FRASER RIVER ACTION PLAN

City of Prince George Snow Disposal at the Lansdowne Road Wastewater Treatment Centre

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CITY OF PRINCE GEORGE:
SNOW DISPOSAL AT THE LANSDOWNE ROAD WASTEWATER TREATMENT CENTRE

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Prepared for:

Environment Canada
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Prepared by:

Dayton & Knight Ltd.
West Vancouver, B.C.

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Any comments regarding this report should be forwarded to:

Technology and Pollution Prevention Section
Environment Canada
224 West Esplanade
North Vancouver, B.C.
V7M 3H7

CITY OF PRINCE GEORGE
SNOW DISPOSAL STUDY AT
THE LANSDOWNE ROAD WASTEWATER TREATMENT CENTRE

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CITY OF PRINCE GEORGE
SNOW DISPOSAL STUDY AT
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SUMMARY

This study was carried out to evaluate the feasibility of disposing of the snow collected from clearing operations in the City of Prince George, by mixing the snow with the effluent from the Lansdowne Road Wastewater Treatment Centre (WWTC).

A snow melting test was carried out on January 15 and 16, 1996. Snow collected from the downtown bowl area of Prince George was hauled to the WWTC and dumped into the chlorine contact chamber at the maximum rate that could be sustained without causing ice accumulation.

The objectives of the study included an evaluation of the effects of snow additions on the quality and toxicity of the WWTC effluent, an estimation of the snow disposal capacity of the WWTC, identification of any operational concerns associated with snow disposal at the WWTC, and a comparison of the net energy and carbon dioxide balance for snow disposal at the WWTC versus a gas-fired snow melter located downtown.

The Lansdowne Road WWTC at Prince George was determined to be suitable as a centre for disposal of the snow collected from the downtown bowl area, subject to a number of limitations. The primary limiting factor was the solids contained in the collected snow; snow additions caused a significant increase in plant effluent TSS concentration, and permitted maximums were exceeded. Based on the limitation of effluent TSS concentration, the times required to dispose of the collected snow from the present annual minimum, annual mean, and annual maximum snowfalls (assuming 24 hour per day operation) were estimated to be 45 days, 64 days, and 91 days, respectively.

The second factor limiting the snow disposal capacity of the WWTC was the capacity of the mixers in the chlorine tank to circulate the added snow. Based on the limitation of mixing capacity, the times required to dispose of the collected snow from the present annual minimum, annual mean, and annual maximum snowfalls (assuming 24 hour per day operation) were

estimated to be 38 days, 53 days, and 76 days, respectively. An increase in mixing energy in the chlorine tank should increase the snow melting capacity at the WWTC, providing that effluent TSS restrictions were not enforced during snow disposal operations.

The snow additions decreased the average temperature of the WWTC effluent from 11°C to 5°C, and increased the average pH from 7.6 to 7.7. From a theoretical standpoint, the combination of lower temperature and higher pH caused by snow additions resulted in a slight increase in the acute ammonia toxicity of the WWTC effluent, and a slight decrease in the chronic ammonia toxicity. There was also an increase in metals concentration and a decrease in water hardness caused by the snow additions, which would tend to increase the metals toxicity of the effluent. However, the snow additions also decreased the temperature of the WWTC effluent, which would theoretically reduce the metals toxicity.

Based on the results of the 96 hour LC,, bioassay test, there was no conclusive evidence that the acute toxicity of the WWTC effluent was increased by the snow additions. The WWTC effluent was non-acutely toxic at 100% concentration both with and without snow additions, according to the 96 hour LC,, bioassay.

Should disinfection be required at the WWTC, the chlorination effectiveness will be reduced by snow additions, due to a decrease in chlorine contact time, an increase in chlorine demand associated with solids contained in the snow, and an increase in effluent pH.

The annual energy consumption associated with the option of snow disposal at the WWTC was estimated to be 1,000 - 5,000 GJ/yr, compared to 22,000 - 46,000 GJ/yr for the option of a gas-fired snowmelter located in the downtown area. The estimated annual carbon dioxide emissions associated with the option of snow disposal at the WWTC were 80-170 tonne/yr, compared to l,OOO-1,300 tonne/yr for the gas-fired snowmelter.

It was recommended that the City pursue the option of snow disposal at the WWTC, since the option is much more energy-efficient and lower in carbon dioxide emissions than using a gas fired snowmelter. The WWTC option required the identification of additional snow storage area of approximately 60,000 m^3 (12,000 m^2 x 5 m deep), to temporarily store the collected snow from extreme snowfall events. Alternatively, temporarily storage of up to 60,000 m^3 would have to be found at a location other than the WWTC.

The City should review options for reducing the solids content of the collected snow (eg. reduced sanding of roadways). Options for reducing the application of rock salt for deicing operations should be reviewed.

The City should consider conducting further bioassay tests, to determine the effect of snow additions on the toxicity of the WWTC effluent. Tests conducted at actual effluent temperatures (less than the standard temperature of 15°C) should be done using minnows that have been acclimated to the lower temperatures for a minimum of two weeks, and preferably three weeks, as specified in Environment Canada procedures.

VILLE DE PRINCE GEORGE
ÉTUDE SUR L'UTILISATION DU CENTRE DE TRAITEMENT DES EAUX USÉES DE LANSDOWNE ROAD COMME SITE D'ÉLIMINATION DE LA NEIGE

RÉSUMÉ

L'étude a été réalisée afin d'évaluer la faisabilité du projet visant à transporter les quantités de neige enlevées lors des opérations de déneigement de la ville de Prince George au Centre de traitement des eaux usées de Lansdowne Road (WWTC) et de les mélanger aux effluents.

On a procédé à des tests sur la fonte de la neige les 15 et 16 janvier 1996. Des quantités de neige provenant du centre-ville de Prince George ont été transportées au WWTC puis un volume maximal a été déversé dans les bassins de chloration de façon à empêcher l'accumulation de glace.

Les objectifs visés par l'Étude comprenaient l'analyse des impacts qu'entraînerait l'ajout de quantités de neige sur la qualité et la toxicité des effluents du WWTC, une évaluation de la capacité d'élimination de la neige au Centre, l'identification de tout problème opérationnel associé à l'élimination de la neige au WWTC et une étude comparée sur l'équilibre entre l'énergie nette et les concentrations de dioxyde de carbone lors de l'élimination de la neige au Centre par rapport à l'utilisation du fondoir de neige au gaz situé au centre-ville.

Il a été prouvé que le WWTC de Lansdowne Road, à Prince George, était un site approprié pour l'élimination de la neige enlevée dans les rues du centre-ville, avec toutefois certaines réserves. En effet, les matières solides contenues dans cette neige constituaient un inconvénient majeur, car l'ajout de ces quantités de neige entraînaient une forte augmentation des concentrations de TSS dans les effluents d'usine, excédant ainsi les quantités maximales réglementaires. Compte tenu des limites de concentrations de TSS dans les effluents d'usine, le temps requis pour éliminer les quantités de neige amassées (si l'on présume que les opérations se déroulent jour et nuit) est d'environ 45 jours, 64 jours et 91 jours respectivement dans le cas des plus faibles quantités annuelles, des quantités moyennes et des plus élevées.

Un autre point défavorable était l'incapacité des mélangeurs de brasser dans un mouvement circulaire les quantités de neige déversées dans le bassin de chloration. Compte tenu des limites des mélangeurs, le temps requis pour éliminer la neige amassée (si l'on présume que les opérations se déroulent jour et nuit) est d'environ 38 jours, 53 jours et 76 jours respectivement dans le cas des plus faibles quantités annuelles, des quantités moyennes et des plus élevées. Une augmentation de la puissance des mélangeurs dans le bassin de chloration devrait accroître la capacité de fonte de la neige au Centre, si les

restrictions en matière de concentrations de TSS dans les effluents ne sont pas appliquées lors de l'enlèvement de la neige.

Les quantités de neige ajoutées entraînent une baisse de la température moyenne des effluents du WWTC, soit de 11 ºC à 5 ºC, et une augmentation du pH moyen de 7,6 à 7,7. D'un point de vue théorique, l'effet combiné de températures plus basses et d'un pH plus élevé produirait une légère augmentation de la toxicité aiguë de l'ammoniac dans les effluents du WWTC, ainsi qu'une légère diminution de la toxicité chronique de l'ammoniac. On a également observé des concentrations de métaux plus importantes associées à une eau moins dure, ce qui devrait augmenter la toxicité des métaux dans les effluents. Cependant, les quantités de neige ajoutées ont également entraîné une baisse de la température des effluents du WWTC, ce qui provoquerait, en théorie, une diminution de la toxicité des métaux.

Selon les bio-essais LC_{50} effectués sur une période de 96 heures, il n'existe aucune preuve concluante selon laquelle l'augmentation de la toxicité aiguë des effluents du WWTC serait attribuable aux quantités de neige ajoutées. Les bio-essais LC_{30} effectués sur une période de 96 heures ont démontré que la toxicité des concentrations de 100 % dans les effluents du Centre, avec ou sans neige, n'était pas aiguë.

Dans les cas de désinfection au WWTC, l'efficacité de la chloration sera atténuée par les quantités de neige ajoutées, en raison de la diminution du temps de contact du chlore, des plus grandes quantités de chlore nécessaires à l'élimination des solides contenus dans la neige, et de l'augmentation du pH des effluents.

On a évalué la consommation annuelle d'énergie associée à l'élimination de la neige au WWTC à environ 1 000 - 5 000 GJ par année comparativement à 22 000 - 46 000 GJ par année pour un fondoir à neige au gaz situé dans le centre-ville. Les émissions annuelles de dioxyde de carbone associées à l'élimination de la neige au Centre se situeraient entre 80 et 170 tonnes par année comparativement à 1 000 -1 300 tonnes par année pour un fondoir de neige au gaz.

Des recommandations favorables à l'élimination de la neige au WWTC ont été faites à la Ville, car cette option est beaucoup plus économique au point de vue énergétique et les émissions de dioxyde de carbone sont moins importantes que dans le cas du fondoir à neige au gaz. Ce choix entraînait également la désignation d'une zone additionnelle pour le dépôt de la neige, dont le volume serait approximativement de 60 000 m^3 (12 000 m^2 x 5 mètres de profondeur), en cas de phénomènes météorologiques extrêmes. Autrement, on devrait trouver ailleurs un site temporaire d'une capacité de 60 000 m^3.

La Ville devra trouver des moyens de réduire les quantités de matières solides dans la neige amassée (p. ex., diminuer l'épandage d'abrasifs sur les routes). Il faudra également réévaluer l'utilisation du sel dans les opérations de déglaçage.

La Ville devra envisager de procéder à de nouveaux bioessais afin de déterminer les impacts des quantités de neige ajoutées sur la toxicité des effluents du WWTC. Au cours des tests effectués à la température actuelle des effluents (soit inférieure à la température de référence de 15 ºC), on suggère d'utiliser des menés qui sont adaptés à des températures basses pendant une période minimum de deux semaines, de préférence trois, tel que spécifié dans les lignes directrices d'Environnement Canada.

CITY OF PRINCE GEORGE
SNOW DISPOSAL STUDY AT
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CITY OF PRINCE GEORGE
SNOW DISPOSAL STUDY AT
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1.0 INTRODUCTION

The City of Prince George currently transports snow from street clearing operations in the downtown area to land disposal sites at Hudson Bay Slough and Carrie Jane Gray Park. A third land disposal site is located at River Road, however, considering the Department of Fisheries concern for snow disposal and resulting habitat damage, the City has not used this site for the last two winter seasons. The lease on the River Road site expires in 1997 and it will not be renewed. The dump sites discharge snow melt runoff to the foreshore of the Fraser River. Environmental and land use concerns associated with the dump sites have led the City to explore other disposal methods. In 1993, the City and the Fraser Pollution Abatement Office (FPAO) of Environment Canada commissioned a study to assess snow disposal options. A City Public Works task group has since identified a further disposal option at the Lansdowne Road Wastewater Treatment Centre (WWTC). Preliminary testing by the City at the WWTC indicated that loading the snow into the chlorine contact tank immediately prior to discharge of the treated effluent had sufficient merit to warrant further study.

The City issued a Request for Proposals (RFP) on December 14, 1995, for a study to evaluate in detail the option of snow disposal at the WWTC. A copy of the RFP is included in Appendix 1. This report contains the results of the study.

2.0 OBJECTIVES AND SCOPE

2.1 Objectives

The Terms of Reference in the RFP contained the following objectives:

a) Confirm the suitability of the WWTC as a snow disposal centre for the collected snow from the downtown bowl area.

b) Determine the snow disposal capacity of the WWTC.

c) Identify any operational concerns for snow disposal at the WWTC.

d) Analyze the net energy balance and net carbon dioxide balance using waste heat at the WWTC versus a separate melting operation downtown.

e) Determine the effect on the effluent quality and toxicity from snow disposal at the WWTC.

2.2 Scope of Work

As specified in the RFP (Appendix 1), the scope of work was to include but not be limited to the following:

a) A general overview and comments on the suitability of the WWTC as a snow disposal facility, including identification of issues not specifically included in the scope of work, but which should be considered in determining the suitability of the WWTC for disposal of the snow from the downtown bowl area only.

b) A determination of the snow disposal capacity at the WWTC, including a consideration of the range of flow rates that can reasonably be expected at the WWTC.

c) An identification of any operational concerns for snow disposal at the WWTC, particularly any items that may affect the treatment processes.

d) An analysis of the net energy balance and net carbon dioxide balance, using waste heat at the WWTC versus a melting facility downtown.

e) A determination of the effect of snow disposal operations at the WWTC on effluent quality and toxicity, including a collation of and comment on the results of testing conducted by City personnel. Tests to be conducted on both the influent and effluent of the chlorine contact chamber during snow melting operations included biochemical oxygen demand (BOD), temperature, total suspended solids (TSS), and metals. Sampling and test recording was done by WWTC personnel.

The work described above was completed, and a draft report was submitted on March 1, 1996. One of the recommendations included in the draft report was that bioassay tests (96 hour LC_{50} using rainbow trout minnows) should be conducted, to evaluate the effect of snow additions on the toxicity of the WWTC effluent. After review of the draft report by the City of Prince George and Environment Canada, the scope of work was expanded to include toxicity testing of samples of the undiluted WWTC effluent and of WWTC effluent mixed with snowmelt water.

3.0 METHODOLOGY

The methodology used to address the terms of reference is summarized in this section.

3.1 Snow Melting

The snow melting test was carried out at the Lansdowne Road WWTC during the period from 10:00 P.M. January 15 through 6:00 A.M. January 16, 1996. Diesel-powered dump trucks were used to transport collected snow to the WWTC site.

Nine tandem axle trucks and one long box truck hauled snow from various locations in the downtown area to the W.W.T.C. for melting.

Space to dump snow directly by truck into the Chlorine Contact Tank was limited and could not accommodate all trucks on the haul route without holding up trucks at the plant to provide adequate time to dump directly to the tank. It was also unclear if the tank had the capability of handling the snow dumped directly from the trucks at the volume it was being hauled into the plant. The loader acted as a metering device allowing continuous adding of the snow from the accumulating stock pile, while occasionally a truck was dumped directly to the tank. In the absence of trucks entering the plant, the loader continued adding snow to the tank. Snow was added to the tank based on observation by the people in attendance including the Senior Treatment Plant Operator, Norm Gobbi. When the snow floating on the surface started to circulate, more snow was added to the tank.

Information provided by the City showed that the tandem axle type had a 400 HP engine, a gross vehicle weight (GVW) of 19,510 kg, and a dump volume of 20 cubic meters. The long-box trailer type had a 460 HP (365 BHP) engine, a GVW of 33,850 kg, and a dump volume of 42 cubic meters. One of the tandem axle truck drivers and the long trailer truck driver recorded the total kilometres driven and the total fuel consumption during the test.

Snow was added to the chlorine contact tank at the WWTC at the maximum rate that could be sustained. The tank was mixed by two mechanical agitators. Snow added to the tank initially floated on the surface; as the snow submerged and began to circulate, more snow was added to the tank. Snow additions to the tank were begun at 9:55 P.M. on January 15, and discontinued at 5:30 A.M on January 16. The average snow density and the volume and time of addition to the chlorine tank for each load of snow was recorded by Prince George staff. A plan of the WWTC, including the snow storage area, is shown on Figure 1. A detail of the chlorine contact tank area is shown on Figure 2.

3.2 Water Quality Testing

As specified in the RFP (Appendix 1), the chlorine tank influent and the effluent were to be tested for temperature and the concentrations of five-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), and metals.

In addition to the testing parameters listed in the RFP, the chlorine tank influent and effluent were tested for pH and salinity, since the pH affects the percentage of ammonia nitrogen that exists in the (toxic) unionized form, and the salinity of the WWTC effluent might be increased through the addition of road salt (mainly sodium chloride) incorporated in the snow removed from city streets (at high levels, salinity can stress or kill aquatic life).

Grab samples of the chlorine contact tank influent and effluent were taken at one-hour intervals over the first seven hours of the test. Each influent sample was taken at the influent chamber near the Northwest corner of the tank, and each effluent sample was taken at the overflow weir, just inside the tank wall. In addition, a composite sample of influent and effluent composed of equal amounts of each of the eight appropriate grab samples was prepared. All samples were analyzed immediately after collection by WWTC personnel at the treatment plant laboratory for BOD_5, TSS, temperature, pH, and ammonia. The BOD_5 and TSS analyses were conducted according to APHA et al. (1992) and ammonia analyses were done using a Hach spectrophotometer. A metals scan and conductivity analysis (indicator of salinity) on all samples was undertaken by ASL Analytical Laboratories in Vancouver, B.C. The methodology used by ASL is included in Appendix 3.

3.3 Statistical Analysis of Data

The student *t* test for paired comparisons was used to statistically evaluate significant differences in the chlorine tank influent and effluent for each of the water quality parameters of interest. A statistical analysis is advisable in comparing two data sets, particularly in cases where relatively large variations in data values are possible. If a data set contains values which vary over a wide range, the mean (average) value of the set may not be very meaningful. For example, if two measurements were taken in the same way, at the same time, in the same place, and one result turned out to be 100 mg/L while the other was 1,000 mg/L, it would be risky to conclude that the average of the two (550 mg/L) was the true result. The risk is increased when trying to compare two data sets which both contain wide variations. A statistical analysis takes the variation of each data set into account, and provides a mathematical means of determining whether any observed differences between the two sets are meaningful (i.e., Astatistically significant@), or whether the random variation among the data is so large that it is not reasonable to conclude that the two sets are different. The more random variation there is among the data, the less chance there is of the statistical analysis detecting a significant difference between the two sets.

In this case, the statistical analysis was used to determine whether the concentration of a particular water quality parameter (say BOD) in the chlorine chamber effluent was significantly different from that in the chlorine chamber influent. The *t* test was used to mathematically determine whether or not the mean (average) value of one data set (say the BOD_5 concentration of the chlorine chamber influent) was significantly different from the mean value of a second data set (say the BOD_5 concentration of the chlorine tank effluent).

The advantage of the *t* test for paired comparisons is that it can be used to make comparisons between matched pairs of data. Each matched pair in this case was made up of the sample of influent and effluent taken at the same time of day. The difference between the influent and effluent concentration at each sampling time was calculated (i.e., effluent concentration minus influent concentration), and the statistical analysis was conducted on the differences. In this way, changes in conditions during the test (e.g., flow rate) were factored out of the analysis, since each matched pair was taken under the same conditions.

The null hypothesis in the paired comparison test is that there is no difference between the means (averages) of the two data sets. The test statistic t_0 is calculated by dividing the mean of the differences between the matched pairs by the product of the standard deviation of the differences and the square root of the number of matched pairs (n). The standard deviation of a data set is a measure of variation among the values of the set; wide variations in values result in a relatively large standard deviation. The calculated value of t_0 is compared to values of the t distribution at a pre-selected level of significance (values of the t distribution are available from tables). If the absolute value of t_0 is greater than the value of the t distribution, the null hypothesis is rejected, and it may be concluded that the mean of one data set is significantly different from that of the other data set. Note that since the standard deviation is in the denominator when calculating the value of t_0, a relatively high standard deviation (variation) in the differences between the matched pairs will reduce the value of t_0, and thereby reduce the chance of detecting a significant difference between the two means.

The t test comparisons were carried out at the 0.05 level of significance. That is, there was a 5% probability that the t test showed a significant difference when none in fact existed.

3.4 Toxicity Testing

The toxicity testing was designed to evaluate the effects of snow additions on the acute toxicity of the WWTC. The previous work showed that the typical mixture of snowmelt water and WWTC effluent based on the maximum snow melting capacity of the plant was approximately 7% snowmelt water and 93% WWTC effluent by volume. The previous work also showed that the average temperature of the WWTC effluent on January 15, 1996, was reduced from 11^{o}C to approximately 5^{o}C by the snow additions. After review of the draft report, the City requested that the following 96 hour LC_{50} bioassay tests using rainbow trout minnows be carried out.

Sample #1 - undiluted WWTC effluent at 15^{o}C (standard temperature for bioassays);

Sample #2 - mixture of 7% snowmelt water and 93% WWTC effluent by volume at 15^{o}C;

Sample #3 - undiluted WWTC effluent at 11^{o}C (actual average temperature of WWTC effluent before snow additions on January 15, 1996);

Sample #4 - same mixture as Sample #2 at 5^{o}C (actual average temperature of WWTC effluent after snow additions on January 15, 1996).

The bioassay testing was undertaken by B.C. Research Inc. (BCR) in Vancouver, according to the procedures described in Appendix 6. The samples for testing were collected at the WWTC on the morning of March 18, 1996, and shipped by overnight delivery to BCR. Six 22.5 L samples of undiluted WWTC effluent and two 22.5 L samples of snowmelt water were taken. The snowmelt water was obtained from snow samples taken from the ploughed windrows along the road to the WWTC. Road sanding and salting procedures at this location are the same as those at the downtown bowl.

The mixture of snowmelt water and WWTC effluent for Samples #2 and #4 were prepared by BCR. All four bioassay tests were begun on March 19, 1996.

3.5 Solids Content of Collected Snow

In addition to the testing parameters listed in the RFP (Appendix 1), tests were carried out to determine the amount of total settleable solids contained in the collected snow, since this material would likely accumulate in the chlorine contact tank and require periodic removal.

In order to estimate the amount of solids contained in the collected snow, two random samples approximately 25 L in volume were taken from the snow storage area. The snow samples were then melted, and the TSS of two replicate portions of each sample of meltwater were analyzed for TSS according to APHA et.al. (1992).

3.6 Net Energy and Carbon Dioxide Balance

An analysis was conducted to compare the net energy and carbon dioxide balances using waste heat at the WWTC versus a melting facility downtown. The fuel consumption associated with trucking and snow-melting at the downtown facility was compared to the fuel consumption associated with trucking the snow to the WWTC, from the standpoint of the total energy consumed and the total carbon dioxide emissions. A description of the procedures used is given below.

3.6.1 Snow Hauling

An estimate of the average distance from the bowl to the proposed downtown snow melter site (1,500 m) and estimates of the total quantities of snow to be collected and hauled from the bowl area at the City of Prince George for the annual minimum, annual average, and annual maximum snowfalls were prepared by others. For a total snowfall of 189.4 cm during the winter of 1992-93, the total snow disposal volume for the bowl area was estimated to be 271,000 m^3. The 1992-93 snow disposal volume for the bowl was scaled to match the design annual minimum (151.2 cm) annual mean (213.7 cm), and annual maximum (306.4 cm) snowfalls, by multiplying by the appropriate ratio (report by Stanley & Associates, 1993). Thus the snow disposal volumes from the downtown bowl area for the annual minimum, annual mean, and annual maximum snowfalls were estimated at 216,000 m^3, 306,000 m^3, and 438,000 m^3. The average distance from the bowl to the WWTC (5,000 m) was estimated from a plan of the City.

The fuel consumption per kilometre (including the empty return trip) for both the tandem axle and long-box dump trucks was estimated by dividing the total fuel consumed over the test by the total number of kilometres driven. The total number of truckloads associated with hauling the collected snow from the annual minimum, average, and maximum snowfalls was estimated by dividing the total volume of collected snow by the volume of a typical truckload. The total fuel consumption associated with hauling the collected snow from each of the three design snowfalls to the WWTC and the downtown melter site was then estimated by multiplying the distance from the bowl to the WWTC (and to the downtown melter site) by the total number of truckloads, and then multiplying the product by the average fuel consumption per kilometre. This calculation was carried out for both types of truck used in the test.

The use and fuel consumption of the loader was assumed to be similar for both the WWTC and downtown snowmelter options. The fuel consumption of the loader was therefore not recorded.

The estimated carbon dioxide emissions for each type of truck used in the test were obtained from the Mobile Sources Emissions Division of Environment Canada. The emissions data were reported by Environment Canada in grams of carbon dioxide per mile driven, considering a typical dump truck duty cycle (i.e., the emissions data includes typical idling time, a payload trip, and an empty return trip). The carbon dioxide emissions associated with trucking the snow to each of the two possible disposal sites was estimated by multiplying the emissions per kilometre by the total number of kilometres driven for disposing of the total volume of collected snow at the bowl area for the annual minimum, average, and maximum snowfalls.

The estimated carbon dioxide emissions provided by Environment Canada for the two types of dump truck used in the test are as follows:

Tandem Axle, 400 hp diesel, GVW 19,510 kg = 2,010 g CO_2/km (dump truck duty cycle)
Long-trailer, 460 hp diesel, GVW 33,850 kg = 3,220 g CO_2/km (tractor duty cycle)

The heat of combustion of diesel fuel (No. 2 fuel oil) is approximately 39 MJ/L (140,000 Btu/US gal - Perry and Green, 1984). The energy consumed by trucking the snow was estimated by multiplying the heat of combustion of diesel fuel by the estimated total fuel consumption associated with trucking the snow to each of the two disposal sites, for each type of truck.

3.6.2 Snow Melting

The estimated fuel consumption per tonne of snow for the natural gas-fired snow melter referenced in the report by Stanley & Associates (1993) was reported by the supplier (MBB

Trecan) to be 225 standard cubic feet of gas per tonne of snow melted (6,372 L of gas at standard conditions per tonne of snow melted). The total natural gas consumption associated with melting of the annual minimum, average, and maximum snowfalls was estimated by multiplying the total weight of snow to be melted (assuming a density of 400 kg/m^3 for the collected snow - see Stanley & Associates, 1993) by the fuel consumption per tonne of snow melted.

Natural gas is variable in composition, and there is no single composition that can be called Atypical@ natural gas. However, natural gas is usually composed of at least 90% methane (Perry and Green, 1984). For the purposes of this report, the carbon dioxide and energy balances were carried using the combustion of pure methane (CH_4). The carbon dioxide (CO_2) emissions from the snow melter were estimated from the formula for the combustion of methane as follows:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

As shown above, one mol of methane yields one mol of carbon dioxide. Therefore, at standard conditions, the combustion of one L of methane yields one L of carbon dioxide. At standard conditions, the density of carbon dioxide is 1.9768 g/L. The combustion of one L of natural gas (methane) at standard conditions then yields 1.9768 g carbon dioxide. The CO2 emissions from the snow melter would then be 12.6 kg carbon dioxide/tonne of snow melted (6372 L gas per tonne snow melted times 1.9768 g carbon dioxide emitted per L of gas consumed). The number of tonnes of snow associated with each collection volume was determined by assuming that the density of collected snow was 400 kg/m^3 (the snow density during the test at the WWCT was 370 kg/m3 - see Appendix 2).

The heat of combustion of natural gas is typically approximately 40 MJ/L (Perry and Green, 1984). The energy consumption of the snow melter was estimated by multiplying the volume of natural gas consumed for each snow collection volume by the heat of combustion.

The total energy consumption and the total carbon dioxide emissions associated with each of the two disposal options was then compared, for the annual minimum, annual average, and annual maximum snowfalls, and for both types of truck used in the test.

4.0 RESULTS

4.1 Snow Disposal Rate

The site snow loading data recorded by WWTC personnel during the test are included in Appendix 2. Included for each type of truck are the GVW, tare weight, net weight per load, engine horsepower, total fuel consumption, total number of kilometres driven, volume per dump, and the time of delivery of each load. The rates of snow hauling to the WWTC and of snow addition to the chlorine tank are summarized on Figure 3. Note that the rate of hauling dropped sharply between the hours of 3:00 A.M. and 4:00 A.M. (lunch break), with a corresponding drop in the snow addition rates.

As described in Section 3, the snow addition rate was for the most part determined by the observed rate of circulation in the chlorine tank (except during the lunch break from 3:00 A.M. to 4:00 A.M). The average rate of snow addition over each hour of the test from 10:00 P.M. to 5:00 A.M. is plotted versus the plant flow through rate on Figure 4. A linear regression showed that there was a strong direct correlation (r squared = 0.98) between the snow melting rate and the treatment plant flow through rate (ie. a higher flow rate of relatively warm water entering the chlorine tank increased the available heat energy for melting snow). The data point representing the average snow addition rate between the hours of 3:00 A.M. and 4:00 A.M. (lunch break) was not included in the regression. The correlation equation for the regression shown on Figure 4 is as follows:

Snow melting rate (tonne/hr) = (0.053) (Plant flow through rate in m^3/hr) + 22.4

To verify the regression equation, a rough theoretical calculation was carried out. The energy available from lowering the temperature of the water from 11 degrees C to 5 degrees C (25.55 MJ/m^3) was estimated by multiplying the average specific heat of water between 5 and 11 degrees C (4,208 J/kg/K) by the average water temperature drop (6 degrees K). The energy required to melt the snow was estimated by assuming that the initial temperature of the snow was -20 degrees C. The energy required to heat the snow to the melting point (42 MJ/tonne of snow) was calculated by multiplying the specific heat of ice (2,100 J/kg/K) by the temperature rise (20 degrees K). The energy required to melt the snow is the heat of fusion of ice (333.5 MJ/tonne of ice). The energy required to heat the melt water from 0^oC to 5^oC (21 MJ/tonne of snow) was calculated by multiplying the average specific heat of water between 0^oC and 5^oC (4215 J/kg/K) by the temperature rise (5 degrees K). The total energy required to raise the temperature of the snow to the melting point, melt it, and raise the temperature of the melt water to 5^oC is then 333.5 + 42 + 21 = 396.5 MJ/tonne. The melting capacity of the WWTC at the average flow rate during the test of 1012 m^3/hr can then be theoretically estimated by the following:

(25.55 MJ/hr x 1012 m^3/hr)/(396.5 MJ/tonne) = 65 tonnes of ice melted per hour

According to the snowmelting regression equation shown earlier, the melting rate at a flow of 1012 m^3/hr was 76 tonnes/hr. The agreement between the theoretical and empirical values is reasonable, considering the approximate nature of the theoretical calculation.

4.2 Water Quality Testing

The laboratory results from the samples tested for temperature, pH, BOD_5, TSS, ammonia nitrogen, and conductivity are contained in Appendix 3. A summary of the results is shown in Table 1. The average concentration of the eight grab samples and the concentration in the composite sample is shown for both the chlorine chamber influent and effluent. The statistical analysis (*t* test) results for each parameter are contained in Appendix 4, and a summary of the results is included in Table 1. Where differences between the influent and effluent concentrations are said to be significant, it means that the *t* test detected a statistically significant difference between the average concentration of the eight grab samples of influent and the average concentration of the eight grab samples of effluent.

As shown in Table 1, the average temperature of the chlorine chamber effluent (5.4 C) was significantly lower than the average temperature of the influent (11.1 C). The average pH of the effluent (7.7) was significantly higher than that of the influent (7.6). The average BOD_5 of the effluent grab samples (49 mg/L) was significantly higher than that of the influent (44 mg/L); similarly, the BOD_5 of the composite effluent sample (46 mg/L) was 5 mg/L higher than that of the influent sample (41 mg/L). The average TSS concentration in the grab samples of effluent (56 mg/L) was significantly higher than that of the influent (11 mg/L), an increase of 45 mg/L. According to the composite samples, the increase in TSS concentration from influent to effluent was also 45 mg/L (from 8 mg/L to 53 mg/L).

The increase in effluent TSS concentration through snow additions is expected to be a function of the amount of snow added to the tank, taking into account the relative dilution by the tank influent. The increase in TSS concentration from influent to effluent is plotted versus the average hourly snow addition rate as a percentage of the average hourly plant flow rate on Figure 5. With the exception of the data point associated with the period from 4:00 A.M. to 5:00 A.M., a reasonable linear correlation exists (r squared = 0.91). The reason for the outlying data point is unknown; possibly, the snow added during that period contained significantly less solids than the snow added during the rest of the test, or the solids were more coarse and therefore more prone to settle out in the tank. The correlation equation for effluent TSS (neglecting the outlying data point) is as follows:

Increase in effluent TSS (mg/L) = 1,449 (snow addition in tonnes snow/m^3 plant flow) - 51.6.

No significant change in ammonia concentration from influent to effluent was detected. The conductivity of the influent was slightly higher than that of the effluent according to both the composite samples and grab samples, but the difference was not significant, according the *t* test.

The laboratory results of metals testing are contained in Appendix 3. The results of the statistical analysis (*t* test) are included in Appendix 4. A summary of the results is shown in Table 2. Note that the *t* test could not be conducted where the concentration of a particular metal was below detection limits in both the influent and the effluent. Metals which were found at significantly higher concentrations in the chlorine chamber effluent compared to the influent were aluminum, barium, copper, iron, manganese, silicon, titanium, and zinc. Metals which were found in significantly lower concentrations in the effluent compared to the influent were calcium, manganese, and phosphorus. No significant difference was detected between the average influent and effluent concentrations of magnesium, potassium, sodium, or strontium. All of the other metals tested (arsenic, beryllium, bismuth, boron, cadmium, chromium, cobalt, lead, lithium, molybdenum, nickel, selenium, silver, thallium, tin, and vanadium) were consistently below detection limits in samples of both influent and effluent.

4.3 Toxicity Testing

The results of the toxicity testing are included in Appendix 6. The results are summarized in Table 3. All four samples resulted in less than 50% mortality of the fish at 100% concentration (i.e., all four were non-acutely toxic according to the 96 hour LC 50 bioassay). No mortalities were recorded for either Sample #1 (undiluted WWTC effluent tested at 15^{o}C) or Sample #2 (WWTC effluent mixed with snowmelt tested at 15^{o}C). For Sample #3 (undiluted WWTC effluent tested at 11^{o}C), one of the ten fish died within the first 48 hours. For Sample #4 (WWTC effluent mixed with snowmelt tested at 5^{o}C), three of the ten fish died within the first 24 hours (Appendix 6).

The lowest dissolved oxygen concentration recorded during any of the bioassays was 8.5 mg/L. The minimum recorded pH was 6.8, and the maximum was 7.5 (Appendix 6). Therefore, the observed fish mortality and stress was unlikely to have been caused by low dissolved oxygen or extremes in pH.

TABLE 1

RESULTS OF ANALYSES OTHER THAN METALS

Parameter	Influent [1]		Effluent [2]		Comments
	Grabs [3]	Comp [4]	Grabs [3]	Comp [4]	
Temperature (° C)	11.1	NA	5.4	NA	Effluent significantly lower than influent [5]
pH	7.6	NA	7.7	NA	Effluent significantly higher than effluent [5]
BOD_5 (mg/L)	41	44	46	49	Effluent significantly higher than effluent [5]
TSS (mg/L)	11	8	56	53	Effluent significantly higher then effluent [5]
Ammonia (mgN/L)	26	26	26	25	No significant difference [5]
Conductivity (umhos/cm)	739	743	775	770	No significant difference [5]

Notes:

1 Chlorine chamber influent
2 Chlorine chamber effluent
3 Average of 8 grab samples
4 Composite samples
5 See Appendix 4 for statistical analysis

TABLE 2

RESULTS OF METALS ANALYSIS

Physical Test Conductivity	Total Metals Concentration (mg/L)				Comments
	Influent [1]		Effluent [2]		
	Grabs [3]	Comp [4]	Grabs [3]	Comp [4]	
Aluminum	<0.20	<0.20	0.55	0.36	Effluent significantly higher than influent [5]
Antimony	<0.20	<0.20	<0.20	<0.20	Influent and effluent less than detection limit
Arsenic	<0.20	<0.20	<0.20	<0.20	Influent and effluent less than detection limit
Barium	0.022	0.022	0.043	0.036	Effluent significantly higher than influent [5]
Beryllium	<0.005	<0.005	<0.005	<0.005	Influent and effluent less than detection limit
Bismuth	<0.10	<0.10	<0.10	<0.10	Influent and effluent less than detection limit
Boron	<0.10	<0.10	<0.10	<0.10	Influent and effluent less than detection limit
Cadmium	<0.010	<0.010	<0.010	<0.010	Influent and effluent less than detection limit
Calcium	36.6	36.3	35.5	34.3	Effluent significantly lower than influent [5]
Chromium	<0.015	<0.015	<0.015	<0.015	Influent and effluent less than detection limit
Cobalt	<0.015	<0.015	<0.015	<0.015	Influent and effluent less than detection limit
Copper	0.048	0.049	0.059	0.061	Effluent significantly higher than influent [5]
Iron	0.076	0.075	0.943	0.685	Effluent significantly higher than influent [5]
Lead	<0.050	<0.050	<0.050	<0.050	Influent and effluent less than detection limit
Lithium	<0.015	<0.015	<0.015	<0.015	Influent and effluent less than detection limit
Magnesium	11.5	11.3	11.3	11.0	No significant difference [5]
Manganese	0.059	0.057	0.130	0.109	Effluent significantly higher than influent [5]

Physical Test Conductivity	Total Metals Concentration (mg/L)				Comments
	Influent [1]		Effluent [2]		
	Grabs [3]	Comp [4]	Grabs [3]	Comp [4]	
Molybdenun	<0.030	<0.030	<0.030	<0.030	Influent and effluent less than detection limit
Nickel	<0.020	<0.020	<0.020	<0.020	Influent and effluent less than detection limit
Phosphorus	3.33	3.26	3.11	3.03	Effluent significantly lower than influent [5]
Potassium	11.1	10.8	10.7	10.2	No significant difference [5]
Selenium	<0.20	<0.20	<0.20	<0.20	Influent and effluent less than detection limit
Silicon	7.45	7.40	7.78	7.42	Effluent significantly higher than influent [5]
Silver	<0.015	<0.015	<0.501	<0.015	Influent and effluent less than detection limit
Sodium	71.5	71.3	82.1	81.3	No significant difference [5]
Strontium	0.157	0.155	0.153	0.148	No significant difference [5]
Thallium	<0.10	<0.10	<0.10	<0.10	Influent and effluent less than detection limit
Tin	<0.30	<0.30	<0.30	<0.30	Influent and effluent less than detection limit
Titanium	<0.010	<0.010	0.019	0.013	Effluent significantly higher than influent [5]
Vanadium	<0.030	<0.030	<0.030	<0.030	Influent and effluent less than detection limit
Zinc	0.028	0.027	0.038	0.035	Effluent significantly higher than influent [5]

Notes:

1 Chlorine chamber influent
2 Chlorine chamber effluent
3 Average of 8 grab samples
4 Composite samples
5 See Appendix 4 for statistical analysis

TABLE 3 - RESULTS OF TOXICITY TESTING

Sample	Bioassay Temperature[1] (°C)	Percent Mortality at 100% Concentration
#1 Undiluted WWTC effluent	15	0
#2 WWTC effluent and snowmelt[2]	15	0
#3 Undiluted WWTC effluent	11	10
#4 WWTC effluent and snowmelt[2]	5	30

[1] - Temperature at which bioassay was conducted.
[2] - Sample was 93% WWTC effluent and 7% snowmelt water by volume.

4.4 Solids Accumulation in Chlorine Tank

The results of testing for the TSS concentration in the two random samples of collected snow are included in Appendix 3. The results were as follows:

Sample #1 - replicate #1=929 mg/L, replicate #2=939 mg/L

Sample #2 - replicate #1=724 mg/L, replicate #2=763 mg/L

The overall average TSS concentration of the meltwater from the collected snow samples was 840 mg/L (0.84 kg solids/tonne of snow). The total weight of snow added to the chlorine contact tank during the time that effluent samples were being taken (10:00 P.M. to 5:00 A.M. was 985 tonnes (Appendix 2). Based on the two random samples of collected snow, the total mass of solids added to the tank was approximately 830 kg. According to the analyses of both grab samples and composite samples, the TSS concentration of the effluent was 45 mg/L higher than that of the effluent (Table 1). The average flow through rate during the 7 hour sampling period was 1,012 m^3/hr. Therefore, approximately 320 kg of the solids added with the snow left the tank in the effluent during the sampling period. Some of the remainder (510 kg) likely left the tank in the effluent after sampling was discontinued, and some likely settled to the bottom of the tank.

Assuming the worst-case (all of the solids not leaving the tank in the effluent during the sampling period settled to the bottom), the amount of solids settling in the chlorine tank due to snow additions was approximately 0.5 kg solids/tonne snow added. For the annual minimum, annual average, and annual maximum snowfalls, the corresponding annual solids accumulations in the chlorine tank would be approximately 108,000 kg, 154,000 kg, and 219,000 kg, respectively. The total cross-sectional area of the chlorine tank at the WWTC is 370 m^2. Assuming that the solids are mainly non-organic in nature (sand and silt), and assuming a solids density of 1,600 kg solids/cubic meter at the bottom of the tank (typical density for coarse soils), the annual depth of solids accumulation in the chlorine tank would be 180 mm for the annual minimum snowfall, 260 mm for the annual mean snowfall, and 370 for the annual maximum snowfall.

4.5 Net Energy and Carbon Dioxide Balance

The tandem axle truck had a capacity of 20 m^3/load, and the long trailer truck had a capacity of 42 m^3/load (Appendix 2). The total number of loads and the total distance travelled for each type of truck to haul the entire snow disposal volume associated with the annual minimum, annual mean, and annual maximum snowfalls to both the WWTC and the downtown snowmelter site are summarized in Table 4.

TABLE 4
NET ENERGY AND CARBON DIOXIDE BALANCE

		Annual Snowfall (Total Snow Disposal Volume in cubic					
		Minimum		Mean (306,000)		Maximum	
		Tandem[3]	LT[3]	Tandem	LT[3]	Tandem	LT[3]
Total number of loads[1]	WWTC	10,800	5,143	15,300	7,286	21,900	10,429
	Melter	10,800	5,143	15,300	7,286	21,900	10,429
Total distance travelled[2]	WWTC	108,000	51,42	153,000	72,85	219,000	104,28
	Melter	32,400	15,42	45,900	21,85	65,700	31,286
Total diesel fuel consumed	WWTC	59,400	29,82	84,150	42,25	120,450	60,486
	Melter	17,820	8,949	25,245	12,67	36,135	18,146
Energy consumed by	WWTC	2,313	1,161	3,276	1,645	4,690	2,355
	Melter	694	348	983	494	1,407	706
CO2 emissions by trucks[5]	WWTC	84	64	119	90	171	129
	Melter	25	19	36	27	51	39
Energy consumed by	WWTC	0	0	0	0	0	0
	Melter	22,022	22,02	31,197	31,19	44,655	44,655
CO2 emissions by melter[7]	WWTC	0	0	0	0	0	0
	Melter	1,088	1,088	1,542	1,542	2,207	2,207
Total energy consumed	WWTC	2,313	1,161	3,276	1,645	4,690	2,355
	Melter	22,715	22,37	32,180	31,69	46,062	45,361
Total CO2 emissions (t)	WWTC	84	64	119	90	171	129
	Melter	1,114	1,107	1,578	1,569	2,258	2,246

1 Volume of tandem = 20 m^3, volume of long trailer (LT) = 42 m^3
2 One-way distance from bowl to WWTC = 5,000 m
One-way distance from bowl to downtown melted side = 1,500 m
3 Average estimated fuel consumption 0.55 L/km for the Tandem, and 0.58 L/km snow for the LT.
4 Assuming combustion of diesel fuel consumes 39 MJ/L of energy
5 Assuming CO_2 emissions from trucks are 780 g CO_2/km for Tandem, and 1240 g CO_2/km for LT.
6 Assuming combustion of natural gas consumes 40 MJ/L.
7 Assuming CO_2 emissions from snowmelter are 12.6 kg/tonne snow melted.

For the tandem axle truck, the fuel consumption was 80 L, and the total distance driven was reported to be 115 km. For the long-trailer truck, the total fuel consumption was 84.5 L, and the total distance driven was 145 km. Using these numbers, it would appear that the long-trailer truck used less fuel per kilometre while hauling more than double the payload of the tandem axle truck. However, it should be noted that the driver of the long-trailer truck was certain of his mileage, while the driver of the tandem axle truck was not, and that the trucks all made a similar number of trips. Therefore, the total distance travelled by the tandem axle truck was assumed to be 145 km, the same as that of the long-trailer truck. The resulting fuel consumption was 0.55 L/km for the tandem, and 0.58 L/km for the long-trailer.

Using the recorded fuel consumption and the total distance travelled, the total fuel consumed by each type of truck to haul the snow disposal volumes associated with the annual minimum, annual average, and annual maximum snowfalls to the WWTC and the downtown melter site were calculated. The results, including the total energy consumed and the total mass of carbon dioxide emitted for each of the two disposal options, are included in Table 4.

The carbon dioxide emissions and energy consumption of a natural gas-fired snow melter for the annual minimum, annual mean, and annual maximum snowfall disposal volumes are included in Table 4, together with the overall total carbon dioxide emissions and energy consumption associated with each of the two snow disposal options.

5.0 DISCUSSION

5.1 Effect of Snow Disposal on WWTC Effluent Quality

The discharge limits at the WWTC under the present permit are 65 mg/L for BOD_5 and 50 mg/L for TSS. Future permit limits after the WWTC upgrade are likely to be maximum concentrations of 45 mg/L for both BOD5 and TSS, and average concentrations of 30 mg/L for BOD_5 and TSS. There are no discharge limits for ammonia or metals specified in the permit.

As shown in Table 1, the snow additions to the chlorine chamber resulted in a significant lowering of the average temperature of the WWTC effluent from 11.1 C to 5.4 C. The snow additions resulted in significant increases in the WWTC effluent average BOD_5 concentration from 41 mg/L to 46 mg/L, and in the effluent average TSS concentration from 11 mg/L to 56 mg/L. The effluent pH and conductivity were marginally increased, and ammonia concentration was unaffected.

Of the water quality parameters listed in Tables 1 and 2, TSS is the only one likely to limit snow melting from the standpoint of effluent discharge limits under the existing permit. The TSS concentrations in the eight grab samples of chlorine chamber effluent ranged as high as 85 mg/L, well over the permit maximum of 50 mg/L. Under present and future permitted discharge limits for TSS, the solids content of the snow will be the water quality parameter which limits melt volumes. The impact of effluent TSS on the snow melting capacity of the WWTC is discussed in Section 5.3.

The BOD_5 of the effluent was increased by 5 mg/L to 49 mg/L in the composite sample, a concentration which is well under the existing permit maximum of 65 mg/L, and slightly over the future permit value of 45 mg/L. However, the expansion/upgrade now in progress at the WWTC is designed to improve process BOD_5 removal to effluent concentrations of 20 mg/L, so an increase of 5 mg/L due to snow additions should not be a concern. A possible source of metals in the snow is the rock salt applied to city streets as a deicer. Rock salt is known to be a source of metals (particularly iron, nickel, lead, zinc, and chromium) and cyanide in surface runoff from roads.

The snow additions caused an increased in the average pH of the WWTC effluent from 7.6 to 7.7. An increase in pH would increase the toxicity of the effluent by increasing the amount of ammonia nitrogen that exists in the toxic unionized form. However, the snow additions also caused a decrease in the average temperature of the WWTC effluent from 11^{o}C to 5^{o}C, and the toxicity of ammonia is reduced at lower temperatures. The maximum allowable concentration of ammonia for the protection of freshwater aquatic life for the WWTC effluent prior to the snow additions (pH = 7.6, temperature = 11^{o}C) is 11.1 mg/L. The maximum allowable ammonia concentration after snow additions (pH = 7.7, temperature = 5^{o}C) is 10.1 mg/L (Dayton & Knight Ltd., 1993). Therefore, the acute ammonia toxicity of the WWTC effluent was slightly increased by the snow additions. However, at a pH of 7.6 and a temperature of 11^{o}C, the maximum average 30-day concentration of ammonia for the protection of freshwater aquatic life is 1.84 mg/L, compared to 1.95 mg/L at a pH of 7.7 and a temperature of 5^{o}C. Therefore, the chronic ammonia toxicity of the WWTC effluent was slightly decreased by the snow additions. The effects of snow additions on effluent toxicity are further discussed in Section 5.2.

The metals analysis summarized in Table 2 shows that the concentrations of some metals typically found in the surface runoff from roadways (e.g., aluminum, copper, iron, zinc) were significantly increased by the snow additions. The effluent average concentrations of those four metals after the addition of snow (0.55 mg/L for aluminum, 0.59 mg/L for copper, 0.943 mg/L for iron, and 0.038 mg/L for zinc) exceeded the recommended maximums for the protection of freshwater aquatic life according to Canadian Water Quality Guidelines (i.e., 0.1 mg/L for aluminum, 0.002 mg/L for copper, 0.3 mg/L for iron, and 0.03 mg/L for zinc). The average concentration of copper prior to snow additions (0.048 mg/L) also exceeded the water quality guidelines.

Other metals typically found is street runoff (e.g., cadmium, chromium, lead, nickel) were below detection limits in both the influent and the effluent; it is likely that these metals were also contained in the collected snow at low concentrations, and that the snow additions increased the effluent concentrations of them as well. Therefore, the metals toxicity of the effluent may have been increased to some degree by the snow additions. However, it should be noted that the snow additions significantly lowered the temperature of the WWTC effluent, and the toxicity of metals is theoretically reduced at lower temperatures, due to lower rates of metabolism in the fish. Since the permit at the WWTC does not include any limits for metals, snow additions to the chlorine chamber are unlikely to be limited by metals concentrations, unless those concentrations are high enough to cause a failure to pass the 96 hour LC_{50} toxicity bioassay. As described in Section 5.2, the 96 hour LC_{50} bioassay tests showed the WWTC effluent to be non-acutely toxic in all cases.

The data in Table 2 show that the water hardness (due to calcium and magnesium) and the phosphorus concentration were marginally reduced by the snow additions, likely due to dilution by the softer snow melt water. A reduction in water hardness tends to increase the toxicity of metals; however, the decrease in hardness due to snow additions was marginal (138.6 mg/L as calcium carbonate in the influent versus 135.1 mg/L as calcium carbonate in the effluent), and is unlikely to have a significant effect on effluent metals toxicity.

5.2 Effect of Snow Disposal on WWTC Effluent Toxicity

The purpose of the bioassay tests was to evaluate the effects of snow additions on the toxicity of the WWTC effluent. According to the 96 hour LC_{50} bioassay, the WWTC effluent was non-acutely toxic with and without snow additions, at both the standard bioassay testing temperature of 15^{o}C and at the actual temperatures recorded in the WWTC effluent during the snow melting test (Appendix 6).

As described earlier, the toxicity of ammonia and metals is theoretically reduced at lower temperatures. However, note that the sample of undiluted WWTC effluent tested at 15^{o}C resulted in no mortalities, while the sample of undiluted effluent tested at 11^{o}C resulted in 10% mortality (one of ten fish). Similarly, the sample of WWTC effluent mixed with snowmelt water tested at 15^{o}C resulted in no mortalities, and the sample of the mixture tested at 5^{o}C resulted in 30% mortality (three out of 10 fish). This apparent anomaly might be explained by biological variation in the test fish (note that some of the fish in the tests with 100% survival appeared stressed - see comments, Appendix 6).

On the other hand, the higher mortality at lower temperatures might have due to stress induced by the temperature drop. The test fish were acclimated to the lower temperatures by reducing the water temperature at a rate of $3^{o}C/24$ hour until the test temperature was reached, and then holding the fish at that temperature for 72 hours prior to initiating the test. This procedure exceeds the recommended requirement of $3^{o}C/12$ hours and a waiting period of 48 hours specified in the draft procedures for bioassays in Washington State (See Appendix 6).

Environment Canada procedures specify a minimum acclimation period of 2 weeks at the test temperature (see Appendix 6). Due to project scheduling constraints and projected warm weather at Prince George (melting of collected snow), it was decided to initiate the bioassay tests after acclimating the fish to the test temperatures for 72 hours. It is therefore possible that the fish in the tests conducted at $5^{o}C$ and $11^{o}C$ were more susceptible to toxicants due to added stress caused by the temperature drop. Further testing would be required to eliminate temperature as a factor.

5.3 Snow Disposal Capacity of the WWTC

The two factors which will limit snow disposal at the WWTC under present conditions are:

- the solids content of the snow, which causes a significant increase in plant effluent TSS concentration; and
- the melting capacity (heat content) of the chlorine tank influent.

The melting capacity of the plant can be estimated from the snow melting regression equation shown in Section 4.1 (the regression was confirmed by a theoretical calculation in Section 4.1). The present average daily flow at the WWTC is 33,400 m^3/d (1,390 m^3/hr). The corresponding present snow melting rate according to the regression equation is 96 tonnes/hr, or 2,300 tonnes per day, assuming 24 hour per day operation. The future design flow rate for the WWTC following the current upgrade/expansion is 45,500 m^3/d (1,900 m^3/hr). The future maximum snow melting rate according to the regression equation is 123 tonnes/hr, or 2,900 tonnes per 24 hour day. The number of days (assuming 24 hour operation) to dispose of the collected snow from the annual minimum, annual mean, and annual maximum snowfalls for present and future plant flow rates were estimated from the snow melting regression equation, and the results are summarized in Table 5 (note that the hourly flow rate based on the present day flow is 1,390 m^3/hr, and the future hourly flow rate based on the average day flow is approximately 1,900 m^3/hr - the regression was assumed to be linear beyond the highest average hourly flow rate of 1,350 m^3/hr used in the regression).

TABLE 5
SNOW DISPOSAL CAPACITY OF THE WWTC

	Number of Days Required to Dispose of Collected Snow					
	Minimum Snowfall		Mean Snowfall		Maximum	
	Present	Future	Present	Future	Present	Future
Melting	38	29	53	42	76	60
Effluent TSS	45	42	64	61	91	87

The theoretical calculation of plant melting capacity carried out in Section 4.1 can be applied to determine the additional melting capacity that would be realized from a greater temperature drop between the tank influent and effluent than was observed during the test (assuming that the mixing power in the tank were increased to allow a faster rate of snow addition). If the mean temperature of the chlorine tank influent were lowered from 11 degrees C to say 3 degrees C by snow additions, repeating the rough calculation described in Section 4.1 shows that the melting capacity of the WWTC at the average daily flow of 33,400 m^3/d would increase from 96 tonnes per hour to 125 tonnes per hour, an increase of 30%. The theoretical calculation shows that the melting capacity of the WWTC during the test was not limited by the available heat energy in the chlorine tank effluent. In general, the factors determining the melting capacity of the WWTC will be the temperature of the chlorine tank influent, the temperature of the snow added to the tank, and the tank mixing capacity. The melting capacity of the plant shown in Table 5 applies only to the conditions under which the test was conducted. The melting capacity will increase with an increasing temperature drop between the chlorine tank influent and effluent. An increase in mixing power in the tank should also increase the melting capacity, since the melting rate during the test was limited by the capacity of the tank mixers to circulate the added snow.

An estimate of the maximum allowable snow addition from the standpoint of effluent TSS concentration can be made using the TSS correlation equation developed in Section 4.2. The average increase in TSS concentration due to snow additions according to both the grab and composite samples was 45 mg/L. The snow additions caused an increase in effluent average TSS concentration to 53 mg/L in the composite sample and 56 mg/L in the grab samples. To ensure meeting present permit limits of 50 mg/L TSS in the plant effluent under present conditions, the average increase in TSS concentration due to snow additions should be limited to about 35 mg/L. Solving the TSS correlation equation from Section 4.2 for an increase in TSS concentration of 35 mg/L results in a snow addition of 0.0578 tonnes of snow added per m^3 of plant flow. For the present average daily flow of 1,390 m^3/hr, the maximum snow addition rate is 80 tonnes/hr, or 1,920 tonnes per day, assuming 24 hour operation. This is equivalent to approximately 3.4 cm of snowfall per day at the downtown bowl area. The corresponding number of days to dispose of the annual minimum, annual average, and annual maximum snowfalls from the downtown bowl area (assuming 24 hour per day operation) are included in Table 5.

At the future design average day flow of 45,500 m^3/d, the average hourly flow rate will be increased by a factor of 1.9 over the average hourly flow rate recorded during the test. However, the future permit will limit the average effluent TSS concentration to 30 mg/L, and the increase in TSS concentration due to snow additions should therefore be limited to about 15 mg/L. The resulting snow addition rate according to the correlation equation in Section 4.2 is 0.0444 tonnes snow/m^3 plant flow (note that this requires extrapolation beyond the known data see Figure 5). At the future design flow rate of 45,500 m^3/d, the maximum snow disposal rate would be 84 tonnes/hr, or 2,020 tonnes/day, assuming 24 hour operation. The corresponding number of days to dispose of the annual minimum, annual average, and annual maximum snowfalls from the downtown bowl area at the WWTC (assuming 24 hour per day operation) are included in Table 5.

As shown in Table 5, the primary limiting factor for snow melting at the WWTC is the TSS concentration in the plant effluent. For present conditions, the times required to dispose of the collected snow at the downtown bowl for the annual minimum, annual mean, and annual maximum snowfalls (assuming 24 hour per day operation) are 45 days, 64 days, and 91 days, respectively. Under future conditions, assuming that the snow collection area were not expanded, the disposal times would be similar, due to a combination of increased dilution capacity caused by increased flow rates at the plant, and lower permitted effluent TSS concentrations.

The second factor limiting snow disposal at the WWTC is the melting capacity of the chlorine contact tank. Based on the test data, the times required to dispose of the collected snow from the annual minimum, annual mean, and annual maximum snow falls under present conditions (assuming 24 hour per day operation) are 38 days, 53 days, and 76 days, respectively. Under future conditions, the disposal times would be similar, due to a combination of increased flow at the plant and lower permitted effluent TSS concentrations. Note that the data in Table 4 are based on relatively cold temperatures (the air temperature was in the range 25-30 degrees C below zero). At warmer temperatures, the available energy (i.e., the temperature of the tank influent) might be higher, and the energy required to raise the temperature of the snow to the melting point would be lower. However, note that in the theoretical calculation carried out in Section 4.1, of the total energy required (375.5 MJ/tonne), nearly 90% (333.5 MJ/tonne) was required to melt the ice, and only 10% was required to bring the ice to the melting point.

5.4 Snow Storage Requirements

The data summarized in Table 5 take no account of the depth and frequencies of individual snowfalls.

The limited snow disposal capacity of the WWTC means that a storage area for collected snow may be required for extreme snowfall events. That is, during periods of high snowfall, the snow collection rate may exceed the maximum snow disposal rate. The storage area required will depend on weather patterns, which are impossible to predict accurately. However, an estimate of the maximum snow storage volume was made, based on the historical snowfall data included in the report by Stanley & Associates (1993).

The estimated cumulative snow storage for the years of record (1988 to 1993) was calculated for the maximum snow disposal rates at the WWTC based on both plant effluent TSS concentration (1,920 tonnes/d or 4,800 m^3/d) and plant melting capacity (2,300 tonnes/d or 5,750 m^3/d). The results are included in Appendix 5. For both snow disposal rates, the maximum accumulated storage required corresponded to the snowfall in late December of 1990. The required storage volume was 92,000 m^3 for a snow disposal rate of 4,800 m^3/d, and 85,000 m^3 for a disposal rate of 5,750 m^3 (assuming a snow density of 400 kg/m^3).

By comparison, the snowmelter discussed in the report by Stanley & Associates (1993) had a maximum melting rate of 300 tonnes/hr, or 18,000 m^3/d (assuming a snow density of 400 kg/m^3). The snow storage calculation was also run for the snowmelter option, and the results are included in Appendix 5. The maximum snow storage requirement (35,000 m^3) again corresponded to late December of 1990.

Note that for the snowmelter option, the maximum storage period was estimated to be 3 days (Appendix 5). Little or no snow storage would be required for this option, since it would likely take 2 or 3 days to collect and haul the snow to the melter site. However, for snow disposal at the WWTC, the required snow storage period stretched over 30 days for a disposal rate of 4,800 m^3/d, and over 24 days for a disposal rate of 5,750 m^3/d. Therefore, a dedicated storage area would be required. To avoid moving the snow twice, the storage area should be at the WWTC if possible.

The area of the existing snow storage at the WWTC is approximately 6,100 m^2 (Figure 1). For the maximum snow storage volume of 92,000 m^3 associated with the snow disposal rate of 4,800 m^3/d (limited by effluent TSS), the required depth of storage would be unreasonable (15 m). At a snow depth of say 5 m, the snow storage area at the WWTC could handle approximately 30,000 m^3. Therefore, additional snow storage area (approximately 12,000 m^2) would have to be found, if all the snow from the downtown bowl were to be disposed of at the WWTC. Alternatively, the surplus snow associated with heavy snowfalls would have to be disposed of elsewhere.

5.5 Operational Concerns Associated with Snow Disposal at the WWTC

The primary operational concern associated with snow disposal at the WWTC appears to be that of solids accumulation in the chlorine tank. Based on limited data, the depth of solids accumulation in the chlorine tank associated with disposal of the snow from the annual minimum, annual mean, and annual maximum snowfalls could be as high as 180 mm, 260 mm, and 370 mm, respectively (Section 4.3). The chlorine tank would then require periodic cleaning to remove and dispose of the settled solids.

In addition, three factors associated with snow additions will reduce the chlorination effectiveness at the WWTC. Since disinfection is not presently required at the WWTC, these factors should not be a concern at present; however, if disinfection is required in future, a decrease in chlorination effectiveness may be of concern. The three factors reducing chlorination effectiveness are as follows:

1) Large snow volumes added to the chlorine contact chamber will result in decreases in the chlorine contact time (and consequently the chlorination effectiveness). The total volume of water flowing through the chlorine tank during the 7 hours that snow was being added was 7,084 m^3. The total mass of snow added was 1,010 tonnes, for a total meltwater volume of 1,010 m^3. The volume of the chlorine tank is 964 m^3. The volume flowing through the chlorine tank was increased by 14% by the snow additions, with a corresponding drop in the average hydraulic retention time from 57 minutes to 50 minutes.

2) The chlorine demand in the tank will be increased by the addition of the solids contained in the collected snow (the significant increase in BOD_5 due to the snow additions shows that some of the solids were organic in nature).

3) The average pH of the plant effluent was increased from 7.6 to 7.7 by the snow additions. As pH increases, the percentage of chlorine that exists in the form of hypochlorous acid decreases, and the percentage that exists in the form of hypochlorite ion increases. Since chlorine in the form of hypochlorous acid is 40 to 80 times more

effective than hypochlorite ion, disinfection with chlorine becomes less effective with increasing pH. A pH increase from 7.6 to 7.7 reduces the percentage of chlorine that exists in the form of hypochlorous acid from 48% of the total to 42% of the total.

The temperature of the plant effluent was significantly lowered by the snow additions. However, since the temperature drop occurred downstream of the biological treatment processes, there should be no adverse effects on the effectiveness of the treatment processes.

5.6 Net Energy and Carbon Dioxide Balance for Snow disposal at the WWTC vs. a Snowmelter Downtown

The net energy and carbon dioxide balance summarized in Table 4 shows that the option of disposing of snow at the WWTC requires approximately 10% of the energy required for the downtown snowmelter option. The savings in diesel fuel realized from the shorter haul distance to the downtown snowmelter site are overwhelmed by the energy consumed by the snowmelting machine. The carbon dioxide emissions resulting from the WWTC option are 6% to 8% of the carbon dioxide emission resulting from the snowmelter option. Based on the data collected during this study, the most economical option in terms of energy use and carbon dioxide emissions is to use the long-trailer type of dump truck to haul the collected snow to the WWTC. Using the tandem axle type of dump truck to haul to the WWTC increases the total energy consumption by approximately 100% and the carbon dioxide emissions by approximately 20% over the long-trailer truck. However, it should be noted that the fuel consumption used in the calculation for the long-trailer truck (0.58 L/km) was nearly the same as that of the tandem axle type (0.55 L/km), even though the long-trailer type hauled nearly double the payload of the tandem. Therefore, it is likely that the there was some error in the recorded fuel consumption of at least one of the trucks. More data are required, to confirm the fuel consumption of each type of truck for snow hauling.

6.0 CONCLUSIONS

The following conclusions are based on the results of the snow melting demonstration at the WWTC.

1) The Lansdowne Road WWTC at Prince George is suitable as a centre for disposal of the snow collected from the downtown bowl area, subject to the following limitations.

2) The primary factor limiting the snow disposal capacity of the WWTC was the solids contained in the collected snow; snow additions caused a significant increase in plant effluent TSS concentration, and permitted maximums were exceeded. Based on the limitation of effluent TSS concentration, the times required to dispose of the collected snow from the present annual minimum, annual mean, and annual maximum snowfalls (assuming 24 hour per day operation) were estimated to be 45 days, 64 days, and 91 days, respectively.

3) The second factor limiting the snow disposal capacity of the WWTC was the capacity of the mixers in the chlorine tank to circulate the added snow. Based on the limitation of mixing capacity, the times required to dispose of the collected snow from the present annual minimum, annual mean, and annual maximum snowfalls (assuming 24 hour per day operation) were estimated to be 38 days, 53 days, and 76 days, respectively.

4) An increase in mixing energy in the chlorine tank would increase the snow melting capacity at the WWTC, providing that effluent TSS restrictions were not enforced during snow disposal operations.

5) The snow additions resulted in an increase in the average pH of the WWTC effluent from 7.6 to 7.7, and a decrease in average temperature from 11^{o}C to 5^{o}C. From a theoretical standpoint, that would cause a slight increase in the acute ammonia toxicity of the WWTC effluent, and a slight decrease in the chronic toxicity. There was also an increase in metals concentration (aluminum, barium, copper, iron, manganese, silicon, titanium and zinc) and a decrease in

water hardness caused by the snow additions, which would tend to increase the metals toxicity of the effluent. However, the temperature drop caused by the snow additions would theoretically reduce the toxicity of metals, due to lower rates of metabolism in aquatic organisms at lower temperatures.

6) Based on the results of the 96 hour LC_{50} bioassay test, there was no conclusive evidence that the acute toxicity of the WWTC effluent was increased by the snow additions. The WWTC effluent was non-acutely toxic at 100% concentration both with and without snow additions, according to the 96 hour LC_{50} bioassay.

7) Should disinfection be required at the WWTC, the chlorination effectiveness will be reduced by snow additions, due to a decrease in chlorine contact time, an increase in chlorine demand associated with solids contained in the snow, and an increase in effluent pH.

8) The annual energy consumption associated with the option of snow disposal at the WWTC was estimated to be 1,000 - 5,000 GJ/yr, compared to 22,000 - 46,000 GJ/yr for the option of a gas-fired snowmelter located in the downtown area.

9) The carbon dioxide emissions associated with the option of snow disposal at the WWTC estimated to be 80-170 tonne/yr, compared to 1,000 - 1,300 tonne/yr for a gas-fired snowmelter located in the downtown area.

10) If all of the snow from the downtown bowls is to be disposed of at the WWTC, a snow storage area of up to 92,000 m^3 will be required. The existing snow storage area at the WWTC can handle approximately 30,000 m^3 (6,100 m^2 by 5 m deep).

11) If additional snow storage area cannot be located, some of the snow from extreme snowfalls will have to be disposed of at a site other than the WWTC.

7.0 RECOMMENDATIONS

The following recommendations are drawn from the results of the study.

1) The City should pursue the option of snow disposal at the WWTC, since the option is much more energy-efficient and lower in carbon dioxide emissions than using a gas fired snowmelter.

2) The City should investigate additional snow storage area of approximately 60,000 m^3 (12,000 m^2 x 5 m deep), to accommodate the collected snow from extreme snowfall events. Alternatively, the City should plan to temporarily store up to 60,000 m^3 of snow from the downtown bowl area at a location other than the WWTC.

3) The City should review options for reducing the solids content of the collected snow (eg. reduced sanding of roadways).

4) Options for reducing the application of rock salt for deicing operations should be reviewed.

5) The City should consider conducting further bioassay tests, to determine the effect of snow additions on the toxicity of the WWTC effluent. Tests conducted at temperatures less than the standard temperature of 15^{o}C should be done using minnows that have been acclimated to the lower temperatures for a minimum of two weeks, and preferably three weeks, as specified in Environment Canada procedures.

8.0 REFERENCES

APHA (American Public Health Association), American Water Works Association, and Water Environment Federation (1992), Standard Methods for the Examination of Water and Wastewater, 18th Edition, APHA, Wash., D.C.

Canadian Council of Resource and Environment Ministers (1987), Canadian Water Quality Guidelines, March, 1987.

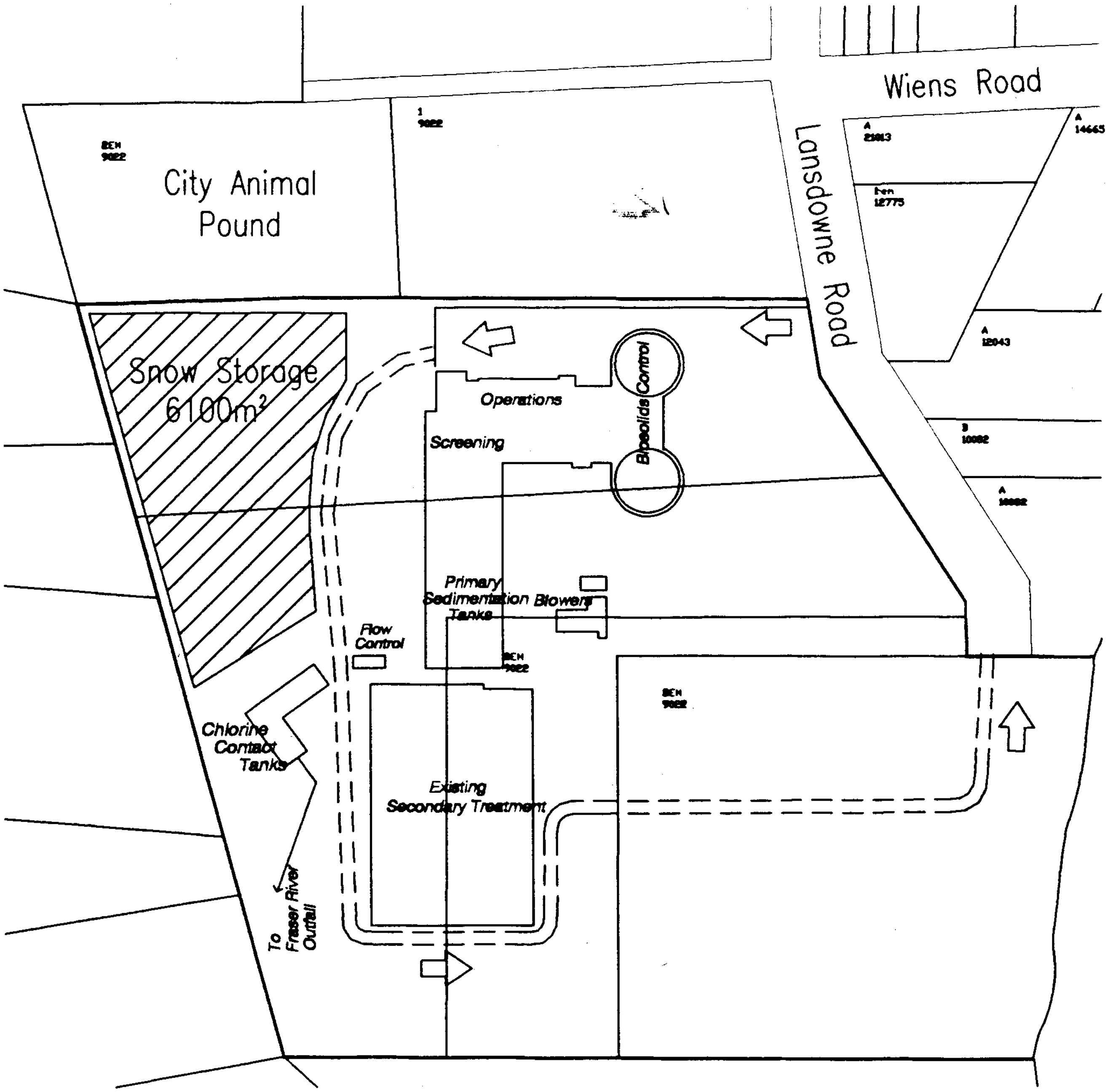
Dayton & Knight Ltd. (1993), Municipal Sewage Discharge Criteria Technical Assessment Report No. 1, Best Available Control Technology, Draft, B.C. Ministry of Environment, Lands and Parks, December 6, 1993.

Perry, R.H. and D. Green (1984), Perry's Chemical Engineers' Handbook, McGraw-Hill Inc., Toronto.

Stanley & Associates (1993), City of Prince George Preliminary Assessment of Snow Disposal Final Report, December 1993

9.0 FIGURES

See the following figures.

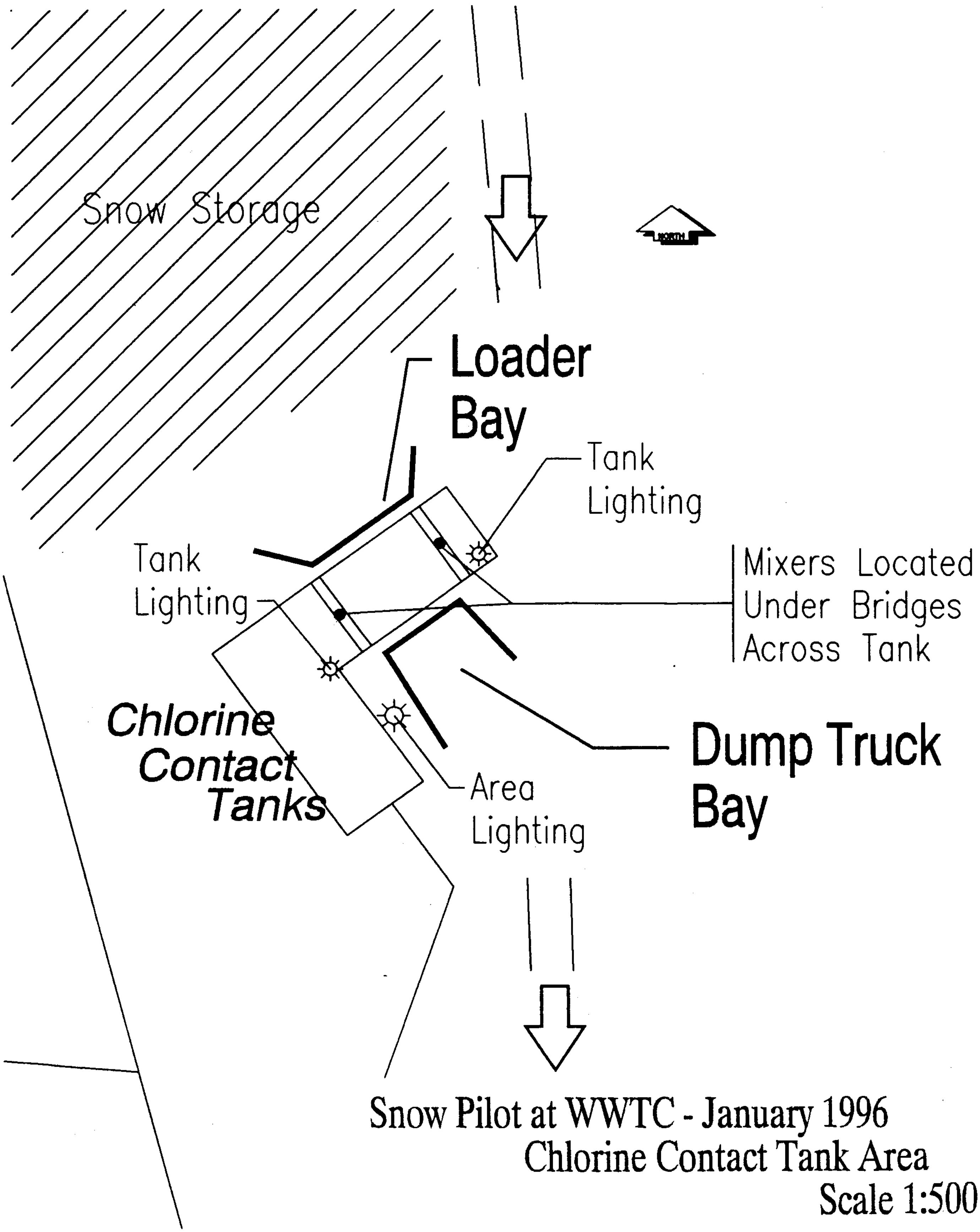


Snow Pilot at WWTC - January 1996

Site Layout

Scale 1:2000

FIGURE 1



Snow Pilot at WWTC - January 1996
Chlorine Contact Tank Area
Scale 1:500

FIGURE 2

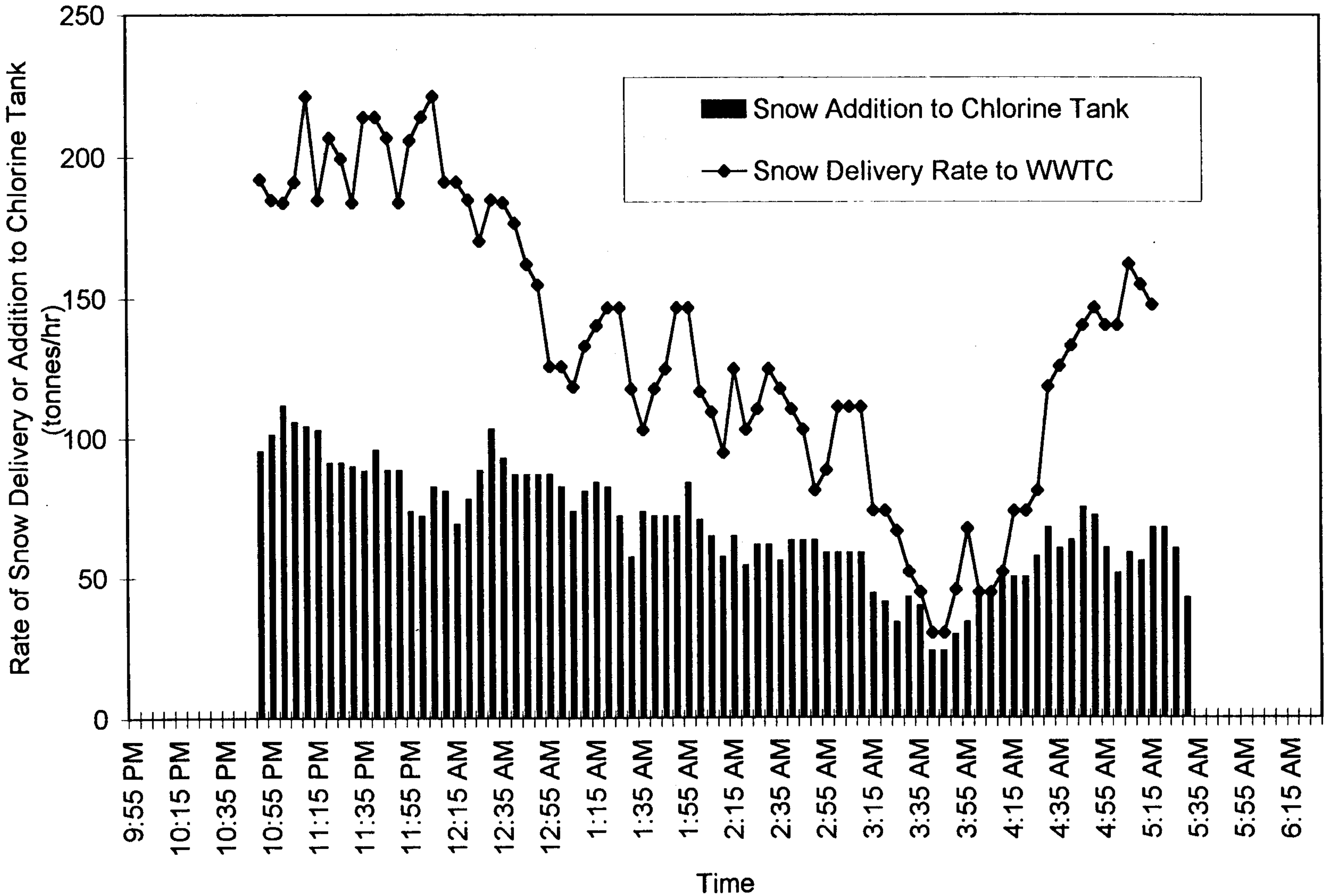


FIGURE 3 - Rates of Snow Delivery and Addition to Chlorine Tank

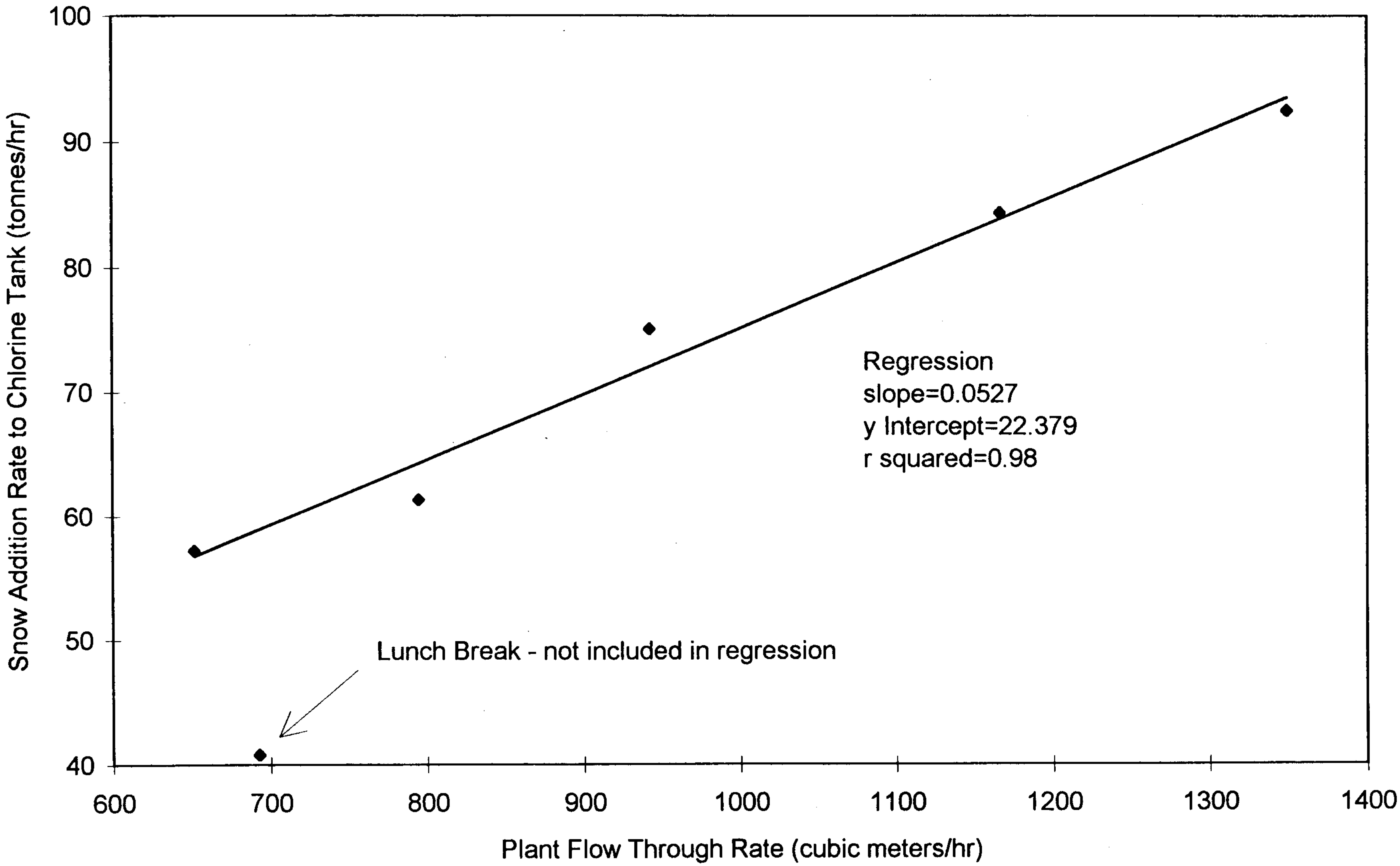


FIGURE 4 - Snow Melting Rate vs. Plant Flow Rate

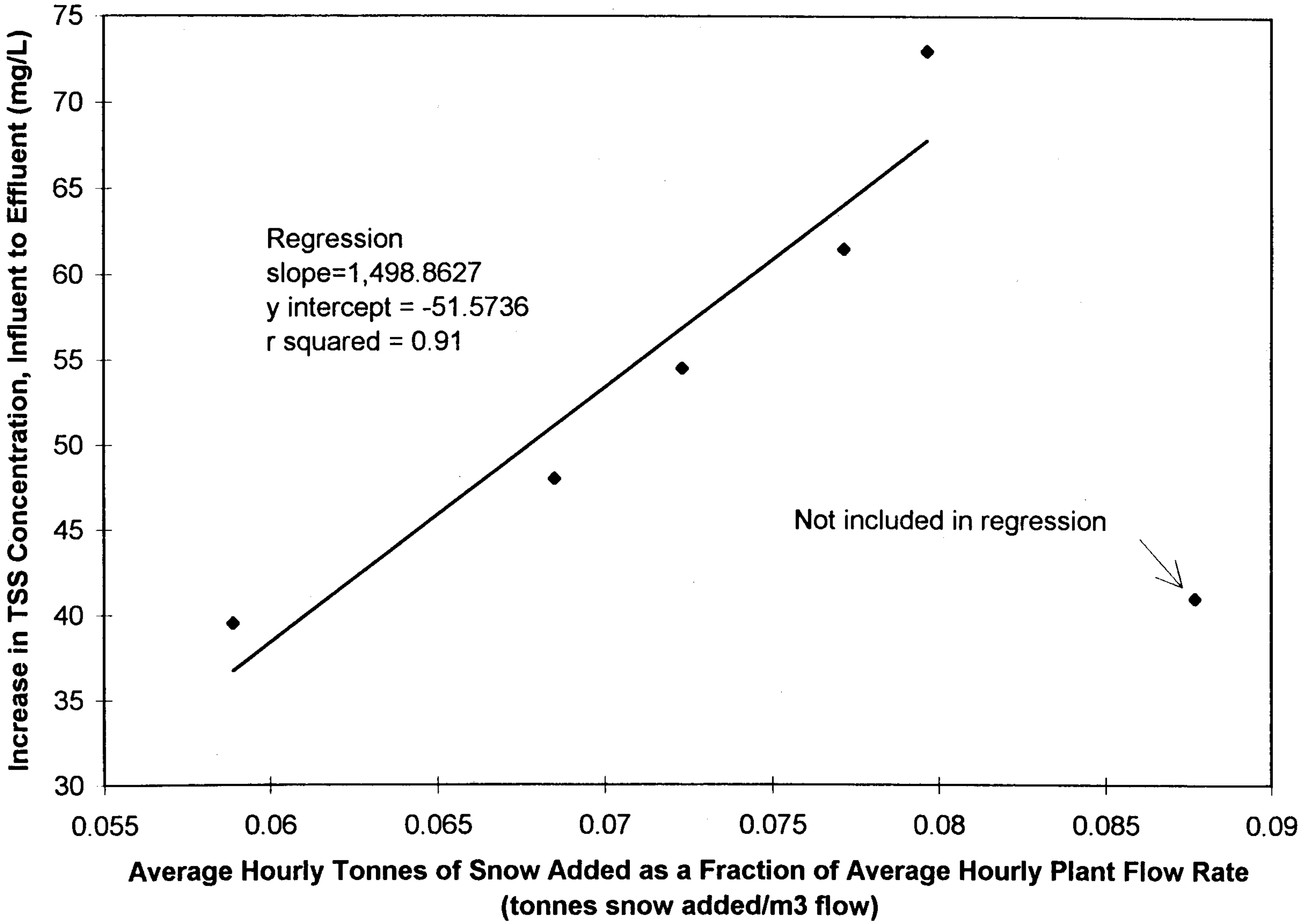


FIGURE 5 - Increase in Effluent TSS Concentration Due to Snow Additions

CITY OF PRINCE GEORGE
SNOW DISPOSAL STUDY AT
THE LANSDOWNE ROAD WASTEWATER TREATMENT CENTRE

APPENDIX 1

REQUEST FOR PROPOSALS

CITY OF PRINCE GEORGE

REQUEST FOR PROPOSAL

P95 - 19

SNOW DISPOSAL STUDY

CLOSING DATE: DECEMBER 29, 1995

Scott Bone
Purchasing Agent

PURCHASING DEPARTMENT
693 - 4th Avenue
Prince George, B.C.
V2L 3H2
Phone: 561-7510
Fax: 563-8420

TERMS OF REFERENCE

SNOW DISPOSAL PILOT STUDY
WASTE WATER TREATMENT CENTRE
CITY OF PRINCE GEORGE

1. INTRODUCTION

The current Prince George snow dump sites along the Fraser River discharge snow melt runoff to the foreshore of the river. Environmental and land use concerns with this snow disposal practice resulted in the City of Prince George, in partnership with the Fraser Pollution Abatement Office(FPAO) of Environment Canada, carrying out an assessment of snow disposal options in 1993. Subsequent to that assessment, the City has identified another disposal option utilizing the waste heat in the effluent from its Waste Water Treatment Centre(WWTC).

2. PURPOSE

The purpose of this study is to:

a) Confirm the suitability of the City's WWTC as a snow disposal centre.

b) Determine the snow disposal capacity of the WWTC.

c) Identify any operational concerns for snow disposal at the WWTC.

d) Analyze the net energy balance and net carbon dioxide balance using waste heat versus a separate melting operation located downtown.

e) Determine the effect on the City's effluent quality and toxicity from snow disposal at the WWTC.

3. BACKGROUND

The City and the FPAO commissioned a study in 1993 to assess snow disposal options including snow melting for snow generated from clearing operations throughout the City. Most snow for disposal is generated in the downtown area and is currently hauled to land disposal sites at Hudson Bay Slough, or Carrie Jane Gray Park. Snow Melting was identified as a viable option for snow disposal from the downtown.

A Public Works task group continued discussion on snow disposal and identified a new option for disposing snow at the City's WWTC on Lansdowne Road.

A preliminary test was conducted by the City at the WWTC in February 1994 when snow was loaded into the Chlorine contact tank immediately prior to discharge of the treated effluent to the river. The observations and preliminary calculations suggest that the WWTC option has sufficient merit to do a detailed review for the disposal of all snow currently generated from clearing operations in the City's downtown. The snow volumes hauled to the three primary downtown disposal sites since 1990/91 are listed in the following table:

	SNOW VOLUME (cubic metres)				
LOCATION	**1990/91**	**1991/92**	**1992/93**	**1993/94**	**1994/95**
Hudson Bay Slough	96,100	5,000	88,400	83,100	40,300
River Road	203,600	34,500	74,300	91,000	200
Carrie Jane Gray*	150,600	33,500	124,300	161,300	58,200
TOTAL	**450,300**	**73,000**	**287,000**	**335,400**	**98,700**

*NOTE: The Carrie Jane Gray volumes do not include snow hauled by private contractors. Snow from private sources is estimated at 50,000 cubic metres per year.

Some minor physical changes at the WWTC will be made at the chlorine contact tank to accommodate truck access to the tank during the testing program.

4. SCOPE OF WORK

The scope of work will include but not be limited to:

a) General overview and comment on the suitability of the WWTC as a snow disposal facility. This would include identifying issues not specifically included in the scope of work but which should be considered in determining the suitability of the WWTC for snow disposal.

b) Determination of the snow disposal capacity at the WWTC. This should consider the range of flow rates that can reasonably be expected at the WWTC.

c) Identification of any operational concerns for snow disposal at the WWTC. Specifically any items that may affect the treatment processes.

d) Analyzing the net energy balance and net carbon dioxide balance using waste heat at the WWTC versus a melting facility located downtown.

e) Determination of the effect on effluent quality and toxicity for City effluent as a result of snow disposal operations at the WWTC. This should include collation and comment based on test results conducted by City treatment plant personnel. It is proposed to test influent to the chlorine contact chamber including BOD, temperature, total suspended solids, metal levels, and identical testing for the effluent during snow melting. Sampling and test recording will be conducted by WWTC personnel.

Effluent toxicity will not be undertaken, however the impact on toxicity may be inferred from the temperature effects of the snow disposal operations.

f) Six (6) copies of the draft report shall be submitted.

A camera ready manuscript, a 3.5" double sided, high density diskette copy, and nine (9) copies of the final report shall be submitted by March 1, 1996.

The camera-ready copy is to be an unbound, single sided original on plain bond paper. No corporate logos or file numbers shall appear in the report. Text shall be in a format compatible with WordPerfect 6.1 or Word 6.0 for Windows.

The report by Stanley Associates Engineering Ltd titled Preliminary Assessment of Snow Disposal will be made available to the successful consultant.

5. <u>PROJECT MANAGER</u>

The contract for this study will be managed by:Mr. F. Blues, A.Sc.T.Manager, Public Works Operations, Phone: (604) 561-7503, Fax: (604) 561-7502

6. <u>CLOSING DATE</u>

Proposal shall be submitted to the City of Prince George Purchasing Department, 693-4th Avenue, Prince George, B.C. V2L 3H2, Attention: Scott Bone, Purchasing Agent before **2:00 PM, FRIDAY, DECEMBER 29, 1995.**

7. <u>CONSULTANT PROPOSAL</u>

The Consultant shall provide four (4) copies of their proposal. The proposal shall include:

a) The personnel on the project team, their project role, the time rate fee for each person and/or categories of personnel if applicable

Professional resumes of each member of the project team are to be included.

b) Fee estimates for time and disbursements to cover the engineering services specified in the Terms of Reference shall be provided.

c) The proposal shall detail the methodology to be used to meet the requirements of these Terms of Reference.

8. <u>TERMS OF PAYMENT</u>

a) Payments will be based on the contract to be formed with the Consultant for the above services.

b) The Consultant will, upon completion of the project, submit an invoice detailing the services performed by him.

c) No payment will be made on the cost for work incurred to remedy errors or omissions for which the Consultant is responsible.

9. <u>COST CONTROL</u>

If at any time during the progress of the work, the Consultant considers that the cost figure outlined in the contract will be exceeded, either by some unforseen event or change in the Terms of Reference, he shall provide the Project Manager with complete details.

* **AT NO TIME SHALL THE TOTAL CONTRACT FEE BE EXCEEDED WITHOUT PRIOR WRITTEN AUTHORIZATION OF THE PROJECT MANAGER.***

10. <u>PROFESSIONAL RESPONSIBILITY</u>

The consultant shall apply his professional stamp or seal to identify his professional responsibility to each drawing, the title page and signature page of all reports required by the Terms of Reference.

11. <u>SCHEDULE</u>

The Consultant shall provide a schedule for the study. The schedule provided will be considered in evaluating the consultant's proposal. The schedule submitted will include a firm completion date.

If unforeseen events or changes in the Terms of Reference occur, scheduled deadlines can be changed. However, it is the Consultant's responsibility to organize and manage his resources to meet the required deadlines. The Project Manager shall be contacted with full details if deadlines are to be exceeded.

12. <u>SITE VISITS</u>

Site visits should be arranged by contacting the Project Manager.

13. <u>PROPOSAL EVALUATION</u>

Proposals will be evaluated using the City's evaluation form and guide. A copy is attached for reference.

Evaluation result totals will be available to interested proponents following completion of the evaluation.

REQUEST FOR PROPOSAL #P95-19
SNOW DISPOSAL PILOT STUDY

CONSULTING SERVICES PROPOSAL EVALUATION FORM

Proposal Name: ______________________

Consultant: ______________________

Date: ______________________

Rated by: ______________________

CATEGORY/FACTOR	Wt. out of 100	Please circle appropriate column: Incomplete	Marginal	Fair	Good	Excellent	Weighted Total
Capability:	(25)						
Proj. Manager experience	7	0.3	0.5	0.7	0.9	1.0	
Company experience	6	0.3	0.5	0.7	0.9	1.0	
Team quality	12	0.3	0.5	0.7	0.9	1.0	
Methodology:	(40)						
Quality of proposal	2	0.3	0.5	0.7	0.9	1.0	
Work plan (procedure)	10	0.3	0.5	0.7	0.9	1.0	
Level of effort (manhours)	10	0.3	0.5	0.7	0.9	1.0	
Innovative considerations	4	0.3	0.5	0.7	0.9	1.0	
Acceptable schedule	4	0.3	0.5	0.7	0.9	1.0	
Liaison/Coordination	4	0.3	0.5	0.7	0.9	1.0	
Realistic inspection	6	0.3	0.5	0.7	0.9	1.0	
Past Performance:	(20)						
Fees and Personnel	6	0.3	0.5	0.7	0.9	1.0	
Keeping to schedule	4	0.3	0.5	0.7	0.9	1.0	
Design problems	6	0.3	0.5	0.7	0.9	1.0	
Contract administration	4	0.3	0.5	0.7	0.9	1.0	
Budget:	(15)	$15 \text{ X } \frac{\text{Lowest Cost}}{\text{Proposal Cost}} = \text{Number of Points}$					
						TOTAL	

Remarks:

GUIDE TO USE OF THE CONSULTING SERVICES PROPOSAL EVALUATION FORM

Factors used in the evaluation should be interpreted in accordance with the guidelines below:

CAPABILITY

PROJECT MANAGER EXPERIENCE

Evaluate the length and quality of experience of the person named in the proposal as the consultant's project manager. The experience does not necessarily have to be all with the same consultant. Obtain performance evaluations from other clients on previous projects.

COMPANY EXPERIENCE

Evaluate the length and quality of experience of the company in doing similar work. Companies with longer experience will have established organization and internal procedures which will smooth the interface between the consultant, the municipality and the contractor.

TEAM QUALITY

Evaluate the length and quality of experience of the team members who have been selected by the consultant to work on this particular project. Of particular importance where applicable is the Design Engineer, architect, technician, and the construction inspector. Also, look at any sub-consultants to be used by the consultant. Consider whether the consultant has sufficient back-up staff to handle the size of job if one or more of the team leaves or if complex issues arise during the course of the project.

METHODOLOGY

QUALITY OF PROPOSAL

Evaluate the effort went into the proposal. A well thought out proposal could be reflective of the way the project will be done.

WORK PLAN

Evaluate the thoroughness of the consultant's approach to the project. Has the consultant thoughtfully assessed the project, beyond just repeating the terms of reference? A well thought out work plan will reduce the possibility of the consultant exceeding their fee estimate and consequently reducing the quality of the work or requesting fee increase.

LEVEL OF EFFORT

Evaluate the total man hours proposed and the distribution among team members. Beware of excessively high or low man hours which may indicate the consultant does not understand the scope of the work or is using less experienced personnel.

INNOVATIVE CONSIDERATIONS

This line allows the discretionary granting of additional points to those consultants who are proposing reasonable innovations which will enhance the project.

ACCEPTABLE SCHEDULE

Evaluate the consultant's schedule for completion of the work. If it meets our target dates and is realistic, give full points. Beware, however, of schedules which allow unrealistic times for municipal processing and decisions by other agencies.

LIAISON/COORDINATION

Evaluate the consultant's approach to dealing with municipal and other agencies during the design process. How closely does the consultant intend to work with them? Is the time allowed for meetings reasonable?

REALISTIC INSPECTION

Evaluate the consultant's proposal for construction inspection. Does the consultant propose too much inspection for simple jobs or too little for complex jobs? Is their estimate of the duration of construction realistic of the purpose of fee calculation?

PAST PERFORMANCE

FEES AND PERSONNEL

Rate the consultant and project team on past performance with the City or with other clients where City experience is insufficient in being able to complete the projects within the fee estimates and with the same personnel as originally proposed. Poor performance in these areas reduces the fairness of direct comparison with other proposals.

KEEPING TO SCHEDULE

Rate the consultant and project team on pst performance with the City or with other clients where City experience is insufficient in sticking to this schedule. Constant late projects indicate that the consultant is accepting work beyond their capacity to handle with the staff and organization he has.

DESIGN PROBLEMS

Rate the consultant and project team on past design performance with the City or with other clients where city experience is insufficient. Have projects generally been constructed as designed or have significant changes been required during construction because of inadequate in that design, survey, geotechnical investigation, etc.?

CONTRACT ADMINISTRATION

Rate the consultant and project team on past performance in contract inspection and administration. Look for things like late Certificates for Payment, control of contractor's extras, construction errors not picked up by inspection, as built records not reflecting actual field conditions.

CITY OF PRINCE GEORGE
SNOW DISPOSAL STUDY AT
THE LANSDOWNE ROAD WASTEWATER TREATMENT CENTRE

APPENDIX 2

SITE SNOW LOADING DATA

SNOW DISPOSAL PILOT AT WWTC

	A	B	C	D	E	F	G	H	I	J	K	L
1	SNOW PILOT DATA:											
2												
3	SNOW DENSITY:		0.37t/m3	GVW	TARE	NET WEIGHT	HORSE	FUEL	TOTAL	VOLUME /		
4				KG	KG	PER LOAD	POWER	CONSUMPT	KM	DUMP(m3)		
5	TANDEM AXLE	TRUCK:		19510	12230	7280	400	80 litres		19.68		
6	LONG TAILER	TRUCK:		33850	18340	15510	365	84.5 litres		41.92		
7	LOADER BUCKET:					1480				4.00		
8												
9			TANK	TANK	TANK	TANK		SITE	SITE	SITE	SITE	
10	TIME:		LOADER	TANDEM	LOADING	MELTING	TIME:	TANDEM	LONG BOX	LOADING	LOADING	
11	FROM	TO	BUCKETS	TRUCKS	tonnes	RATE(t/hr)	FROM	TRUCKS	TRUCKS	tonnes	RATE(t/hr)	
12												
13	21:55	21:59	1	1	8.76			2	0	14.56		
14	22:00	22:04	6	0	8.88		22:00	1	1	22.79		
15	22:05	22:09	7	0	10.36			0	0	0		
16	22:10	22:14	2	0	2.96			0	0	0		
17	22:15	22:19	2	2	17.52			5	0	36.4		
18	22:20	22:24	2	2	17.52			0	0	0		
19	22:25	22:29	0	0	0			3	0	21.84		
20	22:30	22:34	1	0	1.48			2	1	30.07		
21	22:35	22:39	8	0	11.84			0	0	0		
22	22:40	22:44	1	1	8.76			2	0	14.56		
23	22:45	22:49	0	1	7.28			3	0	21.84		
24	22:50	22:54	0	0	0	95.36		2	1	30.07	192.13	
25	22:55	22:59	5	1	14.68	101.28		1	0	7.28	184.85	
26	23:00	23:04	8	1	19.12	111.52	23:00	3	0	21.84	183.9	
27	23:05	23:09	3	0	4.44	105.6		1	0	7.28	191.18	
28	23:10	23:14	1	0	1.48	104.12		2	1	30.07	221.25	
29	23:15	23:19	6	1	16.16	102.76		0	0	0	184.85	
30	23:20	23:24	4	0	5.92	91.16		3	0	21.84	206.69	
31	23:25	23:29	0	0	0	91.16		2	0	14.56	199.41	
32	23:30	23:34	0	0	0	89.68		2	0	14.56	183.9	
33	23:35	23:39	7	0	10.36	88.2		2	1	30.07	213.97	
34	23:40	23:44	6	1	16.16	95.6		2	0	14.56	213.97	
35	23:45	23:49	0	0	0	88.32		2	0	14.56	206.69	
36	23:50	23:54	0	0	0	88.32		1	0	7.28	183.9	
37	23:55	23:59	0	0	0	73.64		4	0	29.12	205.74	
38	00:00	00:04	7	1	17.64	72.16	00:00	2	1	30.07	213.97	
39	00:05	00:09	5	1	14.68	82.4		2	0	14.56	221.25	
40	00:10	00:14	0	0	0	80.92		0	0	0	191.18	
41	00:15	00:19	3	0	4.44	69.2		0	0	0	191.18	
42	00:20	00:24	10	0	14.8	78.08		0	1	15.51	184.85	
43	00:25	00:29	7	0	10.36	88.44		0	0	0	170.29	
44	00:30	00:34	5	1	14.68	103.12		4	0	29.12	184.85	
45	00:35	00:39	0	0	0	92.76		4	0	29.12	183.9	
46	00:40	00:44	2	1	10.24	86.84		1	0	7.28	176.62	
47	00:45	00:49	0	0	0	86.84		0	0	0	162.06	

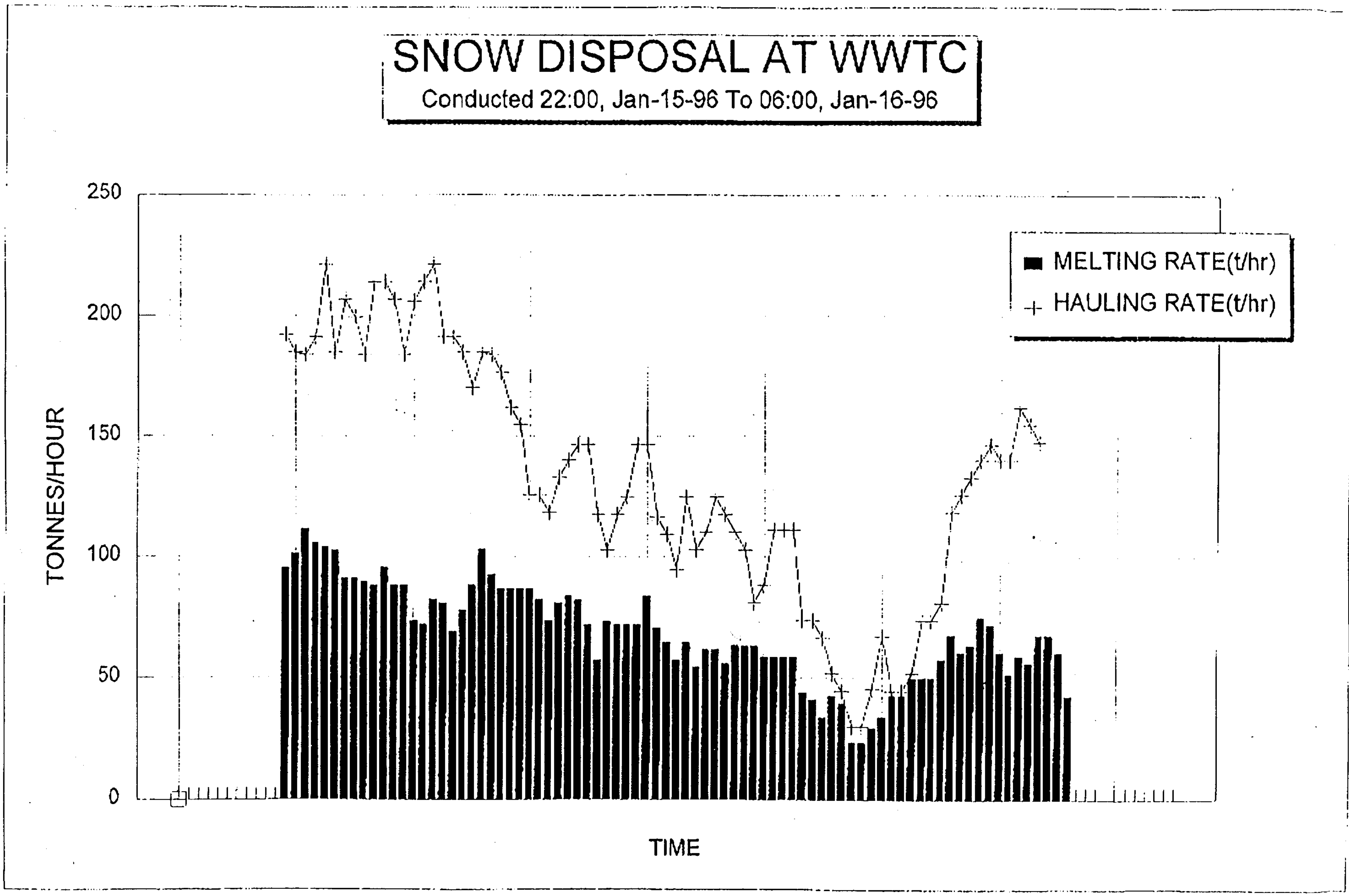
SNOW DISPOSAL PILOT AT WWTC

A	A	B	C	D	E	F	G	H	I	J	K	L
48	00:50	00:54	0	0	0	86.84		0	0	0	154.78	
49	00:55	00:59	0	0	0	86.84		0	0	0	125.66	
50	01:00	01:04	4	1	13.2	82.4	01:00	2	1	30.07	125.66	
51	01:05	01:09	4	0	5.92	73.64		1	0	7.28	118.38	
52	01:10	01:14	0	1	7.28	80.92		2	0	14.56	132.94	
53	01:15	01:19	5	0	7.4	83.88		1	0	7.28	140.22	
54	01:20	01:24	4	1	13.2	82.28		3	0	21.84	146.55	
55	01:25	01:29	0	0	0	71.92		0	0	0	146.55	
56	01:30	01:34	0	0	0	57.24		0	0	0	117.43	
57	01:35	01:39	6	1	16.16	73.4		2	0	14.56	102.87	
58	01:40	01:44	1	1	8.76	71.92		3	0	21.84	117.43	
59	01:45	01:49	0	0	0	71.92		1	0	7.28	124.71	
60	01:50	01:54	0	0	0	71.92		3	0	21.84	146.55	
61	01:55	01:59	8	0	11.84	83.76		0	0	0	146.55	
62	02:00	02:04	0	0	0	70.56	02:00	0	0	0	116.48	
63	02:05	02:09	0	0	0	64.64		0	0	0	109.2	
64	02:10	02:14	0	0	0	57.36		0	0	0	94.64	
65	02:15	02:19	0	2	14.56	64.52		3	1	37.35	124.71	
66	02:20	02:24	2	0	2.96	54.28		0	0	0	102.87	
67	02:25	02:29	0	1	7.28	61.56		1	0	7.28	110.15	
68	02:30	02:34	0	0	0	61.56		2	0	14.56	124.71	
69	02:35	02:39	7	0	10.36	55.76		1	0	7.28	117.43	
70	02:40	02:44	6	1	16.16	63.16		2	0	14.56	110.15	
71	02:45	02:49	0	0	0	63.16		0	0	0	102.87	
72	02:50	02:54	0	0	0	63.16		0	0	0	81.03	
73	02:55	02:59	0	1	7.28	58.6		1	0	7.28	88.31	
74	03:00	03:04	0	0	0	58.6	03:00	1	1	22.79	111.1	
75	03:05	03:09	0	0	0	58.6		0	0	0	111.1	
76	03:10	03:14	0	0	0	58.6		0	0	0	111.1	
77	03:15	03:19	0	0	0	44.04		0	0	0	73.75	
78	03:20	03:24	0	0	0	41.08		0	0	0	73.75	
79	03:25	03:29	0	0	0	33.8		0	0	0	66.47	
80	03:30	03:34	6	0	8.88	42.68		0	0	0	51.91	
81	03:35	03:39	5	0	7.4	39.72		0	0	0	44.63	
82	03:40	03:44	0	0	0	23.56		0	0	0	30.07	
83	03:45	03:49	0	0	0	23.56		0	0	0	30.07	
84	03:50	03:54	4	0	5.92	29.48		0	1	15.51	45.58	
85	03:55	03:59	3	1	11.72	33.92		4	0	29.12	67.42	
86	04:00	04:04	6	0	8.88	42.8	04:00	0	0	0	44.63	
87	04:05	04:09	0	0	0	42.8		0	0	0	44.63	
88	04:10	04:14	0	1	7.28	50.08		1	0	7.28	51.91	
89	04:15	04:19	0	0	0	50.08		3	0	21.84	73.75	
90	04:20	04:24	0	0	0	50.08		0	0	0	73.75	
91	04:25	04:29	5	0	7.4	57.48		1	0	7.28	81.03	
92	04:30	04:34	8	1	19.12	67.72		3	1	37.35	118.38	
93	04:35	04:39	0	0	0	60.32		1	0	7.28	125.66	
94	04:40	04:44	2	0	2.96	63.28		1	0	7.28	132.94	

SNOW DISPOSAL PILOT AT WWTC

A	A	B	C	D	E	F	G	H	I	J	K	L
95	04:45	04:49	3	1	11.72	75		1	0	7.28	140.22	
96	04:50	04:54	2	0	2.96	72.04		3	0	21.84	146.55	
97	04:55	04:59	0	0	0	60.32		1	1	22.79	140.22	
98	05:00	05:04	0	0	0	51.44	05:00	0	0	0	140.22	
99	05:05	05:09	0	1	7.28	58.72		3	0	21.84	162.06	
100	05:10	05:14	3	0	4.44	55.88		0	0	0	154.78	
101	05:15	05:19	3	1	11.72	67.6		2	0	14.56	147.5	
102	05:20	05:24	0	0	0	67.6		0	0	0		
103	05:25	05:29	0	0	0	60.2		0	0	0		
104	05:30	05:34	1	0	1.48	42.56		0	0	0		
105	05:35	05:39	0	0	0			0	0	0		
106	05:40	05:44	0	0	0			0	0	0		
107	05:45	05:49	0	0	0			0	0	0		
108	05:50	05:54	0	0	0			0	0	0		
109	05:55	05:59	0	0	0			0	0	0		
110	06:00	06:04	0	0	0		06:00	0	0	0		
111	06:05	06:09	0	0	0			0	0	0		
112	06:10	06:14	0	0	0			0	0	0		
113	06:15	06:19	0	0	0			0	0	0		
114	06:20	06:24	0	0	0			0	0	0		
115	06:25	06:29	0	0	0			0	0	0		
116												
117	TOTALS:	LOADS	207	31	532.04			111	13			
118		TONNES	306.36	225.68				808.08	201.63			
119												
120	TOTAL TONNES		532.04			TOTAL TONNES		1009.71				
121	HOURS MELTING		7.50			HOURS HAULING		7.33				
122	AVERAGE MELTING RATE		70.94			AVERAGE HAUL RATE		137.75				
123												
124												
125												
126												
127												
128												
129												
130												

SNOW DISPOSAL PILOT AT WWTC



CITY OF PRINCE GEORGE
SNOW DISPOSAL STUDY AT
THE LANSDOWNE ROAD WASTEWATER TREATMENT CENTRE

APPENDIX 3

RESULTS OF WATER QUALITY TESTING

CITY OF PRINCE GEORGE.
SNOW MELTING PILOT STUDY

1/15/96

		INFLUENT GRAB						EFFLUENT GRAB				
TIME	FLOW cfs	TEMP deg. C	pH	BOD mg/L	TSS mg/L	NH3 mg/L		TEMP deg. C	pH	BOD mg/L	TSS mg/L	NH3 mg/L
22:05	14.4	12.0	7.3					12.0	7.3			
22:55	13.7	12.0	7.6					6.5	7.6			
24:00	12.8	11.5	7.7					5.5	7.8			
01:00	10.1	11.0	7.7					5.0	7.7			
02:00	8.4	10.5	7.7					4.5	7.8			
03:00	7.2	10.5	7.7					3.0	7.8			
0400	6.4	11.0	7.7					3.5	7.8			
05:00	6.4	10.0	7.7					3.0	7.9			

INFLUENT COMPOSITE		EFFLUENT COMPOSITE	
BOD mg/L=		BOD mg/L=	
TSS mg/L=		TSS mg/L=	
NH3 mg/L=		NH3 mg/L=	

WEATHER: CLEAR + COLD 2200 hr – −23°C; 2400 hr – −25°C; 0215 hr – −25; 0400 hr – −27; 0530 hr −30°C

SAMPLED BY: N. GOBBI

ANALYZED BY:

COMMENTS: FINAL CLARIFIER TEMP. 11.5°C @ 23:15 hr.
AT 0530 hr AMBIENT TEMP WAS −30°C
NOTICED ICE FORMING NEAR FINAL EFFLUENT WEIRS AT END OF CHLORINE CONTACT TANK.

CITY OF PRINCE GEORGE
SNOW MELTING PILOT STUDY

1/15/96

		INFLUENT GRAB						EFFLUENT GRAB				
TIME	FLOW cfs	TEMP deg. C	pH	BOD mg/L	TSS mg/L	NH3-N mg/L		TEMP deg. C	pH	BOD mg/L	TSS mg/L	NH3-N mg/L
10:05				46	17	28				47	16	29
10:58				42	10	27				48	62	28
12:00				42	11	27				49	55	28
01:00				41	12	25				50	77	26
02:00				39	4	27				46	85	25
03:00				40	13	27				44	55	27
04:00				41	12	25				41	52	25
05:00				39	8	24				42	47	23

INFLUENT COMPOSITE		EFFLUENT COMPOSITE	
BOD mg/L=	44	BOD mg/L=	49
TSS mg/L=	8	TSS mg/L=	53
NH3-N mg/L=	26	NH3-N mg/L=	25

WEATHER: CLR COLD -31.5

SAMPLED BY: J. GOBBI

ANALYZED BY: R.N. BULLOCK RANDY GARTON

COMMENTS: JAN. 16 - 1996 = 120.5 CM³ = 18.0 MM = 17.0 MLS OF H2O SNOW

PRINCE GEORGE WWTC — DAILY LAB WORKSHEET — DATE: Jan 25/96

	SAMPLE #1 #1	SAMPLE #1 #2	SAMPLE #2 #1	SAMPLE #2 #2	
SAMPLE SOURCE	Snow by Contact Tank				
SAMPLE TIME					
TEMPERATURE °C					
D.O. mg/l					
pH					
mls. of SAMPLE					
FILTER & SAMPLE	.7131	.7155	.7018	.7058	
FILTER	.6202	.6216	.6294	.6295	
SAMPLE WEIGHT	.0929	.0939	.0724	.0763	
TSS	929	939	724	763	T.S.S. FROM PLANT WITHOUT SNOW REMOVAL = 150–165
VSS mg/l / VS %	AVG = 840 g/L				
MLVW					
SETTLEABLE SOLIDS					
S.V.I.					
DISH WEIGHT (W3) DRY					
DISH WEIGHT (W2) WET					
DISH WEIGHT (W1) EMPTY					
DISH WEIGHT (W4) BURNED					
SUSPENDED SOLIDS %					
VOLATILE SOLIDS %					

WEIRS: ____________

% CAPTURE: ________

REMARKS:

H_2O in bucket

$Vol = (0.785) \times (D^2_{ft}) (depth_{ft})$

$(0.785) \times (0.94 \times 0.94) (.46 ft)$

$0.785 \times 0.8836 \times .46$

$= 0.32 ft^3$

Total Volume of bucket

$Vol = (0.785) \times (0.94 \times 0.94) \times (1.25 ft)$

$0.785 \times 0.8836 \times 1.25$

$= 0.87 ft^3$

FAX

ASL
analytical service laboratories ltd.
SPECIALISTS IN ENVIRONMENTAL CHEMISTRY
1988 Triumph Street, Vancouver, B.C. V5L 1K5
Telephone (604) 253-4188
Fax (604) 253-6700

FAX

Attention: Mr. Norm Gobbi
Company: City of Prince George
Fax #: 16045617502

From: Liana Campbell
Date: Thursday January 25, 1996

The number of pages in this transmission (including this page) is: 7

Regarding:

Here are the results for file F6977.

Thank-You, Liana

CHEMICAL ANALYSIS REPORT

Date:	January 25, 1996
ASL File No.	F6977
Report On:	Water Analysis (Snow Disposal) Pilot Study
Report To:	**City of Prince George** Public Works Dept.Elect/Mech Div 505 4th Avenue Prince George, BC V2L 3H2
Attention:	**Mr. Norm Gobbi**, Sr Wastewater Treatment Operator
Received:	January 19, 1996

ASL ANALYTICAL SERVICE LABORATORIES LTD.
per:

Liana Campbell, B.Sc.
Project Chemist

Katherine Thomas, B.Sc.
Project Chemist

RESULTS OF ANALYSIS

File No. F6977

I = INFLUENT

		I-1	I-2	I-3	I-4	I-5
		96 01 16 10:05	96 01 16 ~~10:05~~ 10:57	96 01 16 ~~10:05~~ 12:00	96 01 16 ~~10:05~~ 21:00	96 01 16 ~~10:05~~ 22:30
Physical Tests						
Conductivity (umhos/cm)		758	756	746	748	743
Total Metals						
Aluminum	T-Al	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony	T-Sb	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	T-As	<0.20	<0.20	<0.20	<0.20	<0.20
Barium	T-Ba	0.022	0.023	0.023	0.021	0.022
Beryllium	T-Be	<0.005	<0.005	<0.005	<0.005	<0.005
Bismuth	T-Bi	<0.10	<0.10	<0.10	<0.10	<0.10
Boron	T-B	<0.10	<0.10	<0.10	0.11	0.10
Cadmium	T-Cd	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	T-Ca	37.6	36.6	37.3	37.1	36.6
Chromium	T-Cr	<0.015	<0.015	<0.015	<0.015	<0.015
Cobalt	T-Co	<0.015	<0.015	<0.015	<0.015	<0.015
Copper	T-Cu	0.048	0.050	0.049	0.044	0.044
Iron	T-Fe	0.075	0.072	0.077	0.069	0.075
Lead	T-Pb	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium	T-Li	<0.015	<0.015	<0.015	<0.015	<0.015
Magnesium	T-Mg	11.8	11.5	11.6	11.6	11.5
Manganese	T-Mn	0.058	0.058	0.062	0.062	0.062
Molybdenum	T-Mo	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	T-Ni	<0.020	<0.020	<0.020	<0.020	<0.020
Phosphorus	T-P	3.31	3.27	3.50	3.41	3.29
Potassium	T-K	11.2	11.5	11.5	11.2	11.2
Selenium	T-Se	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	T-Si	7.53	7.42	7.52	7.53	7.49
Silver	T-Ag	<0.015	<0.015	<0.015	<0.015	<0.015
Sodium	T-Na	72.8	72.1	72.8	72.8	71.9
Strontium	T-Sr	0.161	0.157	0.160	0.159	0.157
Thallium	T-Tl	<0.10	<0.10	<0.10	<0.10	<0.10
Tin	T-Sn	<0.30	<0.30	<0.30	<0.30	<0.30
Titanium	T-Ti	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium	T-V	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc	T-Zn	0.029	0.026	0.029	0.028	0.028

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS

File No. F6977

E = EFFLUENT.

		I-6	I-7	I-8	E-1	E-2
		96 01 16 ~~10:05~~ 03:00	96 01 16 ~~10:05~~ 04:00	96 01 16 ~~10:05~~ 05:00	96 01 16 10:05	96 01 16 ~~10:05~~ 10:58
Physical Tests						
Conductivity (umhos/cm)		727	716	715	776	1000
Total Metals						
Aluminum	T-Al	<0.20	<0.20	<0.20	<0.20	0.53
Antimony	T-Sb	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	T-As	<0.20	<0.20	<0.20	<0.20	<0.20
Barium	T-Ba	0.021	0.022	0.022	0.024	0.043
Beryllium	T-Be	<0.005	<0.005	<0.005	<0.005	<0.005
Bismuth	T-Bi	<0.10	<0.10	<0.10	<0.10	<0.10
Boron	T-B	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium	T-Cd	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	T-Ca	35.8	36.2	35.9	38.5	35.9
Chromium	T-Cr	<0.015	<0.015	<0.015	<0.015	<0.015
Cobalt	T-Co	<0.015	<0.015	<0.015	<0.015	<0.015
Copper	T-Cu	0.050	0.053	0.045	0.058	0.056
Iron	T-Fe	0.079	0.085	0.077	0.142	0.916
Lead	T-Pb	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium	T-Li	<0.015	<0.015	<0.015	<0.015	<0.015
Magnesium	T-Mg	11.2	11.3	11.2	11.9	11.5
Manganese	T-Mn	0.059	0.058	0.053	0.065	0.124
Molybdenum	T-Mo	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	T-Ni	<0.020	<0.020	<0.020	<0.020	<0.020
Phosphorus	T-P	3.25	3.31	3.32	3.49	3.11
Potassium	T-K	10.5	10.7	10.9	10.8	11.9
Selenium	T-Se	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	T-Si	7.33	7.44	7.37	7.65	7.87
Silver	T-Ag	<0.015	<0.015	<0.015	<0.015	<0.015
Sodium	T-Na	69.2	70.6	69.9	74.0	129
Strontium	T-Sr	0.153	0.155	0.154	0.165	0.155
Thallium	T-Tl	<0.10	<0.10	<0.10	<0.10	<0.10
Tin	T-Sn	<0.30	<0.30	<0.30	<0.30	<0.30
Titanium	T-Ti	<0.010	<0.010	<0.010	<0.010	0.019
Vanadium	T-V	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc	T-Zn	0.028	0.028	0.027	0.029	0.036

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS

File No. F6977

		E-3	E-4	E-5	E-6	E-7
		96 01 16 ~~10:05~~ 12:00	96 01 16 ~~10:05~~ 01:00	96 01 16 ~~10:05~~ 02:00	96 01 16 ~~10:05~~ 03:00	96 01 16 ~~10:05~~ 04:00
Physical Tests						
Conductivity (umhos/cm)		765	777	756	721	703
Total Metals						
Aluminum	T-Al	0.53	0.78	0.87	0.39	0.37
Antimony	T-Sb	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	T-As	<0.20	<0.20	<0.20	<0.20	<0.20
Barium	T-Ba	0.047	0.059	0.066	0.036	0.036
Beryllium	T-Be	<0.005	<0.005	<0.005	<0.005	<0.005
Bismuth	T-Bi	<0.10	<0.10	<0.10	<0.10	<0.10
Boron	T-B	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium	T-Cd	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	T-Ca	35.1	35.0	35.5	35.0	35.3
Chromium	T-Cr	<0.015	<0.015	<0.015	<0.015	<0.015
Cobalt	T-Co	<0.015	<0.015	<0.015	<0.015	<0.015
Copper	T-Cu	0.064	0.057	0.066	0.058	0.058
Iron	T-Fe	0.979	1.54	1.84	0.742	0.678
Lead	T-Pb	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium	T-Li	<0.015	<0.015	<0.015	<0.015	<0.015
Magnesium	T-Mg	11.3	11.4	11.5	11.1	11.1
Manganese	T-Mn	0.139	0.184	0.201	0.116	0.105
Molybdenum	T-Mo	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	T-Ni	<0.020	<0.020	<0.020	<0.020	<0.020
Phosphorus	T-P	3.00	3.16	3.11	2.97	3.05
Potassium	T-K	10.4	10.4	11.1	10.5	10.3
Selenium	T-Se	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	T-Si	7.80	8.09	8.34	7.56	7.58
Silver	T-Ag	<0.015	<0.015	<0.015	<0.015	<0.015
Sodium	T-Na	79.1	82.4	81.2	75.6	72.6
Strontium	T-Sr	0.152	0.154	0.156	0.151	0.150
Thallium	T-Tl	<0.10	<0.10	<0.10	<0.10	<0.10
Tin	T-Sn	<0.30	<0.30	<0.30	<0.30	<0.30
Titanium	T-Ti	0.017	0.028	0.033	0.014	0.011
Vanadium	T-V	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc	T-Zn	0.039	0.039	0.044	0.036	0.039

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS File No. F6977

		E-8	Influent Comp.	Effluent Comp.
		96 01 16 ~~10:05~~ 06:00	96 01 16 ~~10:05~~	96 01 16 ~~10:05~~
Physical Tests				
Conductivity (umhos/cm)		700	743	770
Total Metals				
Aluminum	T-Al	0.41	<0.20	0.36
Antimony	T-Sb	<0.20	<0.20	<0.20
Arsenic	T-As	<0.20	<0.20	<0.20
Barium	T-Ba	0.036	0.022	0.036
Beryllium	T-Be	<0.005	<0.005	<0.005
Bismuth	T-Bi	<0.10	<0.10	<0.10
Boron	T-B	<0.10	<0.10	<0.10
Cadmium	T-Cd	<0.010	<0.010	<0.010
Calcium	T-Ca	33.9	36.3	34.3
Chromium	T-Cr	<0.015	<0.015	<0.015
Cobalt	T-Co	<0.015	<0.015	<0.015
Copper	T-Cu	0.055	0.049	0.061
Iron	T-Fe	0.710	0.075	0.685
Lead	T-Pb	<0.050	<0.050	<0.050
Lithium	T-Li	<0.015	<0.015	<0.015
Magnesium	T-Mg	10.7	11.3	11.0
Manganese	T-Mn	0.107	0.057	0.109
Molybdenum	T-Mo	<0.030	<0.030	<0.030
Nickel	T-Ni	<0.020	<0.020	<0.020
Phosphorus	T-P	2.95	3.26	3.03
Potassium	T-K	10.4	10.8	10.2
Selenium	T-Se	<0.20	<0.20	<0.20
Silicon	T-Si	7.38	7.40	7.42
Silver	T-Ag	<0.015	<0.015	<0.015
Sodium	T-Na	71.6	71.3	81.3
Strontium	T-Sr	0.142	0.155	0.148
Thallium	T-Tl	<0.10	<0.10	<0.10
Tin	T-Sn	<0.30	<0.30	<0.30
Titanium	T-Ti	0.014	<0.010	0.013
Vanadium	T-V	<0.030	<0.030	<0.030
Zinc	T-Zn	0.036	0.027	0.035

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

METHODOLOGY

File No. F6977

Samples were analyzed by methods acceptable to the appropriate regulatory agency. Outlines of the methodologies utilized are as follows:

Conventional Parameters in Water

These analyses are carried out in accordance with procedures described in "Methods for Chemical Analysis of Water and Wastes" (USEPA), "Manual for the Chemical Analysis of Water, Wastewaters, Sediments and Biological Tissues" (BCMOE), and/or "Standard Methods for the Examination of Water and Wastewater" (APHA). Further details are available on request.

Metals in Water

This analysis is carried out in accordance with procedures described in "Standard Methods for the Examination of Water and Wastewater" 19th Edition 1995 published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion or filtration (EPA Method 3005), followed by instrumental analysis by atomic absorption spectrophotometry (EPA Method 7000), inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010), and/or inductively coupled plasma - mass spectrometry (EPA Method 6020).

End of Report

CITY OF PRINCE GEORGE
SNOW DISPOSAL STUDY AT
THE LANSDOWNE ROAD WASTEWATER TREATMENT CENTRE

APPENDIX 4

STATISTICAL ANALYSIS OF WATER QUALITY PARAMETERS

CITY OF PRINCE GEORGE SNOW DISPOSAL STUDY
STATISTICAL ANALYSIS OF WATER QUALITY DATA

Time of Sample	Flow (cfs)	Temperature (deg C) Influent	Temperature (deg C) Effluent	Temperature (deg C) Infl-Effl	pH Influent	pH Effluent	pH Infl-Effl	BOD5 (mg/L) Influent	BOD5 (mg/L) Effluent	BOD5 (mg/L) Infl-Effl
Composite Sample								44	49	5
Grab 10:05 PM	14.4	12.0	12.0	0.0	7.3	7.3	0.0	46	47	1
Grab 10:58 PM	13.7	12.0	6.5	-5.5	7.6	7.6	0.0	42	48	6
Grab 12:00 AM	12.8	11.5	5.5	-6.0	7.7	7.8	0.1	42	49	7
Grab 1:00 AM	10.1	11.0	5.0	-6.0	7.7	7.7	0.0	41	50	9
Grab 2:00 AM	8.4	10.5	4.5	-6.0	7.7	7.8	0.1	39	46	7
Grab 3:00 AM	7.2	10.5	3.0	-7.5	7.7	7.8	0.1	40	44	4
Grab 4:00 AM	6.4	11.0	3.5	-7.5	7.7	7.8	0.1	41	41	0
Grab 5:00 AM	6.4	10.0	3.0	-7.0	7.7	7.8	0.1	39	42	3
Mean		11.1	5.4	-5.7	7.6	7.7	0.1	41	46	5
Standard Deviation		0.73	2.95	2.42	0.14	0.18	0.05	2.25	3.27	3.16
Calculated t				-6.65			3.42			4.14
Test t (0.025, 7)				2.37			2.37			2.37
Significant Difference?				Yes			Yes			Yes

Time of Sample	Flow (cfs)	Tot Susp Solids (mg/L) Influent	Tot Susp Solids (mg/L) Effluent	Tot Susp Solids (mg/L) Infl-Effl	Ammonia (mg N/L) Influent	Ammonia (mg N/L) Effluent	Ammonia (mg N/L) Infl-Effl	Conductivity (umhos/cm) Influent	Conductivity (umhos/cm) Effluent	Conductivity (umhos/cm) Infl-Effl
Composite Sample		8	53	45	26	25	-1	743	770	27
Grab 10:05 PM	14.4	17	16	-1	28	29	1	758	776	18
Grab 10:58 PM	13.7	10	62	52	27	28	1	756	1000	244
Grab 12:00 AM	12.8	11	55	44	27	28	1	746	765	19
Grab 1:00 AM	10.1	12	77	65	25	26	1	748	777	29
Grab 2:00 AM	8.4	4	85	81	27	25	-2	743	756	13
Grab 3:00 AM	7.2	13	55	42	27	27	0	727	721	-6
Grab 4:00 AM	6.4	12	52	40	25	25	0	716	703	-13
Grab 5:00 AM	6.4	8	47	39	24	23	-1	715	700	-15
Mean		11	56	45	26	26	0	739	775	36
Standard Deviation		3.80	20.76	23.70	1.39	2.00	1.13	17.09	96.23	85.54
Calculated t				5.40			0.31			1.19
Test t (0.025, 7)				2.37			2.37			2.37
Significant Difference?				Yes			No			No

Time	Flow (cfs)	Aluminum (mg/L) Influent	Aluminum (mg/L) Effluent	Aluminum (mg/L) Infl-Effl	Barium (mg/L) Influent	Barium (mg/L) Effluent	Barium (mg/L) Infl-Effl	Calcium (mg/L) Influent	Calcium (mg/L) Effluent	Calcium (mg/L) Infl-Effl
Composite Sample		< 0.20	0.36	> 0.16	0.022	0.036	0.014	36.3	34.3	-2.0
Grab 10:05 PM	14.4	< 0.20	< 0.20	0.00	0.022	0.024	0.002	37.6	38.5	0.9
Grab 10:58 PM	13.7	< 0.20	0.53	0.33	0.023	0.043	0.020	36.6	35.9	-0.7
Grab 12:00 AM	12.8	< 0.20	0.53	0.33	0.023	0.047	0.024	37.3	35.1	-2.2
Grab 1:00 AM	10.1	< 0.20	0.78	0.58	0.021	0.059	0.038	37.1	35.0	-2.1
Grab 2:00 AM	8.4	< 0.20	0.87	0.67	0.022	0.066	0.044	36.6	35.5	-1.1
Grab 3:00 AM	7.2	< 0.20	0.39	0.19	0.021	0.036	0.015	35.8	35.0	-0.8
Grab 4:00 AM	6.4	< 0.20	0.37	0.17	0.022	0.036	0.014	36.2	35.3	-0.9
Grab 5:00 AM	6.4	< 0.20	0.41	0.21	0.022	0.036	0.014	35.9	33.9	-2.0

	Al Influent	Al Effluent	Al Infl-Effl	Ba Influent	Ba Effluent	Ba Infl-Effl	Ca Influent	Ca Effluent	Ca Infl-Effl
Mean (Grab Samples)	< 0.20	0.5543	0.31	0.022	0.0434	0.021	36.638	35.525	-1.113
Standard Deviation		0.1973	0.221	0.0008	0.0136	0.014	0.6567	1.3318	1.022
Calculated t			3.959			4.436			-3.079
Test t (0.025, 7)			2.365			2.365			2.365
Significant Difference?			Yes			Yes			Yes

Time	Flow (cfs)	Copper (mg/L) Influent	Copper (mg/L) Effluent	Copper (mg/L) Infl-Effl	Iron (mg/L) Influent	Iron (mg/L) Effluent	Iron (mg/L) Infl-Effl	Magnesium (mg/L) Influent	Magnesium (mg/L) Effluent	Magnesium (mg/L) Infl-Effl
Composite Sample		0.049	0.061	0.012	0.075	0.685	0.610	11.3	11.0	-0.3
Grab 10:05 PM	14.4	0.048	0.058	0.010	0.075	0.142	0.067	11.8	11.9	0.1
Grab 10:58 PM	13.7	0.050	0.056	0.006	0.072	0.916	0.844	11.5	11.5	0.0
Grab 12:00 AM	12.8	0.049	0.064	0.015	0.077	0.979	0.902	11.6	11.3	-0.3
Grab 1:00 AM	10.1	0.044	0.057	0.013	0.069	1.540	1.471	11.6	11.4	-0.2
Grab 2:00 AM	8.4	0.044	0.066	0.022	0.075	1.840	1.765	11.5	11.5	0.0
Grab 3:00 AM	7.2	0.050	0.058	0.008	0.079	0.742	0.663	11.2	11.1	-0.1
Grab 4:00 AM	6.4	0.053	0.058	0.005	0.085	0.678	0.593	11.3	11.1	-0.2
Grab 5:00 AM	6.4	0.045	0.055	0.010	0.077	0.710	0.633	11.2	10.7	-0.5

	Cu Influent	Cu Effluent	Cu Infl-Effl	Fe Influent	Fe Effluent	Fe Infl-Effl	Mg Influent	Mg Effluent	Mg Infl-Effl
Mean (Grab Samples)	0.0479	0.059	0.011	0.0761	0.9434	0.867	11.463	11.313	-0.15
Standard Deviation	0.0033	0.0039	0.006	0.0048	0.5304	0.532	0.2134	0.3563	0.193
Calculated t			5.706			4.607			-2.201
Test t (0.025, 7)			2.365			2.365			2.365
Significant Difference?			Yes			Yes			No

Time	Flow (cfs)	Manganese (mg/L)			Phosphorus (mg/L)			Potassium (mg/L)		
		Influent	Effluent	Infl-Effl	Influent	Effluent	Infl-Effl	Influent	Effluent	Infl-Effl
Composite Sample		0.057	0.109	0.052	3.26	3.03	-0.23	10.8	10.2	-0.6
Grab 10:05 PM	14.4	0.058	0.065	0.007	3.31	3.49	0.18	11.2	10.8	-0.4
Grab 10:58 PM	13.7	0.058	0.124	0.066	3.27	3.11	-0.16	11.5	11.9	0.4
Grab 12:00 AM	12.8	0.062	0.139	0.077	3.50	3.00	-0.50	11.5	10.4	-1.1
Grab 1:00 AM	10.1	0.062	0.184	0.122	3.41	3.16	-0.25	11.2	10.4	-0.8
Grab 2:00 AM	8.4	0.062	0.201	0.139	3.29	3.11	-0.18	11.2	11.1	-0.1
Grab 3:00 AM	7.2	0.059	0.116	0.057	3.25	2.97	-0.28	10.5	10.5	0.0
Grab 4:00 AM	6.4	0.058	0.105	0.047	3.31	3.05	-0.26	10.7	10.3	-0.4
Grab 5:00 AM	6.4	0.053	0.107	0.054	3.32	2.95	-0.37	10.9	10.4	-0.5
Mean (Grab Samples)		0.059	0.1301	0.071	3.3325	3.105	-0.228	11.088	10.725	-0.362
Standard Deviation		0.0031	0.0442	0.042	0.0826	0.1722	0.197	0.3603	0.5445	0.469
Calculated t				4.772			-3.266			-2.187
Test t (0.025, 7)				2.365			2.365			2.365
Significant Difference?				Yes			Yes			No

Time	Flow (cfs)	Silicon (mg/L)			Sodium (mg/L)			Strontium (mg/L)		
		Influent	Effluent	Infl-Effl	Influent	Effluent	Infl-Effl	Influent	Effluent	Infl-Effl
Composite Sample		7.40	7.42	0.02	71.3	81.3	10.0	0.155	0.148	-0.007
Grab 10:05 PM	14.4	7.53	7.65	0.12	72.8	74.0	1.2	0.161	0.165	0.004
Grab 10:58 PM	13.7	7.42	7.87	0.45	72.1	70.0	-2.1	0.157	0.155	-0.002
Grab 12:00 AM	12.8	7.52	7.80	0.28	72.8	129.0	56.2	0.160	0.152	-0.008
Grab 1:00 AM	10.1	7.53	8.09	0.56	72.8	82.4	9.6	0.159	0.154	-0.005
Grab 2:00 AM	8.4	7.49	8.34	0.85	71.9	81.2	9.3	0.157	0.156	-0.001
Grab 3:00 AM	7.2	7.33	7.56	0.23	69.2	75.6	6.4	0.153	0.151	-0.002
Grab 4:00 AM	6.4	7.44	7.58	0.14	70.6	72.6	2.0	0.155	0.150	-0.005
Grab 5:00 AM	6.4	7.37	7.38	0.01	69.9	71.6	1.7	0.154	0.142	-0.012
Mean (Grab Samples)		7.4538	7.7838	0.33	71.513	82.05	10.54	0.157	0.1531	-0.004
Standard Deviation		0.0765	0.3125	0.276	1.4267	19.476	18.91	0.0029	0.0065	0.005
Calculated t				3.383			1.576			-2.272
Test t (0.025, 7)				2.365			2.365			2.365
Significant Difference?				Yes			No			No

Time	Flow	Titanium (mg/L)			Zinc (mg/L)		
	(cfs)	Influent	Effluent	Infl-Effl	Influent	Effluent	Infl-Effl
Composite Sample		< 0.010	0.013	0.003	0.027	0.035	0.003
Grab 10:05 PM	14.4	< 0.010	< 0.010	0.000	0.029	0.029	0.000
Grab 10:58 PM	13.7	< 0.010	0.019	0.009	0.026	0.036	0.026
Grab 12:00 AM	12.8	< 0.010	0.017	0.007	0.029	0.039	0.029
Grab 1:00 AM	10.1	< 0.010	0.028	0.018	0.028	0.039	0.029
Grab 2:00 AM	8.4	< 0.010	0.033	0.023	0.028	0.044	0.034
Grab 3:00 AM	7.2	< 0.010	0.014	0.004	0.028	0.036	0.026
Grab 4:00 AM	6.4	< 0.010	0.011	0.001	0.028	0.039	0.029
Grab 5:00 AM	6.4	< 0.010	0.014	0.004	0.027	0.039	0.029

Mean (Grab Samples)	< 0.010	0.0194	0.008	< 0.010	0.0376	0.025
Standard Deviation		0.0081	0.008		0.0043	0.01
Calculated t			2.843			6.803
Test t (0.025, 7)			2.365			2.365
Significant Difference?			Yes			Yes

CITY OF PRINCE GEORGE
SNOW DISPOSAL STUDY AT
THE LANSDOWNE ROAD WASTEWATER TREATMENT CENTRE

APPENDIX 5

ESTIMATED SNOW STORAGE REQUIREMENTS

PRINCE GEORGE SNOW DISPOSAL STUDY					
ESTIMATE OF SNOW STORAGE					
Maximum Snow Disposal Rate=				4800	m3/d
Snow Disposal Rate Limited by Plant Effluent TSS Concentration					
Year	Month	Day	Daily Snowfall (cm)	Daily Storage (m3)	Cumulative Storage (m3)
1988	November	10	2	0	0
		11	1.4	0	0
		12	1.2	0	0
		15	0.8	0	0
		16	1	0	0
		18	3.4	65	65
		19	1.5	0	0
		20	0.8	0	0
		27	0.4	0	0
		29	0.5	0	0
	December	8	12.2	12,656	12,656
		9	1.4	0	7,856
		10	0	0	3,056
		11	2.4	0	0
		12	7	5,216	5,216
		13	30.7	39,127	44,342
		14	0	0	39,542
		15	0	0	34,742
		16	0	0	29,942
		17	0	0	25,142
		18	1.1	0	20,342
		19	2.6	0	15,542
		20	0	0	10,742
		21	2.6	0	5,942
		22	0	0	1,142
		23	2.4	0	0
		24	0	0	0
		25	0	0	0
		26	1.4	0	0
		27	6	3,785	3,785
		28	12.6	13,229	17,014
		29	0	0	12,214
		30	0	0	7,414
		31	0	0	2,614
1989	January	1	1.2	0	0
		2	0.4	0	0
		3	7.1	5,359	5,359
		4	0	0	559
		5	2.2	0	0
		6	0	0	0
		7	0	0	0
		8	6.6	4,644	4,644
		9	3	0	0

		10	2.6	0	0
		11	4	923	923
		12	3.4	65	988
		13	0.2	0	0
		14	0	0	0
		15	5.2	2,640	2,640
		16	10.2	9,795	12,435
		17	1.4	0	7,635
		18	0	0	2,835
		19	3.6	351	3,186
		20	0	0	0
		21	0	0	0
		22	0	0	0
		23	0	0	0
		24	0	0	0
		25	5	2,354	2,354
		26	0.4	0	0
		27	0	0	0
		28	0	0	0
		29	1.2	0	0
		30	4.6	1,782	1,782
		31	0	0	0
	February	15	3.4	65	65
		16	0	0	0
		19	1	0	0
		20	0.6	0	0
		22	1.4	0	0
		23	1	0	0
		24	7.1	5,359	5,359
		25	0	0	559
		26	0	0	0
		27	6.2	4,071	4,071
		28	0	0	0
	March	6	3.4	65	65
		7	0	0	0
		8	1	0	0
		9	1.4	0	0
		10	4.4	1,496	1,496
		11	1.2	0	0
		12	0.4	0	0
		13	8.2	6,933	6,933
		14	1	0	2,133
		15	0	0	0
		26	2.3	0	0
1989	November	2	0.6	0	0
		6	2.1	0	0
		8	0.2	0	0
		10	5.8	3,499	3,499
		13	0.5	0	0
		15	5.8	3,499	3,499

		17	2.6	0	0
		23	5.9	3,642	3,642
		24	1.7	0	0
		26	0.2	0	0
	December	1	7.4	5,788	5,788
		2	0	0	988
		3	0	0	0
		5	3	0	0
		6	1.8	0	0
		7	10	9,508	9,508
		8	0	0	4,708
		9	0.4	0	0
		10	0.5	0	0
		11	0.4	0	0
		15	1	0	0
		18	2.4	0	0
		19	19	22,386	22,386
		20	3	0	17,586
		21	5.6	3,213	20,799
		22	0.4	0	15,999
		23	0.4	0	11,199
		24	0	0	6,399
		25	0	0	1,599
		26	0	0	0
		27	0	0	0
		28	1.8	0	0
		30	4.2	1,210	1,210
		31	0.4	0	0
1990	January	1	0	0	0
		2	6.4	4,357	4,357
		3	9.6	8,936	13,293
		4	5.4	2,927	16,220
		5	5.6	3,213	19,433
		6	0	0	14,633
		7	4.8	2,068	16,701
		8	0	0	11,901
		9	0	0	7,101
		10	0	0	2,301
		11	0	0	0
		12	1.2	0	0
		13	3.6	351	351
		14	0	0	0
		15	5	2,354	2,354
		16	1.6	0	0
		20	2.4	0	0
		21	8	6,647	6,647
		22	2	0	1,847
		23	0	0	0
		24	5.8	3,499	3,499
		25	1	0	0
		26	11	10,939	10,939

			27	1.6	0	6,139
			28	2.8	0	1,339
			29	0.4	0	0
			30	0	0	0
			31	0	0	0
	February		1	7.6	6,074	6,074
			2	3.6	351	6,425
			3	2	0	1,625
			4	0	0	0
			5	0	0	0
			6	0.4	0	0
			7	0.2	0	0
			8	2	0	0
			9	16.4	18,666	18,666
			10	1.4	0	13,866
			11	2.8	0	9,066
			12	1	0	4,266
			13	0	0	0
			14	6.4	4,357	4,357
			15	8.8	7,791	12,149
			16		0	7,349
			17		0	2,549
			18	1	0	0
			19		0	0
			20	2.6	0	0
			21		0	0
			22		0	0
	March		6	0.8	0	0
			7	4.6	1,782	1,782
			8	2.6	0	0
			9	1	0	0
			10	1.2	0	0
			14	0.4	0	0
			16	2.2	0	0
			20	1.4	0	0
			21	2.4	0	0
1990	November		3	4.2	1,210	1,210
			4	0.4	0	0
			6	1.8	0	0
			7	0.8	0	0
			8	0.8	0	0
			9	4.2	1,210	1,210
			10	1.8	0	0
			11	15.8	17,807	17,807
			12	3	0	13,007
			13	1.8	0	8,207
			14	2	0	3,407
			15	1.6	0	0
			18	10.2	9,795	9,795
			19	11.6	11,798	21,592

		20	3.2	0	16,792
		21	6	3,785	20,577
		22	2	0	15,777
		23	13	13,801	29,578
		24	0	0	24,778
		25	0	0	19,978
		26	0.6	0	15,178
		27	0	0	10,378
		28	0.8	0	5,578
		29	9.6	8,936	14,514
		30	1.8	0	9,714
	December	1	4.8	2,068	11,782
		2	3.2	0	6,982
		3	6.8	4,930	11,912
		4	0	0	7,112
		5	0	0	2,312
		6	0	0	0
		7	0	0	0
		10	0.2	0	0
		11	0	0	0
		12	0	0	0
		13	1.5	0	0
		14	3	0	0
		15	3.4	65	65
		16	9.6	8,936	9,001
		17	4.4	1,496	10,497
		18	0	0	5,697
		19	0.4	0	897
		20	0	0	0
		21	0.6	0	0
		22	3.2	0	0
		23	7	5,216	5,216
		24	0	0	416
		25	13.6	14,659	15,075
		26	6.2	4,071	19,146
		27	6.6	4,644	23,790
		28	0	0	18,990
		29	18.8	22,100	41,090
		30	30.8	39,270	80,359
		31	11.6	11,798	92,157
1991	January	1	0	0	87,357
		2	0	0	82,557
		3	0	0	77,757
		4	0.8	0	72,957
		5	0	0	68,157
		6	0	0	63,357
		7	0.2	0	58,557
		8	0	0	53,757
		9	4.6	1,782	55,539
		10	1.8	0	50,739
		11	0.4	0	45,939

		12	0.4	0	41,139
		13	0	0	36,339
		14	0.4	0	31,539
		15	0.8	0	26,739
		16	4.4	1,496	28,234
		17	0	0	23,434
		18	0	0	18,634
		19	0	0	13,834
		20	0	0	9,034
		21	0	0	4,234
		22	0	0	0
		23	2	0	0
		29		0	0
		30	10.4	10,081	10,081
		31	4	923	11,004
	February	1		0	6,204
		2		0	1,404
		3		0	0
		9		0	0
		16	1.6	0	0
		17	0.6	0	0
		18	1.8	0	0
		20	0.2	0	0
		21	0.2	0	0
		22	0.6	0	0
	March	6	0.6	0	0
		7	1.4	0	0
		9	7.6	6,074	6,074
		10	1.8	0	1,274
		11	0.8	0	0
		12	0.8	0	0
		21	1.4	0	0
		22	5	2,354	2,354
1991	November	2	2.4	0	0
		3	8.2	6,933	6,933
		4	0	0	2,133
		5	6.4	4,357	6,490
		6	7	5,216	11,706
		7	0	0	6,906
		8	0	0	2,106
		9	0	0	0
		15	2.4	0	0
		16	4.6	1,782	1,782
		17	0	0	0
		21	3	0	0
		23	0.8	0	0
		24	3	0	0
		27	2.2	0	0
		28	1.2	0	0
		29	2	0	0

		30	9	8,078	8,078
	December	1	0	0	3,278
		2	9.6	8,936	12,214
		3	4.4	1,496	13,709
		4	0	0	8,909
		5	2.2	0	4,109
		6	3.8	637	4,746
		7	1	0	0
		8	0	0	0
		9	1	0	0
		10	0.6	0	0
		11	0.2	0	0
		12	6	3,785	3,785
		13	7.6	6,074	9,859
		14	5	2,354	12,214
		15	0.6	0	7,414
		16	0	0	2,614
		17	0	0	0
		18	7.2	5,502	5,502
		19	0	0	702
		20	3.8	637	1,339
		21	0	0	0
		29	0.8	0	0
1992	January	2	0.8	0	0
		3	1.8	0	0
		4	3.2	0	0
		5	1	0	0
		8	4	923	923
		9	2	0	0
		12	2.2	0	0
		13	2.6	0	0
		14	0.4	0	0
		17	4	923	923
		19	1.6	0	0
		21	2	0	0
		22	5.4	2,927	2,927
		23	4	923	3,850
		24	0	0	0
		31	2.4	0	0
	February	9	4	923	923
		10	3.6	351	1,274
		11	2.2	0	0
		14	2.4	0	0
		15	1	0	0
		16	8.4	7,219	7,219
		17	0	0	2,419
		18	8.2	6,933	9,352
		19	0.8	0	4,552
		20	0	0	0
		21	5.8	3,499	3,499
		22	0.4	0	0

		23	0	0	0
		24	0.4	0	0
		25	0	0	0
	March	26	0.8	0	0
		27	0.2	0	0
1992	November	3	3.4	65	65
		4	5	2,354	2,419
		5	4.4	1,496	3,915
		6	0	0	0
		7	3.4	65	65
		9	1.4	0	0
		12	3.6	351	351
		13	1.2	0	0
		17	0.4	0	0
		18	0.2	0	0
		20	0.2	0	0
		21	0.2	0	0
		27	3.6	351	351
		28	0	0	0
	December	7	1.2	0	0
		11	0.8	0	0
		12	0.2	0	0
		13	12.4	12,942	12,942
		14	0	0	8,142
		15	0	0	3,342
		16	11.2	11,225	14,568
		17	3.5	208	14,776
		18	4.2	1,210	15,985
		19	20.4	24,389	40,374
		20	4.8	2,068	42,442
		21	10.2	9,795	52,237
		22	8.6	7,505	59,742
		23	11.8	12,084	71,826
		24	0.8	0	67,026
		25	9.8	9,222	76,248
		26	5.8	3,499	79,747
		27	0.8	0	74,947
		28	0	0	70,147
		29	1.6	0	65,347
		30	0	0	60,547
		31	0	0	55,747
1993	January	1	0	0	50,947
		2	5.2	2,640	53,587
		3	17.4	20,097	73,684
		4	0	0	68,884
		5	0	0	64,084
		6	0	0	59,284
		7	0.6	0	54,484
		8	0	0	49,684
		9	0	0	44,884

		10	0	0	40,084
		11	0	0	35,284
		12	0	0	30,484
		13	0	0	25,684
		14	0	0	20,884
		15	0	0	16,084
		16	0	0	11,284
		17	0	0	6,484
		18	0	0	1,684
		19	0	0	0
		20	15.6	17,521	17,521
		21	0	0	12,721
		22	0	0	7,921
		23	0.6	0	3,121
		24	2.2	0	0
		25	1	0	0
		26	0.4	0	0
	February	21	1.4	0	0
		26	0.4	0	0
	March	4	0.2	0	0
		5	1.2	0	0
		8	3.6	351	351
		14	3	0	0
		21	1	0	0
		31	0.4	0	0

PRINCE GEORGE SNOW DISPOSAL STUDY					
ESTIMATE OF SNOW STORAGE					
Maximum Snow Disposal Rate=				5750	m3/d
Snow Disposal Rate Limited by Plant Melting Capacity					
Year	Month	Day	Daily Snowfall (cm)	Daily Storage (m3)	Cumulative Storage (m3)
1988	November	10	2	0	0
		11	1.4	0	0
		12	1.2	0	0
		15	0.8	0	0
		16	1	0	0
		18	3.4	0	0
		19	1.5	0	0
		20	0.8	0	0
		27	0.4	0	0
		29	0.5	0	0
	December	8	12.2	11,706	11,706
		9	1.4	0	5,956
		10	0	0	206
		11	2.4	0	0
		12	7	4,266	4,266
		13	30.7	38,177	42,442
		14	0	0	36,692
		15	0	0	30,942
		16	0	0	25,192
		17	0	0	19,442
		18	1.1	0	13,692
		19	2.6	0	7,942
		20	0	0	2,192
		21	2.6	0	0
		22	0	0	0
		23	2.4	0	0
		24	0	0	0
		25	0	0	0
		26	1.4	0	0
		27	6	2,835	2,835
		28	12.6	12,279	15,114
		29	0	0	9,364
		30	0	0	3,614
		31	0	0	0
1989	January	1	1.2	0	0
		2	0.4	0	0
		3	7.1	4,409	4,409
		4	0	0	0
		5	2.2	0	0
		6	0	0	0
		7	0	0	0
		8	6.6	3,694	3,694
		9	3	0	0

		10	2.6	0	0
		11	4	0	0
		12	3.4	0	0
		13	0.2	0	0
		14	0	0	0
		15	5.2	1,690	1,690
		16	10.2	8,845	10,535
		17	1.4	0	4,785
		18	0	0	0
		19	3.6	0	0
		20	0	0	0
		21	0	0	0
		22	0	0	0
		23	0	0	0
		24	0	0	0
		25	5	1,404	1,404
		26	0.4	0	0
		27	0	0	0
		28	0	0	0
		29	1.2	0	0
		30	4.6	832	832
		31	0	0	0
	February	15	3.4	0	0
		16	0	0	0
		19	1	0	0
		20	0.6	0	0
		22	1.4	0	0
		23	1	0	0
		24	7.1	4,409	4,409
		25	0	0	0
		26	0	0	0
		27	6.2	3,121	3,121
		28	0	0	0
	March	6	3.4	0	0
		7	0	0	0
		8	1	0	0
		9	1.4	0	0
		10	4.4	546	546
		11	1.2	0	0
		12	0.4	0	0
		13	8.2	5,983	5,983
		14	1	0	233
		15	0	0	0
		26	2.3	0	0
1989	November	2	0.6	0	0
		6	2.1	0	0
		8	0.2	0	0
		10	5.8	2,549	2,549
		13	0.5	0	0
		15	5.8	2,549	2,549

		17	2.6	0	0
		23	5.9	2,692	2,692
		24	1.7	0	0
		26	0.2	0	0
	December	1	7.4	4,838	4,838
		2	0	0	0
		3	0	0	0
		5	3	0	0
		6	1.8	0	0
		7	10	8,558	8,558
		8	0	0	2,808
		9	0.4	0	0
		10	0.5	0	0
		11	0.4	0	0
		15	1	0	0
		18	2.4	0	0
		19	19	21,436	21,436
		20	3	0	15,686
		21	5.6	2,263	17,949
		22	0.4	0	12,199
		23	0.4	0	6,449
		24	0	0	699
		25	0	0	0
		26	0	0	0
		27	0	0	0
		28	1.8	0	0
		30	4.2	260	260
		31	0.4	0	0
1990	January	1	0	0	0
		2	6.4	3,407	3,407
		3	9.6	7,986	11,393
		4	5.4	1,977	13,370
		5	5.6	2,263	15,633
		6	0	0	9,883
		7	4.8	1,118	11,001
		8	0	0	5,251
		9	0	0	0
		10	0	0	0
		11	0	0	0
		12	1.2	0	0
		13	3.6	0	0
		14	0	0	0
		15	5	1,404	1,404
		16	1.6	0	0
		20	2.4	0	0
		21	8	5,697	5,697
		22	2	0	0
		23	0	0	0
		24	5.8	2,549	2,549
		25	1	0	0
		26	11	9,989	9,989

		27	1.6	0	4,239
		28	2.8	0	0
		29	0.4	0	0
		30	0	0	0
		31	0	0	0
	February	1	7.6	5,124	5,124
		2	3.6	0	0
		3	2	0	0
		4	0	0	0
		5	0	0	0
		6	0.4	0	0
		7	0.2	0	0
		8	2	0	0
		9	16.4	17,716	17,716
		10	1.4	0	11,966
		11	2.8	0	6,216
		12	1	0	466
		13	0	0	0
		14	6.4	3,407	3,407
		15	8.8	6,841	10,249
		16		0	4,499
		17		0	0
		18	1	0	0
		19		0	0
		20	2.6	0	0
		21		0	0
		22		0	0
	March	6	0.8	0	0
		7	4.6	832	832
		8	2.6	0	0
		9	1	0	0
		10	1.2	0	0
		14	0.4	0	0
		16	2.2	0	0
		20	1.4	0	0
		21	2.4	0	0
1990	November	3	4.2	260	260
		4	0.4	0	0
		6	1.8	0	0
		7	0.8	0	0
		8	0.8	0	0
		9	4.2	260	260
		10	1.8	0	0
		11	15.8	16,857	16,857
		12	3	0	11,107
		13	1.8	0	5,357
		14	2	0	0
		15	1.6	0	0
		18	10.2	8,845	8,845
		19	11.6	10,848	19,692

		20	3.2	0	13,942
		21	6	2,835	16,777
		22	2	0	11,027
		23	13	12,851	23,878
		24	0	0	18,128
		25	0	0	12,378
		26	0.6	0	6,628
		27	0	0	878
		28	0.8	0	0
		29	9.6	7,986	7,986
		30	1.8	0	2,236
	December	1	4.8	1,118	3,354
		2	3.2	0	0
		3	6.8	3,980	3,980
		4	0	0	0
		5	0	0	0
		6	0	0	0
		7	0	0	0
		10	0.2	0	0
		11	0	0	0
		12	0	0	0
		13	1.5	0	0
		14	3	0	0
		15	3.4	0	0
		16	9.6	7,986	7,986
		17	4.4	546	8,532
		18	0	0	2,782
		19	0.4	0	0
		20	0	0	0
		21	0.6	0	0
		22	3.2	0	0
		23	7	4,266	4,266
		24	0	0	0
		25	13.6	13,709	13,709
		26	6.2	3,121	16,831
		27	6.6	3,694	20,524
		28	0	0	14,774
		29	18.8	21,150	35,924
		30	30.8	38,320	74,243
		31	11.6	10,848	85,091
1991	January	1	0	0	79,341
		2	0	0	73,591
		3	0	0	67,841
		4	0.8	0	62,091
		5	0	0	56,341
		6	0	0	50,591
		7	0.2	0	44,841
		8	0	0	39,091
		9	4.6	832	39,923
		10	1.8	0	34,173
		11	0.4	0	28,423

		12	0.4	0	22,673
		13	0	0	16,923
		14	0.4	0	11,173
		15	0.8	0	5,423
		16	4.4	546	5,969
		17	0	0	219
		18	0	0	0
		19	0	0	0
		20	0	0	0
		21	0	0	0
		22	0	0	0
		23	2	0	0
		29		0	0
		30	10.4	9,131	9,131
		31	4	0	3,381
	February	1		0	0
		2		0	0
		3		0	0
		9		0	0
		16	1.6	0	0
		17	0.6	0	0
		18	1.8	0	0
		20	0.2	0	0
		21	0.2	0	0
		22	0.6	0	0
	March	6	0.6	0	0
		7	1.4	0	0
		9	7.6	5,124	5,124
		10	1.8	0	0
		11	0.8	0	0
		12	0.8	0	0
		21	1.4	0	0
		22	5	1,404	1,404
1991	November	2	2.4	0	0
		3	8.2	5,983	5,983
		4	0	0	233
		5	6.4	3,407	3,640
		6	7	4,266	7,906
		7	0	0	2,156
		8	0	0	0
		9	0	0	0
		15	2.4	0	0
		16	4.6	832	832
		17	0	0	0
		21	3	0	0
		23	0.8	0	0
		24	3	0	0
		27	2.2	0	0
		28	1.2	0	0
		29	2	0	0

		30	9	7,128	7,128
	December	1	0	0	1,378
		2	9.6	7,986	9,364
		3	4.4	546	9,909
		4	0	0	4,159
		5	2.2	0	0
		6	3.8	0	0
		7	1	0	0
		8	0	0	0
		9	1	0	0
		10	0.6	0	0
		11	0.2	0	0
		12	6	2,835	2,835
		13	7.6	5,124	7,959
		14	5	1,404	9,364
		15	0.6	0	3,614
		16	0	0	0
		17	0	0	0
		18	7.2	4,552	4,552
		19	0	0	0
		20	3.8	0	0
		21	0	0	0
		29	0.8	0	0
1992	January	2	0.8	0	0
		3	1.8	0	0
		4	3.2	0	0
		5	1	0	0
		8	4	0	0
		9	2	0	0
		12	2.2	0	0
		13	2.6	0	0
		14	0.4	0	0
		17	4	0	0
		19	1.6	0	0
		21	2	0	0
		22	5.4	1,977	1,977
		23	4	0	0
		24	0	0	0
		31	2.4	0	0
	February	9	4	0	0
		10	3.6	0	0
		11	2.2	0	0
		14	2.4	0	0
		15	1	0	0
		16	8.4	6,269	6,269
		17	0	0	519
		18	8.2	5,983	6,502
		19	0.8	0	752
		20	0	0	0
		21	5.8	2,549	2,549
		22	0.4	0	0

		23	0	0	0
		24	0.4	0	0
		25	0	0	0
	March	26	0.8	0	0
		27	0.2	0	0
1992	November	3	3.4	0	0
		4	5	1,404	1,404
		5	4.4	546	1,950
		6	0	0	0
		7	3.4	0	0
		9	1.4	0	0
		12	3.6	0	0
		13	1.2	0	0
		17	0.4	0	0
		18	0.2	0	0
		20	0.2	0	0
		21	0.2	0	0
		27	3.6	0	0
		28	0	0	0
	December	7	1.2	0	0
		11	0.8	0	0
		12	0.2	0	0
		13	12.4	11,992	11,992
		14	0	0	6,242
		15	0	0	492
		16	11.2	10,275	10,768
		17	3.5	0	5,018
		18	4.2	260	5,277
		19	20.4	23,439	28,716
		20	4.8	1,118	29,834
		21	10.2	8,845	38,679
		22	8.6	6,555	45,234
		23	11.8	11,134	56,368
		24	0.8	0	50,618
		25	9.8	8,272	58,890
		26	5.8	2,549	61,439
		27	0.8	0	55,689
		28	0	0	49,939
		29	1.6	0	44,189
		30	0	0	38,439
		31	0	0	32,689
1993	January	1	0	0	26,939
		2	5.2	1,690	28,629
		3	17.4	19,147	47,776
		4	0	0	42,026
		5	0	0	36,276
		6	0	0	30,526
		7	0.6	0	24,776
		8	0	0	19,026
		9	0	0	13,276

		10	0	0	7,526
		11	0	0	1,776
		12	0	0	0
		13	0	0	0
		14	0	0	0
		15	0	0	0
		16	0	0	0
		17	0	0	0
		18	0	0	0
		19	0	0	0
		20	15.6	16,571	16,571
		21	0	0	10,821
		22	0	0	5,071
		23	0.6	0	0
		24	2.2	0	0
		25	1	0	0
		26	0.4	0	0
	February	21	1.4	0	0
		26	0.4	0	0
	March	4	0.2	0	0
		5	1.2	0	0
		8	3.6	0	0
		14	3	0	0
		21	1	0	0
		31	0.4	0	0

PRINCE GEORGE SNOW DISPOSAL STUDY					
ESTIMATE OF SNOW STORAGE					
Maximum Snow Disposal Rate=				18000	m3/d
Snow Disposal Rate Limited Gas-Fired Snowmelter Capacity					
Year	Month	Day	Daily Snowfall (cm)	Daily Storage (m3)	Cumulative Storage (m3)
1988	November	10	2	0	0
		11	1.4	0	0
		12	1.2	0	0
		15	0.8	0	0
		16	1	0	0
		18	3.4	0	0
		19	1.5	0	0
		20	0.8	0	0
		27	0.4	0	0
		29	0.5	0	0
	December	8	12.2	0	0
		9	1.4	0	0
		10	0	0	0
		11	2.4	0	0
		12	7	0	0
		13	30.7	25,927	25,927
		14	0	0	7,927
		15	0	0	0
		16	0	0	0
		17	0	0	0
		18	1.1	0	0
		19	2.6	0	0
		20	0	0	0
		21	2.6	0	0
		22	0	0	0
		23	2.4	0	0
		24	0	0	0
		25	0	0	0
		26	1.4	0	0
		27	6	0	0
		28	12.6	29	0
		29	0	0	0
		30	0	0	0
		31	0	0	0
1989	January	1	1.2	0	0
		2	0.4	0	0
		3	7.1	0	0
		4	0	0	0
		5	2.2	0	0
		6	0	0	0
		7	0	0	0
		8	6.6	0	0
		9	3	0	0

		10	2.6	0	0
		11	4	0	0
		12	3.4	0	0
		13	0.2	0	0
		14	0	0	0
		15	5.2	0	0
		16	10.2	0	0
		17	1.4	0	0
		18	0	0	0
		19	3.6	0	0
		20	0	0	0
		21	0	0	0
		22	0	0	0
		23	0	0	0
		24	0	0	0
		25	5	0	0
		26	0.4	0	0
		27	0	0	0
		28	0	0	0
		29	1.2	0	0
		30	4.6	0	0
		31	0	0	0
	February	15	3.4	0	0
		16	0	0	0
		19	1	0	0
		20	0.6	0	0
		22	1.4	0	0
		23	1	0	0
		24	7.1	0	0
		25	0	0	0
		26	0	0	0
		27	6.2	0	0
		28	0	0	0
	March	6	3.4	0	0
		7	0	0	0
		8	1	0	0
		9	1.4	0	0
		10	4.4	0	0
		11	1.2	0	0
		12	0.4	0	0
		13	8.2	0	0
		14	1	0	0
		15	0	0	0
		26	2.3	0	0
1989	November	2	0.6	0	0
		6	2.1	0	0
		8	0.2	0	0
		10	5.8	0	0
		13	0.5	0	0
		15	5.8	0	0

		17	2.6	0	0
		23	5.9	0	0
		24	1.7	0	0
		26	0.2	0	0
	December	1	7.4	0	0
		2	0	0	0
		3	0	0	0
		5	3	0	0
		6	1.8	0	0
		7	10	0	0
		8	0	0	0
		9	0.4	0	0
		10	0.5	0	0
		11	0.4	0	0
		15	1	0	0
		18	2.4	0	0
		19	19	9,186	9,186
		20	3	0	0
		21	5.6	0	0
		22	0.4	0	0
		23	0.4	0	0
		24	0	0	0
		25	0	0	0
		26	0	0	0
		27	0	0	0
		28	1.8	0	0
		30	4.2	0	0
		31	0.4	0	0
1990	January	1	0	0	0
		2	6.4	0	0
		3	9.6	0	0
		4	5.4	0	0
		5	5.6	0	0
		6	0	0	0
		7	4.8	0	0
		8	0	0	0
		9	0	0	0
		10	0	0	0
		11	0	0	0
		12	1.2	0	0
		13	3.6	0	0
		14	0	0	0
		15	5	0	0
		16	1.6	0	0
		20	2.4	0	0
		21	8	0	0
		22	2	0	0
		23	0	0	0
		24	5.8	0	0
		25	1	0	0
		26	11	0	0

		27	1.6	0	0
		28	2.8	0	0
		29	0.4	0	0
		30	0	0	0
		31	0	0	0
	February	1	7.6	0	0
		2	3.6	0	0
		3	2	0	0
		4	0	0	0
		5	0	0	0
		6	0.4	0	0
		7	0.2	0	0
		8	2	0	0
		9	16.4	5,466	5,466
		10	1.4	0	0
		11	2.8	0	0
		12	1	0	0
		13	0	0	0
		14	6.4	0	0
		15	8.8	0	0
		16		0	0
		17		0	0
		18	1	0	0
		19		0	0
		20	2.6	0	0
		21		0	0
		22		0	0
	March	6	0.8	0	0
		7	4.6	0	0
		8	2.6	0	0
		9	1	0	0
		10	1.2	0	0
		14	0.4	0	0
		16	2.2	0	0
		20	1.4	0	0
		21	2.4	0	0
1990	November	3	4.2	0	0
		4	0.4	0	0
		6	1.8	0	0
		7	0.8	0	0
		8	0.8	0	0
		9	4.2	0	0
		10	1.8	0	0
		11	15.8	4,607	4,607
		12	3	0	0
		13	1.8	0	0
		14	2	0	0
		15	1.6	0	0
		18	10.2	0	0
		19	11.6	0	0

		20	3.2	0	0
		21	6	0	0
		22	2	0	0
		23	13	601	601
		24	0	0	0
		25	0	0	0
		26	0.6	0	0
		27	0	0	0
		28	0.8	0	0
		29	9.6	0	0
		30	1.8	0	0
	December	1	4.8	0	0
		2	3.2	0	0
		3	6.8	0	0
		4	0	0	0
		5	0	0	0
		6	0	0	0
		7	0	0	0
		10	0.2	0	0
		11	0	0	0
		12	0	0	0
		13	1.5	0	0
		14	3	0	0
		15	3.4	0	0
		16	9.6	0	0
		17	4.4	0	0
		18	0	0	0
		19	0.4	0	0
		20	0	0	0
		21	0.6	0	0
		22	3.2	0	0
		23	7	0	0
		24	0	0	0
		25	13.6	1,459	1,459
		26	6.2	0	0
		27	6.6	0	0
		28	0	0	0
		29	18.8	8,900	8,900
		30	30.8	26,070	34,969
		31	11.6	0	16,969
1991	January	1	0	0	0
		2	0	0	0
		3	0	0	0
		4	0.8	0	0
		5	0	0	0
		6	0	0	0
		7	0.2	0	0
		8	0	0	0
		9	4.6	0	0
		10	1.8	0	0
		11	0.4	0	0

		12	0.4	0	0
		13	0	0	0
		14	0.4	0	0
		15	0.8	0	0
		16	4.4	0	0
		17	0	0	0
		18	0	0	0
		19	0	0	0
		20	0	0	0
		21	0	0	0
		22	0	0	0
		23	2	0	0
		29		0	0
		30	10.4	0	0
		31	4	0	0
	February	1		0	0
		2		0	0
		3		0	0
		9		0	0
		16	1.6	0	0
		17	0.6	0	0
		18	1.8	0	0
		20	0.2	0	0
		21	0.2	0	0
		22	0.6	0	0
	March	6	0.6	0	0
		7	1.4	0	0
		9	7.6	0	0
		10	1.8	0	0
		11	0.8	0	0
		12	0.8	0	0
		21	1.4	0	0
		22	5	0	0
1991	November	2	2.4	0	0
		3	8.2	0	0
		4	0	0	0
		5	6.4	0	0
		6	7	0	0
		7	0	0	0
		8	0	0	0
		9	0	0	0
		15	2.4	0	0
		16	4.6	0	0
		17	0	0	0
		21	3	0	0
		23	0.8	0	0
		24	3	0	0
		27	2.2	0	0
		28	1.2	0	0
		29	2	0	0

		30	9	0	0
	December	1	0	0	0
		2	9.6	0	0
		3	4.4	0	0
		4	0	0	0
		5	2.2	0	0
		6	3.8	0	0
		7	1	0	0
		8	0	0	0
		9	1	0	0
		10	0.6	0	0
		11	0.2	0	0
		12	6	0	0
		13	7.6	0	0
		14	5	0	0
		15	0.6	0	0
		16	0	0	0
		17	0	0	0
		18	7.2	0	0
		19	0	0	0
		20	3.8	0	0
		21	0	0	0
		29	0.8	0	0
1992	January	2	0.8	0	0
		3	1.8	0	0
		4	3.2	0	0
		5	1	0	0
		8	4	0	0
		9	2	0	0
		12	2.2	0	0
		13	2.6	0	0
		14	0.4	0	0
		17	4	0	0
		19	1.6	0	0
		21	2	0	0
		22	5.4	0	0
		23	4	0	0
		24	0	0	0
		31	2.4	0	0
	February	9	4	0	0
		10	3.6	0	0
		11	2.2	0	0
		14	2.4	0	0
		15	1	0	0
		16	8.4	0	0
		17	0	0	0
		18	8.2	0	0
		19	0.8	0	0
		20	0	0	0
		21	5.8	0	0
		22	0.4	0	0

		23	0	0	0
		24	0.4	0	0
		25	0	0	0
	March	26	0.8	0	0
		27	0.2	0	0
1992	November	3	3.4	0	0
		4	5	0	0
		5	4.4	0	0
		6	0	0	0
		7	3.4	0	0
		9	1.4	0	0
		12	3.6	0	0
		13	1.2	0	0
		17	0.4	0	0
		18	0.2	0	0
		20	0.2	0	0
		21	0.2	0	0
		27	3.6	0	0
		28	0	0	0
	December	7	1.2	0	0
		11	0.8	0	0
		12	0.2	0	0
		13	12.4	0	0
		14	0	0	0
		15	0	0	0
		16	11.2	0	0
		17	3.5	0	0
		18	4.2	0	0
		19	20.4	11,189	11,189
		20	4.8	0	0
		21	10.2	0	0
		22	8.6	0	0
		23	11.8	0	0
		24	0.8	0	0
		25	9.8	0	0
		26	5.8	0	0
		27	0.8	0	0
		28	0	0	0
		29	1.6	0	0
		30	0	0	0
		31	0	0	0
1993	January	1	0	0	0
		2	5.2	0	0
		3	17.4	6,897	6,897
		4	0	0	0
		5	0	0	0
		6	0	0	0
		7	0.6	0	0
		8	0	0	0
		9	0	0	0

		10	0	0	0
		11	0	0	0
		12	0	0	0
		13	0	0	0
		14	0	0	0
		15	0	0	0
		16	0	0	0
		17	0	0	0
		18	0	0	0
		19	0	0	0
		20	15.6	4,321	4,321
		21	0	0	0
		22	0	0	0
		23	0.6	0	0
		24	2.2	0	0
		25	1	0	0
		26	0.4	0	0
	February	21	1.4	0	0
		26	0.4	0	0
	March	4	0.2	0	0
		5	1.2	0	0
		8	3.6	0	0
		14	3	0	0
		21	1	0	0
		31	0.4	0	0

CITY OF PRINCE GEORGE
SNOW DISPOSAL STUDY AT
THE LANSDOWNE ROAD WASTEWATER TREATMENT CENTRE

APPENDIX 6

RESULTS OF TOXICITY TESTING

FAX COVER SHEET

BCRI

COMPANY NAME Dayton & Knight Ltd.		**ATTENTION TO** Alan Gibb	
FAX NUMBER (604) 922-3253	**CITY** West Vancouver	**PGS** 7 incl. coversheet	**FROM** Janet Pickard
DATE March 25, 1996		**PROJECT NUMBER** 2-11-0200	**SUBJECT** Bioassay Results

SAMPLE NAME Plant Effluent samples
DATE RECEIVED March 19, 1996
TEST SPECIES Rainbow Trout

COMMENTS The hard copies of all reports will follow.

George Pasek, a biologist on staff confirmed that ~~temp~~ the low temp. should not have stressed them & should have reduced toxicity. He thought that the organics may combine a higher temp. into a non-toxic form. Also the vapor pressure at higher temps is lower & some ~~[illegible]~~ toxicants could have volatized off during the 30 minutes of preaeration & aeration during the test. These ideas were confirmed by Jim McKinley & Herb Lanz.

The results are not that conclusive & perhaps should be done again!

Janet

B.C. Research Inc.
3650 Wesbrook Mall
Vancouver, BC
Canada V6S 2L2

Canada
Tel: (604) 224-4331
Fax: (604) 224-0540

USA
Tel: (206) 738-0958
Fax: (206) 733-3590

Dayton & Knight Ltd.

BC Research Inc.
3650 Wesbrook Mall
Vancouver, BC V6S 2L2
Tel: (604) 224-4331
Fax: (604) 224-0540

96-h LC50 Rainbow Trout Bioassay on: Plant Effluent @ 15 C

42-96001

96-h LC50 %v/v:	>100

SAMPLE Taken:
SAMPLE Received: Mar. 19, 1996
Date Started: Mar. 19, 1996
Time Started: 14:25

SAMPLE pH: 6.8
SAMPLE Dissolved Oxygen (mg/L): 7.3
SAMPLE Conductance (µmho/cm): 485

	TEST CONC'N (%v/v)	pH		DISSOLVED OXYGEN		PERCENT SURVIVAL			
		INITIAL	FINAL	INITIAL (mg/L)	FINAL (mg/L)	24h	48h	72h	96h
Control	0	5.8	6.2	10.1	9.8	100	100	100	100
	100	7.0	7.2	8.5	9.4	100	100	100	100
	56	6.9	7.2	9.4	9.4	100	100	100	100
	32	6.8	7.1	9.8	9.4	100	100	100	100
	18	6.8	6.9	10.0	9.6	100	100	100	100
	10	6.8	6.8	10.1	9.7	100	100	100	100

COMMENTS: Some of the fish in the 100% concentration appeared stressed, i.e. 1-2 were moribund, some had protruding eyes. The other fish appeared and behaved normally during the test. The daily readings for temperature/pH/D.O. in the 100% concentration were as follows at 24h: 14.8/7.6/9.0; at 48h: 14.5/7.6/9.5; at 72 h: 14.0/7.7/9.2; and at 96h: 17.0/7.2/9.4.

TEST CONDITIONS:
Number of Organisms: 10
Test Volume (L): 10
Preaeration Time (min.): 30

Test Temperature (°C): 15 ± 1
Test pH Adjusted: No

Bioassay conducted according to EPS 1 RM/13: "Reference Method for Determining Acute Lethality of Effluents to Rainbow Trout", July 1990.

TEST ORGANISM Rainbow Trout *(Oncorhynchus mykiss)*
Acclimated (°C): 15 ± 1
Weight (g): 0.32 ± 0.06
Length (cm): 3.5 ± 0.2

DUPLICATE REFERENCE TOXICANT *(analytical grade phenol)*
Tests were conducted on: Mar. 12, 1996
Tests gave 96-h LC50 of 10.34 mg/L (6.8, 13.0) and 10.0 mg/L (6.8, 13.0)

DILUTION WATER (Vancouver dechlorinated hardened tap water)
Alkalinity (mg $CaCO_3$/L): 5
EDTA Hardness (mg $CaCO_3$/L): 8
Total Suspended Solids (mg/L): <1
Other parameters available on request.

Residual Chlorine (mg/L): < 0.005
Conductance (µmho/cm): 17

ANALYST **VERIFIED BY**

96-h LC50 is the 96-h median lethal concentration (ie. that causing 50% mortality). The 95% confidence limits are in parentheses. Values are calculated by computer following C.E. Stephan "Methods for Calculating an LC50" (ASTM STP 634, 1977).

Dayton & Knight Ltd.

BC Research Inc.
3650 Wesbrook Mall
Vancouver, BC V6S 2L2
Tel: (604) 224-4331
Fax: (604) 224-0540

96-h LC50 Rainbow Trout Bioassay on:
93% Plant Effluent & 7% Snowmelt @ 15 C

42-96002

96-h LC50 %v/v:	>100

SAMPLE Taken:
SAMPLE Received: Mar. 19, 1996
Date Started: Mar. 19, 1996
Time Started: 14:28

SAMPLE pH: 6.9
SAMPLE Dissolved Oxygen (mg/L): 8.8
SAMPLE Conductance (µmho/cm): 460

	TEST CONC'N (%v/v)	pH INITIAL	pH FINAL	DISSOLVED OXYGEN INITIAL (mg/L)	DISSOLVED OXYGEN FINAL (mg/L)	PERCENT SURVIVAL 24h	48h	72h	96h
Control	0	5.8	6.2	10.1	9.8	100	100	100	100
	100	7.1	7.5	9.1	9.3	100	100	100	100
	56	7.0	7.4	9.7	9.4	100	100	100	100
	32	6.9	7.2	9.9	9.3	100	100	100	100
	18	6.8	7.0	10.1	9.3	100	100	100	100
	10	6.8	6.9	10.1	9.5	100	100	100	100

COMMENTS: Some of the fish in the 100% concentration were less responsive and developed protruding eyes during the test. All other fish appeared and behaved normally during the test. The daily readings for temperature/pH/D.O. in the 100% concentration were as follows at 24h: 15.3/7.6/9.1; at 48h: 15.1/7.7/9.3; at 72 h: 14.7/7.7/9.2; and at 96h: 15.9/7.5/9.3.

TEST CONDITIONS:

Number of Organisms: 10
Test Volume (L): 10
Preaeration Time (min.): 30

Test Temperature (°C): 15 ± 1
Test pH Adjusted: No

Bioassay conducted according to EPS 1 RM/13: "Reference Method for Determining Acute Lethality of Effluents to Rainbow Trout", July 1990.

TEST ORGANISM Rainbow Trout *(Oncorhynchus mykiss)*

Acclimated (°C): 15 ± 1
Weight (g): 0.32 ± 0.06
Length (cm): 3.5 ± 0.2

DUPLICATE REFERENCE TOXICANT *(analytical grade phenol)*

Tests were conducted on: Mar. 12, 1996
Tests gave 96-h LC50 of 10.34 mg/L (6.8, 13.0) and 10.0 mg/L (6.8, 13.0)

DILUTION WATER (Vancouver dechlorinated hardened tap water)

Alkalinity (mg $CaCO_3$/L): 5
EDTA Hardness (mg $CaCO_3$/L): 8
Total Suspended Solids (mg/L): <1
Other parameters available on request.

Residual Chlorine (mg/L): < 0.005
Conductance (µmho/cm): 17

ANALYST **VERIFIED BY**

Janet Pickard

96-h LC50 is the 96-h median lethal concentration (ie. that causing 50% mortality). The 95% confidence limits are in parentheses. Values are calculated by computer following C.E. Stephan "Methods for Calculating an LC50" (ASTM STP 634, 1977).

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96-h LC50 Rainbow Trout Bioassay on:
Plant Effluent @ 11 C

42-96003

96-h LC50 %v/v:	>100

SAMPLE Taken:		**SAMPLE pH:**	6.8
SAMPLE Received:	Mar. 19, 1996	**SAMPLE Dissolved Oxygen (mg/L):**	7.3
Date Started:	Mar. 19, 1996	**SAMPLE Conductance (µmho/cm):**	485
Time Started:	14:10		

	TEST CONC'N (%v/v)	pH INITIAL	pH FINAL	DISSOLVED OXYGEN INITIAL (mg/L)	DISSOLVED OXYGEN FINAL (mg/L)	PERCENT SURVIVAL 24h	48h	72h	96h
Control	0	6.3	6.7	11.3	10.2	100	100	100	100
	100	7.0	7.4	8.9	10.1	100	90	90	90
	56	7.0	7.3	9.9	10.2	100	100	100	100
	32	6.9	7.3	10.6	10.2	100	100	100	100
	18	6.8	7.2	11.0	10.3	100	100	100	100
	10	6.8	7.1	11.0	10.3	100	100	100	100

COMMENTS: The fish in the 100% concentration showed little movement. All other fish appeared and behaved normally during the test. The daily readings for temperature/pH/D.O. in the 100% concentration were as follows at 24h: 9.8/7.6/10.7; at 48h: 10.1/7.7/11.0; at 72 h: 10.1/7.7/10.2; and at 96h: 10.2/7.4/10.1.

TEST CONDITIONS:

Number of Organisms:	10	**Test Temperature (°C):**	11 ± 1
Test Volume (L):	10	**Test pH Adjusted:**	No
Preaeration Time (min.):	30		

Bioassay conducted according to EPS 1 RM/13: "Reference Method for Determining Acute Lethality of Effluents to Rainbow Trout", July 1990.

TEST ORGANISM Rainbow Trout *(Oncorhynchus mykiss)*

Acclimated (°C): 15 ± 1
Weight (g): 0.32 ± 0.06
Length (cm): 3.5 ± 0.2

DUPLICATE REFERENCE TOXICANT *(analytical grade phenol)*

Tests were conducted on: Mar. 12, 1996
Tests gave 96-h LC50 of 10.34 mg/L (6.8, 13.0) and 10.0 mg/L (6.8, 13.0)

DILUTION WATER (Vancouver dechlorinated hardened tap water)

Alkalinity (mg $CaCO_3$/L):	5	**Residual Chlorine (mg/L):**	< 0.005
EDTA Hardness (mg $CaCO_3$/L):	8	**Conductance (µmho/cm):**	17
Total Suspended Solids (mg/L):	<1		

Other parameters available on request.

ANALYST **VERIFIED BY**

Janet Pickard

96-h LC50 is the 96-h median lethal concentration (ie. that causing 50% mortality). The 95% confidence limits are in parentheses. Values are calculated by computer following C.E. Stephan "Methods for Calculating an LC50" (ASTM STP 634. 1977).

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96-h LC50 Rainbow Trout Bioassay on:
93% Plant Effluent & 7% Snowmelt @ 5 C

42-96004

96-h LC50 %v/v:	>100

SAMPLE Taken:
SAMPLE Received: Mar. 19, 1996
Date Started: Mar. 19, 1996
Time Started: 15:03

SAMPLE pH: 6.9
SAMPLE Dissolved Oxygen (mg/L): 8.8
SAMPLE Conductance (µmho/cm): 460

	TEST CONC'N (%v/v)	pH INITIAL	pH FINAL	DISSOLVED OXYGEN INITIAL (mg/L)	DISSOLVED OXYGEN FINAL (mg/L)	PERCENT SURVIVAL 24h	48h	72h	96h
Control	0	6.3	7.0	12.8	12.1	100	100	100	100
	100	7.0	7.5	10.1	12.0	70	70	70	70
	56	7.0	7.5	11.4	12.1	100	100	100	100
	32	6.9	7.4	12.0	12.2	100	100	100	100
	18	6.8	7.3	12.4	12.2	100	100	100	100
	10	6.8	7.2	12.6	12.2	100	100	100	100

COMMENTS: All surviving fish appeared and behaved normally during the test. The daily readings for temperature/pH/D.O. in the 100% concentration were as follows at 24h: 3.8/7.7/12.6; at 48h: 4.2/7.8/13.0; at 72 h: 4.5/7.7/12.2; and at 96h: 4.5/7.5/12.0.

TEST CONDITIONS:

Number of Organisms: 10
Test Volume (L): 10
Preaeration Time (min.): 30
Test Temperature (°C): 5 ± 1
Test pH Adjusted: No

Bioassay conducted according to EPS 1 RM/13: "Reference Method for Determining Acute Lethality of Effluents to Rainbow Trout", July 1990.

TEST ORGANISM Rainbow Trout *(Oncorhynchus mykiss)*

Acclimated (°C): 15 ± 1
Weight (g): 0.32 ± 0.06
Length (cm): 3.5 ± 0.2

DUPLICATE REFERENCE TOXICANT *(analytical grade phenol)*

Tests were conducted on: Mar. 12, 1996
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DILUTION WATER (Vancouver dechlorinated hardened tap water)

Alkalinity (mg $CaCO_3$/L): 5
EDTA Hardness (mg $CaCO_3$/L): 8
Total Suspended Solids (mg/L): <1
Other parameters available on request.
Residual Chlorine (mg/L): < 0.005
Conductance (µmho/cm): 17

ANALYST **VERIFIED BY**

96-h LC50 is the 96-h median lethal concentration (ie. that causing 50% mortality). The 95% confidence limits are in parentheses. Values are calculated by computer following C.E. Stephan "Methods for Calculating an LC50" (ASTM STP 634, 1977).

DRAFT

BIOLOGICAL TESTING METHODS 80-12
FOR THE DESIGNATION OF DANGEROUS WASTE

PART A. STATIC ACUTE FISH TOXICITY TEST

PART B. ACUTE ORAL RAT TOXICITY TEST

Prepared by

The Hazardous Waste and Toxics Reduction Program
Washington State Department of Ecology

Revised April 1996

DRAFT

from the same batch year class, and the standard length (tip of snout to end of caudal peduncle) of the longest fish should be no more than twice that of the shortest fish (Figure 1).

(fish diagram)

Make all efforts to ensure test fish are disease-free prior to initiation of toxicity test. Options include:

1. Selecting fish from a source (hatchery) which will certify that all fish are disease-free.
2. Discriminately selecting test fish from a reputable source, and/or on the observations and judgment of knowledgeable individual.
3. Treating all fish which arrive on-site using treatments commonly used by sources (hatcheries) which produce certified disease-free fish.

All test fish should be obtained from a hatchery that has been certified disease-free for the following diseases; bacterial kidney disease (*Renibacterium salmoninarum*); Costia (*Ichythobodo*); bacterial gill disease (Myxobacteria species); and Furunculosis (*Aeromonas salmonicida*).

As an alternative to obtaining certified disease-free fish, fish may treated on-site to control external parasites and latent bacterial infection. The treatment requires two steps: immerse fish in an aerated solution of 200 ppm Formalin for 60 min; then, 24 h after Formalin treatment, begin and continue a commercial feed medicated diet (e.g., Terramycin) for 10 d.

If fish are ~~severely~~ diseased, destroy the entire lot immediately.

Between use of different test fish groups, holding and acclimation tanks should be sterilized according to the procedures in Cleaning and Disinfection.

Care and Handling

Properly care for and handle test fish to minimize unnecessary stress. To avoid unnecessary stress, test do not subject fish to rapid changes in temperature or water quality. In general, aquatic organisms should not be subjected to more than a 3°C change in water temperature in any 12 h period. Maintain test fish in dilution water at test temperature for at least the last 48 h before they are placed in the test chambers.

We lowered temp. 3°C/day (24h) + held fish @ ≈5.0°C for 72h.

FAX COVER SHEET

BCRI

COMPANY NAME Dayton & Knight Ltd.		**ATTENTION TO** Alan Gibb	
FAX NUMBER (604) 922-3253	**CITY** West Vancouver	**PGS** 3 incl. coversheet	**FROM** Janet Pickard
DATE March 26, 1996		**PROJECT NUMBER** 2-11-0200	**SUBJECT** Bioassay Results

SAMPLE NAME

DATE RECEIVED

TEST SPECIES Rainbow Trout

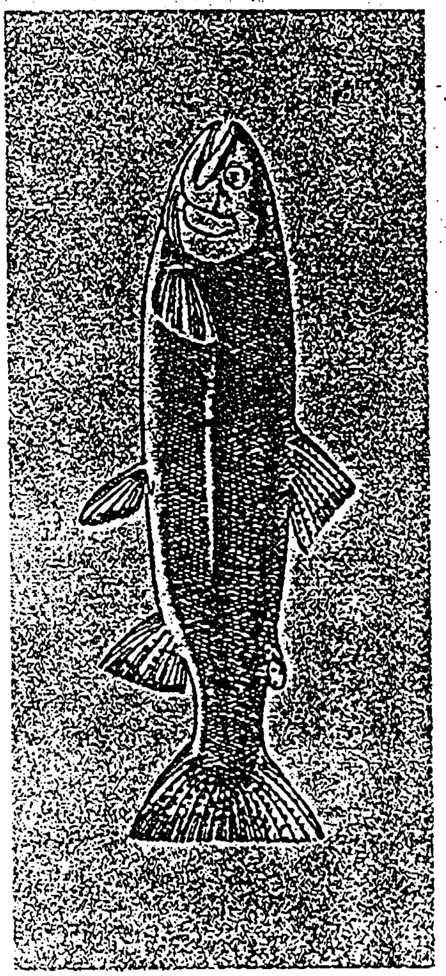
COMMENTS This is the EP~~A~~S document.
Cheers,
Janet

B.C. Research Inc.
3650 Wesbrook Mall
Vancouver, BC
Canada V6S 2L2

Canada
Tel: (604) 224-4331
Fax: (604) 224-0540

USA
Tel: (206) 738-0958
Fax: (206) 733-3590

Environmental Protection Series



Biological Test Method:

Acute Lethality Test Using Rainbow Trout

Report EPS 1/RM/9
July 1990

Canada

Environment Canada   Environnement Canada

1.4 L/gfish·d^{-1} or 0.69 g fish·d/L)[c]. Additionally, to prevent overcrowding, a tank should contain at any given moment at least one litre of water for every 10 grams of fish held (Sprague, 1973). Unusual circumstances such as acclimation of fish to reconstituted water may require the filtration and recirculation of water, or its periodic renewal in static systems. In such cases, ammonia and nitrite should be measured frequently to check that they do not reach harmful levels. Target values, recommended for the protection of freshwater aquatic life, are ≤0.02 mg/L of unionized ammonia (OME, 1984) and ≤0.06 mg/L of nitrite (CCREM, 1987).

Water entering holding and acclimation tanks must not be supersaturated with gases. In situations where gas supersaturation within the water supply is a valid concern, total gas pressure within water supplies should be frequently checked (Bouck, 1982). Remedial measures (e.g., use of aeration columns or vigorous aeration in an open reservoir) must be taken if dissolved gases exceed 100% saturation. Water temperature, dissolved oxygen, pH, and flow should be monitored for each holding or acclimation tank, preferably daily. Weekly or more frequent monitoring of levels of ammonia, nitrite, and total residual chlorine (if municipal water source is used) in holding or acclimation tanks is recommended.

2.4.4 Temperature

The water temperature for holding populations of fish for subsequent test purposes may be outside the acceptable limits for the test provided that it is compatible with good fish health (i.e., 4 to 18°C). When preparing a batch of fish for the acclimation period, water temperature may be changed at a rate not exceeding 3°C/d, until the acclimation temperature of 15± 2°C is achieved. Fish are to be acclimated to 15± 2°C for a minimum of two weeks, and preferably ≥three weeks, prior to initiating the toxicity test.

2.4.5 Dissolved Oxygen

The dissolved oxygen (DO) content of the water within the holding and acclimation tanks should be 80 to 100% air saturation. Supplementary aeration to the tanks using filtered, oil-free compressed air, should be provided if necessary to maintain this level of DO.

2.4.6 pH

The pH of the water used for holding and acclimating fish should be within the range of 6.0 to 8.5. Water with pH values between 7.5 and 8.0 is desirable (Klontz *et al.*, 1979).

2.4.7 Feeding

Fish should be fed a recognized standard commercial pelleted fish food suitable for rainbow trout. Depending on water temperature and fish size, feeding should be one or more times daily, normally with a daily ration approximating 1 to 5% of wet body weight (Appendix C). The pellet size and type, feed ration and frequency, and method and maximum duration for storing food, should be chosen in consideration of fish size and age, water temperature and the manufacturer's recommendation.

2.4.8 Cleaning of Tanks

Troughs and tanks used for holding and acclimating fish should be kept clean. Siphoning of excess food and faeces should be conducted once a day or as frequently as necessary to eliminate the buildup of excess

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[c] If necessary (e.g., if fish are being acclimated to reconstituted water, receiving water or some other water source that is restricted in amount), water-volume requirements for fish acclimation may be decreased substantially by recirculating the flow to the fish tank through a filter suitable for removing metabolic wastes. If a recirculation system is used, ammonia and nitrite concentrations in the acclimation tank should be monitored and kept below levels harmful to fish health.