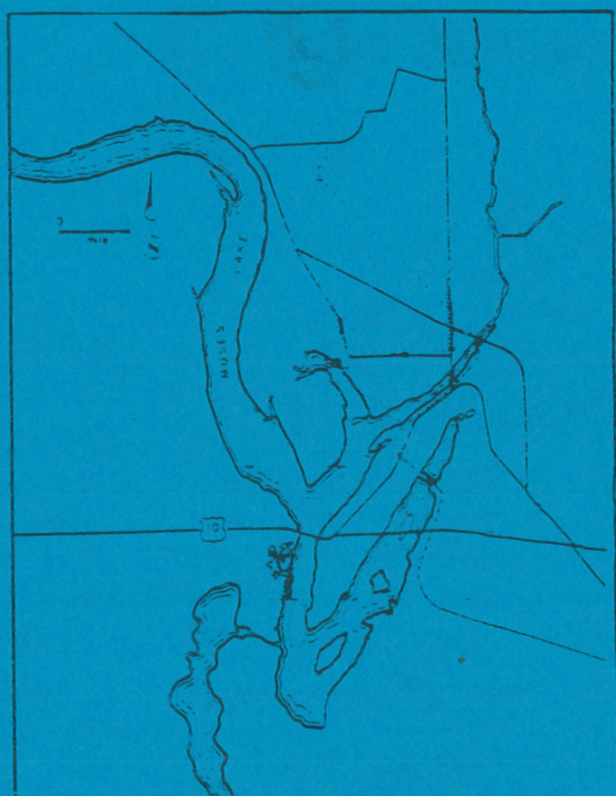
MOSES LAKE AREA

WATER QUALITY MONITORING REPORT
(1997)

Prepared for

MOSES LAKE IRRIGATION AND REHABILITATION DISTRICT



August 1998

RICHARD C. BAIN Jr. CONSULTING ENGINEER
ELLENSBURG, WASHINGTON

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INTRODUCTION

The Moses Lake Irrigation and Rehabilitation District authorized water quality monitoring within Moses Lake, its tributaries and selected shallow groundwater wells and springs in the surrounding area in March of 1997. The monitoring program was designed to cover the spring, summer and autumn of 1997.

There were a total of 19 monitoring locations of which eleven were sampled on a regular basis. Most of these stations were sampled in a previous monitoring project during the 1991 water year. Many of the stations were also monitored as part of the Moses Lake Clean Lake Project or as part of a series of investigations carried out by University of Washington graduate students working under the supervision of Professor Eugene B. Welch. The previous Moses Lake Clean Lake monitoring programs covered watershed stations for the 1982-83 and 1986-87 water years. The University of Washington studies generally covered the period 1977 through 1988 and were principally focused on the quality of Moses Lake itself although information was obtained from the tributaries and from one spring. Additionally a special monitoring program was carried out by Brown and Caldwell, consulting engineers in 1977 which provided data from many of the same locations covered by the University studies.

Moses Lake and its watershed lands have been the subject of four major water quality control projects since 1977. These include a series of major dilution water releases from the U.S. Bureau of Reclamation East Low Canal made during most years since 1977, elimination of direct sewage effluent discharge from the City of Moses Lake to the Lake in 1979, a major nonpoint pollution source control program known as the Moses Lake Clean Lake Project which took place in the late 1980's and a Moses Lake area monitoring project in 1991-1992. These water quality programs provide information on nutrient concentrations and loadings to Moses Lake and focus on ways to improve water clarity and generally reduce nuisance algae growths, including floating scums of blue green algae.

Moses Lake Area Background

Moses Lake itself is a shallow warm water lake covering an area of approximately 6800 acres (10.6 square miles). The watershed tributary to Moses Lake encompasses approximately 2,450 square miles, principally within the Crab Creek drainage. The lake and adjacent watershed lands are shown on Figure 1. Physical characteristics of Moses Lake are provided in Table 1.

Table 1 Physical Characteristics of Moses Lake, Washington[1]	
Surface Area	6,800 acres
Maximum depth	38 feet
Mean depth	18.5 feet
Volume	126,000 acre-feet
Total length	20.5 miles
Parker Horn	
Mean depth	12.6 feet
Area	758 acres
Volume	9,520 acre-feet
Pelican Horn	
Mean depth	15.6 feet
Area	1,600 acres
Volume	25,000 acre-feet

The City of Moses Lake and adjacent urban areas occupy much of the south eastern shoreline including areas within the lake known as Parker Horn and Pelican Horn. Crab Creek waters enter the lake at the upper end of Parker Horn; USBR dilution water releases from the East Low Canal enter Crab Creek via Rocky Coulee Wasteway approximately one mile north of Parker Horn. A portion of the diluted water within Parker Horn is pumped across a narrow peninsula to Pelican Horn in order to dilute nutrients and improve local water quality. In years past a City of Moses Lake sewage effluent discharge occurred in Pelican Horn.

The northern or main arm of Moses Lake is fed by a small spring fed tributary known as Rocky Ford Creek. See upper left hand corner of Figure 1. In 1987 a small dam was constructed at the lower end of Rocky Ford Creek as part of the Moses Lake Clean Lake Project. This dam was designed to prevent upstream migration of carp into the creek system as part of a program to enhance water quality within the creek and Moses Lake. High phosphorus concentrations were associated with the Rocky Ford Creek system due to springs and aggravated by carp activity within the creek. The carp barrier provided a detention pond and made subsequent rehabilitation of the creek feasible. Carp had eroded the banks and uprooted vegetation within the creek. Carp remaining in the Creek were eradicated by the Department of Wildlife and a trout fishery was established. During 1996 stop logs were removed by vandals which compromised the structures water quality control features by lowering the detention pond water surface and allowing carp to migrate upstream into Rocky Ford Creek. The State Department of Fisheries and Wildlife has been contacted and plans to repair the structure and rehabilitate Rocky Ford Creek during 1998.

[1] Sylvester and Oglesby, 1964, based on a lake water surface elevation of 1046.

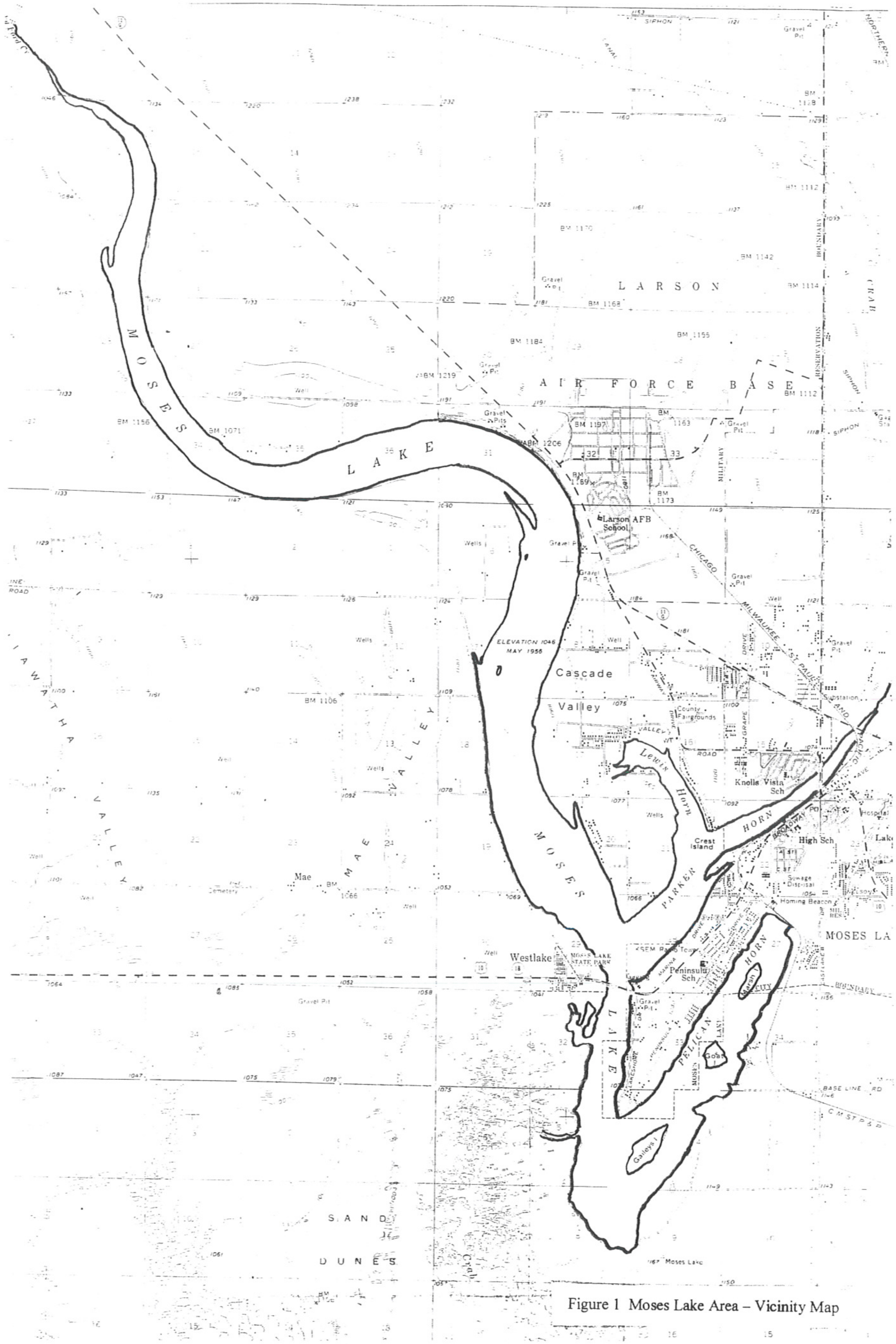

Figure 1 Moses Lake Area – Vicinity Map

The Moses Lake Clean Lake Project also focused on nitrogen sources, particularly the deep percolation of nitrates from irrigation of agricultural lands within Blocks 40 and 41 of the USBR Columbia Basin Project. The project provided on-farm assistance to local irrigators which included cost share assistance for irrigation system upgrades and for irrigation water management programs. These major on-farm activities resulted in funding of improvements on 366 farms and directly involved 5,346 acres. Subsequent project spin-offs occurred approximately 7350 acres by the 1989 irrigation season. Nutrient loss savings and overall benefits of the Clean Lake Program were summarized in a March 1990 Final Report.

Moses Lake Area Groundwater

The geology and groundwaters of the Columbia Basin Project area have been described by the U.S. Geological Survey (USGS) and State Department of Natural Resources (DNR), Division of Geology and Earth Resources. The USGS published generalized maps of basalt surface contours and groundwater gradients which are useful in evaluating groundwater movement in the vicinity of Moses Lake[2].

Recharge for both the unconsolidated aquifers and the basalt aquifer is primarily from irrigation. Groundwater discharge areas are Rocky Ford Creek, Moses Lake and Crab Creek. The recharge to the Rocky Ford stream area comes from the northwest (Ephrata), and north (Soap Lake), and the northeast (Adrian). Recharge to the portion of Crab Creek between Adrian and Moses Lake is primarily from the east and northeast. Direct groundwater recharge to Moses Lake is from both east and west.

Typical ground water gradients in the Moses Lake area are shown in Figure 2. These gradients are based on data from the U.S. Geological Surveys provided to the U.S. Bureau of Reclamation.

Directions of groundwater movement can be inferred from the gradients shown on Figure 2. The gradients toward Moses Lake are quite clear. Groundwater from the watershed is assumed to flow into Moses Lake directly or through the many springs that are found along Crab Creek and Rocky Ford Creek.

Purpose of the 1997 Monitoring Program

The 1997 Water Quality Monitoring Program was carried out to provide comparative data as well as additional background information on the water quality of Moses Lake and its tributary sources of nutrients, including groundwater seepage. Data from the 1997 monitoring program were collected so direct comparisons could be made with data collected in previous years at the same locations. Other factors including weather (e.g. aspects such as temperature) and lake operations were also to be considered in the analysis.

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[2] Walters, K. and Grolier, M. 1960. Geology and Ground Water Resources of the Columbia Basin Project Area, Washington Vol. 1, Water Supply Bulletin No. 8, Prepared by the State of Washington in Cooperation with U.S. Geological Survey.

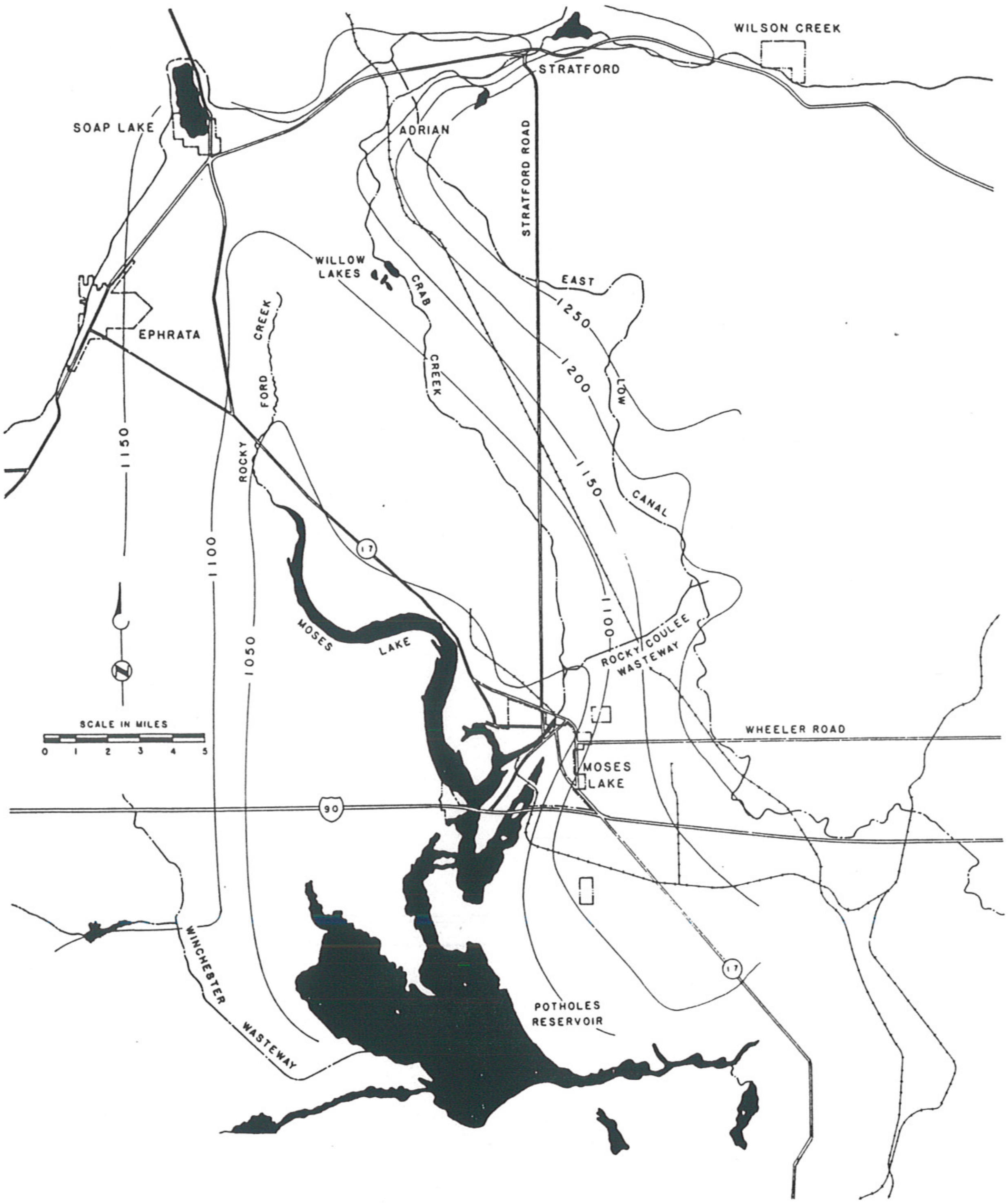


Figure 2 Groundwater Contours near Moses Lake

Acknowledgements

The support and interest of the Moses Lake Irrigation and Rehabilitation District directors (DeForrest Fuller, President, Norm Estoos and Glen Rathbone) is greatly appreciated. Soil Test Farm consultants and Laucks Laboratories in Yakima did the chemical analyses. Aquatic analysts of Wilsonville, Oregon determined the dominant algae in Moses Lake samples. Chuck Cruse of Ellensburg provided his boat and services in the in-lake sampling. Francis Jensen and John O'Callahan and other staff at the U.S. Bureau of Reclamation Project office in Ephrata provided data on feed water releases and water temperatures. Information on on-site sewage regulations was provided by the Grant County Health District. An update on sewering of Moses Lake urban areas was obtained from Lori Barlow, assistant planner for the City of Moses Lake. Information and reports from U.S. Geological Survey studies of the Central Columbia Plateau was obtained through Sandy Williamson. Special thanks go to the various local cooperators who allowed us to sample their wells and springs.

DESCRIPTION OF THE 1997 MONITORING PROGRAM

Water samples were collected at eleven locations on a regular basis over the 1997 calendar year (March-October 1997). In addition there were several supplemental surface water sampling locations occupied during the study including four in-lake transect stations and spot checks of several additional wells and the discharge from a small dam on Rocky Ford Creek. The sampling frequency for the regular surface water and groundwater stations was generally monthly for surface waters and semi-monthly for groundwaters although additional sample collections did occur over the period of study, principally during the spring-summer months. There were six regular surface water sampling locations and five regular groundwater sampling locations. Surface water sampling locations visited regularly included the three principal tributaries to Moses Lake and three near shore occasions within the Lake itself. Groundwater was characterized by routine sampling from four wells and one spring and spot checks at four other wells.

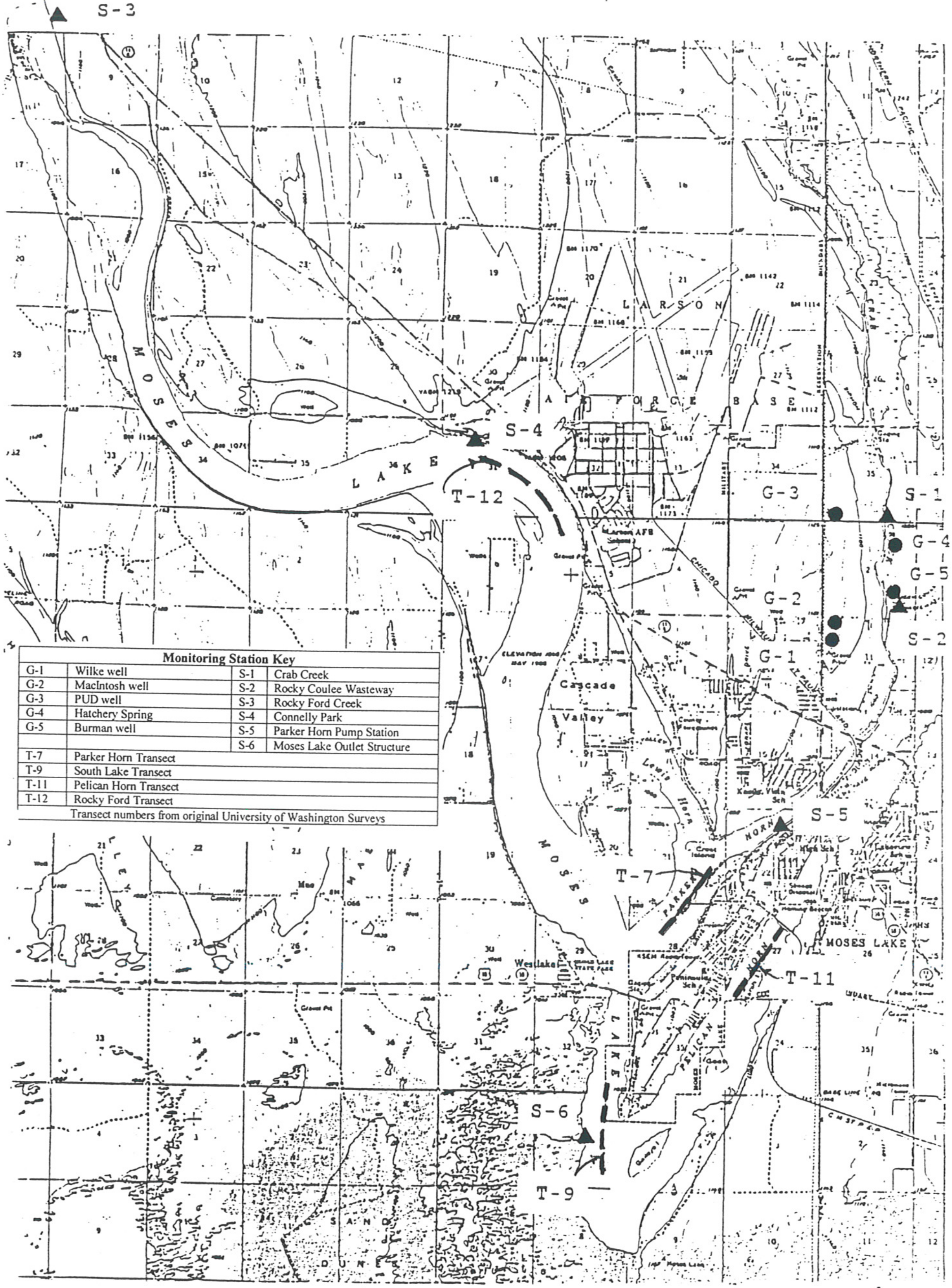
Surface Water Sampling Locations

The six routine sampling stations included the following locations within the watershed and along the Moses Lake shoreline. See Map, Figure 3 for location of these routine sampling locations.

S-1 Crab Creek at the Road 7 Bridge
S-2 Rocky Coulee Wasteway at the Road K Bridge
S-3 Rocky Ford Creek at the Highway 17 Bridge
S-4 Moses Lake at Connelly Park Fishing Peninsula
S-5 Moses Lake at Parker Horn Pumping Station
S-6 Moses Lake at USBR outlet Structures

Supplemental sampling locations included Rocky Ford Creek at the Moses Lake Irrigation and Rehabilitation District carp barrier/detention dam (S-7) and at four locations within Moses Lake itself. The four lake stations selected were transect stations previously occupied by the University of Washington students and researchers under the direction of Dr. Eugene Welch. These in-lake locations include transects in Pelican and Parker Horns, the Upper (Rocky Ford) Arm of the Lake and a south lake area near the outlet structures. These University transects are identified according to station numbering used in previous University reports and are given the prefix (T) for transect station. See Figure 3 for locations of the transects used in this study.

T-7 Lower Parker Horn Area of Moses Lake
T-9 South Lake (near Moses Lake Outlets)
T-11 Middle Pelican Horn Area of Moses Lake
T-12 Rocky Ford Arm of Moses Lake



Monitoring Station Key

G-1	Wilke well	S-1	Crab Creek
G-2	MacIntosh well	S-2	Rocky Coulee Wasteway
G-3	PUD well	S-3	Rocky Ford Creek
G-4	Hatchery Spring	S-4	Connelly Park
G-5	Burman well	S-5	Parker Horn Pump Station
		S-6	Moses Lake Outlet Structure
T-7	Parker Horn Transect		
T-9	South Lake Transect		
T-11	Pelican Horn Transect		
T-12	Rocky Ford Transect		
Transect numbers from original University of Washington Surveys			

Figure 3 Water Qualilty Monitoring Stations

Groundwater Sampling Locations

The groundwater locations were selected to characterize upper level groundwaters within the alluvium and included four shallow wells and one spring. The groundwater sampling locations are identified on the Watershed Monitoring Map (Figure 3) and are also listed below.

G-1 Wilke Well at residence on Stratford Road South of Harris Road
G-2 MacIntosh Well at residence on Harris Road
G-3 Public Utility District Well on Road 7 east of Stratford Road
G-4 Columbia Basin Hatchery Spring on Road K
G-5 Burman Well at Residence off Road K north of Rocky Coulee Wasteway

Four additional wells were sampled on a spot check basis. These included two wells on the east side of Crab Creek north of the intersection of State Highway 17 and Broadway Extended near the north boundary of the City of Moses Lake, one at Tyco, the other at Rathbone Sales. Both of these wells were checked for nitrates and fecal coliform. One well in the Cascade Valley area near Lewis Horn was sampled for nitrates and fecal coliform bacteria. A well in the Mae Valley area west of the lake at the Estoos property was sampled three times for nitrates and once for fecal coliform.

Sampling Procedures

Sampling procedures differed between the routine surface water sampling stations, the in-lake transects and the groundwater wells and springs. A local laboratory (Soil Test Farm Consultants) was selected to analyze groundwater, tributary and near shore samples. A Yakima laboratory (Laucks) was selected for analysis of in-lake transect samples. Procedures for each station group are described separately below.

Tributary/Lakeshore Stations Surface water was collected near the surface in a clean plastic bucket and poured into a one liter polyethylene bottle furnished by Soil Test Laboratory staff. The bottle was then placed in a portable cooler. The bucket was suspended from a rope where bridges, piers or other structures were encountered at the sampling point.

In-Lake Transect Stations Water was collected at six points along each transect in a wide mouthed one liter polyethylene jar held approximately 18 inches below the water surface and poured into a clean plastic bucket. The mixed contents from the six transect samples were then poured into one liter glass bottles provided by Laucks Laboratories and placed in a cooler. In addition readings of water temperature and water depth were obtained at each transect sampling point from instruments on the sampling boat and water transparency was measured with a Secchi Disc.

<u>Groundwater Wells/Springs</u> Samples from each well were obtained from an outside faucet at each building location and from water supply feed piping within the hatchery complex. One liter polyethylene bottles were filled and placed in a cooler. Samples were transported to the local laboratory (Soil Test Consultants of Moses Lake) within a few hours of collection. Samples were collected at six of the well locations on a one time basis for coliform bacteria testing. Special sterile containers were supplied by the laboratory, Central Washington University; samples were delivered to this laboratory in Ellensburg within 24 hours. Samples were also collected for microscopic evaluation to determine dominant algae present in August 1997.

MONITORING PROGRAM RESULTS

The 1997 Monitoring Program results includes field measurements (e.g. water temperature, transparency), chemistry laboratory results and microscopic evaluations to determine dominant algae. Water temperature records from a sensor at the USBR outlet structure and lake water surface evaluations are also provided.

Field and Laboratory Results

Results from the 1997 Moses Lake area monitoring program are summarized in tables covering the different sampling location categories. Tables 2 and 3 summarize laboratory results from the groundwater monitoring wells and the hatchery spring covering nitrate-nitrogen and total phosphorus respectively. Tables 4 and 5 summarize laboratory results for the routine surface water stations on the tributaries and along the Moses Lake shoreline covering nitrate-nitrogen and total phosphorus respectively. Table 6 summarizes the two transect surveys on Moses Lake and provides average Secchi Disc depths, average near surface temperature and total phosphorus for each of the four transects sampled within the Lake.

The regular monitoring station summaries in Tables 2 through 5 also include comparisons from previous monitoring results in 1991-92, 1982-83 and 1986-87 where available. These data and other data from past University of Washington and Brown and Caldwell studies as well as other data sources from the Moses Lake Clean Lake Project are discussed in the following section of this report.

Samples were split between the two laboratories during the June 5, 1997 in-lake survey. Analyses performed on replicate samples by each laboratory included nitrate/nitrite nitrogen, ammonia nitrogen and total phosphorus. The results showed general agreement for nitrate/nitrite nitrogen and total phosphorus and generally poorer agreement for ammonia-nitrogen.

Where phosphorus was notably high (e.g. the deeper samples taken at the South Lake transect) each laboratory reported the highest concentration; similarly a sample split at the Connelly Park boat launch yielded similar results where phosphorus was high. Also lowest phosphorus values were reported at Parker Horn and the shallow transect at the South Lake sampling location. However phosphorus results deviated by 0.05 to 0.10 mg/l.

The pattern of nitrate/nitrite results were similar between the two laboratory with general consistency where high values were reported or where low values were reported. For example the highest nitrate nitrogen value in the series of samples was reported for Parker Horn and both laboratories reported highest concentrations for this sample. Lowest nitrate values were reported for the deep station in South Lake and both laboratories reported their lowest concentrations there. However deviations in results were typically 0.12 mg/l or higher.

TABLE 2

Nitrate-Nitrogen Concentrations (mg/l)
In Moses Lake Area Monitoring Wells/Springs

	Wilke Well	McIntosh Well	PUD Well	Hatchery Spring	Burman Well
1997					
Range	1.7-3.4	0.1-4.1	05-2.9	2.5-3.3	1.2-2.3
Mean	2.45	2.90	1.11*	3.02	1.60
Median	2.35	3.75	0.75	3.10	1.45
Comparisons with Previous Monitoring Results					
1991-92					
Mean	2.42	3.81	2.44	2.09	2.20
Median	2.45	3.95	2.40	2.00	0.95
1986-87					
Mean	1.80	3.78	1.92	2.17	1.74
1982-83					
Mean	2.05	4.37	2.35	2.28	1.82

*Detection limit was used to determine mean where value was reported below detection limit.

TABLE 3
Phosphorus Concentrations (mg/l)
In Moses Lake Area Monitoring Wells/Springs

	Wilke Well	McIntosh Well	PUD Well	Hatchery Spring	Burman Well
1997					
Range	<.02-.40	<.02-.04	<.02-.08	<.04-.12	.08-.17
Mean	.04*	<.03*	<.05*	.09	.12
Median	.05	<.03*	<.05*	.09	.11
Comparisons with Previous Monitoring Results					
1991-92					
Mean	.016	.051	.033	.048	0.115
Median	.01	0.05	.02	.04	0.11
1986-87					
Mean	.017	.068	.053	.053	.118
1982-83					
Mean	.088	.077	.072	.056	.106

*Values reported below detection limits were used to estimate means/medians. One unusually high phosphorus value (0.4 mg/l) skewed the mean and was excluded; if the high value is included the mean for total phosphorus is estimated to be about 0.13 mg/l.

TABLE 4

Nitrate-Nitrogen Concentrations in Surface Waters
Moses Lake Area Monitoring Program

				Moses Lake Shoreline		
	Crab Creek	Rocky Coulee Wasteway	Rocky Ford Creek	Connelly Park	Parker Horn	USBR Outlet
1997						
Range	0.6-2.2	0.2-2.5	1.0-2.0	0.2-0.9	.2-2.3	0.1-1.1
Mean	1.37	1.77	1.62	0.42	0.98	0.50
Median	1.40	2.10	1.65	0.40	0.75	0.45
Comparisons with Previous Monitoring Results						
1991-92						
Mean	0.81	1.1	1.0	0.28	0.84	0.17
Median	0.90	1.2	1.0	0.23	0.80	0.10
1986-87				SEE IN-LAKE DISCUSSION		
Mean	1.88	1.24	1.34			
1982-83						
Mean	.93	1.84	1.64			

TABLE 5

Total Phosphorus Concentrations in Surface Waters
Moses Lake Area Monitoring Program

	Tributary Waters			Moses Lake Shoreline		
	Crab Creek	Rocky Coulee Wasteway	Rocky Ford Creek	Connelly Park	Parker Horn	USBR Outlet
1997						
Range	.08-.90	.08-.15	.13-.24	.08-.70	.11-.19	<.03-.17
Mean	0.14*	.13	.19	.29	.16	.10**
Median	.14	.12	.19	.15	.17	.09
1991-92						
Mean	0.03	0.06	0.15	.02	0.03	0.03
Median	.02	0.05	0.14	.01	0.03	0.01
Comparisons With Previous Monitoring Results						
1986-87				SEE IN-LAKE DISCUSSION		
Mean	.08	.07	.17			
1982-83						
Mean	.07	.10	.20			

*Single high value (0.90 mg/l) excluded from mean for Crab Creek.
**One Value below detection limit (0.03 mg/l) was treated at detection level in determining mean.

TABLE 6 Water Quality Data from Moses Lake Transects June 5, 1997 Lake Survey					
	Clarity (feet)	Water Temperature (°F)	Inorganic Nitrogen (mg/l)	Phosphorus (mg/l)	Chlorophyll (mg/l)
Rocky Ford Arm (T-12)	6.66	70.8	0.60	0.14	28
Parker Horn (T-7)	4.90	72.2	0.56	0.10	13
Pelican Horn (T-11)	2.40	72.7	0.19	0.15	20
South Lake Shallow (T-9)	8.75	71.7	0.49	0.09	24
South Lake-Deep (T-9)	N/A	64.0	0.89	0.32	4
	August 13, 1997				
Rocky Ford Arm (T-12)	4.40	79.7	0.04	0.12	17
Parker Horn (T-7)	2.98	81.8	0.05	0.06	31
Pelican Horn (T-11)	1.90	80.3	0.10	0.09	15
South Lake-Shallow (T-9)	6.52	80.2	0.07	0.05	8
South Lake-Deep (T-9)	N/A	71.5	2.42	0.39	1

Ammonia nitrogen results did not compare as well. Although highest values (deep South Lake station and Connelly Park boat launch) were consistent these deviated more than the nitrates. Stations with lowest ammonia concentrations (Parker Horn and the Shallow South Lake station) deviated by over 0.30 mg/l. Patterns were worse for some intermediate concentration levels (e.g. the Rocky Ford Arm transect deviated by nearly 0.8 mg/l). Reporting was to one decimal at one laboratory and two decimals and the second reflecting greater sensitivity or confidence in the method used and/or the volume of water processed. The laboratory data reported in Table 5 reflects only the later laboratory results for both in-lake surveys.

Microscopic Evaluations

Algal composition was assessed by identifying algae present in microscopic evaluations. Two samples of water collected during the August survey were sent to Aquatic Analysts of Wilsonville, Oregon for microscopic evaluation. The analysts reported that dominant algae in Parker Horn was a filamentous centric diatom called Melosira granulata although two bluegreen algae Oscillatoria sp. And Anabaena circinalis were also common. In contrast, the Pelican Horn sample did not have a dominant species but contained a variety of algae with approximately similar abundance. These included Melosira ambigua another filamentous centric diatom as well as Scenedesmus sp, Ankistrodesmus falcatus, Selenastrum sp., Oocystis sp., Fragilaria crotonensis, Chroococcus minutus and various periphytic diatoms (e.g. Navicula, Cymbella, and Gomphonema). The Pelican Horn sample also contained a lot of debris including fragments of diatom cell walls. Although the Pelican Horn sample had a lot of diatoms some of the common algae were green algae which helps to explain the green discoloration evident during the sampling of this area.

Water Temperatures

Water temperatures were obtained during the monitoring of the lake and tributaries using a field thermometer. In addition water temperature data records for the main lake outlet structure were obtained for 1996 and 1997 from the USBR. The 1996 calendar year was provided because a malfunction of the temperature sensor occurred in April 1997 so no data was available for most of the period covered by this monitoring project. The 1996 data record is provided on Figure 4. Review of the available records for 1997 show the lake was about 4°F warmer on April 7, 1997 than on the same date in 1996. See Appendix for available daily records for 1996 and 1997.

Water temperatures reached 81.8°F in Parker Horn in early August and were above 80°F in Pelican Horn and near the lake outlet at that time. Review of 1996 temperature data show no readings above 76.5°F suggesting 1997 was a warmer year at the lake. Review of other available records (e.g. 1992) show water temperatures above 80 occurred periodically in the summer months indicating the 1997 water temperature conditions encountered during August were not unusual.

Water Levels

Water levels in Moses Lake are also monitored by the MLIRD and the USBR. Water surface elevations for the 1997 calendar year are shown on Figure 5. Available tabulated daily readings for 1996 and 1997 are provided in the Appendix.

Figure 4 Moses Lake Water Temperature –
1996 Calendar Year
(1997 data not available)

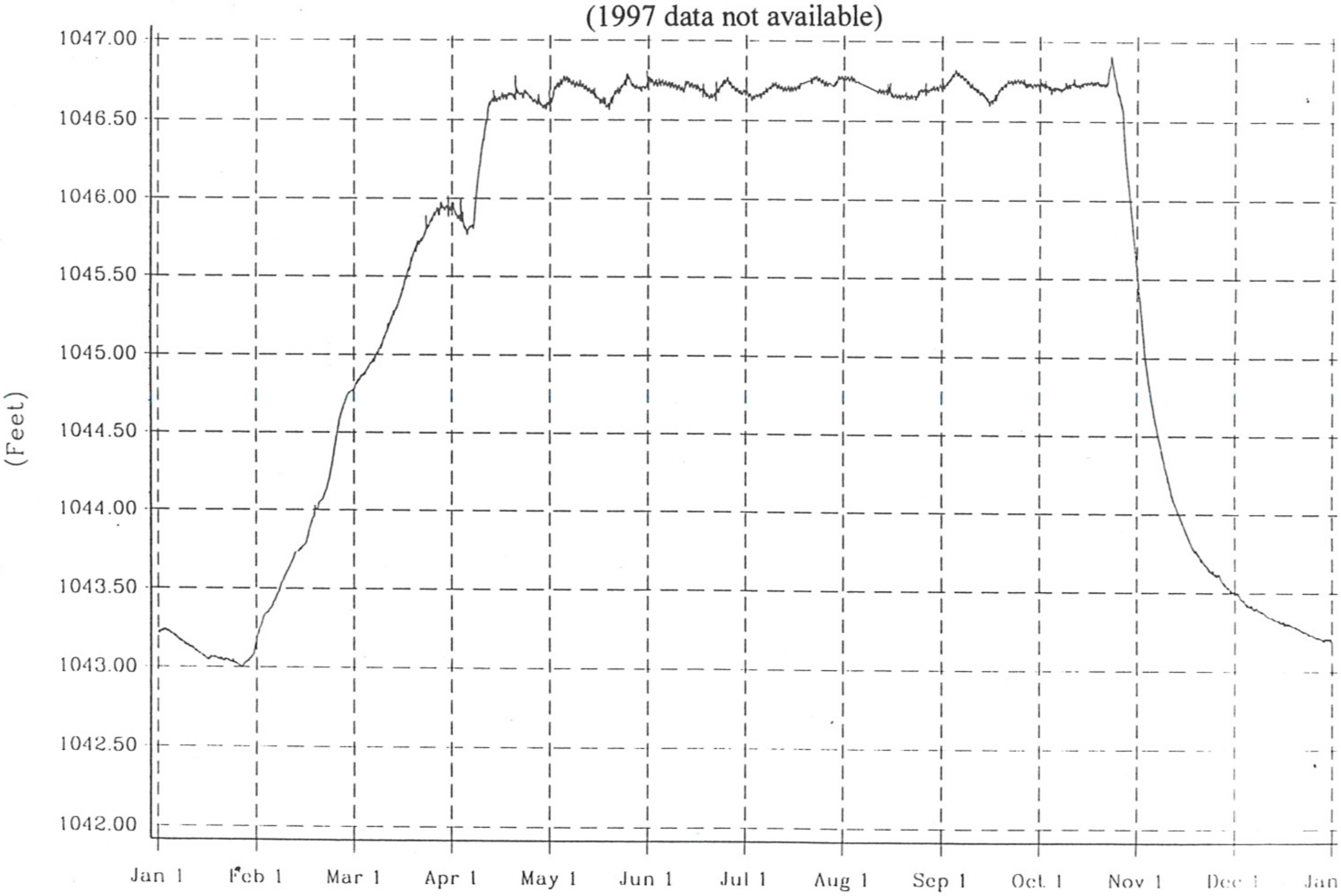


Figure 5 Moses Lake Water Surface Elevations
1997 Calendar Year

EVALUATION OF RESULTS

Results of the 1997 water quality monitoring of Moses Lake area surface waters and ground waters were evaluated considering water quality data from previous monitoring programs, water quality criteria, releases from the USBR East Low Canal and continuing on-farm irrigation water management encouraged previously by the Moses Lake Clean Lake Project and the National Resources Conservation Service in their continuing technical assistance programs.

Water Quality Data Comparisons

Data summarized in Tables 2 through 5 were compared with previous monitoring programs dating back to 1982 for ground water and 1977 for surface waters.

Groundwater Data Comparisons Nitrate-nitrogen and total phosphorus data are provided on Tables 2 and 3, respectively covering the 1997 monitoring effort and mean concentrations from the earlier monitoring programs in 1991-92, 1982-83 and 1986-87. These data include three wells on the west side of Crab Creek and a spring and a well on the east side of the creek. The average (mean) nitrate nitrogen concentration dropped in two of the three west side wells as compared with results from the earlier surveys and was essentially constant in the third west side well as compared with 1991-92 results. An interesting trend noted in several of the west side wells was the occasional presence of very low nitrate concentrations during non irrigation periods. For example, the PUD well had less than 0.05 mg/l reported in March 1997 and contained only 0.10 mg/l nitrate nitrogen in the late October sampling. The later sample was analyzed and the low nitrate concentrations were confirmed by the laboratory. Similarly the McIntosh well (one mile south) showed very low nitrate concentrations in October 1997. All three west side wells showed elevated nitrates during the irrigation season based on samples in late May and mid July.

In contrast, the east side sampling locations showed generally mixed results. The Burman well showed a significant decline in nitrate; however the hatchery spring showed a significant increase over results in previous years. The Burman well results may be influenced by recent well drilling activity on this property as the older (109 foot) well was being replaced by a new well during 1997. According to the owner the hookup of the new well was not completed during the sampling period but he reported the older well had been producing better flow after the drilling of the new well. The nitrate concentrations in the Burman well samples were notably lower in July and October 1997 (1.2 mg/l) as compared with samples collected earlier (1.7-2.3 mg/l). The hatchery spring nitrate values were consistently higher than in previous monitoring as illustrated by the range of reported results (2.6-3.3 mg/l) for 1997 compared with averages of 1.92-2.44 mg/l in the three previous monitoring periods.

Total phosphorus data are more consistent with past results but with significant differences between individual wells. For example the west side wells show relatively low concentrations with means of 0.05 mg/l or less. In contrast the Burman well shows an elevated total phosphorus concentration ranging from 0.08 to 0.17 mg/l (mean 0.12 mg/l). A generally similar geographical distribution was evident in 1991-92, 1982-83 and 1986-87 when the means for the west side wells ranged from 0.017 to 0.088 mg/l while the Burman well averaged from 0.106 to 0.118 mg/l. The Columbia Basin Hatchery spring averaged 0.09 mg/l in 1991-92 as compared with 0.48 to 0.56 for the earlier surveys which reflects the trend noted for nitrates at this spring.

One possible reason for the very different results from the Burman well include the location of a dairy between the Burman farmstead and the hatchery. Also, as indicated previously there are a large number of irrigated farms north of the Burman well location which were participants in the earlier Moses Lake Clean Lake Project on-farm programs which included irrigation system upgrades and irrigation water management activities. These aspects and their possible implications are discussed later in this report.

Several additional wells were sampled in 1997 that had not been previously tested in the area wide monitoring programs. These included two wells on the east side of Crab Creek near the northern boundary of the City of Moses Lake, a well in the Cascade Valley and a well on the west side of Moses Lake in the Moe Valley area. Each of these wells was sampled twice.

The wells near the City limits on the east side of Crab Creek were at business locations (Tyco and Rathbone Sales). These wells were on adjacent parcels and test results were nearly identical. The Tyco well averaged 4.95 mg/l nitrate nitrogen and less than 0.03 mg/l total phosphorus. The Rathbone Sales well averaged 4.80 mg/l nitrate-nitrogen and about 0.04 mg/l total phosphorus. Both of these wells are very close to an old cattle sales stockyard.

The Cascade Valley well averaged 2.0 mg/l nitrate nitrogen and less than 0.03 mg/l total phosphorus. The Moe Valley well averaged 3.95 mg/l nitrate nitrogen and 0.13 mg/l total phosphorus; one of the two samples from this well had a nitrate nitrogen value of 5.4 mg/l and a total phosphorus concentration of 0.16 mg/l.

Surface Water Data Comparisons Nitrate-nitrogen and total phosphorus concentrations in surface waters monitored in 1997 are summarized on Tables 4 and 5. Comparisons with earlier monitoring results are also summarized for the tributaries. The Moses Lake shoreline stations were not sampled in the 1980s but were monitored in 1991-92. A discussion of Moses Lake water quality is provided later in this report and includes consideration of in-lake surveys and shoreline sampling results.

Concentrations of nitrate-nitrogen in Crab Creek show a increase from the earlier surveys averaging 1.4 mg/l in 1997 as compared with 0.81 mg/l in 1991-92 and 0.88 and 0.93 for 1986-87 and 1982-83 respectively. Total phosphorus concentrations in Crab Creek increased compared with 1991-92 results but averages were similar to results in the 1980s.

The 1997 mean nitrate value for Crab Creek was influenced somewhat by elevated values (2.2 mg/l) in high spring run-off sampled in March; however relatively high nitrates were detected on other 1997 survey dates particularly during summer surveys in July, August and September when nitrates ranged from 1.4-1.5 mg/l. Total phosphorus values were skewed by one exceptionally high value in late May (0.9 mg/l) but the reported mean for 1997 (0.14 mg/l) is elevated compared with previous years which ranged from .03-.08 mg/l even though the single high value is excluded. If the 0.9 mg/l total phosphorus found in the May survey is included the 1997 mean for phosphorus is 0.26 mg/l.

Rocky Coulee Wasteway nutrient concentrations were generally elevated compared with previous sampling period results averaging 1.77 mg/l nitrate nitrogen compared with 1.1 mg/l in 1991-92 and 1.24 mg/l in 1986-87. The 1982-83 sampling results for nitrate were similar to those in 1997. Phosphorus concentrations were significantly higher in 1997 (mean 0.13 mg/l) compared with previous surveys which averaged from 0.06-0.10 mg/l total phosphorus. These elevated values in 1997 are attributed to the fact that dilution water releases were not made from the East Low Canal as they had been during at least part of the monitoring period in each of the previous survey.

Rocky Ford Creek exhibited generally similar trends with higher average nitrate-nitrogen (1.62 mg/l) in 1997 as compared with 1.0 to 1.64 mg/l in the early surveys. Total phosphorus was 0.19 mg/l in 1997 as compared with 0.15 to 0.20 in the previous surveys. Phosphorus concentrations in Rocky Ford Creek remain significantly higher than the other tributaries, consistent with previous findings.

Water Quality Objectives and Goals

There are several water quality objectives that have been established for parameters measured under the monitoring program. These include public health related criteria for fecal coliform bacteria and nitrate-nitrogen which have been codified in the State groundwater standards and three water quality goals which were suggested for Moses Lake surface waters.

Fecal coliform bacteria are routinely tested to insure drinking water supplies are not contaminated by disease vectors such as bacteria or virus. The traditional test is for coliform bacteria, usually fecal coliform, which are used as an indicator organism for other potential pathogens. State and Federal drinking water standards call for coliform testing on a regular basis for public water supplies. Private sources such as domestic wells are also checked in this way, but usually only on a spot check basis to satisfy owners or other interested parties, such as lending institutions. Drinking water is considered safe when less than 2.2 bacterial colonies are found per 100 ml.

The water quality standard for nitrate-nitrogen in ground waters was established at 10 mg/l by the Department of Ecology (DOE) in the late 1980s. Earlier water quality criteria guidance published by the Environmental Protection Agency (EPA) suggested the 10 mg/l level for protection of bottle fed infants from methemoglobinemin, a potentially fatal condition attributed to reactions in the gastrointestinal tract where nitrate is reduced to nitrite which then reacts with hemoglobin in the bloodstream. Early drafts of the DOE ground water standards and some more recent studies have included a 5.0 mg/l nitrate nitrogen limit as an early warning value.

The site specific Moses Lake related water quality goals were published in a June 1978 report by Brown and Caldwell, Consulting Engineers. These goals were based on information available in scientific literature and data from Moses Lake. The goals established in the Brown and Caldwell study are 0.05 mg/l for total phosphorus, 20 ug/l for chlorophyll and 4 feet (1.2 meters) for transparency as measured by Sceehi Disc.

Groundwater Standards Compliance Groundwater data for nitrates shown in Table 2 demonstrate that the DOE standards are being met. During the 1991-92 sampling elevated nitrate nitrogen values (up to 5.5 mg/l) appeared in the Burman well during August and September samplings. Additional wells were sampled on a spot check basis on the east side of Crab Creek near the city of Moses Lake. Although the Burman well water quality had improved compared with 1991-92 and did not have nitrate elevated above 2.3 mg/l in 1997 samplings, two downgradient wells near Moses Lake were consistently higher with nitrate nitrogen approaching the DOE early warning concentration (5.0 mg/l). Also one sample from a well in Mae Valley slightly exceeded the early warning value reaching 5.4 mg/l nitrate nitrogen. This shallow well had been of concern to the owner as quality appeared to fluctuate noticeably.

Coliform bacteria tests were run on many of the wells involved in the 1997 testing program. These were carried out as a service to the cooperating landowners and to provide supplemental data for the monitoring project. All samples were collected in special sterile containers provided by Central Washington University. Six of the wells were tested and all but one were found to be satisfactory by the laboratory. The exception was a shallow well.

Surface Water Quality Goal Achievement Goals for Moses Lake water quality established in the late 1970s covered total phosphorus, chlorophyll and water clarity. Conditions observed in 1997 at lake shore and lake survey stations were compared with these numerical standards.

Phosphorus concentrations were elevated above the 0.05 mg/l goal at all lake shore stations in 1997. The goal was met at the lake outlet in late May but was not met in any other near shore samplings. Lake shore waters were significantly worse than 1991-92 in tributary inflows (Crab Creek, Rocky Ford Creek) and in Rocky Coulee Wasteway where very little feed water was released from the East Low Canal. Total phosphorus at the lake shore stations averaged 0.18 mg/l in 1997 over triple the concentration goal. Total phosphorus averaged 0.10 mg/l at the four in-lake stations for the two sampling surveys in 1997. Deep water samples gathered from near the outlet were significantly higher averaging 0.35 mg/l.

Chlorophyll measurements were made during the two in-lake surveys. See Table 6 chlorophyll averaged 21.3 ug/l in shallow water samplings in the June survey and 17.8 ug/l in the August survey. The goal for chlorophyll (20 ug/l) was achieved in half of the samples. A spot check measurement for chlorophyll was also made at the Parker Horn near shore station in mid September 1997 when the water was visibly discolored. This sample contained 49 ug/l chlorophyll.

The water clarity goal was achieved at some in-lake stations, particularly in the Rocky Ford Arm and in the South Lake area near the outlet. Secchi disc measurements at these two stations averaged 5.5 feet and 7.6 feet respectively compared with the 4 foot goal. In contrast, the clarity goal was not achieved in Pelican Horn where waters were visibly turbid and discolored during both surveys. Secchi disc readings in Pelican Horn averaged 2.15 feet. Parker Horn Secchi disc readings were 4.9 feet in June but fell slightly below 3 feet in August 1997.

Secchi disc measurements were also made at near shore stations. Readings near the USBR outlet structure averaged 4.3 feet, slightly better than the goal. Readings at the Parker Horn Pump Station averaged 2.6 feet with a range from 0.9 to 4.5 feet. The high value (4.5 feet) occurred in mid October after algae blooms had diminished. Clarity at Connelly Park ranged from 2 feet to 6 feet in the boat launch area.

Comparisons with Watershed Activities/Projects

Various actions, activities and projects in the watershed were considered that have potential water quality impacts in the Moses Lake area.

1. Dilution water releases from the USBR East Low Canal via Rocky Coulee Wasteway and Crab Creek to the Parker Horn area of Moses Lake.

2. On-farm irrigation system upgrades and irrigation water management associated with the Moses Lake Clean Lake Project in the Block 40 and Block 41 area of the USBR Columbia Basin Project.

3. Construction of a carp barrier/retention dam structure on lower Rocky Ford Creek and subsequent rehabilitation of Rocky Ford Creek to eradicate carp and their and disturbance of the creek channel/vegetation.

4. Sewer construction in areas previously served by septic tank/leach field systems in the greater Moses Lake area.

5. Groundwater quality evaluations by the U.S. Geological Survey covering the Central Columbia Plateau and related watershed and groundwater management plans and programs.

Dilution Water Considerations Water is usually released from the USBR canal system through Rocky Coulee Wasteway to Moses Lake to feed Potholes Reservoir. The

USBR released only 25,886 acre feet from the East Low Canal in 1997. This volume was the lowest reported in the past 20 years with the exception of 1984 when no flow releases occurred. See Table 7 for dilution water release figures since 1976. Note most years exceeded 100,000 acre feet and one third of the years experienced releases in excess of 200,000 acre feet.

The water volume released during the previous monitoring period (1991-1992) was among the higher over the past 20 years. The water quality information from 1991-92 showed significantly better water quality in the lake as compared with 1997 when very little feed water was released into the lake. Studies in 1977 demonstrated conclusively that feed water releases diluted algal nutrients and improved Moses Lake water quality.

Table 7
Moses Lake Dilution Water Releases
(1976-1997)

Year	Dilution Release (acre-feet)
1976	64,070
1977	150,630
1978	81,840
1979	214,540
1980	19,540
1981	56,050
1982	144,180
1983	73,250
1984	0
1985	154,350
1986	106,230
1987	137,770
1988	207,300
1989	207,800
1990	229,980
1991	286,098
1992	267,846
1993	120,976
1994	289,356
1995	132,211
1996	60,685
1997	25,886

<u>On-Farm Irrigation Upgrades/Management</u> The Moses Lake Clean Lake Project stimulated on-farm irrigation upgrades such as rill to sprinkler conversions. Since the project was completed in the early 1990s the NRCS and local Conservation District have stressed irrigation water management and stimulated additional on-farm irrigation system improvements. On-farm irrigation improvements under the Moses Lake Clean Lake Project occurred mainly on the east side of Crab Creek. Several water quality benefits were associated with on-farm improvements; these involved a reduction of deep percolation of soluble nitrates and a reduction in irrigation tailwater which could reduce nutrient loadings to Crab Creek from return flow.

The Clean Lake Project funded conversions from rill irrigation to sprinklers and upgrades of more labor intensive sprinkler systems (handlines, wheelines) to center pivot systems. A cost share incentive of up to $50,000 per farm was provided to participating growers; the cost share program was funded by EPA. The DOE provided technical assistance grants; the MLIRD provided local match monies for the technical assistance work as well as for monitoring and project management/reporting. Participating growers were obligated by cost share agreement to carry out irrigation water management practices such as soil moisture testing, split fertilizer applications and irrigation scheduling.

The area east of Crab Creek and down gradient from most of the participating farms was monitored at the Burman well and at the Columbia Basin Hatchery spring. The 1991-92 groundwater data locations showed a downward trend in soluble nitrate concentration with the exception of the August-September 1992 values at the Burman well. The lower nitrate concentrations observed at the Burman well for all but the August and September samples may be due to reduced nitrate leaching from upgradient agricultural areas which participated in irrigation system upgrades and irrigation water management programs sponsored by the Moses Lake Clean Lake Project.

The Burman well water quality was further improved based on the 1997 sampling results. The average nitrate nitrogen reported in 1997 was 1.6 mg/l compared with 2.2 mg/l in 1991-92, 1.7 mg/l in 1986-87 and 1.8 in 1982-83. However total phosphorus levels were virtually unchanged averaging 0.11 to 0.12 mg/l in these recent surveys.

The hatchery spring nitrate levels were elevated in 1997 over levels noted in previous years. This spring yielded the highest average nitrate concentrations (3.0 mg/l) of all the regular groundwater monitoring stations. This shallow source could be influenced by local practices in upgradient agricultural areas.

The west side wells showed a lowering of nitrates, particularly in the sampling from winter through early spring. A dramatic drop in nitrate nitrogen was observed in the PUD well; particularly low values (approaching detection limits) occurred during samplings in the fall/winter and early spring months. Low values were also experienced in the McIntosh well which is two miles south nearer the lake and presumed to be downgradient of the PUD well. The PUD well monitoring was extended through June 1998 to better document water quality changes.

A cyclic change in nitrate nitrogen was evident from repeated samplings of the PUD well. The concentration increased from a low in March 1997 below laboratory detection limits (0.05 mg/l) to 2.9 mg/l on May 30. Nitrate nitrogen then dropped steadily to 0.1 mg/l in October after which the nitrates remained low (0.3 mg/l in early February) through the winter and then began climbing in the spring averaging 1.4 mg/l in samples collected in late April and early May 1998 reaching 1.6 mg/l in June 1998. The higher nitrates always occurred during the irrigation season samples in 1997 and 1998 and very low values occurred in the two winter periods. This observation is consistent with a pattern observed in the area by the USGS in their recent report on Water Quality in the Central Columbia Plateau[3].

Rocky Ford Creek Carp Barrier A small dam built on Lower Rocky Ford Creek as part of the Moses Lake Clean Lake Project to block carp migrations into the creek from Moses Lake. The creek area upstream of this barrier was then rehabilitated by the Department of Fish and Wildlife to create a high quality trout stream. The downstream barrier which consisted of wooden stop logs at the spillway also created a retention pond for phosphorus associated with suspended sediments and trapped vegetation and emergent plants. Carp had previously disrupted the creek disturbing attached vegetation and phosphorus rich sediments which contributed nutrients to the lake.

Surveys in 1991-92 showed a drop in phosphorus concentrations in waters flowing to the lake as compared with pre barrier sampling surveys (1982-87). These phosphorus reductions were reported to range from 13 to 33 percent and were attributed to the carp barrier, the upstream rehabilitation of Rocky Ford Creek.

Over half of the stop logs in the small dam were removed by vandalism in the mid 1990s before the 1997 survey began. The Department of Fish and Wildlife and the Moses Lake Irrigation and Rehabilitation District have discussed the situation and it was agreed to leave the structure in its present damaged condition through 1997. Some upstream property owners had complained that the structure aggravated flooding impacts along Rocky Ford Creek. Although these properties lie north of State Highway 17 and the dam lies over a mile downstream of this highway crossing it was decided not to repair the structure until after the 1997-98 winter period. Thus the Rocky Ford Creek carp barrier was not operating during the 1997 sampling. The structure was repaired in April 1998.

Phosphorus concentrations in the Rocky Ford Arm during 1997 were significantly higher than in the 1992 surveys. The average from 1992 in lake sampling in the Rocky Ford Arm was 0.06 mg/l contrasted with 0.13 mg/l in 1997. Rocky Ford Creek itself averaged slightly higher phosphorus in 1997 (0.19 mg/l) compared with 0.15 mg/l in 1991-92. Rocky Ford Creek quality and the lack of significant USBR, feed water releases during 1997 compulate these data interpretations. Accordingly effects of damages to the carp barrier on water quality cannot be precisely described other than the benefits attributed to the structure and the upstream creek rehabilitation were lost as a result of vandalism.

On-Site Sewage System Changes There have been some changes in the population served by septic tank/leach field systems. In 1986 the MLIRD sponsored a study of urban wastewater disposal covering the greater Moses Lake area. At that time it was estimated that 20,000 people lived within the urban area of Moses Lake of which approximately 10,000 lived inside the city limits. At that time about 1500 people within the City were not served by the sewer system. The sewered waters from Moses Lake are

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[3] U.S. Geological Survey. Water Quality in the Central Columbia Plateau, Washington and Idaho, 1992-95, Circular 1144, Published 1998.

transferred to a sandy area south and east of the city and is not considered a source of nutrients to Moses Lake. A small treatment plant near the air field north of the city ultimate discharges to groundwater that may reach Moses Lake. Approximately 4000 people are believed to be served by this facility.

The City has sewered several near shore areas that were not sewered in 1986. These include the lower Peninsula, the Laguna area on the west shore of the Lake and the Crestview area on the east side of Lewis Horn. The City has an ordinance that requires hookup if a septic system fails. City planning staff reported in early 1998 that most residences had been hooked up to the sewer.

There were a number of densely developed areas within the jurisdiction of Grant County that were served by septic tanks/leach field systems in 1986. Some of these (e.g. Longview Tracts) have since been annexed into the city but have not been sewered.

Population growth in the area has been relatively strong over the past decade and there are now 25,000 to 30,000 residents in the urban area of Moses Lake. Although sewering projects have eliminated on-site systems in several lake shore areas at least half of the urban population is contributing to groundwater either through individual leach fields or the percolation of treated effluent near the airport.

Ground Water Quality Evaluations Groundwater quality in the Central Columbia Plateau has been studied intensively in recent years by the U.S. Geological Survey as part of their National Water Quality Assessment (NAWQA) Program. Numerous reports have been issued raising concern over pollution of the areas groundwater wells from nitrates and pesticides. Nitrate levels exceeded safe drinking water standards in about 20 percent of all wells tested. The highest exceedance rates occur where fertilizer use and irrigation are greatest[4].

A recent USGS circular summarizing the NAWQA studies specifically states that the primary source of nitrate in groundwater is agricultural fertilizers; other sources cited include cattle feedlots, food processing plants, septic tanks and wastewater discharges. Nitrates were highest in shallow wells in irrigated areas and the concentrations found were among the highest in the United States.

Most of the wells that exceeded the maximum contaminant level (MLL) for nitrate were found in the Quincy-Pasco subunit of the Central Columbia Plateau. This area includes Moses Lake although highest nitrate levels were more typically found south of Quincy and in western Franklin County, particularly near Pasco. See excerpts re nitrate in groundwater from USGS circular 1140 provided in the Appendix.

Concerns over groundwater quality have led to proposed Federal listings of the regional aquifers. Local response has delayed forming listing of a sole source aquifer by

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[4]U.S. Geological Survey, Water Quality in the Central Columbia Plateau, Washington and Idaho, 1992-95, USGS Circular 1144, published 1998.

the Environmental Protection Agency pending outcome of groundwater management planning.

Water Well Data

Water well reports provided by well drillers are filed with the Department of Ecology (DOE) Regional office in Spokane. These reports have been required since 1974; older well records are generally not available from the DOE office.

Well reports from the area around Moses Lake were obtained in 1997 and reviewed to determine typical depths, and strata encountered. Some of the monitored wells are covered in the reports obtained; one of these was the Grant County PUD well discussed previously.

All of the well reports obtained report sandy gravels or boulders in the upper layers. Most of the wells were drilled to depths between 100 and 200 feet and were developed in basalt. Static water levels were typically less than 80 feet. Yield tests reported produced high volumes 30-80 gpm; one well was air tested at 400 gpm.

Gravel layers extended down 100 feet in some wells and were usually at least 25 feet before basalt was encountered. Often the upper layer of basalt encountered was fractured. Thus the upper materials are highly porous and in many wells the static water level lies within this less consolidated material.

Several example water well reports are appended for reference including the PUD well in Section 26 (T20NR28E), the Fuller well in Section 21 (Cascade Valley) and representative wells from Sections 11 and 12 (T19NR28E) north of Moses Lake.

The well reports demonstrate that percolating water (e.g. from irrigation seepage) would move rapidly downward through gravels into the shallow groundwater since no confining layer of less permeable strata appears to exist until the deeper basalts are encountered. Furthermore these deeper layers are often cited as fractured or rotten basalt and water is also developed from these strata.

The relatively high permeability of the surface geology and surface soils near Moses Lake suggest that nitrate leaching from fertilizers would reach groundwaters in a relatively short time once nitrogen had moved below crop root zones. This may help to explain why nitrate nitrogen is higher in the early irrigation season reflecting the timing of fertilizers applications and leaching from irrigations.

Results from the 1997-98 water quality monitoring program were compared with data from previous studies where changes in water quality were significant the effects of various water quality control programs were also considered. These programs include dilution water releases from the East Low Canal to Moses Lake through Parker Horn, pumped water transfers from Parker Horn to Pelican Horn, diversion of sewage effluent from Pelican Horn, upgrades of irrigation systems and irrigation water management programs in Blocks 40 and 41 of the Columbia Basin Irrigation Project as a result of the Moses Lake Clean Lake Project and construction of a carp barrier/retention pond on Rocky Ford Creek.

Comparisons with Past Monitoring Results

Comparisons of water quality results are described separately for the surface waters tributary to the lake, groundwater monitoring and Moses Lake itself. Hydrologic data records were also used do develop nutrient loadings entering Moses Lake and discharging from the outlet works to Potholes Reservoir.

The 1997-98 water quality program results were compared with data and conclusions from previous studies. Previous monitoring efforts include a similar monitoring project in 1991-92 and earlier monitoring of surface waters and groundwaters under the Moses Lake Clean Lake Project 1986-87 and 1982-83 and special investigation of effects of dilution water releases by Brown and Caldwell in the mid 1970s.

Surface waters flowing into Moses Lake and quality of local wells and springs are discussed separately. Comparisons of tributary and groundwater monitoring, include survey data from 1982-83, 1986-87, 1991-92 and 1997-98. In-lake survey data are compared from University studies and from the 1991-92 monitoring project.

In-Lake monitoring was carried out by University of Washington scientists between 1969 and 1988. Water quality objectives and goals were developed in 1977 based on investigations by Brown and Caldwell[5]. Sampling locations within Moses Lake were established after review of the University studies and methods for transect sampling were finalized after discussions with Professor Eugene Welch, lead investigator for the University of Washington. Much of the University work was summarized by Dr. Welch for the Irrigation District in 1989[6].

Groundwater Quality

Four reference wells and a spring near Moses Lake have been monitored since 1982, surveys were in 1982-83, 1986-87, 1991-92 and 1997-98. Samples were generally taken every two months during these monitoring periods but occasionally sampling was done more frequently. Data are compared for all surveys in Table 2 and Table 3.

In general the 1997 average nitrate levels were lower in these locations as compared with previous years averaging 2.2 mg/l as compared with an average of 2.5 mg/l in the three prior surveys. All of the wells were lower in 1997 compared with 1992 sampling but the spring at the Columbia Basin Hatchery had a higher average nitrate concentration (3.0 mg/l) as compared with 1992 (2.1 mg/l). The most significant finding was observed fluctuations in nitrate in wells on the west side of Crab Creek which dropped near

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[5] Brown and Caldwell, Moses Lake – 1977 Pilot Project, Volume II, June 1978.

[6] Welch, E.B. et al, Moses Lake Quality-Results of Dilution, Sewage Diversion and BMP's-1977 through 1988, University of Washington, Department of Civil Engineering, 1989.

detection limits in the fall/winter (<0.05-0.1 mg/l) but were elevated (1.4-2.9 mg/l) during the irrigation season.

Improvements were noteworthy at the Burman well which had elevated nitrates in 1992 which were possibly related to a nearby dairy that was under investigation by regulatory agencies at that time. Nitrate levels had climbed to over 6 mg/l in the late summer of 1992 but had dropped to only 1.2 mg/l in July and October 1997.

Phosphorus concentrations were generally consistent between 1997 and 1992 with the wells on the west side of Crab Creek having relatively low values 0.03-0.05 mg/l compared with the west side locations (Burman well and Hatchery Spring) where total phosphorus averages ranged from 0.09-0.12 mg/l. Slightly elevated phosphorus has been consistently observed in the Burman well but the Hatchery spring values appear to have increased compared with past monitoring where average phosphorus concentrations were generally about 0.05 mg/l.

Tributary Surface Waters

Samples gathered from Crab Creek, Rocky Ford Creek and the Rocky Coulee Wasteway in 1997 contained more nitrates on average than in 1992. Flows were significantly higher in Crab Creek in the spring of 1997 but were lower in Rocky Coulee Wasteway due to low volumes of feedwater releases from the East Low Canal. No flow records are available for Rocky Ford Creek as the USGS discontinued their gaging station operation in 1991.

Nitrate and total phosphate data from 1997 and prior years are summarized in Tables 4 and 5. These data show that Crab Creek had higher nitrate concentrations in 1986-87. Phosphorus levels were higher in 1997 than in prior years although 1986-87 values were elevated compared to 1992 when average nutrient concentrations were low. Natural run-off and upgradient irrigation activities both influence Crab Creek water quality.

Rocky Ford Creek nitrate levels were higher in 1997 but were not greatly different from previous monitoring results dating from the early 1980s. Phosphorus levels remained elevated in these waters consistent with measurements in prior years where total phosphorus levels consistently exceeded values measured in Crab Creek. See Table 5 for comparisons.

Rocky Coulee Wasteway had higher average concentrations of both nitrate and phosphorus in 1997 as compared with most previous years but this is readily explained by the lack of low nutrient releases from the East Low Canal during the spring/summer of 1997.

Moses Lake Water Quality

Comparisons were made between 1997 data and results from previous monitoring programs for three Moses Lake water quality indicators. These include total phosphorus, chlorophyll and water clarity.

Total Phosphorus Comparisons Total phosphorus averaged 0.10 mg/l in the surface waters of Moses Lake in 1997 as compared with 0.08 mg/l in the 1992 lake surveys. This increase in nutrient content is significant and represents a reversal of the documented decline in phosphorus levels noted by the University of Washington and in the 1992 monitoring. See Figure 6. Benefits from a variety of major water quality control programs were attributed to reductions in phosphorus. These earlier programs including dilution releases (since 1977), pumped transfers to Pelican Horn (since 1982), diversion of the City of Moses Lake sewage effluent discharge (since 1984) and Moses Lake Clean Lake Project cost share and irrigation water management programs dating from 1988 that were designed to address percolation of nitrates and tailwater discharges from irrigated areas near Moses Lake as well as phosphorus sources in Rocky Ford Creek.

Goals established in 1977 called for total phosphorus levels of 0.05 mg/l or less. The 1992 total phosphorus values averaged about 0.05 mg/l and essentially achieved this goal. The average water quality in Parker Horn and in the South Lake near the outlet in 1992 fell below 0.035 mg/l. In contrast, the 1997 total phosphorus averages at these two stations were double those found in 1992. The average of all transects (0.10 mg/l) in 1997 was also double the 1992 average for all transect stations and double the total phosphorus goal.

The deterioration in water quality documented in 1997 is attributed primarily to the paucity of dilution water released from the USBR East Low Canal. The feedwater releases through Moses Lake to Potholes Reservoir were among the lowest recorded in the past 20 years as shown previously in Table 7. The 1997 release was only 25,886 acre feet, less than 10 percent of the 267,846 acre feet released in 1992 when phosphorus goals were met in the lake at most locations. Elevated nutrient levels and high springtime flows in Crab Creek also would have affected lake water quality, particularly in Parker Horn.

Effects of dilution water releases are especially significant in Parker Horn since the USBR water is routed through this section of the lake. Releases are generally made during the spring and provide greatest benefit during the late spring and early summer. In 1992 the high dilution volume lowered total phosphorus in Parker Horn to less than 0.02 mg/l in early June whereas the 1997 total phosphorus on June 5 was 0.10 mg/l, five times higher.

The 1997 survey characterizes a year when the impact of dilution water releases on Moses Lake water quality were essentially eliminated. Other remedies such as the diversion of sewage effluent and implementation of best management practices for irrigated agricultural areas under the Clean Lake Project had apparent benefits since

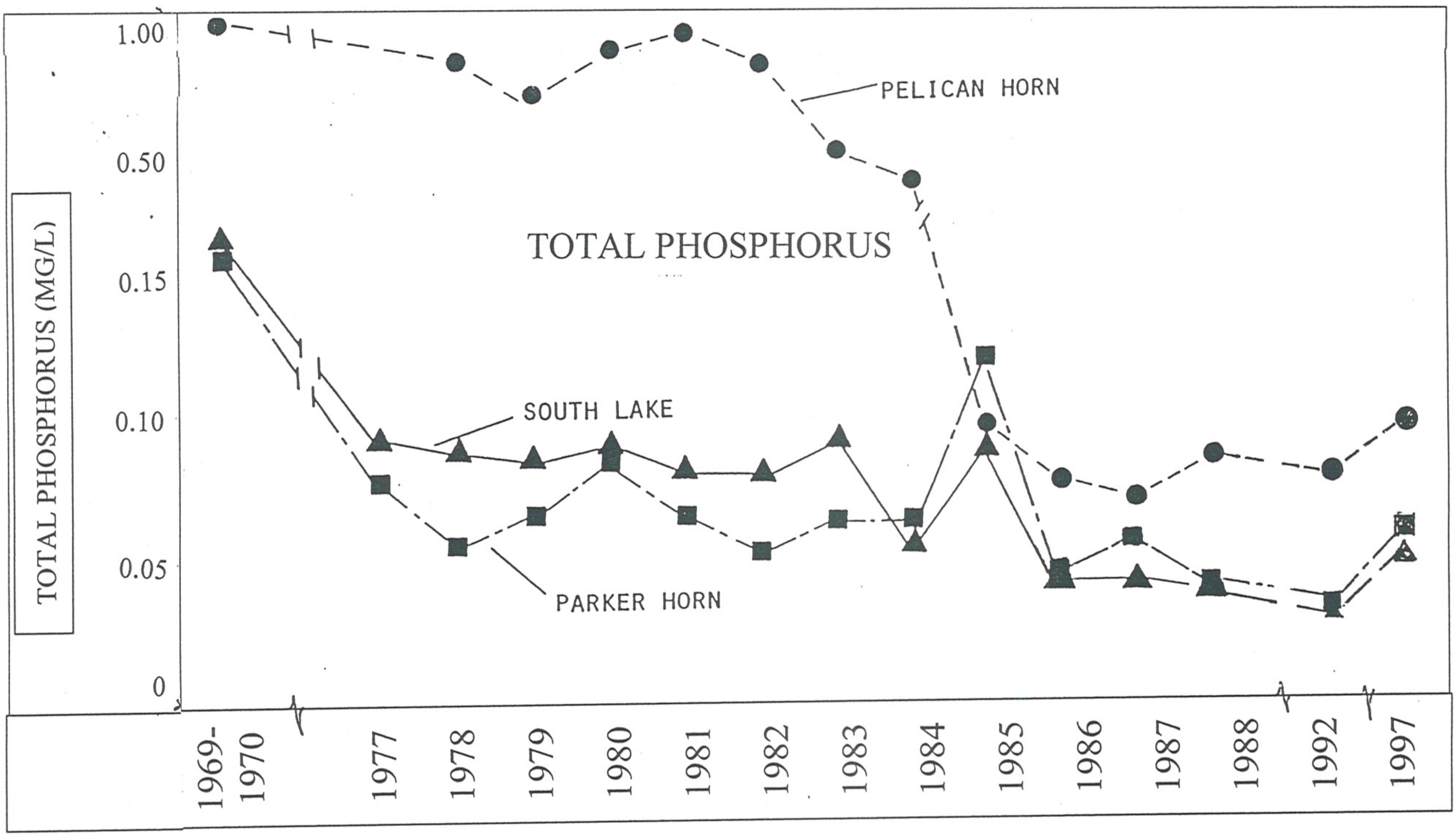


Figure 6 Mean total phosphorus concentrations from transect samples in three sections of Moses Lake

water quality was nevertheless improved over baseline conditions as established by earlier University of Washington studies. For example, overall lake quality in 1969 averaged over 0.15 mg/l in Parker Horn and South Lake and over 0.50 mg/l in Pelican Horn prior to effluent diversion in 1984. Pelican Horn averaged 0.12 mg/l total phosphorus in 1997.

Parker Horn water quality was not affected by the City of Moses Lake sewage effluent which was discharged to Pelican Horn until 1984. However, Parker Horn quality is directly affected by Crab Creek which flows into this reach of the lake and is therefore more affected by irrigated agriculture except during periods when nutrients are effectively diluted by East Low Canal releases. Although little dilution water was released in 1997 Parker Horn had an average of 0.08 mg/l total phosphorus, about half the concentration recorded in 1969-70 by the University of Washington. This finding is encouraging and suggests that past water quality control efforts may have had carryover benefits in a year of minimal dilution water release.

Chlorophyll a Comparison

Chlorophyll a is a pigment in green plants including planktonic algae. Data are available for chlorophyll from past studies by the University and the 1992 and 1997 surveys. See Figure 7.

Chlorophyll a averaged less than 5 ug/l at all transect stations in 1992 and averaged about 10 ug/l in 1988 in contrast with baseline conditions (1969-70) when average chlorophyll concentrations exceeded 50 ug/l. The 1997 chlorophyll concentrations averaged about 20 ug/l, significantly higher than in 1988-1992 but significantly lower than in the 1969-70 period before water quality controls were implemented.

The chlorophyll goal established in 1977 was 20 ug/l. The 1997 chlorophyll levels averaged slightly less than the goal but reached 28 ug/l in the Rocky Ford Arm in June and 31 ug/l in Parker Horn in August 1997. In contrast, chlorophyll measurements in 1992 did not exceed 5.6 ug/l and most values were in the range 1.2 – 2.4 ug/l. Thus although the 1997 chlorophyll levels met the goal in about half of the samples, water quality as measured by chlorophyll content was significantly poorer in 1997 as compared with the 1992 lake monitoring results or the 1988 survey by the University of Washington.

Transparency Comparisons

Water clarity or transparency as measured by Seechi disc has been documented in Moses Lake since the 1969-70 baseline study. The same transect stations have been used since 1977. Water clarity has generally improved since the 1970s although changes are less dramatic, particularly in Pelican Horn. See Figure 8.

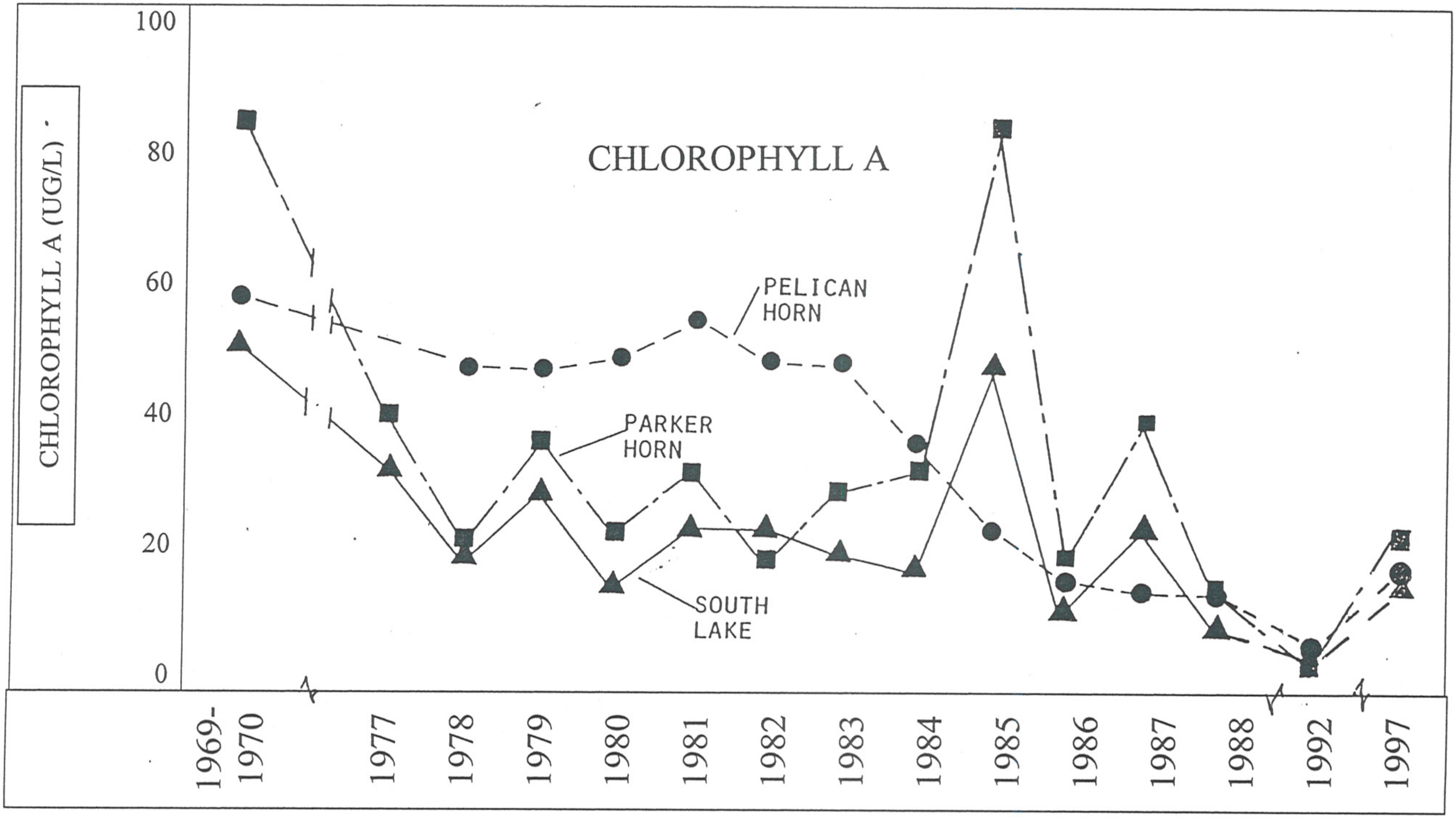


Figure 7 Mean chlorophyll concentrations from transect samples in three sections of Moses Lake

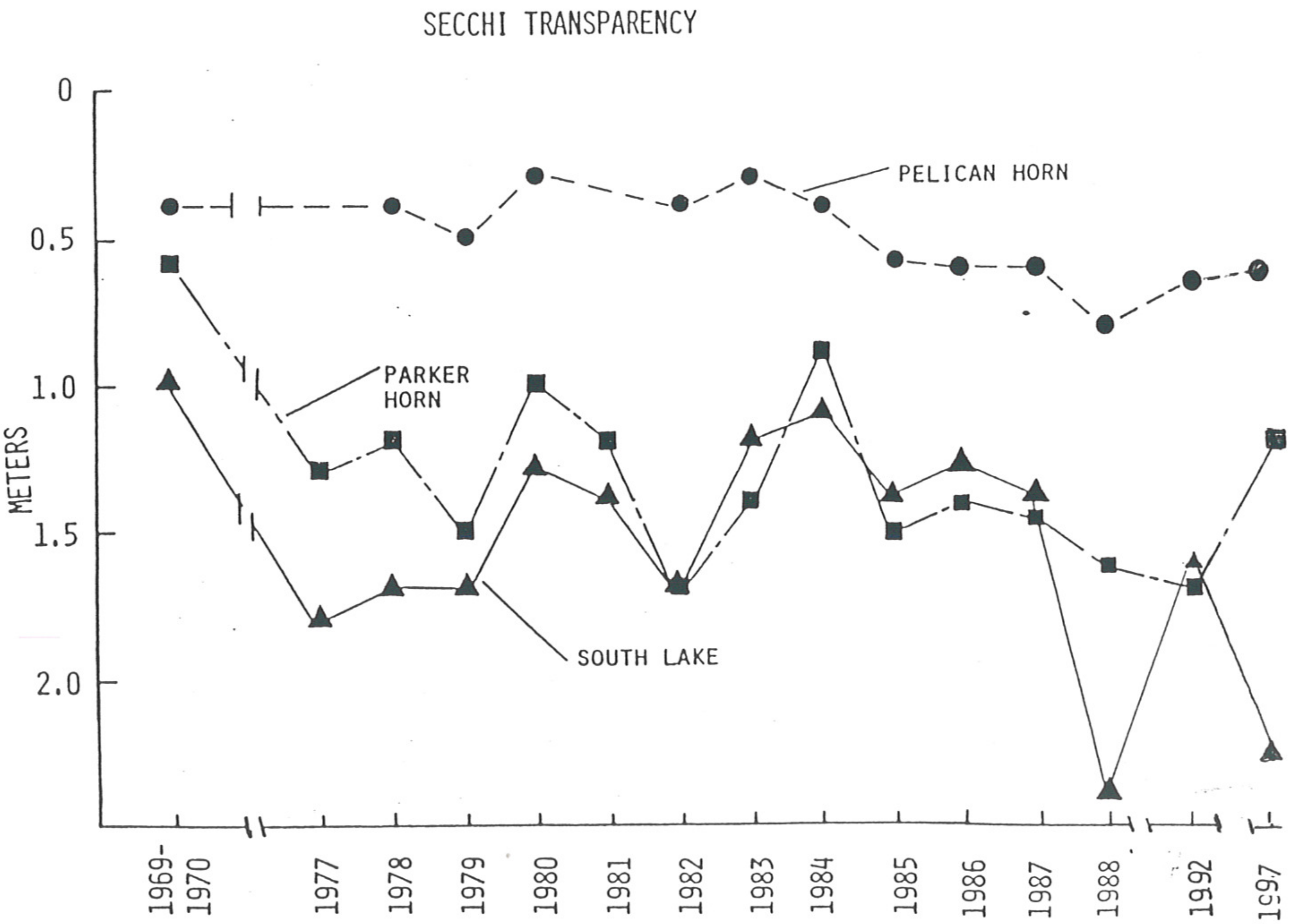


Figure 8 Average Water Transparency At Three Locations in Moses Lake

Parker Horn transparency has improved since 1969-70 when readings were about 0.6 meters reaching 1.5 meters by 1992. The 1997 transparency in Parker Horn averaged 1.2 meters, double the average readings in 1969-70.

Pelican Horn transparency averaged about 0.65 meters in 1997 essentially the same as was observed in 1992. Pelican Horn is quite shallow and affected by wind as well as residual nutrients in bottom sediments enriched by past sewage effluent discharge. Thus changes in Pelican Horn water clarity are expected to be slower since this poorly flushed horn is more likely to produce higher algal concentrations and contain significantly more detritus stirred up from the bottom. Microscopic evaluations of a Pelican Horn sample collected in August showed significant amounts of debris, including fragments of diaton shells which also tend to cloud the water.

Overall the average transparency of Moses Lake was 1.46 meters in 1997 as compared with 1.25 meters in 1992. Although 1997 data show an apparent improvement the Secchi disc data is more susceptible to change due to wind conditions and should not be relied on as much as the total phosphorus indicator which is generally more reflective of eutrophication conditions in the lake.

Near Shore Lake Stations

Three near shore locations (Connelly Park, Parker Horn Pump Station and the USBR outlet structure) were also sampled during 1997 which can be compared with 1992 results when similar monitoring was performed. Nitrate concentrations observed at the lake shore stations were higher at all locations and nearly tripled values found in 1992 at the outlet structure which represents the water quality mixture flowing from the lake. Total phosphorus averages were also elevated in 1997 and the outlet station value was approximately triple (0.10 mg/l) that found in 1992 (0.03 mg/l).

CONCLUSIONS AND RECOMMENDATIONS

Monitoring of Moses Lake area water quality was carried out during 1997 in order to provide comparative data and additional background information. Comparisons of past water quality were made using data from similar surveys carried out since 1969 for Moses Lake waters and 1982 for tributaries and groundwaters.

Conclusions

1. Total phosphorus and nitrate concentrations in Crab Creek were significantly higher in 1997 as compared with the previous survey in 1992, although nitrates were lower than those found in 1986-87. Flows in Crab Creek were also higher than in 1992.
2. Total phosphorus and nitrate concentrations in Rocky Ford Creek were higher than those found in 1992 but averages were similar to values from the 1980s. This tributary consistently has elevated phosphate levels.

3. Water wells sampled on the west side of Crab Creek exhibited lower nitrate concentrations and two of the three wells showed significantly lower values during the non irrigation season.
4. The spring on the east side of Crab Creek had higher nitrate and total phosphorus concentrations than observed in previous monitoring programs dating back to the early 1980s.
5. The reference water well monitored on the east side since the early 1980s had lower average nitrate concentrations than observed in previous years, although total phosphorus values remained elevated at this location.
6. Several wells spot checked near an old cattle auction yard north of the City had elevated nitrate levels near 5 mg/l, over double the average found in the reference wells and spring.
7. Average total phosphorus concentrations measured at four transects within Moses Lake in 1997 were approximately double those found in 1992 at the same locations and exceeded recommended levels.
8. Average chlorophyll concentrations measured in surface water transect samples in Moses Lake in 1997 were significantly elevated over values measured in 1992 but were generally lower than levels reported prior to 1985.
9. Water transparency was relatively unchanged based on data gathered in 1997 as compared with data gathered since 1985 but was improved over earlier years.
10. Dilution water releases into Moses Lake from the East Low Canal were less than 10 percent of those provided in 1992 and were among the lowest recorded in the past twenty years.
11. Lake temperatures were not recorded during the recreation season in 1992 due to a malfunction in the recording device at the USBR outlet.
12. On-site septic systems have increased in number due to population growth in surrounding County areas but have been reduced within the City of Moses Lake through sewering programs that have extended service to three areas (Peninsula, Crestview, Laguna) that were not sewered in 1992.

Recommendations

1. Release of dilution water from the East Low Canal should be a priority method for feeding Potholes Reservoir by the Columbia Basin Irrigation Project as these flows significantly benefit Moses Lake water quality.
2. Continued emphasis is needed on mitigation of near shore urban development impacts and on-farm irrigation water management needs as related to water quality of Moses Lake and its tributaries, including local ground waters.
3. Future water quality surveys should be carried out using similar methods and sampling locations to document water quality and to serve as a basis for identifying changes or trends. The frequency of such investigations should probably be every four or five years.
4. The USBR should be recognized for its continued cooperation with the Moses Lake Irrigation and Rehabilitation District in providing dilution water which is so useful in managing Moses Lake water quality.
5. Grant County should be encouraged to provide sewer service for dense developments in the Moses Lake area, particularly in near shore areas and where gravelly soils predominate. Community systems and drain field developments with significant set backs from the lake shore are encouraged where sewering is not feasible.

APPENDIX

United States Department of the Interior

BUREAU OF RECLAMATION
Ephrata Field Office
P. O. Box 815
Ephrata, Washington 98823

IN REPLY REFER TO:

EPH-2905
RES-3.10

MAR 19 1998

Mr. Richard Bane
3462 McManamy Road
Ellensburg, WA 98926

Subject: Moses Lake Temperature and Water Level Records, 1996 and 1997

Dear Mr. Bane:

Enclosed are the lake temperatures and water surface elevations for Moses Lake, calendar years 1996 and 1997.

You will note that there is no data for water temperature after April 7, 1997. The temperature sensor malfunctioned on April 8, 1997 and went unnoticed until December 1997. As of March 4, 1998, we are again collecting water temperature data at our outlet works.

If you have any questions, please feel free to contact John O'Callaghan, of my staff, at (509) 754-0244.

Sincerely,

William D. Gray
Manager, Ephrata Field Office

Enclosure

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

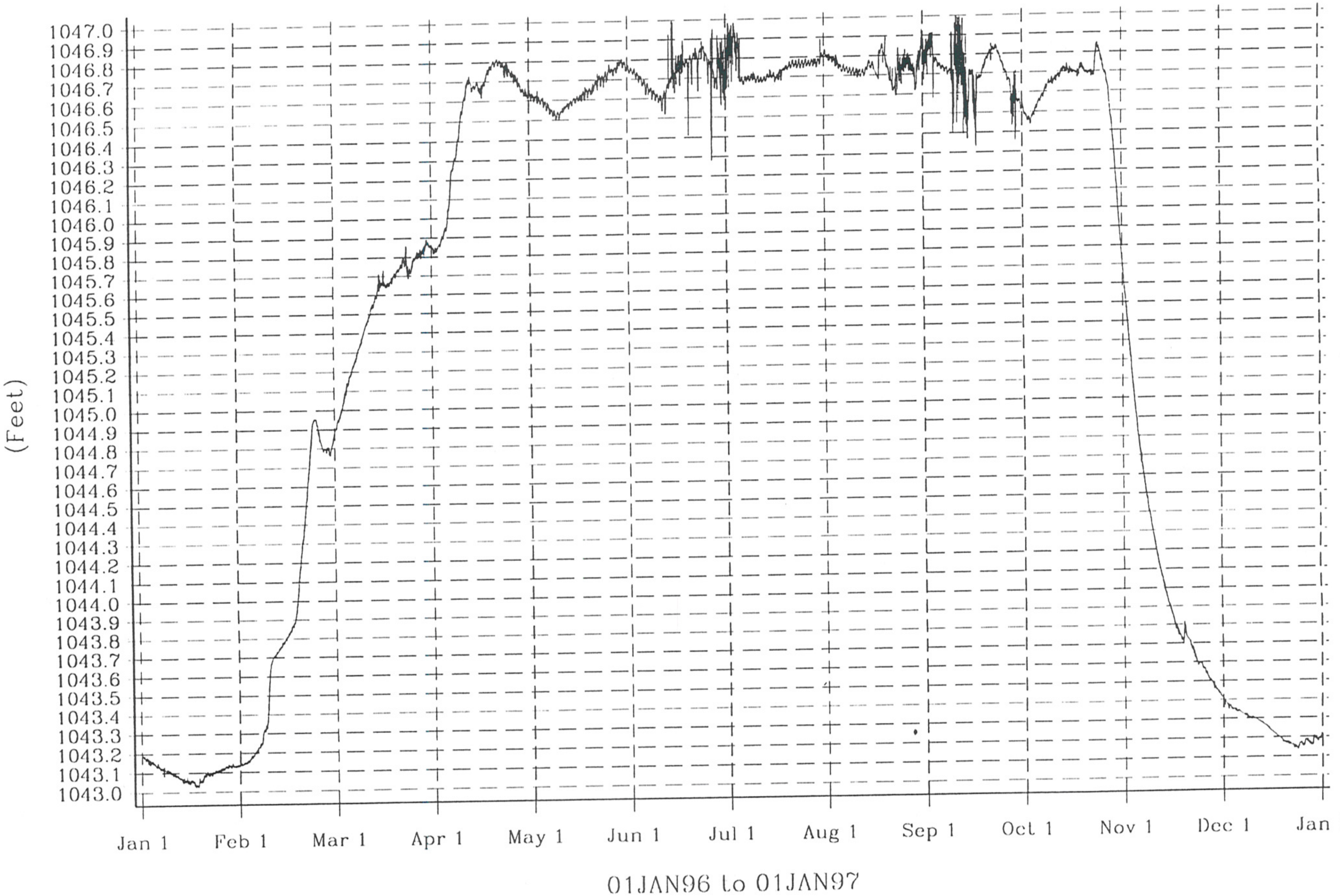
Water Year: 1996
Daily Gage Heights, in feet, of Moses Lake

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1043.18	1043.14	1044.91	1045.83	1046.62	1046.74	1046.83	1046.81	1046.79	1046.50	1045.56	1043.39
2	1043.17	1043.15	1044.96	1045.84	1046.61	1046.74	1046.88	1046.79	1046.84	1046.47	1045.35	1043.37
3	1043.16	1043.16	1045.02	1045.86	1046.61	1046.72	1046.92	1046.79	1046.87	1046.46	1045.16	1043.35
4	1043.15	1043.18	1045.09	1045.91	1046.59	1046.71	1046.86	1046.78	1046.77	1046.49	1044.98	1043.35
5	1043.14	1043.20	1045.15	1045.96	1046.59	1046.68	1046.70	1046.75	1046.75	1046.53	1044.82	1043.34
6	1043.13	1043.23	1045.20	1046.10	1046.57	1046.65	1046.67	1046.73	1046.74	1046.56	1044.67	1043.34
7	1043.12	1043.28	1045.25	1046.25	1046.55	1046.64	1046.69	1046.73	1046.72	1046.59	1044.55	1043.32
8	1043.11	1043.33	1045.30	1046.32	1046.53	1046.63	1046.69	1046.72	1046.71	1046.62	1044.43	1043.31
9	1043.10	1043.52	1045.35	1046.43	1046.52	1046.61	1046.70	1046.72	1046.78	1046.65	1044.33	1043.30
10	1043.10	1043.68	.	1046.55	1046.52	1046.60	1046.68	1046.71	1046.77	1046.65	1044.23	1043.31
11	1043.09	1043.71	1045.46	1046.64	1046.55	1046.58	1046.68	1046.71	1046.80	1046.67	1044.14	.
12	1043.07	1043.74	1045.51	1046.71	1046.56	1046.60	1046.68	1046.71	1046.80	1046.68	1044.07	1043.28
13	1043.06	1043.76	1045.55	1046.67	1046.57	1046.68	1046.69	1046.71	1046.62	1046.71	1043.99	1043.27
14	1043.06	1043.79	1045.60	1046.67	1046.59	1046.77	1046.70	1046.74	1046.51	1046.71	1043.92	1043.26
15	1043.05	1043.82	1045.66	1046.67	1046.60	1046.74	1046.71	1046.75	1046.70	1046.71	1043.86	1043.25
16	1043.05	1043.85	1045.67	1046.65	1046.60	1046.77	1046.69	1046.75	1046.56	1046.70	1043.80	.
17	1043.04	1043.89	1045.65	1046.70	1046.61	1046.80	1046.70	.	1046.66	1046.70	1043.76	.
18	1043.03	1044.01	1045.66	1046.75	1046.63	1046.78	1046.71	1046.82	1046.69	1046.70	1043.72	.
19	1043.05	1044.20	1045.68	1046.78	1046.64	1046.73	1046.74	1046.82	1046.74	1046.73	1043.76	1043.18
20	1043.08	1044.36	1045.71	1046.79	1046.64	1046.76	1046.75	1046.76	1046.78	1046.70	.	1043.17
21	1043.09	1044.55	1045.73	1046.80	1046.67	1046.82	1046.76	1046.69	1046.81	1046.70	1043.68	1043.17
22	1043.09	1044.76	1045.76	1046.79	1046.68	1046.77	1046.76	1046.64	1046.82	1046.69	1043.63	1043.16
23	1043.10	1044.93	1045.78	1046.76	1046.69	1046.84	1046.76	1046.62	1046.82	1046.73	1043.59	1043.15
24	1043.11	1044.94	1045.72	1046.76	1046.70	1046.83	1046.76	1046.73	1046.77	1046.83	1043.58	1043.16
25	1043.11	1044.85	1045.73	1046.74	1046.71	1046.77	1046.76	1046.73	1046.72	1046.77	1043.55	1043.16
26	1043.12	1044.80	1045.79	1046.72	1046.75	1046.66	1046.77	1046.76	1046.68	1046.70	1043.51	1043.18
27	1043.13	1044.80	1045.81	1046.69	1046.74	1046.69	1046.76	1046.76	1046.58	1046.64	1043.49	1043.17
28	1043.13	1044.78	1045.82	1046.66	1046.76	1046.77	1046.77	1046.74	1046.59	1046.48	1043.46	1043.16
29	1043.13	1044.85	1045.84	1046.64	1046.78	1046.72	1046.77	1046.66	1046.56	1046.30	1043.44	1043.20
30	1043.13	.	1045.87	1046.63	1046.78	1046.70	1046.79	1046.77	1046.53	1046.04	1043.42	1043.19
31	1043.13	.	1045.86	.	1046.76	.	1046.80	1046.85	.	1045.79	.	1043.21

Note: Missing data denoted by a '.'

Moses La.

1996 Water Surface Elevations.



Plot Date: December 23, 1997

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

ater Year: 1996
aily Water Temperature, in deg. F., of Moses Lake

ay	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	36.34	36.71	36.86	44.80	52.24	63.32	68.72	73.70	69.21	61.91	49.17	37.46
2	36.04	36.75	36.64	44.83	53.07	65.08	69.67	71.42	69.38	61.66	48.71	36.26
3	36.28	36.71	36.65	45.14	54.14	65.06	68.36	70.99	68.72	60.72	48.11	36.32
4	36.40	36.64	36.80	46.17	54.08	62.92	67.54	69.65	68.55	60.93	47.40	36.25
5	36.55	36.32	37.11	47.16	55.58	65.50	68.09	68.70	67.91	60.89	47.23	36.35
6	36.60	36.16	37.03	46.79	54.92	67.58	68.97	68.54	67.72	60.90	46.83	36.42
7	36.34	35.76	37.07	48.44	54.47	66.80	68.98	69.01	67.15	60.66	46.81	36.39
8	36.57	35.88	37.37	49.42	55.47	67.71	69.46	69.48	67.14	61.01	46.43	36.01
9	36.47	36.06	37.48	48.45	56.16	65.86	69.03	69.38	67.62	61.09	46.55	36.09
10	36.19	36.65	.	47.49	56.21	66.94	70.60	70.23	67.65	60.38	46.53	35.98
11	36.44	36.90	38.17	49.16	58.00	66.72	72.09	69.11	68.39	60.49	46.55	.
12	36.70	37.04	38.72	49.45	57.37	68.37	71.25	70.40	68.17	60.70	46.47	36.01
13	37.01	37.27	39.26	50.03	56.53	69.40	72.12	71.59	67.62	60.23	46.12	36.06
14	36.86	37.56	40.61	51.79	57.97	70.16	72.92	70.80	67.29	58.92	46.19	36.56
15	36.62	37.74	40.70	52.81	58.65	67.58	71.91	71.59	66.80	57.91	46.16	36.51
	36.84	38.06	40.51	50.74	59.51	68.36	71.14	70.92	66.79	57.36	45.96	.
17	36.86	37.90	41.45	50.82	59.30	66.59	71.19	.	66.17	56.75	45.07	.
18	36.81	38.04	44.61	50.74	59.29	65.63	69.92	70.10	65.22	55.66	45.21	.
19	35.84	37.54	43.35	51.35	58.78	65.98	69.33	70.62	65.06	54.81	43.43	37.89
20	35.93	37.53	43.54	51.94	59.14	66.14	69.05	69.62	64.46	54.09	.	37.94
21	36.47	37.93	44.75	51.91	59.70	66.75	69.72	69.89	63.77	53.49	41.45	38.04
22	36.09	38.26	44.39	52.15	58.64	65.64	70.86	70.05	63.55	53.00	40.71	38.13
23	35.87	38.31	44.66	52.41	60.24	66.88	71.08	70.39	63.67	52.64	40.81	38.56
24	35.31	38.21	44.69	52.21	61.02	66.77	72.39	70.40	62.90	51.77	39.22	38.74
25	35.58	38.12	44.04	52.24	60.67	67.11	73.02	70.59	61.80	51.44	39.05	38.95
26	35.94	37.69	45.15	51.55	62.36	67.47	75.68	72.24	61.41	51.23	38.86	38.87
27	35.87	37.69	45.20	51.76	60.82	67.16	75.51	71.09	61.53	50.72	38.39	39.14
28	36.00	37.31	44.57	52.38	61.95	66.99	74.97	70.75	62.27	50.61	37.47	39.36
29	36.37	36.69	44.08	52.36	61.62	68.06	76.45	70.90	61.37	50.43	37.67	39.28
30	36.40	.	44.20	52.85	61.89	68.00	75.26	70.06	61.80	49.68	37.73	39.17
31	36.54	.	44.47	.	62.02	.	74.28	69.78	.	49.53	.	38.47

Note: Missing data denoted by a '.'

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Water Year: 1997

Daily Gage Heights, in feet, of Moses Lake

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1043.23	1043.23	1044.81	1045.92	1046.64	1046.75	1046.65	1046.76	1046.72	1046.73	.	1043.50
2	1043.24	1043.30	1044.84	1045.88	1046.70	1046.73	1046.64	1046.76	1046.74	1046.72	.	1043.47
3	1043.23	1043.34	1044.87	1045.90	1046.72	1046.72	1046.65	1046.76	1046.76	1046.71	1044.97	1043.45
4	1043.22	1043.36	1044.89	1045.83	1046.74	1046.73	1046.65	1046.75	1046.79	1046.69	1044.84	1043.43
5	1043.21	1043.41	1044.92	1045.79	1046.75	1046.73	1046.66	1046.74	1046.80	1046.70	1044.71	1043.41
6	1043.19	1043.45	1044.95	1045.82	1046.75	1046.72	1046.67	.	1046.78	1046.70	1044.60	1043.41
7	1043.17	1043.50	1044.99	1045.86	1046.73	1046.72	1046.69	.	1046.77	1046.70	1044.49	1043.40
8	1043.16	1043.56	1045.02	1046.09	1046.72	1046.71	1046.70	.	1046.75	1046.71	1044.40	1043.39
9	1043.15	1043.60	1045.06	1046.26	1046.72	1046.70	1046.72	.	1046.72	1046.72	1044.30	1043.38
10	1043.13	1043.62	1045.11	1046.40	1046.72	1046.70	1046.71	.	1046.71	1046.72	1044.22	1043.37
11	1043.12	1043.71	1045.17	1046.52	1046.70	1046.69	1046.71	1046.68	1046.69	1046.74	1044.13	1043.35
12	1043.10	1043.73	1045.22	1046.61	1046.69	1046.73	1046.69	1046.68	1046.68	1046.72	1044.08	1043.34
13	1043.09	1043.75	1045.27	1046.64	1046.68	1046.72	1046.69	1046.68	1046.67	1046.72	.	1043.34
14	1043.08	1043.77	1045.31	1046.63	1046.66	1046.71	1046.70	1046.69	1046.64	1046.73	.	1043.33
15	1043.06	1043.83	1045.37	1046.63	1046.64	1046.71	1046.70	1046.69	1046.62	1046.74	.	1043.31
16	1043.05	1043.92	1045.44	1046.65	1046.62	1046.69	1046.69	1046.65	1046.63	1046.74	.	1043.31
17	1043.06	1043.99	1045.51	1046.65	1046.62	1046.69	1046.71	1046.65	1046.65	1046.74	1043.78	1043.30
18	1043.06	1044.03	1045.57	1046.66	1046.59	1046.66	1046.72	1046.65	1046.69	1046.74	1043.76	1043.30
19	1043.05	1044.07	1045.64	1046.65	1046.60	1046.65	.	1046.65	1046.71	1046.74	1043.74	1043.29
20	1043.05	1044.12	1045.69	1046.68	1046.64	1046.65	.	1046.66	1046.73	1046.73	1043.71	1043.28
21	1043.04	1044.19	1045.72	1046.66	1046.67	1046.67	1046.75	1046.65	1046.74	1046.73	1043.68	1043.27
22	1043.05	1044.31	1045.74	1046.65	1046.68	1046.69	1046.77	1046.65	1046.74	1046.78	1043.66	1043.26
23	1043.04	1044.43	1045.81	1046.67	1046.71	1046.72	1046.76	1046.65	1046.75	1046.88	1043.64	1043.25
24	1043.03	1044.58	1045.83	1046.64	1046.74	1046.74	1046.75	1046.68	1046.75	1046.79	1043.62	1043.24
25	1043.02	1044.66	1045.87	1046.62	1046.77	1046.74	1046.73	1046.69	1046.75	1046.69	1043.61	1043.23
26	1043.01	1044.70	1045.91	1046.61	1046.72	1046.71	1046.73	1046.69	1046.73	1046.63	1043.59	1043.22
27	1043.00	1044.76	1045.91	1046.61	1046.70	1046.69	1046.73	1046.69	1046.73	1046.48	1043.56	1043.22
28	1043.03	1044.77	1045.95	1046.58	1046.70	1046.68	1046.72	1046.70	1046.72	1046.32	1043.54	1043.21
29	1043.05	.	1045.93	1046.59	1046.69	1046.67	1046.74	1046.70	1046.72	.	1043.52	1043.21
30	1043.07	.	1045.93	1046.61	1046.70	1046.67	1046.76	1046.70	1046.72	.	1043.50	1043.21
31	1043.14	.	1045.95	.	1046.74	.	1046.77	1046.71	.	.	.	1043.21

Note: Missing data denoted by a '.'

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

ter Year: 1997
ily Water Temperature, in deg. F., of Moses Lake

y	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	38.61	41.39	42.89	51.53	.	.	.	.	.	.	.	.
2	38.99	41.61	43.22	51.71	.	.	.	.	.	.	.	.
3	39.19	41.82	43.26	51.86	.	.	.	.	.	.	.	.
4	39.26	41.66	43.01	52.01	.	.	.	.	.	.	.	.
5	39.23	42.01	43.27	52.49	.	.	.	.	.	.	.	.
6	39.58	41.99	43.40	52.71	.	.	.	.	.	.	.	.
7	39.79	41.98	43.53	52.47	.	.	.	.	.	.	.	.
8	39.70	41.88	43.95	.	.	.	.	.	.	.	.	.
9	40.05	42.03	44.49	.	.	.	.	.	.	.	.	.
10	40.44	42.24	44.90	.	.	.	.	.	.	.	.	.
11	40.02	41.89	44.80	.	.	.	.	.	.	.	.	.
12	40.70	42.00	44.79	.	.	.	.	.	.	.	.	.
13	41.36	42.01	45.38	.	.	.	.	.	.	.	.	.
14	41.72	42.14	45.72	.	.	.	.	.	.	.	.	.
15	41.69	.	45.71	.	.	.	.	.	.	.	.	.
	41.32	.	45.60	.	.	.	.	.	.	.	.	.
17	40.89	.	45.73	.	.	.	.	.	.	.	.	.
18	40.76	41.53	46.60	.	.	.	.	.	.	.	.	.
19	40.73	41.54	47.13	.	.	.	.	.	.	.	.	.
20	41.03	42.40	47.56	.	.	.	.	.	.	.	.	.
21	41.50	42.35	48.60	.	.	.	.	.	.	.	.	.
22	41.38	42.51	50.19	.	.	.	.	.	.	.	.	.
23	40.98	42.29	49.34	.	.	.	.	.	.	.	.	.
24	40.92	42.15	49.65	.	.	.	.	.	.	.	.	.
25	41.50	42.55	49.99	.	.	.	.	.	.	.	.	.
26	41.72	42.02	49.27	.	.	.	.	.	.	.	.	.
27	42.11	42.47	50.49	.	.	.	.	.	.	.	.	.
28	42.07	42.56	50.56	.	.	.	.	.	.	.	.	.
29	41.96	.	51.08	.	.	.	.	.	.	.	.	.
30	41.65	.	51.59	.	.	.	.	.	.	.	.	.
31	41.34	.	51.26	.	.	.	.	.	.	.	.	.

Note: Missing data denoted by a '.' Data after April 7, 1997 not available due to a malfunction in field hardware.

Aquatic Analysts

September 5, 1997

Richard Bain
3462 McManamy Road
Ellensburg, WA 98926

Dear Richard,

I've looked at the 2 algae samples you collected from Moses Lake on August 13, 1997:

Parker Horn

The dominant alga was a filamentous centric diatom, Melosira granulata; it accounted for the greater majority of the algal biovolume in that sample. The filamentous bluegreen alga, Oscillatoria sp., was fairly common. Anabaena circinalis, another filamentous bluegreen alga, was somewhat common.

Pelican Horn

This sample did not have a strong dominant; it contained many species of algae. The most abundant was Melosira ambigua, a filamentous centric diatom. Other algae observed at approximately similar abundances were Scenedesmus spp., Ankistrodesmus falcatus, Selenastrum sp., Oocystis sp., Fragilaria crotonensis, Chroococcus minutus, and many periphytic diatom species within the genera Navicula, Cymbella, Fragilaria, and Gomphonema.

This sample from Pelican Horn contained alot of debris, including fragments of diatom cell walls, and other undefinable globs of stuff.

Richard, I hope this is what you were looking for. I filtered the samples into permanent slide mounts, so if you'd like further information, I can provide you with more.

Thank you for requesting my services.

Best regards,

Jim Sweet
Aquatic Analysts

29882 S.W. Camelot St. Wilsonville, Oregon 97070 503/570-9007 e-mail: jwsweet@aol.com

United States Department of the Interior

BUREAU OF RECLAMATION
Ephrata Field Office
P. O. Box 815
Ephrata, Washington 98823

IN REPLY REFER TO:
EPH-2905
PRJ-13.10

MAY 13 1998

Mr. Dick Bain
Civil and Environmental Engineering
3462 McManamy Road
Ellensburg WA 98926

Subject: Potholes Reservoir Feed Water through Moses Lake

Dear Dick:

Per our phone conversation today, here are the annual total flows down Rocky Coulee Wasteway broken down between Project waters and runoff. Project waters include feed to Potholes Reservoir, canal waste, canal drain out water and drainage flows.

Year	Project	Runoff	Total
1990	229,980	0	229,980
1991	286,098	0	286,098
1992	267,846	0	267,846
1993	120,976	2,670	123,646
1994	289,356	0	289,356
1995	132,211	500	132,711
1996	60,685	1,931	62,617
1997	25,886	760	26,646

If you have any further questions regarding this data, please contact John O'Callaghan at (509) 754-0244.

Sincerely,

ACTING FOR
William D. Gray
Manager, Ephrata Field Office

115c

soiltest farm consultants, inc.

2925 WAPATO DRIVE (Exit 176, I-90), MOSES LAKE, WASHINGTON 98837
(509) 765-1622 1-800-764-1622 FAX (509) 765-0314

RICHARD BAIN
3462 MCMANAMY RD
ELLENSBURG WA 98926

DATE REC. 3/27/97
DATE SAMPLED 3/27/97
REPORT # 159-1

SAMPLE I.D.	LAB #	EC m.mhos/cm	NO3-N mg/L	NH4-N mg/L	TOTAL P mg/L	TSS mg/L	TURBIDITY NTU
MOSES LAKE PARKER HORN	195	448	2.3	1.5	0.18	43	40
MOSES LAKE CONNELLY PARK	196	366	0.5		0.08		
MOSES LAKE OUTLET	197	415	1.1		0.08		
ROCKY FORD CREEK HWY 17	198	384	1.9		0.18		
CRAB CREEK @ RD 7	199	430	2.2	1.0	0.20	40	40
ROCKY COULEE WASTE WAY	200	566	2.2		0.08		
PUD WELL	201	365	0.05*		0.02*		
FULLER WELL	202	705	1.9		0.02*		
MCINTOSH WELL	203	615	3.7		0.02*		
WILKE WELL	204	429	1.7		0.02*		
BURNHAM WELL	205	697	2.3		0.08		
COL BASIN FISH HATCHERY	206	537	2.6		0.04		
ESTOOS WELL	207	709	5.4		0.10		

ALL TESTING DONE IS IN COMPLIANCE WITH PROVISIONS SET FORTH IN CHAPTER 173-50 WAC

*BELOW DETECTION LIMIT

AMOUNT: $405.00

ANALYST/QC [signature]

REVIEWED BY [signature]

soiltest farm consultants, inc.

2925 WAPATO DRIVE (Exit 176, I-90), MOSES LAKE, WASHINGTON 98837
(509) 765-1622 1-800-764-1622 FAX (509) 765-0314

RICHARD BAIN
3462 MCMANAMY RD
ELLENSBURG WA 98926

DATE REC. 5/1/97
DATE SAMPLED 4/30/97
REPORT # 194-1

SAMPLE I.D.	LAB #	EC m.mhos/cm	NO3-N mg/L	NH4-N mg/L	TOTAL P mg/L	TSS mg/L
MOSES LAKE OUTLET	250	404	0.8		0.06	
MOSES LAKE PARKER HORN	251	481	0.8	1.0	0.11	4
MOSES LAKE CONNELLY PARK	252	390	0.9		0.70	
ROCKY COULEE WASTE WAY	253	476	2.1		0.22	
CRAB CREEK @ RD 7	254	468	0.6	1.0	0.90	7
'OCKY FORD CREEK HWY 17	255	376	2.0		0.13	
TYCO, INC.	256	466	5.0		<0.03	

ALL TESTING DONE IS IN COMPLIANCE WITH PROVISIONS SET FORTH IN CHAPTER 173-50 WAC

AMOUNT: $226.80

ANALYST/QC [signature]

REVIEWED BY [signature]

soiltest farm consultants, inc.

2925 WAPATO DRIVE (Exit 176, I-90) MOSES LAKE, WASHINGTON 98837
(509) 765-1622 1-800-764-1622 FAX (509) 765 0314

RICHARD BAIN
3462 MCMANAMY RD
ELLENSBURG WA 98926

DATE RECEIVED 5/30/97
DATE REPORTED 6/5/97
REPORT # 225-3
DATE SAMPLED 5/29/97

SAMPLE I.D.	LAB #	EC m.mhos/cm	NO3-N mg/L	NH4-N mg/L	TOTAL P mg/L
MOSES LAKE OUTLET	346	417	0.7	-	<0.03
MACINTOSH WELL	347	589	4.1		<0.03
HATCHERY SPRING	348	515	2.9		0.09
CRAB CREEK @ RD 7	349	468	1.0	1	0.15
BURMAN WELL	350	698	1.7		0.17
ROCKY COULEE WASTEWAY	351	444	2.1		0.09
PUD WELL	352	513	2.9		0.07
WILKIE WELL	353	439	3.4		0.07
TYCO WELL	354	283	4.9		<0.03

ALL TESTING DONE IS IN COMPLIANCE WITH PROVISIONS
SET FORTH IN CHAPTER 173-50 WAC

AMOUNT: $243.00

ANALYST/QC [signature]

REVIEWED BY [signature]

soiltest farm consultants, inc.

2925 WAPATO DRIVE (Exit 176, I-90), MOSES LAKE, WASHINGTON 98837
(509) 765-1622 1-800-764-1622 FAX (509) 765-0314

RICHARD BAIN
3462 MCMANAMY RD
ELLENSBURG WA 98926

DATE RECEIVED 7/9/97
DATE REPORTED 7/23/97
REPORT # 256 3
DATE SAMPLED 7/9/97

SAMPLE I.D.	LAB #	NO3-N mg/L	EC m.mhos/cm	TOTAL P mg/L	NH4-N mg/L	TSS mg/L
MOSES LAKE @ PUMP STATION	458	0.7	357	0.15		
MOSES LAKE OUTLET	459	0.1	362	0.10		
MOSES LAKE @ CONNELLY PARK	460	0.2	352	0.34		
ROCKY COULEE WASTEWAY	461	0.9	232	0.12		
ROCKY FORD CREEK	462	1.0	361	0.18		
CRAB CREEK	463	1.5	475	0.14	1.0	8

ALL TESTING DONE IS IN COMPLIANCE WITH PROVISIONS
SET FORTH IN CHAPTER 173-50 WAC

AMOUNT: $176.40

ANALYST/QC ______

REVIEWED BY ______

soiltest farm consultants, inc.

2925 WAPATO DRIVE (Exit 176, I-90), MOSES LAKE, WASHINGTON 98837
(509) 765-1622 1-800-764-1622 FAX (509) 765-0314

RICHARD BAIN
3462 MCMANAMY RD
ELLENSBURG WA 98926

DATE RECEIVED 7/9/97
DATE REPORTED 7/23/97
REPORT # 256-4

SAMPLE I.D.	LAB #	NO3-N mg/L	EC m.mhos/cm	TOTAL P mg/L
BURNHAM WELL 7/9	464	1.2	725	0.12
RATHBONE SALES WELL 6/30	465	4.7	418	<0.03
HUCK FULLER WELL 6/10	466	2.1	720	<0.03
WILKE WELL 7/9	467	3.0	440	0.40
NORM ESTES WELL 7/8	468	2.5	577	0.16
MCINTOSH WELL 7/9	469	3.8	595	<0.03
PUD WELL 7/9	470	1.4	369	0.08

ALL TESTING DONE IS IN COMPLIANCE WITH PROVISIONS SET FORTH IN CHAPTER 173-50 WAC

AMOUNT: $176.40

ANALYST/QC [signature]

REVIEWED BY [signature]

soiltest farm consultants, inc.

2925 WAPATO DRIVE (Exit 176, I-90), MOSES LAKE, WASHINGTON 98837
(509) 765-1622 1-800-764-1622 FAX (509) 765-0314

R CHARD BAIN
3462 MCMANAMY RD
ELLENSBURG WA 98926

DATE RECEIVED 8/12/97
DATE REPORTED 8/28/97
REPORT # 285-1

SAMPLE I.D.	LAB #	NO3-N mg/L	TOTAL P mg/L
ROCKY FORD CREEK 8/13	539	1.5	0.23
MOSES LAKE @ CONNELLY PARK 8/13	540	0.2	0.22
ROCKY COULEE WASTEWAY 8/13	541	2.5	0.12
CRAB CREEK 8/13	542	1.5	0.09
COLUMBIA BASIN HATCHERY 7/9	543	3.3	0.10
PARKER HORN PUMP STATION 8/13	559	0.2	0.18

ALL TESTING DONE IS IN COMPLIANCE WITH PROVISIONS
SET FORTH IN CHAPTER 173-50 WAC

AMOUNT: 74.50

ANALYST/QC ________

REVIEWED BY ________

soiltest farm consultants, inc.

2925 WAPATO DRIVE (Exit 176, I-90), MOSES LAKE, WASHINGTON 98837
(509) 765-1622 1-800-764-1622 FAX (509) 765 0314

RICHARD BAIN
3462 MCMANAMY RD
ELLENSBURG WA 98926

DATE RECEIVED 9/17/97
DATE REPORTED 10/1/97
REPORT # 318-4

SAMPLE I.D.	LAB #	NO3-N mg/L	TOTAL P mg/L
MOSES LAKE OUTLET 9/17	643	0.2	0.17
MOSES LAKE @ CONNELLY PARK 9/17	644	0.2	0.22
MOSES LAKE @ PARKER HORN 9/17	645	1.4	0.19
CRAB CREEK @ RD 7 9/17	646	1.4	0.10
ROCKY COULEE WW 9/17	647	2.4	0.15
ROCKY FORD CREEK 9/17	648	1.5	0.24

ALL TESTING DONE IS IN COMPLIANCE WITH PROVISIONS
SET FORTH IN CHAPTER 173-50 WAC

AMOUNT: $118.80

ANALYST/QC ____________

REVIEWED BY ____________

soiltest farm consultants, inc.

2925 WAPATO DRIVE (Exit 176, I-90), MOSES LAKE, WASHINGTON 98837
(509) 765-1622 1-800-764-1622 FAX (509) 765-0314

RICHARD BAIN
62 MCMANAMY RD
LLENSBURG WA 98926

DATE RECEIVED 10/14/97
DATE REPORTED 10/27/97
REPORT # 340-3

MPLE .D.	LAB #	NO3-N mg/L	TOTAL P mg/L
SES LAKE OUTLET 10/14	691	0.1	0.15
ATHBONE SALES WELL 10/14	692	0.4	0.15
SES LAKE @ PARKER HORN 10/14	693	4.9	0.05

?

LL TESTING DONE IS IN COMPLIANCE WITH PROVISIONS
T FORTH IN CHAPTER 173-50 WAC

OUNT: $59.40

NALYST/QC ____________

EVIEWED BY ____________

soiltest farm consultants, inc.

2925 WAPATO DRIVE (Exit 176, I-90), MOSES LAKE, WASHINGTON 98837
(509) 765-1622 1-800-764-1622 FAX (509) 765-0314

CHARD BAIN
462 MCMANAMY RD
ELLENSBURG WA 98926

DATE RECEIVED 10/28/97
DATE REPORTED 11/6/97
REPORT # 346-2
DATE SAMPLED 10/22/97

SAMPLE I.D.	LAB #	NO3-N mg/L	TOTAL P mg/L	TSS mg/L
CKY COULEE WASTEWAY	713	0.2	0.12	35
SH HATCHERY SPRING	714	3.3	0.12	
ROCKY FORD CREEK @ HWY 17	715	1.8	0.19	7
INTOSH WELL	716	0.1	0.04	
MOSES LAKE @ CONNELLY PARK	717	0.3	0.10	14
CKY FORD CREEK BELOW DAM	718	1.8	0.19	7
RMAN WELL	719	1.2	0.10	
CRAB CREEK @ RD 7	720	1.4	0.08	6
LKE WELL	721	1.7	0.04	
PUD WELL	722	0.1	<0.03	

LL TESTING DONE IS IN COMPLIANCE WITH PROVISIONS
T FORTH IN CHAPTER 173-50 WAC

OUNT: $243.00

ALYST/QC

EVIEWED BY

soiltest farm consultants, inc.

2925 WAPATO DRIVE (Exit 176, I-90), MOSES LAKE, WASHINGTON 98837
(509) 765-1622 1-800-764-1622 FAX (509) 765-0314

RICHARD BAIN
3462 MCMANAMY RD
ELLENSBURG WA 98926

DATE RECEIVED 5/12/98
DATE REPORTED 5/14/98
REPORT # 208-1

SAMPLE I.D.	LAB #	NO3-N ppm
PUD WELL	311	1.3

ALL TESTING DONE IS IN COMPLIANCE WITH PROVISIONS SET FORTH IN CHAPTER 173-50 WAC

AMOUNT: $9.00

ANALYST/QC ____________

REVIEWED BY ____________

soiltest farm consultants, inc.

2925 WAPATO DRIVE (Exit 176, I-90), MOSES LAKE, WASHINGTON 98837
(509) 765-1622 1-800-764-1622 FAX (509) 765-0314

RICHARD BAIN
3462 MCMANAMY RD
ELLENSBURG WA 98926

DATE RECEIVED 6/9/98
DATE REPORTED 6/23/98
REPORT # 229-1

SAMPLE I.D.	LAB #	NO3-N ppm
PUD WELL	371	1.6

ALL TESTING DONE IS IN COMPLIANCE WITH PROVISIONS SET FORTH IN CHAPTER 173-50 WAC

AMOUNT: $9.00

ANALYST/QC ____________

REVIEWED BY ____________

soiltest farm consultants, inc.

2925 WAPATO DRIVE (Exit 176, I-90), MOSES LAKE, WASHINGTON 98837
(509) 765-1622 1-800-764-1622 FAX (509) 765-0314

RICHARD BAIN
3462 MCMANAMY RD
ELLENSBURG WA 98926

DATE RECEIVED 7/17/98
DATE REPORTED 7/20/98
REPORT # 275-1

SAMPLE I.D.	LAB #	NO3-N ppm
PUD WELL	544	1.3

ALL TESTING DONE IS IN COMPLIANCE WITH PROVISIONS SET FORTH IN CHAPTER 173-50 WAC

AMOUNT: $9.00

ANALYST/QC ________

REVIEWED BY ________

Lauchs Since 1908
Testing Laboratories, Inc.
940 South Harney St., Seattle, WA 98108 (206) 767-5060 FAX (206) 767-5063

Chemistry, Microbiology, and Technical Services

CLIENT: R.C. Bain
3462 McMan
Ellensburg, WA 98926

ATTN : -

Certificate of Analysis

Work Order# : 97-06-325
DATE RECEIVED : 06/10/97
DATE OF REPORT: 07/03/97

Work ID : Moses Lake Monitoring
Taken By : Client
Transported by: PonyExp
Type : Water

SAMPLE IDENTIFICATION:

	Sample Description	Collection Date		Sample Description	Collection Date
01	Moses Lk-Connelly Lk Trans	06/05/97 11:05	06	Moses Lk-Connelly Park	06/05/97 11:00
02	Moses Lk-Pelican Horn Tran	06/05/97 12:40	07	Moses Lk-Connelley Park	06/05/97 11:05
03	Moses Lk-Parker Horn Trans	06/05/97 13:10	08	Moses Lk-Pelican Horn	06/05/97 12:40
04	Moses LK-Outlet Shallow	06/05/97 11:45	09	Moses Lk-Parker Horn Trans	06/05/97 13:10
05	Moses Lk-Outlet-Deep Trans	06/05/97 12:00			

Unless otherwise instructed all samples will be discarded on 08/08/97 with the exception of samples which are consumed during the analysis, such as microbiological samples.

Respectfully submitted,
Laucks Testing Laboratories, Inc.

J. M. Owens

Laucks Since 1908
Testing Laboratories, Inc.
940 South Harney St., Seattle, WA 98108 (206) 767-5060 FAX (206) 767-5063
Chemistry, Microbiology, and Technical Services

CLIENT : R.C. Bain

Certificate of Analysis

Work Order # 97-06-325

TESTS PERFORMED AND RESULTS:

Analyte	Units	01	02	03	04
Ammonia as N (EPA 350.1)	mg/L	0.22	0.12	0.12	0.13
Chlorophyll A (SM 10200H)	mg/m3	28.	20.	13.	24.
Nitrate + Nitrite as N	mg/L	0.38	0.07	0.44	0.36
Total Phosphate as P	mg/L	0.14	0.15	0.10	0.09

Analyte	Units	05	06
Ammonia as N (EPA 350.1)	mg/L	0.87	0.35
Chlorophyll A (SM 10200H)	mg/m3	4.	96.
Nitrate + Nitrite as N	mg/L	0.02	0.38
Total Phosphate as P	mg/L	0.32	0.24

Laucks Since 1908
Testing Laboratories, Inc.
940 South Harney St., Seattle, WA 98108 (206) 767-5060 FAX (206) 767-5063
Chemistry, Microbiology, and Technical Services

CLIENT: R.C. Bain
3462 McMan
Ellensburg, WA 98926

ATTN : R.C. Bain

Certificate of Analysis

Work Order# : 97-08-466
DATE RECEIVED : 08/15/97
DATE OF REPORT: 09/04/97

Work ID : Moses Lake Monitoring
Taken By : Client
Transported by: PonyExp
Type : Water

SAMPLE IDENTIFICATION:

	Sample Description	Collection Date
01	Moses Lk Connelly Park	08/13/97 10:30
02	Moses Lk Outlet-shallow	08/13/97 11:00
03	Moses Lk Outlet - deep	08/13/97 11:00
04	Moses Lake-Pelican Horn	08/13/97 11:50
05	Moses Lake - Parker Horn	08/13/97 12:15
06	Moses Lk Parker Horn pump	08/13/97 12:00

FLAGGING:

The flag "U" indicates the analyte of interest was not detected, to the limit of detection indicated.

Unless otherwise instructed all samples will be discarded on 10/13/97 with the exception of samples which are consumed during the analysis, such as microbiological samples.

Respectfully submitted,
Laucks Testing Laboratories, Inc.

J. M. Owens

Laucks Since 1908
Testing Laboratories, Inc.
940 South Harney St., Seattle, WA 98108 (206) 767-5060 FAX (206) 767-5063
Chemistry, Microbiology, and Technical Services

CLIENT : R.C. Bain

Certificate of Analysis

Work Order # 97-08-466

TESTS PERFORMED AND RESULTS:

Analyte	Units	01	02	03	04
Ammonia as N (EPA 350.1)	mg/L	0.03	0.05	2.4	0.02
Chlorophyll A (SM 10200H)	mg/m3	17.	8.	1.	15.
Nitrate + Nitrite as N	mg/L	0.01	0.02	0.02	0.08
Total Phosphate as P	mg/L	0.12	0.05	0.39	0.09

Analyte	Units	05	06
Ammonia as N (EPA 350.1)	mg/L	0.03	0.05 U
Chlorophyll A (SM 10200H)	mg/m3	31.	23.
Nitrate + Nitrite as N	mg/L	0.02	0.25
Total Phosphate as P	mg/L	0.06	0.08

Laucks Since 1908
Testing Laboratories, Inc.
940 South Harney St., Seattle, WA 98108 (206) 767-5060 FAX (206) 767-5063
Chemistry, Microbiology, and Technical Services

CLIENT : R.C. Bain

Certificate of Analysis

Work Order # 97-09-589

TESTS PERFORMED AND RESULTS:

Analyte	Units	01
Chlorophyll A (SM 10200H)	mg/m3	49.

USGS
science for a changing world

Water Quality in the Central Columbia Plateau

Washington and Idaho, 1992–95

U.S. Department of the Interior
U.S. Geological Survey

Circular 1144

Nitrate concentrations in many drinking water wells exceed the maximum contaminant level (MCL).

In the Central Columbia Plateau, 84 percent of drinking water comes from ground water. Both public supply and domestic water systems depend largely on ground water [5, 6] (fig. 5). Current nitrate data are generally available for public supply wells, which must be sampled regularly. Domestic wells, however, are generally sampled only for special studies. About 20 percent of wells in the Study Unit exceed the *MCL* for nitrate in drinking water [1, 7]; the MCL is set by the U.S. Environmental Protection Agency at 10 milligrams per liter (mg/L) [8]. Reducing nitrate in ground water has been the focus of cooperative efforts between Federal, State, and local agencies.

Nitrate concentration has been suggested as an indicator of overall ground-water quality [9, 10], and drinking water with high nitrate concentrations is a potential health risk, particularly for infants [7, 8, 11].

The Quincy-Pasco subunit has the highest percentage of wells exceeding the MCL

The Columbia Basin Irrigation Project brings more than 2,500,000 *acre-feet* (800 billion gallons) of water per year from the Columbia River to the Quincy-Pasco subunit, enabling intensive irrigated agriculture.

In much of the North-Central subunit, deep ground water is the only source of water. Most of this subunit's high nitrate concentrations are in the shallower wells bordering the Quincy-Pasco subunit.

The Palouse subunit, dominated by nonirrigated agriculture, has generally lower nitrate concentrations than the rest of the Study Unit.

Table 2. Percentage of drinking water wells sampled in 1985–96 with nitrate concentrations[a] exceeding the U.S. Environmental Protection Agency maximum contaminant level of 10 milligrams per liter [--, insufficient data; %, percent]

		Class A public supply wells [b]	Class B public supply wells [c]	Shallow domestic wells [d]
County [e]	Adams	3%	25%	- -
	Douglas	7%	- -	- -
	Franklin	28%	29%	33%
	Grant	1% [f]	3%	35%
	Whitman	7%	4%	6%
Subunit	Quincy-Pasco	9%	15%	35%
	North-Central	3%	5%	- -
	Palouse	7%	5%	5%
Study Unit		6%	12%	- -

[a] For wells sampled more than once, the most recent value was used. [b] 411 public water systems with at least 15 hook-ups; average depth 270 feet [9]. [c] 270 public water systems with less than 15 hook-ups; average depth 210 feet. [d] 67 domestic wells sampled for the NAWQA Land Use Study component (p. 24); average depth 140 feet [3]. [e] Percentages were not calculated for counties that fall partly outside the study area. [f] Most wells are deep, averaging 500 feet (see Moses Lake area, fig. 6).

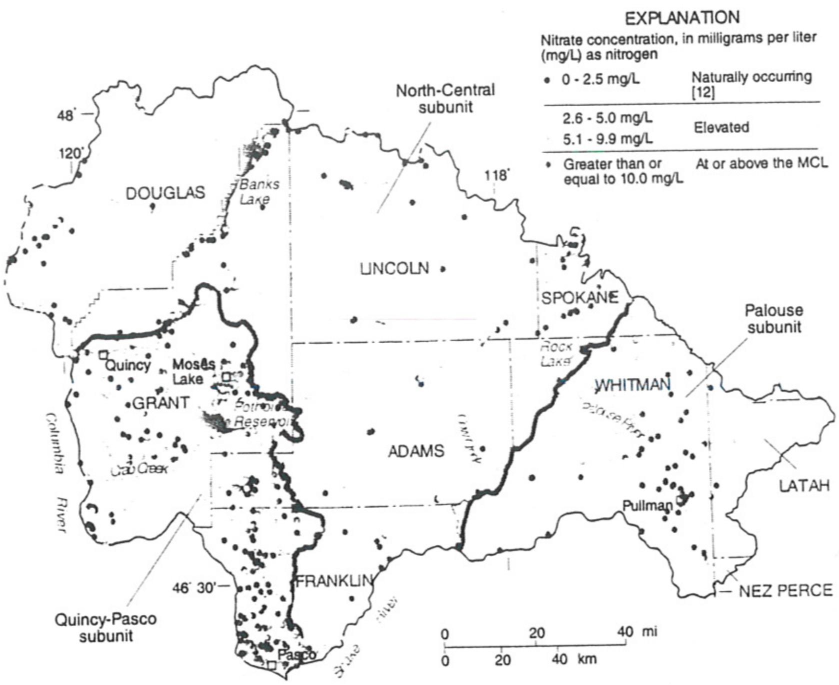


Figure 6. Most public supply wells [13] and domestic wells that exceed the maximum contaminant level (MCL) for nitrate are in the Quincy-Pasco subunit. (Wells were sampled from 1985 to 1996; for wells sampled more than once, the most recent value was used.)

Intensive application of fertilizers and irrigation water causes high nitrate concentrations in the Quincy-Pasco subunit

Synthetic fertilizers became widely available after World War II. Fertilizers are the source of 84 percent of nitrate inputs to the Central Columbia Plateau [16]. Other sources of nitrate include cattle feedlots, food processing plants, septic tanks, and treated wastewater; these are local and thus less important sources in most of the Study Unit.

Agricultural acreage continues to increase in the plateau, but nationally recommended application rates for fertilizer have been lowered in the last few years. As a result, fertilizer sales (fig. 7) and application have leveled off [12]. Irrigation, however, continues to increase in the plateau [fig. 8].

Two primary factors contribute to the Quincy-Pasco subunit's high nitrate concentrations: high rates of fertilizer application [fig. 9] and irrigation water. Ninety-four percent of all the water used in the plateau supports agricultural irrigation in the arid Quincy-Pasco subunit [5]. This extensive irrigation has greatly increased rates of recharge (fig. 10), which is water moving from the land surface to ground water. Recharge, especially at higher rates, moves nitrate into shallow ground water.

Trends in nitrate concentrations vary across the Study Unit

Nitrate concentrations in the Central Columbia Plateau's ground water have generally increased since the 1950s. Although fertilizer application leveled off in about 1985, it is too early to be certain of any corresponding leveling off or decrease in nitrate concentrations in the regional ground-water system.

Individual wells may show trends that reflect only local conditions. For example, at Ringold Springs, one of the largest springs in the Study Unit, nitrate concentrations may have leveled off. However, the improvement is probably not as dramatic as is suggested by the decrease shown in figure 11.

Across the plateau, nitrate concentrations continue to increase in most areas. Examples of varying nitrate trends in ground- and surface-water systems are discussed on page 9.

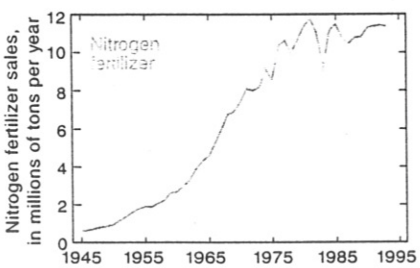


Figure 7. Sales of nitrogen fertilizer in the United States have leveled off [14, 15]. Graph modified from [12].

Figure 9. Annual application rates of nitrogen fertilizer are highest in the Quincy-Pasco subunit (rates are in pounds per acre (lb/acre)), (1991 data shown) [16].

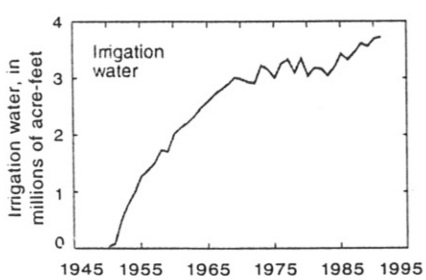


Figure 8. The amount of irrigation water diverted from the Columbia River has steadily increased [16].

Figure 10. Average rates of recharge are highest in the Quincy-Pasco subunit (rates are in inches per year (in/yr)) [17].

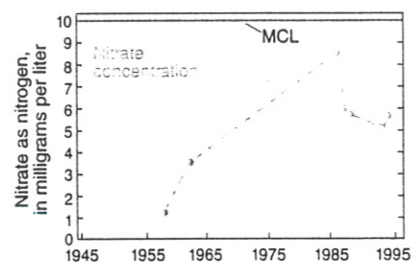


Figure 11. Nitrate concentrations may have leveled off at Ringold Springs, a large spring in the Study Unit (site A, fig. 14), from 1957 to 1994 [18]. However, data are limited and the peak concentration in 1986 may have been unusual.

Irrigation increases the variability of nitrate concentrations

Trends in individual wells may not reliably represent trends for a large area. In the Quincy-Pasco subunit, samples from springs and surface-water sites can give further insight into trends and variability of nitrate in ground water.

In the Quincy-Pasco subunit, nitrate concentrations in ground water can be much higher during the irrigation season (fig. 12). In some parts of the subunit, however, low-nitrate water leaking from irrigation canals may dilute nitrate in ground water, so that summer concentrations are close to naturally occurring levels (2–3 mg/L) [12].

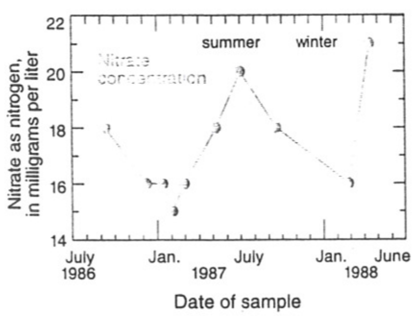


Figure 12. In a well in western Franklin County (site B, fig. 14), nitrate concentrations are higher during the peak irrigation season (Mar.–Oct.) [18].

The average nitrate concentration in regional shallow ground water is 6 mg/L or more. In fresh water diverted from the Columbia River for irrigation, nitrate concentrations are 1 mg/L or lower. As shown in figure 13, some wells close to canals have below-average nitrate concentrations due to dilution by water leaking from canals [18].

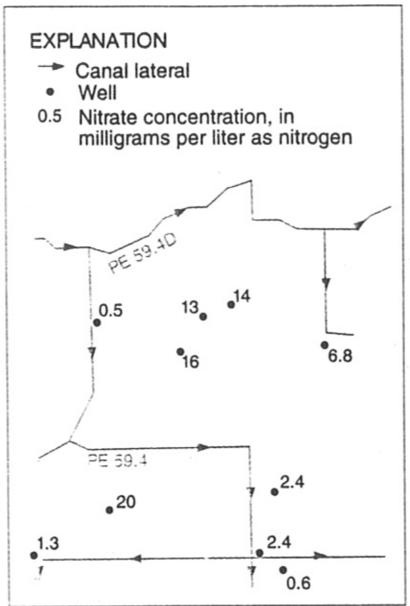


Figure 13. In an irrigated area in western Franklin County (area C, fig. 14), PE 59.4 Lateral has a nitrate concentration of 1.3 milligrams per liter. Most wells close to the canal have lower nitrate concentrations [18].

Deeper ground water, which is farther from sources of nitrate applied on the land surface, is less susceptible to contamination. Also, when irrigation raises the *water table* significantly, as has occurred in the Quincy-Pasco subunit, recently recharged ground water flows rapidly to surface waters instead of to deeper ground water. This prevents some of the nitrate present in recently recharged ground water from moving to deeper ground water. Figure 15 shows that nitrate concentrations are generally lower at greater depths. Many public supply wells are relatively deep, so have lower nitrate concentrations and exceed the MCL less frequently than do the shallower domestic wells (table 2).

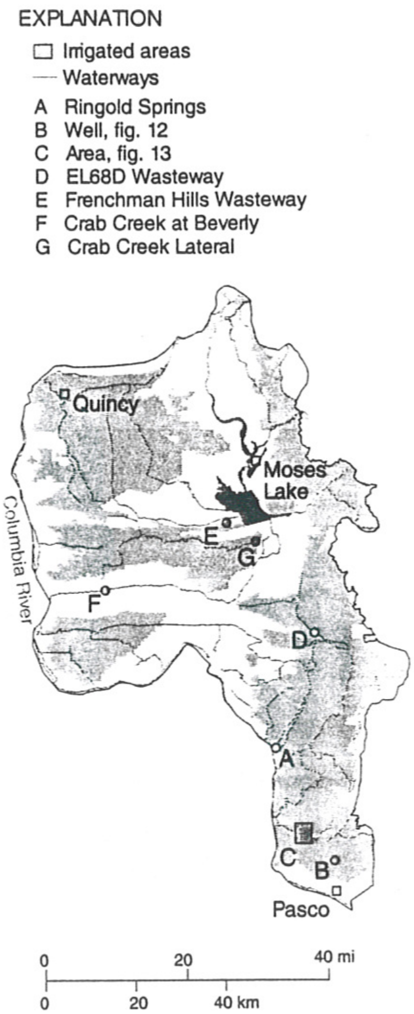


Figure 14. Sites in the Quincy-Pasco subunit (also the Columbia Basin Irrigation Project area) used to describe trends in nitrate concentrations.

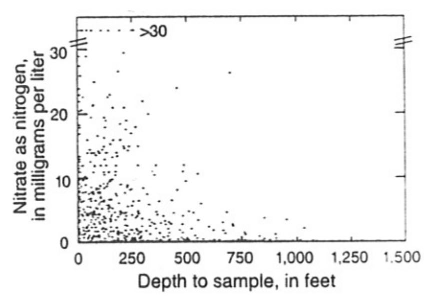


Figure 15. Nitrate concentrations are lower at greater depths; however, in irrigated areas (see fig. 14) some deep wells have elevated nitrate concentrations.

Sampling surface water at base flow is a cost-effective way to monitor trends in ground-water quality

Nitrate concentrations vary considerably in wells, requiring many samples to determine trends. However, in the Quincy-Pasco subunit many irrigation *wasteways* and other surface drains receive large contributions from ground-water discharge. For example, about 60 percent of total nitrogen discharged annually by EL68D Wasteway (site D, fig. 14) comes from ground-water discharges to the wasteway. From November to February, irrigation water is not delivered and storms large enough to produce runoff are rare. During this time, streamflow is low and ground water is the predominant source of nitrate in surface water conveyed by wasteways (fig. 16). Therefore, in the Quincy-Pasco subunit, samples of surface water during winter can be used to monitor nitrate trends in ground water for a large area. *Base-flow* surface-water sampling can also be used to track occurrence and trends in other dissolved constituents in ground water, including *pesticides* such as atrazine (p. 13).

Base-flow sampling in Palouse subunit streams is less indicative of ground water for several reasons. Base flow in the Palouse subunit occurs during the summer when plant growth is high; uptake of nitrogen by aquatic plants can greatly decrease nitrate concentrations in surface water. In addition, a substantial percentage of Palouse River flow in the summer is high-nitrate discharge from wastewater-treatment plants.

In the Quincy-Pasco subunit, nitrate concentrations are generally increasing . . .

In most parts of the Quincy-Pasco subunit, base-flow concentrations of nitrate in wasteways and other surface drains have increased since the 1960s — indicating an increase in nitrate concentrations in ground water. *Best management practices* (BMPs) in use in parts of the subunit may in time decrease these concentrations. However, changes in ground-water quality may not be apparent for decades or longer.

. . . but trends vary.

In Frenchman Hills Wasteway, base-flow nitrate concentrations doubled from about 3 to about 6 mg/L between 1966 and 1990 and appear still to be increasing (fig. 17). Ground water is the source of nearly 100 percent of base flow in the wasteway, so nitrate concentrations in nearby ground water have likely followed the same trend.

Base-flow nitrate concentrations are still increasing in Crab Creek at Beverly, but the increase has slowed since 1980. This trend is similar to trends that occurred in fertilizer sales (fig. 7) and irrigation (fig. 8) in much of the drainage basin. In addition, concentrations may be leveling off at this site because of contributions from the Crab Creek Lateral subbasin, where concentrations are decreasing.

In Crab Creek Lateral, base-flow concentrations of nitrate decreased from about 8 mg/L in 1966 to about 6 mg/L in 1991. This decrease may be partially explained by changing farming practices. For example, although the total amount of irrigated cropland draining to Crab Creek Lateral has not decreased, from 1974 to 1990 the proportion of this land used for orchards increased from 9 to 29 percent. Orchards require less applied nitrogen than do many of the row crops that they replaced [16].

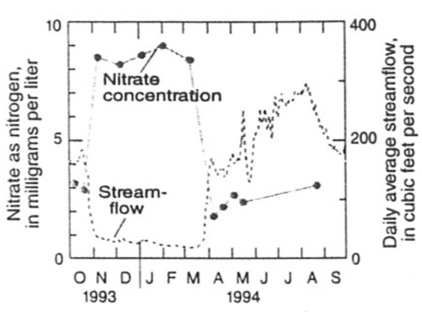


Figure 16. Nitrate concentrations at EL68D Wasteway (site D, fig. 14) are highest during the winter when the main source is ground-water discharge and there is little dilution by canals or return flows [2].

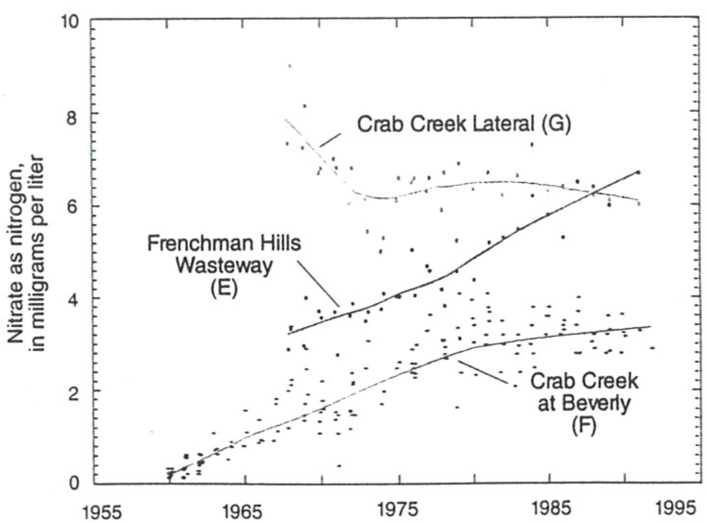


Figure 17. Three sites in the Quincy-Pasco subunit show varying trends in nitrate concentrations at base flow (Nov.-Feb.) from 1960–91. In Frenchman Hills Wasteway (site E, fig. 14), concentrations doubled. At Crab Creek at Beverly (site F), the increase has slowed since 1980. In Crab Creek Lateral (site G), there has been a decrease.

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

[redacted]rt Card No. W080417
UNIQUE WELL I.D. # Acc 798
Water Right Permit No. ______

(1) OWNER: Name Grey Goodwin Address 534 Specific Moses Lake wa

(2) LOCATION OF WELL: County Grant Lot #6 NW 1/4 SW 1/4 Sec 12 T. 19 N., R. 28E W.M.

(2a) STREET ADDRESS OF WELL (or nearest address) 11058 Montezume Drive Moses Lake wa

(3) PROPOSED USE: ☒ Domestic ☐ Irrigation ☐ DeWater ☐ Industrial ☐ Test Well ☐ Municipal ☐ Other

(4) TYPE OF WORK: Owner's number of well (If more than one) 1
☐ Abandoned ☒ New well ☐ Deepened ☐ Reconditioned
Method: ☐ Dug ☐ Cable ☒ Rotary ☐ Bored ☐ Driven ☐ Jetted

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 142 feet. Depth of completed well 142 ft.

(6) CONSTRUCTION DETAILS:
Casing Installed: 6" Diam. from +1 ft. to 35 ft. Shoe
☒ Welded ☐ Liner installed ☐ Threaded
_" Diam. from ___ ft. to ___ ft.
_" Diam. from ___ ft. to ___ ft.

Perforations: Yes ☐ No ☒
Type of perforator used ______
SIZE of perforations ___ in. by ___ in.
___ perforations from ___ ft. to ___ ft.
___ perforations from ___ ft. to ___ ft.
___ perforations from ___ ft. to ___ ft.

Screens: Yes ☐ No ☒
Manufacturer's Name ______
Type ______ Model No. ______
Diam. ___ Slot size ___ from ___ ft. to ___ ft.
Diam. ___ Slot size ___ from ___ ft. to ___ ft.

Gravel packed: Yes ☐ No ☒ Size of gravel ______
Gravel placed from ___ ft. to ___ ft.

Surface seal: Yes ☒ No ☐ To what depth? 20 ft. ft.
Material used in seal Bentonite
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? ______ Depth of strata ______
Method of sealing strata off ______

(7) PUMP: Manufacturer's Name ______
Type: ______ H.P. ______

(8) WATER LEVELS: Land-surface elevation above mean sea level ______ ft.
Static level 16 ft. below top of well Date 5-16-96
Artesian pressure ______ lbs. per square inch Date ______
Artesian water is controlled by ______ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☐ If yes, by whom? ______
Yield: 50-60 gal./min. with ______ ft. drawdown after 2 hrs.
" " " "
" " " "
Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ______
Bailer test ___ gal./min. with ___ ft. drawdown after ___ hrs.
Airtest ___ gal./min. with stem set at ___ ft. for ___ hrs.
Artesian flow ___ g.p.m. Date ___
Temperature of water 61.1 Was a chemical analysis made? Yes ☐ No ☒

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
Dirt	0	2
Gravel	2	29
Basalt Brown	29	35
Basalt Black	35	41
Basalt Brown	41	65
Basalt Grey	65	72
Basalt Brown	72	79
Basalt Black Brown Seam.	79	84
Basalt Grey	84	109
Basalt Black Brown H2O	109	128
Basalt [illegible] Grey [illegible]	128	133
~~Basalt Grey~~	[illegible]	[illegible]
Basalt Brown H2O	133	141
Basalt Black	141	142

Work Started 5-15-96, 19__. Completed 5-16-96, 19__

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME Joy Drilling Co (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address Moses Lake wa
(Signed) [signature] (WELL DRILLER) License No. 0469
Contractor's Registration No. JOYDRC1370H Date 5-16, 1996

(USE ADDITIONAL SHEETS IF NECESSARY)

WATER WELL REPORT

STATE OF WASHINGTON

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

Start Card No. W087587
UNIQUE WELL I.D. # ACL 955
Water Right Permit No. ______

(1) OWNER: Name Marty Pfeiffer Address 6286 Rd 3 NE Moses Lake Wa 98837

(2) LOCATION OF WELL: County Grant NW 1/4 SW 1/4 Sec 12 T. 19 N., R 28 W.M.

(2a) STREET ADDRESS OF WELL (or nearest address) Rd K NE

(3) PROPOSED USE: [x] Domestic [ ] Irrigation [ ] DeWater [ ] Industrial [ ] Test Well [ ] Municipal [ ] Other

(4) TYPE OF WORK: Owner's number of well (If more than one) ______
[ ] Abandoned [x] New well [ ] Deepened [ ] Reconditioned
Method: [ ] Dug [ ] Cable [x] Rotary [ ] Bored [ ] Driven [ ] Jetted

(5) DIMENSIONS: Diameter of well 6" inches.
Drilled 140 feet. Depth of completed well 140 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 6" Diam. from +2 ft. to 23 ft.
[x] Welded ______" Diam. from ______ ft. to ______ ft.
[ ] Liner installed ______" Diam. from ______ ft. to ______ ft.
[ ] Threaded

Perforations: Yes [ ] No [x]
Type of perforator used ______
SIZE of perforations ______ in. by ______ in.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.

Screens: Yes [ ] No [x]
Manufacturer's Name ______
Type ______ Model No. ______
Diam. ______ Slot size ______ from ______ ft. to ______ ft.
Diam. ______ Slot size ______ from ______ ft. to ______ ft.

Gravel packed: Yes [ ] No [x] Size of gravel ______
Gravel placed from ______ ft. to ______ ft.

Surface seal: Yes [x] No [ ] To what depth? 18 ft.
Material used in seal Bentonite
Did any strata contain unusable water? Yes [x] No [x]
Type of water? Surface Depth of strata 18-21
Method of sealing strata off ______

(7) PUMP: Manufacturer's Name Grandfos
Type: Sub H.P. 2

(8) WATER LEVELS: Land-surface elevation above mean sea level ______ ft.
Static level ______ ft. below top of well Date ______
Artesian pressure 5 # lbs. per square inch Date 1-26-97
Artesian water is controlled by ______ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes [ ] No [x] If yes, by whom? ______
Yield: ______ gal./min. with ______ ft. drawdown after ______ hrs.
" " "
" " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ______
Bailer test ______ gal./min. with ______ ft. drawdown after ______ hrs.
Airtest 50 + gal./min. with stem set at 130 ft. for 1 hrs.
Artesian flow ______ g.p.m. Date ______
Temperature of water ______ Was a chemical analysis made? Yes [ ] No [x]

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
Top Soil	0	2
Soil & gravel	2	8
gravel & Sand	8	12
gravel & Clay	12	19
Fractured Basalt	19	23
Black Basalt	23	134
Fractured Basalt & water	134	138
Black Basalt	138	140

RECEIVED ... EASTERN REGIONAL OFFICE

Work Started 1-25, 19 . Completed 1-26, 1997

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME Matheus Drilling (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address 9455 Stone Crest Rd Moses Lake Wa
(Signed) Mitch Mathes (WELL DRILLER) License No. 1267

Contractor's Registration No. MathedC117BG Date 1-26, 1997

(USE ADDITIONAL SHEETS IF NECESSARY)

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. W059929
UNIQUE WELL I.D. # ABM 48
Water Right Permit No. ______

(1) OWNER: Name Robert Chudomelka Address PO BOX 1202 Moses Lake

(2) LOCATION OF WELL: County Grant ______ 1/4 NE 1/4 Sec 11 T. 19 N., R. 28

(2a) STREET ADDRESS OF WELL (or nearest address) 4843 Orchard Dr NE Moses Lake wa

(3) PROPOSED USE: [X] Domestic [ ] Irrigation [ ] DeWater [ ] Industrial [ ] Test Well [ ] Municipal [ ] Other

(4) TYPE OF WORK: Owner's number of well (If more than one) 1
[ ] Abandoned [X] New well [ ] Deepened [ ] Reconditioned
Method: [ ] Dug [ ] Cable [X] Rotary [ ] Bored [ ] Driven [ ] Jetted

(5) DIMENSIONS: Diameter of well 8" inches.
Drilled ______ feet. Depth of completed well ______ ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 8" Diam. from +1 ft. to 37 ft.
[ ] Welded ______" Diam. from ______ ft. to ______ ft.
[ ] Liner installed ______" Diam. from ______ ft. to ______ ft.
[ ] Threaded

Perforations: Yes [ ] No [X]
Type of perforator used ______
SIZE of perforations ______ in. by ______ in.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.

Screens: Yes [ ] No [X]
Manufacturer's Name ______
Type ______ Model No. ______
Diam. ______ Slot size ______ from ______ ft. to ______ ft.
Diam. ______ Slot size ______ from ______ ft. to ______ ft.

Gravel packed: Yes [ ] No [X] Size of gravel ______
Gravel placed from ______ ft. to ______ ft.

Surface seal: Yes [X] No [ ] To what depth? 20 ft. ft.
Material used in seal Bentonite
Did any strata contain unusable water? Yes [X] No [ ]
Type of water? Surface Depth of strata 27 ft.
Method of sealing strata off Casing.

(7) PUMP: Manufacturer's Name ______
Type: ______ H.P. ______

(8) WATER LEVELS: Land-surface elevation above mean sea level ______ ft.
Static level 55 ft. ft. below top of well Date 6-6-95
Artesian pressure ______ lbs. per square inch Date ______
Artesian water is controlled by ______ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes [ ] No [X] If yes, by whom? ______
Yield: 400 gal./min. with air L. St ft. drawdown after 2 hrs.
" " " "
" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ______
Bailer test ______ gal./min. with ______ ft. drawdown after ______ hrs.
Airtest ______ gal./min. with stem set at ______ ft. for ______ hrs.
Artesian flow ______ g.p.m. Date ______
Temperature of water 60° Was a chemical analysis made? Yes [ ] No [X]

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
Dirt & Boulders.	0	6
Gravel & Boulders.	6	27
Clay Brown	27	34
Basalt Brown & Black	34	37
Basalt Grey	37	119
Black Broken. H2O	119	133
Black.	133	134

Work Started 6-5-95, 19. Completed 6-6-95, 19

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME Joy Drilling Co. (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address Moses Lake wa.
(Signed) [signature] (WELL DRILLER) License No. 0969
Contractor's Registration No. JOYDRC1370H Date 6-6-95, 19

(USE ADDITIONAL SHEETS IF NECESSARY)

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. ____

UNIQUE WELL I.D. # ____

Water Right Permit No. ____

(1) OWNER: Name Grant County PUD Address P.O. Box 878, Ephrata, WA 98823

(2) LOCATION OF WELL: County Grant SW 1/4 SW 1/4 Sec 26 T. 20 N., R 28 W

(2a) STREET ADDRESS OF WELL (or nearest address) Larson Substation

(3) PROPOSED USE: ☐ Domestic ☐ Irrigation ☐ DeWater ☐ Industrial ☐ Test Well ☐ Municipal ☒ Other

(4) TYPE OF WORK: Owner's number of well (If more than one) ____
☒ Abandoned ☒ New well ☐ Deepened ☐ Reconditioned
Method: ☐ Dug ☐ Cable ☒ Rotary ☐ Bored ☐ Driven ☐ Jetted

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 250+ feet. Depth of completed well 250+ ft.

(6) CONSTRUCTION DETAILS:
Casing Installed: 6 " Diam. from +4 ft. to 250 ft.
☒ Welded ____ " Diam. from ____ ft. to ____ ft.
☐ Liner installed ____ " Diam. from ____ ft. to ____ ft.
☐ Threaded

Perforations: Yes ☐ No ☒
Type of perforator used ____
SIZE of perforations ____ in. by ____ in.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.

Screens: Yes ☐ No ☒
Manufacturer's Name ____
Type ____ Model No. ____
Diam. ____ Slot size ____ from ____ ft. to ____ ft.
Diam. ____ Slot size ____ from ____ ft. to ____ ft.

Gravel packed: Yes ☐ No ☒ Size of gravel ____
Gravel placed from ____ ft. to ____ ft.

Surface seal: Yes ☒ No ☐ To what depth? 250+ ft.
Material used in seal Bentonite
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? ____ Depth of strata ____
Method of sealing strata off ____

(7) PUMP: Manufacturer's Name ____
Type: ____ H.P. ____

(8) WATER LEVELS: Land-surface elevation above mean sea level ____ ft.
Static level ____ ft. below top of well Date ____
Artesian pressure ____ lbs. per square inch Date ____
Artesian water is controlled by ____ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☒ If yes, by whom? ____
Yield: ____ gal./min. with ____ ft. drawdown after ____ hrs.
" " " "
" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ____
Bailer test ____ gal./min. with ____ ft. drawdown after ____ hrs.
Airtest ____ gal./min. with stem set at ____ ft. for ____ hrs.
Artesian flow ____ g.p.m. Date ____
Temperature of water ____ Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
Very Large Boulders, Sand, Gravel	0	10
Sand, Gravel, Boulders	10	37
Basalt, Black	37	47
Basalt & Sand	47	55
Basalt, Black, Hard	55	65
Rotten Basalt	65	69
Basalt, Black, Hard	69	99
Fractured Basalt, Black	99	108
Basalt, Black, Hard	108	121
Rotten Fractured Basalt	121	145
Basalt, Black, Hard	145	173
Rotten Basalt	173	210
Very Hard Basalt, Black	210	245
Rotten Black Basalt, Shale, Blue Water	245	250

6" Drive Shoe Utilized

RECEIVED NOV 19 1993 DEPARTMENT OF ECOLOGY EASTERN REGIONAL OFFICE

Work Started 11-2-93, 19. Completed 11-9-93, 19

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME Ponderosa Drilling & Development, Inc. (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)

Address E. 6010 Broadway, Spokane, WA 99212

(Signed) ____ (WELL DRILLER) (Bob Britton) License No. 0043

Contractor's Registration No. PO-ND-EI*248JE Date November 11, 19 93

(USE ADDITIONAL SHEETS IF NECESSARY)