EVALUATION OF STORM DRAINAGE FROM HIGHWAY 97 TO OKANAGAN LAKE AT KELOWNA, B.C.

WORKING REPORT

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SUMMARY

An evaluation by the Aquatic Studies Branch of the site of a newly constructed stormwater collection system located on Highway 97 near Kelowna and discharging into Okanagan Lake was requested by the Waste Management Branch, Okanagan Region. The evaluation indicated that average monthly precipitation for the Kelowna area is about 28.5 mm. Over the 6.6 hectare highway catchment area, a flow of about 1900 cubic metres per month could be generated from this precipitation . The median storm precipitation during the period May 1981 to April 1982 was about 1.6 mm per event, capable of generating a volume of about 100 cubic metres. Precipitation occurs during years of "normal" precipitation on a total of 123 days per year.

The newly constructed outfall can discharge 5.5 m^3/s. This flow regime could be reached if stormwater systems associated with new developments were connected to the highway stormwater drainage system. Alternatively, storms with a return period less frequent than every ten years could generate these flows.

The literature provided a wide range of values for concentrations of pollutants in stormwater from highway runoff. Values chosen for calculating loadings were generally from the high end of the ranges. A runoff coefficient of 0.82 was chosen for the system, representing the ratio of paved to total area. Calculated daily loadings from the system into Okanagan Lake for a 10 mm storm would be less than 0.5% of the permitted loadings from the Kelowna STP. The stormwater loadings would be reduced to about one-eighth of the values for a 10 mm storm with a storm of only 1.6 mm. Actual daily phosphorus and nitrogen loadings from the highway drainage system would be less than 2% of the loadings discharged by the upgraded Kelowna treatment plant and the Brandt's Creek treatment works. The anticipated lead loading from the highway drainage would exceed those from both these treatment plants, however the zinc loading would be about the same.

The calculated stormwater loadings of lead, zinc, total Kjeldahl nitrogen, and total phosphorus from the highway were higher than estimated for equivalent residential catchment areas which may be draining into the lake. Urban stormwater however provides minimal loadings of nitrogen and phosphorus to the Okanagan Lake relative to municipal-type sewage for the entire lake drainage basin.

It is likely that mean oil and grease values will not exceed 3 mg/L. Values expected for fecal coliform have not been predicted but should be less than those found in stormwater from residential catchment areas. Polychlorinated biphenyls are not anticipated to be measurable, however the chloride content in the stormwater could be a concern when salt is used on highways during winter.

It is recommended that sediments adjacent to the outfall be monitored immediately. As well, it is recommended that the stormwater from the highway drainage system be monitored before and after construction of developments which will utilize the highway storm drainage system. Detailed stormwater monitoring of a residential area within Kelowna should be considered in order to obtain ranges of values for stormwater runoff for areas receiving less precipitation than Vancouver. Such a monitoring program could also provide information on the impact of stormwater management strategies undertaken by the City of Kelowna.

Consideration to treat the stormwater from the highway catchment area should await the outcome of any monitoring that is undertaken.

1.0 INTRODUCTION

In May 1982 the Aquatic Studies Branch was asked by the Waste Management Branch, Okanagan Region to prepare a list of options for evaluating storm drainage to be discharged through a Ministry of Transportation and Highways stormwater drainage system into Okanagan Lake.

An inspection of the site, located to the south of Kelowna in a new section of four-lane highway on Highway 97, was carried out on June 4, 1982 by Messrs. L. Swain of the Aquatic Studies Branch, J. Bryan of the Waste Management Branch, and B. Bell of the Ministry of Transportation and Highways. As a result of the inspection, two alternatives were forwarded to the Region for their consideration. One dealt with outlining costs associated with actually monitoring the storm drainage. The second was to prepare an evaluation of the storm drainage system without benefit of field study. The Region subsequently advised that an evaluation of the system without a field study was desirable at this time.

The following is an evaluation of the system, based upon literature derived values for flow runoff rates and contaminant levels.

2.0 SITE AND SYSTEM DESCRIPTION

The site of the drainage system is a section of four-lane highway, approximately 2.7 kilometres (9000 feet) in length leading to the south end of the Kelowna Bridge which crosses Okanagan Lake at Kelowna.

Concerns of local residents that the stormwater from the roadway not intrude upon adjacent land did not permit the usual arrangement of ditches to be incorporated into the highway design. For that reason a stormwater collection system was constructed. Catch basins were located along both sides of the pavement as well as in the proposed centre median. The highway is to be curbed. The system drains to an outfall structure located on the shore of Okanagan Lake. The collection system was virtually completed at the time of the site inspection although paving had not been completed.

The Ministry of Transportation and Highways has made provision to include four connections to the stormwater collection system for possible future use. These connections, referred to as catchbasin/manholes, could contribute runoff to the collection system in later years from as yet unbuilt residential-type catchment areas. Flows entering the collection system from these sources would come from a 525 mm pipe at a 1% slope, and from three separate 750 mm pipes laid at slopes of 2%, 2.5%, and 5%.

The collection system has been designed on the basis of a ten-year return period. The Ministry of Transportation and Highways has determined that the calculated discharge from such a storm would be 4.13 m^3/s (146 cfs).

The highway is to be bordered on both sides by berms approximately 3 metres (10 ft.) in height constructed to reduce noise. With curbs placed along the length of the highway, it is doubtful if runoff from the sound berms or other adjacent areas to the highway could enter the collection system, unless directed there purposely. Excess infiltration into the sewer is considered a minimal factor in determining flows from the system since rubber gaskets have been used for all joints.

It is estimated that there is an average paved width of 19 metres along the total length of the highway. As well, there is an additional width for the centre median of about 4 metres. This will result in an area of about 6.6 hectares (16.4 acres) draining into the collection system.

The runoff coefficient, R, is the ratio of actual runoff to the maximum theoretically possible for any storm over a given catchment area. Assuming that the ratio of total paved area to total catchment area is representative of the maximum runoff coefficient, the maximum R would be 0.82. Since catch basins are located along the length of the centre median, the centre median area may contribute runoff, making this analogy not precisely correct.

3.0 LITERATURE REVIEW

A dearth of literature exists for the quality of stormwater discharges from highways in comparison to the data for stormwater discharges from urban, industrial, or commercial catchment areas. For this reason, most of the data which do exist vary greatly. The major contaminants of concern originating in runoff from this highway catchment area are likely to be lead, zinc, nitrogen, and phosphorus. Lead and zinc would result from vehicle emissions and tire wear respectively. Nitrogen and phosphorus are of concern in the Okanagan Lake region, and are likely to be generated from precipitation and dustfall(6). A summary of literature values for these contaminants is included in Table 1.

Hedley and Lockley reported monthly values of metals in runoff from the Aston Expressway near Birmingham, England(1). Monthly average values ranged from 0.45 mg/L to 4.94 mg/L for lead and from 0.65 mg/L to 8.01 mg/L for zinc. Based upon the volume of runoff cited for the Birmingham study area, flow-weighted mean concentrations were calculated to be 2.41 mg/L for lead and 3.56 mg/L for zinc.

Laxen and Harrison, in reviewing lead in highway runoff, cited the findings of Sylvester and DeWalle who reported lead concentrations from 2 mg/L to 8 mg/L(2). They also cited the work of Siccama and Porter who reported lead concentrations from 1 mg/L to 14 mg/L, the work of Pitt and Amy who reported a mean lead concentration of 6.2 mg/L, and finally the work of Shaheen who reported lead concentrations from 1 mg/L to 4 mg/L(2).

Clark et al., reported on work carried out on highway I-5 near Seattle, Washington(3). Values for lead ranged from 0.1 mg/L to 5.5 mg/L in discrete samples, and from 0.2 mg/L to 1.5 mg/L in composite samples, with an average composite concentration of 0.8 mg/L. Values for zinc ranged from 0.03 mg/L to 1.9 mg/L in discrete samples, and from 0.2 mg/L to 1.0 mg/L in composite samples, with an average composite concentration of 0.40 mg/L.

Total Kjeldahl nitrogen values ranged from 0.18 mg/L to 3.96 mg/L in discrete samples, and from 0.64 mg/L to 1.96 mg/L in composite samples, with an average concentration of 1.11 mg/L. Total phosphorus values ranged from 0.12 mg/L to 1.08 mg/L in discrete samples, and from 0.20 mg/L to 0.55 mg/L in composite samples, with an average concentration of 0.34 mg/L.

Clark et al., also cited Aye who had noted average composite values for the United States(3). National average composite values were: for lead, 0.96 mg/L; for zinc, 0.41 mg/L; for total Kjeldahl nitrogen, 2.99 mg/L; and for total phosphorus, 0.79 mg/L.

Polls and Lanyon reported on values obtained for seven storms and the associated runoff from a highway in north-eastern Illinois(4). The range of values for total Kjeldahl nitrogen was from 0.1 mg/L to 3.7 mg/L, with a mean value of 1.2 mg/L. Soluble phosphorus values ranged from 0.02 mg/L to 0.13 mg/L, with a mean value of 0.07 mg/L.

Christensen and Guinn reported deposition rates for lead and zinc in terms of vehicle kilometres(5). Values cited were 0.0049 gram of lead/vehicle km and 0.0030 gram of zinc/vehicle km.

With respect to runoff coefficient (R), Swain determined an average value for R of 0.40 for a residential catchment area(6). This compares to a ratio of 0.50 for impervious to total area for the same catchment area. This illustrates that the use of ratios of impervious to total area may not necessarily reflect the actual runoff coefficient which would be expected to be less than the ratio.

4.0 EVALUATION

The "normal" monthly precipitation distribution for the Kelowna meteorological station is given in Table 2. Precipitation during "normal" years can be measured on 123 days of the year(14). The data in Table 2 indicate a total "normal" mean precipitation equivalent of 342 mm of rainfall per year. The monthly distribution is fairly regular, with an average monthly precipitation of 28.5 mm rainfall equivalent. The equivalent volume of precipitation over the entire 6.6 hectare catchment area is about 1890 cubic metres per month.

Table 3 presents precipitation data for the period from May 1981 to April 1982 inclusive, according to total rainfall. The data in Table 3, plotted in Figure 1, indicate that 34% of all storms had rainfall in a range from 0.2 to 1.0 mm while an additional 23% had between 1 mm and 2 mm of rainfall. Based upon the cumulative percentage, the median rainfall could be assumed to be about 1.6 mm per storm event. A total flow of only 106 cubic metres would be generated for the 6.6 hectare catchment area under this median rainfall condition.

The maximum possible discharge into Okanagan Lake, based upon the slope of 4.1% and size of the existing outfall (1050 mm diameter), the Manning Equation, and an assumed roughness coefficient of 0.013, would be 5.5 m^3/s. The Ministry of Transportation and Highways has indicated that a design calculated discharge for a ten-year return period would be 4.13 m^3/s. Thus, if the Manning calculation is accurate, the maximum pipe capacity would be utilized only if a lower return period storm occurred, or if stormwater from other catchment areas was added to the system. Under the present conditions the maximum pipe capacity would only be reached with storms with a return period less frequent than every 10 years.

The Ministry of Transportation and Highways, as indicated in Section 2.0, has made provision in the system design for additional flows through

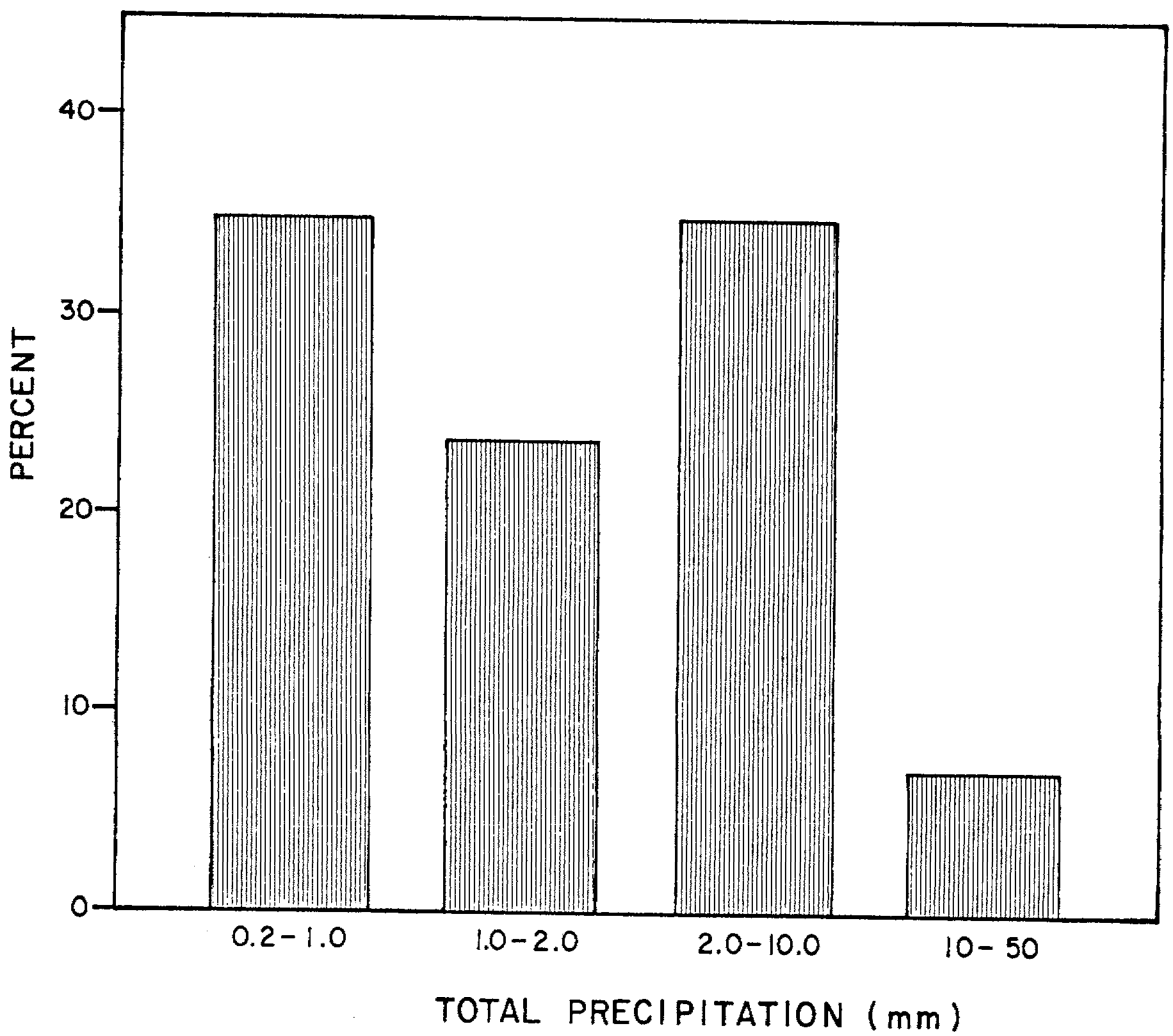

FIGURE 1. DISTRIBUTION OF TOTAL PRECIPITATION BETWEEN STORMS IN PERIOD MAY 1981-APRIL 1982

the catchbasin/manholes. These future additions could add a flow, based upon the slopes of incoming pipes, their diameters, a roughness coefficient of 0.013, and the Manning Equation, of 5.9 m^3/s. Flows of this magnitude would severely reduce the ability of the storm drain to handle this flow. It is therefore conceivable that the difference between the ten-year design calculated discharge and the maximum possible discharge could be composed of additional future flows. The addition of these flows would also increase the impact from the system in terms of loadings and increased frequency of more severe loadings. However, no attempt to project figures based upon such scenarios will be undertaken in this evaluation since future development could still be several years distant.

Values were cited in Section 3.0 for the concentrations of lead, zinc, total phosphorus, and total Kjeldahl nitrogen in runoff from highway surfaces. Deposition rates per vehicle kilometre were also cited for lead and zinc. Table 4 provides Ministry of Transportation and Highways data for total traffic volumes in both directions over a 24-hour period. These data were collected during the peak traffic volume months of July and August. Volumes at other times of the year would be less than indicated in Table 4.

The use of vehicle deposition rates would seem to be a reasonable method to project contaminant concentrations, since data exist on rainfall and traffic volumes near the actual site. The use of concentrations of contaminants from other areas is not valid since traffic volumes and rainfall rates vary from site to site.

Based upon traffic data for July and August 1980, a total length of highway of 2.79 kilometres, and deposition rates reported by Christensen and Guinn, the total monthly loadings due to vehicle deposition would be 11 850 grams of lead and 7250 grams of zinc. If these loadings were trapped on the highway surface and the centre median and subsequently picked up by the runoff, the average concentrations during months of average precipitation, assuming a runoff volume of 1891.5 m^3 would be 6.25 mg/L of total lead and 3.84 mg/L of total zinc.

For the purpose of loading calculations, the values of 6.25 mg/L and 3.84 mg/L, respectively will be used for lead and zinc. These values are in the range which could have been found by other researchers (Table 1). However the maximum monthly loading can only be 11.85 kg of lead and 7.25 kg of zinc, the total vehicle deposition. Not necessarily all the amount deposited would be removed by any one storm. For total Kjeldahl nitrogen and total phosphorus, the national average values put forth by Aye and cited in Clarke et al., will be used[3]. These values were 2.99 mg/L and 0.79 mg/L, respectively. A value of 0.82 will be assumed for the runoff coefficient.

Comparisons made in the following sections to loadings from residential areas are based upon data collected at a site in Vancouver where approximately 1800 mm/year of precipitation occurred [6]. The difference in precipitation between the Vancouver site and the Kelowna site affects the concentrations used in each case.

4.1 "WORST-CASE" SITUATION

Swain has found that high pollutant concentrations of lead, nitrogen and to a lesser extent, zinc and total phosphorus, can be expected in at least the first portion of a storm[6]. A "worst-case" situation would be one in which the highest concentration of pollutants was discharged in a large volume of water. In such a "worst-case" situation all rainfall may become runoff. The "worst-case" situation for lead and zinc would occur in the summer when the highest traffic volumes occur. During a period of about two months, the maximum quantities of 11.85 kg of lead/month and 7.25 kg of zinc/month could be discharged to the lake. The total amounts of these contaminants which could be discharged by any single storm event would vary, depending upon the time since the last storm event, and the degree of washoff of contaminants. Discharged quantities of phosphorus and nitrogen would depend upon dustfall and precipitation (Section 3.0).

Table 5 indicates the loadings for lead, zinc, phosphorus, and nitrogen resulting from the highway drainage system for a 90th percentile storm of 10 mm. In such a case, the loadings would be 4.13 kg of lead, 2.53 kg of zinc, 1.97 kg of nitrogen, and 0.52 kg of phosphorus. Although the loadings would still depend upon the time since the last storm event, Swain has cited the work of the URS Research Company that a removal efficiency of 90% can be attained with a rainfall of about 13 mm[6]. Since rainfall normally occurs only on 123 days with at least one of the storm events being of this magnitude, these loadings can be expressed on a daily basis in terms of a total year by reducing them with the ratio of 123:365, or to 1.39 kg/d of lead, 0.85 kg/d of zinc, 0.66 kg/d of nitrogen, and 0.18 kg/d of phosphorus.

When compared to average daily loadings permitted from the Kelowna STP (Table 5) for nitrogen and phosphorus, the loadings from the runoff based upon one day when a rainfall of 10 mm occurs were less than 0.5% of the plant loadings. Actual loadings from the Kelowna STP decreased in July 1982 with the implementation of tertiary treatment. If values obtained for July 1982 are representative of actual loadings, the nitrogen and phosphorus loadings will decrease to 7.05 kg/d of Kjeldahl nitrogen and 1.45 kg/d of total phosphorus. Actual mean values for lead and zinc loadings from the treatment plant are only 0.022 kg/d and 0.148 kg/d, respectively.

A residential area experiencing a similar storm and runoff coefficient for the same equivalent area of catchment but with concentrations consistent with those found by Swain[6] would contribute 0.04 kg of lead, 0.08 kg of zinc, 1.02 kg of nitrogen, and 0.11 kg of phosphorus. If the loadings in the Kelowna area are higher than calculated for a Vancouver site by a ratio inversely proportional to precipitation rates, the loadings just cited could be increased by a factor of 5:1. Even so, the predicted highway loadings are considerably higher than predicted loadings associated with stormwater from an equivalent residential area.

Actual average loadings from the Brandt's Creek treatment works which handle food processing wastes were 5.13 kg/d of Kjeldahl nitrogen and 1.51

kg/d of total phosphorus (Table 5). The daily loadings of phosphorus and nitrogen from the highway drainage are about one-sixth of those from Brandt's Creek treatment works. Swain has indicated that food processing wastes often require the addition of nutrients to achieve successful biological treatment[13].

4.2 "NORMAL" SITUATION

Loadings associated with a "normal" situation can be determined in two ways. One is to determine the average daily flow from the catchment area based upon the normal yearly precipitation of 342 mm over the entire catchment area and a runoff coefficient of 0.82. The second way is to assume a median storm rainfall estimated to be 1.6 mm per storm event.

Using the first approach, it can be predicted that the average daily runoff would be about 51 m^3/d. This would result in average daily loadings of 0.32 kg/d of lead, 0.19 kg/d of zinc, 0.15 kg/d of nitrogen, and 0.04 kg/d of phosphorus.

The second way assumes a median storm rainfall estimated to be 1.6 mm during one event and the same runoff coefficient of 0.82. The data in Table 5 indicate the loadings from the highway catchment area for lead, zinc, nitrogen, and phosphorus for such a situation. The loadings associated with highway runoff were 0.54 kg lead, 0.33 kg zinc, 0.26 kg nitrogen, and 0.07 kg phosphorus. Since these loadings can occur on any one of 123 days rainfall occurs in a year, they can be expressed as 0.02 kg/d lead, 0.11 kg/d zinc, 0.09 kg/d nitrogen, and 0.18 kg/d phosphorus when the ratio of 123:365 is applied to represent these as daily loadings throughout any one year.

A residential area experiencing a similar storm could be estimated as having a runoff coefficient of 0.40 and the flow-weighted concentrations for lead, zinc, phosphorus and nitrogen determined by Swain[6] for a Vancouver area. In such a case, residential stormwater would contribute total storm loadings of 0.002 kg lead, 0.013 kg zinc, 0.164 kg nitrogen, and

0.007 kg phosphorus. Making allowance for the difference in precipitation would increase the loadings by a 5:1 factor. However, the predicted loadings from the highway surface are considerably higher than predicted loadings associated with an equivalent residential area.

Actual loadings from the Kelowna STP and the Brandt's Creek treatment works for Kjeldahl nitrogen and phosphorus were considerably higher than the predicted loadings from a "normal" rainfall on the highway catchment areas (approximately sixty times higher on a daily basis).

4.3 OTHER CONTAMINANTS

Oil and grease concentrations were reported by Swain to range to as high as 27.6 mg/L in residential Vancouver, although the mean value was 3 mg/L[6]. These data were collected for a 12.95 hectare residential catchment area. It is speculated that concentrations from the highway might be approximately the same as these. Although vehicles will not be parked along the highway leaking oils and greases as might be the case in residential areas, there will be some leakage along the highway from the associated larger traffic volumes.

Fecal coliform values ranged from <20 to >24 000 MPN/100 mL, with a median value of 2400 MPN/100 mL for the Vancouver residential area[6]. It is anticipated that these figures would be significantly reduced for the case of highway runoff, since large numbers of pets roaming residential areas will not be characteristic of the highway catchment area. Exact figures cannot be predicted for bacteriological quality, but coliforms could be a concern for any nearby water users of Okanagan Lake. It is understood that Madsen Marina, located to the south of the stormwater outfall on Okanagan Lake, is the closest water user to the outfall.

Polychlorinated biphenyls can be associated with stormwater runoff. In testing for the presence of Arochlor 1242, Arochlor 1254, and Arochlor 1260, Swain reported that none of these could be detected above the minimum detectable level of 0.0004 mg/L[6]. The large traffic volumes over this stretch of highway could perhaps contribute enough polychlorinated biphenyls to the road surface to permit their detection in the stormwater during low flows.

Oliver et al., have indicated that the application of salt to roadways can increase chloride levels in lakes[7]. They also reported an approximate tripling of chloride values in the Rideau River near Ottawa after a severe storm[7]. It is known that when snowfalls occur, the Ministry of Transportation and Highways apply both sand and salt.

4.4 OTHER CONSIDERATIONS

The City of Kelowna's sewage system is a completely separate system. It has been estimated that only 15% to 20% of the City of Kelowna has storm sewers, the remaining sections being served by ditches[10]. It has been further estimated that only about half of the area serviced by storm sewers discharges to Okanagan Lake[10].

In an attempt to improve the quality of stormwater entering the lake, the City has undertaken a number of measures. One of these has been to formulate a plan to consolidate the 15 to 20 existing small outfalls into four major trunk mains and associated outfalls within the next ten years. Three trunk mains will be provided with sedimentation basins, or existing ponds. The fourth will utilize a recharge system, where provision is made in the design of the trunk main to provide retention at certain sections within the pipe, prior to flows continuing on to the next pipe section where more retention would be provided. Thus some treatment eventually will be provided to all stormwater entering the lake (within about ten years). One sedimentation basin has already been constructed which provides an estimated 4 to 8 hours retention with normal flows[10].

Since septic tanks would likely be widely used in the proposed residential areas which are to connect to the Ministry of Transportation and

Highways storm sewer, it is possible that drainage from tile fields or leaking septic tanks could find its way into the storm sewer system. One method to monitor this would be to obtain background data on the storm sewer prior to the construction of any new residential areas. This monitoring could measure quality and quantity, with any major change in either being attributable to new residential developments.

4.5 IMPACT ON OKANAGAN LAKE

The outfall from the stormwater collection system is a spillway on the shore of the lake. A visual inspection of the area would lead one to anticipate that the waters of Okanagan Lake are not stagnant in the area. Thus the dilution afforded the runoff will be substantial in the long term.

However, localized impacts could be of concern in the future. Such impacts could take the form of a build-up of contaminants in the sediments. Wave action along the shoreline and fluctuating lake levels could disturb and redistribute accumulated sediments, likely making any build-up very localized. Some examination of sediments may be warranted.

Of more concern in the future could be the bacteriological quality of the stormwater. Since the stormwater is not to be discharged through a diffuser section in Okanagan Lake itself, dilution will be greatly reduced from what could be achieved with a diffuser. The concern for dilution between the stormwater outfall and the water intake for Madsen's Marina would depend upon prevailing current direction and velocity, the location of the water intake, and the intended use of the water. The intake is located approximately 100 metres from shore and 2 metres from the bottom(8). Since the water is generally used for toilets and ablutions(8), the potential effect on the closest water user is considered to be minimal.

A secondary consideration must be the fact that the area receiving the stormwater already is affected to some degree from drainage from the highway bridge itself. The distance across the bridge span from shore to shore is 1.4 kilometres[9]. This distance is about one-half the length of highway in the catchment area. With consideration being made for the runoff coefficient associated with the highway catchment area, about one-half the loading which will be discharged from the highway catchment area is already entering Okanagan Lake from the bridge itself.

The relation of the loadings of phosphorus and nitrogen from urban stormwater to the entire Okanagan Lake is small in comparison to that from municipal sewage treatment plants. The loading of nitrogen from stormwater was 1.7% and that of phosphorus was 0.7% compared to that from the municipal sewage treatment plants from 1969 to 1971[11].

Data for 1980 indicate that the loading of phosphorus to Okanagan Lake from urban stormwater was 2.8% of the loading from municipal sewage treatment plants[12]. The reason for this increase over 1969-1971 was an approximate increase of 70% in the loading from storm sewers and a decrease of 55% in the 1970 loading from municipal treatment works. It is anticipated that nitrogen values would follow the same trend noted for phosphorus.

The impact of the Kelowna STP on Okanagan lake has been reduced with the implementation of tertiary treatment in July 1982. If the data examined for the Kelowna STP are representative, the predicted equivalent daily loading of lead of 0.18 kg/d from the highway drainage is larger than from the Kelowna STP (0.022 kg/d). The loading of zinc is approximately equal (0.11 kg/d and 0.148 kg/d, respectively). However, even with tertiary treatment, the predicted daily loadings of Kjeldahl nitrogen and phosphorus from the highway drainage (0.09 kg/d and 0.02 kg/d, respectively) are less than from the Kelowna STP (7.05 kg/d and 1.45 kg/d, respectively).

The other impact on the lake near Kelowna comes from the Brandt's Creek treatment works. These treatment works handle food processing wastes from such operations as Sun-Rype and Calona Wines. Data have not been collected for lead or zinc at this treatment plant, however values could be expected to be low due to the nature of the wastes being treated. Average loadings of total Kjeldahl nitrogen and total phosphorus from these treatment works are approximately equivalent to the nitrogen and phosphorus loadings from the tertiary treatment facilities at the Kelowna STP. Thus the relationship of the nitrogen and phosphorus loadings from the highway drainage to the Brandt's Creek treatment works is about the same as to the tertiary treatment facilities at the Kelowna STP.

5.0 CONCLUSIONS

The storm sewer system installed by the Ministry of Transportation and Highways will not flow at full capacity unless areas adjacent to the catchment area are connected in the future when developed, or storms with a frequency of less than once every ten years occur. The addition of such residential areas could increase the severity and frequency of impact from the storm sewer system.

The use of vehicle deposition rates per vehicle kilometre provides a rational basis to determine expected concentrations of lead and zinc, depending upon the number of vehicles and distance travelled. These rates permit one to examine stormwater in areas of widely varying precipitation with a fair degree of confidence.

For a 10 mm storm, the loading of nitrogen and phosphorus from the storm sewer system is less than 0.5% of that permitted from the Kelowna STP on a daily basis. This is reduced to less than 0.1% with 1.6 mm of precipitation. With respect to similar sized residential areas experiencing a 10 mm storm and a 1.6 mm storm, considerably more lead, zinc, nitrogen and phosphorus is discharged from the highway catchment than from a residential catchment. This is the case even when allowances are made for differences in precipitation between Vancouver and Kelowna.

Actual average phosphorus and nitrogen loadings to Okanagan Lake from the Kelowna STP and the Brandt's Creek treatment works are approximately equivalent. Each is approximately sixty times higher than the anticipated daily loading from the highway drainage under 1.6 mm precipitation or nine to fifteen times the situation for a 10 mm storm event. However, the loading of lead from the highway drainage is predicted to be higher than the lead loading from the Kelowna STP. The zinc loading from these two sources is predicted to be about equal.

Other contaminants which could enter Okanagan Lake as a result of the storm sewer include oil and grease, fecal coliforms, salt, and possibly polychlorinated biphenyls although their use in vehicles has been eliminated. These contaminants are presumably already entering the lake from runoff from the Kelowna Bridge and from the existing City of Kelowna storm drainage system.

Some monitoring of the sediments near the outfall should be undertaken immediately to detect any future substantial changes in sediment quality. Limited monitoring of the runoff should be undertaken prior to and following construction of the residential areas which drain into the catch basin/-manholes in order that any substantial change in runoff quality can be detected. However, an intensive monitoring program does not appear to be warranted for the highway drainage system when other sources to Okanagan Lake are more substantial.

The impact of runoff from the storm drainage system on present water users is anticipated to be small. In general, the impact of the stormwater relative to loadings from municipal-type sewage to Okanagan Lake although growing, is still considered to be minimal.

Construction of treatment works for the stormwater drainage from the highway should be considered if an approach consistent with the apparent City of Kelowna stormwater management plan is deemed appropriate. However such a decision would be a policy decision, beyond the scope of this report. These works may also be desirable considering the fact that the highway drainage will likely contribute more lead and zinc than the Kelowna STP. However even with tertiary treatment at the Kelowna STP, the highway drainage contributes less than 2 percent of the nitrogen and phosphorus discharged on a daily basis from the Kelowna treatment plant.

6.0 RECOMMENDATIONS

The following are based upon technical considerations and an assessment of the stormwater collection system for the highway catchment area prior to any possible future expansion of that system.

1. Monitoring of sediments adjacent to the stormwater outfall should be undertaken immediately and hereafter on a yearly basis in order to detect changes attributable to the stormwater outfall. This program could be terminated after three years if no changes in sediments were noted.
2. Limited monitoring of stormwater from the highway catchment should be undertaken prior to and following construction of any residential areas which will drain into the highway collection system. This program would indicate future changes in the stormwater quality. The program could be as simple as taking grab samples periodically and at the same time noting the vertical depth of flow in the pipe.
3. The stormwater from the highway catchment area should be treated if sediment monitoring (1 above) indicates that deleterious changes are occurring in the lake sediments. Treatment should only proceed after a short program (about 6 months) has characterized the effluent. The information from the program would be essential for the treatment works design.

The following recommendation is meant to provide additional information important from a Province-wide perspective in terms of stormwater loadings relative to other contaminant sources.

Detailed monitoring of a residential catchment area should be considered for the Kelowna area to:

a) obtain ranges of values associated with stormwater runoff for an area of British Columbia receiving considerably less precipitation than Vancouver; and
b) determine the impact of stormwater management strategies undertaken by the City.

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TABLE 1

LITERATURE VALUES ASSOCIATED WITH HIGHWAY RUNOFF

Parameter	Hedley and Lockley(1)		Laxen and Harrison(2)			
	Monthly Average (mg/L)	Flow-Weighted Average (mg/L)	Sylvester & DeWulle (mg/L)	Sicamba & Porter (mg/L)	Pitt & Amy (mg/L)	Shaheen (mg/L)
Lead	0.45 - 4.94	2.41	2 - 8	1 - 14	6.2	1 - 4
Zinc	0.65 - 8.01	3.56				
Total Kjeldahl Nitrogen	-	-				
Total Phosphorus	-	-				

Parameter	Clark *et al.*(3)				Polls and Lanyon(4)		Christensen and Guinn(5)
	Discrete Samples (mg/L)	Composite Samples (mg/L)	Average (mg/L)	Work of Aye National Avg. (mg/L)	Range (mg/L)	Mean (mg/L)	grams/vehicle km
Lead	0.1 - 5.5	0.2 - 1.5	0.8	0.96	-	-	0.0049
Zinc	0.03 - 1.9	0.2 - 1.0	0.4	0.41	-	-	0.0030
Total Kjeldahl Nitrogen	0.18 - 3.96	0.64 - 1.96	1.11	2.99	0.1 - 3.7	1.12	-
Total Phosphorus	0.12 - 1.08	0.20 - 0.55	0.34	0.79	0.02*-0.13*	0.07*	-

* Soluble

TABLE 2
MONTHLY PRECIPITATION SUMMARY
KELOWNA METEOROLOGICAL STATION

"Normal" Precipitation in Rainfall Equivalents (mm)			
	Rain	Snow	Total
January	7.4	27.9	32.3
February	7.3	16.3	23.6
March	11.2	8.9	20.1
April	18.7	0.5	19.2
May	28.7	-	28.7
June	31.6	-	31.6
July	28.7	-	28.7
August	29.9	-	29.9
September	24.9	-	24.9
October	24.4	0.8	25.2
November	15.8	11.4	27.2
December	8.9	39.1	48.0
Total	237.5	104.9	342.4

TABLE 3
DISTRIBUTION OF TOTAL PRECIPITATION
MAY 1981- APRIL 1982
KELOWNA METEOROLOGICAL STATION

Month	Number of storms with precipitation greater than the value recorded				
	≥0.2 mm	≥1.0 mm	≥2.0 mm	≥10 mm	≥50 mm
April 1982	8	3	2	-	-
March 1982	12	10	8	1	-
February 1982	11	6	4	-	-
January 1982	19	10	8	1	-
December 1981	17	10	5	-	-
November 1981	11	9	2	-	-
October 1981	12	9	7	1	-
September 1981	11	9	5	2	-
August 1981	7	3	3	2	-
July 1981	12	8	5	2	-
June 1981	16	10	7	-	-
May 1981	10	9	6	2	-
Total	146	96	62	11	0

TABLE 4
TRAFFIC VOLUMES
PTH97 AT KELOWNA
B.C. MINISTRY OF HIGHWAYS AND TRANSPORTATION

Year	Total Traffic Volume (Vehicles) 24-Hour Period - Both Directions
1977	23,411
1978	24,827
1979	25,575
1980	28,479
1981	32,000 (estimated by the Ministry of Transportation and Highways)

TABLE 5
CALCULATED LOADINGS

Parameter	Highway Loadings				Equivalent Residential Area* (kg)		Kelowna STP		Brandts Creek Actual Mean*** (kg/d)
	10 mm Storm		"Normal" (1.6 mm Storm)				Permitted (kg/d)	Actual** Mean (kg/d)	
	kg	kg/d+++	kg	kg/d+++	Worst-Case	Normal			
lead	4.13	1.39	0.54	0.18	0.04	0.002	-	0.022	-
zinc	2.53	0.85	0.33	0.11	0.08	0.013	-	0.148	-
total Kjeldahl nitrogen	1.97	0.66	0.26	0.09	1.02	0.164	136.4+	155.7++	5.13
total phosphorus	0.52	0.18	0.07	0.02	0.11	0.007	45.46	30.4++	1.51

* Values based upon same area of catchment and rainfall as used for highway loadings, except flow-weighted concentrations determined by Swain[6] for a Vancouver area were used while a runoff coefficient of 0.4 was assumed for "normal" residential calculations.

** Values based upon data for period from January 1, 1977 to August 1982. The average flow for period was 7419 m^3/d (n=1290), average lead value was 0.003 mg/L (n=1), average zinc value was 0.02 mg/L (n=1), average total Kjeldahl nitrogen was 20.99 mg/L (n=72), and the average total phosphorus was 4.10 mg/L (n=86).

*** Values based upon data for period from January 1977 to January 1982. The average flow for the period was 715 m^3/d (n=1232), average total Kjeldahl nitrogen value was 7.17 mg/L (n=172), and the average total phosphorus was 2.11 mg/L (n=181).

\+ Total nitrogen.

\++ Tertiary treatment came on-line in July 1982. If data for July 7, 1982 were representative, the new average loadings will be 7.05 kg/d for total Kjeldahl nitrogen and 1.45 kg/d for total phosphorus.

\+++ Extrapolated to a daily loading basis by using the ratio of total number of days on which precipitation normally occurs (123) to the total number of days in a year.