DISCUSSION PAPER NO. 1

Capital Regional District

Core Area and West Shore Sewage Treatment
Decision Information Report

Design Criteria

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1 Objective

The objective of this discussion paper is to develop design criteria for the planning of wastewater treatment to the year 2065. It is intended that the criteria will be used by the Steering Committee in the development of a regional wastewater treatment strategy. This strategy will include the proposed level of treatment, as well as the number and location of future wastewater treatment plants.

2 Background Data

The Core Area Liquid Waste Management Plan (LWMP) was completed in July 2000 (CRD, 2000). This work has been used as a basis for developing the wastewater flow design criteria. Further engineering planning has been carried out since the LWMP. Where applicable, data generated from this subsequent work has been used.

The most relevant work on wastewater flow projections has been done by Kerr Wood Leidal Associates Ltd (KWL). The most recent reports (KWL, 1999 and KWL, 2003) are as follows:

- Macaulay Point Sewerage Area
  Northwest Trunk Sanitary Sewer System Summary Report on Design Flows and Hydraulic Analyses, November 1999

- Clover Point Sewerage Area
  Northeast Trunk/East Coast Interceptor Upgrade Capacity Deficiency Study, May 2003

These reports include estimates of future residential populations and equivalent populations (residential plus industrial, commercial and institutional equivalents), per capita wastewater flows, and wet weather flows. In both cases, the ultimate flow projection horizon was 2045. This data is used in this discussion paper to project the flows to 2065.

Population projections have also been carried by the Province through BC STATS using the PEOPLE software. This is a component/cohort survival population model that uses area specific assumptions on fertility, mortality and migration. The most recent projection for the Capital Regional District estimates an annual average population growth rate of 0.7% for the period from 2005 to 2030 (BCATS, 2006).

3 Population Projections

3.1 Macaulay Point Sewerage Area

The 1999 Northwest system report started with 1992 population data and extrapolated the equivalent populations out to 2045. These projections include the expected equivalent populations in the West Shore communities that would be serviced by a regional sewerage system. Analysis of current wastewater flow data at the Macaulay Point plant indicates that the expected rate of growth since the mid-1990s has not occurred and the 2005 equivalent population is less than what was originally forecast. We have thus adjusted the 2005 equivalent population to correspond to actual measured flows and reforecast the future populations using the same growth rates as in the 1999 report. The equivalent population growth has been extrapolated to 2065 by fitting a computer generated trend curve.

The results are presented in Table 3-1.

Table 3-1: Macaulay Point Sewer Catchment Population Estimates

Year	Equivalent Population (in 1000s)
2005	163
2015	199
2030	253
2045	307
2065	379

As may be seen from this information, the estimated equivalent population in 2065 would be in the order of 379,000 persons. The average annual growth rates in the first 25 years and the last 35 years are 1.8 % and 1.2 %, respectively. The average annual growth rate is about 1.4% over the 60-year period. This is higher than BC STATS project for the overall region and reflects the expected higher rate of the growth in the West Shore area.

3.2 Clover Point Sewerage Area

KWL's 2003 Northeast system report started with 2001 population data and extrapolated the equivalent populations out to 2045. We have used the 2003 KWL population estimates to develop a graph and have extrapolated the Clover Point catchment equivalent population to 2065. No adjustments were done to the original projections, as current wastewater flows matched the forecast flows at the Clover Point plant. The projected populations are presented in Table 3-2.

Table 3-2: Clover Point Sewer Catchment Population Estimates

Year	Equivalent Population (in 1000s)
2005	165
2015	176
2030	192
2045	209
2065	231

As may be seen, the equivalent 2065 population is predicted to be in the order of 231,000 person equivalents. The average annual growth rate ranges from about 0.7% in the early years of the projection to about 0.5% in the later years. The average annual growth rate is about 0.6% over the 60 years – considerably lower than the projected growth rate in the Macaulay Point sewerage area. This is also lower than the BC STATS projection and reflects the maturation of the development in this sewerage area.

3.3 Sensitivity of Population Projections

The combined equivalent population projections for both sewerage areas indicate an increase from 328,000 in 2005 to 610,000 in 2065. This reflects an average annual growth rate of about 1.0%. This is slightly higher than the BC STATS projection of 0.7% (note that the BC STATS project is only for the first 25 years). We believe that the estimates represent a reasonable, albeit slightly conservative, basis for the required wastewater management decision making. If the long-term growth rate is marginally higher or lower, it will not impact the fundamental decisions on wastewater treatment plant siting and sequencing strategies.

Short-term growth rates, particularly in the West Shore communities, need to be considered. Significant development is planned in the District of Langford in the coming years. As the Decision Information process continues, decisions will be made on how this growth will be serviced – decentralized wastewater management or connection to the regional sewerage system. The sensitivity of decisions on component sizing and phasing should be reviewed, based on the expected development timing.

As the CRD moves into the preliminary engineering stage on specific components, equivalent population projections should be revisited. It is understood that CRD Planning will be undertaking the development of a comprehensive growth prediction model in 2007. This will be very useful in refining the timing of growth in the sewerage areas.

4 Wastewater Flows

4.1 Definitions

The flows developed by KWL have several components:

- *Per capita equivalent dry weather base sanitary flow* (BSF) that is independent of infiltration and inflow.
- G*round water infiltration* (GWI) component that gets added to the per capita dry weather base sanitary flow to create the average dry weather flow (ADWF) in the sewer.
- *Peak wet weather flows*, based on a number of rainfall return periods.

The *per capita equivalent dry weather base sanitary flows* were extracted by KWL from dry weather flow data by noting the amount of flow that occurred during the middle of the night, when there is very little activity, and taking a percentage of that flow as the GWI. The resulting per capita equivalent dry weather base sanitary flow for the two catchments ranges from 225 to 250 L/d.

The *groundwater infiltration* (GWI) represents leakage of groundwater into the sewer system through cracked pipes or pipe joints. As a result, older sewer systems typically have higher GWI rates than newer sewer systems. GWI can be estimated on the basis of pipe diameter and length of pipe or on an average area basis. The KWL reports have used the latter approach and provide estimated GWI for the driest period and for the wettest period of the year.

The values that have been estimated by KWL for the summer dry weather GWI are as follows:

- *Macaulay Point Sewerage Area*
  Summer dry weather GWI is estimated to be 63 L/s. This equates to 1018 L/ha/d for a tributary area of 5390 ha.

- *Clover Point Sewerage Area*
  Summer dry weather GWI is estimated to be 172 L/s. This is calculated on the basis of 3876 L/ha/d for a tributary area of 3829 ha.

This difference in dry weather GWIs for the two catchment areas reflects the fact that the Clover Point sewer catchment is older with more likelihood of sewer system deterioration than in the Macaulay Point sewer catchment. The GWI contributions are assumed to stay constant over the projection period. This reflects the improved performance of new sewer systems, as well as the gradual improvements in infiltration reductions in existing sewers.

4.2 Average Dry Weather Flows

Based on the projections of future equivalent population, per capita equivalent dry weather sanitary flows and the ground water infiltration flows, the estimated 2065 design *average dry weather flows* (ADWF) are:

Macaulay Point Sewerage Area:	90,800 m^3/d
Clover Point Sewerage Area:	67,300 m^3/d

The calculations are shown on Table 4-1 and 4-2. On the Macaulay Point system, recent replacement of the flow meter at the Macaulay Point plant has led to the conclusion that the previous estimate of BSF was likely high. Based on discussions with CRD staff, we have revised the unit BSF from the previous 250 L/d to 225 L/d. The future equivalent population estimates have also been revised, as discussed in Section 3.1. The Clover Point system estimates are unchanged from the 2003 KWL work, as current measured flows match predicted flows.

Table 4-1: Estimation of Macaulay Point ADWF

Year	Estimated Population (1000s)	Unit BSF* (L/d)	BSF** (m^3/d)	Summer DWGWI*** (m^3/d)	Estimated ADWF (m^3/d)
2005	163	225	36700	5500	42200
2015	199	225	44800	5500	50300
2030	253	225	57000	5500	62500
2045	307	225	69100	5500	74600
2065	379	225	85300	5500	90800

* Unit Base Sanitary Flow has been revised from the 1999 report as discussed in the text.
** Based on equivalent population times unit BSF
*** DWGWI is baseline dry weather groundwater infiltration based on KWL data

Table 4-2: Estimation of Clover Point ADWF

Year	Estimated Population (1000s)	BSF* (m^3/d)	Summer DWGWI** (m^3/d)	Estimated ADWF (m^3/d)
2005	165	37500	14900	52400
2015	176	40000	14900	54900
2030	192	43700	14900	58600
2045	209	47400	14900	62300
2065	231	52400	14900	67300

* Base sanitary flow based on KWL Table 3-1 Northeast Trunk report, May 2003.
Unit BSF used in the calculation ranges from 225 to 250 L/d, depending on the subcatchment.
** DWGWI is baseline dry weather groundwater infiltration based on KWL data.

4.3 Peak Wet Weather Flows

Peak wet weather flow (PWWF) is made up of several components including:

- Peak domestic flow based on the baseline sanitary flow factored up to reflect the changes in diurnal (24hr) flows
- Groundwater infiltration
- Rainfall-dependent inflow and infiltration

Wet weather flows are typically based on storm events. The magnitude of storm events varies based on the frequency of their return. For example, a storm that occurs on average once every five years will have a lower rainfall (and therefore infiltration and inflow) than a storm that occurs once every 25 years. KWL developed estimates of PWWF as Peak Dry Weather Flow (PDWF) plus storm events for a number of different storm events, including 1, 2, 5, 10, 25, 50 and 100-year storm events for both the Macaulay Point and Clover Point sewer catchment areas.

For the purposes of this document, the 25-year storm event has been used. The calculated values reflect the wastewater flow that would reach the Macaulay Point and Clover Point plants, based on the upgrading of the current capacity of the sewer systems. At the present time, there are hydraulic bottlenecks that limit the peak flow that can reach the plants. Under this current condition, bypasses occur at the designated overflow points in the upstream areas of the sewer systems. If the CRD were to increase the hydraulic capacity of the sewer systems over time, as part of the wet weather flow management strategy, the peak flows reaching the plants would increase and the volumes discharged out the upstream overflows would decrease. This needs to be considered in development of the treatment strategy.

The results of the analysis of PWWF and comparison to ADWF for Macaulay Point and Clover Point are shown in Tables 4-3 and 4-4, respectively. The Macaulay Point peak flows have been adjusted downwards from the KWL 1999 report, based on reforecast of the population growth and unit BSF, discussed in the previous section. The Clover Point peak flows are unchanged from the 2003 KWL work.

As may be seen, the ratio of the PWWF to the ADWF for Macaulay Point ranges from 6.3 down to 3.5 in the future. The reduction in the Peaking Factor is due to the infiltration and inflow component of PWWF decreasing over time, as new sewers serving new development are constructed. For Clover Point, the PWWF to ADWF ratio will range from 10.4 to 8.4. While this ratio does decrease, it remains high, indicating that there will still be a significant wet weather I&I component to the flow during the wet months. As noted above, this reflects future growth through primarily redevelopment in this sewerage area.

Table 4-3: Macaulay Point Peak Wet Weather Flows

Year	Calculated PWWF* (m^3/d)	Estimated ADWF (m^3/d)	Ratio of PWWF to ADWF
2005	265,100	42200	6.3
2015	281,100	50300	4.7
2030	305,000	62500	4.2
2045	329,000	74600	3.8
2065	360,900	90800	3.5

* Based on KWL's November 1999 Report, Table 6-1 for 25 yr storm. Original values have been adjusted based on the revised population forecasts and lower unit BSF. Values beyond 2045 have been estimated using a curve-fit equation.

Table 4-4: Clover Point Peak Wet Weather Flows

Year	Calculated PWWF* (m^3/d)	Estimated ADWF (m^3/d)	Ratio of PWWF to ADWF
2005	546,600	52400	10.4
2015	549,200	54900	10.0
2030	553,200	58600	9.4
2045	557,100	62300	8.9
2065	562,300	67300	8.4

* Based on KWL 2003 report (Tables 5-1 to 5-5) and 25-year return storm. Values beyond 2045 have been estimated using a curve-fit equation.

5 Wastewater Loads

5.1 Per Capita Loads

In addition to being capable of physically handling wastewater flows, wastewater treatment plants must also be capable of handling the organic and suspended solids loadings. These loadings are measured as biochemical oxygen demand (BOD_5) and total suspended solids (TSS). Typical loading values for North American cities are about 80 grams of BOD_5 per capita per day and about 90 grams of TSS per capita per day.

Previous engineering studies (Stantec, 2006) have developed loading estimates for the two sewerage areas. For Macaulay Point sewer catchment, the Stantec data infer that the average TSS loading over the 2000 to 2003 period was about 51.3 g/capita/day. Following the same logic, their data suggests that the average BOD_5 loading was about 52.2 g/capita/day. Presumably, because of the relatively low industrial and commercial loading on the Macaulay Point sewer system, the loadings are lower than normal. A value of 60 g/capita/day is proposed for both BOD_5 and TSS loadings to the system.

For the Clover Point sewer catchment, the Stantec data infer that the average TSS loading over the 2000 to 2003 period was about 75.4 g/capita/day. Similarly, the Stantec report data, suggest that the average BOD_5 loading was about 97.8 g/capita/day over the 2000 to 2003 period. These figures are higher and may represent the influence of loadings from commercial and light industrial enterprises that are not present in the Macaulay Point sewer catchment. For the purposes of this study, values of 80 g/capita/day for TSS and 100 g/capita/day for BOD_5 are proposed.

5.2 Influent Loads

The overall loads are summarized in Table 5-1. From these values, it can be seen that despite the differences in contributing populations, the BOD_5 and TSS loadings to the two sewer catchments are similar in magnitude.

Table 5-1: BOD and TSS Loadings for the Two Sewer Catchments

Year	Clover Point			Macaulay Point		
	Estimated Equivalent Population (1000s)	BOD_5 Loading (kg/d)	TSS Loading (kg/d)	Estimated Equivalent Population (1000s)	BOD_5 Loading (kg/d)	TSS Loading (kg/d)
2005	165	16500	13200	163	9780	9780
2015	176	17600	14080	199	11940	11940
2030	192	19200	15360	253	15180	15180
2045	209	20900	16720	307	18420	18420
2065	231	23100	18480	379	22740	22740

6 Treatment Criteria

6.1 Wet Weather Flow Management

The management of wet weather flows will be a critical element of the long-term strategy. Given the intermittent nature and magnitude of wet weather flow events in the CRD sewerage systems, it is not practical to provide secondary treatment for the entire flow. This has been recognized in the LWMP to date, as well as in the Ministry of Environment's Municipal Sewage Regulation (MSR, 1999).

Under the MSR, if the peak flows to the wastewater treatment plant exceed two times the average dry weather flow (ADWF), then on an interim basis, the following levels of treatment can be provided:

- For Flows up to Two Times ADWF - secondary treatment
- For Flows over Two Times ADWF - primary treatment only

Note that this approach is specified for existing sewerage systems on an interim basis. The ultimate goal stated in the MSR is to provide secondary treatment of all discharges, as well as elimination of sanitary sewer overflows (SSO) and combined sewer overflows (CSO).

As noted in Section 4, the CRD sewerage systems experience significant wet weather flow events, with peaking factors well above two times ADWF. While the LWMP provides a strategy for reduction of SSOs, CSOs and the magnitude of peak wet weather events, it will be many decades before the ultimate goal will be reached. The management of wet weather flows will thus be a reality for the planning horizon of the wastewater treatment project.

As the CRD has an approved LWMP, and is in the process of a LWMP amendment, there is potentially greater flexibility in the wet weather management approach than is indicated in the MSR. For example, it may be feasible to provide secondary treatment for a lower flow ratio than two times AWDF if, for flows over this amount, a level higher than primary treatment, such as enhanced primary treatment, is provided. This concept can be pursued further in subsequent development of the Decision Information Report.

6.2 Effluent Criteria

6.2.1 Discharges to Marine Waters

Standards for effluent criteria are established in the Provincial MSR for secondary treatment. For discharge of flows to marine waters, the criteria are:

Biochemical Oxygen Demand (BOD_5)	45 mg/L
Total Suspended Solids (TSS)	45 mg/L
pH	6 to 9

These values are stated as a maximum, not to be exceeded. In order to stay under these values, the average parameter concentrations need to be appreciably lower. A typical secondary wastewater treatment process would produce an average BOD_5 and TSS effluent quality of 15 mg/L and 15 mg/L, respectively.

The requirement for disinfection, and thus the establishment of fecal coliform criteria, is dependent on the use of the receiving water. For marine discharges, two use conditions are potentially applicable – shellfish bearing waters and recreational use waters. The approach to the decision on whether disinfection is required is a back calculation, based on a fecal coliform receiving water criteria and the reductions due to initial dilution, secondary dispersion and die-away. This is thus a site-specific consideration that needs to be considered in the development of options.

For marine waters, defined as embayed, the MSR indicates that phosphorus reduction could be required if it can be shown by an environmental impact study that the receiving waters would not be subject to an undesirable degree of biological activity because of the phosphorus addition. This will thus have to be considered, if new discharges in embayed waters are considered. There is no phosphorus removal requirement for discharges to open marine waters. The existing discharges from the Clover Point and Macaulay Point outfalls are considered to be open marine waters.

The requirement for ammonia reduction is determined from a back calculation from the allowable ammonia concentration at the edge of the initial dilution zone. The allowable receiving water concentration is dependent upon the seawater pH and temperature. Given the large initial dilution that occurs at the Clover Point and Macaulay Point outfalls, ammonia reduction is not expected to be required. If new marine discharges are proposed, the ammonia reduction criteria should be examined.

No specific effluent criteria are proposed for parameters such as metals, trace organic compounds and endocrine disrupting chemicals, as these are not specified in the MSR. These are of importance, however, in the overall CRD wastewater management strategy. We propose that the potential to reduce the concentrations of these parameters, through wastewater treatment technologies, be considered in a subjective manner in the decision making criteria during the subsequent phases on the process.

6.2.2 Water Reuse

Water reuse may be part of the selected wastewater management strategy. The MSR provides various criteria, depending upon the nature of the water reuse. It is most likely that the applications considered by the CRD would require an effluent suitable for unrestricted reuse. The specific criteria are:

Biochemical Oxygen Demand (BOD_5)	10 mg/L
Turbidity	5 NTU
Fecal Coliform	2.2 MPN / 100 ml

These criteria are to be met at all times. Specific process technology considerations are also stipulated to ensure the consistent quality of the reuse water.

7 Odour Management

From the point of view of public perception of a treatment plant, the management of odours is one of the most important factors that should be incorporated into the treatment plant design. The issue of treatment plant odours is very complex. In order to completely describe odour characteristics, five dimensions need to be considered: frequency, intensity, duration, offensiveness and location.

The regulation of odours from wastewater treatment plants is still in a state of development worldwide. There are a number of different approaches to managing odours, ranging "avoidance of nuisance" laws to establishment of criteria for individual chemicals. The most common management tool that is emerging is the use of ambient criteria for odour. This is essentially using our most sensitive tool, the human nose, for measuring odour levels.

In this approach, odour is commonly measured using an odour panel, composed of specially trained individuals. The panel is presented with a series of diluted air samples. The most dilute sample is tested first. Less dilute samples are gradually presented to the panel until 50% of the panel can detect the odour. This is defined as the odour detection threshold. Higher odour concentrations are expressed in terms of multiples of the detection threshold. For example, if an odour sample must be diluted with 5 equivalent volumes of odour-free air to reach the odour detection threshold, then the odour concentration is 5 odour units (OU) per cubic metre.

There are no specific regulatory criteria for odour control in British Columbia for wastewater treatment plants. Typically, treatment plant owners who have adopted a proactive stance have selected design ambient criteria for odour at the plant property line. The specific criteria suggested for use by the CRD is as follows:

> *The property line odour criteria are based on a limit of 5 OU_e/m^3 as an hourly average 98 percentile regardless of wind direction. The concentration is based on a 15-min rolling average.*

This is a very stringent criterion that is currently being used in many European countries where wastewater treatment plants are located adjacent to residential areas. It will require that the significant foul air sources be contained and routed through some type of air scrubbing equipment. At this level of odour management, odour complaints from surrounding development should be virtually eliminated.

8 Noise

Noise is another key element in plant design. Noise at a treatment plant is typically associated with rotating equipment such as aeration blowers and with truck traffic entering and leaving the site.

In general noise standards should comply with local municipal bylaws for the applicable zoning. Typical criteria are 45 decibels and 55 decibels at the fence line for evening and daytime periods, respectively.

Control of noise can be accomplished by locating noise generating equipment inside concrete buildings, lined with sound attenuating acoustic materials. Scheduling deliveries and removals during the working day, when the background noise level is higher, can mitigate truck noise.

9 Land Requirements

In order to assist in development of the Decision Information Report, typical land areas for various levels and types of treatment plants are provided in Table 9-1. Area requirements for the actual process tankage, as well as the overall site area are shown. Overall site area includes the space required for administration and maintenance facilities, access and site roads and general site landscaping and buffer areas. The land areas are based on a plant with an average annual design flow capacity of 100 ML/d. This would handle the wastewater flow from a population of about 300,000.

Table 9-1: Typical Land Area for 100 ML/d Wastewater Treatment Plant

Process	Tankage Area (ha)	Site Area (ha)
Conventional Activated Sludge; UV; Biosolids Digestion & Dewatering	2.20	9.4
Biological Aerated Filters, UV; Biosolids Dewatering	0.94	3.8
Enhanced Primary Treatment; UV: Biosolids Dewatering	0.58	2.0
Enhanced Primary – Actiflo™	0.25	1.3
Primary – Ultra Fine Screening	0.12	1.1

This information is for general guidance only. In the past, wastewater treatment plants have been located away from other areas of development on large tracts of land. Given the ample space, layout efficiency was not a major concern. Today, with plants being located within developed areas, plant layouts are more compact. Advances in technology are also allowing smaller plant footprints. In the development of plant siting options, specific layouts for a given site need to be developed in order to determine whether the available land area is sufficient.

For comparison with the above required site areas for various technologies, the available land areas at the two existing CRD plant sites are:

Macaulay Point Site	3 ha
Clover Point Site	1.5 ha

Clearly, both sites are fairly constrained in terms of available area.

10 References

1 BC STATS, 2006. PEOPLE Run 31, Capital Regional District, RD 17, May 2006, Ministry of Labour and Citizens' Services, Province of British Columbia.

2 Kerr Wood Leidal Associated Ltd., 1999. *Northwest Trunk Sanitary Sewer System Summary Report on Design Flows and Hydraulic Analyses*, Capital Regional District, November, 1999.

3 Kerr Wood Leidal Associated Ltd., 2003. *Northeast Trunk/East Coast Interceptor Upgrade Capacity Deficiency Study*, Capital Regional District, May 2003.

4 Capital Regional District, 2000. *Core Area Liquid Waste Management Plan, Capital Regional District, Environmental Services Department*, July 2000.

5 Municipal Sewage Regulation, 1999. *Waste Management Act Municipal Sewage Regulation*, Province of British Columbia, BC Reg. 1299/99, July 1999.

6 Stantec Consulting Ltd., 2006. *Conceptual Design of Sewage Treatment Plants for Macaulay Point and Clover Point, Final Report,* Capital Regional District, January 2006.