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WILSON CREEK DRAINAGE - SURFACE AND GROUND WATER QUALITY

July 1978 to July 1979

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Washington State Department of Ecology
Water and Wastewater Monitoring Section
Olympia WA 98504

DOE 80-13

PREFACE

The study reported here developed from recommendations made to the Water and Wastewater Monitoring Section by Harold Porath of the Central Regional Office, Department of Ecology. Lew Kittle designed the study and initiated field sampling. Most of the remaining field work was the responsibility of Shirley Prescott. Art Johnson and she prepared the project report. Thanks are due to the Department of Ecology Tumwater laboratory staff for conducting the sample analyses and to Carol Perez for typing this manuscript.

ABSTRACT

Surface water and ground water quality were monitored in Wilson Creek drainage, central Washington State, from July 1978 through July 1979 to evaluate impacts from irrigated agriculture, urban runoff, municipal and industrial waste disposal, and residential development. Return flows from irrigated agriculture were identified as the cause of increased turbidity, solids, nutrient, and bacteria levels in the central and lower drainage. Kittitas sewaqe treatment plant effluent substantially reduced water quality in Cooke Creek. The other point and non-point sources monitored did not appear to significantly impact water quality.

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INTRODUCTION

The Washington State Department of Ecology's "Five-Year Water Quality Strategy"[1] identifies and prioritizes management segments within the state failing to meet the federal and state 1983 "fishable-swimmable" goal. Kittitas Valley's Wilson Creek drainage is one of several irrigated agricultural basins bordering the Yakima River classified as "water quality limited due to non-point sources (WQ-NPS)". Based on severity and frequency of violations of Class A water quality criteria, it was ranked 12th of 36 WQ-NPS surface water segments evaluated. As a top priority problem of the Department's Central Regional Office, it was selected for study by the Water and Wastewater Monitoring Section in FY 1978.

STUDY AREA DESCRIPTION

Kittitas Valley is located in the approximate geographic center of Washington State on the eastern slope of the Cascades. The Wenatchee Mountains, Bolyston Mountains, and Manastash Ridge form the valley's borders to the north, east, and south.

The valley's climate is semi-arid, with an average rainfall of only about 9 inches. Most of this falls as snow from late November through February. With irrigation, valley soils support an agricultural economy. Approximately 90,000 acres are currently under irrigation for the production of cattle, sheep, hay, small grains, corn, and potatoes.

Ellensburg (population 13,000), and the community of Kittitas (population 745) are the major urban centers. An additional 9,300 people live in unincorporated areas of the valley.

Wilson Creek and its 7 major tributaries, the subjects of this study, drain the eastern half of Kittitas Valley and empty into the Yakima River at river mile 147.0 (Figure 1). Wilson, Naneum, Coleman, Cooke, Caribou, and Park creeks originate in the foothills of the Wenatchee Mountains and flow toward the Yakima River in a generally south-westerly direction. Badger Creek flows out of the opposite corner of the valley, draining the Badger Pocket area before meeting Wilson Creek as Wipple Wasteway.

Three large irrigation canals, Highline, Cascade, and Town, circle the valley bringing irrigation water diverted from the upper Yakima at river miles 202.5, 168.9, and 161.3, respectively. During the April-to-October irrigation season, these and a maze of smaller canals, ditches, and diversions, radically change the natural course of drainage for creeks flowing through the valley. Figure 2 shows the general flow paths of creeks and major irrigation canals during late summer. Highline Canal, skirting the valley's upper rim, receives little significant irrigation return flow. During late summer and fall this canal becomes the source of downstream water in Cooke, Caribou, Park, and Badger creeks when their upper reaches dry. About 4 miles below Highline, Wilson Creek and its tributaries meet Cascade Canal. Park and Badger creeks flow under Cascade, but Mercer, Wilson, Naneum Coleman, Cooke, and Caribou flow directly into the canal and are swept eastward to be replaced by canal water shunted into their respective downstream reaches. The lower sections of these creeks, therefore, are branches of Cascade Canal during the irrigation season.

Town Canal is 1-1/2 miles below Cascade. Cooke Creek is again diverted eastward here while the remainder of the creeks flow under this last canal and finally merge with Wilson Creek near the community of Thrall before entering the Yakima River,

Yakima River water is not diverted into Highline, Cascade, or Town canals from October to April. For this period the creeks follow their "natural" courses. The dates that the canals were filled and drained during this study are as follows: Highline Canal filled April 25, 1978, drained October 15, 1978, filled April 13, 1979; Cascade and Town canals, filled April 20, 1978, drained October 15, `^¯9, filled April 15, 1979.

SURVEY SCOPE AND OBJECTIVES

The following land-use activities of potential impact to water quality in Nilson Creek drainage were selected for study:

1. Return Flows from Irrigated Agriculture.

   Objective: Determine the extent to which irrigation return flows degrade water quality in Wilson Creek and its tributaries. Identify pollutant sources by land use types.

   Wilson Creek drainage has been designated Class A (excellent) waters by the State of Washington in accordance with present and potential water uses and in consideration of its natural water quality potential. The water quality criteria for Class A waters and beneficial uses to be protected under this classification are listed in Appendix A.

   All major creeks in Wilson Creek drainage are diverted for irrigation of pasture, hay and row crops, and receive irrigation return flows. Limited data[2,3] collected by DOE, the U.S. Bureau of Reclamation, the U.S. Geological Survey, and other agencies suggest significant degradation of water quality in Wilson, Coleman, and Cherry creeks with respect to fecal coliforms, nutrients, suspended solids, and turbidity. Wilson Creek drainage has been identified[4] as the major source of pollution in the Cle Elum-to-Umtanum reach of the Yakima River (river miles 191 to 139.9). Local farmers maintain their irrigation practices are not responsible for the valley's water quality problems. The regional office will use information generated by this study in conjunction with 208 sediment sampling programs to estimate the magnitude of impacts to water quality from on-going agricultural practice.; in the valley.

2. Ellensburg Urban Runoff.

Objective: Determine if runoff from the city of Ellensburg adversely affects water quality in Wilson Creek.

Wilson Creek and its branch, Mercer Creek, flow directly through Ellensburg. Low survival of trout planted in lower Wilson Creek has been reported by the Washington State Department of Game who suggest that urban runoff may be responsible. Heavy metals, particularly lead from auto exhaust, are thought to be of potential significance.

3. Schaake Feedlot/Twin City Foods Sprayfield Runoff.

Objective: Determine if runoff from the Schaake feedlot or Twin City Foods sprayfield impacts water quality in Wilson Creek via Tjossem Ditch.

Surface water runoff and shallow water tables pose potential waste management problems for both the above companies. Schaake feedlot is a 7,000-head capacity operation bordered by Wilson Creek and Tjossem Ditch, 1/2 mile south of Ellensburg. Tjossem Ditch, fed by diversion of the Yakima River at river mile 152.2 during the irrigation season, meets Wilson Creek at river mile 5.2 below Ellensburg. Sprinklers are used to irrigate pastures surrounding the feedlot and to control dust in the cattle pens during summer. Surface slopes are such that site runoff would be directed toward Tjossem Ditch. An anaerobic lagoon at the east end of the livestock pens collects cattle wastes.

Twin City Foods sprayfield, also between Wilson Creek and Tjossem Ditch, is an 80-acre site south of the Ellensburg sewage treatment plant (STP) used for land disposal of wastes by spray irrigation. Overuse of the sprayfield in the Fall of 1977 caused vegetable processing wastes to flow into Tjossem Ditch. The Ellensburg STP sometimes uses this field for sludge wasting.

4. Ellensburg STP Sludge Disposal.

Objective: Determine if water quality in Wilson Creek is degraded by Ellensburg STP's sludge disposal practices.

Ellensburg STP is a relatively new (March 1973) secondary-level, activated sludge plant at the southern edge of the city. Its effluent is discharged to the Yakima River at river mile 151.5. Most of the sewage sludge is disposed of by spraying on a five-acre site behind the plant adjacent to Wilson Creek. Evidence of sludge flowing into the creek has been reported by the regional office.

5. Kittitas STP Effluent.

Objective: Document the contamination of Cooke Creek by the Kittitas STP.

Kittitas STP, at the south end of the town of Kittitas, discharges its effluent into Cooke Creek. The plant is an antiquated secondary treatment facility whose secondary clarifier has been bypassed for a number of years. Disinfection practices are poor. (As of this writing, an aerated lagoon system is under construction at the STP. Cooke Creek will continue to act as receiving water for the upgraded facility.)

6. Groundwater Quality.

Objective: Determine the quality of groundwater in the area of the Grasslands and Birchwood residential developments.

Grasslands (740 acres) and Birchwood (65 acres) are residential developments bordering Town Canal east of Ellensburg. Residents draw their domestic water from individual wells and dispose of wastewater via septic tanks and drainfields. Shallow ground-water conditions during the irrigation season and poor drainage have resulted in flooding and are potential threats to groundwater quality. The Kittitas County Planning Department halted development of Birchwood because of lack of proper drainage and the need for an adequately protected community water supply. The regional office requested data on existing groundwater quality to help assess the impact of future development in the Ellensburg area,

MATERIALS AND METHODS

The 59 station sampliny rtetwork pictured in Figure 1 (surface water stations) and Figure 3 (groundwater stations) was established to meet the above study objectives, The study area encompassed approximately 190 square miles of Wilson Creek drainage. Individual surface water station descriptions are listed in Appendix B.

To evaluate the impacts of irrigated agriculture, three stations each (two on Park Creek) were established on Wilson Creek and its tributaries: one above Highline Canal, removed as much as practical from agricultural influences (stations 6, 7, 19, 20, 21, 22, and 24); one mid-way along the irrigated valley floor (stations 4, 5, 9, 10, 12, 14, 17, and 25); and one in the lower drainage before confluence with Wilson Creek (stations 27, 28, 29, 30, 31, 32, 34, and 40). Irrigation canal stations on Highline (stations 1, 18, and 23), Cascade (stations 2, 8, and 13), and Town (stations 3, 11, and 26) were selected to detect progressive changes in irrigation water quality. An additional station was placed on Wilson Creek just above its mouth on the Yakima River (station 33). Mid-way through the study stations were added on Wilson Creek at its confluence with Wipple Wasteway (station 42), Reecer Creek (station 43), Cherry Creek (station 44), and Wipple Wasteway above the Cherry Creek confluence (station 45).

Above and below stations were also established for Ellensburg urban runoff (stations 4, 5, and 37, 38, 39), the Ellensburg STP sludge disposal site (stations 35 and 36), and the Kittitas STP outfall (stations 15 and 16). Five stations along Tjossem Ditch (T1 through T5) monitored Schaake feedlot and Twin City Foods sprayfield.

Groundwater quality in the Grasslands-Birchwood developments was evaluated in 9 observation wells in and around the developments. Town Canal was also sampled at stations 11 and 41 where it entered and left the groundwater study area. The DOE Water Resources Investigations Section directed this portion of the study.

Surface waters were sampled every two weeks during the irrigation season. Weather limited sampling for the remainder of the year to only three to four collections per station. Groundwater samples were collected monthly. Routine water sampling began in July 1978 and ended in July 1979. Some additional field work continued into December 1979.

At each surface water station four parameters were measured in situ: temperature; pH; specific conductivity; and dissolved oxygen (Winkler-Azide modification). Flow was determined from staff gage readings, weir measurements, or directly with a flow meter. Additional water samples were collected, packed in ice, and shipped to the DOE Tumwater laboratory, and analyzed according to *Methods for Chemical Analysis of Water and Wastes*[5] for the following parameters:

1. Fecal coliform (col/100 ml)
2. Total Kjeldahl-nitrogen (mg/l)
3. Ammonia-nitrogen (mg/l)
4. Nitrite-nitrogen (mg/l)
5. Nitrate-nitrogen (mg/l)
6. Total phosphate-phosphorus (mg/l)
7. Turbidity (NTU)
8. Chemical oxygen demand (mg/l)
9. Total suspended solids (mg/l)
10. Total hardness (mg/l)
11. Total alkalinity (mg/l)

Field parameters measured in the groundwater study included temperature, pH, specific conductivity, and well water level. Laboratory analyses were limited to parameters 1, 3, 4, 5, 6, 7, 10, and 11, above, plus total coliforms, chlorides, calcium hardness, and total iron.

Water and sediment samples for heavy metals analysis were collected from Wilson and Mercer creeks above and below both Ellensburg and the Ellensburg STP. Grab samples of water (500 ml, unfiltered, acidified in the field) and sediment (approximately 50 g) were collected once each month from July through September 1978 and returned to the DOE Tumwater laboratory for determination of lead, mercury, and zinc content by atomic absorbtion spectrophotometry.

RESULTS AND DISCUSSION

I. Return Flows from Irrigated Agriculture.

A Surface Water Quality During the Irrigation Season.

Table 1 summarizes the results for water quality parameters measured at selected surface water stations in Wilson Creek drainage. All data are limited to samples collected during the 1978 and early 1979 irrigation season. Parameter means and ranges for each of the study's 50 surface water stations are listed individually in Appendix C.

Temperature - Creek temperatures did not increase greatly between upper and lower drainage stations. Individually, both Wilson and Naneum creeks were exceptions to this pattern being about 5°C warmer in their lower reaches than where sampled above Highline Canal. Temperatures in drainage waters generally remained within the Class A standard of 18°C. Cooke and Caribou creeks at stations 14, 15, and 17 near Kittitas sometimes exceeded this standard by as much as 4°C during the summer. Equally high temperatures, however, occurred naturally in the upper reaches of Cooke and Coleman creeks away from agricultural influence. Lack of vegetative cover along these shallow streams was probably the reason for elevated temperatures.

pH - pH is a scale extending from 0 very acidic, to 14, very alkaline, with a middle value (pH 7) being neutral.

Slightly increased pH was noted downstream in both the creeks and the irrigation canals. Drainage waters were typically slightly alkaline. Most measurements taken fell within the 6.5-8.5 pH standard for Class A waters. The same Cooke and Caribou creek stations mentioned above and also Wilson Creek stations 34-37 below Ellensburg, occasionally were found to be in the pH range of 8.6-8.9, a marginal violation of the standard.

Specific Conductivity - The ability of water to conduct an electric current is measured by its conductivity which in turn may be related to the amount of dissolved solids or salts (salinity) present. As a general rule, dissolved solids in milligrams/ liter equals 55 to 75 percent of a solution's specific conductivity in micromhos/centimeter.[6]

Highline Canal had the lowest conductivity of all waters sampled in the drainage. Table 1 shows that its conductivity remained essentially unchanged throughout the approximately 20-mile section of canal monitored in this study, indicating very little influx from agricultural runoff. The Cascade and Town Canal data, however, show abrupt increases in conductivity between stations 2 and 13 on Cascade Canal and 11 and 26 on Town Canal. This is probably largely due to Cascade Canal merging with Mercer, Wilson, Naneum, Coleman, Cooke, and Caribou creeks and Town Canal merging with Cooke Creek. Unknown numbers of small irrigation return flows also enter these canals, tending to increase their conductivity.

As might be expected, conductivity increased the further downstream creeks were sampled in the drainage. Maximum conductivities were reached in the lower drainage, usually ranging from 200 to 300 μmhos/cm, but occasionally approaching 500 μmhos/cm. Although high conductivity (salinity) can render water useless for irrigation purposes, the maximums measured in this study were considerably below the 750 μmhos/cm threshold sufficient to damage crops[7]. A maximum conductivity of 500 μmhos/cm has also been suggested if a population of mixed fish species is to be maintained.[7] Conductivity in the lower drainage was also within this criterion.

Hardness and Alkalinity - Changes in hardness and alkalinity followed the same pattern as described for specific conductance. Both parameters increased by approximately 3-fold between the upper and lower drainages. Water in Highline Canal and the upper creeks was soft, less than 75 mg/l, while middle and lower drainage waters were in the moderately hard range of 75 to 150 mg/l.

As a measure of water's buffering capacity, an alkalinity above 20 mg/l is recommended to maintain the stable pH regime important to aquatic life.[8] At the other extreme, alkalinity in irrigation water should be less than 600 mg/l to prevent plant damage from chlorosis (iron deficiency) or sodium toxicity.[8] Alkalinity in Wilson Creek drainage ranged from a minimum of 27 mg/l in creek waters to a maximum of 192 mg/l in Wipple Wasteway - both well within critical levels.

Chemical Oxygen Demand and Dissolved Oxygen - Chemical oxygen demand (COD) is a measure of the amount of oxidizable, oxygen-demanding material in water. Values greater than 50 mg/l are usually considered indicative of contamination by excessive quantities of organic matter. The potential for stream oxygen depletion also rises significantly when the COD exceeds this level.

Table 1 shows that COD in creeks impacted by irrigated agriculture return water was roughly double that where agricultural influence was absent. The highest mean values for individual stations sampled were 23 mg/l in Schnebly Creek and 26 mg/l in middle Coleman Creek (see Appendix C). Nine stations (9, 12, 13, 15, 28, 29, 31, 37, and 38) had single measurements approaching or exceeding 50 mg/l, indicating that although average COD's were low to moderate, excessive organic pollution may occur periodically in the drainage. The presence of oxidizable inorganic compounds can also cause elevated COD. Dissolved oxygen did not appear to be affected at these high COD's.

Dissolved oxygen (D.O.) concentrations were not significantly different between the upper, middle, and lower sections of the drainage. D.O. was usually at or above saturation values and typically ranged between 9 and 12 mg/l at most stations. The Class A standard specifies a D.O. of greater than 8 mg/l. Only upper Park Creek at station 22 was significantly in violation of the standard, having an average D.O. of 6.1 mg/l and minimums as low as 3.5 mg/l. The reason for these violations was not determined,

Because routine sampling was confined to daylight hours, a 24-hour series of D.O. measurements was taken on June 21-22, 1979 to determine what level oxygen concentrations might fall to at night in the slow flowing, warmer reaches of the lower drainage. Station 42 on Wilson Creek below its confluence with Naneum Creek and station 32 on Wipple Wasteway below the Cherry Creek confluence were sampled, The results for Wilson Creek indicated a D.O. drop of 2.5 mg/l to a low concentration of 7.1 mg/l, slightly below the Class A standard. Stream temperatures had dropped from 18°C in the afternoon to 15.9°C at the time of the low measurement (0530). Wipple Wasteway D.O. did not change appreciably over the 24-hour period. The maximum drop was only 0.6 mg/l to a low concentration of 8.7 mg/l. Respiration by the extensive growths of aquatic plants in Wilson Creek was probably responsible for most of the observed change in D.O. These growths are absent from the turbid waters of other creeks in the lower drainage.

Fecal Coliforms - Fecal coliforms are predominantly non-pathogenic bacteria found in the intestinal tracts of humans and other warmblooded animals. Their presence in water samples indicates that the water in question has come in contact with fecal material from warmblooded animals.

The fecal coliform data summarized in Table 7 is presented in detail in Figure 4 which shows the median concentrations measured at all drainage stations sampled.

Highline Canal and the upper creeks are shown to have been we?l within the Class A standard for fecal coliforms. This standard specifies a median value of no more than 100 colonies per 100 ml. Upper Caribou and Park creek stations were downstream from irrigated pastures and, as a result, had increased coliform levels relative to the other upper creeks.

All drainage waters sampled below Highline Canal were in violation of the Class A standard. The worst contamination appeared to be in the middle valley. The middle reaches of Mercer and Caribou creeks were not sampled above their confluence with Cascade Canal, but were probably similar in bacterial quality to the other nearby streams.

Cascade and Town canals exceeded the Class A standard where they first entered the drainage at stations 2 and 3. Cascade Canal reached high coliform concentrations downstream due primarily to input from Wilson Creek and its tributaries. Town Canal, on the other hand, may have remained relatively uncontaminated up to its confluence with Cooke Creek below Kittitas.

Fecal contamination in the portion of the drainage below Town Canal was reduced to roughly half that of the middle valley but remained well above Class A standards. Coliforms were lowest in Wilson Creek and tended to increase in streams to the east due, at least partly, to the influence of Cascade and Town canals on flow patterns in the drainage. Lower Caribou Creek was anomalously high compared to other creeks in the lower drainage. Wilson Creek's final discharge to the Yakima River had a large fecal content relative to the Yakima's Class A waters.

A few water samples were also subjected to qualitative tests for the presence of the human bacterial pathogens *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Salmonella-Shigella*. These tests were limited to 6 samples collected on December 3, 1979 at stations 12, 16 (below Kittitas STP), 17, 36, 38 and 39. *Salmonella-Shigella* were not detected but all samples were positive for *S. aureus* and *P. aeruginosa* which are associated with environmentally acquired respiratory tract and skin infections. Both livestock and humans are potential sources of these bacteria. The presence of *S. aureus* and *P. aeruginosa* should be viewed as further evidence of low bacterial quality in the drainage. No conclusions about health implications are warranted since these tests were few in number and do not show the concentrations of organisms present.

Nutrients

Mitrate-nitrogen (NO_3-N) and total phosphate-phosphorus (T-PO_4-P) concentrations in Wilson Creek drainage are illustrated in Figures 5 and 6 Both nutrients were uniformly low in the upper creeks, throughout Highline Canal, and in Cascade and Town canals where these two enter the drainage. Higher nutrient levels are shown for upper Caribou and Park creeks, again reflecting the impact of irrigated land upstream.

In contrast to the middle valley maximum exhibited by the fecal coliform data, N03-14 and T-PO_4-P reached their maximum concentrations in the lower valley. Mean NO_3-N showed increases of 50 to 100-fold over the initially low levels in the upper drainage. Cherry Creek, Park Creek, and Wipple Wasteway had the highest concentrations. Values as high as 3.2 mg/l were measured in Wipple Wasteway.

$T-PO_4-P$ increased about 3-fold between upper and lower parts of the drainage, The stations with the higher concentrations, .10 to .15 mg/l, were distributed more uniformly throughout the irrigated portion of the drainage than was the case for NO_3-N.

Mercer, Wilson, and Naneum creeks appeared to have considerably lower concentrations of both NO_3-N and $T-PO_4-P$ than did the other creeks,

Data for total Kjeldahl-nitrogen (ammonia + organic nitrogen), ammonia-nitrogen (NH_3-N), and nitrite-nitrogen (NO_2-N) are shown only in Table 1. Kjeldahl-nitrogen doubled and tripled downstream from the upper creek stations and in Cascade and Town canals. NH_3-N and NO_2-N, however, were usually low throughout the drainage. Occasionally concentrations of 0.7 to 0.4 NH_3-N were detected.

No state water quality standards have been established tor nutrients. Ammonia, nitrite, and nitrate can be toxic at sufficiently high concentrations, but these levels are not often reached in natural waters. One concern about increased nutrient concentrations is the potential for stimulating nuisance growths of algae. The algal bloom thresholds for NO_3-N and $T-PO_4-P$ in running waters are estimated to be 0.3 mg/l[9] and 0.1 mg/l[8], respectively. These levels were exceeded throughout most of lower Wilson Creek drainage and also in Coleman, Cooke, and Caribou creeks in the middle valley. In spite of this, excessive algal growth has not been a problem. The relatively clear waters of lower Wilson Creek do support large growths of rooted aquatic plants in the summer, but these plants draw nutrients from sediment as well as the surrounding water.

A second, and in this case perhaps more important, cause for concern is the nutrient loss from croplands that these high nitrate and phosphorus concentrations represent. These losses are quantified in a later section of this report.

Turbidity - The Class A turbidity standard states that "turbidity shall not exceed 5 NTU (nephelometric turbidity units) over background turbidity when the background turbidity is 50 NTU or less". The background or "natural, ambient condition" is difficult to establish. Wilson Creek below Ellensburg flows through land not as intensively farmed as the rest of the drainage. The mean turbidity at station 34 at the lower end of this portion of Wilson Creek, prior to its confluence with Naneum and Coleman creeks, was 3 NTU. Using this value as a reasonable background level, the mean turbidity shown in Table 1 for Wipple Wasteway (station 32) and Wilson Creek below Wipple Wasteway (station 33) exceeds the Class A standard. Wilson's discharge to the Yakima River (mean turbidity also 3 NTU) can be expected to result in violations of the turbidity standard in the Yakima for an undetermined distance downstream.

Other stations (see Appendix C) with a mean turbidity in excess of a 3-NTU background during the study were lower Park Creek at station 27 (11 NTU), Cherry Creek at station 44 (9 NTU), and Wipple Wasteway at station 45 (15 NTU) above its confluence with Cherry Creek. The maximum turbidity measured in the drainage was 50 NTU at the lower Park Creek station in July 1978.

Creek stations where the mean turbidity met the Class A standard but with periodic turbidities of 5 NTU or more in excess of a 3-NTU background included all remaining stations in the lower drainage and also Schnebly Creek and middle Coleman Creek stations.

Suspended Solids

The distribution of total suspended solids concentrations in the drainage is depicted in Figure 7. The distribution of high and low values is similar to that described for NO_3-N and T-PO_4-P. Suspended sediment and phosphate are often correlated in agricultural runoff because of phosphate's tendency to adsorb to soil particles.

This study, appropriately, used grab samples to identify major sources of agricultural pollutants in the drainage. Since suspended sediment distribution in a stream is a function of velocity and turbulence, these data probably underestimate the actual concentrations present especially in the wider sections of lower Wilson Creek, Cherry Creek, and Wipple Wasteway which were sampled from the stream bank. Peak times of sediment loading such as storm events were not monitored in this study.

High suspended sediment concentrations can be detrimental to aquatic plants and animals due to reduced light penetration, interference with feeding, gill clogging, spawning area siltation, etc. Proposed criteria for protection of stream life[8] are as follows: 25 mg/l - high level of protection; 80 mg/l - moderate level of protection; 400 mg/l - low level of protection. Refering to Figure 7, it appears that stream habitat is degraded by increased suspended sediment in Schnebly Creek, middle Coleman Creek, and in the central and eastern portion of the lower drainage.

The soil losses represented by the suspended sediment concentrations measured in this study are estimated below.

B. Nutrient and Suspended Solids Loadings in Lower Wilson Creek Drainage.

Loadings of NO_3-N, T-PO_4-P, and total suspended solids in pounds per day at Wilson Creek above the Naneum confluence (station 34), Wilson Creek below the confluence (station 42), Cherry Creek (station 44), Wipple Wasteway (station 45), and the Yakima River above Wilson Creek are estimated in Table 2. The data span the spring and early summer of 1979 during the onset of the irrigation season. Data for the earlier part of the study are incomplete.

Flows in the lower drainage increased in May, coincident with the filling of irrigation canals and the start of irrigation. A progressive increase in flow is evident from spring through early summer (flows usually begin dropping in late August or September).

Nutrient and suspended solids loads in Wilson Creek above the Naneum/Coleman confluence are shown to be low. Loadings increased by an order of magnitude below the confluence.

Cherry Creek, at only 1/4 to 1/2 the flow of Wilson Creek at station 42, carried an equal NO_3-N load and about half the T-PO_4-P load. With the onset of irrigation, Cherry Creek's suspended solids load rapidly increased to a level 15 times that found in Wilson. Solids in Wilson Creek decreased during the first part of the 1979 irrigation season contrary to the trend in the other creeks.

On a flow-weighted loading basis, Wipple Wasteway contributed the lowest loads of nutrients and solids of the three terminal creeks in the drainage. An alternate approach to evaluating pollutant concentrations is on a yield-per-drainage area basis. Data on the area of land drained by each creek aren't available, but by inspection it is obvious that Badger Creek/Wipple Wasteway represents a small area of the drainage relative to Wilson or Cherry creeks. On a yield-per-area basis, land-use related water quality problems in and around Badger Pocket may be the most significant in the drainage.

Although Wilson Creek's flow during the period covered in Table 2 was only 4 to 7 percent of that in the Yakima River, its input of nutrients and suspended solids to the river was substantial. Nitrate-nitrogen loadings at Wilson Creek's mouth ranged from approximately 180 to 490 percent of the Yakima's NO_3-N load. Total phosphate-phosphorus loads in the Yakima would be expected to have increased by an estimated 10 to 30 percent below Wilson Creek; suspended solids by as much as 70 percent.

C. Seasonal Changes in Water Quality

Only three or four sample collections per station, depending on weather conditions, were made between the end of the 1978 irrigation season and the resumption of irrigation in 1979. Based on this limited survey of the drainage during winter, the seasonal changes in water quality parameters described below were observed.

Fecal coliform concentrations were at a minimum during winter in a17 parts of the drainage sampled. This may be the result of less surface runoff in the absence of irrigation combined with reduced animal access to creek waters.

Nitrates, phosphates, and suspended solids were uniformly low throughout the year-long study period in the upper creeks above Highline Canal, In the irrigated portion of the drainage, nitrate and phosphate concentrations were highly variable from one sampling period to the next and showed no clear seasonal trends. Suspended solids concentrations, on the other hand, were reduced when irrigation stopped, remained relatively low during winter, and increased when irrigation was resumed.

D. Water quality in Relation to Land Use

Cause and effect is difficult to establish when dealing with non-point pollution arising from a multiplicity of land management activities. Even with the large number of stations employed in this study, the transient nature of pollutants discharged in runoff from a given field, the non-conservative behavior of some of these pollutants, the on again-off again diversions of (and returns to) creek waters, and the movements of livestock preclude identification of pollutant sources except in broad geographical terms,

The results of a land use survey conducted in June 1979 as part of this study are shown in Figure 8. This map, substantially reduced for this report, was prepared by driving the study area and recording observations on acreage devoted to pasture, hay, small grains, row crops, orchards, and rangeland. Notes were also taken on irrigation methods used.

Figure 8 shows that non-irrigated rangeland predominates above Highline Canal. The land between this study's upper and middle creek stations is almost exclusively devoted to irrigated cattle and sheep pasture and hay production. Livestock pastures are primarily flood irrigated. Scattered acreage along Coleman, Cooke, and Caribou creeks were in small grains and corn,

The central and eastern drainage below Cascade Canal is intensively farmed to row crops and small qrains. Corn is the predominant row crop grown. Signficantly less acreage here is used for raising livestock. Most of these fields are irrigated by rill and furrow methods, although orchards and some pastures are spray irrigated. The western part of the lower drainage around Wilson Creek is not as intensively farmed as other parts of the valley. Much of this land is suburban or undeveloped.

The erosion potential of land within the drainage devoted to the above types of agriculture is shown in Figure 9. When compared with the land use patterns described above, some of the reasons for the previously described distribution of water quality problems in the drainage become evident.

As would be expected, the creeks with the highest fecal coliform levels were those draining the extensive pastures above Cascade Canal. In the lower drainage, fecal contamination becomes reduced with increased acreage being devoted to row crops, small grains, etc. Lower Wilson Creek, being a diversion of upper Cascade Canal during irrigation season and flowing through a high percentage of non-agricultural land, was less contaminated than other parts of the lower drainage.

Relative soil erosion potential is greatest in the eastern portion of the drainage. These same erosive and steeper sloped soils are often rill and furrow irrigated, especially in the central and eastern portions of the lower drainage. The frequency of soil disturbance and duration of time fields are left exposed is highest here. Predictably, creeks such as Park, Cherry, Badger, and Wipple Wasteway which drain this area have large concentrations of phosphates, suspended sediments, and leached nitrates.

The shallow slopes and stable soils of most of the irriydted pasture and hay land below Highline Canal are reflected in the relatively low nutrient and suspended solids levels in Mercer, Wilson, and Naneum creeks and, to a lesser extent, middle Cooke and Caribou creeks. Coleman and Schnebly creeks are high in nutrients, solids, and other parameters compared to other creeks at this point in the drainage and appear to be draining areas of increased land-use-related water quality impacts.

The stabilizing influence of the natural plant cover on rangeland soils above Highline Canal, equal in erodibility to soils in the lower drainage, is shown in low phosphate and suspended sediment in the upper creeks. Nitrates are also low here, where the leaching action of applied irrigation water is absent. Low livestock concentrations, low surface runoff, and plant cover help minimize the potential for bacterial contamination.

E. Short-term, Intensive Surveys of Fecal Coliforms, Nutrients, and Suspended Solids in Cooke, Caribou, and Badger Creeks,

Following the completion of routine water sampling of Wilson Creek drainage in July 1979, the Central Regional Office suggested several of the creeks deemed lowest in water quality be sampled in detail. Therefore, during August 20-22, 1979 Cooke, Caribou, and Badger creeks were surveyed on foot and sampled for fecal coliforms, NO_3-N, T-PO_4-P, and suspended sediment at as many sites as practical. Only the upper portion of Cooke Creek was sampled due to construction activity in Kittitas influencing downstream water quality. The results of these surveys are shown in Figures 10-12.

One significant observation is that wide variations in pollutant concentration often occurred within the same short stretch of creek or between adjacent irrigation return flows. Mote, for instance, the changes in fecal coliforms in Cooke Creek or NO_3-N in Caribou Creek. This demonstrates the problems inherent in using single stations to characterize water quality several miles upstream in a system as complicated as the Wilson Creek drainage. While the general distribution of water quality problem areas in these creeks described earlier is supported, parameter concentrations at any particular point in a creek are seen to sometimes bear little relation to upstream (or downstream) conditions. Diversion, dilution, influx of low quality return flows, sedimentation, bacterial die-off, and biological nutrient transformation and uptake can act to bring about rapid changes in creek water quality. Flow measurements along streams of this type used for irrigation often exhibit bewildering arrays of high and low flows.

F. Management Strategies for Improving Wilson Creek Drainage Water Quality.

The major water quality problems in Wilson Creek drainage are fecal contamination, high nitrate, phosphate, and suspended sediment concentrations, and excessive turbidity. Management strategies developed under 208 general planning for the state[10] and appropriate to Wilson Creek drainage for reducing these problems are outlined below. An environmental assessment of Wilson Creek drainage published in 1975[3] by the JARA Company contains a more detailed discussion of these and other management practices including cost/benefit analyses and suggested steps for program implementation.

Fecal Contamination - Unconfined livestock production on pasture land can be compatible with good water quality. Pollution is generally more dependent on management and hydrogeological factors than on total numbers of animals involved or waste volumes generated.

The principal water quality parameter impacted by livestock is bacterial quality. This also is often the most difficult water quality standard to meet for non-point sources. Impacts on physical/chemical parameters such as nutrients or suspended sediment are usually a result of soil erosion brought about by loss of plant cover in localized areas with high livestock concentrations, Pasture management practices resulting in optimum forage production are likely to reduce adverse environmental impacts,

Livestock degrade bacterial quality in Wilson Creek drainage primarily because of having direct access to water in creeks and irrigation ditches and flood irrigated pastures. Scattered throughout the drainage are also numerous specific and easily identifiable problem areas where animals are concentrated, either by design or by behavior. These areas have high soil erosion potential due to bank destabilization and can be considered point sources of utrients and sediments as well as fecal contamination,

The following management practices should be considered:

1. Prohibit direct animal access to surface waters by Fencing and providing troughs for watering. Where large numbers of animals must cross a stream, provide a fenced bridge or earth fill crossing with a culvert. Employ sprinkler irrigation to reduce water runoff.

2. Follow recognized stocking rates and control grazing (e.g., rotation, deferred and seasonal grazing) to reduce erosion and waste accumulation.

3. Points of animal concentrations should be located away from streams and away from hillsides sloping directly to streams. Periodically move feeding, shelter, and watering areas to avoid waste accumulation, soil compaction, and erosion. Use culverts to pipe water under confinement areas. Construct berms to intercept slope runoff or regrade slopes,

4. Provide plant cover between streams or drainage paths and animal concentrations to intercept contaminants and stabilize banks.

Nitrate - Nitratc in subsurface irrigation return flows originates primarily from water leaching down through the soil column. Surface irrigation return flow concentrations of nitrate are about the same as in the applied irrigation water - in the absence of recent applications of nitrate fertilizers. The key to reducing nitrate in return flows lies in avoiding applications of irrigation water in excess of plant requirements and in the timing, amount, and method of fertilizer application. Experience has shown dissolved constituents, such as nitrate, are not easily controlled.

Nitrate in Wilson Creek drainage appears to originate primarily in the lower drainage. Potential control measures are as follows:

1. Convert to sprinkler or trickle irrigation systems (where applicable) to apply water more efficiently and reduce surface and subsurface return flow.;. (The strong winds in Kittitas Valley may impair uniform application of water by sprinkling.)

2. Reduce losses from field ditches by lining or replace with pipes.

3. Re-use irrigation return flows where practical. Low specific conductivities (salinities) indicate water quality would be acceptable for re-use.

Phosphate, Suspended Sediment, and Turbidity - High phosphate concentrations in agricultural runoff are usually correlated with high suspended sediment concentrations since phosphates have a strong tendency to attach to soil particles. Similarly, increased suspended sediment loads in a stream increase the water's turbidity, although factors such as particle size, shape, and refractive index influence the directness of the relationship. Management practices reducing soil erosion can be expected to reduce phosphate losses to nearby waterways and increase water clarity,

The highest levels of phosphate, suspended solids, and turbidity were found, along with nitrate, in lower Wilson Creek drainage. Erosion control methods to be considered for implementation are as follows:

1. Convert to sprinkler systems to reduce erosion and runoff.

2. On land not converted to sprinklers, install erosion control facilities (sediment ponds, recirculation ponds, grassed ditches, collector pipes).

3. Improve bank stability on streams and ditches by grass seeding, riprapping, concrete lining, etc.

The size and complexity of Wilson Creek drainage suggests that achieving significant improvements in water quality may require an expensive and long-term program. Such a program should incorporate the following features:

1. Be economically feasible for individual farmers.

2. Demonstrate measurable improvements in water quality and in better nutrient utilization and reduced soil erosion on the farm.

3. Have local support, with the agricultural community an informed and active participant.

2. Ellensburg Urban Runoff.

Ellensburg's urban runoff impact to Wilson Creek cannot be isolated with the stations used in this study. Station 5 is not a usable control since Cascace Canal intercepted Wilson Creek downstream from this station for most of the sampling period. Also, Mercer Creek received irrigation return flows at a point halfway between its control station 4 and downstream station 39. Water quality below Ellensburg at stations 37, 38, and 39 on Mercer and Wilson creeks was, however, among the best of all stations sampled below Highline Canal which suggests that urban runoff impacts to Wilson Creek are small or at least infrequent.

Results from creek sediment samples analyzed for lead (Pb) could be interpreted as showing that urban runoff from Ellensburg causes increased Pb concentrations downstream in Mercer and Wilson creeks. The average Pb concentration in the 8 sediment samples taken from stations 4 and 5 above Ellensburg was 12 mg/kg compared to 36 mg/kg in 10 samples from stations 37, 38, and 39 below town. An alternate and equally plausible explanation for this three-fold increase lies in the fact that stations 37-39 were located along city roads much more heavily traveled than the country roads by stations 4 and 5.

Average zinc (Zn) and mercury (Hg) sediment concentrations above and below Ellensburg were 70 mg/kg and 102 mg/kg Zn and .146 mg/kg and .108 mg/kg Hg. These concentrations, as well as the Pb concentrations mentioned above, are within the same range as background heavy metals concentrations in other parts of central and eastern Washington.

The questions raised by the Washington State Department of Game's unsuccessful attempts to establish trout in Wilson Creek below Ellensburg are addressed in Table 3 which shows the ranges and means for selected water quality parameters measured at stations 34-38. These data indicate that this two-mile reach of the creek should be a suitable habitat for trout. Parameters important to the maintenance of healthy fish populations were usually within acceptable criteria limits during the period studied. Exceptions to this are noted in the table for temperature and total Hg. The 20°C maximum temperature was recorded only once (station 35 in July 1979). Two of 18 water samples contained 0.30 μg/l total Hg. It should be noted that the method's minimum detection limits were not sensitive to levels approaching the protection criteria for Hg (0.5 μg/l for freshwater). The problem of evaluating heavy metals concentrations having low suggested levels of protection relative to analytical detection limits has been noted by other researchers[11].

In spite of the seemingly adequate water quality in Wilson Creek, a 1978 spring-through-fall Department of Game survey[12] of the creek's fish and benthic invertebrate populations in the vicinity of stations 34-36 found trout absent, although ample invertebrate populations and several species of rough fish (suckers, squawfish, shiners, etc.) existed.

The lower reaches of other creeks in Wilson Creek drainage have trout and support a small sport fishery. The data collected in this study do not show why lower Wilson Creek is unable to support a similar fishery. Solution of this problem requires more study.

3. Schaake Feedlot/Twin City Foods Sprayfield Runoff.

Water quality data pertinent to the impact of Schaake feedlot and Twin City Foods sprayfield on Wilson Creek via Tjossem Ditch are found in Table 4. Fecal coliforms were significantly higher in samples from below both the feedlot and the sprayfield. These levels, however, were not greatly above Class A standards and returned to low levels prior to Tjossem Ditch meeting Wilson Creek. Other parameters measured remained essentially unchanged throughout the length of the ditch. No reduction in water quality was observed below Twin City Foods sprayfield during the fall vegetable processing season. Comparison with the data tabulated for Wilson Creek shows Wilson Creek's quality to be inferior in a number of respects.

In the event of feedlot or sprayfield runoff to Tjossem Ditch, it is probable that Tjossem Pond at the end of the ditch would reduce the impact to Wilson Creek by acting as a detention basin.

Although Tjossem Ditch did not impact Wilson Creek, the dike around the waste lagoon at the east end of Schaake feedlot is subject to occasional failures which allow cattle wastes to reach the creek. In May 1978 and again on June 19, 1979 the lagoon was observed overflowing its banks, contaminating Wilson Creek. The June discharge, estimated at 5 gpm, was sampled as it entered Wilson Creek after transit of a brush-choked slough. Selected analytical results were as follows: specific conductivity, 760 μmhos/cm; COD, 810 mg/l; D.O., 0 mg/l; fecal coliforms, >4,000 colonies/100 ml; total Kjeldahl-nitrogen, 34 mg/l; NH_3-N, 17 mg/l; T-PO_4-P, 6.6 mg/l. Diking around this lagoon should be improved to contain wastes under all flow and groundwater regimes

4. Ellensburg STP Sludge Disposal.

Data from field measurements and water and sediment samples taken above and below Ellensburg STP's sludge disposal site along Wilson Creek are presented in Table 5. The reason for elevated total Kjeldahl-nitrogen above the STP at station 35 is not known. With this exception, analytical results from samples collected below the disposal area were almost indistinguishable from results of those taken above. It is apparent that the STP's sludge disposal practices were not measurably influencing water quality in Wilson Creek during this study.

Ellensburg STP wasted an average of 237,000 gallons of sludge per month in 1979. Currently all sludge is being disposed of on nearby Twin City Foods sprayfield. Sludge-drying lagoons are presently being built in the five-acre site behind the STP formerly used for sludge spraying. Spray irrigation of sludge will be discontinued after construction is completed.

5. Kittitas STP Effluent.

Water quality data from stations on Cooke Creek above and below the Kittitas STP outfall are summarized in Table 6. Cooke Creek was low in quality even above the outfall. Further degradation of its waters was evident for a number of parameters at station 16 located approximately 100 feet below the discharge pipe.

Temperature and pH changed very little. Specific conductivity, hardness, and alkalinity increased slightly, but remained within the range observed in other nearby creeks. The mean COD below the outfall, 27 mg/l, was the highest mean value measured in the drainage and some evidence of D.O. depression was indicated. Dissolved oxygen concentrations at station 16 were found to be in violation of the Class A standard 30 percent of the times measured, with a minimum of 5.1 mg/l being detected. The point of maximum D.O. sag downstream was not determined.

The major STP effluent impacts were seen in increased concentrations of fecal coliforms and nutrients. The coliform content of these waters was among the highest in the drainage. A qualitative test for human bacterial pathogens, mentioned previously, confirmed the presence of *Staphylococcus aureus* and *Pseudomonas aeruginosa*. In-stream residual chlorine was detectable (DPD method) on two occasions. These concentrations, 0.2 mg/l and 0.3 mg/l, were considerably in excess of levels harmful to aquatic life.[9]

Nutrients concentrations increased significantly below the outfall, especially NH_3-N and T-PO_4-P. Un-ionized ammonia did not, however, reach levels toxic to stream life,

Suspended solids and turbidity, the final parameters in Table 5, were not significantly impacted below the outfall.

Additional signs of pollution from insufficiently treated sewage discharged to Cooke Creek were the *Sphaerotilus* ("sewage funqus") growths and sewage odors evident below the outfall during most sample collections.

As noted elsewhere in this report, Cooke Creek is diverted into Town Canal below the Kittitas STP from mid-April to mid-October.

6. Groundwater Quality.

Table 7 shows the static water levels (SWL) measured in each well monitored within the Grasslands-Birchwood area and illustrates the effect irrigation has on private wells. The shallow wells are hydraulically connected to nearby canals and ditches used for irrigation. When Town and Cascade canals were drained in October, water levels declined, even to the point of drying in one case (well 005), depending on their depth. According to residents, this process takes five to seven weeks from time of drainage. During the period of measurement, almost complete recharge was observed to occur within three weeks.

The water table is only about 18 inches deep during the irrigation season.[13] Also, the interdicting of drainage ditches by roads constructed in the Grasslands development has caused localized spring and summer flooding. Additional construction impairing drainage can be expected to cause similar flooding and may result in septic tank back-ups or water level changes in nearby wells, depending on gradient from construction.

The deeper wells are not affected as much by the canals. However, depending on the surface casing and seal, these wells are still in hydraulic continuity with surface waters. One of these, the 73-foot Simpson well (009) has been cased and sealed. Although located very close to Town Canal, SWL in this well is 20+ feet below land surface datum (LSD). Other shallower and some deeper wells in the area may have water levels of 2 to 8 feet below LSD during the irrigation season and 5 to 21 feet during winter and early spring. Both the Ackler (008) and Simpson wells show a more delayed reaction to recharge than do any of the other wells, probably because of their depth and manner of construction.

The results of analyses of water quality samples collected from these wells are summarized in Table 8 and compared to criteria for drinking water. While groundwater was moderately hard throughout this area and iron concentrations often above the 0.3 mg/l objectionable taste threshold[8], the overall quality of the domestic wells was within drinking water quality standards.

As expected, the shallow irrigation wells (003, 004, 005) were much more susceptible to contamination than the better sealed and cased domestic wells. Wells of this type are fit for irrigation purposes only.

There was a tendency for total coliform counts to be greatest during periods when irrigation well water levels were highest. This trend was also seen in some of the deeper wells.

No reduction in Town Canal water quality was observed between stations 11 and 41 on either side of the groundwater study area

SUMMARY AND CONCLUSIONS

The major findings from this 1978-1979 study of surface water and groundwater quality in Kittitas Valley's Wilson Creek drainage can be summarized as follows:

1. Return Flows from Irrigated Agriculture.

    -- The lower reaches of Mercer, Wilson, Naneum, Coleman, Cooke, and Caribou creeks are diversions of Cascade Canal from approximately mid-April to mid-October. The same is true of Cooke Creek below Town Canal.

    -- Temperature, pH, and D.O. were generally within Class A standards in Wilson Creek and its tributaries.

    -- Specific conductivity and alkalinity were within acceptable ranges for use as irrigation water and for protection of aquatic life.

-- Water hardness ranged from soft in the upper creeks to moderately hard in the lower drainage.

-- Highline Canal and creek waters above Highline met Class A fecal coliform standards.

-- The greatest fecal contamination was seen in the middle drainage with all waters sampled below Highline Canal in violation of the Class A coliform standard. Wilson Creek drainage was contributing water high in fecal bacteria to the Yakima River.

-- NO_3-N and T-PO_4-P were uniformly low in the upper creeks, Highline Canal, and in Cascade and Town canals where these two first enter the drainage.

-- Maximum NO_3-N and T-PO_4-P concentrations were found in the lower drainage. Mean NO_3-N concentrations increased 50 to 100-fold over upper creek levels; T-PO_4-P increased about 3-fold.

-- Ammonia-nitrogen and nitrite-nitrogen were low in the majority of samples analyzed.

-- Mean turbidity in Wipple Wasteway and at the mouth of Wilson Creek violated the Class A turbidity standard. Periodic violations of the turbidity standard were also observed in other creeks in the lower drainage and in Schnebly Creek and middle Coleman Creek.

-- Maximum suspended solids concentrations were found in the lower drainage. The grab sampling method employed probably underestimated these concentrations.

-- NO_3-N, T-PO_4-P, and suspended solids loadings were estimated for the terminal portion of the drainage for the period March-July 1979. Loadings were low in Wilson Creek prior to its confluence with Naneum/Coleman Creek. Below this confluence, nutrient loading in Wilson Creek was similar to that in Cherry Creek. Cherry Creek's suspended solids load, however, increased to as much as 15 times Wilson's load in the early summer. Nutrient and suspended solids loading in Wipple Wasteway prior to its confluence with Cherry Creek, was low relative to the above creeks, but on a yield-per-drainage-area basis may be the most significant.

NO_3-N, T-PO_4-P, and suspended solids loads at the mouth of Wilson Creek represent a significant increase in loading for the Yakima River.

-- A trend was observed toward higher fecal coliform and suspended solids concentrations during the irrigation season. NO_3-N and T-PO_4-P concentration were highly variable at all times of the year.

-- The largest sources of fecal contamination were livestock pastured in the middle drainage between Cascade and Highline canals.

-- The most significant sources of NO_3-N, T-PO_4-P, and suspended solids were the extensive row-cropped land in the central and eastern portion of the lower drainage.

-- Creeks flowing through non-irrigated rangeland above Highline Canal met all Class A standards and were low in nutrients and suspended solids.

-- Wide variations in pollutant concentrations and flows within the same short stretch of creek and between adjacent irrigation return flows make description of drainage water quality from limited numbers of stations difficult.

-- Management strategies for improving water quailty in Wilson Creek drainage are available.

2. Ellensburg Urban Runoff

-- The data are not adequate to isolate urban runoff impacts to Wilson Creek water quality.

-- Water quality at stations on Wilson Creek below Ellensburg was among the best of all stations sampled on the irrigated valley floor. Urban runoff impacts are, therefore, not thought to be substantial.

-- The water quality parameters measured in this study do not explain the absence of trout in Wilson Creek below Ellensburg. More study of this problem will be required.

3. Schaake Feedlot/Twin City Foods Sprayfield Runoff.

-- Median fecal coliform concentrations were slightly above Class A standards in Tjossem Ditch below Schaake Feedlot and in the vicinity of Twin City Foods sprayfield.

-- Neither Schaake feedlot nor Twin City Foods sprayfield were observed to adversely impact Wilson Creek water quality through surface runoff into Tjossem Ditch.

-- Schaake feedlot's waste lagoon is subject to occasional failures which allow cattle wastes to flow into Wilson Creek. Improved diking around the lagoon is needed

4. Ellensburg STP Sludge Disposal.

-- Ellensburg STP's sludge disposal practices were not impacting Wilson Creek during periods sampled in this study.

5. Kittitas STP Effluent.

-- Kittitas STP effluent was significantly degrading water quality in Cooke Creek with respect to fecal coliforms, nutrients, and aesthetics.

6. Groundwater Quality.

-- Wells in the Grasslands-Birchwood development area are hydraulically connected to nearby irrigation canals and ditches.

-- Construction impairing drainage is likely to cause localized flooding, septic tank back-ups, and changes in well water levels.

-- Water in the domestic wells meets drinking water standards

-- The shallow irrigation wells contain water of poor bacterial quality and are fit for irrigation purposes only.

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FIGURES

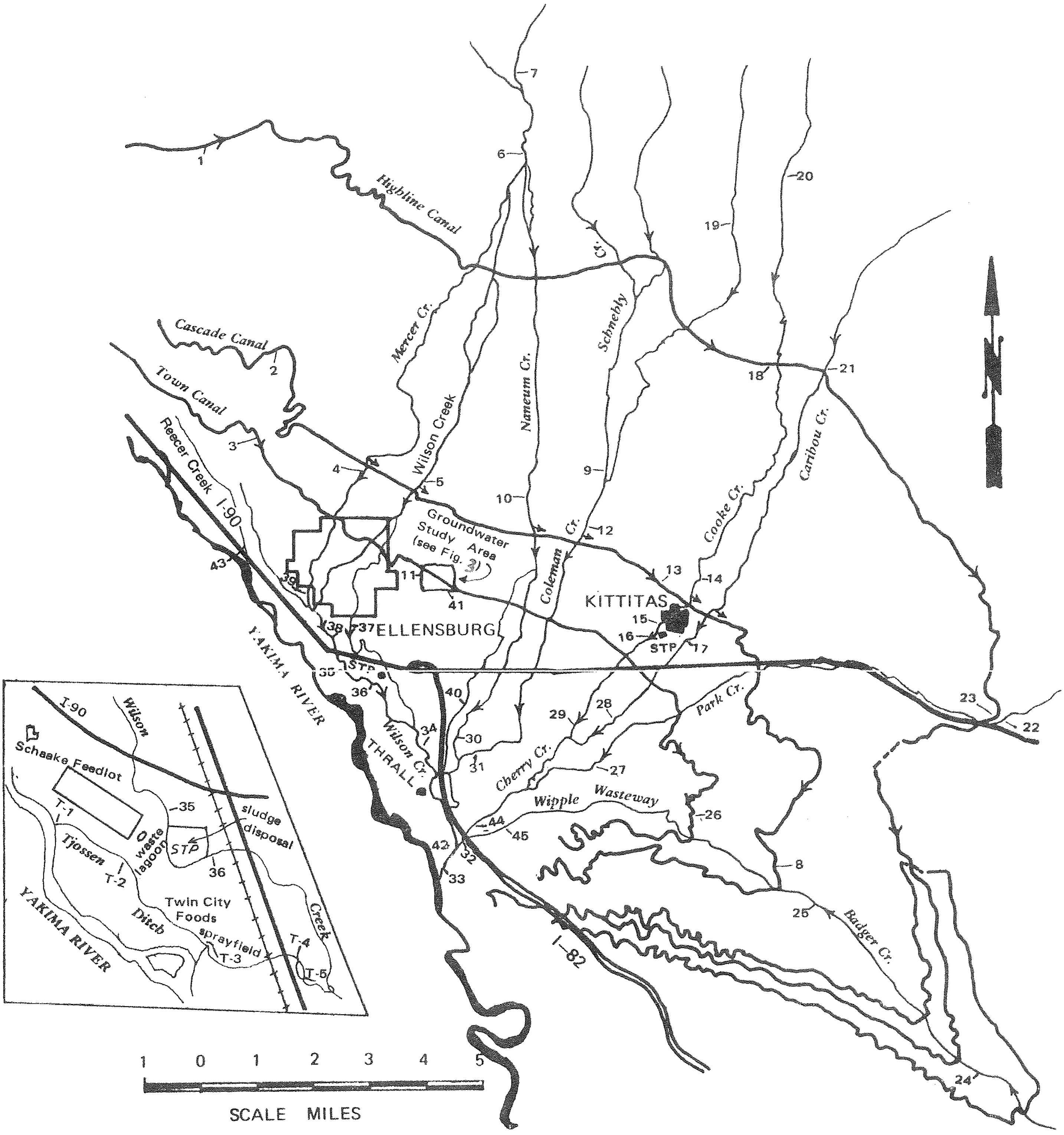


FIG. 1 Wilson Creek drainage water quality study area and station locations, Kittitas Valley, July 1978 - July 1979

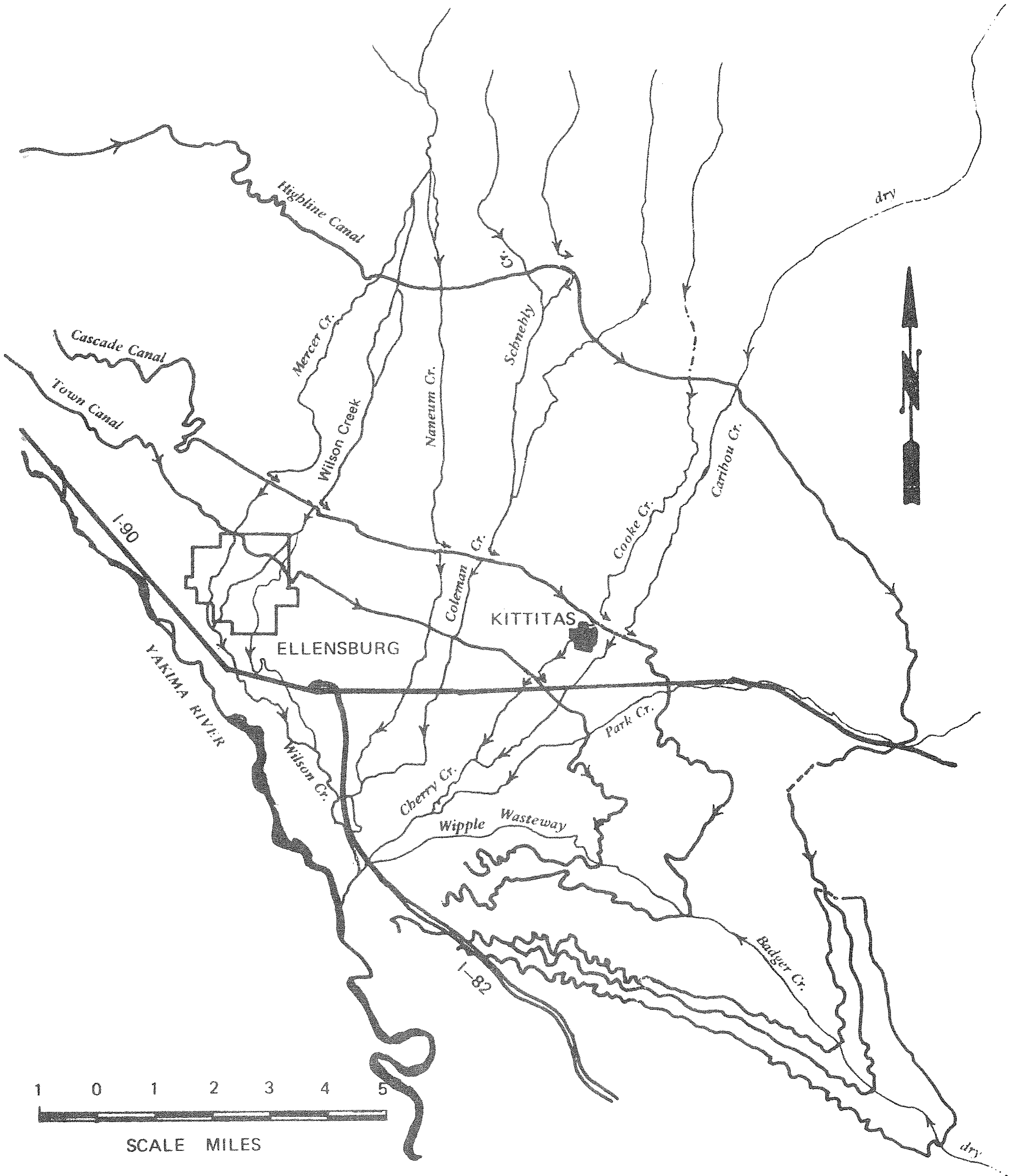


FIG. 2 Flowpaths in Wilson Creek drainage for major creeks and irrigation canals. (from observations on September 5 - 6, 1979)

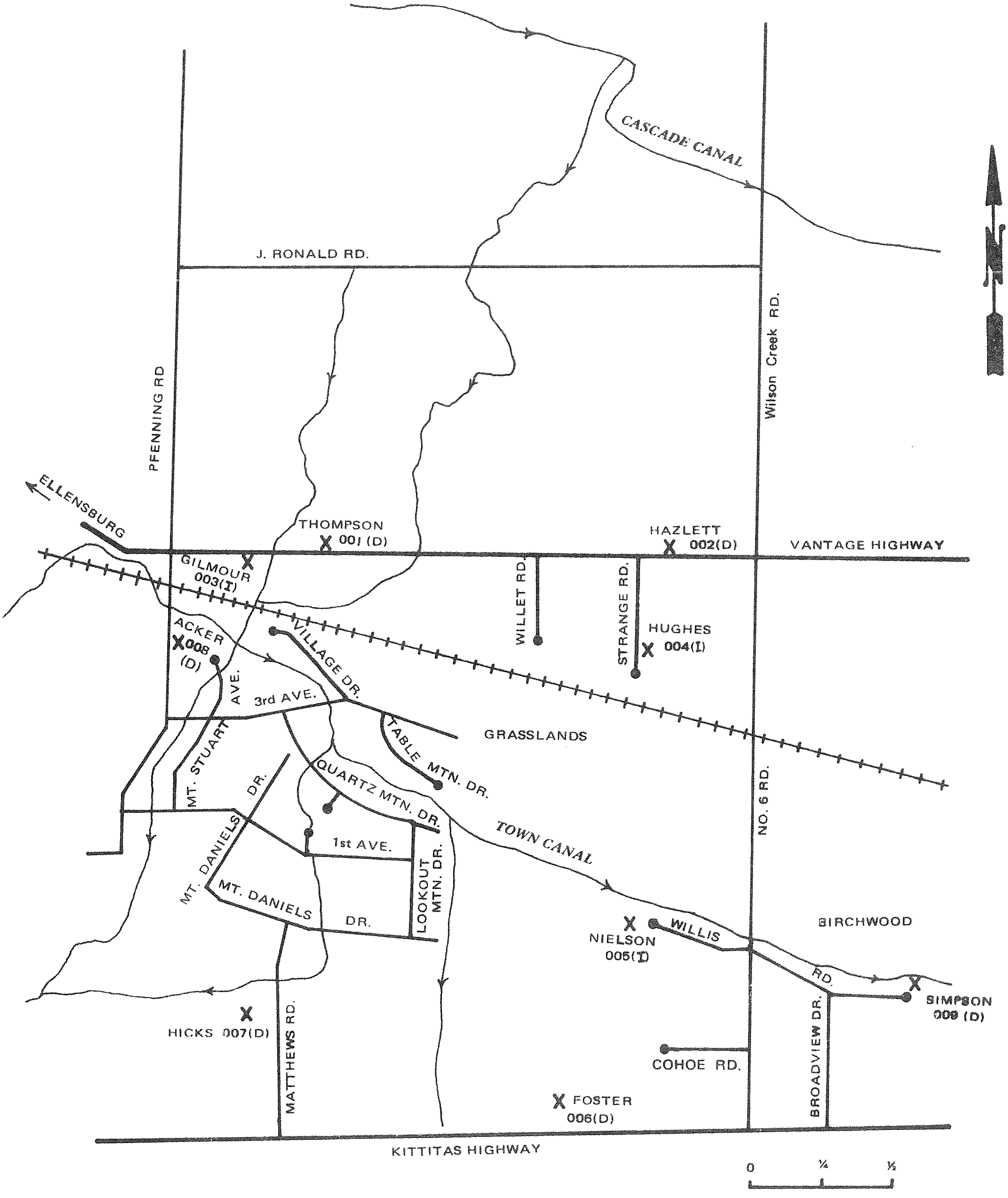


FIG. 3 **Wells (x) sampled in the Grasslands - Birchwood development area near Ellensburg (D = domestic well, I = irrigation well)**

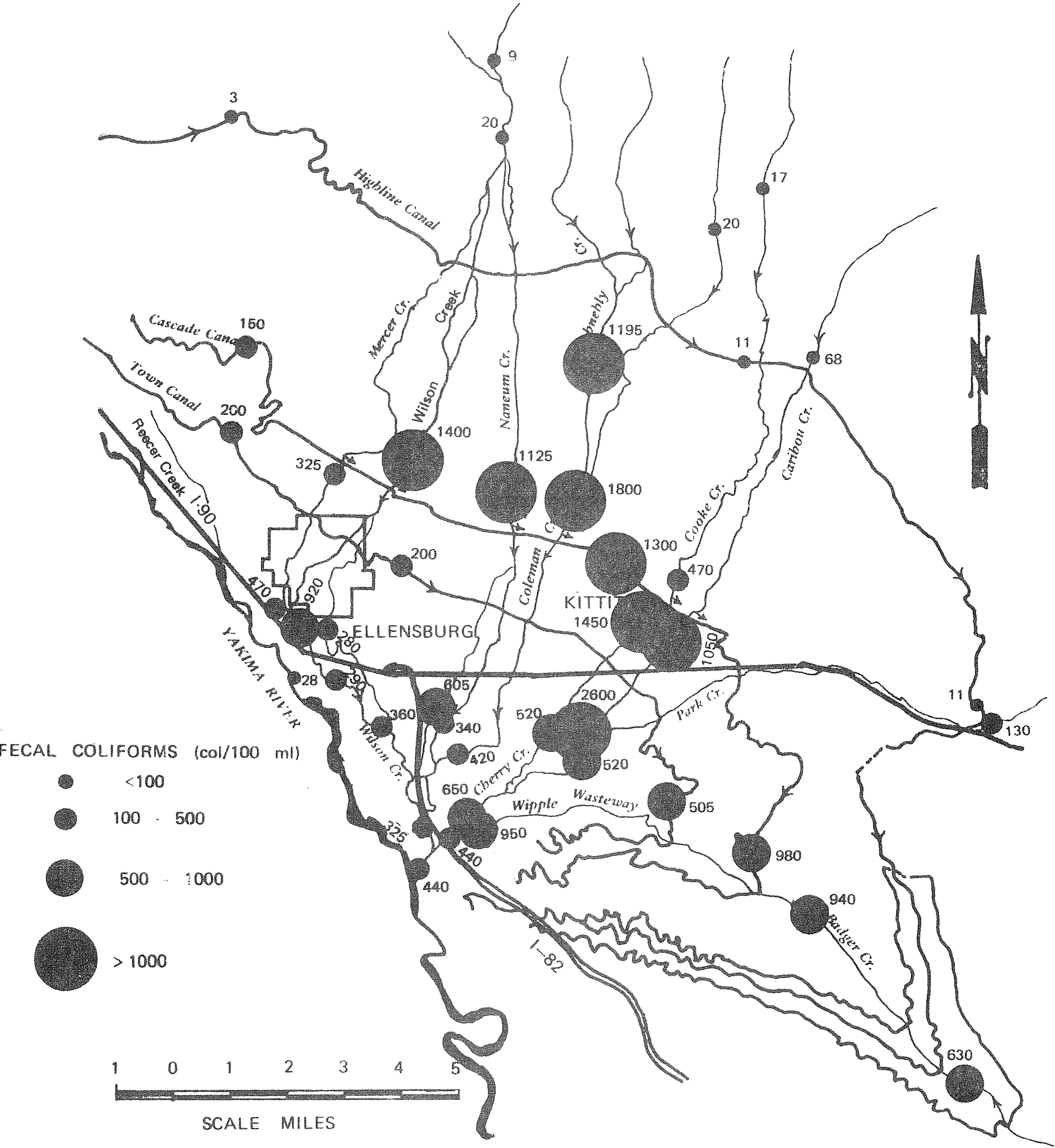


FIG. 4 Median fecal coliform concentrations in Wilson Creek drainage, July - October 1978 and May - July 1979

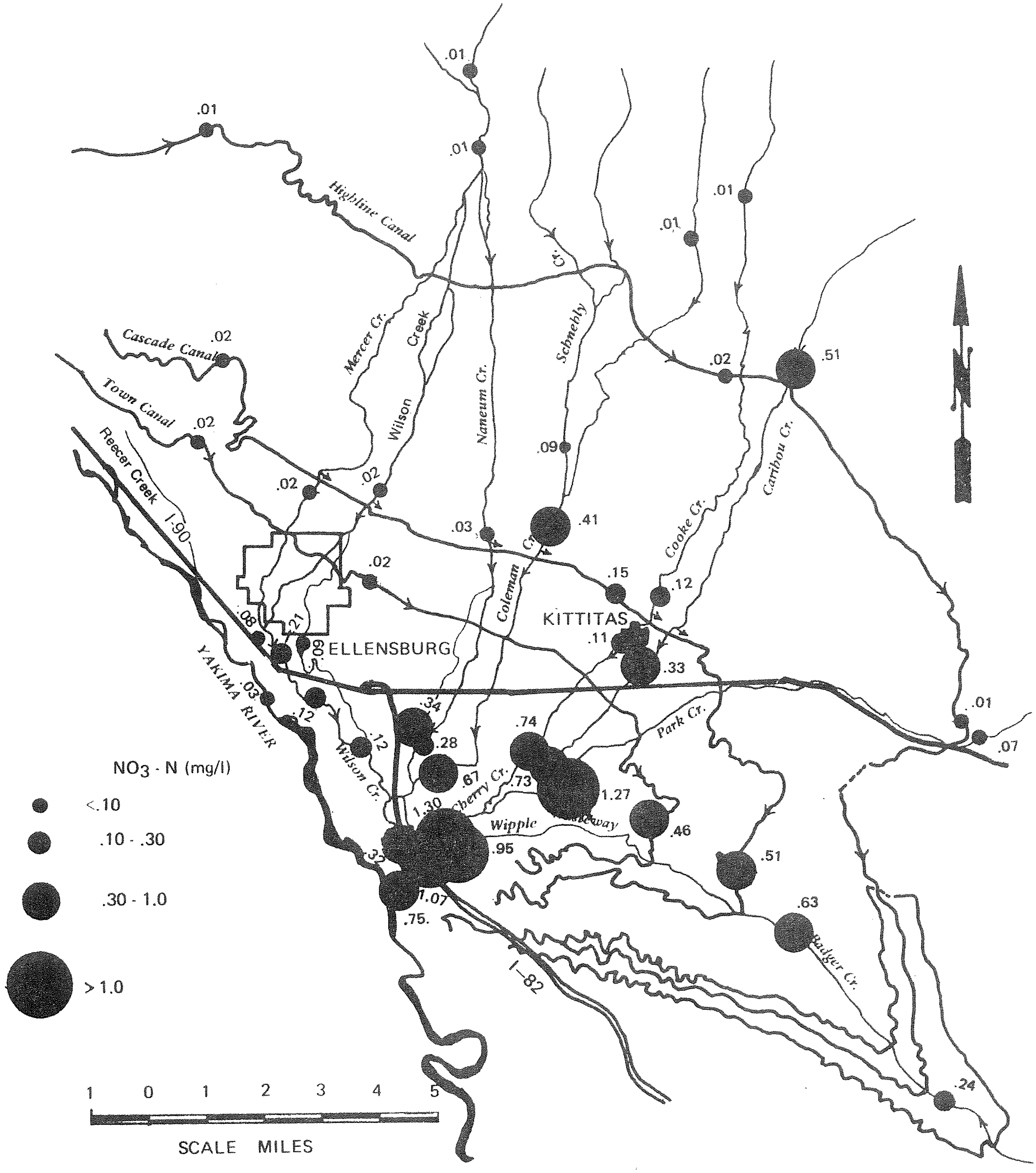


FIG. 5 Mean nitrate - nitrogen (NO_3 - N) concentrations in Wilson Creek drainage, July - October 1978 and May - July 1979

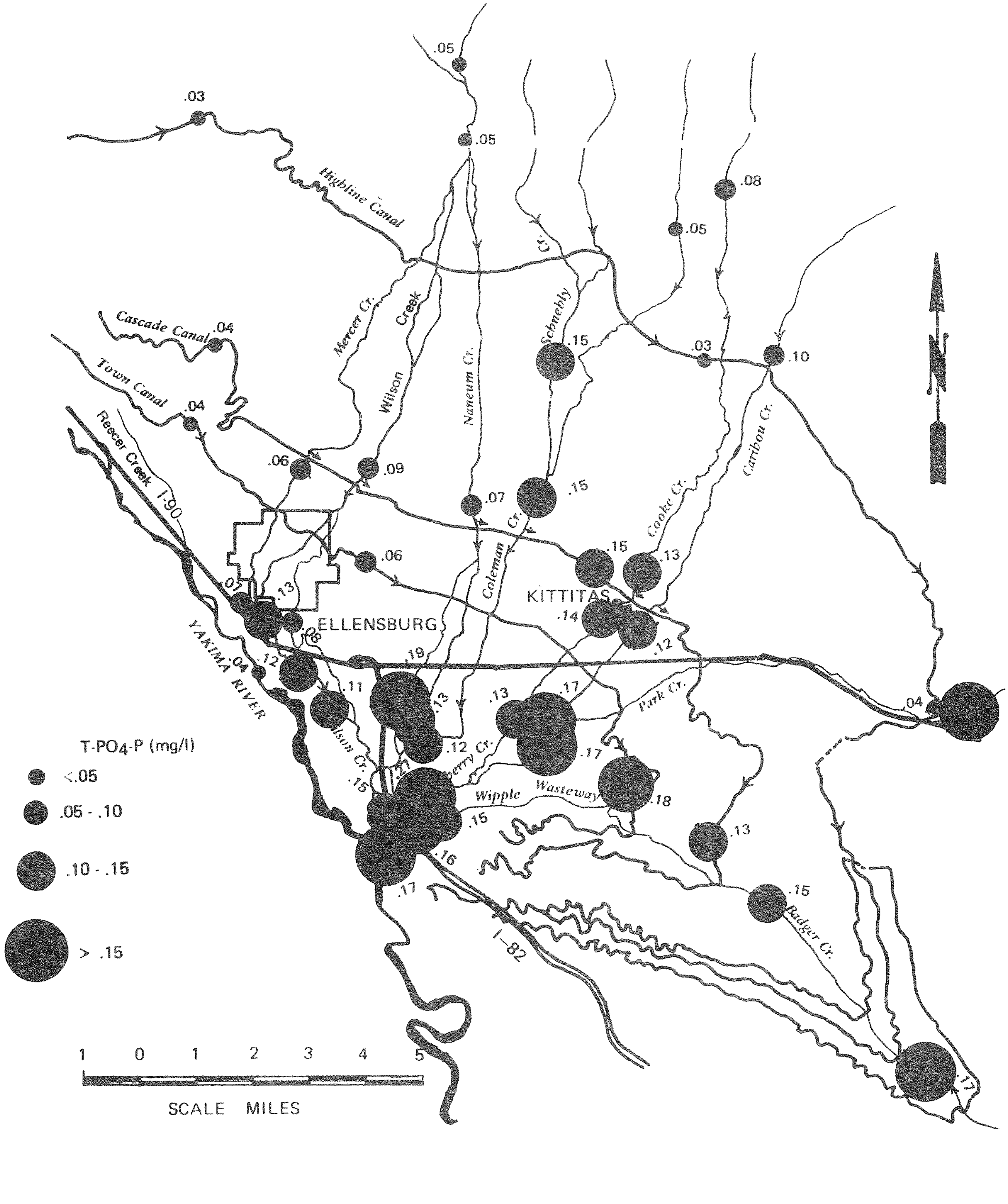


FIG. 6 **Mean total phosphate - phosphorus (T - PO_4 - P) concentrations in Wilson Creek drainage, July - October 1978 and May - July 1979**

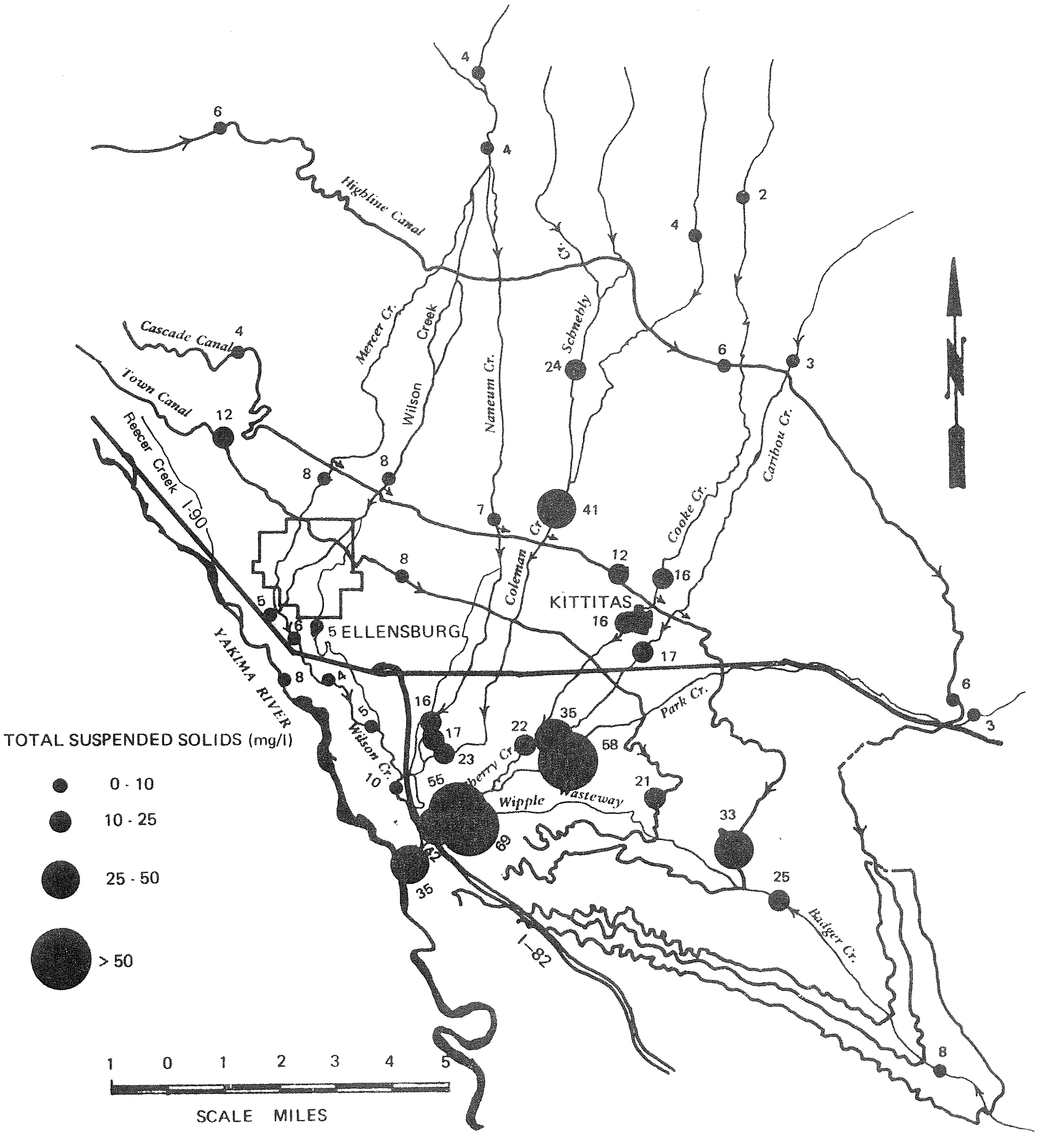


FIG. 7 Mean total suspended solids concentrations in Wilson Creek drainage, July - October 1978 and May - July 1979

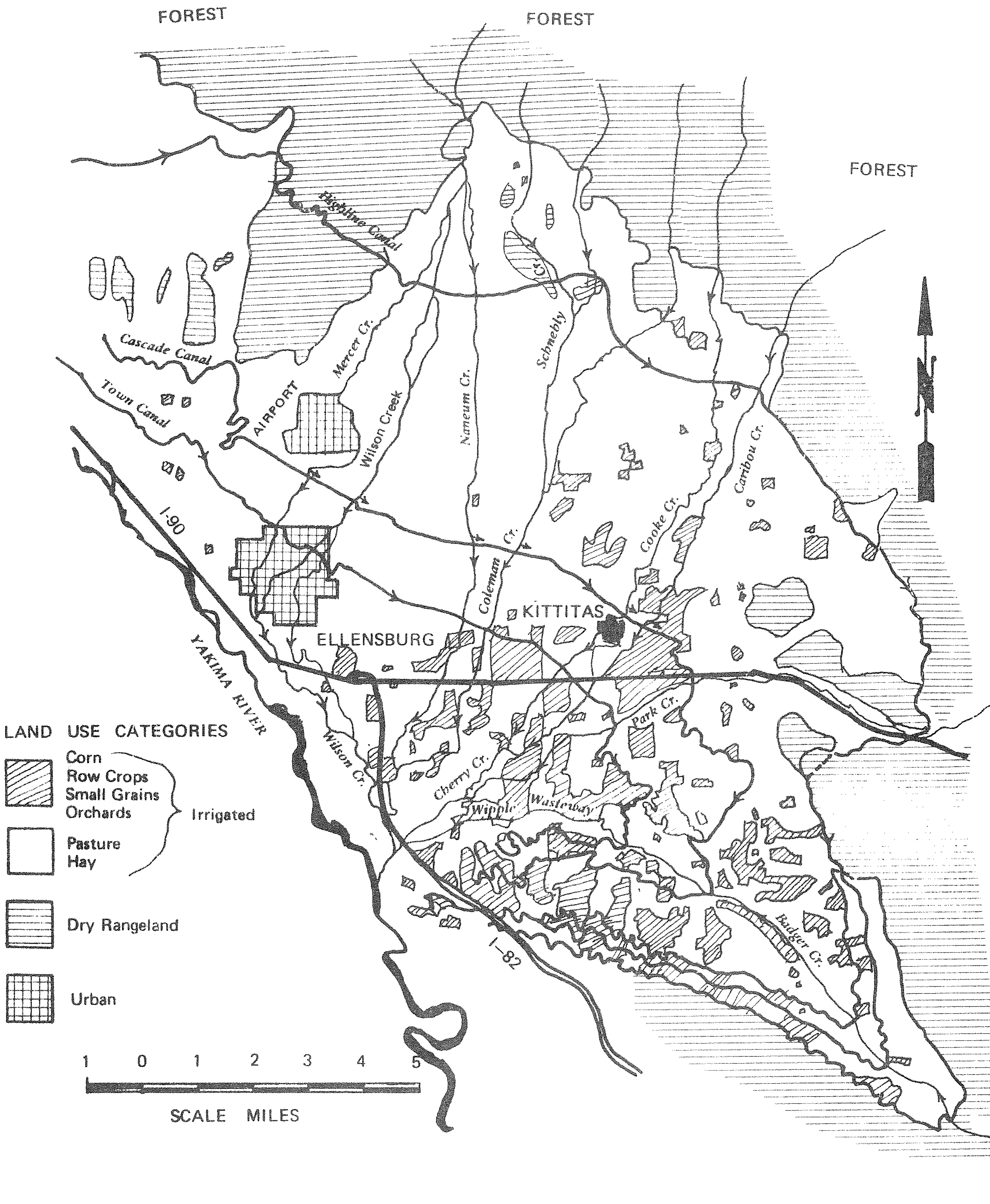
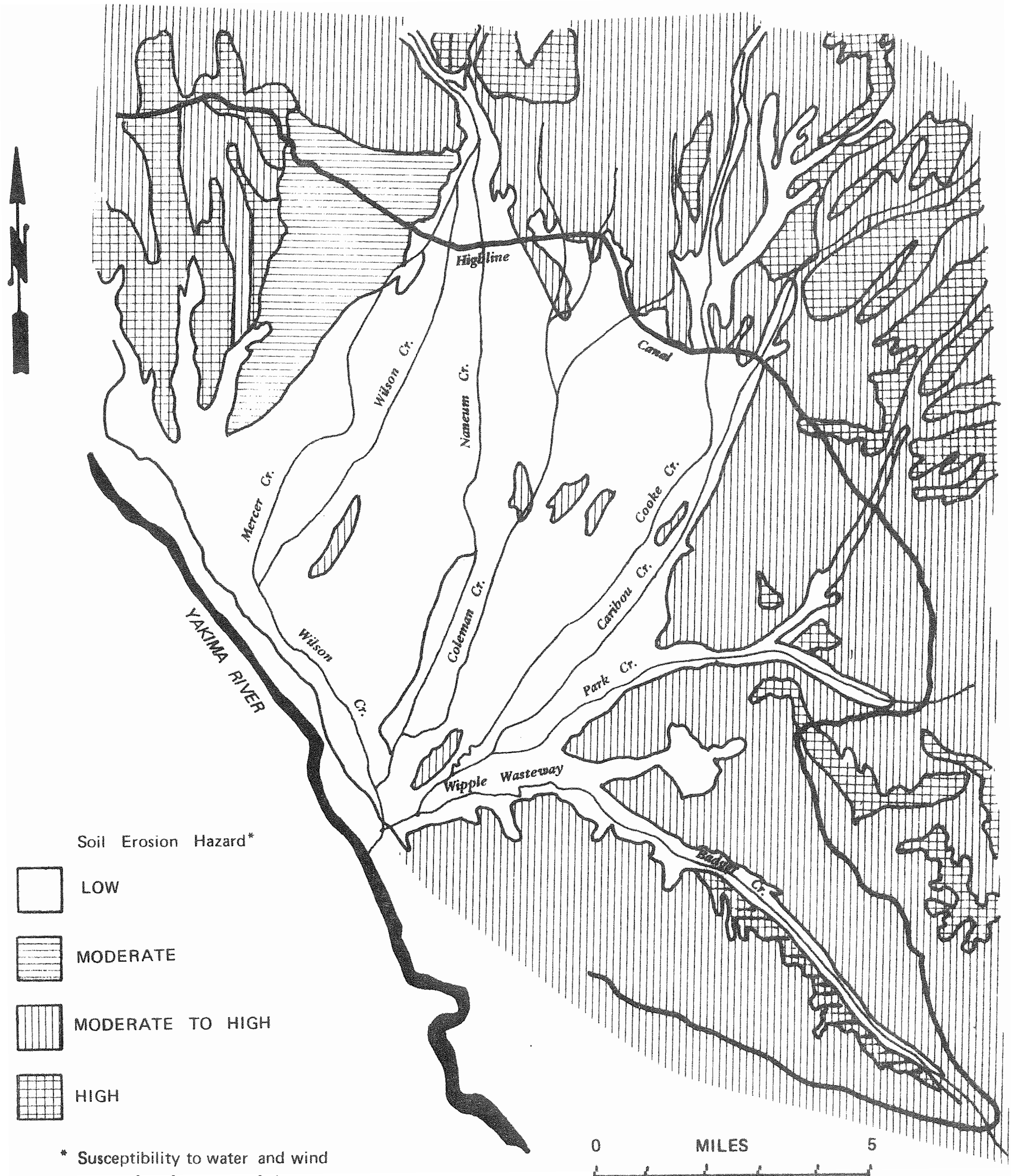


FIG. 8 Land use in Wilson Creek drainage. (from June 25 - 27, 1979 field survey)



* Susceptibility to water and wind erosion based on soil and slope characteristics, climate and experience with soil types.

FIG. 9 **Relative soil erosion hazard in Wilson Creek drainage. (modified from <u>Environmental Assessment of Ellensburg Valley in the Wilson Creek Watershed, Washington</u>, JARA, 1975)**

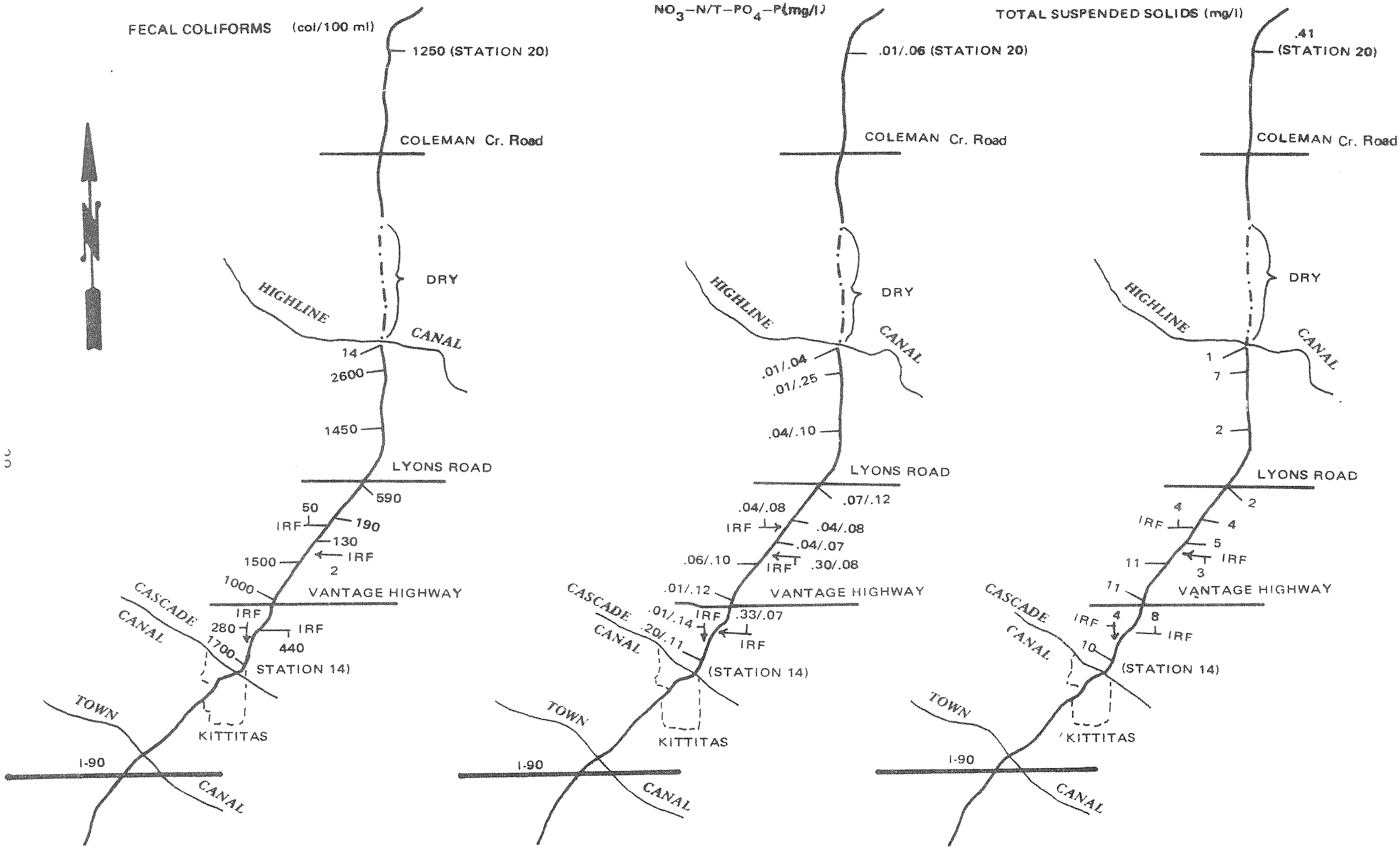


FIG. 10 Fecal coliforms, nitrate - nitrogen (NO_3 - N), total phosphate - phosphorus (T - PO_4 - P) and total suspended solids in Cooke Creek and selected irrigation return flows, 20 August 1979. (IRF = irrigation return flow)

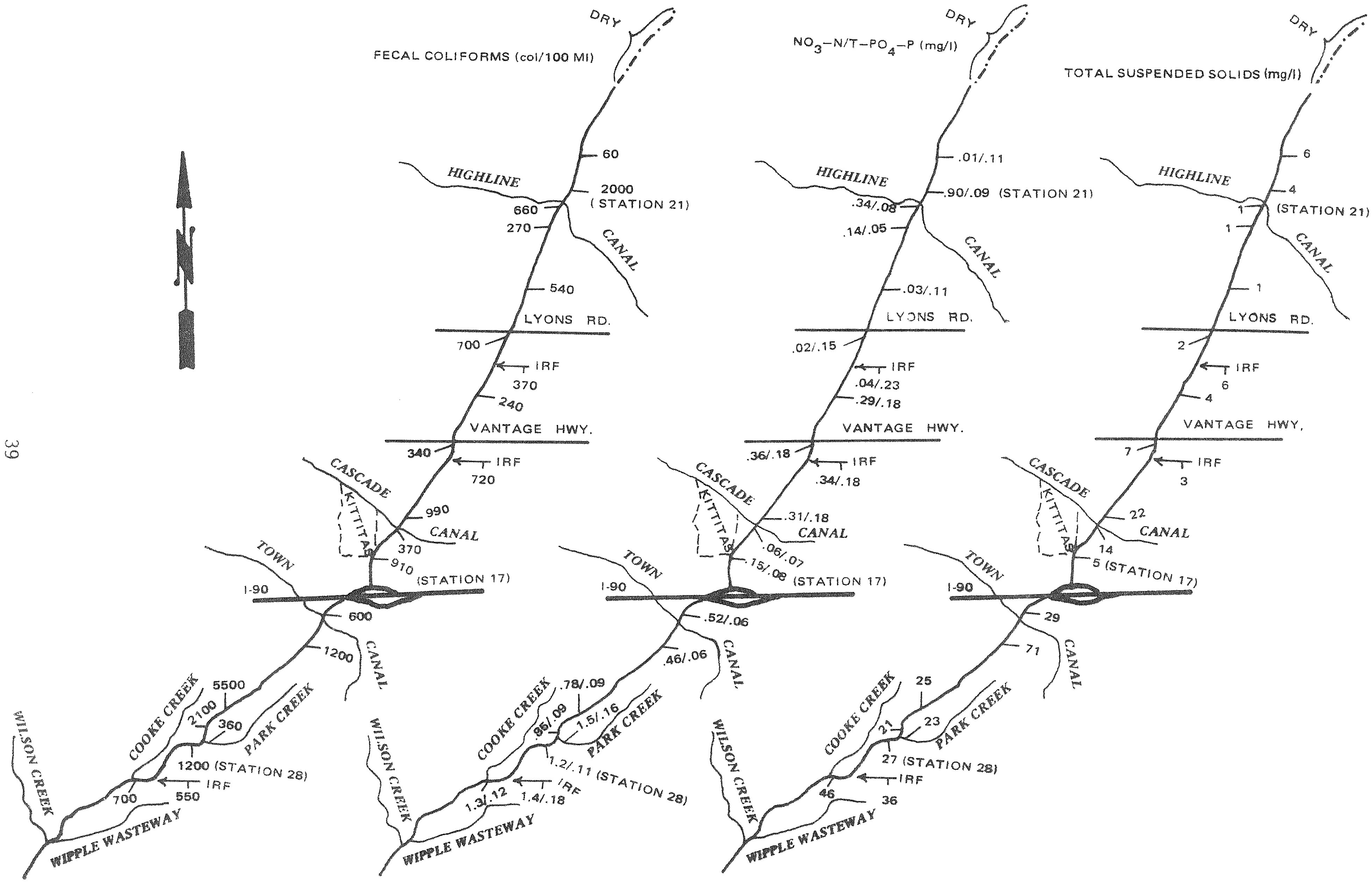


FIG. 11 Fecal coliforms, nitrate - nitrogen (NO_3 - N), total phosphate - phosphorus (T - PO_4 - P) and total suspended solids in Caribou Creek and selected irrigation return flows, 21 August 1979. (IRF = irrigation return flow)

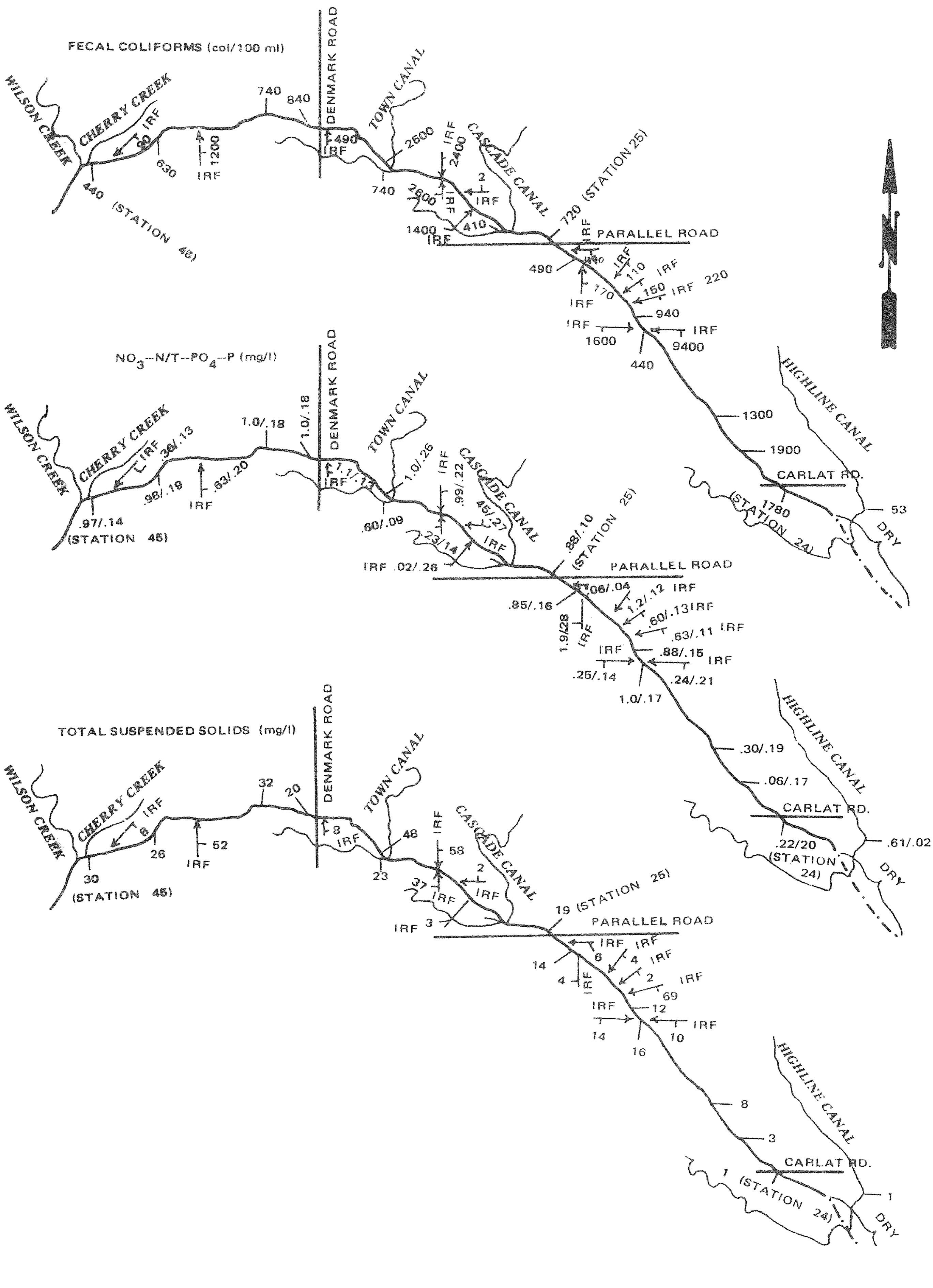


FIG. 12 Fecal coliforms, nitrate - nitrogen (NO_3 - N), total phosphate - phosphorus (T - PO_4 - P) and total suspended solids in Badger Creek and selected irrigation return flows, 22 August 1979. (IRF = irrigation return flow)

TABLES

Table 1. Water quality[a] during the 1978 and 1979 irrigation seasons at selected surface water stations in Wilson Creek drainage, July-October 1978 and May-July 1979.

Sampling Site(s)	Station Number	Temp. (°C)	pH	Specific Conductivity (µmhos/cm)	Total Hardness, as $CaCO_3$ (mg/l)	Total Alkalinity, as $CaCO_3$ (mg/l)	COD (mg/l)	D.O. (mg/l)	Fecal Coliforms (col/100 ml)	Total Kjeldahl nitrogen (mg/l)	Ammonia-nitrogen NH_3-N (mg/l)	Nitrite-nitrogen NO_2-N (mg/l)	Nitrate-nitrogen NO_3-N (mg/l)	Total Phosphate-phosphorus T-PO_4-P (mg/l)	Turbidity (NTU)	Total Suspended Solids (mg/l)
Upper Creeks	6,7,19, 20	12.0	7.6	81	41	40	8	9.6	17	.21	.02	<.01	.01	.06	2	4
Highline Canal																
Input	1	12.3	7.2	46	24	19	6	12.3	3	.25	.03	<.01	.01	.03	3	6
Middle	18	13.9	7.3	47	28	19	6	10.6	11	.11	.02	<.01	.02	.03	3	6
End	23	13.9	7.3	47	29	18	6	10.3	11	.11	.02	<.01	.01	.04	3	6
Middle Creeks	5,10, 12,14, 25	14.3	7.7	173	81	80	17	9.4	1,150	.44	.04	<.01	.24	.12	5	19
Cascade Canal																
Input	2	13.0	7.3	69	35	33	9	10.3	150	.29	.02	<.01	.02	.04	3	4
Middle	13	15.8	7.8	206	101	96	20	10.2	1,300	.68	.04	<.01	.15	.15	6	12
End	8	14.3	7.6	196	88	85	15	8.7	980	.73	.06	<.01	.51	.13	12	33
Town Canal																
Input	3	12.6	7.2	86	41	40	8	10.3	200	.31	.02	<.01	.02	.04	4	12
Middle	11	13.9	7.6	88	51	39	8	10.6	200	.23	.02	<.01	.02	.06	4	8
End	26	13.9	7.7	323	134	141	18	9.2	510	.64	.05	<.01	.46	.18	6	21
Lower Naneum, Coleman, Cooke, Caribou, Park, Creeks	27,28, 29,30, 31,40	13.8	7.8	229	104	103	17	9.7	830(480[b])	.66	.05	<.01	.67	.15	7	29
Lower Wilson Creek	34	14.4	7.9	186	89	82	10	10.7	360	.32	.03	<.01	.12	.11	3	5
Wipple Wasteway	32	14.4	7.8	285	121	124	17	9.8	440	.50	.05	<.01	1.10	.16	10	42
Wilson Creek Mouth	33	13.8	7.8	261	121	114	12	10.4	440	.49	.04	<.01	.75	.17	8	35
Yakima River[c]	T-1	14.2	7.6	71	39	33	8	9.9	28	.18	.02	<.01	.03	.04	3	8

[a] Geometric means except coliforms which are medians.

[b] Excluding station 28 on Caribou Creek.

[c] Yakima River diversion to Tjossem Ditch at river mile 152.2, 5.? miles upstream from Wilson Creek confluence.

Table 2. Nitrate-nitrogen (NO_3-N), total phosphate-phosphorus (T-PO_4-P), and total suspended solids (TSS) loadings for lower Wilson Creek, Cherry Creek, Wipple Wasteway, and the Yakima River, March-July 1979.

Date	Wilson Creek above Naneum confluence (Station 34) Flow (mgd)	NO_3-N (pounds per day)	T-PO_4-P (pounds per day)	TSS (pounds per day)	Wilson Creek above Wipple Wasteway (Station 42) Flow (mgd)	NO_3-N (pounds per day)	T-PO_4-P (pounds per day)	TSS (pounds per day)	Cherry Creek (Station 44) Flow (mgd)	NO_3-N (pounds per day)	T-PO_4-P (pounds per day)	TSS (pounds per day)	Wipple Wasteway above Cherry Creek confluence (Station 45) Flow[d] (mgd)	NO_3-N (pounds per day)	T-PO_4-P (pounds per day)	TSS (pounds per day)	Wilson Creek mouth at Yakima River (Station 33) Flow[e] (mgd)	NO_3-N (pounds per day)	T-PO_4-P (pounds per day)	TSS (pounds per day)	Yakima River[a] above Wilson Creek confluence Flow (mgd)	NO_3-N (pounds per day)	T-PO_4-P (pounds per day)	TSS (pounds per day)
3/13	10.7	17	8	890	93.1	233	47	15,500	25.2	200	23	4,200	8.8	132	13	294	127	827	--	21,200	2,410	--	--	--
4/18	3.8	6	2	220	89.2	116	97	30,500	22.6	124	28	9,610	7.9	112	--	7,910	120	519	110	36,900	1,780	--	--	--
5/09	31.5	55	89	3,150	145	242	483	56,800	32.3	256	148	12,900	11.3	76	41	5,660	189	926	628	87,900	2,550	--	5,530	128,000
5/22	27.1	23	25	1,810	116	330	146	17,500	32.9	521	82	11,000	11.5	106	--	6,330	160	1,270	215	42,900	2,760	460	--	230,000
6/05	32.4	43	30	1,350	114	304	104	7,590	34.5	374	58	8,920	12.1	101	22	7,270	161	1,190	254	56,200	3,320	554	1,100	471,000
6/19	--	--	--	--	130	163	152	9,750	59.5	--	79	35,200	20.8	153	31	16,100	210	1,240	316	91,200	3,020	252	1,000	151,000
7/10	--	--	--	--	126	904	126	4,210	66.9	670	--	67,000	23.4	195	6	13,500	216	1,750	379	148,000	5,720	954	1,430	668,000

a. Flow data from USGS gaging station at Umtanum corrected for contribution from Wilson Creek 6 miles upstream; water quality data from Yakima River diversion to Tjossem Ditch (station T-1).

b. DOE gaging.

c. Bureau of Reclamation gaging station.

d. Estimated as 35% of Cherry Creek flow (personal communication Onni Perala, Bureau of Reclamation).

e. Sum of flows at stations 42, 44, and 45.

Table 3. Ranges and means for Wilson Creek water quality data at stations 34-38 below Ellensburg, July 1978 - July 1979, compared to criteria for protection of salmonids.

Parameter	Minimum	Maximum	Mean	Salmonid Protection Criteria[a]
Temperature (°C)	0.0	20.0	12.7	18.0 (maximum average weekly) 9.0 (spawning)
pH	6.3	8.8	7.9	6.5 - 9.0
D.O. (mg/l)	8.5	14.3	11.5	>7.5
Un-ionized ammonia[b]	--	.002	--	<0.02
Nitrite-nitrogen, NO_2-N (mg/l)	<.01	.01	<.01	<0.06
Total Suspended Solids (mg/l)	1	70	8	<25 (high protection level) <80 (moderate protection level)
Alkalinity as $CaCO_3$ (mg/l)	57	150	81	>20
Total lead (μg/l)[c]	<10	<50	<40	<25 (at 75 - 150 mg/l hardness)
Total mercury (μg/l)[c]	<.20	.30	<.20	<.05
Total zinc (μg/l)[c]	<10	<10	<10	<50 (at 75 - 150 mg/l hardness)

[a]Sources: National Academy of Sciences. 1972. *Water Quality Criteria - 1972.*
U.S. Environmental Protection Agency. 1976. *Quality Criteria for Water.*
American Fisheries Society. 1979. *A Review of the EPA Red Ronk: Quality Criteria for Water.*

[b]Total ammonia-nitrogen is abbreviated as NH_3-N in this report but actually consists of ionized and un-ionized ammonia (NH_3 + NH_4+). The maximum level of these two forms was calculated from data on temperature, pH, and total ammonia-nitrogen.

[c]Metals data July - September 1978.

Table 4. Tjossem Ditch and Wilson Creek water quality data[a], July-September 1978 and May-July 1979.

Station Location	Station Number	Temp. (°C)	pH	Specific Conductivity (µmhos/cm)	COD (mg/l)	D.O. (mg/l)	Fecal Coliforms (col/100 ml)	Total Kjeldahl-nitrogen (mg/l)	Ammonia-nitrogen NH_3-N (mg/l)	Nitrate-nitrogen NO_3-N (mg/l)	Total Phosphate-phosphorus T-PO_4-P (mg/l)	Total Sus. Solids (mg/l)	Turb. (NTU)
Yakima River Diversion	T-1	14.2	7.6	71	8	9.9	28	.18	.02	.03	.04	8	
Below Schaake Feedlot	T-2	14.3	7.4	74	9	10.2	128	.23	.04	.03	.04	7	3
Yakima River Return	T-3	14.0	7.4	75	7	9.7	220	.26	.04	.03	.04	7	3
Above Tjossem Pond	T-4	15.2	7.6	74	6	10.2	190	.25	.03	.03	.03	5	3
Below Tjossem Pond	T-5	17.5	8.1	112	7	10.1	28	.29	.03	.01	.04	4	3
Wilson Creek above Tjossem Ditch Confluence	34	14.4	7.9	186	10	10.7	360	.32	.03	.12	.11	5	

[a]Geometric mean except coliforms which are medians

Table 5. Wilson Creek water quality and sediment data[a] for stations above and below Ellensburg STP sludge disposal site, July 1978-1979[b]

Station Location	Station Number	Temp. (°C)	pH	Specific Conductivity (umhos/cm)	Total Hardness, as $CaCO_3$ (mg/l)	Total Alkalinity, as $CaCO_3$ (mg/l)	COD (mg/l)	D.O. (mg/l)	Fecal Coliforms (col/100 ml)	Total Kjeldahl-nitrogen (mg/l)
Above Sludge Disposal Site	35	10.7	7.9	184	88	80	9	12.6	400	.68
Below Sludge Disposal Site	36	10.7	8.0	184	88	80	9	12.3	280	.40

Station Location	Station Number	Ammonia-nitrogen NH_3-N (mg/l)	Nitrate-nitrogen NO_3-N (mg/l)	Total Phosphate-phosphorus T-PO_4-P (mg/l)	Total Suspended Solids (mg/l)	Turbidity (NTU)	Sediment Pb (mg/kg)	Sediment Hg (mg/kg)	Sediment Zn (mg/kg)
Above Sludge Disposal Site	35	.05	.14	.11	6	3	<50	<.20	<10
Below Sludge Disposal Site	36	.05	.15	.11	6	3	<50	<.20	<10

[a]Geometric means except coliforms which are medians.

[b]Sediment data July-September 1978 only.

Table 6. Cooke Creek water quality data[a] for stations above and below Kittitas STP, July 1978 - July 1979.

Station Location	Station Number	Temperature (°C)	pH	Specific Conductivity (μmhos/cm)	Total Hardness, as $CaCO_3$ (mg/l)	Total Alkalinity, as $CaCO_3$ (mg/l)	COD (mg/l)	D.O. (mg/l)	Fecal Coliforms (col/100 ml)
100 ft. above STP outfall	15	13.5	8.1	228	107	108	19	9.7	890
100 ft. below STP outfall	16	13.3	7.8	271	120	124	27	8.7	1,200

Station Location	Station Number	Total Kjeldahl-nitrogen, (mg/l)	Ammonia-nitrogen, NH_3-N (mg/l)	Nitrite-nitrogen, NO_2-N (mg/l)	Nitrate-nitrogen, NO_3-N (mg/l)	Total Phosphate-phosphorus, T-PO_4-P (mg/l)	Total Suspended Solids (mg/l)	Turbidity (NTU)
100 ft. above STP outfall	15	.63	05	.01	.13	.12	14	6
100 ft. below STP outfall	16	.83	.28	.01	.20	.37	17	7

[a]Geometric means except coliforms which are medians.

Table 7. Static water level measurements[a] of domestic and irrigation wells in the Grasslands-Birchwood development area near Ellensburg, July 1978 - July 1979.

	Well #001	Well #002	Well #003	Well #004	Well #005	Well #006	Well #007	Well #008	Well #009
Approx. Depth (feet)	50	--	6	18	8	50	75	60	73
Type	Domestic	Domestic	Irrigation	Irrigation	Irrigation	Domestic	Domestic	Domestic	Domestic
Owner	Thompson	Hazlett	Gilmour	Hughes	Nielsen	Foster	Hicks	Ackler	Simpson
Date Sampled	**Static Water Level Measurements[a]**								
07/26/78	3.9	d	--	4.0	2.2 (3.0)[b]	--	5.8	--	--
08/09/78	--	--	(3.9)[b]	--	--	7.3	--	8.7	20.2
08/23/78	4.0	--	--	3.1	(3.5)[b]	--	6.0	--	--
09/20/78	4.5	--	1.2	3.1	3.5	8.1	[illegible]	7.9	20.5
Week of 10/16/78 - Started to drain Cascade and Town canals									
10/25/78	(4.9)[b]	--	1.5	3.7	3.6	8.1	6.0	6.0	20.3
12/11/78	5.2	--	2.7	6.3	dry	(11.1)[b]	8.1	(25.8)[b]	21.5
01/24/79	7.3	--	5.6	8.4	dry	--	10.1	10.2	23.1
03/22/79	4.4	--	3.1	9.5	dry	15.8	10.6	11.8	23.2
04/18/79	--	--	3.0	11.0	dry	21.5	12.1	10.3	24.5
Week of 04/16/79 - Started to fill Cascade and Town canals									
05/08/79	--	--	2.5	7.5	1.6	9.6	6.9	19.8	26.0
06/06/79	--	--	1.6	4.2	2.1	--	(13.0)[b]	15.6	20.0
07/11/79	3.3	--	1.8	3.9	2.2	--	7.1	8.1[c]	(26.7)[b]

[a]In feet from land surface datum (LSD).

[b]After recent pumping.

[c]Casing now extends about 2 feet above LSD.

[d]Not accessible. Water quaiity samples taken only.

Table 8. Well water quality[a] in the Grasslands-Birchwood development area near Ellensburg, July 1978 - July 1979

	Well #001	Well #002	Well #003	Well #004	Well #005	Well #006	Well #007	Well #008	Well #009	
Approx. Depth (feet)	50	--	6	18	8	50	75	60	73	
Type	Domestic	Domestic	irrigation	Irrigation	Irrigation	Domestic	Domestic	Domestic	Domestic	Drinking Water Criteria[b]
Owner	Thompson	Hazlett	Gilmour	Hughes	Nielsen	Foster	Hicks	Ackler	Simpson	
Temperature (°C)	11.8	10.7	10.5	12.0	12.6	10.7	10.9	11.0	12.1	
pH	6.9	7.0	6.9	7.2	7.6	7.1	7.0	6.9	7.1	5.0 - 9.0
Specific Conductivity (µmhos/cm)	203	242	299	554	346	403	422	267	262	
Turbidity (NTU)	5	2	41	1	2	2	8	29	3	5
Total Coliforms[b] (col/100 mi)	2	<1	20	115	30	1	<2	<3	1	4 col/100 ml
Fecal Coliforms[b] (col/100 ml)	<1	<1	<2	<1	1	<1	<1	<1	<1	
Nitrate-nitrogen, NO_3-N (mg/l)	<.02	1.2	<.02	2.5	1.5	.66	.31	.14	.41	10 mg/l
Nitrite-nitrogen, NO_2-N (mg/l)	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	1 mg/l
Ammonia-nitrogen, NH_3-N (mg/l)	.01	.04	.09	.02	.03	.06	.02	.04	<.02	.5 mg/l
Total phosphate-phosphorus, T-PO_4-P (mg/l)	.04	.07	.14	.20	.78	.11	.03	.07	.10	
Total Hardness, as $CaCO_3$ (mg/l)	104	111	138	223	156	180	184	121	117	
Total Alkalinity, as $CaCO_3$ (mg/l)	106	107	139	185	146	182	200	122	117	400 mg/l
Chlorides (mg/l)	3	2	7	35	6	3	2	2	1	250 mg/l
Calcium Hardness (mg/l)	100	97	127	178	152	172	187	110	103	
Total Iron (mg/l)	1.4	<.05	6.3	<.02	.56	.06	.76	2	.19	.3 mg/l

[a] Arithmetic means except coliforms which are medians.

[b] Sources: Department of Social and Health Services, Washington State, 1978. *Rules and Regulations of the State Board of Health Regarding Public Water Systems.*
U.S. Environmental Protection Agency, 7976. *Quality Criteria for Water.*
National Academy of Sciences, 1972. *Water Quality Criteria - 1972.*

APPENDICES

APPENDIX A

Washington State Water Quality Standards
for Class A Waters*

(2) CLASS A (EXCELLENT).

(a) General Characteristic. Water quality of this class shall meet or exceed the requirements for all or substantially all uses.

(b) Characteristic Uses. Characteristic uses shall include, but are not limited to, the following:

(i) Water supply (domestic, industrial, agricultural).

(ii) Wildlife habitat, stock watering.

(iii) General recreation and aesthetic enjoyment (picnicking, hiking, fishing, swimming, skiing, and boating).

(iv) Commerce and navigation.

(v) Fish and shellfish reproduction, rearing, and harvesting.

(c) Water Quality Criteria.

(i) Fecal Coliform Organisms

(A) Freshwater - Fecal Coliform Organisms shall not exceed a median value of 100 organisms/100 ml, with not more than 10 percent of samples exceeding 200 organisms/100 ml.

(B) Marine water - Fecal Coliform Organisms shall not exceed a median value of 14 organisms/100 ml, with not more than 10 percent of samples exceeding 43 organisms/100 ml.

(ii) Dissolved Oxygen.

(A) Freshwater - Dissolved oxygen shall exceed 8.0 mg/l.

(B) Marine water - Dissolved oxygen shall exceed 6.0 mg/l, except when the natural phenomenon of upwelling occurs, natural dissolved oxygen levels can be degraded by up to 0.2 mg/l by man-caused activities.

(iii) Total Dissolved Gas - the concentration of total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection.

*From Chapter 173-201 WAC - Water Quality Standards for Waters of the State of Washington (1/17/78) 33 p.

(iv) Temperature - water temperatures shall not exceed 18.0° Celsius (freshwater) or 16.0° Celsius (marine water) due to human activities. Temperature increases shall not, at any time, exceed $t = 28/(T + 7)$ (freshwater) or $t = 12/(T - 2)$ (marine water).

When natural conditions exceed 18.0° Celsius (freshwater) and 16.0° Celsius (marine water), no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3° Celsius.

For purposes hereof, "t" represents the permissive temperature change across the dilution zone; and "T" represents the highest existing temperature in this water classification outside of any dilution zone.

Provided that temperature increase resulting from nonpoint source activities shall not exceed 2.8° Celsius, and the maximum water temperature shall not exceed 18.3° Celsius (freshwater).

(v) pH shall be within the range of 6.5 to 8.5 (freshwater) or 7.0 to 8.5 (marine water) with a man-caused variation within a range of less than 0.5 units.

(vi) Turbidity shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10 percent increase in turbidity when the background turbidity is more than 50 NTU.

(vii) Toxic, radioactive, or deleterious material concentrations shall be below those of public health significance, or which may cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect any water use.

(viii) Aesthetic values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

APPENDIX B

Kittitas Valley Surface Water Station Descriptions

Station Number	Location
1	Highline Canal at Reecer Creek Road
2	Cascade Canal at Reecer Creek Road
3	Town Canal at Reecer Creek Road
4	Mercer Creek at Bender Road
5	Wilson Creek at Sanders Road
6	Wilson/Naneum at Ferrell Road
7	Naneum Creek above Wilson Creek Confluence
8	Cascade Canal at Bock Road
9	Schnebly Creek at Fred Schnebly Road
10	Naneum Creek at Game Farm Road
11	Town Canal at Pfenning Road
12	Coleman Creek at Watson Road
13	Cascade Canal at Denmark Road
14	Cooke Creek at No. 81 Road
15	Cooke Creek about 100 feet above STP Outfall
16	Cooke Creek about 100 feet below STP Outfall
17	Caribou Creek at East Kittitas Road
18	Highline Canal at Cooke Canyon Road
19	Coleman Creek at Coleman Creek Road
20	Cooke Creek at Cooke Canyon Road
21	Caribou Creek above Highline Canal at Diversion
22	Park Creek at Stevens Road
23	Highline Canal at Park Creek Siphon-Boystron Road
24	Badger Creek at Clarat Road
25	Badger Creek at Parallel Road
26	Town Canal at Coleman Road
27	Park Creek at Ferguson Road
28	Caribou Creek at Ferguson Road
29	Cooke Creek at Ferguson Road
30	Naneum Creek at No. 6 Road
31	Coleman Creek at No. 6 Road
32	Wipple Wasteway at Thrall Road
33	Wilson Creek above Yakima River Confluence
34	Wilson Creek at Tjossem Road
35	Wilson Creek above Ellensburg STP
36	Wilson Creek below Ellensburg STP
37	Wilson Creek at Kittitas Highway
38	Wilson Creek at Damman Road
39	Mercer Creek at Anderson Road
40	Naneum Canal at No. 6 Road
41	Town Canal at Ferguson Road
42	Wilson Creek at Thrall Road
43	Reecer Creek at Damman Road
44	Cherry Creek at No. 6 Road
45	Wipple Wasteway at Thrall Road
T-1	Tjossem Ditch at Yakima River Diversion
T-2	Tjossem Ditch below Schaake Feedlot
T-3	Tjossem Ditch at Yakima River Return
T-4	Tjossem Ditch at Canyon Road
	Tjossem Ditch below Tjossem Pond

Appendix C. Geometric means[a] and ranges for Wilson Creek drainage surface water quality parameters measured July-October 1978 and May-July 1979.

Sampling Site	Station Number	Temperature (°C)	pH	Specific Conductivity (µmhos/cm)	Total Hardness $CaCO_3$ (mg/l)	Total Alkalinity $CaCO_3$ (mg/l)	COD (mg/l)	D.O. (mg/l)	Fecal Coliform (Col/100 ml)
Highline Canal	1	12.3 6.0-16.0	7.2 6.6-7.8	46 40-59	24 18-32	19 14-75	6 4-15	12.3 11.3-14.2	3 1-55
Cascade Canal	2	13.0 8.0-18.0	7.3 6.5-8.1	69 60-91	35 25-46	33 24-73	9 4-15	10.3 9.2-11.8	150 37-300
Town Canal	3	12.6 7.0-17.0	7.2 6.5-7.6	86 75-101	41 33-52	40 33-55	8 4-19	10.3 9.2-11.7	200 80-1,500
Mercer Creek	4	13.2 6.2-20.0	7.5 6.5-8.3	104 73-178	52 30-116	51 34-113	12 4-41	9.9 7.8-12.1	325 140-1,600
Wilson Creek	5	12.5 6.0-18.0	7.3 6.3-7.8	134 102-183	63 47-88	63 49-91	14 7-23	8.9 6.3-11.0	1,400 320-6,800
Wilson/Naneum Creek	6	10.0 5.0-17.0	7.4 6.0-7.9	74 56-91	38 28-52	37 27-61	10 4-34	10.0 7.2-12.0	20 4-73
Naneum Creek	7	9.0 4.0-17.0	7.5 6.6-8.0	74 58-91	35 28-48	35 27-43	8 4-22	10.0 7.1-12.3	9 1-76
Cascade Canal	8	14.3 10.5-17.5	7.6 7.1-8.2	196 168-266	88 68-120	85 67-110	15 4-32	8.7 7.6-10.6	980 250-4,100
Schnebly Creek	9	15.0 7.0-20.0	7.8 7.0-8.5	243 187-320	113 76-168	113 81-157	26 15-51	8.8 6.0-11.5	1,195 110-10,000
Naneum Creek	10	13.0 6.0-19.0	7.5 7.0-8.0	108 68-105	58 44-92	57 32-173	15 8-23	9.2 7.8-11.0	1,125 60-20,000
Town Canal	11	13.9 9.9-18.0	7.6 6.9-8.2	88 75-103	50 37-73	39 34-36	8 4-15	10.6 9.4-11.6	200 33-830
Coleman Creek	12	15.3 9.0-20.0	7.7 7.3-8.3	242 201-300	109 87-132	111 94-137	23 4-48	9.5 8.5-11.7	1,800 330-4,800
Cascade Canal	13	15.8 10.0-20.0	7.8 7.3-8.5	206 168-230	101 77-120	96 83-110	20 4-49	10.2 5.8-15.0	1,300 130-4,000
Cooke Creek	14	16.3 9.0-22.0	8.2 7.5-8.8	192 122-252	91 60-124	91 56-135	17 4-45	9.8 8.5-11.4	470 250-1,900
Cooke Creek	15	15.4 8.0-20.5	8.1 7.4-8.9	223 186-267	105 84-128	106 85-142	22 4-49	9.3 7.4-11.7	1,450 600-9,200
Cooke Creek	16	14.9 9.5-20.5	7.7 6.9-8.7	282 197-390	123 88-160	127 86-189	28 19-45	8.2 5.1-8.9	1,250 20-40,000
Caribou Creek	17	16.3 11.5-22.0	7.9 7.4-8.6	228 168-324	108 80-136	104 74-151	20 4-37	9.1 7.2-10.8	1,050 680-1,600
Highline Canal	18	13.9 7.0-19.0	7.3 7.0-8.0	47 40-54	28 20-56	19 14-29	6 2-26	10.6 8.6-12.6	11 2-24
Coleman Creek	19	14.8 6.8-22.0	7.7 7.1-8.1	82 60-105	44 36-60	42 30-50	8 2-26	9.1 8.1-10.7	20 7-85
Cooke Creek	20	14.2 3.8-23.0	7.6 7.0-8.2	95 61-114	46 32-56	46 31-59	7 2-19	9.2 7.8-11.8	17 2-120
Caribou Creek	21	13.7 8.9-17.5	7.7 7.2-8.2	240 168-349	104 76-140	114 98-180	7 2-19	9.5 7.5-10.7	68 18-290
Park Creek	22	15.4 8.0-25.0	7.0 6.4-7.4	115 64-166	51 28-120	47 31-65	20 12-31	6.1 3.5-9.4	130 21-860
Highline Canal	23	13.9 7.0-18.0	7.3 6.8-7.8	47 53-51	29 20-76	18 15-27	7 2-16	10.3 9.5-11.6	11 1-24
Badger Creek	24	13.9 8.0-21.5	7.4 6.9-8.0	178 55-297	76 32-128	78 25-143	19 4-39	9.7 8.4-11.3	630 36-25,000
Badger Creek	25	13.6 10.0-19.0	7.6 6.9-8.0	187 97-474	85 53-158	80 40-188	17 9-31	9.6 8.1-11.1	940 350-3,600
Town Canal	26	13.9 10.5-17.5	7.6 7.2-8.2	323 268-373	134 110-180	141 120-160	18 7-28	9.2 7.1-11.5	505 120-1,200

[a]Fecal coliforms are medians.

Appendix C. - Continued

Kjeldahl Nitrogen (mg/l)	Ammonia-Nitrogen, NH_3-N (mg/l)	Nitrite-nitrogen, NO_2-N (mg/l)	Nitrate-nitrogen, NO_3-N (mg/l)	Total Phosphate-phosphorus, T-PO_4-P (mg/l)	Total Suspended Solids (mg/l)	Turbidity (NTU)
.25 .20-.39	.03 .01-.07	.01 .01-.01	.01 .01-.11	.03 .01-.25	6 3-43	3 1-30
.29 .26-.32	.02 .01-.04	.01 .01-.01	.02 .01-.34	.04 .02-.23	4 1-14	3 1-8
.31 .30-.32	.02 .01-.06	.01 .01-.01	.02 .01-.10	.04 .01-.23	12 4-150	4 1-10
.54 .44-.70	.02 .01-.11	.01 .01-.01	.02 .01-.19	.06 .03-.26	8 3-62	3 1-8
.34 .30-.42	.03 .01-.23	.01 .01-.01	.02 .01-.25	.09 .02-.34	8 3-18	4 2-7
.22 .14-.38	.02 .01-.10	.01 .01-.01	.01 .01-.10	.05 .02-.29	4 2-7	2 1-4
.16 .11-.22	.01 .01-.02	.01 .01-.01	.01 .01-.07	.05 .02-.27	4 2-7	2 1-3
.73 .48-.95	.06 .02-.27	.01 .01-.01	.51 .21-2.70	.13 .04-.41	33 6-120	12 3-33
.68 .39-1.60	.04 .01-.11	.01 .01-.01	.09 .01-1.40	.15 .08-.54	24 4-110	6 1-30
.27 .18-.62	.02 .02-.06	.01 .01-.01	.03 .07-17.0	.07 .03-.36	7 2-26	4 1-8
.23 .20-.27	.02 .01-.10	.01 .01-.01	.02 .01-.36	.06 .03-.25	8 3-21	4 2-12
.69 .34-1.80	.05 .02-.11	.01 .01-.01	.41 .14-1.50	.15 .09-.24	41 8-170	8 2-32
.68 .53-1.0	.04 .02-.09	.01 .01-.02	.15 .01-.45	.15 0D-.46	12 2-65	6 2-21
.47 .36-.72	.04 .02-.16	.01 .01-.04	.12 .01-.42	.13 .06-.38	16 5-76	5 2-30
.63 .52-1.0	.05 .02-.15	.01 .01-.01	.11 .01-.34	.14 .07-.46	16 [illegible]-80	6 2-23
.81 .38-1.40	.25 .05-1.10	.01 .01-.04	.23 .01-1.10	.39 .13-1.10	16 6-58	7 3-20
.55 .25-.88	.04 .01-.14	.01 .01-.01	.33 .12-.68	.12 .03-.40	17 6-60	5 3-15
.11 .01-.48	.02 .01-.07	.01 .01-.01	.02 .01-.39	.03 .01-.20	6 2-33	3 1-20
.28 .17-.51	.02 .01-.12	.01 .01-.01	.01 .01-.08	.05 .02-.34	4 2-8	2 1-3
.16 .05-.50	.02 .01-.05	.01 .01-.01	.01 .01-.05	.08 .04-.32	2 1-6	1 1-2
.24 .14-.36	.02 .01-.07	.01 .01-.01	.51 .11-.90	.10 .06-.44	3 1-12	2 1-3
.55 .44-.77	.04 .01-.30	.01 .01-.05	.07 .01-.98	.20 .11-.32	3 1-6	2 1-5
.11 .01-.44	.02 .01-.19	.01 .01-.01	.01 .01-.01	.04 .02-.20	6 3-36	3 1-24
.57 .34-1.40	.05 .01-.16	.01 .01-.02	.24 .02-.98	.17 .03-.47	8 1-42	4 1-12
.43 .24-.61	.04 .02-.13	.01 [illegible]	.63 .25-1.90	.15 .05-.30	25 8-78	5 1-18
.64	.05		.46 .01-1.10	.18 .07-.41	21 12-46	6 3-10

Appendix C. - Continued

Sampling Site	Station Number	Temperature (°C)	pH	Specific Conductivity (µmhos/cm)	Total Hardness $CaCO_3$ (mg/l)	Total Alkalinity $CaCO_3$ (mg/l)	COD (mg/l)	D.O. (mg/l)	Fecal Coliform (Col/100 ml)
Park Creek	27	12.9	7.7	326	135	145	20	9.5	520
		9.5-16.0	7.3-8.1	292-387	100-190	130-169	1-39	7.9-10.8	250-2,400
Caribou Creek	28	13.7	7.9	264	121	122	21	9.9	2,600
		10.0-17.5	7.4-8.4	205-348	87-160	96-160	11-52	8.4-11.9	200-5,300
Cooke Creek	29	14.5	7.9	227	97	102	21	9.6	520
		9.2-20.0	7.4-8.5	129-298	64-140	62-130	4-82	7.6-12.1	52-2,800
Naneuiii Creek	30	14.1	7.7	161	79	73	10	9.6	340
		8.0-21.0	7.2-8.3	127-203	60-150	60-93	4-23	7.2-11.1	160-10,000
Coleman Creek	31	14.1	7.8	206	97	93	17	10.1	420
		10.0-19.0	7.3-8.3	147-273	69-140	76-137	7-54	9.1-11.1	100-1,700
Wipple Wasteway	32	14.4	7.8	285	121	124	17	9.8	440
		10.0-18.5	7.2-8.6	190-450	84-188	91-192	7-35	8.6-11.5	90-1,200
Wilson Creek	33	14.2	7.8	261	115	114	13	10.4	440
		7.5-18.5	7.4-8.2	184-368	87-170	87-158	4-35	9.3-12.2	98-800
Wilson Creek	34	14.4	7.9	186	89	82	10	10.7	360
		8.0-18.0	7.2-8.6	146-253	70-120	70-109	4-19	9.2-12.6	42-1,200
Wilson Creek	35	15.3	8.0	177	85	79	10	12.5	480
		8.3-20.0	7.2-8.7	127-257	63-130	65-107	4-27	10.4-14.3	130-3,800
Wilson Creek	36	15.2	8.1	177	86	79	10	12.0	290
		8.0-19.0	7.2-8.8	123-235	63-120	62-111	4-24	10.3-13.8	36-1,200
Wilson Canal	37	14.8	8.0	146	73	63	13	10.6	280
		8.1-19.0	7.5-8.7	109-283	57-100	56-88	4-100	10.0-12.2	33-2,900
Wilson Creek	38	14.7	7.4	211	104	94	16	9.8	920
		8.0-18.0	6.9-7.6	174-248	84-150	78-110	4-85	8.5-11.9	290-4,400
Mercer Creek	39	14.9	7.5	210	103	97	11	9.6	260
		8.2-18.0	7.0-8.2	182-239	92-150	84-110	4-37	8.3-11.3	120-1,300
Naneum Canal	40	13.3	7.6	191	95	85	14	9.3	605
		7.0-17.0	7.2-8.3	163-238	76-130	70-110	4-29	8.7-10.8	83-1,800
Town Canal	41	14.2	7.6	92	47	40	8	10.6	135
		10.5-18.0	6.9-8.3	78-103	35-52	34-45	4-15	9.3-11.6	50-700
Wilson Creek	42	14.9	8.2	213	111	100	9	11.9	325
		11.0-18.0	8.0-8.7	124-230	84-160	93-118	4-17	10.3-13.0	100-920
Reecer Creek	43	13.8	7.5	114	65	50	6	10.3	470
		8.0-17.0	7.1-8.1	100-130	44-130	43-58	4-8	9.7-11.0	140-540
Cherry Creek	44	14.2	7.9	302	141	138	21	9.7	650
		12.0-16.0	7.9-8.1	271-350	120-170	130-140	15-27	9.3-10.5	530-2,000
Wipple Wasteway	45	14.9	7.9	284	124	119	12	9.9	950
		14.0-16.0	7.8-8.2	221-324	96-140	100-130	6-23	9.4-10.8	170-1,200
Tjossem Ditch	T-1	14.2	7.6	71	39	33	8	9.9	28
		8.1-18.0	7.1-8.4	55-101	25-110	26-46	3-35	8.3-11.4	10-1,000
Tjossem Ditch	T-2	14.3	7.4	74	44	36	9	10.2	128
		9.2-18.0	7.0-8.3	52-120	29-120	24-62	4-68	9.3-11.4	43-680
Tjossem Ditch	T-3	14.2	7.4	75	44	39	7	9.7	220
		9.9-17.0	6.9-7.8	52-117	25-110	26-69	3-23	6.5-11.9	20-1,200
Tjossem Ditch	T-4	15.2	7.6	74	43	35	6	10.3	190
		12.2-19.0	7.0-8.1	52-114	28-88	26-52	3-19	8.7-12.2	60-1,200
Tjossem Ditch	T-5	17.5	8.1	112	53	52	7	10.1	28
		11.5-22.8	6.9-8.7	54-299	25-160	26-130	3-19	8.9-12.0	1-680

[a]Fecal coliforms are medians.

Appendix C. - Continued

Total Kjeldahl Nitrogen (mg/l)	Ammonia-nitrogen, NH_3-N (mg/l)	Nitrite-nitrogen, NO_2-N (mg/l)	Nitrate-nitrogen, NO_3-N (mg/l)	Total Phosphate-phosphorus, T-PO_4-P (mg/l)	Total Suspended Solids (mg/l)	Turbidity (NTU)
.65 .29-1.50	.05 .01-.40	.01 .01-.01	1.27 1.0-1.80	.17 .07-.42	58 12-166	11 2-50
.77 .38-1.30	.06 .02-.18	.01 .01-.02	.73 .37-3.10	.17 .09-.52	35 11-240	7 1-46
.73 .33-1.10	.05 .02-.24	.01 .01-.01	.74 .20-2.20	.13 .04-.37	22 10-48	6 2-14
.57 .22-1.0	.05 .01-.25	.01 .01-.03	.28 .03-.88	.13 .05-.55	17 5-50	6 2-20
.53 .19-.87	.03 .01-.14	.01 .01-.02	.67 .24-1.90	.12 .08-.20	23 12-110	7 2-32
.50 .12-1.0	.05 .01-.10	.01 .01-.02	1.07 .54-3.20	.16 .09-.40	42 7-74	10 2-31
.49 .26-.83	.04 .02-.07	.01 .01-.02	.75 .40-.97	.17 .09-.40	35 7-82	8 1-26
.32 .13-.53	.03 .01-.08	.01 .01-.01	.12 .02-.21	.11 .06-.34	5 1-12	3 2-4
.68 .37-1.60	.05 .02-.78	.01 .01-.01	.11 .03-.21	.12 .05-.75	6 1-22	3 2-7
.40 .32-.55	.04 .02-.11	.01 .01-.01	.12 .05-.54	.12 .05-.39	4 1-8	2 2-4
.45 .25-1.80	.02 .01-.04	.01 .01-.01	.09 .01-.72	.08 .06-.32	5 1-10	2 1-4
.59 .22-2.50	.03 .01-.05	.01 .01-.01	.21 .01-.37	.13 .07-.32	6 1-12	2 1-4
.56 .23-.96	.03 .01-.05	.01 .01-.01	.21 .08-.31	.13 .08-.33	6 1-18	2 1-5
.70 .34-.99	.04 .02-.08	.01 .01-.01	.34 .15-1.40	.19 .05-.24	16 7-59	5 2-22
-- --	.02 .01-.05	.01 .01-.00	.01 .01-.03	.05 .02-.26	12 5-97	3 2-11
.41 .25-.65	.03 .01-.07	.01 .01-.02	.32 .15-.86	.15 .10-.40	10 4-47	4 2-11
-- --	.03 .03-.04	.01 .01-.01	.08 .03-.15	.07 .04-.28	5 2-12	3 3-4
.73 .71-.76	.06 .03-.17	.01 .01-.01	1.30 .95-1.90	.27 .16-.55	55 31-120	9 3-14
.80 .68-.94	.06 .04-.11	.01 .01-.02	.95 .81-1.10	.15 .03-.43	69 59-93	15 8-22
.18 .04-.37	.02 .01-.06	.01 .01-.01	.03 .01-.07	.04 .02-.26	8 4-17	3 1-11
.23 .09-.55	.04 .01-.55	.01 .01-.01	.03 .01-.07	.04 .02-.31	7 4-12	3 2-11
.26 .15-.47	.04 .01-.26	.01 .01-.01	.03 .01-.59	.04 .02-.19	7 3-23	3 1-6
.25 .13-.41	.03 .01-.20	.01 .01-.01	.03 .01-.09	.03 .02-.23	7	3 1-7
.29 .21-.34	.03 .01-.16	.01 .01-.01	.01 .01-.05	.04 .02-.19		3 1-7