A STUDY OF FECAL COLIFORM AND FECAL STREPTOCOCCUS DENSITIES IN FIVE BRITISH COLUMBIA RIVERS*

Submitted to:

Water Quality Branch
Inland Waters Directorate
Environment Canada
502-1001 West Pender Street
Vancouver, BC

Submitted By:

M. Ferg
Vancouver, BC
August 1980

* This report presents the results of a student project carried out in the summer of 1979; the report was prepared by the author under contract #DSS 06SB, KL 374-0-00-22.

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Introduction

The use of biological parameters is accepted as an integral part of an in-depth water quality investigation of a natural waterway. These parameters often give support to the more rigorously quantitative chemical variables being employed. In addition, certain groups and/or species from the algal, fish, macrobenthic and microbial communities are especially sensitive to variations in water quality conditions.

In preliminary surveys, microbiological data are especially useful because they are readily obtained and relatively simple to interpret. As a result, a reasonably quick evaluation of the potential of the water for public use can be made and proposals for further study can be formulated.

a) Indicators of Sanitary Water Quality

The bacterial groups investigated in this project are unique in relation to other biological indicators presently in use because they are direct, not secondary, measures of contamination. Geldreich (1970) has stated that, "ideally recreational water quality indicators are microorganisms or chemicals in the water that can be quantitatively related to potential health hazards resulting from recreational use therein". Because they are indigenous components of fecal pollution, the two groups being studied, fecal coliforms and fecal streptococci, closely fit the stated ideal indicator and are also able to specify a source of nutrients to a greater degree than

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other organisms. For example, other organisms such as aquatic oligochaetes and periphytic diatoms and algae are often good indicators of nutrient loading in a water system. However, they are not valuable in specifying that the nutrient input was from fecal material.

The rationale for the use of fecal coliforms as the indicator of choice over a more specific indicator such as Eschesichia coli or a more generalized indicator such as total coliforms is well founded. Geldreich (1976) has found that "fecal coliforms represent over 96% of the coliforms derived from human feces and 93 to 98% of those discharged in fecal excrement from other warm blooded animals including livestock, poultry, cats, dogs and rodents". As a result, fecal coliforms indicate fecal contamination whereas total coliforms may include non-fecal bacteria and may therefore mask true concentrations and sources of contamination. It would also be unrealistic to use E. coli alone because "restriction of the fecal coliform group for the detection of E. coli may ignore fecal discharges from 5 to 7% of those individual human or other warm-blooded animals where intestinal flora are temporarily void of E. coli, but still contain other fecal coliforms of differing biochemical reactions" (Geldreich 1976). Fecal coliforms form the

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middle ground between the two extremes, and as such were the indicators of choice for this study.

The source of fecal contamination can then be further isolated by examining the relative concentrations of the two types of fecal bacteria being studied - fecal coliforms and fecal streptococci. Although fecal streptococci are present in human feces they are present in much larger concentrations in other warm-blooded animals. The ratio of fecal coliforms to fecal streptococci, therefore, may express the relative importance of human and non-human fecal contamination in the water. It has been shown that "a FC : FS ratio of less than 0.7 usually indicates contamination from domesticated farm animals, whereas a ratio greater than 4 indicates a human source" (Feachem 1975).

The use of coliform counts in the analysis of sanitary water quality may not necessarily provide a valid estimate of health risks. Smith and Twedt (1971) have stated that "little information is available on the quantitative relationship between indicator organisms, such as the coliforms and streptococci, and pathogens such as Salmonella. Such information is basic to the bacteriological indicator concept". Bacteria may also be unrepresentative of health threats from viruses, pathogenic amoebae, and hookworm larvae (Geldreich 1972).

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Ideally, the type of indicator chosen should be appropriate to the expected contamination source, and epidemiological analysis is necessary to determine the local correlation of indicator and pathogen. The proportionate occurrence of indicator and pathogen will also vary according to population size. The smaller the population size, the more variable the mathematical relationship, if such can be determined, between pathogen and indicator.

b) Microbiological Standards

The validity of the application of generalized microbiological standards to specific water uses has been questioned, usually on the basis of the lack of epidemiological data. The U.S. National Academy of Science has concluded that "no specific recommendation is made concerning the presence or concentrations of microorganisms in bathing water because of the paucity of valid epidemiological data" (U.S.E.P.A., 1972). However, a logarithmic mean value of 200 fecal coliforms per 100 ml is frequently applied as a bathing beach standard (U.S. Dept. Int., 1968). The most likely use relevant to sanitary water quality for the rivers investigated in this study is either "non-contact" recreation, or irrigation. The suggested criterion for each of these uses is 1000 fecal coliforms/100 ml (U.S. Dept. Int., 1968). It should be emphasized that such figures are arbitrary and not based on epidemiological evidence.

Water samples from five British Columbia rivers were collected and analyzed in the summer of 1979 to determine their concentrations of fecal coliforms and fecal streptococci. The five rivers chosen for study included the Skeena, Columbia, Similkameen, Sumas and Okanagan Rivers. The particular rivers chosen, with the exception of the Skeena, all cross the Canada - USA international boundary and as such come under the mandate of the Water Quality Branch. The Skeena River data was collected because of the dearth of information on sanitary water quality, with the exception of the area immediately surrounding the city of Prince Rupert, B. C. (Hoos 1975). In addition, it was thought that such experience would be useful in planning future studies such as the Stikine River project, where the impact of upstream inputs on the Alaskan estuary would be assessed.

Published bacteriological data on the other rivers selected is also scanty.

The Water Quality Branch undertook a preliminary survey of bacterial concentrations in these rivers in order to identify potential problem areas and decide whether more extensive work would be necessary.

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Methods

Sampling locations were selected according to the following criteria:

i) Proximity to Canada - USA boundary

ii) Apparent efficiency of mixing in stream (Rodina 1972)

Point (ii) is quite critical. Bank sampling or surface sampling from a boat was done and depth sampling for bacteria was found to be impractical in the scope of this study.

a) Sampling locations and methods

Sampling methods varied according to the logistical variables encountered *in situ*.

i) Sumas River

A preliminary reconnaisance of the river was made on May 11, 1979 near the Huntingdon border station south of Abbotsford, B. C. The bridge across the river at this point houses the Water Survey of Canada depth gauge for the Sumas River and is located within a few metres of the Canada - USA border. The river was shallow and uniform enough at this point for cross

sectional sampling to be done by hand with only chestwaders required. Because of these favourable conditions the cross section chosen was approximately one metre upstream (south) of the bridge. Details of the cross section can be found in Appendix I.

Sampling was done on May 22, 23 and 24 and also June 19, 20 and 21.

An uncapped sterile 250 ml bottle was clamped onto the end of a wooden dowel onshore and samples were taken by wading, taking care not to resuspend loose sediment and possibly contaminate the sample. To guard against contamination the sample bottle was held upstream from the experimenter and well under the surface of the water to prevent surface debris from entering the bottle. After collection the samples were aseptically recapped and placed on ice. In addition, conductivity and pH measurements were made in situ before returning to the laboratory.

Samples were analyzed within several hours of collection, upon return to the Water Quality Branch Biology Laboratory in North Vancouver.

ii) Columbia River

Cross sectional data were obtained from 5 points equidistant from each other in a well-mixed portion of the river near Waneta, B.C., immediately upstream of the confluence of the Pend d'Oreille River with the Columbia River. The cross section is within one mile of the Canada - USA border. Sampling was done from a boat with the same hand held apparatus as was used on the Sumas River.

Depth samples were also attempted but found to be impractical because of the specific limitations of the plastic bag sampler, which was designed for oceanographic use. However, the sampler in a modified form could easily be adapted for use in flowing waters.

Samples for the Columbia River were collected June 5, 6 and 7, 1979 and analyzed immediately at a temporary laboratory in Trail, B. C.

iii) Okanagan River

Samples were obtained on July 4 and 5, 1979 from a well mixed portion of the Okanagan River a few meters below the Road #22

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bridge, south of Oliver, B. C. Sample collection was by wading and using the hand held sampling device about 5 m off the right bank of the river, with all samples being collected from the single station. Samples were then analyzed along with the Similkameen River samples at a temporary laboratory in Oliver.

iv) Similkameen River

As with the Okanagan River, samples were obtained on July 4 and 5, 1979, at a location close to Highway #3. Samples were taken with the hand held sampling device from the left bank of the river, from boulders under the bridge which is easily seen from Highway #3, 27 km northwest of Osoyoos. A single station was used and the samples were analyzed within a few hours, in conjunction with the Okanagan River samples.

v) Skeena River

Sampling was done in replicate on July 27 and 28 at 3 cross sections chosen to represent the major water inputs to the

Skeena estuary. The Aberdeen cross section was located on the Skeena River between Aberdeen Point and Windsor Point, approximately 8 km upstream of the confluence with the Ecstall River. The Ecstall cross section was located on the Ecstall River approximately 6 km upstream of the confluence with the Skeena River at Port Essington. These two sampling stations represent the two major freshwater inputs to the Skeena estuary.

The Skeena River was also sampled on a cross section below the confluence with the Ecstall River, on a line perpendicular to water flow extending from Veitch Point across the river.

Sampling on the Skeena and Ecstall rivers was done at 1/4, 1/2, and 3/4 of the distance across the river for each of the 3 cross sections. Samples were obtained in a similar way to those from the Columbia River, from a launch based on the main research vessel, the Pandora II, which was anchored near Veitch Point. Laboratory facilities were located on the Pandora II and samples were analyzed within a few hours of collection. A general comment regarding sampling procedure which may be useful in further studies is in order. In a study of bacterial

concentrations in the Fraser River, water samples varied greatly in concentration with respect to surface or subsurface sampling. "surface concentrations were, on the average, several times larger than subsurface concentrations" (Rusch 1972). It is probable that higher surface concentrations are due to surface debris rather than free bacteria in the water; therefore, great care should be taken to not take samples from the surface as these may not represent the quality of water throughout the water column.

b) Methods of Analysis

Two methods of analysis were used for fecal coliform determination, the membrane filter (MF) technique and the most probable number (MPN) technique using the multiple tube fermentation test. Procedures for the use of these methods were followed as outlined in "Standard Methods for the Examination of Water and Wastewater, 14th edition" (APHA 1975). Although both methods of analysis are widely used the MF procedure is generally acknowledged to be the more accurate of the two tests, presumably because it is based on real concentration estimates whereas the MPN technique depends on probability estimates. In fact, it has been stated over 20 years ago that "the lack of precision of MPN estimates of bacterial densities is generally

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recognized - at least by those who perform the tests" (Woodward 1957), yet it is still in use.

The MF technique was therefore employed when possible but it was limited to areas of low turbidity since "coliforms trapped in turbidity particles may not produce gas in the presumptive medium unless released by vigorous sample agitation" (USEPA 1978). In such highly turbid waters the MPN technique is the alternative (Geldreich 1967). For analysis of fecal streptococci, only the MF technique was used.

The MPN procedure was used as well as the MF technique on the Skeena river because of the possibility of high sediment loads during this study. This method is, however, inconvenient because of preparation and analytical time required, expense, and the large amount of apparatus required. The accuracy of the MPN test is also questionable, as previously mentioned.

c) Biochemical Analysis

The culture plates used in MF procedures were retained for biochemical confirmation. Fecal coliforms were confirmed by IMViC testing and

fecal streptococci were tested for catalase activity, growth at 45 C, and growth in the presence of 40% bile. The methods used for biochemical analysis were obtained from Standard Methods for the Examination of Water and Wastewater (1979) and The EPA Microbiological Manual (1978) for fecal coliforms and fecal streptococci, respectively. The results from confirmation tests indicated that no adjustments for atypical colonies needed to be made to the original plate counts.

Results and Discussion

Surveys of sanitary water quality are carried out with two goals in mind. The first goal is to assess current water quality by quick and inexpensive means. The second goal is to attempt to pinpoint bacterial pollutant sources in order to negate or minimize the input from these sources. The first goal is accomplished by comparing measured bacterial concentrations to established standards. To accomplish the second goal one must evaluate the mechanisms of input to the water resource.

There are three major sources of bacterial input to rivers and streams (Kunkle 1970). These are: land surfaces, presumably from surface runoff or rainfall which finds its way to adjacent streams; the channels of

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rivers or streams, since both channel banks and bottom can retain and release bacterial indicators with increased stream discharge; and direct inputs such as sewers in urban areas, septic tanks and input from farm animals in rural areas.

In order to determine the source of indicator bacteria, one must differentiate between animal and human sources, and/or also evaluate the characteristics of the watershed near the sampling station. There are certain specific criticisms of the validity of the FC : FS ratio. One basic criticism from a statistical viewpoint involves the interpretive use of FC : FS ratios in remote areas. Counts of indicator bacteria are likely to be very low, and occasional high values many result in distorted FC : FS ratios. Additionally, the FC : FS ratio is considered valid only in the first 24 hours after release from the source of fecal contamination, because of different death rates of coliforms and streptococci (Geldreich and Kenner, 1969). These problems must be overcome before the FC : FS ratio is useful for anything more than qualitative comparisons.

a) Skeena River

The problem of low bacterial densities distorting the FC : FS ratios

is of particular significance in the Skeena River. Concentrations of fecal streptococci were less than 20 per 100 ml and concentrations of fecal coliforms by the MF technique were less than 30/100 ml (Table I). Counts by the MF technique may have been low estimates of fecal coliform density because of the ability of sediments to suppress colony formation. Because of the low concentrations of indicator organisms, FC : FS ratios were not calculated.

Fecal coliform concentrations by the MPN technique in the Skeena and Ecstall rivers were below 100 per 100 ml, with the exception of the Aberdeen cross section which averaged 110 per 100 ml. These values fall within the currently accepted bathing beach standard of 200/100 ml. The highest fecal coliform numbers occurred on the Skeena River above the confluence with the Ecstall River, and the lowest values occurred on the Ecstall River.

Sources of fecal coliform bacteria in the Skeena may be wildlife, direct inputs from upstream communities such as Terrace, B. C., resuspension of sediments during freshet, and discharges from fishing boats. Although fecal coliform values were low in the estuary, winter values may be higher because of lower flows and greater survival of fecal coliforms at low water temperatures (Davenport et al, 1976).

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b) Columbia River

Because of its remote character the Skeena River was not expected to have concentrations of fecal bacteria high enough to pose a water quality problem. The Columbia River, however, with numerous communities along its banks was expected, a priori, to have measurable concentrations of fecal coliforms from human sources. As Table 1 demonstrates, arithmetic means of both fecal coliforms and fecal streptococci were less than 20 per 100 ml. During this limited sampling survey, it appears that the Columbia river did not have a sanitary water quality problem, indicating extensive dilution and/or efficient disinfection of any sewage treatment plant effluents located upstream.

Sources of Fecal Pollution in Rural Areas

The three remaining rivers studied, the Okanagan, Similkameen and Sumas, are particularly interesting because the land use in each of their watersheds is predominantly agricultural, although the Okanagan River has a significant urban component. As a result, the presence of farm animals and the use of organic fertilizer may affect the

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interpretation of fecal coliform counts unless the FC : FS ratio is used. Fecal contamination would probably be largely introduced through surface runoff, wading cattle (which were in evidence on the Sumas) or resuspension of bottom sediment. Samples from streams in other watersheds where grazing and manure spreading were common indicated that upland contributions of bacteria to the streams were minor (and) much less important than contributions from activities near the channels, for example, barns near streams (Kunkle 1970).

If the animal waste is well away from the stream the bacteria will not likely reach it via groundwater percolation, since most of the bacteria will be trapped in the soil. This retention of bacteria is dependent on soil characteristics with more permeable soil allowing more bacteria through to the groundwater. In the case of permeable soil, Evans and Owens (1972) have stated "it is possible that there may be a relationship between the rate of pick up of suspended sediment and the rate at which bacterial cells are washed out of soil by percolating water". Geldreich (1970) has found that such soils "have fecal coliform populations forming 82.9% of the total coliform population". It is likely that groundwater contributions of bacteria would be more significant in winter because of the generally increased role of groundwater in supplying water flow at that time of year.

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In studying the effects of rural runoff in increasing pollutant levels in streams, Weidner et al (1969) found that significantly higher levels of fecal streptococci than fecal coliforms occurred in stormwater runoff from rural areas. If there is a significant runoff contribution this should be apparent in the FC : FS ratio, which would be low and further lowered after a rainfall. In addition, enteric microbial populations in the stream itself can be expected to increase following a rainfall. This increase may occur because of the possible overflow of sewer systems, increased movement of groundwater associated with septic tanks and other contaminated soils, and increased surface runoff which washes superficially deposited animal waste into receiving waters.

A third possible source of bacterial contamination is the resuspension of sedimemts from the channel bottom and banks. This mode of transport is more unlikely to occur in the Similkameen than the Sumas or Okanagan rivers, because of the rather stable gravel and boulder bottom.

c) Similkameen River

The area surrounding the Similkameen river consists of ranches, farms with pasture, and cattle rangeland, with a few small towns

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interspersed along its banks. The most likely source of bacterial input for the Similkameen river is surface runoff; barns and grazing cattle are generally well away from the banks, thereby minimizing the transport of bacteria via groundwater over such distances. Surface transport of animal fecal material to the river via drainage ditches and small streams would possibly occur. Direct input by sewer systems would probably be minimal because of the relatively small human population in the Similkameen watershed.

As a result, one would expect the Similkameen river to have minimal concentrations of fecal bacteria and those detected to be of animal origin. As expected, negligible concentrations of fecal indicator bacteria were detected, with all plates having a density of less than 20 colonies per 100 ml (Table 1). This indicates a rather pristine river from a microbiological point of view. The counts are too low to interpret regarding farm animal versus human sources of fecal bacteria.

d) Okanagan River

The Okanagan River is located in the heart of the most extensive tree fruit growing area in Canada. The Okanagan river is also part of the

water system that attracts thousands of summer visitors to its sandy beaches and warm water each summer. The agricultural and recreational use of this water resource is extensive and it is important that the Okanagan river water be of high quality.

Concentrations of fecal indicator bacteria in the Okanagan river were found to be low but measurable. The arithmetic mean of fecal coliform concentrations was 25 bacteria per 100 ml, well below the swimming standard of 200/100 ml. Concentrations of fecal streptococci averaged less than 20 per 100 ml and were therefore insignificant (Table 1). These very limited data show that, in this cursory survey, treated sewage from communities in the Okanagan Valley did not produce elevated levels of fecal coliforms in the Okanagan River below Oliver.

e) Sumas River

The Sumas River is located in an area consisting largely of dairy farms. This type of land use would imply some fecal contamination of the river by animal waste either directly, or through runoff from fields and barns. Groundwater contamination of the river may also be a problem because grazing extends right to the waters edge,

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indicating a short distance of transport for potentially contaminated groundwater. Resuspension of bottom and bank sediments, the third possible mode of bacterial contamination, may also be a factor in the Sumas river because of the soft mud bottom and numerous wading cattle.

The Sumas river was expected to have significant levels of fecal contamination but very little of human origin. FC : FS ratios were, therefore, expected to be low.

In May, 1979 the arithmetic mean was 480 fecal coliforms per 100 ml (Table 1) indicating a significant water quality problem if the water were to be used for swimming. Concentrations of fecal streptococci averaged 300 per 100 ml, resulting in a mean FC : FS ratio of 1.6 which is inconclusive with respect to origin of contamination. The June results showed higher concentrations of fecal streptococci, with little change in the fecal coliform concentrations. Mean FC : FS ratios of 0.8 - 0.9 in June indicated a tendency toward contamination from non-human sources in the Sumas river, as expected.

Approximately one quarter of a mile downstream of the sampling station on the Sumas River, the presence of a waterfowl refuge may influence concentrations of fecal pollution indicators.

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Summary

This preliminary survey was carried out in order to identify potential problem areas in sanitary water quality, with particular regard to waters which cross the international boundary. Every attempt was made to obtain an accurate and precise estimate of fecal coliform densities during the limited period of sampling. Because of the variability of coliform densities in small volumes of water, replicate samples were collected, where possible on a river cross section, on 2 - 3 consecutive days. Samples were taken during the day, with the hope of capturing the peak of the fluctuations in domestic sewage concentration.

Data was summarized by using the arithmetic mean rather than the commonly used geometric mean. Several different treatments of fecal coliform and fecal streptococcus data have been employed and discussion continues over which is the most appropriate reflection of actual concentrations. Variously, the arithmetic mean, the geometric mean, and the median of analyzed sample concentrations have been used. The arithmetic mean is higher than the geometric mean and may be biased toward extreme values; conversely the geometric mean may present an overly optimistic picture of sanitary water quality (Pipes 1977).

In summary, the results from this very limited survey of five British

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Columbia rivers showed that concentrations of fecal coliforms in all cases were lower than the criteria suggested for irrigation and non contact recreation, 1000/100 ml. Only the site on the Sumas River, located in an agricultural area used predominantly for dairy farming, exceeded the swimming standard of 200/100 ml. Results from the lower portion of the Skeena River basin showed that fecal coliform concentrations were low and originated predominantly from the Skeena rather than the Ecstall River. Coliform counts from the Similkameen, Okanagan and Columbia rivers were low and it would appear that no relevant use of these rivers would be restricted by sanitary water quality. All rivers sampled exceeded the very stringent Canadian drinking water standard.

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TABLE 1 - SYNOPSIS OF FECAL BACTERIA RESULTS *

a) Skeena River

Samples collected July 27/79 and July 28/79.

i) MF Technique - arithmetic means of 4 samples per section

Station I.D.	FC (mean)	FS (mean)
Veitch cross section	< 20	< 20
Aberdeen cross section	27	< 20
Ecstall cross section	< 20	< 20

ii) MPN Technique - arithmetic means of 9 samples per section

Station I.D.	FC
Veitch cross section	34
Aberdeen cross section	110
Ecstall cross section	< 20

b) Columbia River

Samples collected June 5-7/79

MF Technique - arithmetic means of 4 samples per station

Station I.D.	FC (mean)	FS (mean)	FC : FS
Columbia left bank (CLB)	7	6	1.2
Columbia left mid-stream (CLMS)	7	5	1.4
Columbia mid-stream (CMS)	8	5	1.5
Columbia right mid-stream (CRMS)	11	4	2.8
Columbia right bank (CRB)	7	0	-
Overall arithmetic mean	< 20	< 20	greater than 0.7 but less than 4.0

c) Similkameen River

Samples collected July 4/79 and July 5/79
Single station - MF Technique

Arithmetic means of 9 samples for FC analysis
and 3 samples for FS analysis

FC (mean)	FS (mean)	FC : FS
9	7	2.6

d) Okanagan River

Samples collected July 4/79 and July 5/79
Single station - MF Technique

Arithmetic means of 9 samples for FC analysis
and 3 samples for FS analysis

FC (mean)	FS (mean)	FC : FS
25	5	5.0

e) Sumas River

Samples collected May 22-24/79 and June 19-21/79
MF Technique - arithmetic means of six samples/station

Station I.D.	Date	FC (mean)	FS (mean)	FC : FS
Sumas East Bank (SEB)	May 22-24/79	500	330	1.5
Sumas Mid stream (SMS)	May 22-24/79	500	370	1.4
Sumas West Bank (SWB)	May 22-24/79	430	210	2.0
Overall arithmetic mean		480	300	1.6
SEB	June 19-21/79	500	620	0.8
SMS	June 19-21/79	530	560	0.9
SWB	June 19-21/79	470	580	0.8
Overall arithmetic mean		500	590	0.8

* All numbers are counts/100 ml

Table 2 - pH, conductivity and temperature data

Location	Date	Time	pH	Conductivity	T (c)
Okanagan River	July 4/79	0810	7.8	220	21
	July 5/79	1000	8.0	220	21
Similkameen River	July 4/79	0705	7.3	110	14
	July 5/79	0900	8.0	115	15
Sumas River	May 22/79	1500	-	320	12
	May 23/79	1045	7.7	300	12
	May 24/79	0925	7.7	230	14
	June 19/79	1045	7.7	275	14
	June 20/79	1130	7.7	290	13.5
	June 21/79	1130	7.7	290	14.5
Columbia River	June 5/79	1035	8.0	125	15
	June 6/79	0930	-	-	12
	June 7/79	0925	-	140	12

Appendix I - Bacteriological Results, Summer 1979

A) Skeena River

MPN Results

July 27/79	MPN	July 27/79	MPN	July 27/79	MPN
Veitch RB	33	Aberdeen RB	170	Ecstall RB	5
Veitch MS	33	Aberdeen MS	27	Ecstall MS	2
Veitch LB	14	Aberdeen LB	170	Ecstall LB	2
July 28/79					
Veitch RB1	49	Aberdeen RB1	49	Ecstall RB1	33
Veitch RB2	79	Aberdeen RB2	240	Ecstall RB2	23
Veitch MS1	22	Aberdeen MS1	130	Ecstall MS1	5
Veitch MS2	33	Aberdeen MS2	49	Ecstall MS2	8
Veitch LB1	13	Aberdeen LB1	49	Ecstall LB1	22
Veitch LB2	33	Aberdeen LB2	110	Ecstall LB2	13
Arithmetic mean	34.3		110.4		12.6

MF Results

July 27/79	FC	FS
Veitch	22	3(<20)
Aberdeen	38	7(<20)
Ecstall	2(<20)	2(<20)

July 28/79	FC	FS		FC	FS		FC	FS
Veitch RB	23	9	Aberdeen RB	25	3	Ecstall RB	7	1
Veitch MS	7	2	Aberdeen MS	18	7	Ecstall MS	6	3
Veitch LB	2	3	Aberdeen LB	28	7	Ecstall LB	2	0

MF total arithmetic means:

	FC	FS
Veitch	13.5	4.2
Aberdeen	27.2	6.0
Ecstall	4.2	1.5

RB - Right Bank
MS - Mid stream
LB - Left Bank

B) Columbia River

Station	Date	Time	Fecal Coliform MF/100 ml	Fecal Streptococci MF/100 ml
CLB	June 5/79	1035	18	12
CLB	June 5/79	1040	6	12
CLB	June 6/79	0930	2	0
CLB	June 7/79	0925	3	-
CLMS	June 5/79	1035	10	12
CLMS	June 5/79	1040	10	2
CLMS	June 6/79	0930	5	0
CLMS	June 7/79	0925	4	-
CMS	June 5/79	1035	8	4
CMS	June 5/79	1040	12	12
CMS	June 6/79	0930	6	0
CMS	June 7/79	0925	6	-
CRMS	June 5/79	1035	20	10
CRMS	June 5/79	1040	14	2
CRMS	June 6/79	0930	3	0
CRMS	June 7/79	0925	8	-
CRB	June 5/79	1035	10	0
CRB	June 5/79	1040	6	0
CRB	June 6/79	0930	3	0
CRB	June 7/79	0925	8	-
CDS	June 6/79	1630	6	-

CLB - Columbia Left Bank approximately 30 feet offshore
CLMS - Columbia 1/4 off Left Bank
CMS - Columbia mid stream
CRMS - Columbia 1/4 off Right Bank
CRB - Columbia Right Bank approximately 30 feet offshore
CDS - Columbia depth sample

C) Similkameen River

Station	Date	Time	Fecal Coliform MF/100 ml	Fecal Streptococci MF/100 ml	FC : FS
Sim NB	July 4/79		8	6	1.3
Sim NB	July 4/79		12	2	6.0
Sim NB	July 4/79		10	14	.6
Sim NB	July 5/79		12	-	-
Sim NB	July 5/79		3	-	-
Sim NB	July 5/79		6	-	-
Sim NB	July 5/79		15	-	-
Sim NB	July 5/79		9	-	-
Sim NB	July 5/79		8	-	-
Overall arithmetic mean			9	7	2.6

Sim NB - Similkameen North Bank

D) Okanagan River

Station	Date	Time	Fecal Coliform MF/100 ml	Fecal Streptococci MF/100 ml	FC : FS
OKWB	July 4/79	0810	10	8	1.2
OKWB	July 4/79	0810	30	6	5.0
OKWB	July 4/79	0810	24	2	12.0
OKWB	July 5/79	1000	33	-	-
OKWB	July 5/79	1000	28	-	-
OKWB	July 5/79	1000	28	-	-
OKWB	July 5/79	1000	19	-	-
OKWB	July 5/79	1000	24	-	-
OKWB	July 5/79	1000	29	-	-
Overall arithmetic mean			25	5	5.0

OKWB - Okanagan West Bank

E) Sumas River

Station	Date	Time	Fecal Coliform MF/100 ml	Fecal Streptococci MF/100 ml
SEB	May 22/79	1515	160	80
SEB	May 22/79	1515	400	40
SEB	May 23/79	1100	460	640
SEB	May 23/79	1100	560	560
SEB	May 24/79	0950	780	-
SEB	May 24/79	0950	660	-
SEB	June 19/79	1045	770	920
SEB	June 19/79	1045	700	990
SEB	June 20/79	1130	590	290
SEB	June 20/79	1130	550	270
SEB	June 21/79	1130	160	-
SEB	June 21/79	1130	220	-
SMS	May 22/79	1515	200	80
SMS	May 22/79	1515	100	380
SMS	May 23/79	1100	520	570
SMS	May 23/79	1100	680	450
SMS	May 24/79	0950	900	-
SMS	May 24/79	0950	690	-
SMS	June 19/79	1045	710	760
SMS	June 19/79	1045	670	940
SMS	June 20/79	1130	640	240
SMS	June 20/79	1130	590	320
SMS	June 21/79	1130	260	-
SMS	June 21/79	1130	290	-

SWB	May 22/79	1515	320	20
SWB	May 22/79	1515	140	40
SWB	May 23/79	1100	460	440
SWB	May 23/79	1100	320	350
SWB	May 24/79	0950	720	-
SWB	May 24/79	0950	600	-
SWB	June 19/79	1045	660	980
SWB	June 19/79	1045	650	700
SWB	June 20/79	1130	490	290
SWB	June 20/79	1130	510	360
SWB	June 21/79	1130	240	-
SWB	June 21/79	1130	250	-

SEB - Sumas east bank (right bank)

Comments: Samples taken at 1/2 river depth 1 metre upstream of bridge, halfway between centre bridge piling and right bank bridge piling.

SMS - Sumas midstream

Comments: Samples taken at 1/2 river depth 1 metre upstream of centre piling of bridge.

SWB - Sumas west bank (left bank)

Comments: Samples taken at 1/2 river depth 1 metre upstream of bridge, halfway between centre bridge piling and left bank bridge piling.