1	3.5	150	13.4		(10)
5311 Spo Parkwater	12/65		2.2	2.0	150	12.6		(10)
" "	5/66		2.0	2.5	144	10.8		(10)
" "	11/66		0.9	2.0	150	15.9		(10)
" "	6/67		0.7	2.0	144	14.0		(10)
5407C (Orchard 2)	5/70	284	1.1	4.5	120	19.1	3.6	(3)
5418D (WWP 1-4)	9/70	260	1.2	3	132	16.7	3.9	(3)
5311 (Spo 2 wells)	4/71	280	1.6	2.8	150	21	3.7	(3)
5312H (Orchard 1)	4/71	296	1.8	2.2	154	19	4.4	(3)
5313A (WWP 1-3)	7/71	260	1.1	2.2	124	13	3.2	(3)
5312H (Orchard 1)	9/71-9/72(13)	309 ±23	1.2 ±.3	4.9 ±3.1	192 ±63	22.8 ±6.9	5.2 ±1.3	(3)
5407C (Orchard 2)	6/73-3/74(4)	313 ±7	1.0 ±.2	2 ±0	158 ± 5	15.5 ± .6	3.5 ±.6	(4)
5313A (WWP 1-3)	6/73-3/74(4)	266 ± 4	0.9 ±.1	1.8 ±.5	135 ± 6	12.5 ± .6	3.0 ±.2	(4)
5418D (WWP 1-4)	6/73-12/73(3)	277 ± 6	1.1 ±.1	2.3 ±.6	137 ± 6	13 ±1	3.5 ±.4	(4)
5311 (Spokane)	5,8/75(2)	310 ±10	1.4 ±1.0	9 ±5	166 ± 9	10 ±7	2.0 ±.6	(3)
5312H (Orchard 1)	7/75	320	.6	4.5	160	17.6	1.8	(3)
5407C (Orchard 2)	7/75	306	.5	3	172	17.8	1.2	(3)

TABLE 5. (continued 5/7)

WELL LOCATION	DATE	COND.	NO_3-N	CL	HARD.	SO_4	NA	REF.
5313A (WWP 1-3)	7/75	249	1.1	2	166	13.8	3.2	(3)
5418D (WWP 1-4)	7/75	261	1.3	2.3	172	12.6	3.6	(3)
5407C (Orchard 2)	10/77	309	1.1	2.0	160	18	3.3	(5)
5313A (WWP 1-3)	3,10/77(2)	260 ± 8	1.3 ±.1	1.9 ±.1	140 ± 0	14 ±3	2.9 ±.2	(5)
5418D (WWP 1-4)	3,10/77(2)	273 ± 9	1.0 ±.1	1.8 ±.1	145 ± 7	14 ±7	3.1 ±.4	(5)
5312H (Orchard 1)	5,10/77,5/78(3)	333 ±23	1.3 ±.3	2.0 ±.2				(7)
5312H (Orchard 1)	6/77-5/78(8)	321 ±21	1.5 ±.2	2.4 ±.5	147 ±10	14.5	3.8	(8)
5407C (Orchard 2)	6/77-5/78(9)	307 ±14	1.3 ±.2	1.9 ±.4	172 ±13			(8)
5313A (WWP 1-3)	5,10/77,5/78(3)	244 ±24	1.2 ±.2	1.8 ±.6				(7)
5313A (WWP 1-3)	6/77-5/78(11)	255 ±12	1.3 ±.2	1.7 ±.3	141 ± 7			(8)
5418D (WWP 1-4)	5,10/77,5/78(3)	266	1.4	1.7				(7)
5418D (WWP 1-4)	6/77-5/78(10)	264 ±14	1.3 ±.2	1.6 ±.2	148 ±11			(8)
Edgecliff-Dishman								
Dishman	1944	312		3	146	10	2	(1)
5419C (Dishman)	4/71	400	4.6	11	170	17.4	8.4	(3)
5419D (Edgecliff)	4/71	300	3.7	10	188	15.3	6.5	(3)
5419D (Edgecliff)	6/73-3/74(4)	382 ±12	2.7 ±.3	7.5 ±2.4	185 ± 6	13.3 ±1.0	6.3 ±.5	(4)
5419C (Dishman)	9/75	421	3.6	8.8	200	19.7	8.2	(3)
5419D (Edgecliff)	9/75	378	3.6	7	180	13.8	7.3	(3)
5419D (Edgecliff)	3/77	380	3.7	8.3	190	15	8.6	(5)
5419D (Edgecliff)	6/77-5/78(10)	401 ±12	3.7 ±.5	9.3 ±1.7	199 ± 8			(8)
5419C (Dishman)	2-5/78(4)	437 ±11	4.8 ±.4	10.1 ± .4	235 ±20			(8)
Spokane Ray								
5322L (Ray)	10/45		.46	7.4	147	22	14	(2)
	6/51	294		6.0	166			
	11/64		2.0	2.6	152	11.8		(10)
	6/65		2.1	5.5	150	12.1		(10)
	12/65		2.2	5.5	150	13.4		(10)
	5/66		2.4	3.5	142	10.5		(10)

TABLE 5. (continued 6/7)

WELL LOCATION	DATE	COND.	NO_3-N	CL	HARD.	SO_4	NA	REF.
5322L (Ray)	11/66		1.7	3.0	150	13.7		(10)
	6/67		0.7	2.0	148	12.4		(10)
	9/71	340	2.7	11.5	212	16.3	8.2	(3)
	6/74	348	2.8	7.0	178			(9)
	5/75	381	1.8	10	212	18.4	6.6	(3)
	5,10/77, 5/78(3)	370 ±24	4.0 ±.3	8.2 ±.8				(7)
	6/77-5/78(10)	406 ±33	4.0 ±.3	8.0 ±1.1	195 ±15	17.5		(8)
Inland Empire Ice Company								
5213B (Icehouse)	5/42	288	1.6	5.2	138	13	6.4	(2)
	1/48			7.1	146	23		(11)
	6/73-3/74(4)	367 ±38	1.5 ±.2	17.3 ±7.9	165 ±13	17.5 ±2.4	8.5 ±2.1	(4)
	6/74	353	1.1	22.5	164			(9)
	3,10/77(2)	312 ±23	2.2 ±.3	12.9 ±5.1	150 ± 0	17.5 ±2.1	8.3 ±.4	(5)
	5,10/77,5/78(3)	354 ±40	2.2 ±.2	14.0 ± 0				(7)
5213B (Icehouse)	6/77-6/78(10)	331 ±31	2.1 ±.3	14.3 ±6.1	165 ±10			(8)
Spokane Hoffman								
5304B	9/44		.2	2.5	140	16	1.0	(2)
	6/51	245		3.5				(2)
	11/64		1.4	2.8	152	12.2		(10)
	6/65		2.5	3.0	140	13.8		(10)
	5/66		1.9	2.0	140	11.6		(10)
	6/67		0.9	2.0	144	13.6		(10)
	9/71	26	.8	19.5	124	11.9	3.4	(3)
	6/74	291	1.1	2.0	154			(9)
	5/75	285	.6	3	160	14.7	3.3	(3)
	6/77-5/78(10)	292 ±26	1.4 ±.4	2.3 ±.7	154 ±16	13		(8)
N. Spokane W.D.								
6327E	6/51	219		2.9	130			(11)
	6/51	248	.9	2.3	111	11	2.6	(2)
	11/70	260	11.0	2.5	134	15.3	5.7	(3)
	8/71	236	1.8	1.5	112	11.0	5.4	(11)

TABLE 5. (continued 7/7)

WELL LOCATION	DATE	COND.	NO_3-N	CL	HARD.	SO_4	NA	REF.
6327E	6/74	252	1.5	4.0	136			(3)
	5,10/77,5/78(3)	285 ±25	1.4 ±.3	4.7 ±1.7				(9)
	6/77-5/78(9)	253 ±28	1.1 ±.5	3.6 ±1.5	145 ±18			(8)

REFERENCES:

(1) Chemical Analyses of Waters of the State of WA - WA State Department of Health, 1949
(2) Weigle, J.M. and M.J. Mundorff. Records of wells, water levels and quality of groundwater in the Spokane Valley, Washington, U.S. Geological Survey, 1952.
(3) State Health Department Lab Report on file with Spokane County Health District
(4) EPA Groundwater Monitoring Spokane Valley, Washington, 1974
(5) EPA Results of U.S.G.S. Groundwater Monitoring, 1977
(6) Drost, B.W. and H.R. Seitz. Spokane Valley Rathdrum Prairie Aquifer - Washington and Idaho. U.S.G.S. Open File Report 77-829
(7) U.S.G. Groundwater Data for Spokane County 208 Study
(8) Spokane County 208 Study Data
(9) Corps of Engineers Spokane Metropolitan Water Resources Study
(10) City of Spokane Historical Records
(11) U.S.G.S. Historical Records

NOTES: ( ) Following date or std. deviation contains number of samples

± Shows standard deviation

Some historical conductivities were obtained as 1.67 times Total Dissolved Solids.

PLATES

TECHNICAL ADVISORY COMMITTEE
(TAC)

Robert S. Turner, Chairman
Spokane County Engineer

Roger James/John Bjork
City Utilities Department

E. Terry Clegg/Keith Thackray
City Plan Commission

Fred Dayharsh/Tom Mosher
Spokane County Planning Commission

Mayor W.L. Clearwaters, Citizen Representatives Core Chairman
Millwood Town Hall

Ed Pickett, Director of Environmental Health
Spokane County Health District

James Trull, Manager
Consolidated Irrigation District

Tom Justus, P.E., District Engineer
Department of Social & Health Services

Jud Melton/Eugene Andreucetti
Soil Conservation Service

Larry Petersen/Jon Arnquist/Rhys Sterli
Department of Ecology

COORDINATING REPRESENTATIVES

Jose Urcia, Director
Regional Planning Conference

Jack Ross
Panhandle Health Dist. I

Larry Belmont
Panhandle Health Dist. I

Roy Olson
Panhandle Health Dist. I

CITIZEN REPRESENTATIVES CORE COMMITTEE (CRC)

Chairman, Mayor W.L. Clearwaters

Vice Chairman, Margaret Fellows

Second Vice Chairman, H. Allen Lewis

Chet Arnold
Board of Realtors

John Aukofer
Citizen

Pansy Baker
Citizen

Rich Bakes
Spokane Chamber

Bradley Bale, M.D.
Spokane Medical Society

Dick Barrett
City Plan Commission

Bruce Blackmer
Amer. Inst. Architects

Ellwood Carlson
Home Builders Assoc.

John Chervenell
Transportation

W.L. Clearwaters, Mayor
City of Millwood

Vern Connerley (resigned)
Citizen

Tony Danelo
Water Purveyors

Leslie Dill
Sand and Gravel

Patrick Downey
Citizen

Wick Dufford
Legal

Jim L. Ellis
WA Assoc. Engineers

Karl B. Emery
Int. Grass Growers

Stan Fahlgren
Citizen

Margaret Fellows
League of Women Voters

Gerald Greeley
Local Union

Morey Haggin
Audobon Society

Marion Hay
Industry

Fred Hobbs
Sand and Gravel

Phyllis Lamb
Citizen

Bruce Lang
Education

John Leopard
Env. Council WA

H. Allen Lewis
Citizen

Ted McCoury
Comp. Plan Co-ord.

Dr. Edwin Olson
Education

Don Pedersen
Valley Chamber

Clarence Pence
Co. Health District

Robert Price
Quality of Life

Grace Rawlings
Citizen

Hazel Richard (resigned)
Citizen

Lonnie Roe
Industry

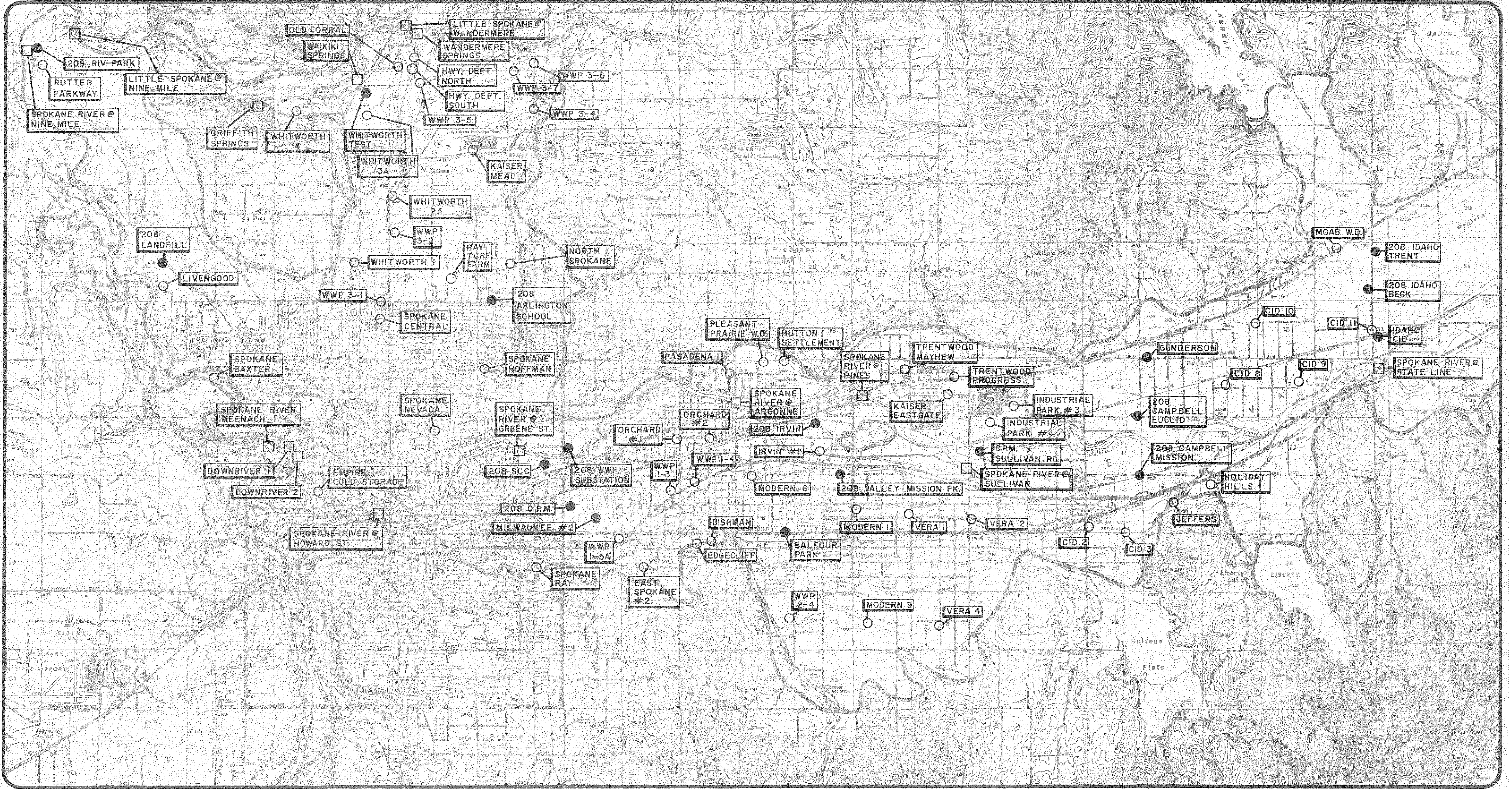
Francis J. Schadegg
Urban Planning

Ray Soltero
Education

Eldon Thomas
Co. Planning Commission

Jean Wall
AAUW

SAMPLING POINT LOCATION MAP



LEGEND:

— AQUIFER BOUNDARY

● DEPTH SELECTIVE SAMPLING WELL

○ PRIVATE OR PURVEYOR WELL

□ SURFACE SAMPLING POINT

SPOKANE COUNTY
WATER QUALITY
MANAGEMENT PROGRAM
(GROUND DISPOSAL)

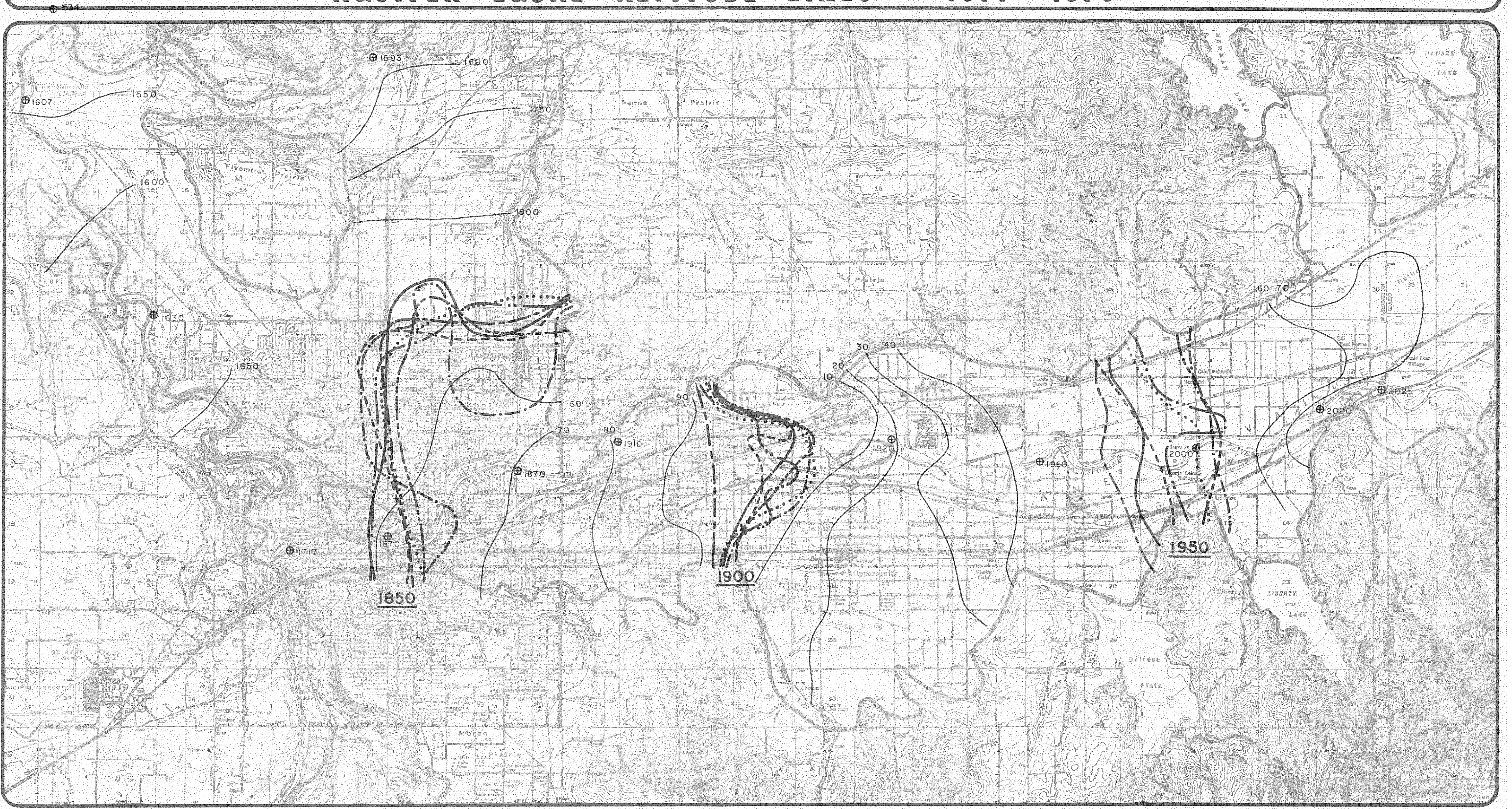
N

0 1 2
SCALE

PLATE

1

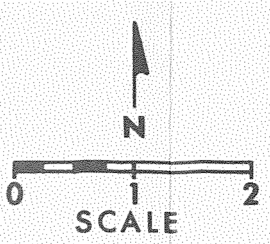
AQUIFER EQUAL ALTITUDE LINES 1977-1978



LEGEND:

— AQUIFER BOUNDARY
— — MAY 1978
═ MARCH 1978
- - - - JANUARY 1978
— — — OCTOBER 1977
— · — · JULY 1977
· · · · · · · · · MAY 1977
— · · — MARCH 1977
⊕ RIVER: SURFACE ELEVATION

SPOKANE COUNTY
WATER QUALITY
MANAGEMENT PROGRAM
(GROUND DISPOSAL)



PLATE

2