CHAPTER 5
Water Quality

Previous sections of this report have discussed the quantity of water available within the Okanagan Basin. Of equal importance is the quality of this resource in the tributary streams, lakes, and rivers as it flows through the basin. The term quality refers not only to the condition of water for drinking purposes and other consumptive uses, but also to the condition of bodies of water as a suitable habitat for aquatic life and for recreation (non-consumptive uses).

Under the Okanagan Basin Agreement, studies were carried out to determine: the present quality of the tributary streams and main valley lakes; the sources and amounts of nutrients and other chemical constituents entering the water of the basin; the extent and range of possible future sources and levels of pollution; and to test and evaluate methods for the control of nutrient discharges through the treatment of municipal and industrial wastes. The purpose of this chapter is to present the results of these quality studies. The results of studies on the main valley lakes, known collectively as limnological studies, are presented in a separate section because of the complex nature of lakes and the different types of studies required to assess their condition. The extent and range of possible future sources and levels of pollution are presented in Chapter 15.

5.1 WATER QUALITY FOR CONSUMPTIVE AND OTHER BENEFICIAL USES

During the period 1969 to 1972 a number of monitoring programs were carried out to determine the concentrations of various chemical constituents in the streams and lakes of the Okanagan Basin, and the number of coliform bacteria as a measure of the presence of pathogenic (disease causing) bacteria. The results of these monitoring programs have been used to evaluate the present condition and suitability of these waters for such designated uses as domestic water supplies, irrigation, recreation, and aquatic life, as well as for estimating present and future loadings to the main valley lakes.

5.1.1 Water Quality Criteria

In water quality the term 'Criteria' may be generally defined as a scientific requirement on which a decision or judgement may be based concerning the suitability of a water to support a designated use. A severe short coming in determining these scientific requirements, as related to water quality, is the lack of adequate knowledge concerning many of the quality characteristics upon which criteria should be based.

The use of water for drinking purposes is generally conceded to be the most essential use of water, however, other designated uses may have water quality requirements which are more stringent than those for drinking water. For example: water that is suitable for domestic supplies often requires further treatment before it can be used in industrial processes; softened water for municipal systems can be detrimental for irrigation; and aquatic life in streams and lakes may be destroyed or inhibited by concentrations of copper and zinc that are permissible in domestic water supplies. Further complicating factors affecting water quality criteria are the variations in natural conditions affecting water quality such as the climate, geography, and geology of a watershed. There is also a lack of adequate knowledge concerning the effect of many of the trace elements on water quality and health.

The water quality criteria presented in Table 5.1 is included primarily for guideline purposes and should only be used in conjunction with a thorough knowledge of local conditions. The criteria embrace a quality level which is generally acceptable for recreation, aquatic life and as a raw water supply prior to treatment to provide drinking water.

5.1.2 Quality of Tributary Streams

Examples of the raw water quality of selected streams are shown in Table 5.2 and the location of sampling stations in Figure 5.1. The streams selected are those in which one or more of the acceptable standards were exceeded during the monitoring period. The ranges shown are the minimum and maximum values obtained over the two year sampling period 1969-71. In general, the maximum values were recorded during the spring freshet period, while the minimum values were recorded during the remainder of the year. On four of the streams -Mission, Kelowna, Vernon, and Deep Creeks, values are shown for two stations, one located at the mouth of the stream and the other above urban development. All other values were recorded at the mouths of the streams.

Almost all streams sampled in the basin exceeded color and turbidity standards during the spring freshet period. The high color levels are due largely to the natural characteristics of the watershed and are undesirable for aesthetic reasons rather than any health hazard.

Turbidity results from the natural and induced erosion of the banks of tributary streams and is undesirable from a health point of view because of its absorptive affect on chlorine which is added to outfall effluents to kill pathogenic bacteria.

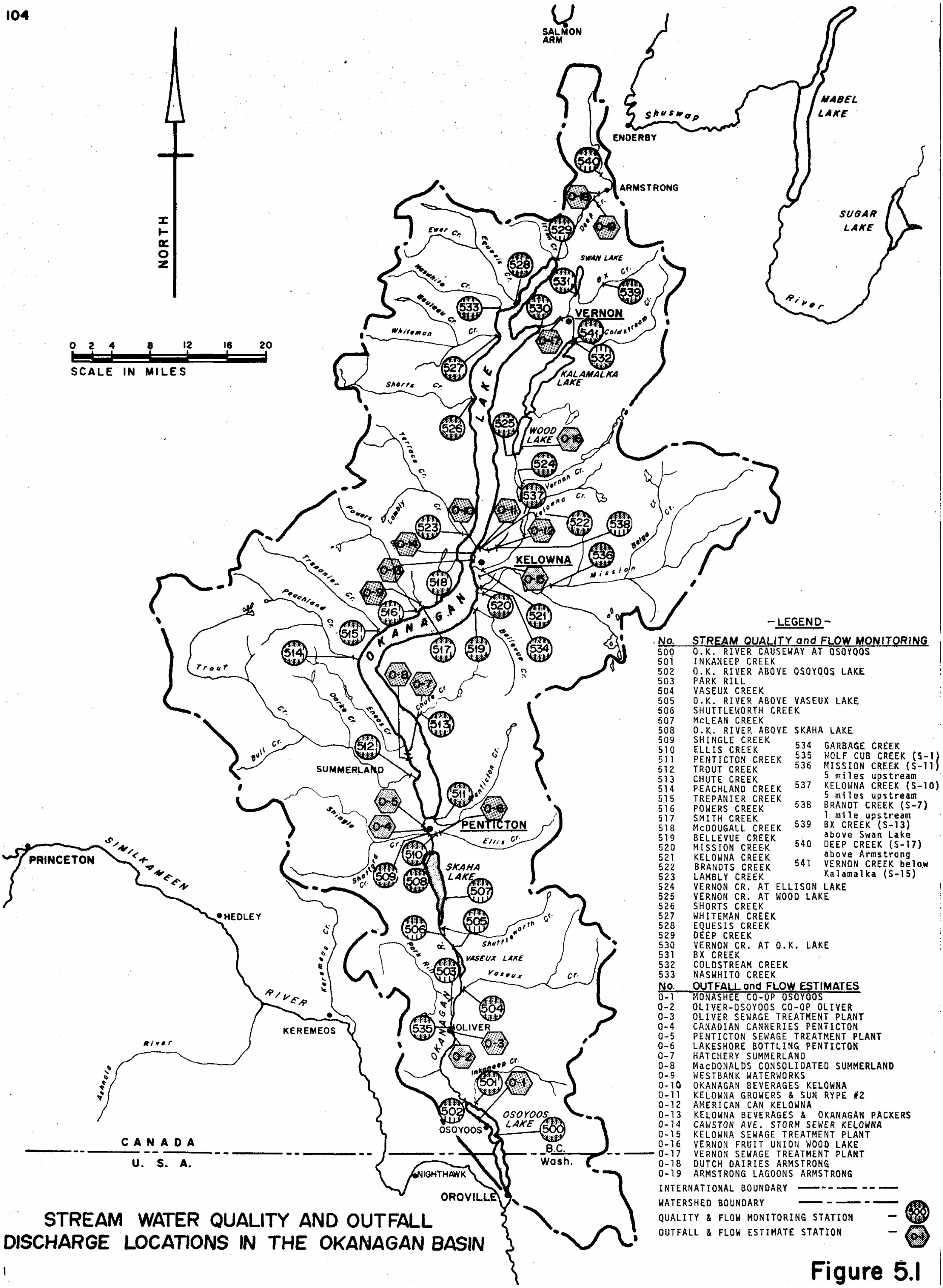
Manganese and phosphorus levels were also high in many of the streams sampled, particularly during the freshet period. Manganese in natural stream-flow comes most often from soils and sediments, in waste effluents from the manufacturing industry (batteries, ceramics, paints, etc.) and agriculture

TABLE 5.1

GENERALLY ACCEPTED ALLOWABLE CRITERIA - RAW WATER SOURCES

FOR DRINKING WATER, AQUATIC LIFE AND RECREATION - FOR SIGNIFICANT WATER QUALITY PARAMETERS IN THE OKANAGAN BASIN

WATER QUALITY PARAMETER AND (REFERENCE)	CRITERIA - MAXIMUM ALLOWABLE CONCENTRATIONS		COMMENTS
	DRINKING WATER	AQUATIC LIFE	
Color (1)	15 units	--	Indicated limits on colour in drinking water are primarily to meet aesthetic satisfaction. Excessive colour may also indicate presence of undesirable organic substances. In excess of 50 Units it tends to block out sunlight and interfere with propagation of fish food organisms.
Turbidity (2,3)	5 J.T.U.	10 J.T.U.	From aesthetic viewpoint turbidity in excess of 1 Jackson Turbidity Unit (J.T.U.) may be objected to by majority of consumers. Excessive turbidity may also interfere with clarification and disinfection processes.
Copper (1,2,4,5,6,7)	1.0 ppm.	0.1	Drinking water limits based on considerations of taste and staining characteristics. Copper concentrations in excess of .02 parts per million (ppm) may be lethal to trout and salmon.
Iron (1,2,4,5,6)	0.3 ppm.	0.2 ppm.	Iron is a highly objectionable element in water supplies for domestic uses and the acceptable limit is based on considerations of effects on household use. In concentrations greater than 0.3 ppm it may impart a brownish colour to laundered goods and stain plumbing fixtures. The taste of water and beverages may be affected by concentrations greater than .05 ppm. A concentration of 0.2 ppm is the lethal threshold for some fish species.
Manganese (1,2,4,5)	0.05 ppm.	1.0 ppm	Excessive concentrations of manganese may cause staining particularly in conjunction with iron, has an unpleasant taste and fosters the growth of some micro organisms in reservoirs, filters and distribution systems.
Dissolved Oxygen	--	5.0 ppm. minimum	A minimum of 5 ppm of dissolved oxygen is considered necessary for all fish populations. The absence of dissolved oxygen promotes an aerobic decomposition which is accompanied by undesirable odors High concentrations of oxygen are beneficial rather than harmful.
Nitrogen (1,8)	10.0	--	The limit on nitrogen (nitrate + nitrite) of 10 ppm is based on the relationship established between this chemical and the possible occurance of infantile methaemoglobinemia. No cases of this disease have occurred where the drinking water consistently contained less than 10 ppm of nitrogen.
Phosphates (1,4,8)	0.2	.05 to .1	Limitations on phophorus concentrations are primarily to prevent excessive growth of photosynthetic organisms (algae and weeds) in reservoirs and the resultant problems of odor and taste. A concentration of 0.2 may be high under some conditions. Preferable limits for aquatic life are .05 ppm in lakes, and 0.1 ppm in flowing streams.
Zinc (1,2,3,4,5,6)	5.0 ppm.	0.1 ppm.	Acceptable limit for drinking water is based primarily on aesthetic effect as excessive amounts may impart milky appearance and a metallic taste to water. This element has no serious effect on human health but may be lethal to fish and other aquatic life in concentrations greater than 0.1 ppm.
Coliform (1) Drinking Water -Total -Faecal	 1000/100ml 100/100ml	 -- --	The acceptable limit for total coliform organisms in untreated water supplies prior to filtration and chlorination as enumerated by the Most Probably Number multiple tube fermentation test should not exceed a density of 1000 per 100 millileters (ml) in 90% of the samples in any consecutive 30 day period should not exceed a density of 100 organisms per 100 ml.
Coliform Water Contact Sports (9-10) -Total -Faecal	 240/100ml 200/100ml	 -- --	Maximum safe levels of coliform for water contact sports such as swimming.



STREAM WATER QUALITY AND OUTFALL DISCHARGE LOCATIONS IN THE OKANAGAN BASIN

Figure 5.1

where it is used to spray manganese deficient trees. Manganese in concentrations in excess of 0.2 parts per million may cause undesirable tastes, stain kitchen utensils and plumbing fixtures, and foster the growth of some micro-organisms in reservoirs, filters and distribution systems. A level of one part per million in raw water supplies is lethal to fish and other aquatic life.

The element phosphorus does not occur free in nature but is found in the. form of phosphates in minerals and soils. Phosphorus is a key nutrient in animal and plant life and is extremely important in processes involving the transfer of energy in all living cells.

The high levels of total phosphorus in streams are the result of a combination of natural and urban sources. Watershed deforestation and erosion undoubtedly increase the amount of total phosphorus in streams although most of this is in the form of suspended debris rather than in the soluble orthophosphorus form (Table 6.3 Chapter 6). Industrial and municipal outfalls, and groundwater return flows add to the concentration of phosphorus in the lower reaches of the streams as indicated by the increases in total phosphorus between the upper and lower stations of Mission, Deep, and Kelowna Creeks. The reduction in phosphorus content between the upper and lower station on Vernon Creek is due to the water passing through Ellison, Wood, and Kalamalka Lakes where much of it is deposited or assimilated, before reaching Okanagan Lake. The major problem associated with phosphorus is excessive algae and aquatic plant growth, which can result in undesirable tastes and odors in drinking water.

Low oxygen contents were recorded in Shuttleworth, Ellis, Brandts, Bellevue, Lambly and Deep Creeks. Brandts Creek and Deep Creek are affected by industrial and urban waste discharges which reduce oxygen levels. Most of the other creeks however are in relatively undeveloped areas and the reason for these low readings is not known. Dissolved oxygen concentrations of less than 5 parts per million are lethal to some fish. The high total nitrogen recorded at the mouth of Vernon Creek may be attributed to municipal waste effluent discharge from the City of Vernon.

Other chemical standards exceeded, included iron in Penticton, Ellis and Brandts Creeks, alkalinity in Lambly Creek and hardness in Brandts and Deep Creeks. These represent relatively isolated conditions however, and are not considered a major problem at this time.

One of the most important criteria for raw water supplies, the limits of which are exceeded in many streams, is the presence of pathogenic bacteria (bacteria causing or capable of causing disease). For many years the coliform group of bacteria has been used to indicate the presence of pathogenic bacteria.

Coliform bacteria are themselves harmless to humans, but if present in sufficient numbers, generally indicate the presence of pathogenic bacteria of intestinal origin. The absence of coliform bacteria is the best available evidence that a drinking water is bacteriologically safe. Of thirty streams tested for coliforms levels, 10 exceeded the acceptable criteria for both total coliform and fecal coliform including those of Inkaneep, Westbank, Brandts, Equesis, and Kelowna Creeks as shown in Table 5.2. With the exception of Inkaneep and Equesis Creeks all those shown are affected by urban development and associated waste discharges. Other streams which exceeded acceptable coliform standards include McLeans, BX, and Coldstream Creeks, the latter two of which drain confined farm animal operations. The median values shown are based on approximately 20 or more tests taken over the two year sampling period 1969-71.

In summary the quality of many streams in the lower reaches is not generally acceptable as raw water supply (untreated) for drinking water purposes, due to excess concentrations of color, turbidity, manganese, phosphorus, and particularly coliform densities. The quality of water in the upper reaches of most streams was not determined, but on the basis of the few streams sampled above major urban developments, would appear to be of a higher quality than in the lower reaches. Except for coliform and turbidity, the standards exceeded render the water undesirable for aesthetic and household use purposes, rather than as a health hazard.

5.1.3 Quality of Main Valley Lake Water (a) Drinking water and Aquatic Life

Examples of the raw water quality of the main valley lakes and Okanagan River are shown in Table 5.3. Some information on water quality was also obtained for a few of the headwater lakes, and five of these are included for comparison purposes. Osoyoos and Wood Lake have high phosphorus concentrations and Wood Lake has oxygen deficiencies at certain times of the year, but otherwise the water quality of the main valley lakes is generally acceptable for consumptive use purposes.

Ellison Lake, which is a very shallow lake, exceeds most of the limits for acceptable water quality.

It is interesting to note that four of the five headwater lakes shown in Table 5.3 exceed color and total phosphorus criteria. The high color content is considered to be a natural condition of the watershed and indicates the source of the high color content in most of the streams. The total phosphorus is considered to be largely organic matter in the insoluble form.

Okanagan River, which joins the main lakes downstream of Okanagan Lake exceeds acceptable limits for color, turbidity, iron, and total phosphorus

TABLE 5.2

RAM WATER QUALITY OF SELECTED STREAMS IN THE OKANAGAN BASIN (1969-1971 DATA)

CREEK NAME	LOCATION AND STATION	PHYSICAL		CHEMICAL CONSTITUENTS							BIOLOGICAL		
		COLOR True Color Units	TURBIDITY Jackson Turbidity Units	CHLORIDE (as Cl) parts per million	FLUORIDE (as FL) parts per million	IRON (as Fe) parts per million	COPPER (as Cu) parts per million	MANGANESE (as Mn) parts per million	TOTAL PHOSPHORUS parts per million	TOTAL NITROGEN parts per million	OXYGEN (dissolved O_2) parts per million	TOTAL COLIFORM DENSITY Organisms per 100 mls	FECAL COLIFORM DENSITY Organisms per 100 mls
GENERALLY ACCEPTED CRITERIA FOR DRINKING WATER STANDARDS		15	5	250	1.5	0.3	1.0	0.05	0.065	10	Should be greater than 5	1000	100
		MINIMUM AND MAXIMUM VALUES FOR PERIOD 1969 to 1971											
Inkaneep	At Mouth (501)	5-75	1.8-165	0.5-2.8	.15-.49	.06-.27	.001-.006	.001-.044	.007-.359	0.01-1.00	8.0-14.1	1,263	116
Vaseux	At Mouth (504)	5-65	0.2-11	0.3-0.6	.13-.35	.01-.13	.001-.006	.001-.010	.003-.039	0.01-1.06	9.8-14.0	70	5
Shuttleworth	At Mouth (506)	0-75	0.2.140	0.5-11.5	.12-.34	.01-.28	.001-.006	.001-.100	.003-.424	0.11-1.56	4.2-16.4	918	65
Ellis	At Mouth (510)	5-85	0.9-260	0.6-10.2	.07-.29	.02-.65	.001-.015	.001-.750	.007-.457	0.03-2.68	2.8-13.9	542	8
Penticton	At Mouth (511)	10-70	0.7-62	0.4-8.7	.05-.15	.09-.68	.001-.008	.001-.090	.003-.359	0.01-9.27	8.0-14.5	516	26
Trout	At Mouth (512)	0-40	0.2-210	0.8-4.4	.09-.24	.01-.12	.001-.015	.001-.060	.003-1.27	0.06-2.86	7.6-15.3	850	20
Peachland	At Mouth (514)	0.65	0.2-57	0.0-1.3	.13-.66	.01-.18	.001-.011	.001-.01	.003-.245	0.18-2.79	8.6-13.7	348	6
Powers	At Mouth (516)	5-65	0.3-60	0.6-2.8	.02-.39	.01-.25	.001-.008	.001-.03	.007-.330	0.14-2.17	8.5-13.9	490	14
Westbank	At Mouth (517)	5-45	4.0-230	5.0-11.0	.29-.50	.01-.10	.001-.007	.001-.018	.038-1.27	.059-4.66	8.6-13.5	5,420	232
Bellevue	At Mouth (519)	0-60	0.2-35	0.7-3.3	.05-.15	.01-.12	.001-.008	.001-.050	.001.1.24	0.06-1.98	1.4-13.3	240	6
Mission	At Mouth (520)	5-50	0.5-43	0.3-1.9	.05-.17	.01-.10	.001-.011	.001-.056	.003-.783	.031-2.08	7.9-15.0	500	88
Mission	Above Urban Area (536)	5-50	0.4-26	0.4-0.8	.05-.15	.05-.08	.001-.004	0.01-.018	.007-.205	.030-.730	8.0-13.7	109	9
Brandt's	On Guy Street (522)	10-70	2.4-115	11.6-41.8	.37-.99	.03-.52	.001-.011	.011-.610	.058-2.70	0.19-7.69	0 -13.8	169,000	980
Lambly	At Mouth (523)	0-75	0.1-16	0.4-1.0	.06-.13	.01-.18	.001-.004	.001-.015	.007-1.79	0.01-6.55	4.7-14.1	86	4
Shorts	At Mouth (526)	0-50	0.2-150	0.2-0.9	.02-.28	0 -.13	.001-.006	.001-.010	.007-3.40	0.01-4.50	6.5-14.1	918	13
Equesis	At Mouth (528)	0-45	0.5-160	0.2-0.8	.12-.29	.01-.10	.001-.006	.001-.047	.009-1.21	0.02-7.15	9.6-13.7	939	123
Kelowna	At Mouth (521)	5-65	3.1-13	3.1-13.0	.13-.27	.01-.21	.001-.007	.001-.230	.020-.750	0.31-4.10	6.9-14.6	5,420	1,122
Kelowna	Above Urban Area (537)	5-90	1.7-44	1.1-419	.10-.23	.04-.19	.001-.010	.044-.200	.072-.300	0.08-3.3	7.0-11.7	800	238
Deep	Above Armstrong (540)	5-75	0.3-11	1.2-1.5	.14-0.3	.03-.09	.001-.005	.014-.210	.033-.108	0.08-9.06	7.6-12.3	1,300	163
Deep	At Mouth (529)	10-110	0.5-70	2.2-43.0	.16-.31	.01-.22	.001-.007	.001-.340	.050-.717	0.22-3.75	3.8-13.5	1,300	129
Vernon	At Okanagan Lake (530)	5-20	1.8-61	1.6-35.0	.15-.31	.01-.18	.001-.009	.001-.330	.039-1.86	0.19-12.0	6.2-12.3	5,420	438
Vernon	Above Ellison Lake (524)	0-110	0.2-1000	0.4-1.7	.060-.15	.01-.16	.001-.013	.001-.130	.007-6.69	0.01-3.61	6.9-14.5	109	8
Coldstream	At Mouth	0-45	0.4-51	0.9-5.0	.13-.38	.01-.08	.001-.012	.001-.060	.016-.750	.140-3.92	4.1-14.1	1,410	377

NOTE: Values underlined exceed acceptable criteria

TABLE 5.3

ALITY OF - OKANAGAN RIVER AND SELECTED LAKES IN THE OKANAGAN BASIN (1969-1971 DATA)

LOCATION AND STATION	PHYSICAL: COLOR True Color Units	PHYSICAL: TURBIDITY Jackson Turbidity Units	CHEMICAL CONSTITUENTS: CHLORIDE (as Cl) parts per million	FLUORIDE (As Fl) parts per million	IRON (as Fe) parts per million	COPPER (as Cu) parts per million	MANGANESE (as Mn) parts per million	TOTAL PHOSPHORUS parts per million	TOTAL NITROGEN parts per million	BIOLOGI…: OXYGEN* (Dissolved O_2) parts per million	TOTA… COLIF… DENS…
CCEPTED CRITERIA G WATER STANDARDS	15	5	250	1.5	0.3	1.0	0.05	0.065	10	Should be greater than 5	100 Organi… per 100…
	MINIMUM AND MAXIMUM VALUES FOR PERIOD 1969-1971 (shown where available)										
.2 Mi. Upstream from soyoos L. (502)	0-35	0.6-9.4	1.1-2.2	0.16-28	.01-.11	.001-.009	.001-.050	.003-.390	.030-2.38	8.2-14.3	348
.5 Mi. Upstream from aseux Lake (505)	0-10	0.3-25	0.7-1.6	0.17-24	.01-.06	.001-.006	.001-.028	.003-.130	.003-1.48	8.5-14.9	40
ntrance to Skaha Lake 508)	0-25	0.3-15.6	0.8-3.4	0.16-.20	.01-.32	.001-.004	.001-.047	.007-.241	.050-2.52	7.9-12.9	109
id-Lake at Border	3.4	1.19	1.60	.193	.010	.013	.005	-	-	9.0-9.0	-
id-Lake 1 Mi. No. of ica Creek	-	1.40	1.25	.240	.060	.013	.016	.207	.150	8.0-8.5	-
id-Lake Opposite aleden	5.0	0.90	1.40	.119	.080	.018	.006	.052	.250	8.5-9.2	-
id-Lake Opposute Summ-rland	10.0	0.40	1.00	.200	.013	.011	.004	.030	.060	8.1-9.1	-
id-Lake At Kelowna ridge	0.0	0.60	1.10	.160	-	.014	.004	.020	-	8.5-8.5	-
d-Lake 3 Mi. So. of anagan Landing	5.0	0.60	0.80	.210	.260	.024	.005	.033	.186	-	-
d-Lake Opposite Ratt-esnake Point	10.0	1.00	1.50	.330	.047	.015	.003	.022	.204	8.6-9.2	-
ddle of the lake	5.0	2.10	2.65	.340	.007	.016	.008	.134	.387	0.5-13.4	-
Vernon Creek Basin	20.0	14.00	0.90	.130	.790	.015	.067	.235	.597	1.4-1.4	-
Trout Creek Basin- drainage	-	1.20	2.60	-	-	-	.008	.037	-	-	-
adwater of Mission Cr.	65.0	-	0.60	-	-	-	.008	.087	-	8.3-8.3	-
adwater of Powers Cr.	50.0	1.10	0.40	-	-	-	.008	.215	-	8.0-8.0	-
adwater of Lambly Cr.	65.0	5.60	0.50	-	-	-	.008	.205	-	9.3-9.3	-
adwater of Oyama Creek	30.0	-	0.40	-	-	-	.008	.160	-	8.6-8.6	-

ygen content refers to the bottom waters only.

underline exceed acceptable criteria

content during the freshet period. Most of the parameters that are exceeded reflect the discharges of tributary streams in the vicinity of the sampling area. For example the high iron content in Okanagan River at the entrance to Skaha Lake is probably a result of the high iron content in Ellis Creek which joins Okanagan River just above the sampling point.

(b) Recreational Bathing Areas

Because of the importance of water-based recreation in the Okanagan Basin, to both residents and tourists, and public concern regarding the quality of bathing areas, a separate study on the coliform levels at three major beaches in the Okanagan was carried out between July and September, 1971. The major objectives of the study were to determine the coliform levels at these beaches;

the minimum number of samples required to calculate a meaningful coliform count for closing or opening bathing areas; and the probably source of such coliforms.

The three beaches selected for this study were Kin Beach at Vernon, on the north end of Okanagan Lake; Okanagan Beach at Penticton at the south end of Okanagan Lake; and Skaha Beach at Penticton, on the north end of Skaha Lake. Each beach front was sampled on a grid pattern with sixty sampling sites at three different distances from the shore. These points encompassed the whole swimming area of each beach from the shore to the farthest swimming points, usually marked by buoys. Initially, samples were taken at three different depths; surface, one foot, and mid-depth, but as the results of the initial sampling indicated that coliform levels tended to be higher for the surface samples, the remaining ones were all collected at the surface. Skaha Lake was the only beach area sampled in September.

The results of this study showed all tests for fecal coliform to be less than the B.C. Health Branch standard of 200 organisms per 100 milliliters, and for all samplings of total coliform at Okanagan and Skaha beaches the median coliform levels were less than the standard of 240 organisms per 100 milliliters, At Kin Beach, the acceptable level of total coliform was exceeded in two out of the four sampling periods. It was also found that to obtain a reliable coliform count for any one beach, more than ten random samples encompassing the entire beach area are required for each sampling. Below this number the results become too erratic, and are not representative of the beach area as a whole.

A second test used for the presence of pathogenic bacteria in the Skaha Beach areas was "Moore's Gauge Swab Test" (Ref. No.11). Test installations were secured at various locations in the bathing area. In all cases the swab samples submitted for examination of pathogenic organisms yielded negative results. This is supported by similar studies by Geldrich (12) which showed that there was little evidence of pathogenic organisms in water samples that had fecal coliform tests of approximately 200 organisms per 100 milliliters.

An examination of coliform test on streams and outfalls indicate the main contributors of fecal coliform to be those centers with sewage treatment outfalls as shown in Table 5.4. The contribution from streams was relatively small in comparison to these outfalls. The City of Vernon Sewage Treatment Plant, Dutch Dairies at Armstrong, and the City of Armstrong Lagoons contribute fecal coli-form to the Kin Beach area at Vernon, and the City of Penticton Sewage Treatment Plant contribute fecal coliform to Skaha Beach at Penticton.

Insufficient data were obtained in this study to evaluate all of the factors contributing to changes in coliform levels of bathing beaches. Future studies should consider such factors as bathing population, the circulation pattern of lake water in beach areas, and the weather, on coliform densities.

TABLE 5.4

COLIFORM RESULTS - OUTFALL SAMPLING LOCATIONS

Location of Outfall	Point of Discharge	COLIFORM - TOTAL		COLIFORM - FECAL	
		Number of Samples	Median*1	Number of Samples	Log Mean*1
Village of Oliver S.T.P.	Okanagan River	18	2,000	6	110
Canadian Canners [2] Penticton	Okanagan River	1	2,400,000	-	-
City of Penticton S.T.P.	Okanagan River	20	2,750	9	949
Westbank Lagoon	Westbank Creek	7	54,200	2	110
Calona Wines and O.K. Beverages, Kelowna	Brandt's Creek	1	2,000	-	-
City of Kelowna S.T.P.	Okanagan Lake	18	89,050	6	423,983
City of Vernon S.T.P.	Vernon Creek	25	2,000	7	431
Dutch Dairies Armstrong	Deep Creek	20	160,900	2	987,500
City of Armstrong Lagoons	Deep Creek	21	160,900	4	16,375

*1 Most probable number per 100 milliliters.

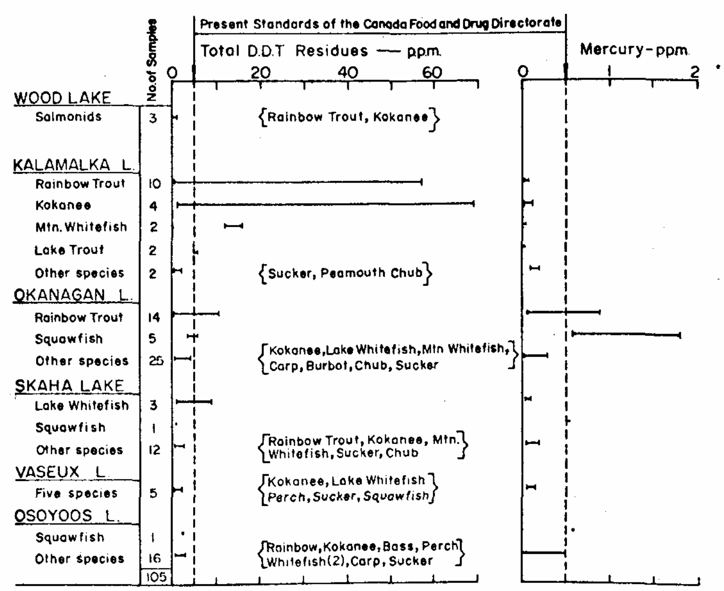
*2 In 1972 Canadian Canners at Penticton commenced discharging effluent to Penticton Sewage Treatment Plant.

5.1.4 Pesticides and Trace Metals

Studies on the use of pesticides within the Okanagan Basin, and on the levels of mercury and the pesticide D.D.T. in fish, were carried out to obtain some preliminary information on this aspect of water quality.

A review of the use of pesticides in the Okanagan Basin over the past 10 years show that the sales of D.D.T. declined from a 10 year peak of 836,000 pounds in 1965 to 27,700 pounds in 1970. The most serious problem associated with D.D.T. and related compounds was their persistance in the environment and accumulation in the food chain, culminating in a provincial (British Columbia) ban on this type of pesticide in 1971. Although a number of new pesticides have appeared in the past 10 years. Entomologists have recognized that pesticides are not the final answer to insect control, and that other forms of control are desirable along with the intelligent use of less persistent pesticides. The recommended use of pesticides in the tree fruit industry and estimated sales are detailed for the period 1960 to 1970 in Technical Supplement IV "Water Quality in the Okanagan Basin".

Levels of the pesticide D.D.T and the trace element mercury, found in the flesh of fish from the main valley lakes, are compared to standards of the Canada Food and Drug Directorate in Figure 5.2. Acceptable levels for mercury are exceeded in squawfish and to a lesser extent in large rainbow trout in Okanagan Lake. Squawfish and large rainbows owe their accumulation of mercury to their heavy utilization of other fish for food. High levels of D.D.T. were also found in rainbow trout and kokanee from Kalamalka Lake.



CONCENTRATION RANGES of DDT and MERCURY in the FLESH of FISHES from the OKANAGAN MAIN VALLEY LAKES, 1971.

Figure 5.2

5.1.5 Summary of Stream Water Quality Problems

Those streams in which major quality problems are evident are reviewed below:

(i) Vernon Creek

Vernon Creek above Ellison Lake had excessive loadings of phosphorus and manganese during the spring runoff period. The amount of total phosphorus in the soluble orthophosphorus form did not at any time exceed a concentration of 0.1 parts per million even though the total phosphorus concentrations reached levels of 6 to 7 parts per million. This indicates most of this was in the form of organic leaves and twigs carried down by runoff in the spring of the year. The source of the high levels of manganese in this and other headwater streams is not known.

Vernon Creek between Kalamalka Lake and Okanagan Lake exceeded the criteria for manganese, phosphorus, nitrogen and total coliform. This portion of the Vernon Creek Watershed includes the drainage from BX Creek. The whole area is highly developed either for agriculture or urban use. The City of Vernon also discharges its treated waste effluent into this section of Vernon Creek.

(ii) Coldstream Creek

This stream drains a large agricultural area before discharging into Kalamalka Lake. Those constituents which exceed acceptable levels include phosphorus and both total and fecal coliforms. Both phosphorus and coliform probably result from the dairy and beef cattle enterprises along this stream which carry some 1200 head.

(iii) Deep Creek

Constituents in this stream that exceeded acceptable levels included manganese, phosphorus, and total coliform. The Deep Creek watershed basically drains the north end of the valley proper and is not representative of other creek basins. The area is extensively farmed with over 50% of the drainage area in cropland or pasture. The City of Armstrong also discharges its treated effluent from lagoons to Deep Creek along with a number of other agriculturally orientated industries. Deep Creek is one of the few creeks that had dissolved oxygen concentrations of less than 5 parts per million, indicative of the lack of good conventional waste treatment practices in this sub-basin.

(iv) Westbank Creek

This stream had particularly high levels of both fecal and total coliform, due primarily to the discharge of treated effluent from the Westbank sewage treatment plant.

(v) Kelowna Creek

The lower portion of the Kelowna Creek watershed is highly developed (Figure 5.3) for both farm land and urban development. Very high levels of both total and fecal coliform were recorded at its mouth, in addition to excesses of phosphorus and manganese. Two quality stations were located on this stream, one at the mouth and the other above the main urban development. While the creek at the station above the urban area exceeded criteria for fecal coliform, probably as a result of livestock enterprises, this number increases five fold as the stream traversed the urban area of Kelowna as shown by the following results:

	Total Coliform Log Mean Density per 100 ml.	Fecal Coliform Log Mean Density per 100 ml.
Kelowna Creek above developed area (537)	800	238
Kelowna Creek below developed area (521)	5420	1122

This indicates the effect of urbanization on the contamination of streams traversing highly populated. areas.

(vi) Brandt's Creek

This is a small creek that passes through the industrial area adjacent to the City of Kelowna and receives most of its waste loadings from industrial sources. The water quality in Brandt's Creek is the lowest in the basin with extremely high coliform densities very low oxygen content, and high concentrations of phosphorus, manganese, and iron. An industrial waste treatment plant is now being constructed in this area which should significantly improve the water quality of this tributary.

(vii) Inkaneep Creek

This creek is a tributary of Osoyoos Lake with cattle grazing and feed-lots in the lower reaches on Indian Reserve land. Phosphorus and coliform levels in this stream exceeded acceptable water quality standards.

In summary, most of the water quality problems in the tributaries occur either because of the natural characteristics of the watershed, or from point source loadings from municipal waste treatment plants, industries and agricultural operations. Logging operations in the tributary headwaters also contribute excess loadings of total phosphorus to many streams, although only a small percentage of this is normally in the soluble orthophosphorus form.

5.2 EFFECT OF LAND USE ON HATER QUALITY

During the period of July to October, 1972 a detailed but brief water quality survey was carried out on Kelowna and Lambly Creeks to provide a preliminary assessment of the effect of various forms of land use on stream water quality. The choice of these two Creeks was made on the basis of the number of existing hydrometric stations, prior information from water quality monitoring programs and accessibility.

The watersheds of the two creeks are situated directly across Okanagan Lake from one another. Lambly Creek, on the west side of the lake drains an area of 95 square miles and is the more rugged of the two. It is essentially undeveloped except for logging. In contrast the Kelowna Creek watershed, which has a drainage area of 86 square miles, is highly developed in its lower reaches. Although their drainage areas are approximately equal, the quantity of runoff during 1972 from Lambly Creek (58,800 acre feet) was about three times that of Kelowna Creek (18,700 acre feet). Of these total runoffs, 16% or 3,000 acre feet were recorded at the mouth of Kelowna Creek during the study period (July to October) as compared to 7% or 3,900 acre feet from Lambly Creek. This difference is largely due to the storage of water in the Kelowna Creek headwaters in the spring for release as irrigation water in the summer months.

The results presented below should be interpreted with care because of the short monitoring period and low volume of annual runoff which occurred during this period. Larger differences might be expected during the spring freshet or on a yearly basis.

The land use of these two basins, and the sub-divisions used for studying the effect of land use activities on water quality, are shown in Figures 5.3 and 5.4. In general these landuse activities may be summarized as follows:

Kelowna Creek - Range grazing in the upper reaches

- Irrigation for orchards in the lower reaches
- Industry between Rutland and Kelowna
- Domestic discharge to the ground below Rutland

Lambly Creek - Logging in the headwaters of Terrace Creek

- No activity in the remainder of the watershed

The estimated loadings of selected chemical constituents and their drainage area coefficients are shown in Tables 5.5 and 5.6. The drainage area coefficients were obtained by dividing the change in loading between monitoring stations by the area contributing to the creek. The accuracy of these results is largely dependent on the accuracy of stream flow measurements which in many

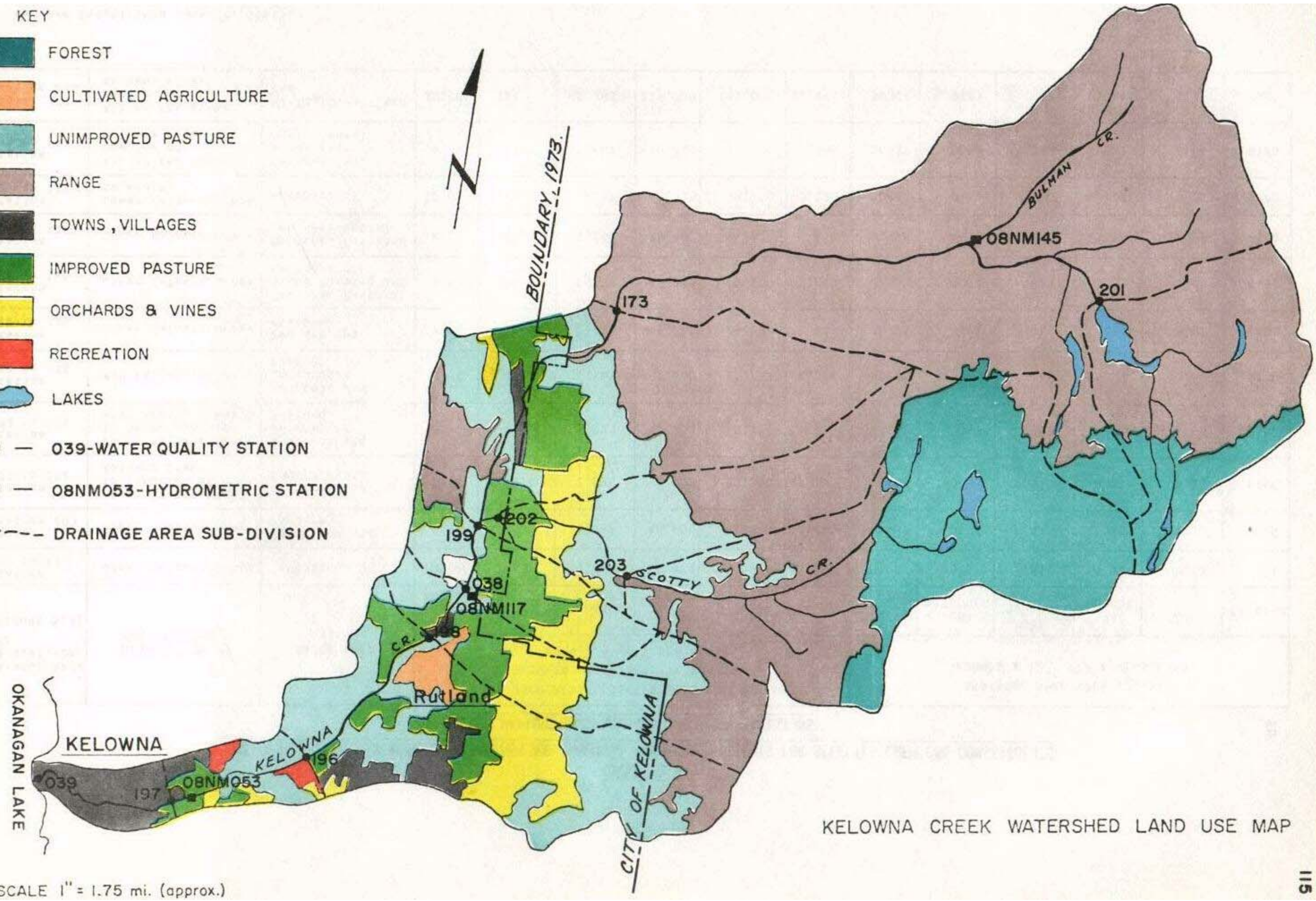

KEY
FOREST
CULTIVATED AGRICULTURE
UNIMPROVED PASTURE
RANGE
TOWNS, VILLAGES
IMPROVED PASTURE
ORCHARDS & VINES
RECREATION
LAKES
039-WATER QUALITY STATION
08NM053-HYDROMETRIC STATION
DRAINAGE AREA SUB-DIVISION
BOUNDARY, 1973.
BULMAN CR.
08NM145
201
173
202
199
203
SCOTTY CR.
038
08NM117
198
CR.
Rutland
KELOWNA
KELOWNA
196
197
08NM053
039
OKANAGAN LAKE
CITY OF KELOWNA
KELOWNA CREEK WATERSHED LAND USE MAP
SCALE 1" = 1.75 mi. (approx.)

Figure 5.3

TABLE 5.5

KELOWNA CREEK - INCREMENTAL LOADINGS AND DRAINAGE AREA COEFFICIENTS FOR SELECTED CHEMICAL CONSTITUENTS FROM VARIOUS LAND USE DRAINAGE SUB-DIVISIONS

DRAINAGE AREA SUB-DIVISION (SEE FIGURE 5.3)	DESCRIPTION OF SUB-DIVISION	MAJOR LAND USE	MEAN INCREMENTAL DIFFERENCES IN LOADING BETWEEN WATER QUALITY STATIONS POUNDS X 10^{-6} PER SECOND						DRAINAGE AREA COEFFICIENTS POUNDS X 10^{-6} PER ACRE-SECOND					
			ORTHO PHOS-PHORUS	KJELDAHL NITROGEN	TOTAL INORGANIC CARBON	TOTAL RESIDUE	FILTERABLE CARBON	CALCIUM	ORTHO PHOS-PHORUS	KJELDAHL NITROGEN	TOTAL INORGANIC CARBON	TOTAL RESIDUE	FILTERABLE RESIDUE	CALCIUM
Station 201 to 173	Upper Kelowna Creek	Rangeland	10.07	271	4,770	65,400	57,400	6,240	.00066	.0180	.316	4.33	3.80	.4131
Above Station 203	Upper Scotty Creek	Rangeland and Pasture	5.41	173	3,762	46,900	43,600	7,060	.00061	.0196	.428	5.33	4.96	.8025
Station 203 to 202	Lower Scotty Creek to junction of Kelowna Creek	Orchards and Improved Pasture	7.96	49.7	2,595	22,030	20,300	4,120	.00318	.0199	1.030	8.81	8.13	1.6450
Station 173 to 199	Upper Kelowna Creek to below junction with Scotty Creek	Improved and Unimproved Pasture	5.10	-43.5	5,333	40,200	40,100	11,490	.00071	-.0061	.750	5.65	5.64	1.6160
Station 199 to 038	Mid Kelowna Creek	Improved and Unimproved Pasture	3.34	97.7	2,567	37,600	25,700	4,370	.00177	.5170	1.360	19.90	13.60	2.3130
Station 038 to 198	Lower Kelowna Creek	Orchard and Pasture	12.28	-8.8	2,182	15,700	29,200	3,984	.00369	-.0027	.658	4.74	8.81	1.1860
Station 198 to 196	Lower Kelowna Creek	Orchard, Pasture, Mixed Farming and Residential	1.56	91.1	6,725	69,800	60,900	10,220	.00100	.0098	.724	7.51	6.55	1.0990
Station 196 to 197	Lower Kelowna Creek	Pasture, Parkland and Residential	-8.89	50.5	-1,240	-15,400	-13,900	-410	-.00976	.0553	-1.360	-16.90	-15.20	-.4500
Station 197 to 039	Lower Kelowna Creek to mouth.	Residential	-2.03	-14.1	-597	-2,320	-8,100	-3,073	-.00262	-.0169	-.720	-2.79	-9.76	-3.6900
Station 038 to 197	All of the lower portion of Kelowna Creek [1]	Residential, Industrial, Agricultural	4.95	133	7,667	70,200	76,300	13,900	.00037	.0099	.569	5.21	5.66	1.0200
Above Station 038	All of the upper portion of Kelowna Creek [2]	Agricultural Land Use	33.90	731	17,985	219,300	192,000	32,460	.00084	.0181	.452	5.44	4.75	.8020

1 Between Established Quantity Stations.

2 Above Established Quantity Station.

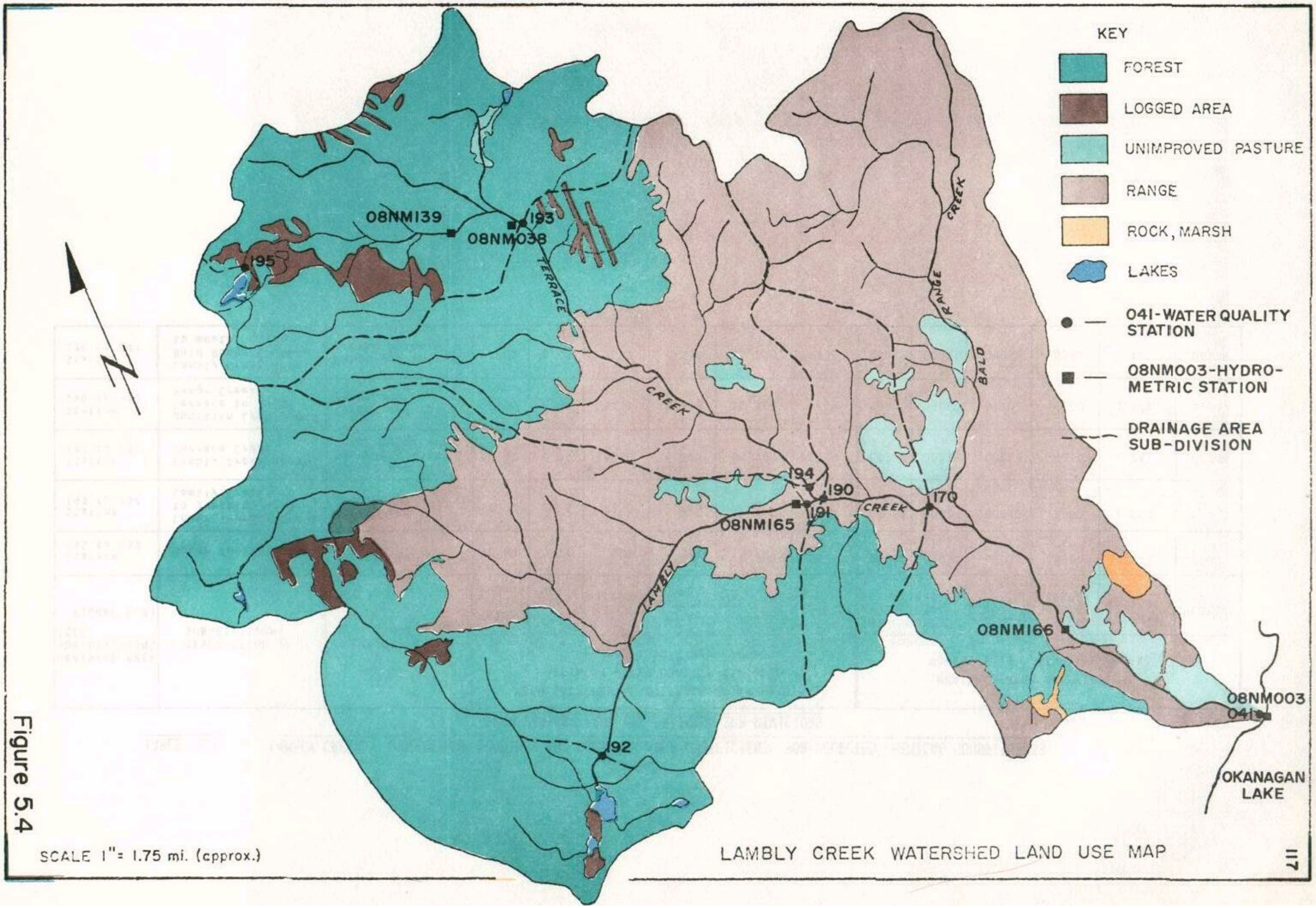


Figure 5.4 LAMBLY CREEK WATERSHED LAND USE MAP

TABLE 5.6 LAMBLY CREEK - INCREMENTAL LOADINGS AND DRAINAGE AREA COEFFICIENTS FOR SELECTED CHEMICAL CONSTITUENTS FROM VARIOUS LAND USE DRAINAGE SUB-DIVISIONS

DRAINAGE AREA SUB-DIVISIONS (SEE FIGURE 5.4)	DESCRIPTION OF SUB-DIVISIONS	MAJOR LAND USE	MEAN INCREMENTAL DIFFERENCES IN LOADINGS BETWEEN WATER QUALITY STATIONS POUNDS X 10^{-6} PER SECOND						DRAINAGE AREA COEFFICIENTS POUNDS X 10^{-6} PER ACRE-SECOND					
			TOTAL PHOS-PHORUS	ORTHO PHOS-PHORUS	KJELDAHL NITROGEN	TOTAL INORGANIC CARBON	FILTERABLE RESIDUE	CHLORIDE	TOTAL PHOS-PHORUS	ORTHO PHOS-PHORUS	KJELDAHL NITROGEN	TOTAL INORGANIC CARBON	FILTERABLE RESIDUE	CHLORIDE
Station 195 to 193	Upper Terrace Creek	Forest and Logging	0.89	0.14	1.5	344	2,390	8.1	.00010	.00001	.00017	.0390	.271	.00092
Station 193 to 194	Lower Terrace Creek to junction with Lambly Creek	Forest and Rangeland	4.02	2.85	72.3	2,748	19,360	87.9	.00051	.00024	.00610	.2660	1.633	.00742
Station 192 to 191	Lambly Creek above Terrace Creek	Forest and Rangeland with some logged areas	8.12	2.04	105.0	6,605	50,900	116.8	.00227	.00013	.00669	.4210	3.241	.00744
Station 190 to 170	Junction Lambly and Terrace to Bald Range Creek	Forest and Rangeland	9.80	2.62	47.6	2,748	16,260	75.2	.00033	.00060	.01106	.6550	3.777	.01749
Station 170 to 041	Lambly Creek from Bald Range Creek to mouth	Range and Unimproved Pasture	2.02	5.56	8.7	-538	38,270	154.3	.00012	.00035	.00054	-.0334	2.421	.00976

cases had to be estimated due to the lack of hydrometric gauging stations. The results for Lambly Creek are probably the more accurate as the five gauging stations on this creek are well distributed throughout the watershed. Negative loadings result either from the failure of the flow estimation model to account for groundwater flow into the creeks in the lower reaches, or from errors in the flow estimates.

5.2.1 Kelowna Creek Results

Analysis of the Kelowna Creek drainage area coefficients showed few significant differences among any of the parameters with the exception of drainage area 199 to 038. This indicates that the make up of different landuse activities has had little effect on water quality for the period sampled. The drainage area between stations 199 to 038 had significantly different coefficients for total residue, total fixed residue, calcium and hardness; and high values of Kjeldahl (organic nitrogen, total inorganic carbon and filterable residue. These observations tend to indicate an inflow of groundwater or return irrigation flow. The Kjeldahl nitrogen loadings from above station 038 were approximately five times greater than that between Station 038 and 197, and locations of livestock confinement losts in area 203 to 202, 199 to 038, and 198 to 196 correspond to the largest Kjeldahl nitrogen loadings recorded. Nitrate-nitrite loadings from area 038 to 197 were approximately six times greater than those from the area above station 038, indicative of groundwater loadings from such sources as irrigation and residential areas. The high occurrence of negative values for drainage area 197 to 039 and 196 to 197 results from negative loadings at these stations and indicates an error in the flow estimates.

5.2.2 Lambly Creek Results

Analysis of the Lambly Creek drainage area coefficients indicate that significant differences among stations occurred only in the four parameters;

total phosphorus, total inorganic carbon, filterable residue and chloride. No specific land use activity or point sources were found to explain the higher input of phosphorus between Station 192 to 191. The high drainage area coefficients for total inorganic carbon, filterable residue and chloride for the area between Stations 170 to 190, and to a lesser extent between 192 and 191, are indicative of the effects of soil disturbance in the form of road building, log yarding, landslides, and drainage from the well used logging roads that are tangent to the Creek at many points. On the other hand logging further removed from the Creek in the drainage area between Stations 195 and 193 did not result in higher drainage coefficients for that area over other areas on Lambly Creek.

The largest orthophosphorus loading to Lambly Creek originated from the area closest to the mouth. This could have been introduced to the stream by groundwater flow, or a portion of the total phosphorus solubilized between the last two stations. The differences in nitrogen loadings did not reflect any specific land use activities, the largest loadings occurring in the largest drainage areas.

5.2.3 Comparison of Lambly and Kelowna Creeks

For every parameter the maximum drainage area coefficients for Lambly Creek are lower than the maximums for Kelowna Creek. This is indicative of the different nature of the Creeks in terms of slopes, accessibility, population density, agriculture and near-creek activities. Coefficients for the upper reaches of Kelowna Creek were comparable to those for Lambly Creek where both areas are relatively similar in topography and land use.

5.2.4 Summary

While some general findings can be drawn from the study of land use on Lambly and Kelowna Creeks, it has not been possible to identify specific land use activities with specific coefficients that could be used to predict the effect of future economic growth on water quality in the basin as a whole. Conclusions that can be made within the limitations of the study period data are as follows:

(i) That forest-harvesting outside the immediate area of Lambly

Creek watercourse has had little effect on stream water quality.

(ii) That logging-road construction and logging activity close to

Lambly Creek has caused deterioration of stream water quality, as evidenced by significantly higher drainage area coefficients and high concentrations of indicator parameters.

(iii) That specific point-sources of pollution on Kelowna Creek have

more effect on water quality than general land use activities, and sources near the creek have a more direct effect than those located at a greater distance.

5.3 NUTRIENT LOADINGS TO THE MAIN VALLEY LAKES

Monitoring of significant sources of nutrients to the main valley lakes over the three study years has provided the estimate of mean total annual loadings shown in Table 5.7. The term 'nutrients' in this report refers to the elements nitrogen and phosphorus which are considered the most important elements in respect to the enrichment of the lake waters in recent years, and the resulting increase in biological productivity in the form of algal blooms and aquatic plant growth.

This estimate indicates that tributary streams and municipal outfalls together account for over 55% of the total nitrogen and 75% of the total phosphorus entering the main valley lakes. A brief description of each of these sources is presented below.

TABLE 5.7

SOURCES AND ESTIMATED ANNUAL INPUT
OF THE NUTRIENTS NITROGEN AND PHOSPHORUS
TO THE MAIN VALLEY LAKES

SOURCE	TOTAL NITROGEN		TOTAL PHOSPHORUS	
	Pounds	Percent	Pounds	Percent
Tributary Streams *[1]	628,740	36.6	77,540	31.3
Municipal Outfalls	326,000	19.0	115,120	46.5
Industrial Outfalls	29,200	1.7	1,960	0.8
Storm Sewers	5,700	0.3	700	0.3
Dustfall and Precipitation	216,000	12.6	23,020	9.3
Groundwater				
- Agriculture	192,260	11.2	1,520	0.6
- Septic Tanks	274,280	16.0	25,100	10.0
- Other	28,720	1.7	640	0.2
- Natural	15,520	0.9	2,560	1.0
Subtotal - Groundwater		29.8		11.8
TOTALS	1,716,420	100.0	248,160	100.0

*[1] Includes natural and diffuse loadings from agriculture and septic tank sources.

5.3.1 Tributary Streams

The stream monitoring program carried out over the two year period of July, 1969 to August, 1971 included only those streams considered to be representative of the major streams tributary to the main valley lakes. To provide an estimate of the total contribution of nutrients from all streams, loadings were pro-rated on the basis of monitored and total drainage basin areas for a given lake. A comparison of the number and drainage area of monitored streams, to the total for each of the main valley lakes is shown in Table 5.8.

Streams influenced by municipal and industrial waste discharges to surface waters (Vernon, Deep, Brandt, and Westbank Creeks) and those which connect the main Valley Lakes (Vernon Creek and Okanagan River), were not considered as representative tributary streams in respect to watershed quality and were omitted for this pro-rating procedure.

The annual input or loadings of nitrogen and phosphorus were estimated by first averaging all quality and quantity data obtained for each stream for the two year sampling period. The averaged flow and nutrient concentrations were then used to compute the average annual input (loading) from the stream in question. The loadings to each of the main valley lakes were obtained by

TABLE 5.8

COMPARISON OF STREAMS MONITORED
FOR WATER QUALITY TO TOTAL FOR BASIN

LAKE	MONITORED STREAMS		TOTAL FOR LAKE BASIN		Percentage of Drainage Basin Monitored
	Number	Drainage Area Square Miles	Number	Drainage Area Square Miles	
Wood	1	40	5	78	51
Kalamalka	1	79	5	139	57
Okanagan	21	1,545	47	1,885	82
Skaha	2	205	8	280	73
Vaseux	2	35	3	54	65
Osoyoos	2	75	7	144	52
TOTALS	29	1,979	75	2,580	77

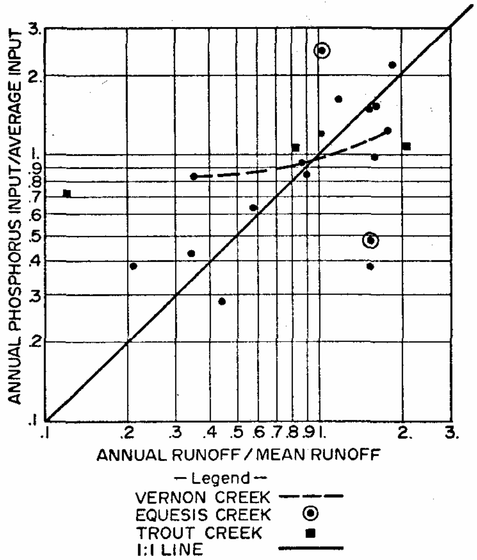
totalling individual stream inputs to the lake including estimates for unmonitored streams as obtained from the above pro-rating procedure.

To provide an estimate of the accuracy of these methods and results, a study was carried out on the variation in annual loadings with runoff for eight major tributaries using 1969-71 data and additional information obtained in 1972. The results of this study (Figure 5.5) indicate that loadings may vary from one half to two and a half times the mean loading between a dry year and a wet year. The nutrient input, based on average stream flows however, varies only by 7 to 12 percent from the 1969-71 estimates used in this report. The estimated annual loadings for tributary streams are therefore considered to be a reasonably accurate presentation of the long term contribution assuming 1971 development conditions.

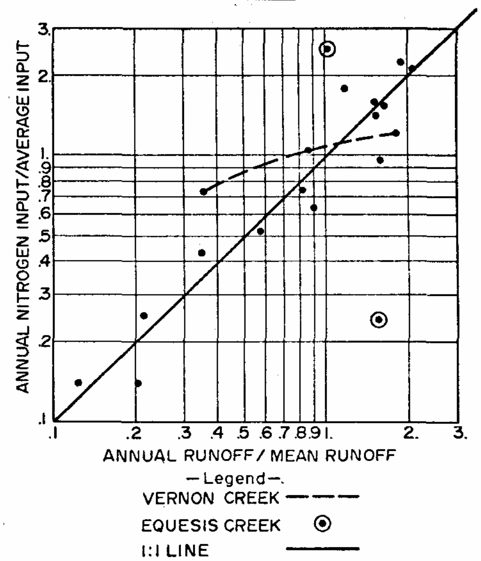
The nutrient input of individual streams was also assessed to determine the relative importance of each stream in the future control of nutrients. Nutrients and other chemicals in streams originate from plant and animal organic matter in the watershed, soil erosion, and dissolved minerals from bedrock and soil formations. Deforestation and other activities in a watershed will affect the rate of snowmelt and runoff to a stream and the amount of organic matter of erodable soils in the stream waters. Groundwater return flows and industrial and urban development will also contribute to stream loadings in the lower reaches.

A review of the estimated annual loadings of the major tributary streams (Figure 5.6) indicates that those streams with larger drainage areas generally contribute higher amounts of nutrients. The eight streams Mission, Trout, Shorts, Lambly, Deep, Kelowna, Whiteman and Coldstream - contributed over 60%

STANDARDIZED NUTRIENT LOADING CURVE FOR EIGHT TRIBUTARIES



STANDARDIZED PHOSPHORUS LOADING CURVE



STANDARDIZED NITROGEN LOADING CURVE

— RANGE OF ANNUAL RUNOFFS TO THE MAIN VALLEY LAKES FOR EIGHT MAJOR TRIBUTARIES - 1970 DEVELOPMENT CONDITIONS.

CREEK NAME	DRY YEAR ACRE FEET	AVERAGE YEAR ACRE FEET	WET YEAR ACRE FEET	1969-1971 MEAN ACRE FEET
TROUT CREEK	11,700	41,200	108,600	30,500
MISSION CREEK	66,000	107,300	202,000	116,700
VERNON CREEK	11,100	28,960	80,900	20,700
KELOWNA CREEK	2,090	7,320	23,200	8,400
PEACHLAND CREEK	6,880	12,200	24,300	7,200
PENTICTON CREEK	11,200	23,700	47,060	16,700
EQUESIS CREEK	9,210	16,800	33,000	12,700
POWERS CREEK	2,900	8,530	20,500	14,300
TOTAL FOR 8 CREEKS	121,000	246,000	539,600	227,200
RATIO TO 1969-1971 ESTIMATE	0.54	1.08	2.38	1.00

— RANGE OF ANNUAL NUTRIENT INPUTS TO THE MAIN VALLEY LAKES FOR EIGHT MAJOR TRIBUTARIES - 1970 DEVELOPMENT CONDITIONS.

NUTRIENT INPUT	TOTAL PHOSPHORUS				TOTAL NITROGEN			
CREEK NAME	DRY YEAR POUNDS	AVERAGE YEAR POUNDS	WET YEAR POUNDS	1969-1971 MEAN POUNDS	DRY YEAR POUNDS	AVERAGE YEAR POUNDS	WET YEAR POUNDS	1969-1971 MEAN POUNDS
TROUT CREEK	4,600	16,400	43,400	12,200	16,200	57,000	150,200	42,200
MISSION CREEK	9,000	14,600	27,400	15,800	83,800	136,200	256,600	148,200
VERNON CREEK*	800	2,200	6,200	1,600	20,600	56,600	157,800	40,400
KELOWNA CREEK	600	2,200	7,200	2,600	6,800	23,800	75,600	27,400
PEACHLAND CREEK	800	1,400	2,800	800	14,600	25,800	51,400	15,200
PENTICTON CREEK	1,000	2,200	4,600	1,600	14,000	29,800	59,200	21,000
EQUESIS CREEK	1,400	2,400	4,600	1,800	8,200	15,000	29,600	11,400
POWERS CREEK	400	1,000	2,200	1,600	7,000	20,400	49,000	34,200
TOTAL FOR 8 CREEKS	18,600	42,400	98,400	38,000	171,200	364,600	829,400	340,000
RATIO TO 1969-1971 ESTIMATE	0.50	1.12	2.59	1.00	.051	1.07	2.44	1.00

* Does not include loadings from Vernon Sewage Treatment Plant.

SOURCE - Technical Supplement IV Okanagan Basin Study.

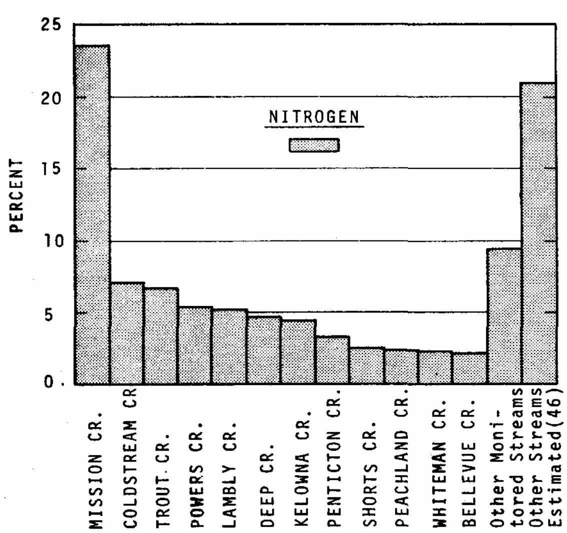
ESTIMATED VARIATION IN ANNUAL NUTRIENT LOADINGS WITH STREAMFLOW FOR EIGHT MAJOR TRIBUTARIES

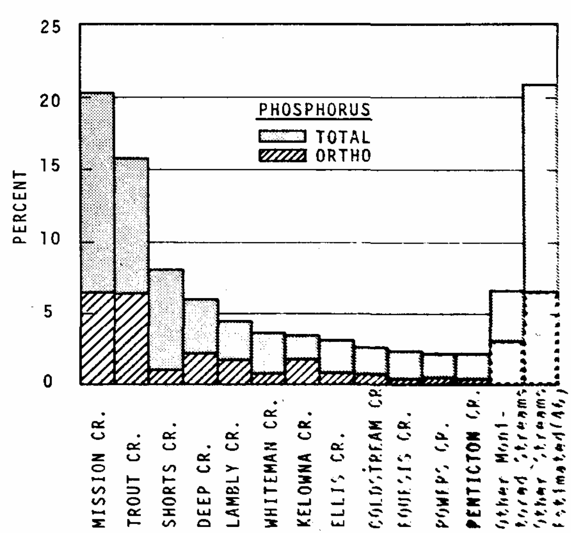
Figure 5.5

TRIBUTARY STREAM AND LAKE BASIN	DRAINAGE AREA IN SQUARE MILES	TOTAL NITROGEN		TOTAL PHOSPHORUS		ORTHO PHOSPHORUS	
		POUNDS PER YEAR	PERCENT OF TOTAL	POUNDS PER YEAR	PERCENT OF TOTAL	POUNDS PER YEAR	PERCENT ORTHO TO TOTAL PHOSPHORUS
WOOD LAKE							
Vernon Cr. (to Wood Lake)	40.0	10,000	1.6%	400	0.5%	160	40%
KALAMALKA LAKE							
Coldstream Cr.	79.3	44,800	7.1%	2,000	2.6%	700	35%
OKANAGAN LAKE							
Deep Cr. *	99.0	29,600	4.7%	4,600	5.9%	1,700	37%
Shorts Cr.	72.0	16,000	2.5%	5,400	7.0%	780	14%
Whiteman Cr.	76.0	14,600	2.3%	2,800	3.6%	1,460	20%
Equesis Cr.	77.0	11,400	1.8%	1,800	2.3%	720	16%
Nashwito Cr.	31.7	600	0.1%	800	1.0%	220	11%
Peachland Cr.	58.9	15,200	2.4%	800	1.0%	300	37%
Trepanier Cr.	99.6	10,000	1.6%	1,000	1.3%	380	15%
Powers Cr.	55.8	34,200	5.4%	1,600	2.1%	860	21%
Westbank (Smith)Cr.*	4.3	1,200	0.2%	0	-	0	-
McDougall Cr.	18.6	1,000	0.2%	200	0.3%	220	11%
Bellevue Cr.	34.0	13,800	2.2%	800	1.0%	340	42%
Mission Cr.	336.1	148,200	23.5%	15,800	20.3%	5,060	32%
Kelowna (Mill) Cr.	85.9	27,400	4.4%	2,600	3.4%	1,320	51%
Lambly (Bear) Cr.	103.3	32,800	5.2%	3,400	4.4%	1,320	39%
Pentiction Cr.	69.5	21,000	3.3%	1,600	2.1%	260	16%
Trout Cr.	289.4	42,200	6.7%	12,200	15.7%	4,980	40%
Chute Cr.	34.1	400	0.1%	0	-	0	-
SKAHA LAKE							
Shingle Cr.	117.1	6,000	1.0%	600	0.7%	120	20%
Ellis Cr.	64.6	10,000	1.6%	2,400	3.1%	600	25%
McLean Cr.	23.0	200	-	0	-	0	-
VASEUX LAKE							
Shuttleworth Cr.	35.0	6,200	1.0%	200	0.3%	60	30%
OSOYOOS LAKE							
Inkaneep Cr.	75.3	1,000	0.2%	400	0.5%	120	30%
MONITORED TRIBUTARY STREAM SUBTOTALS	1979.5	497,800	79.1%	61,400	79.1%	21,680	35%
OTHER STREAMS (ESTIMATED)	601.7	131,200	20.9%	16,200	20.9%	5,060	31%
TOTAL - TRIBUTARY STREAMS	2581.2	629,000	100%	77,600	100%	26,740	34%

*Note Figures shown exclude contributions to streams from Municipal outfalls

RELATIVE NUTRIENT CONTRIBUTIONS OF TRIBUTARY STREAMS





ESTIMATED ANNUAL LOADINGS OF NUTRIENTS TO THE MAIN VALLEY LAKES FROM TRIBUTARY STREAMS Figure 5.6

of the total input of nitrogen and phosphorus to the main valley lakes between 1969-71. Those creeks in sparsely developed areas - Shorts, Whiteman, Naswhito, etc, contributed significant amounts of total phosphorus, but less than 20% of this was in the soluble orthophosphorus form.

Estimates of the portion of loadings to streams that occur from agricultural and septic tank sources are shown in Tables 5.9a and b. These loadings are primarily from surface runoff or groundwater which enters the tributary streams and has been measured as a part of the total stream loading.

TABLE 5.9a

ESTIMATED LOADING OF NITROGEN TO STREAMS
FROM NATURAL, AGRICULTURAL AND SEPTIC TANK SOURCES
Pounds Per Year

STREAMS TRIBUTARY TO	NATURAL	AGRICULTURAL SOURCES	SEPTIC TANK SOURCES	TOTAL
Wood Lake	20,000*	Not estimated	Not estimated	20,000
Kalamalka Lake	55,760	14,900	8,340	79,000
Okanagan Lake	344,200	85,220	66,800	496,220
Skaha Lake	3,620	16,060	2,520	22,200
Vaseux Lake	6,340	40	3,220	9,600
Osoyoos Lake	100	1,000	620	1,720
TOTALS	430,020	117,220	81,500	628,740
PERCENT	68%	19%	13%	100%

* Includes inflow to Wood Lake from Vernon Creek and diffuse loadings from agricultural and septic tank sources.

5.3.2 Municipal Outfalls

Six municipalities currently (1971) discharge treated waste effluent into the surface waters of the basin. The estimated annual inputs of nutrients from these municipal discharges is shown in Table 5.10. The figures are based on a two-year monitoring period, the mean concentrations of nutrients from all samples taken, and the mean annual discharge from each treatment plant. Orthophosphorus loadings, which represent the soluble portion of total phosphates, have been included to show the high percentage of this element that is in the soluble form following secondary (biological) treatment as compared to the low percentage that is in the soluble form in tributary stream discharges (Figure 5.6).

TABLE 5.9b

ESTIMATED LOADING OF PHOSPHORUS TO STREAMS
FROM NATURAL, AGRICULTURAL AND SEPTIC TANK SOURCES
Pounds Per Year

STREAMS TRIBUTARY TO	NATURAL	AGRICULTURAL SOURCES	SEPTIC TANK SOURCES	TOTAL
Wood Lake	800*	Not estimated	Not estimated	800
Kalamalka Lake	3,080	20	500	3,600
Okanagan Lake	60,500	2,820	4,560	67,880
Skaha Lake	3,640	340	220	4,200
Vaseux Lake	-	-	260	260
Osoyoos Lake	700	60	40	800
TOTALS	68,720	3,240	5,580	77,540
PERCENT	89%	4%	7%	100%

* Includes inflow to Wood Lake from Vernon Creek and diffuse loadings from agricultural and septic tank sources.

TABLE 5.10

ESTIMATED ANNUAL INPUT OF NUTRIENTS TO SURFACE
WATERS FROM MUNICIPAL OUTFALLS

		ESTIMATED ANNUAL LOADING Pounds/Year			
Municipality	Point of Discharge	Total Nitrogen	Total Phosphorus	Ortho-Phosphorus	Percent Ortho-phosphorus Total Phosphorus
Armstrong	Deep Creek	10,400	4,140	3,420	83%
Vernon	Vernon Creek	76,320	35,540	29,700	84%
Kelowna	Okanagan Lake	115,540	40,840	34,600	85%
Westbank	Smith Creek	3,460	1,640	1,460	89%
Penticton	Okanagan River	112,180	28,900	23,040	80%
Oliver	Okanagan River	8,100	4,060	3,660	90%

The accuracy of the figures shown in Table 5.10 is dependent primarily on the accuracy of the flow measurements and is considered to be within 10% of the values shown.

During the summer and fall of 1971 the City of Vernon diverted approximately 50% of its treated discharge to a pilot spray irrigation project. This was taken into account when determining the mean annual discharge of nutrients to Vernon Creek from this municipal outfall. In 1971 the City of Penticton completed a chemical tertiary treatment unit for the removal of phosphorus, but this unit was not in operation during the monitoring period and the effect of this facility is not reflected in the values shown. The amount of phosphorus removed by this tertiary unit in 1972-73 has been estimated at 50 to 60%.

5.3.3 Industrial Outfalls

Thirteen major industrial outfalls (waste effluent discharged to surface waters) were monitored on a monthly basis between August, 1969 and July, 1971. These outfalls included all the major industrial waste discharges in terms of volume and organic loads, and several of the small industrial establishments considered to be representative of numberous other plants of the same category. In addition, 36 minor outfalls were sampled at least twice during the monitoring period. Data collected on those industries with positive discharges to surface waters were used to estimate the annual nutrient loadings from each industrial source as shown in Table 5.11. Those industries which discharge their waste effluent into ground disposal systems are considered as groundwater sources. As in the case of streams and municipal outfalls mean concentration's and mean discharges were used to estimate annual loadings for industrial outfalls.

The total contribution of nutrients from industrial outfalls represents less than two percent of the total annual input of nutrients from a11 other sources and except for local problems which they may cause, are not currently of prime importance in the control of nutrients to surface waters.

The accuracy of the loadings from industrial outfalls is almost directly proportional to the accuracy of flow measurements which could be in error by a factor or 50%. The flows of these outfalls were not monitored on a continuous basis, but rather were estimated at the time of sampling. This percentage error will not seriously affect the results because of the negligible amounts involved under 1971 development conditions.

5.3.4 Storm Sewers

A study to determine the amount of nutrients and other impurities discharging into the surface waters of the Basin from the storm sewers of the cities

TABLE 5.11

ESTIMATED ANNUAL INPUT OF NUTRIENTS TO SURFACE WATERS FROM INDUSTRIAL OUTFALLS

Industrial Source	Point of Discharge	ESTIMATED ANNUAL LOADING Pounds/Year			Percent Ortho-phosphorus To Total Phosphorus
		Total Nitrogen	Total Phosphorus	Ortho-Phosphorus	
Okanagan Beverages and Calona Wines	Brandt's Creek	80	100	26	26
Kelowna Growers Exchange and Sun-Rype No. 2	Brandt's Creek	980	280	66	24
American Can Company	Brandt's Creek	Trace	Trace	Trace	--
Cascade Co-Op	Brandt's Creek	100	20	10	50
S.M. Simpson Ltd.	Okanagan Lake	120	300	2	1
Kelowna Memorial Arena	Kelowna Storm Sewer	Trace	Trace	--	--
B. C. Orchards Co-Op	Okanagan Lake	360	140	78	56
Kelowna Beverages and OK Packers	Okanagan Lake	1,640	160	64	40
Pyramid Co-Op	Okanagan Lake	Trace	Trace	Trace	--
Naramata Co-Op	Okanagan Lake	20	20	6	20
Fish and Wildlife Hatchery*1	Okanagan Lake	14,460	380	134	35
Cornwall Canners Limited	Okanagan Lake	660	220	122	55
McLean & Fitzpatrick	Osoyoos Lake	4,640	20	0	--
Oliver-Osoyoos Co-Op	Osoyoos Lake	5,300	80	56	70
International Curling Club	Osoyoos Lake	380	20	8	40
Monashee Co-Op	Osoyoos Lake	100	80	44	55
Total Other Industries		360	140	--	--
TOTAL POUNDS PER YEAR		29,200	1,960	616	34 (Average)

*1 The Fish and Wildlife Hatchery at Summerland obtains its water from Shaughnessey Spring. This water supply is contaminated by nitrates having a mean total nitrogen concentration of 4 milligrams per liter. This contamination is reflected in the annual effluent loadings from the Hatchery (Ref. Technical Supplement VI).

of Vernon, Kelowna and Penticton, was carried out through the spring and summer of 1972. The storm sewer system in each city is completely separate from the sewage collection system and these three represent the only ones in the basin in 1971. The annual loadings from this source were determined by combining the concentrations of nutrients found in samples of storm sewer water from both snowmelt and rainfall, with the volume of storm water discharged by each city. The volume of storm water was based on annual precipitation, drainage area, and an estimate of the percentage of rainfall actually discharged through the storm sewers (coefficient of runoff). The results of this study are summarized in Table 5.12.

TABLE 5.12

ESTIMATED ANNUAL DISCHARGE OF NUTRIENTS FROM STORM SEWERS TO SURFACE WATERS

CITY	Area Served by Storm Sewers (acres)	Average Annual Precipitation (inches)	Total Nitrogen (pounds)	Total Phosphorus (pounds)	Soluble Phosphorus (Orthophosphorus) Percent
Vernon	1,100	15.22	2,560	380	19
Kelowna	655	12.09	920	180	14
Penticton	1,300	11.32	2,220	140	25
TOTAL IN POUNDS			5,700	700	

The information obtained under this study was considered to be the minimum required to obtain an indication of the order of magnitude of nutrients from this source. The accuracy is therefore limited, but due to the small amount involved compared to the total of all sources (less than one half percent) this source is not considered as significant at this time.

5.3.5 Dustfall and Precipitation

Twenty-three sampling stations for this study were selected on sites adjacent to the main valley lakes and near populated areas and monitored for the period October, 1971 to September, 1972. Samples were collected in tubular plastic dustfall containers and exposed to the atmosphere for monthly periods before retrieval and analysis. The stations selected were considered to be the minimum number to provide an estimate of the nutrient contribution from dustfall and precipitation on the surfaces of the lakes. The median areal distribution of soluble nutrients obtained from the sampling stations was calculated using the analytical results and the monthly wind frequency as measured at Penticton. This wind frequency was assumed to be representative of the wind frequency throughout the Okanagan Valley. The median areal distribution of nutrients was then combined with the surface area of each respective lake to provide an estimate of the annual input of nitrogen and phosphorus from dustfall and precipitation.

The results of this study indicate that this source of nutrients represents a significant input (10%) to the lake system (Table 5.13). The accuracy of these results is considered as acceptable for providing order of magnitude figures only, although they are generally in agreement with other published data on dustfall and precipitation for other lake basins in Canada and the United States. One of the problems encountered with some sampling stations was contamination because of their accessiblity to the public. While the samples were filtered prior to analysis and only the soluble portion of the sample analysed, some error may have been introduced into the results because of foreign material being deliberately introduced into some of the sample containers.

TABLE 5.13

ESTIMATED ANNUAL INPUT OF TOTAL SOLUBLE NITROGEN AND PHOSPHORUS INTO THE MAIN VALLEY OKANAGAN LAKES FROM DUSTFALL AND PRECIPITATION

Main Valley Lake	Lake Surface Area (Square Miles)	Median Areal Distribution Pounds/Square Mile/Month		Estimated Annual Loading (Pounds)	
		Total Phosphorus (PO_4)	Total Nitrogen	Total Phosphorus (P)	Total Nitrogen (N)
Wood	3.46	10	90	140	3,800
Kalamalka	9.68	16	80	600	9,200
Okanagan					
- North	36.12	150	112	5,900	48,600
- Central	63.99	20	74	4,960	56,800
- South	34.10	66	160	8,740	65,400
Skaha	7.58	56	248	1,660	22,600
Vaseux	1.02	8	292	40	3,600
Osoyoos*	5.77	44	88	980	6,000

* Canadian portion of lake only.

5.3.6 Groundwater

Groundwater sources encompass all nutrients transported to the surface water system by groundwater flows. These nutrient sources include agriculture, septic tanks, and other unidentified sources including those which occur naturally through the dissolving of various elements by moving water. These groundwater sources in general represent the greatest unknown of all nutrient sources due primarily to the difficulty in measuring groundwater flows. Part of the water that falls as precipitation on the watershed percolates through the soil to the groundwater table and eventually finds its way to the surface waters of tributary streams and the main valley lakes. In the Okanagan Basin this is augmented by groundwater return flows from irrigation. Studies of the latter indicate that up to 50% of the water applied for irrigation purposes eventually returns to the lake system, and is considered to make up the largest portion of the total groundwater flow in irrigated areas. The transport of this water through the ground is very slow however, and it's ultimate destination very difficult to determine. Part of the return flow from irrigation water applied during April to November, for example, may not return to the surface water system for 6 to 12 months. Therefore while estimates of the concentrations of nutrients in the groundwater can be determined fairly accurately, the groundwater flow and resulting loadings are much more difficult to assess.

Four studies were undertaken in an attempt to provide order of magnitude figures on the amounts of nutrients entering the main valley lakes via groundwater. These groundwater sources include both direct drainage to the lakes as well as groundwater flows to tributary streams. The studies included a theoretical analysis of all potential source loadings, augmented by pilot studies on septic tanks, land fills, and spray irrigation-lysimeter tests. The study on source loadings involved the documentation of all nutrients that might ultimately reach receiving waters in the ground. These included such sources as irrigation water, fertilizers, agricultural animals, wildlife, dustfall and decaying organic matter. A larger percentage of these groundwater loadings return to the tributary streams themselves and therefore have been measured as part of the stream loadings. The remaining groundwater enters the main valley lakes directly. The pilot studies on septic tanks, land fills, and spray irrigation-lysimeter tests were carried out in conjunction with the waste treatment section. Briefly, they provide information on the transport of water and nutrients through various soil types under controlled conditions.

Estimates of the position of groundwater source loadings that return to the tributary streams were presented in Table 5.9. Groundwater source loadings that return directly to the main valley lakes are shown in Tables 5.14a arid 5.14b.

These results indicate that groundwater contributes approximately 26% of the total nitrogen and 12% of the total phosphorus entering the main valley lakes. Nitrogen is a transient element which is readily transported by water through the soil, while phosphorus becomes bonded with the soil particles and is transported only when conditions of excess phosphorus occur. Most of the phosphorus that is transported however, is in the soluble (orthophosphorus) form, and the orthophosphorus loadings may be considered equal to the total phosphorus loadings.

The overall accuracy of these results is considered to be correct to within one order of magnitude, but greater variations may occur within the basin as a

TABLE 5.14 a

ESTIMATED ANNUAL INPUT OF TOTAL NITROGEN TO THE MAIN VALLEY LAKES FROM GROUNDWATER

	Agriculture	Septic Tanks	Other	Natural
Wood	9,860	17,160	2,440	1,220
Kalamalka	4,340	10,220	500	440
Okanagan	93,060	129,960	18,240	6,140
Skaha	15,480	27,560	4,520	1,360
Vaseux	4,920	2,980	600	1,620
Osoyoos	64,600	86,400	2,420	4,740
	192,260	274,280	28,720	15,520
Total Nitrogen Input via Groundwater, Pounds per Year				510,780

TABLE 5.14_b

ESTIMATED ANNUAL INPUT OF TOTAL PHOSPHORUS TO THE MAIN VALLEY LAKES FROM GROUNDWATER

	Agriculture	Septic Tanks	Other	Natural
Wood	400	1,660	260	40
Kalamalka	20	940	-	20
Okanagan	520	11,060	240	2,060
Skaha	40	2,600	60	160
Vaseux	20	280	20	80
Osoyoos	520	8,560	60	200
	1,520	25,100	640	2,560
Total Phosphorus Input via Groundwater, Pounds per Year				29,820

whole. Further, since phosphorus has been considered as the key element in controlling lake enrichment, this degree of error will not have the same importance on the overall results as it would had nitrogen been indicated as the controlling element.

5.3.7 Summary

A series of studies were carried out to determine the sources- and amounts of the nutrients nitrogen and phosphorus entering the main valley lakes. The results of this study are summarized in Table 5.7 and Table 5.15. The main purpose of these investigations was to identify significant sources of these nutrients and to determine if these can be controlled to maintain or enhance the water quality of the main valley lakes for consumptive use, recreations, and aesthetic enjoyment. Based on limnological findings and recommendations,

TABLE 5.15

MAJOR NUTRIENT LOADINGS TO THE MAIN VALLEY LAKES

ESTIMATED ANNUAL INPUT OF TOTAL PHOSPHORUS INTO THE MAIN VALLEY LAKES -1971

LAKE		ANNUAL LOCAL WATERSHED LOADINGS - POUNDS PER YEAR 1969-1971						CONTRIBUTED FROM UPSTREAM LAKE OUTFLOW (lb/yr)	TOTAL LOADING TO LAKE (lb/Yr)
		TRIBUTARY STREAMS[2]	MUNICIPAL TREATMENT PLANTS	DUSTFALL AND PRECIPITATION	GROUNDWATER SEPTIC TANKS	OTHER SOURCES*1	SUBTOTAL		
WOOD		800	-	140	1,660	720	3,320	-	3,320
KALAMALKA		3,600	-	600	940	40	5,180	-	5,180
	North	19,480	39,680	5,900	1,560	920			
OKANAGAN	Central	29,800	42,480	4,960	4,840	2,620	185,720	1,600	187,320
	South	18,600	-	8,740	4,660	1,480			
SKAHA		4,200	28,900	1,660	2,600	500	37,860	10,600	48,460
VASEUX		260	-	40	280	120	700	18,800	19,500
OSOYOOS (Canada)		800	4,060	980	8,560	980	15,380	22,140	37,520
SUB TOTALS		77,540	115,120	23,020	25,100	7,380	248,160	53,140	301,300

*1 Includes Industrial Outfalls, Storm Sewers, and Groundwater from Agricultural Land and Natural Sources.

*2 Includes Natural and Diffuse Loadings to streams from Agriculture and Septic Tank Sources

ESTIMATED ANNUAL INPUT OF TOTAL NITROGEN INTO MAIN VALLEY LAKES - 1971

LAKE		ANNUAL LOCAL WATERSHED LOADINGS - POUNDS PER YEAR (MEAN VALUES)							CONTRIBUTED FROM UPSTREAM LAKE OUTFLOW (lb/Yr)	TOTAL LOADING TO LAKE (lb/Yr)
		TRIBUTARY*2 STREAMS	MUNICIPAL TREATMENT PLANTS	DUSTFALL AND PRECIPITATION	GROUNDWATER SEPTIC TANKS	AGRICULTURE	OTHER*3 SOURCES	SUBTOTALS		
WOOD		20,000	-	3,800	17,160	9,860	3,760	54,580	-	54,580
KALAMALKA		79,000	-	9,200	10,220	4,340	940	103,700	-	103,700
	North	87,820	86,720	48,600	18,160	12,560	4,880			
OKANAGAN	Central	322,400	119,000	56,800	55,600	43,980	12,960	1,142,760	40,400	1,183,160
	South	86,000	-	65,400	56,200	36,520	29,160			
SKAHA		22,200	112,180	22,600	27,560	15,480	7,640	207,660	181,600	389,260
VASEUX		9,600	-	3,600	2,980	4,920	2,220	23,320	268,800	292,120
OSOYOOS (Canada		1,720	8,100	6,000	86,400	64,600	17,580	184,400	317,800	502,200
SUB TOTALS		628,740	326,000	216,000	274,280	192,260	78,800	1,716,420	808,600	2,525,020

*3 Includes Industrial Outfalls, Storm Sewers, and Groundwater from Natural Sources.

phosphorus was subsequently determined to be the element which should be limited to control lake enrichment and biological growth. Studies on loading sources of these nutrients support this choice. The estimated amount of nitrogen entering the main valley lakes is about seven times greater than that of phosphorus, and only about 30% of this loading can be considered as controllable by current technological methods.

Approximately 60% of the phosphorus loadings are considered controllable, the major portion of which comes from municipal outfalls and septic tanks. Further, the evaluations presented later in this report indicate that the control of these two sources will probably meet the desired objective of maintaining or enhancing the quality of the main valley lakes over and in some cases beyond the study horizon of 2020. This does not infer that long-term measures to control other sources of nutrients should not be examined, tested and if feasible, implemented. Tributary streams, for example, represent the second largest source of phosphorus and the protection of major streams by permanent green belts could significantly reduce phosphorus loadings. The implementation and assessment of such a program however, could take a number of years and the effects may take much longer to materialize.

5.4 WASTE TREATMENT PILOT PROJECTS

Waste collection and treatment systems are used to process urban wastes for public health and aesthetic reasons. These wastes are ultimately discharged to the streams and lakes of the valley where they are assimilated as food by plant and animal life. The waters of the basin therefore play an essential role as receiving waters for man's wastes. The assimilative capacity of these lakes however, is limited and increasing levels of treatment are often required to offset increased waste loadings and maintain an acceptable balance of food and biological productivity in the lake environment.

A number of pi lot studies and test installations were undertaken as part of the water quality studies to determine the feasibility and value of advanced waste treatment processes for the control of nutrient discharges, and problems associated with waste disposal. These included:

- A review and Evaluation of Advanced wastewater Treatment Methods.
- A Lysimeter Spray Irrigation Study
- Monitoring of Spray Irrigation of Sewage Treatment Plant Effluent at Vernon.
- Phosphorus Removal by Lime Treatment
- Influence of Septic Tank Effluent on Receiving water Nutrient Gain from Groundwater
- Nutrient Contributions from Refuse Disposal Sites.

The results of each of these studies are summarized in this section.

5.4.1 Review of Present Treatment Practices

Of an estimated 115,000 people in the basin (1971) 56,000 (50%) were on municipal collection and sewage treatment systems, leaving 59,000 (50%) on septic tank installations. Of a known 52 industrial producers of waste products, 9 discharge through ground filtration systems, 12 are primarily cooling water effluent, and the balance are untreated.

Municipal sewage treatment systems in the Okanagan Basin include secondary treatment plants or lagoons. The primary purpose of both types of systems is to separate the solid wastes from the liquid wastes by biological treatment and settling ponds, so that the clarified effluent can be disposed of to surface waters. The liquid waste represents by far the largest portion of sewage and comes primarily from the water used to transport the solid wastes to the treatment plant. Secondary treatment also reduces organic loadings in the treated effluent which otherwise would reduce or deplete the dissolved oxygen content of surface waters. Before discharging, the clarified effluent is chlorinated to remove pathogenic bacteria. The above is referred to as secondary or 'conventional' treatment in this report, as compared to advanced or tertiary treatment which is primarily for the removal of nutrients. Tertiary treatment for the removal of phosphates has recently been installed in Penticton, and Vernon has initiated an experimental program of spray irrigation, using secondary effluent as an advanced form of treatment.

While the present level of waste treatment in the Okanagan is equal to or better than that of most other parts of Canada or North America, certain problems do exist in the conventional treatment processes that require correction before advanced or tertiary treatment can really be effective. These include the age and in some cases outdated forms of conventional treatment, and the overloading of the plants in the summer months due to the heavy influx of tourists. The studies and findings on advanced treatment in this report assume that a high standard of conventional treatment is maintained at all times.

5.4.2 Review and Evaluation of Advanced Wastewater Treatment Methods

A literature review of advanced wastewater treatment methods with emphasis on removal of nutrients, was carried out as a prelude to selecting those that seemed most appropriate for testing under local conditions. This review included an assessment of the efficiency, cost and ease of operation of each nutrient removal method. A comparison of these nutrient removal processes and their costs is included in Table 5.16. Based on this review, and the consideration of these processes by a group of consulting engineers on waste treatment for the major urban centers in the Valley, it was recommended that the pilot studies include the monitoring of a pilot spray irrigation system being installed by the City of Vernon, a lysimeter study at Penticton to determine the suitability of Okanagan soils for wastewater treatment, and a pilot study in-

TABLE 5.16

COMPARSION OF NUTRIENT REMOVAL PROCESSES*

PROCESS	CLASS	REMOVAL EFFICIENCY Percent	ESTIMATED COST Dollars per Million Gallons	WASTES TO BE DISPOSED OF	REMARKS
Ammonia stripping	Chemical	80-98	9- 25	-	Efficiency based on ammonia nitrogen only.
Anaerobic denitrification	biological	60-95	25- 30	none	
Algae harvesting	biological	50-90	20- 35	liquid and sludge	Large land area needed.
Conventional biological treatment	biological	30-50 nitrogen 10-30 phosphorus	30-100	sludge	
Ion exchange	chemical	80-92 nitrogen 86-96 phosphorus	170-300	liquid	Efficiency and cost depend on degree of pretreatment.
Electrochemical treatment	chemical	80-85	4-8	liquid and sludge	
Electrodialysis	chemical	30-50	100-250	liquid	Cost based on 1-10 mgd capacity, 1000 p.p.m. solids.
Reverse osmosis	physical	65-95	250-400	liquid	
Distillation	physical	90-98	400-1000	liquid	
Land application	physical	60-90 phosphorus	75-150	none	Large land area needed.
Modified activated sludge	biological	60-80	30-100	sludge	
Chemical precipitation	chemical	88-95	10-70	sludge	
Chemical precipitation with filtration	chemical	95-98	70-90	liquid and sludge	
Sorption	chemical	90-98	40-70	liquid and solids	Cost based on water treatment costs.

* From Eliasson and Tchobanogious (13)

volving lime addition to raw sewage for the purpose of phosphorus removal in the City of Kelowna treatment plant. The latter involved an evaluation of the feasibility for adapting existing facilities in Kelowna to handle this advanced treatment process.

Pilot installations for the removal of nitrogen were considered, but not included because of similar studies being carried out by the Canada Centre for Inland Waters, and because of expected difficulty in controlling sufficient amounts of this element in the basin to warrant its removal from waste effluents only.

5.4.3 Lysimeter Spray Irrigation Study at Penticton B.C.

This study was designed to provide information concerning the ability of three typical Okanagan Basin soils to act as conditioners of secondary effluent from sewage treatment plants, when crops are grown as an integral part of the operation. It was considered that if spray irrigation of treated sewage is to be used as a method of preventing nutrients from reaching the surface waters of the basin, then it must be determined in advance that this is a viable method in those areas of the basin that have nutrient problems. A. lysimeter consists of an enclosed unit of soil which permits tests to be carried out under controlled conditions (Figure 5.7).

The parameters considered the most important in these tests were soil type, crop type, and rate of wastewater application. Thirty individual lysimeters were installed in a block on a site of the Penticton Sewage Treatment Plant to provide for the testing of these various parameters. Duplicate lysimeters were used for each set of conditions. The three soil types chosen were considered representative of the soil textures found in the Valley, particularly for locations where full scale spray irrigation projects might be implemented in the near future. These included:

Enderby silt-loam: a fairly prevalent soil type in the valley north of Vernon, and similar to silt loams in the Penticton area.

Armstrong gravelly sandy loam: similar to soils found in all areas of the valley. It is probably representative of the soil type most prevalent in the Okanagan Basin. The collection site is immediately adjacent to the Vernon spray irrigation site.

Osoyoos sandy loam: indicative of the soil commonly found in the area from Okanagan Falls to the United States border. A similar soil is also found in the O'Keefe Ranch area near Vernon.

The two crops used in this study provided extremes in nitrogen utilization, Reed Canary grass being a relatively high nitrogen user, while alfalfa produces most of its own nitrogen through root nodules. Both crops were expected to be about equal in terms of phosphorus uptake.

NUTRIENT INVENTORY FROM LYSIMETER TESTS

LYSIMETER NO.	SOIL TYPE	CROP	IRRIGATION WATER		TOTAL NITROGEN (pounds)				TOTAL PHOSPHORUS (pounds)			
			SOURCE	APPLICATION RATE	APPLIED	CROP UPTAKE	LEACHATE	RESIDUAL (SOIL STORAGE)	APPLIED	CROP UPTAKE	LEACHATE	RESIDUAL (SOIL STORAGE)
1	Osoyoos Sand	Alfalfa	Domestic Water	High*1	.00022	.016	.00016	-.016	.00049	.0014	.000060	-.0014
2 and 3	Osoyoos Sand	Reed Canary Grass	Treated Secondary Effluent	High	.16500	.052	.00650	.107	.03700	.0076	.000300	.0290
4 and 5	Osoyoos Sand	Alfalfa	Treated Secondary Effluent	High	.16500	.065	.00560	.094	.03700	.0062	.000200	.0310
26 and 27	Osoyoos Sand	Alfalfa	Treated Secondary Effluent	Normal*2	.06400	.051	.00220	.011	.01440	.0054	.000100	.0090
28 and 29	Osoyoos Sand	Reed Canary Grass	Treated Secondary Effluent	Normal	.06600	.026	.00180	.038	.01470	.0042	.000200	.0100
30	Osoyoos Sand	Alfalfa	Domestic Water	Normal	.00045	.016	.00030	-.016	.00004	.0013	.000090	-.0013
6	Vernon Loam	Alfalfa	Domestic Water	High*1	.00110	.042	.00110	-.042	.00010	.0032	.000010	-.0031
7 and 8	Vernon Loam	Reed Canary Grass	Treated Secondary Effluent	High	.15200	.087	.00540	.060	.03420	.0130	.000010	.0210
9 and 10	Vernon Loam	Alfalfa	Treated Secondary Effluent	High	.17000	.082	.00380	.084	.03820	.0085	.000020	.0300
21 and 22	Vernon Loam	Alfalfa	Treated Secondary Effluent	Normal *3	.08400	.079	.00130	.004	.01890	.0072	.000010	.0120
23 and 24	Vernon Loam	Reed Canary Grass	Treated Secondary Effluent	Normal	.08800	.067	.00110	.020	.01980	.0110	.000020	.0090
25	Vernon Loam	Alfalfa	Domestic Water	Normal	.00057	.035	.00065	-.035	.00005	.0026	.000003	-.0026
11	Enderby Silt	Alfalfa	Domestic Water	High*1	.00100	.020	.00320	-.022	.00009	.0023	.000600	-.0029
12 and 13	Enderby Silt	Reed Canary Grass	Treated Secondary Effluent	High	.15100	.076	.00890	.066	.03400	.0040	.001400	.0290
14 and 15	Enderby Silt	Alfalfa	Treated Secondary Effluent	High	.15500	.052	.01400	.089	.03490	.0065	.001000	.0270
16 and 17	Enderby Silt	Alfalfa	Treated Secondary Effluent	Normal*4	.08600	.052	.00360	.030	.01920	.0050	.000400	.0140
18 and 19	Enderby Silt	Reed Canary Grass	Treated Secondary Effluent	Normal	.08600	.055	.00350	.028	.01920	.0088	.000500	.0100
20	Enderby Silt	Alfalfa	Domestic Water	Normal	.00057	.027	.00076	-.027	.00005	.0022	.000200	-.0022

*1 High Rate of Application is 2½ times that of the normal.

*2 Lysimeters containing Osoyoos sand normal application-4.75 imp. gal. every 4-5 days.

*3 Lysimeters containing Vernon loam normal application -16.5 imp. gal. every 14 days.

*4 Lysimeters containing Enderby Silt normal application-24.2 imp. gal. every 21 days.

AVERAGE COLIFORM CONCENTRATIONS IN APPLICATION AND LEACHATE WATERS

(Domestic Water Source)

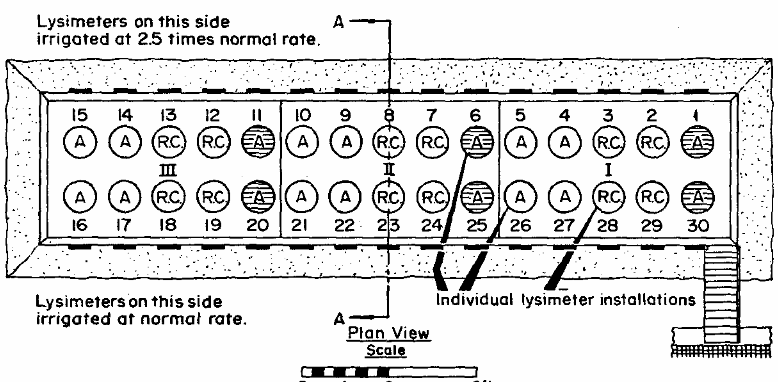
COLIFORM TYPE	APPLICATION WATER	COLIFORMS IN LEACHATE FROM LYSIMETER NUMBER (No./100ml)					
		1	30	6	25	11	20
Total	27	<2	6	<2	2	36	16
Fecal	<2	<2	<2	<2	<2	4	<2

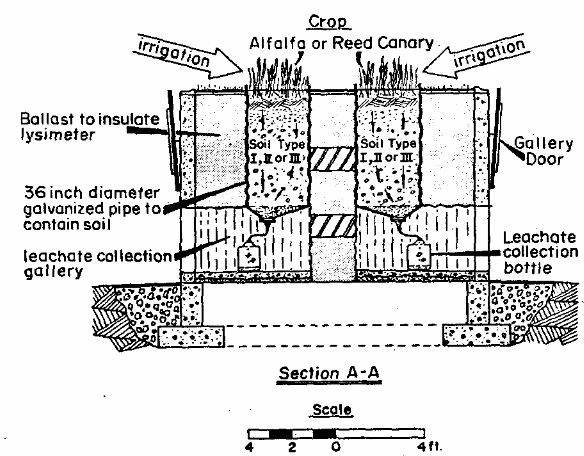
AVERAGE COLIFORM CONCENTRATIONS IN APPLICATION AND LEACHATE WATERS

(Secondary Effluent Source)

COLIFORM TYPE	APPLICATION WATER	COLIFORMS IN LEACHATE FROM LYSIMETER NUMBER (No./100 ml.)					
		2,3 4 & 5	26,27 28 & 29	7,8 9 & 10	21,22 23 & 24	12,13 14 & 15	16,17 18 & 19
Total	746	4	3	3	10	195*	69*
Fecal	28	<2	<2	<2	3	4	<2

* Values dropped to less than 2 per 100 millileters in three out of four lysimeters when short circuiting corrected.





PENTICTON LYSIMETER INSTALLATION

Applied Research Pilot Project

Figure 5.7

Two different rates of effluent application were used, the first being the 'normal' rate as recommended for each soil type, which provides sufficient water to ensure that some passes through, the soil column to prevent the buildup of undesirable constituents in the root zone. The second rate was arbitrarily chosen at 2 1/2 times the normal rate, to determine the effect of high rates of application, since the possibility exists that effluent disposal on land may involve higher rates of application than 'normal' due to economic and land availability aspects.

The treated effluent from the secondary clarifiers of the City of Penticton Sewage Treatment Plant was used for most of the tests. In addition, six of the lysimeters were selected as control units for comparison purposes, and irrigated with water from the City domestic supply system.

The testing program was carried out between May and October, 1972. Quantity and quality data were obtained on both the applied liquid and the liquid passing through the soil columns (leachate) to the bottom of the lysimeters, where it was collected. The nutrient uptake by the crops was also measured to provide a nutrient budget for each experiment. Because the survival of pathogenic bacteria in the water passing through the soil column could be of concern to users of groundwater near such a project, monitoring of total and fecal coliform was included as part of the testing procedure.

The results of this study are summarized in Figure 5.7. The values shown under the column 'residual' represent the nutrients which are not removed in the leachate or the crops, and are therefore accounted for by soil storage. These results indicate only a small fraction of the applied nutrients are carried through the soil column in the leachate water.

Phosphorus storage in the Osoyoos sand and Vernon loam amounted to between 50% and 80% of the phosphorus applied in the secondary effluent. The results for the Enderby silt were not considered reliable because of apparent short circuiting (flow of water between the soil column and side of the lysimeter rather than through the soil column) of the applied liquid through the lysimeter. Phosphorus in the leachate from the Osoyoos sand amounted to less than 1.4% of the total applied, and for the Vernon loam, less than o.1%. For Enderby silt, the amount was higher (2 to 4%) due to the higher initial phosphorus content of the Enderby silt, and the apparent short circuiting that occurred in these units. The percentage of phosphorus taken up by the crops was 12 to 22% for the high rate of application, and 26 to 46% for the low rate of application.

with the exception of one set of lysimeters containing Enderby silt, the total nitrogen in the leachate was 4% or less of the total applied.

Results obtained on coliform tests showed levels in the leachate for both the total and fecal types to be less than 10 per 100 millileters for all lysimeters following correction of the short circuiting in the Enderby silt units.

In general, the following conclusions have been reached from these lysimeter tests.

(i) The use of spray irrigation for the reconditioning of secondary effluent appears to be a very acceptable practice for all three types of soils tested. This statement is true for both application rates tested, but is evident that significant leaching of impurities would occur sooner at higher application rates.

(ii) Both Reed canary grass and alfalfa are useful crops for removing nutrient forms from the secondary effluent. With time, the alfalfa will probably allow a larger amount of nitrogen to escape to groundwater because of nitrogen fixing nodules on the roots.

(iii) Storage of excess nitrogen and phosphorus is evidently occurring in the soil. To maintain a balance of nutrients applied vs. nutrients harvested, in the crops, would require the use of a short irrigation season, and hence reduce the effectiveness of this proposed method of nutrient control in the Okanagan Valley.

(iv) The finer soils have a higher storage capacity for the various nutrient forms due to their higher adsorptive capacities.

(v) Good correlation was obtained between the lysimeter study and the full-scale irrigation project at Vernon discussed in the following section. Consequently, the results of the lysimeter investigations of the other soil types should be useful in predicting results from fullscale irrigation of these soils.

(vi) Coliform concentrations in groundwater return flow are very low after passing through four feet of any of the three soil types tested. Hence, there is no apparent concern in full-scale facilities where the travel distances will be much greater before any water is withdrawn from the groundwater regime for use.

5.4.4 Monitoring Spray Irrigation of Sewage Treatment Plant Effluent at Vernon, B.C.

Prior to the beginning of the Okanagan Basin Study, the City of Vernon had elected to initiate a pilot spray irrigation project in an attempt to find and acceptable solution for the disposal of its treated waste effluent. Vernon currently (1973) discharges its treated wastewater into Vernon Creek which flows into the Vernon Arm of Okanagan Lake. The high nutrient input associated with this discharge has resulted in problems of weed and algal growth. The pilot project involved the irrigation of 75 acres of alfalfa and a tract of native hillside located southeast of Vernon. The area is on a high slightly sloping tract of land, has well drained sandy to silty loam soil and was considered ideal for this type of wastewater disposal.

Based on the recommendations arising out of the report on advanced wastewater treatment methods, the monitoring of this project was undertaken by the Study. It was considered complementary to the lysimeter study discussed in 5.5.3, and provided comparative results under actual field conditions. Monitoring of the project was carried out over the two irrigation seasons of 1971 (June 21 to October 26) and 1972 (May 4 to October 25). The irrigation rate for the alfalfa crop was 3.2 inches of water every ten days, however because of shut down periods for harvesting, pump repairs, etc., the average application rate over the entire irrigation season was somewhat less.

To provide the necessary data for calculating a nutrient budget, analyses. of samples were carried out on the liquid being applied to field, the excess water not used by the crops (leachate), and the crops themselves. Analyses of the applied liquid and the crops were carried out in the same manner as for the lysimeter study. To monitor the excess water or leachate, small wells (well points) were installed around the lower periphery of the irrigated areas, to the full depth of the soil with the screened bottom of the pipe resting on the impervious glacial till. Selected shallow wells in the Vernon Creek Valley were also monitored to ascertain if the excess irrigation water would measurably affect the quality of groundwater in the Valley. The location of these wells and the results of the monitoring program are detailed in Figures 5,8 and 5.9.

The long term usefulness of spray irrigation as a means of disposal for treated wastewater is dependent upon the amount of impurities that are leached through the soil and upon the change or build-up of nutrient levels and other impurities in the soil. The former is important for estimating the potential pollution of groundwater, while the latter may affect the health of the crops being grown, and their usefulness after harvest.

The results shown in Figure 5.9 indicate only 6% of the nitrogen applied, and 0.3% of the phosphorus are being leached through the soil column to the groundwater table. The percentage losses on native grass hillsides are about the same, but can be expected to increase substantially as slope water wells did not provide any conclusive results on the effect of leachate water on the downslope groundwater, due in part to the small quantity of leachate from the irrigation site. A comparison of concentrations in the leachate from the irrigation site and the downslope groundwater did indicate the only nutrient with a significantly higher concentration in the irrigation leachate is one of the nitrogen forms - kjeldahl nitrogen (Table 5.17). From this it may be

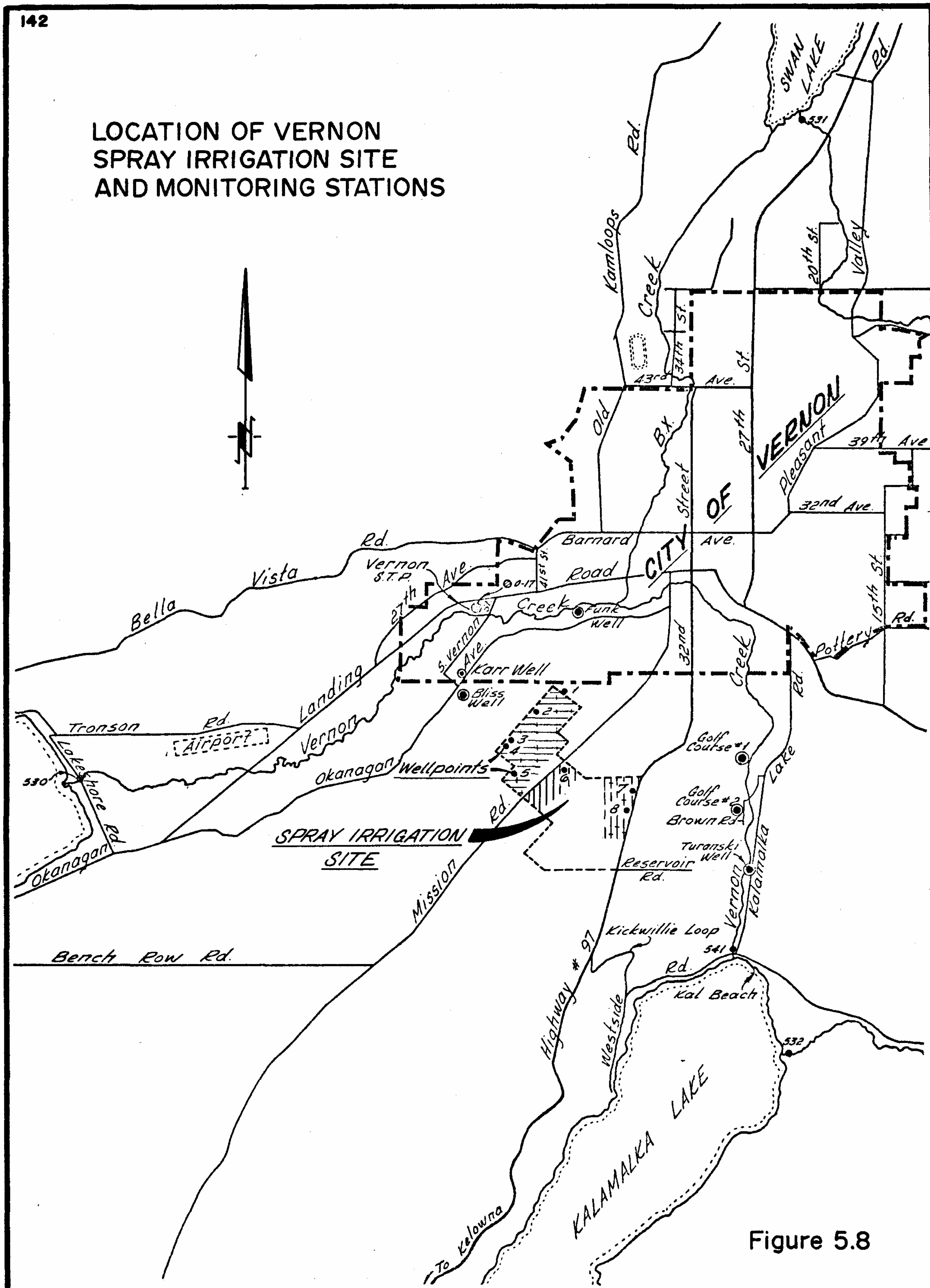
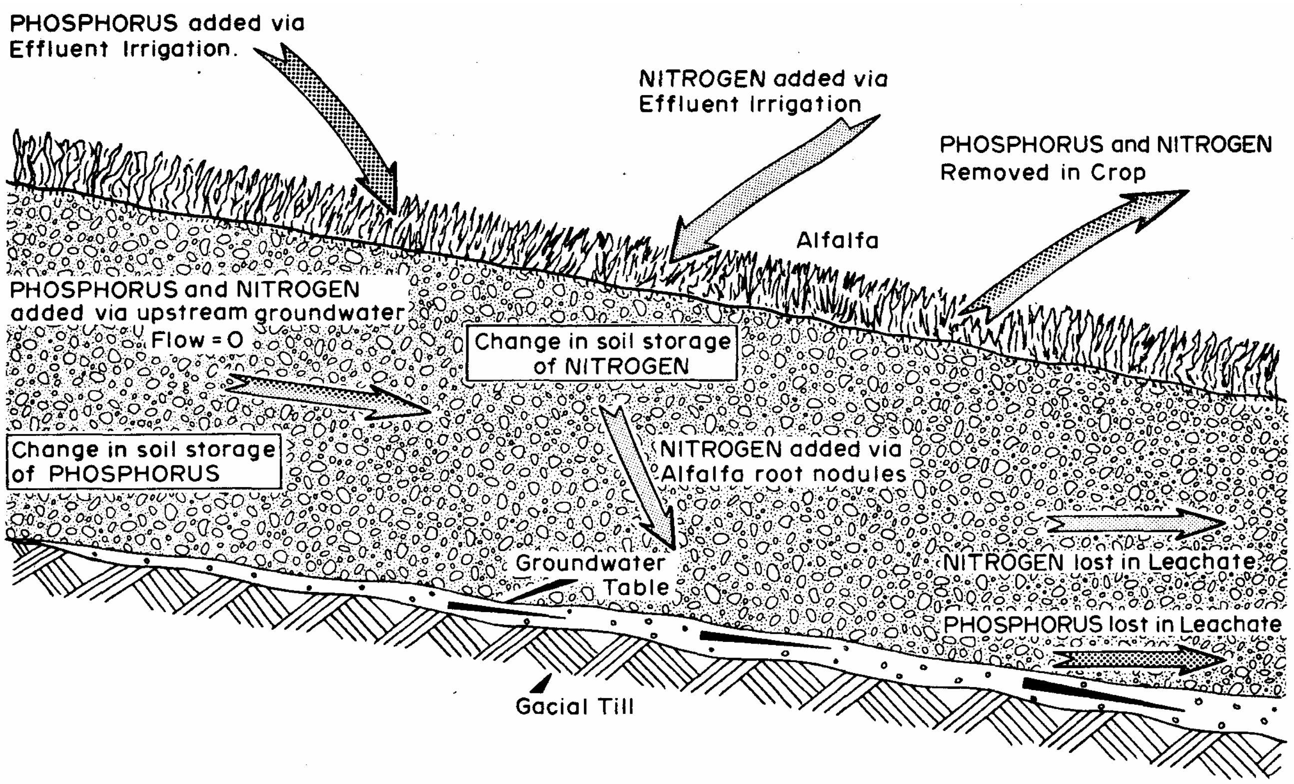

LOCATION OF VERNON
SPRAY IRRIGATION SITE
AND MONITORING STATIONS
SWAN LAKE
Rd.
531
Kamloops Rd.
Creek
20th St.
Valley
34th St.
43rd Ave.
27th St.
Old
B.X.
Street
VERNON
OF
CITY
Pleasant
39th Ave
32nd Ave.
Barnard Ave.
Rd.
Vista
Bella
Vernon S.T.P.
27th Ave.
0-17
41st St.
Road
Creek
Funk Well
15th St.
Rd.
Pottery
S. Vernon Ave.
Karr Well
Bliss Well
Landing
32nd
Creek
Rd.
Tronson Rd.
Airport
Lakeshore Rd.
530
Vernon
Okanagan
Wellpoints
Golf Course #1
Lake
Golf Course #2
Brown Rd.
Turanski Well
Okanagan
SPRAY IRRIGATION SITE
Mission Rd.
Reservoir Rd.
Vernon
Kalamalka
Bench Row Rd.
Highway #97
Kickwillie Loop
541
Rd.
Kal Beach
532
Westside
KALAMALKA LAKE
To Kelowna

Figure 5.8



SCHEMATIC DRAWING OF NUTRIENT BALANCE AT VERNON SPRAY IRRIGATION SITE

NUTRIENT BUDGET SUMMARY FOR VERNON ALFALFA PLOT
(75 Acres)

CROP YEAR	SOURCE (Sink)	TOTAL KJELDAHL NITROGEN pounds per year	NITRATE NITROGEN pounds per year	TOTAL PHOSPHORUS pounds per year	REMARKS
1971	Effluent	6,600	2,460	2,950	
	(Leachate)	(90)	(80)	(10)	
	(Crop)	(12,840)	neg.	(1,830)	
	Nodule Fixation	nil	7,500	nil	Assuming 100 lbs/acre/yr for first year crop
	Increase in Soil Storage	3550		1,110	
1972	Effluent	7,700	2,500	3,700	
	(Leachate)	(130)	(560)	(10)	
	(Crop)	(21,950)	neg.	(2,680)	
	Nodule Fixation	nil	15,000	nil	Assuming 200 lbs/acre/yr for second year crop
	Increase in Soil Storage	2560		1,010	

NUTRIENT BUDGET-VERNON PILOT SPRAY IRRIGATION PROJECT.

Figure 5.9

TABLE 5.17

COMPARISON OF NUTRIENT CONTENT OF IRRIGATION
LEACHATE WATER AND DOWNSLOPE GROUNDWATER
IN PARTS PER MILLION

YEAR	PARAMETER	ALFALFA LEACHATE	HILLSIDE LEACHATE	TURANSKI WELL	GOLF COURSE #2 WELL	GOLF COURSE #1 WELL	FUNK WELL	BLISS WELL
1971	Total Kjeldahl Nitrogen (TKN)	0.890	0.750	0.150	0.090	0.130	0.810	0.070
	Nitrate Nitrogen	0.810	3.700	18.600	0.720	1.080	4.650	0.150
	Total Phosphorus	0.070	0.038	0.020	0.004	0.008	0.097	0.021
1972	TKN	1.030	0.650	0.170	0.080	0.160	0.800	0.300
	Nitrate Nitrogen	4.410	0.800	12.100	0.960	1.070	10.500	0.300
	Total Phosphorus	0.093	0.032	0.014	0.010	0.160	0.160	0.032

assumed that pollution of the groundwater in the area will not occur unless a substantial imbalance of nutrients applied versus nutrients harvested occurs.

Soil storage of both nitrogen and phosphorus increased over the two year study period, although at a slow rate when considered on a per acre basis. This build-up of nutrients was due in part to irrigating the area after the growing season was over. For an irrigation season of six months, the annual phosphorus buildup in the soil was calculated at 13 pounder per acre, or about 25% of that applied in the effluent. The percentage of buildup of nitrogen is considered to be about the same (25% of nitrogen applied), but was difficult to estimate accurately because of the ability of alfalfa root nodules to fix their own nitrogen. No precise estimate of the useful life of the Vernon soil type can be made from the two years of testing, but experience elsewhere over a fourteen year period has indicated no detrimental deterioration of similar soils and crops sprayed with secondary effluent.

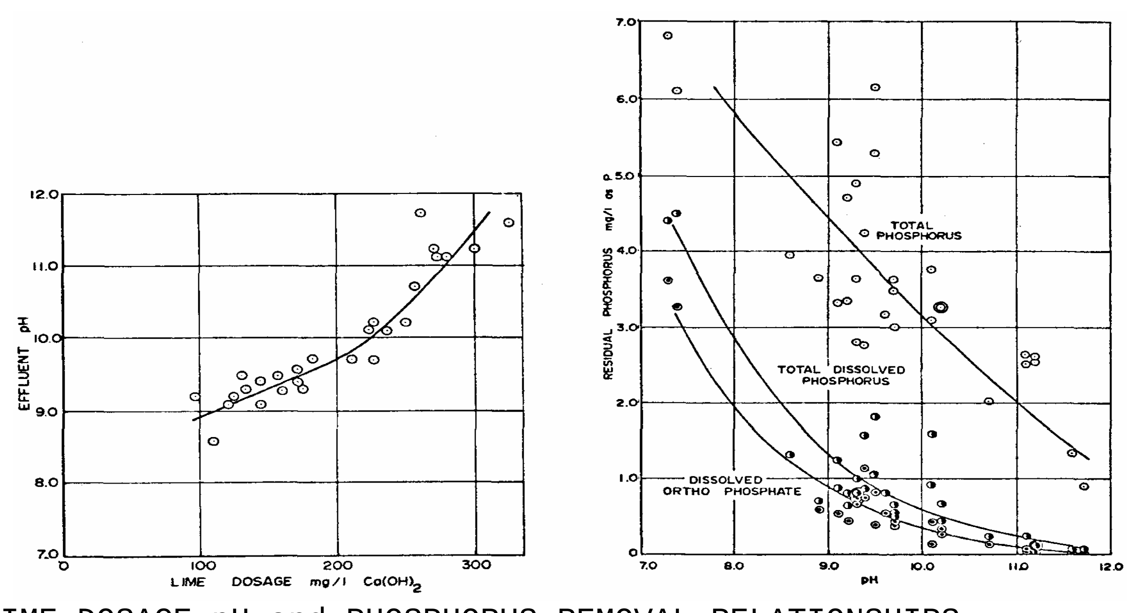
The alfalfa crop grown with secondary effluent was found to be more than satisfactory from a nutritional point of view, and tests for coliform survival in the hay indicated these to be very low within three weeks of baling provided the moisture content of the cut alfalfa was not too high.

5.4.5 <u>Phosphorus Removal by Chemical Treatment at Kelowna</u>

The purpose of this study was to evaluate the chemical process for the removal of phosphorus, in which lime or alum is added to the sewage prior to treatment, in terms of its applicability to the existing Kelowna sewage treatment plant facilities. This type of treatment was investigated because of its economic attractiveness compared to other methods of phosphorus removal.

A pilot scale facility was set up at the Kelowna Pollution Control Centre to enable a controlled investigation of this form of treatment without disrupting the normal day to day operation of the Kelowna Plant. The study itself consisted of the operation of a constant flow primary treatment plant with lime additions, storage of the organic and chemical sludge produced in the pilot treatment unit, and the intermittent disposal of this sludge in the full scale incineration system. Raw sewage from the main plant was used in all tests. Operational data were gathered over the five month period of May to October 1972.

The results of adding lime during primary treatment are presented graphically in Figure 5.10, and show the addition of lime to raw sewage to be effective in removing phosphorus, especially that portion in the soluble form. For example a lime dosage of 250 milligrams per liter resulted in a pH of 10.5 and reduced the total phosphorus concentration from 8.3 to 2.5 milligrams per liter. This dissolved phosphorus for the same dosage was reduced from 5.5 milligrams per liter to 0.4 milligrams per liter.



LIME DOSAGE,pH,and PHOSPHORUS REMOVAL RELATIONSHIPS

Figure 5.10

The second part of the test operation involved the disposal of the lime sludge in the full scale dewatering and incineration system of the Kelowna Treatment Plant to determine the operational characteristics of the lime sludge. During the initial run it became apparent that special precautions would have to be taken to prevent excessive drying of the lime sludge and the attendant possibility of binding and plugging the centrifuge.

These precautions included diluting the lime sludge prior to dewatering to reduce the solids content to between 5% and 8%, and adjusting the centrifuge feed rate during the dewatering process to compensate for a dewatered sludge being either too wet or too dry.

The quantity of phosphorus that can be said to be completely removed from the system is that contained in the settled portion of the incinerator ash. For the test runs this varied from 37% to 80% of the phosphorus initially present in the lime sludge feed. This indicates that phosphorus removal is dependent on the efficiency of the sludge disposal portion of the plant and greater efficiency with respect to particulate removal would result in better phosphorus removal.

One of the problems encountered in this lime treatment process was the accumulation of calcium carbonate in surfaces throughout the pilot facility. This scaling problem could be detrimental to certain parts of the main plant including sewage lift pumps, piping, and trickling filters, and suitable precautions would be required to counteract this effect.

A broad comparison of this type of treatment (pre-recipitation) to that of tertiary treatment (post-precipitation as constructed at Penticton) is as fol1ows:

(i) <u>Pre-Precipitation</u>

- Less capital investment required to convert an existing treatment facility. Post-precipitation requires a duplication of facilities, i.e., additional clarifiers; pre-precipitation utilizes the existing primary facilities.

- Less chemical costs. The amount of lime required to remove phosphorus generally increases exponentially with decreasing phosphorus residual. With pre-precipitation, the activated sludge system can be depended upon to remove a further 1 to 1.5 milligrams per liter of phosphorus and thus as established by this study a final effluent phosphorus concentration of between 1 and 1.5 milligrams per liter could be obtained with a lime dosage of 250 milligrams per liter. Tertiary treatment would probably require a greater lime dose, perhaps 350-450 milligrams per liter, to effect a similar overall removal.

- The removal of organics in the primary stage of treatment is enhanced, thus effectively increasing the capacity of the secondary system. No such advantage is possible with tertiary treatment.

- Less sludge is produced because of the smaller quantity of lime used to remove an equivalent amount of phosphorus.

(ii) Tertiary Treatment

- No chance of upsetting the secondary treatment system. Black (4) reports that pH levels above 9.5 - 10.0 prior to the activated sludge process may result in biological upset with a downgrading of the degree of treatment with respect to biological oxygen demand (B.O.D.) and suspended solids(S.S.).

- Sludge disposal can be kept separate from that used for the normal primary and secondary sludges if desired.

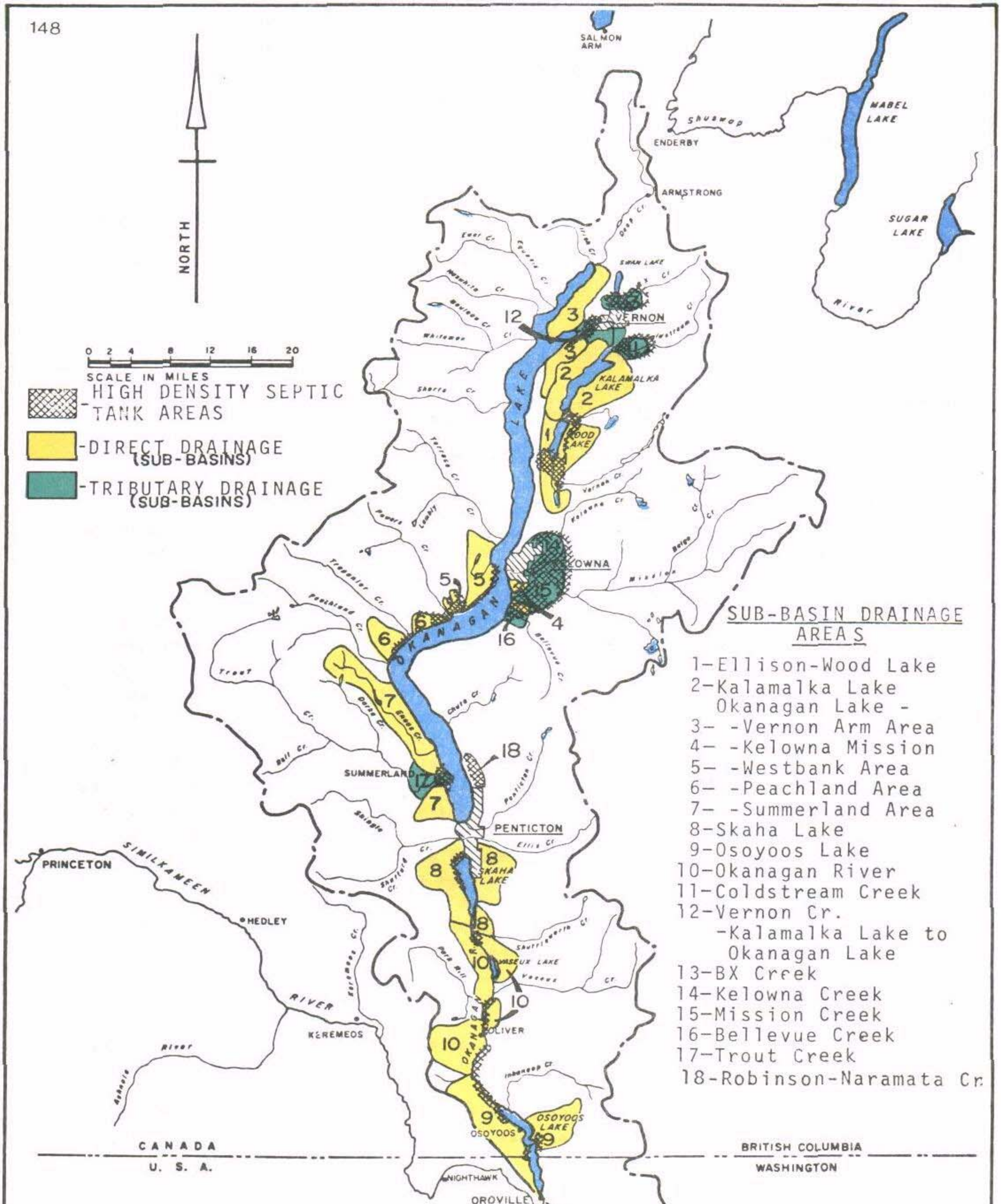
5.4.6 Nutrient Contributions from Septic Tanks

Over 50 % of the population in the Okanagan Valley are serviced by septic tank installations (1972) which contribute to the nutrient loadings of the surface waters of the basin. A septic tank is a simple form of waste treatment unit which primarily conditions sewage for disposal through a field of drain tiles into the ground. Transport of these nutrients involves a downward movement through unsaturated soils to the water table, and then horizontal movement with the groundwater to a surface water course.

To estimate the influence of this nutrient source on the basin, studies were carried out; to determine the relative density of septic tanks throughout the basin; to assess the parameters that affect the vertical movement of nutrients through unsaturated soil; and to estimate the nutrient loadings that actually reach the main valley lakes and tributary streams. To estimate the nutrient contribution from septic tanks, a test facility was constructed at the site of the Vernon sewage treatment plant, utilizing three different soil types typical of conditions in areas of the Valley where large numbers of septic tanks have been installed. A separate study was alos carried out by the Province of British Columbia on the suitability of soils in the Wood-Kalamalka Lake sub-basin for septic tanks and available results of this work have also been considered in estimating the nutrient contribution from septic tank sources.

An enumeration of the number and location of 'equivalent single family units' that are serviced by septic tanks in the valley has provided the information shown in Figure 5.11 and Table 5.18. An 'equivalent single family unit' is defined as that concentration of activity that produces the same annual nutrient loading to a soil as a single family residence. This method was employed to allow the inclusion of apartment blocks, motels, and campsites, etc.

The total population figures shown in Table 5.18 include the equivalent average annual tourist population that contributes to septic tank discharges,



HIGH DENSITY AREAS SERVICED BY SEPTIC TANKS-OKANAGAN VALLEY-1972

Figure 5.11

TABLE 5.18

HIGH DENSITY AREAS SERVICE BY SEPTIC TANK INSTALLATIONS

DESCRIPTION OF AREA (See Figure 5.11)	POPULATION (1972)		EQUIVALENT SINGLE FAMILY UNITS	
	Less than 500 feet from water	Greater than 500 feet from water	Less than 500 feet from water	Greater than 500 feet from water
(1) Ellison-Wood Lake	1,894	2,063	541	589
(2) Kalamalka Lake	774	854	221	244
Okanagan Lake -				
(3) -Vernon Arm	1,271	200	363	57
(4) -Kelowna Mission	2,745	2,363	784	675
(5) -Westbank Area	1,785	1,855	510	530
(6) -Peachland Area	1,763	690	475	197
(7) -Summerland Area	2,726	5,982	493	1,709
(8) Skaha Lake	1,205	1,796	344	513
(9) Osoyoos Lake	1,038	2,956	582	844
(10) Okanagan River	1,209	2,046	342	584
(11) Coldstream Creek	1,033	1,099	295	314
(12) Vernon Creek Kalamalka Lake to Okanagan Lake	809	1,855	231	530
(13) BX Creek	634	1,898	181	542
(14) Kelowna Creek	378	8,481	108	2,423
(15) Mission Creek	910	1,754	260	501
(16) Bellevue Creek	753	273	215	78
(17) Trout Creek	102	942	29	269
OTHER	4200	5900	1146	1684
TOTALS	25229	43007	7120	12283

TABLE 5.19

FRACTION OF NUTRIENT LOADINGS APPEARING IN LEACHATE FROM SOIL COLUMNS

NUTRIENT	SOIL TYPE		
	Silty Loam (Med.-Fine) from Coldstream	Loamy Sand (Medium) Kelowna	Sand from (Coarse) Summerland
Total Kjeldahl Nitrogen	0.05	0.03	0.15
Nitrate Nitrogen	0.01	0.06	0.85
Total Nitrogen	0.06	0.09	1.00
Total phosphorus	0.02	0.40	1.00
Dissolved Orthophosphorus	0.02	0.40	1.00

and the sewered areas of Rutland and Osoyoos because ground disposal of effluent is practices in both cases. The figures do not include houses and septic tank units in the outlying areas of the basin where population is sparse and the distances to ground water or surface water are great.

The test facility constructed at Vernon indicated the two most important factors affecting the vertical movement of nutrients through unsaturated soil were soil type and depth to groundwater. Measurement of the nutrients from septic tank effluent passing through a four foot soil column for three different soil types provided the data shown in Table 5.19.

All of the factors shown in Table 5.19 are based on the more or less steady state conditions that were evident after six months of testing. The results indicate that the Summerland sand had exhausted its adsorptive capacity within three to four months (i.e. through 4 feet of soil depth) and that most of the nutrients were passing through the soil column to the groundwater table. The Kelowna loamy sand also showed a partial breakthrough of phosphorus after about four months at a depth of two and a half feet, while the leachate from the finer silty loam had no appreciable concentration of phosphorus in it after the five months of testing. The question of how long each of the soils would continue to absorb nutrients is difficult to answer although it is obvious the finer soils were fairly effective over the duration of the test period, while the medium and course soils were not. It is also interesting to note that the majority of septic tanks in the valley are located in coarse or intermediate soil areas, and in the shallow or medium depth to groundwater areas.

Results of the more detailed studies on the Wood-Kalamalka Lake sub-basin by the Province of British Columbia support these findings. Most soils in this sub-basin are considered to have only limited suitability for the subsurface disposal of septic tank effluent because of high water tables, proximity to surface waters, imperivous layers, coarse textured subsoils, steep slopes, and seepage water. Based on a classification of the suitability of various soils in this sub-basin for septic tank effluent, only two areas, one at Enderby, and one at Hulcar near Armstrong, met Class 1 standards. Class 1 standards include a depth of greater than 6 feet to the water table and/or impermeable layer, a ground slope of 0 to 5% for single dwellings, a distance of greater than 200 feet to surface water and a soil type consisting of silt loam, clay loam, sandy loam, fine sand or clay.

Selection of coarse soils for septic tank installations has historically been recommended to avoid potential health problems, although the results of this study show that such soils are much less desirable than fine soils when the problem of nutrient transport is considered. Further, because most of the population and development is located in the main valley near surface waters, the depth to groundwater is not great.

Based on the above studies and those of the Province in the Mood-Kalamalka Lake area estimates were made of the total amount of nutrients reaching the groundwater table. To determine the amount of nutrients actually reaching surface waters via groundwater, these assumptions were made:

(i) 100% of all nutrients that reach groundwater within 500 feet of a surface water course will find their way to the surface water;

(ii) 70% of nitrate N that reaches groundwater farther than 500 feet from a surface water course will find its way to that water course; and

(iii) 30% of the other nutrient forms that reach groundwater farther than 500 feet from a surface water course will find their way to that water course.

These assumptions make the results approximate at best, but relatively accurate estimates would have required detailed and expensive studies of the groundwater regime which were not possible within the time limits and resource of this study.

The estimated amount of nutrients reaching surface waters from septic tank sources via groundwater are 25,000 pounds of phosphorus per year and 275,000 pounds of nitrogen per year. While these estimates may be in error by as much as 50%, much more intensive and costly surveys would be required to improve the accuracy of these results.

While septic tank loadings may be small in comparison to municipal loadings, they will have a significant effect on the quality of local waters adjacent to septic tank effluent sources, and consequently may affect adjacent recreational beach areas.

One of the other parameters measured in these septic tank studies was coliform and the efficiency of the three soil types in removing conform organisms. The application liquid had an average total coliform count greater than 2,400,000 bacteria per 100 milliliters, and a fecal coliform count in excess of 1,000,000 per 100 milliliters. Efficiencies of the three selected soil types in removing coliform organisms fluctuated from day to day, but the following more important long term trends were established:

(i) The removal efficiences of both total and fecal coliforms is in excess of 99.7% for all three soil types;

(ii) The finer textured soil in lysimeter #3 is consistently better than the coarser soils in its ability to remove coliforms; and

(iii) The trends in all four lysimeters is toward an increase in leachate coliforms content with lime.

In summary these studies indicate that most soils in the valley have limited suitability for removing nutrient loadings from high density septic tank areas, because of their coarse nature and the shallow depth to groundwater. While these conditions could be improved by more stringent regulations and installation techniques, existing statutes do not provide for the control of these installations in respect to nutrient loadings to surface waters.

5.4.7 Nutrient Contributions from Refuse Disposal Sites

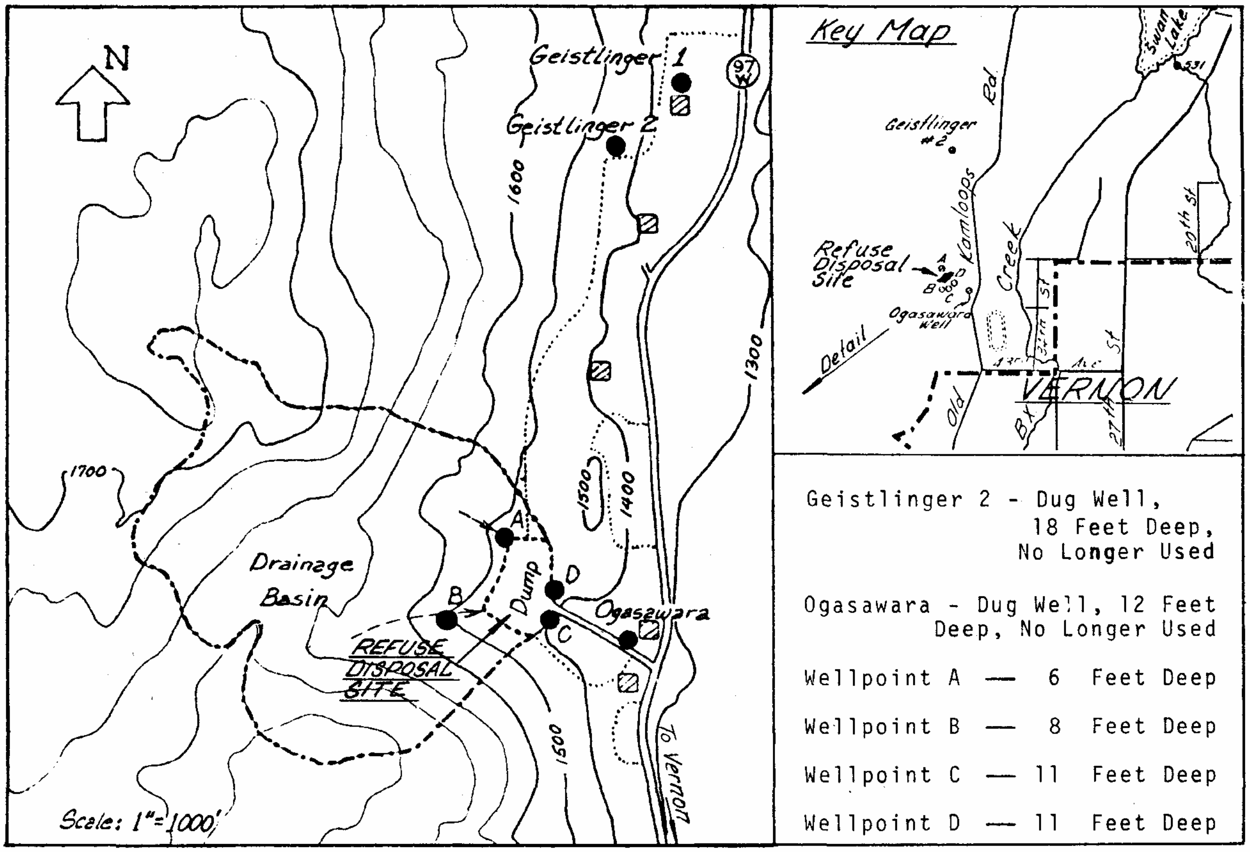
The final study of a pilot nature involved refuse disposal sites (garbage dumps). The purpose of this investigation was to characterize the potential of a representative site, which had been used for some years, as a source of groundwater contamination, and to estimate the nutrient input to groundwater from this source. The study included both a laboratory scale landfill leaching experiment which was conducted at the Vernon Sewage Treatment Plant, and an onsite investigation of an old disposal site about one half mile north east of the City of Vernon, which had been operated as a burning dump over a period of 75 years.

(a) Refuse Disposal Site

The on-site investigation involved the monitoring of two existing down-slope wells, two well points installed immediately above the site and two well points directly below the site. (Figure 5.12). Monitoring commenced in July 1971 and continued on a once a month sampling schedule to October 1972. The existing well immediately downslope of the disposal site (Ogasawara Well) was selected to reflect any changes in groundwater quality due to contamination from the disposal site. The Geistlinger well located 3,500 feet north of the site was selected to indicate the natural quality conditions of the area for comparison purposes.

The average concentrations recorded over the monitoring period are also shown in Figure 5.11. During the winter of 1971-72, 95 inches of snow, or twice the annual average of 48 inches fell in the Vernon Area, and early snow-cover prevented the ground from freezing. This had the effect of allowing a greater than normal proportion of spring melt to infiltrate the ground rather than to run off the surface. This was evident at the disposal site where there was very little surface runoff in the area during the spring thaw. Water levels rose in all wells with the exception of wellpoint D in which there was never any water. Nitrate was found to be the dominant form of nitrogen with average concentrations varying from a low of 1.2 milligrams per liter in Wellpoint A to a high of 63 milligrams per liter (parts per million) in Wellpoint C. The average concentrations of phosphorus ranged from .024 milligrams per liter in the Ogasawara Well to 0.61 milligrams per liter in Wellpoint A. Concentrations of various water quality parameters in the Ogasawara Well (1) remained fairly constant throughout the monitoring period, and the quality of the last sample taken from Well point C corresponds closely to that occurring year round in the Ogasawara Well.

GROUNDWATER MONITORING SITES



GROUNDWATER QUALITY

AVERAGE CONCENTRATION OF CONSTITUENTS

Milligrams Per Liter

LOCATION	pH	TOTAL KJELDAHL NITROGEN(TKN)	NITRATE NITROGEN (NO_3-N)	NITRITE NITROGEN (NO_2-N)	TOTAL PHOSPHORUS
Ogasawara[2]	7.7	0.30	5.6	0.009	0.024
Geistlinger #2[1]	8.0	0.48	2.3	0.005	0.031
Wellpoint A	8.3	0.63	1.2	0.005	0.061
Wellpoint B	8.1	0.94	10.8	0.005	0.030
Wellpoint C	8.1	0.06	63.0	0.021	0.029

1. Averages do not include results from the October 5 and October 15 sampling.

MONITORING RESULTS FOR THE VERNON REFUSE DISPOSAL SITE

Figure 5.12

Some contamination of groundwater by the refuse disposal site did occur in the spring of the study period when groundwater levels were at their highest. This contamination was most likely caused by the intrusion of groundwater into a portion of the bottom of the dump rather than by surface water percolating through the fill. The nutrient input from this occurrence was all in the form of nitrate nitrogen and was estimated at 4,900 pounds. No phosphorus contamination was recorded. The quality of water in the existing domestic well 6,000 feet downslope of the dump site was only minimally affected by this contamination.

(b) Column Leaching Experiment

Eight leaching columns were set up at the Vernon Sewage treatment plant to simulate refuse disposal site conditions, and ascertain quality and quantity characteristics of water percolating through refuse material. Eight inch clear tubing was used under the experimental conditions shown in Table 5.20.

TABLE 5.20

EXPERIMENTAL CONDITIONS FOR LEACHING COLUMNS

COLUMN	COLUMN HEIGHT inches	FILL MATERIAL	FILL HEIGHT inches	DISTILLED WATER APPLICATION PER WEEK
1	30	From Vernon Refuse Disposal Site (45 lbs.) (Covered)	20	Equal to actual Precipitation of preceding week.
II	86	From Vernon Refuse Disposal Site (170 lbs.) (Covered)	74	Equal to actual Precipitation of preceding week.
III	86	Same as for Column II.	74	1.5 inches per week.
IV	86	Fresh Refuse (45 lbs.) (Covered)	74	1.5 inches per week.
V	30	Same as Column I except to exposed to atmosphere	20	Natural precipitation only.
VI	86	Same as Column II except to exposed to atmosphere	74	Natural precipitation only.
VII		Same as Column III		
VIII	86	Same as Column III	74	Leachate from Column VII

The fill from the refuse disposal site was a composite excavated from three locations to a depth of six feet. It was considered to be representative of a fairly homogeneous mixture of ash and decomposed refuse and did not contain any fresh refuse. Large material was screened out, with rocks and large pieces of metal being discarded, and tins and bottles were broken up and returned to the composite. The fresh refuse was composited based on reference material on the makeup of such composites. The results of this column leaching experiment are summarized in Table 5.21.

TABLE 5.21

DATA RESULTS FROM LEACHING EXPERIMENTS

	NO. OF SAMPLES	LEACHATE QUANTITY LITERS	TOTAL ORGANIC CARBON (T O C)	pH	TOTAL KJELDAHL NITROGEN (TKN)	NITRATE NITROGEN (NO_3-N)	NITRATE NITROGEN (NO_2-N)	TOTAL PHOSPHORUS
			ppm		ppm	ppm	ppm	ppm
Column I	2	6.1	14	8.7	2.0	92	0.99	0.05
Column II	1	3.6	9	8.4	0.6	170	1.86	0.03
Column III	8	23.3	15	8.5	1.6	106	1.07	0.27
Column IV	7	21.5	10,400	6.8	712.0	332	6.30	18.00
Column VIII	5	14.1	19	8.5	3.2	530	1.49	0.23

No leachate was collected from the columns exposed to the atmosphere (V and VI) over the period of the study during which these columns received approximately 15 inches of natural precipitation. Leaching from Column I began after the application of 3.5 inches of water; from Column II after 6 inches, from Column III after 16 inches and from Column VIII after 9.5 inches. The leachate from Column VII was added to Column VIII to provide a greater column depth test.

These tests indicate that no leaching of pollutants from refuse disposal sites occurs from the percolation of rain water through the dump material. Since garbage dumps and sanitary land fills in the Okanagan Valley are all subject to about the same or less precipitation than the Vernon area, it is concluded that the potential input of nutrients and other contaminants from refuse disposal sites to groundwater, and hence to surface waters, is negligible. The tests also showed that water percolating through fresh refuse had higher concentrations of organic carbon, total nitrogen, total phosphorus and dissolved heavy metals than did water percolating through an equal depth of decomposed refuse material.