STATE OF WASHINGTON
Dixy Lee Ray
Governor

DEPARTMENT OF ECOLOGY
7272 Cleanwater Lane, Olympia Washington 98504

Publication No. 80-e07
WA-37-1010, -1020, -1030

M E M O R A N D U M
September 4, 1980

To: Clar Pratt, Central Regional Office, DOE

From: Tim Determan, Water & Wastewater Monitoring Section, DOE

Subject: Analyses of Bacteriological Data Generated in Yakima Related to Post-St. Helen's Eruption Activities

## INTRODUCTION

At your request I reviewed water quality data recently collected at a number of points along the Yakima River and associated tributaries and irrigation systems. These data were generated as part of a water quality monitoring study designed and carried out by the Department of Ecology (DOE) Central Regional Office. Field sampling was performed by the DOE Central Region Environmental Quality Section, the City of Yakima, and the Yakima Indian Nation. The Water and Wastewater Monitoring Section out of Olympia assisted with initial sample analysis and provided a degree of technical assistance.

The monitoring effort was initiated to evaluate the effects of a bypass of untreated sewage that occurred at Yakima STP during the aftermath of the first Mt. St. Helens eruption on April 18, 1980. The plant failure has been attributed to hydraulic overloading caused by large quantities of volcanic ash entering the plant via the combined sewer-storm drain system. Water quality in the Yakima River and other receiving waters were measured and an assessment was conducted to measure the effectiveness of corrective actions.

I was instructed to review the data in order to perform statistical analyses and provide advice on sampling strategy to staff members of the DOE Central Regional Office. I chose to concentrate on the bacteriological data because of the wide concern about public health aspects of the Yakima STP bypass. During the analyses, I consulted with Bill Yake and John Bernhardt from the Water and Wastewater Monitoring Section and John Hodgson and Clar Pratt of the Environmental Quality Section of the Central Regional Office.

Figure 1 is a map of the Yakima Valley showing approximate locations of sampling stations. Three hydrologic regimes were monitored: The Yakima River mainstem; three inflowing tributaries (Ahtanum and Wide Hollow creeks and Moxee Drain); and two diversions (the Wapato and Sunnyside Valley Irrigation Districts) Most DOE and City of Yakima stations were activated on May 22, 1980, following commencement of the bypass the same day. The Yakima Indian Nation stations were activated on May 28, 1980 due to the concern of the Yakima Nation Council that untreated effluent from the Yakima city STP was producing water quality problems in the Wapato irrigation system. Their monitoring effort was begun following consultation with DOE Central Regional staff. An additional DOE station was established downstream from the STP discharge point and immediately upstream from the tributary inflow on June 3, 1980. Station descriptions are given in Table 1. Table 2 contains information on sampling frequencies and parametric coverage.

## METHODS

In nature, fecal coliforms are found in clumped distribution and are only rarely homogeneous in streams or other surface waters. This is particularly true close to a suspected point of discharge. As a result, fecal coliform data do not follow a normal distribution.

The non-normality of bacterial data renders parametric statistical methods inappropriate. There are, however, several ways around this problem. An analyst can either use special non-parametric statistical methods, or "transform" the data so that the data more closely approximate a normal distribution. I have used both approaches to analyze the data. The non-parametric Wilkoxon's signed-ranks test was used to study diurnal fluctuations. A modified parametric t-test was used to compare means.

## RESULTS AND DISCUSSION

Analysis of diurnal fluctuations. Samples were initially taken twice daily at approximately 9:00 a.m. and 3:00 p.m. Several assumptions are implicit in this strategy. The first assumption is that a daily fluctuation in fecal coliform levels would be induced in receiving waters due to daily fluctuations in sewage flow associated with a normally operated treatment plant. The second assumption is that daily fluctuations would be traceable downstream. Several problems became evident during analysis of the flow fluctuation data. First, total daily flow from the bypass was not measured and could not be related proportionally to the daily river flow. Second, the bacteriological data from the STP effluent (Station CY2) were reported only as TNTC (too numerous to count) and were statistically unusable. The degree of fluctuation of the discharge, therefore, could not be calculated under prevailing conditions nor could loading characteristics of the plant be determined. Another weakness of the data is the lack of knowledge of river flow travel time which is important in comparing fluctuations at various locations.

Despite the lack of supporting data, the assumption of diurnal fluctuation has been well established in normally operated STP's. For this reason, I performed an analysis of fluctuation significance, recognizing that the utility of the conclusions is limited as a result. In order to evaluate this question, the data for the stream stations and irrigation canals were initially transformed to base-ten logarithms. The difference between a.m. and p.m. values were calculated for each station and date and the differences sorted for testing according to station or groups of stations. I then applied Wilkoxon's Signed-ranks Test for Two Groups (Sokal and Rohlf, 1969).

Table 3 summarizes the results and conclusions. No significant diurnal fluctuation was detected at Moxee Bridge (CY1) upstream from the Yakima STP, the Yakima River above the Wapato Diversion (CY6), or the Sunnyside Valley Irrigation District (DOE 13(9), DOE 14, DOE 15). The "lack" of fluctuation at Station CY6 may be an artifact of the sampling regime. A more correct method would have been to sample a slug of river water as it passed each station downstream. In any case, the use of the assumption of STP coliform fluctuations to identify Yakima STP as a source of downstream pollution is not possible with these data.

Significant fluctuations were noted in the Wapato Irrigation District, particularly at Harrah (DOE 8) and among the Yakima Indian Nation stations (Table 3). The lack of significant fluctuations in the Yakima River above the Wapato Irrigation System and in the Sunnyside Valley district suggests that the causes for these fluctuations are to be found within the Wapato Irrigation District rather than in the Yakima River upstream and appears to be independent of the STP bypass.

A Comparison of Means. Table 4 summarizes the data for the entire period of study. Both the geometric mean and the median appear to be comparable. These data show relatively unpolluted waters entering the city from the northwest via the Yakima River (Station CY1). From here, the Yakima River picked up fecal coliform three orders of magnitude above upstream levels. Station DOE (3) located above the tributaries also showed levels significantly higher than the tributaries themselves. This suggests that the tributaries contributed an insignificant level of contamination to the Yakima River during the episode.

The high concentrations observed at Station DOE (3) underwent a considerable reduction before reaching the diversion canals. The concentration of bacteria in the Yakima River at the Wapato Diversion (Station CY6) was one tenth the level found above the tributaries. There appeared to be little difference in the levels of bacteria entering the Wapato and Sunnyside irrigation systems.

A self-purification process or diluting effect was evident further downstream. The Yakima River at Prosser complied with the fecal coliform standards in terms of median value. However, since one of seven samples exceeded 400 FC per 100 ml for Class B waters, complete compliance was not attained.

Special note should be taken of the increased levels of FC in the Yakima River at the Toppenish-Zillah Road. This elevated level may be caused by a highly localized source and is worthy of additional investigation.

To evaluate the accuracy of my preliminary conclusions, I performed a parametric test of equality of means on a number of groups of transformed data. These analyses are shown in Table 5. I applied a method in which unequal variance is assumed (Sokal and Rholf, 1969).

First, I compared Yakima River Station CY1 (upstream from Moxee Bridge) with historical data (December 1970 to September 1975) from nearby DOE ambient station 37A210. There was no difference. I also compared Wide Hollow Station DOE 3(4) and nearby ambient station 37E070 sampled between December, 1970 and April, 1974. The ambient data for both sources were for all months. Comparisons between these two stations and their ambient analogs showed no significant differences. Ambient station 37A190 on the Yakima River at Parker was sampled monthly from October, 1970 to the present during all months. I compared data from this station with Station CY6 at the Wapato Diversion for all months and for the months of the episode only. These means were significantly different both for the entire record and for the months of the episode only (May, June, and July). Since there is no evidence that pollutant loads in the tributaries have increased significantly, these current high Yakima River levels are likely to be due to the STP discharge.

Additional comparisons were made between some other individual stations or systems. I found no significant difference between fecal coliform levels at Station CY6 (Yakima River at the Diversion), and Station DOE 7 (Wapato Canal at Lateral C Road) or between levels at Station DOE 7 and Station DOE 13(9). This indicates that similar levels of fecal coliforms entered each irrigation system from the Yakima River. Moreover, the DOE stations within the Wapato Irrigation District carried the same level of pollutants as the stations in the Sunnyside valley system. These levels were comparable to those in the tributaries. Thus, the evidence suggests that the irrigation systems and the tributaries were polluted to the same degree.

I also tested for equality of means between pooled DOE stations and Yakima Indian Nation stations. The means turned out to be significantly different. In addition, mean fecal coliform values at Station DOE 7 tested lower than those at Station YN7, the closest neighbor. According to John Hodgson, Snokist, Inc. laboratories have been sterilizing sampling bottles and performing analyses for both agencies during most of the sampling effort. The difference in results may be due to either differences between field sampling methods or among station locations.

Fecal Coliform: Fecal Strep Ratios. Several authors have reported the utility of FC:FS ratios in identification of the source of animal wastes as human or non-human (Geldrich and Kenner, 1969). The species of fecal streptococci in humans differs from those of livestock. An FC:FS ratio of less than 0.7 may be indicative of contamination from domesticated farm animals, while a ratio exceeding 4 indicates a human source. However, because of unequal rates of bacterial die-off, FC:FS ratios change in such a way that the ratio is valid only during the initial 24-hour period after release. Feachem (1975) made use of the unequal die-off rates to show that if a series of FC:FS ratios are obtained over time, an estimate of age of the fecal contaminant is possible. A predominantly human source would have a high ratio initially >4 which would decrease, whereas a non-human source should exhibit an initially low ratio <0.7 which would increase. This method is useful, however, only if the waste stream receives no additional wastes over the period of study. The conformity of the ratios to expected values in a body of water receiving wastes from mixed human and non-human sources would be difficult to predict. The value would be between 0.7 and 4.0 depending upon the relative population proportions.

Similarly, over time, a mixed source would not fit the predicted pattern because the human component of the ratio would decrease while the non-human component would increase. In any case, the interpretation of FC:FC ratios obtained under field conditions would require extensive knowledge of numerous other factors such as land-use, population distribution, flow rates, and hydrologic characteristics of the area under study.

FC:FS ratios were obtained within the Wapato Irrigation District by the Yakima Indian Nation at the suggestion of the DOE Central Regional Office. These ratios were to be used to evaluate the relative importance of the Yakima STP (a human source) as compared to internal factors (mixed human and non-human sources) affecting water quality conditions in the Wapato irrigation system. A brief statistical summary is contained in Table 6. (The data show wide variation for all stations.) Yakima Nation Stations YN1 and YN2 show low mean values. We could conclude that the primary source of contamination was fresh livestock or aged human waste. On the other hand, the remaining stations show values exceeding 4.0, attributable to either fresh human waste or aged animal waste. Any further analysis must await further supporting information. Unfortunately, we have no ratios from other components of the Yakima River system, such as the tributaries, the upstream Station YN1, or the Sunnyside Valley canal, nor do we have ratios from the Yakima STP. Our ability to draw comparisons and evaluations is therefore extremely limited.

RECOMMENDATIONS

According to Central Regional Office sources, the Yakima STP returned to primary treatment on May 25, 1980. It is anticipated that full secondary treatment will be implemented by July 23, 1980. The following alterations to the sampling schedule have been submitted in light of my data analysis:

1. As I stated earlier, no valid bacteriological data have been reported for the STP effluent (Station CY2). Although at this late date it is probably irrelevant, the analyst should dilute further STP samples in order to get a specific count. This is important in order to quantify the effects of mixing, dilution, and die-off between Stations CY2 and 3. For past data, an estimate of the lower limit of the count may be obtained by dividing the maximum suggested number of colonies (60 per plate; APHA, 1975) by the dilution factor used for each sample. This information should be found in the laboratory records of the analyst.

2. The list of stations to be sampled by DOE and the City of Yakima should be reduced by dropping Station DOE 11(8). The data obtained from Station CY6 should be sufficient to assess downstream effects.

3. The Wapato Canal at Harrah and Yakima River near the Toppenish-Zillah Road should be subjected to closer scrutiny to locate the causes of the problems discussed previously. This work would be in the nature of a sanitary survey.

4. The difference between the results obtained by DOE and the Yakima Indian Nation at the Wapato Irrigation District should be evaluated. A single station should be selected and several large batch samples split between the two agencies for analysis.

5. All sampling should cease after an analyses of data obtained during a two-week period following return of the Yakima STP to normal operating conditions.

6. Our experience during this episode has shown a number of weaknesses in the study. It is recommended that a meeting be set up between the Central Regional Office and our section to discuss these problems and devise improved response procedures should Mount St. Helens erupt again.

TD:cp

Attachments

## REFERENCES CITED


APHA, 1975. *Standard Methods for the Examination of Water and Wastewater.* 14th Ed., American Public Health Assn. 1193 pp.

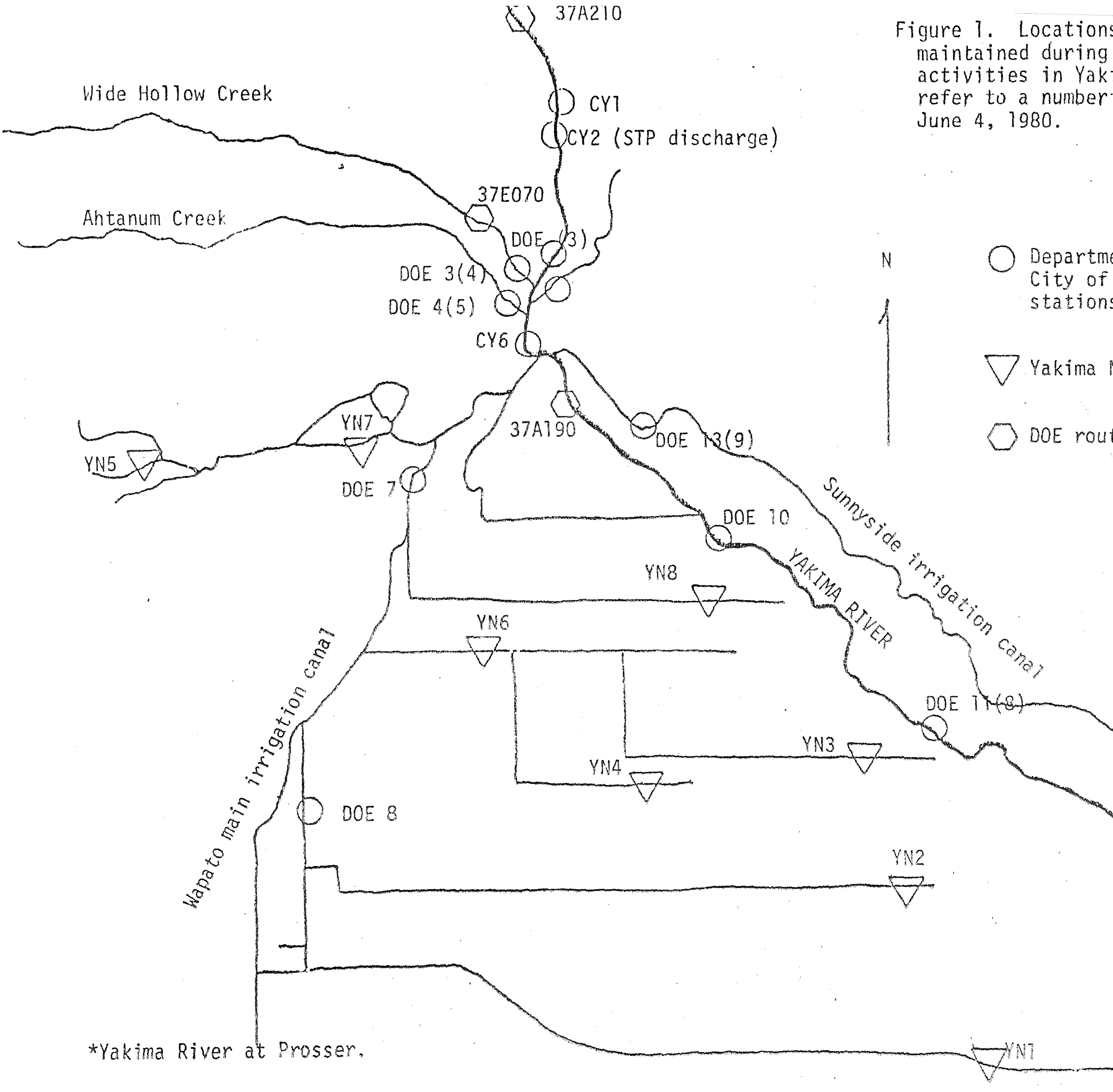
Dept. of Ecology, 1980. Laws and regulations; water pollution. State of Washington.

Feachem, R., 1975. An improved role for faecal coliform to faecal streptococci ratios in the differentiation between human and non-human pollution sources. *Water Research 9*, 689-690 pp.

Geldreich, E.E. and B. A. Kenner, 1969. Concepts of fecal streptococci in stream pollution, *J.W.P.C.F. 47:8*, R.336-R.352.

Rohlf, J.F. and R.R. Sokal, 1969. *Statistical Tables*, W.H. Freeman and Co., San Francisco, CA, 253 pp.

Sokal, R.F. and J.F. Sokal, 1969. *Biometry*, Freeman and Co., San Francisco, CA, 776 pp.




*Yakima River at Prosser.

Figure 1. Locations
maintained during
activities in Yak
refer to a number
June 4, 1980.

Table 1. Station numbers and locations sampled during post-eruption activities in the Yakima Valley. Parenthesized numbers refer to numbering system adopted June 4, 1980. Stations discontinued on that date are indicated by an asterisk.

| Station Number | Station Description | Collected By |
|---|---|---|
| CY1 | Moxee Bridge, Yakima River | City of Yakima |
| CY2 | Yakima STP effluent | City of Yakima |
| DOE (3) | Yakima River above tributary streams winding along I-82 | Dept. of Ecology |
| DOE 3(4) | Wide Hollow Creek at Highway 97 bridge | Dept. of Ecology |
| DOE 4(5) | Ahtanum Creek at Highway 97 bridge | Dept. of Ecology |
| DOE 5(10) | Moxee Drain near USGS gaging station - Thorp Road | Dept. of Ecology |
| CY6 | Yakima River at Wapato Canal diversion | City of Yakima |
| DOE 7 | Wapato Canal at lateral C | Dept. of Ecology |
| DOE 8* | Wapato Canal at Harrah | Dept. of Ecology |
| DOE 10* | Yakima River at Donald Road bridge | Dept. of Ecology |
| DOE 11(8) | Yakima River at Toppenish-Zillah bridge | Dept. of Ecology |
| DOE 12* | Yakima River at Prosser | Dept. of Ecology |
| DOE 13(9) | Sunnyside Canal at SR-12 | Dept. of Ecology |
| DOE 14* | Sunnyside Canal at Zillah Loop | Dept. of Ecology |
| DOE 15* | Sunnyside Canal at Thacker | Dept. of Ecology |

Wapato Irrigation District (Yakima Indian Nation); sampled by Bryon Kent

| | |
|---|---|
| YN1 | Marion Drain - Marion Drain Road east of Highway 97 |
| YN2 | Upper lateral canal - Larue Road and Highway 97 |
| YN3 | Lateral canal - Besker and Branch roads |
| YN4 | Lateral canal - Campbell Road north of McDonald Road |
| YN5 | Lateral Highline canal - Brownstown Road in Section 31 |
| YN6 | Lateral canal - Lateral B and Evans Road |
| YN7 | Kays Road distribution ditch - between Cor and Riggs roads on Kays Road |
| YN8 | Drain - west side of Donald Road bridge |

Table 2. Sampling frequencies and parametric coverage at stations sampled during post-eruption activities in the Yakima Valley.

| Parameters | Sampling Frequency |
|---|---|
| **May 22 - June 6** | |
| 1. COD; BOD; D.O.; pH; SS at all Yakima River mainstem stations | once/day; twice/week |
| 2. Fecal coliform at all stations | twice day; 7 days/wk |
| 3. Fecal streptococci at Wapato Irrigation District stations | twice/day; 7 days/wk |
| **June 7 - June 20** | |
| 1. COD; BOD; D.O.; pH; SS at all Yakima River mainstem stations | once/day; twice wk |
| 2. Chlorine residual, Yakima STP effluent | once/day; twice/wk |
| 3. Fecal coliform at all systems | once/day; twice/wk |
| 4. Fecal streptococci at Wapato Irrigation District stations | once/day; twice/wk |
| **June 23 - July 14** | |
| 1. COD; BOD; D.O.; pH; SS at all Yakima River mainstem stations | once/day; once/wk |
| 2. Chlorine residual, Yakima STP effluent | once/day; once/wk |
| 3. Fecal coliform at all stations | once/day; once/wk |
| 4. Fecal streptococci at Wapato Irrigation District stations | once/day; once/wk |
| **July 14 - July 31** | |
| 1. COD; BOD; D.O.; pH; SS at all Yakima River mainstem stations | once/day; twice/wk |
| 2. Chlorine residual, Yakima STP effluent | once/day; twice/wk |
| 3. Fecal coliform at all stations | once/day; twice/wk |
| 4. Fecal streptococci at Wapato Irrigation District stations | once/day; twice/wk |

Table 3. Summary of results and conclusions of tests to determine the signficance of diurnal fluct coliform levels within the Yakima River. Samples were taken during post-St. Helen's erup Wilkoxon's signed-ranks two-tailed test was used. Significance was accepted at the 5% le

| Location [Station] | n | Σ+ | Σ- | Calculated Rank Sum $T_s$ | Wilkoxon Rank Sum $T_{\alpha[\infty]}$[1] |
|---|---|---|---|---|---|
| Moxee Bridge [CY1] | 11 | 32.5 | 33.5 | 32.5 | 10, 11 |
| Tributaries [DOE 3(4), DOE 4(5)] | 20 | 26.0 | 184.0 | 26.0 | 52, 53 |
| Moxee Drain [DOE 5(10)] | 10 | 7.0 | 48.0 | 7.0 | 8, 9 |
| Yakima River (Wapato Diversion) [CY6] | 12 | 59.0 | 19.0 | 19.0 | 13, 14 |
| Wapato Irrigation District [DOE 7, DOE 8] | 22 | 31.0 | 222.0 | 31.0 | 65, 66 |
| Wapato Canal at Lateral C [DOE 7] | 12 | 23.0 | 55.0 | 23.0 | 13, 14 |
| Wapato Canal at Harrah [DOE 8] | 10 | 0.0 | 55.0 | 0.0 | 8, 9 |
| Wapato Irrigation District (Yakima Nation) [YN1-YN8] | 48 | 258.0 | 911.0 | 258.0 | 396, 397 |
| Sunnyside Valley Irrigation District [DOE 13(9), DOE 14, DOE 15] | 34 | 362.0 | 233.0 | 233.0 | 162, 163 |

1/Taken from Rohlf and Sokal, 1969 (Table DD)

Table 4. Summary of bacteriology data (FC/100 ml) obtained from May 22, 1980 to June 16, 1980. numbers refer to a revised numbering system adopted on June 4, 1980.

| Station Number | Station Description | Median | Geometric mean [± antilog log S] | | n | Water Classif |
|---|---|---|---|---|---|---|
| **I Yakima River System** | | | | | | |
| CY1 | Moxee bridge | 68 | 58 | [23-123] | 24 | |
| DOE (3) | Above tributary streams | 11,650 | 10,965 | [7275-16520] | 4 | |
| CY6 | Above Wapato Canal diversion | 1,136 | 1,072 | [295-3890] | 29 | |
| DOE 10 | Donald Road | 492 | 417 | [155-1122] | 14 | |
| DOE 11(8) | Toppenish-Zillah Road | 1,800 | 871 | [224-3548] | 15 | |
| DOE 12 | Prosser | 186 | 190 | [115-316] | 7 | |
| **II Tributaries and Drains** | | | | | | |
| DOE 3(4) | Wide Hollow Creek | 1,073 | 1,230 | [759-1995] | 25 | Undes |
| DOE 4(5) | Ahtanum Creek | 500 | 489 | [295-813] | 25 | Undes |
| DOE 5(10) | Moxee Drain | 710 | 776 | [447-1349] | 24 | Undes |
| **III Wapato Irrigation District** | | | | | | |
| DOE 7 | Lateral C Road | 680 | 675 | [257-1778] | 28 | Undes |
| DOE 8 | Near Harrah | 670 | 1,122 | [275-4571] | 21 | Undes |
| **IV Sunnyside Valley Irrigation District** | | | | | | |
| DOE 13(9) | SR-12 | 705 | 708 | [263-1905] | 28 | Undes |
| DOE 14 | Zillah Loop Road | 1,855 | 1,585 | [631-3981] | 24 | Undes |
| DOE 15 | Canal at Thacker | 1,291 | 1,122 | [575-2188] | 21 | Undes |

1/ The Yakima River is classified as Class A upstream from the Sunnyside Dam (near Parker) and Cla point. Class A waters are not to exceed a median value (M) of 100 FC per 100 ml and 10% of all 200 FC per 100 ml. Class B waters are not to exceed a median value of 200 FC per 100 ml, while samples are to exceed 400 FC per 100 ml. All undesignated surface waters within the state are (Washington State Water Quality Standards, December 17, 1977).

Table 5. A summary of tests of equality of means on Yakima River fecal coliform data, using a method in which variancies are assumed to be unequal (Rholf and Sokal, 1969). Data were transformed using base-ten logarithms. Significance is at the 5% level.

| Station or System | $\bar{Y}$ | s | n | $t_{.05}$ 1/ | $t'_s$ | Conclusion |
|---|---|---|---|---|---|---|
| **A. Comparisons with historical record** | | | | | | |
| 1. Ambient Station 37A210 vs. CY1 (Moxee Bridge) | | | | | | |
| 37A210 | 0.81 | 3.07 | 26 | 2.062 | 1.568 | No significant difference |
| CY1 | 1.76 | 0.33 | 24 | | | |
| 2. Ambient Station 37E070 vs. DOE 3(4) (Wide Hollow Creek) | | | | | | |
| 37E070 | 2.61 | 0.63 | 4 | 2.064 | 1.514 | No significant difference |
| DOE 3(4) | 3.09 | 0.21 | 25 | | | |
| 3. Ambient Station 37A190 vs. CY6 (Yakima River at Wapato Diversion) | | | | | | |
| 37A190 | 1.55 | 1.57 | 86 | 1.999 | 7.41 | Significantly different |
| CY6 | 3.03 | 0.56 | 28 | | | |
| 4. Ambient Station 37A190 (May through July) vs. CY6 (Yakima River at Wapato Diversion) | | | | | | |
| 37A190 (May-July) | 1.87 | 0.92 | 23 | 2.067 | 5.29 | Significantly different |
| CY6 | 3.03 | 0.56 | 28 | | | |
| **B. Comparisons between stations or systems** | | | | | | |
| 1. CY6 (Yakima River at Diversion) vs. DOE 7 (WID at Lateral C Road) | | | | | | |
| CY6 | 3.03 | 0.56 | 28 | 2.052 | 1.52 | No significant difference |
| DOE 7 | 2.83 | 0.42 | 28 | | | |
| 2. DOE 7 (WID at Lateral C Road) vs. DOE 13(9) (SVID at SR-12) | | | | | | |
| DOE 7 | 2.83 | 0.42 | 28 | 2.052 | 0.176 | No significant difference |
| DOE 13(9) | 2.85 | 0.43 | 28 | | | |
| 3. Wapato Irrigation District (DOE Stations) vs. Sunnyside Valley Irrigation District | | | | | | |
| WID | 2.92 | 0.52 | 49 | 2.002 | 1.13 | No significant difference |
| SVID | 3.02 | 0.41 | 73 | | | |
| 4. Wapato Irrigation District (DOE Stations) vs. Tributaries (Stas. 3(4), 4(5), 5(10)) | | | | | | |
| WID | 2.92 | 0.52 | 49 | 2.000 | 0.863 | No significant difference |
| Tributaries | 2.89 | 0.28 | 74 | | | |
| 5. Wapato Irrigation District (DOE) vs. Wapato Irrigation District (Yakima Nation) | | | | | | |
| WID (DOE) | 2.92 | 0.52 | 49 | 1.975 | 2.818 | Significantly different |
| WID (Yakima) | 3.16 | 0.54 | 168 | | | |
| 6. WID (Lateral C Road) vs. WID (Kays Road) | | | | | | |
| WID (Lateral C) | 2.83 | 0.42 | 28 | 2.086 | 3.56 | Significantly different |
| WID (Kays) | 3.24 | 0.38 | 21 | | | |

1/ Taken from Rohlf and Sokal, 1969.

Table 6. FC:FS ratios obtained from eight stations within the Wapato irrigation district. Samples were taken by the Yakima Indian Nation.

| Station Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | All Stations |
|---|---|---|---|---|---|---|---|---|---|
| Mean ($\bar{x}$) | 1.06 | 1.89 | 4.94 | 7.99 | 5.17 | 6.94 | 5.30 | 6.47 | 4.97 |
| Standard Deviation (s) | 1.37 | 0.85 | 3.29 | 5.34 | 4.10 | 4.03 | 2.91 | 4.65 | 3.32 |
| Number of Units (n) | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 168 |