Potassium Acetate Deicer Impacts at Anchorage, Alaska: Data Report

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Prepared for: Watershed Management Section
Project Management and Engineering
Department of Public Works
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Prepared by: Water Research & Management, Inc.
P.O. Box 393
Sauk Rapids, Minnesota 56379-0393

Contributors:

Principal Author: Tim Chmielewski, Limnologist
Water Research & Management, Inc.

Reviewers: Scott R. Wheaton, Watershed Scientist
Watershed Management Section
Municipality of Anchorage

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1.0 Project Scope

Information described in this data report was collected to meet a preliminary street deicer assessment (HDR 1994) and draft design (HDR 1996) criteria. Variations from the draft design can be found in Section 2. The following report contains validated field data collected between October 1995 and April 1996, deicer use data from 1994-1996 winter/spring seasons, data summaries and plots, QC/QA, a description of the departures from the project assessment design, and degree of usefulness of resulting data.

1.1 Project Purpose

Purpose of the project was to gain baseline data on deicer use within the Municipality of Anchorage (MOA), carbonaceous oxygen demand ($CBOD_5$) in Anchorage waters and assessment of $CBOD_5$ reaction rates relative to MOA streams. Information acquired will be used to help the Municipality determine whether potassium acetate should be used to control ice and snow on roads throughout the city and if so provide guidance with respect to its use.

1.1.1 Problem Statement

The city of Anchorage is concerned with maintaining the quality of habitat in its streams and lakes. During winter thaws and spring snow melt, runoff from commercial and residential districts adds potentially polluting compounds and sediments to the city's receiving waters. As an alternative to sanding, which adds sediments and salts to receiving waters, the city used a chemical deicer, potassium acetate, during the winter of 1994-1995. Use of any deicing agent has a potential negative side. In this case, of primary interest was its potential negative impact on the dissolved oxygen content of receiving waters and, to a lessor degree, potential nutrient enrichment of the receiving waters.

1.1.2 Information Limitations

Data derived from this assessment should be considered as being representative of a point or points in time and along a continuum. The uncertainty of whether the quantity and quality of seasonal runoff may or may not be representative of the, norm due to precipitation and melt scenarios, makes it difficult to assess how much deicer might actually reach a water body, or the influence of the deicer on that water body. Runoff during 1995-1996 was less than normal, but the final melt period in late March might have been near the norm. Still, whether a normal range of deicer concentrations was in the runoff is not well understood. A portion of the deicer presumably evaporates on warm pavement, some fraction is carried away by vehicle tires and some by snow plowing and removal. Additionally, the amount of deicer applied just prior to a melt period may vary greatly. The nature of available deicer application and records suggests any attempt to quantify anything more specific than a gross range of deicer application near a particular basin has a large margin of built-in error. Data from snow samples should be used with caution when attempting to project the quantity of deicer being hauled to snow dumps. While water quality parameters from the two basins were similar, snow was sampled on only two different occasions. Overall, data acquired during this project should be considered to be valid and representative of a deicer use and impacts in the Municipality during the winter of 1995-1996.

1.2 Project Organization

This investigation was performed with the participation of the Project Management and Engineering Division (Watershed Management Section) of the Municipality of Anchorage, Department of Public Works (DPW), Northern Testing Laboratories and HDR, Inc. The MOA provided all project funding.

HDR, Inc., and MOA’s Watershed Management Section developed the original deicer assessment and draft assessment design in 1994-1995. HDR staff performed all data collection and reporting. Northern Testing Laboratories (state certified) conducted all chemical analyses.

1.3 Data Report Organization

The main body of this report is divided into three sections: Project Scope, Data Collection and Data Summary. The Project Scope describes the need for, and intended use of, the collected information as identified in the draft design. The second section, Data Collection, briefly describes the method and logic used in the collection of information during this project. This section also summarizes the quality of collected data relative to the original design objectives. The final section, Data Summary, briefly describes the general range of attribute characteristics of the collected information. All tables and figures follow the main text of the report. Selected observations, data tabulations and draft sampling methodology are appended.

2.0 Data Collection

The following section describes how data reported in this document is intended to represent project goals. It describes briefly how data was collected and how those efforts varied from the draft design. Finally it summarizes success in achieving data quality objectives and identifies data collection problems.

2.1 Data Purpose

The primary goals of this study were to provide the Municipality with information on potential water quality impacts of potassium acetate on Anchorage receiving waters and to offer insight as to how potential impacts might be avoided through improved deicer application practices. To facilitate these goals, objectives of the study included; obtaining basic data to characterize dissolved oxygen, phosphorus, and pH in basins, streams, and impoundments. Along with these objectives was the need to assess the quality of melt water runoff in residential and commercial land use basins determine a decay rate for oxygen demand ($CBOD_5$) relative to MOA receiving waters for use in modeling and impacts on dissolved oxygen and nutrient loading.

2.2 Data Collection

This sub section summarizes the history of data collection for the project. Its primary focus is on the description of unusual circumstances or difficulties in data collection, specifically identifying variations form the protocols or schedules prescribed in the draft project design document. Validated project data can be found in Appendix A.

2.2.1 Data Collection History

Automated data collection, primarily temperature and stream flow, began in late December 1995 and continued through March 1996. Manual grab sampling was intermittently conducted between January and March 1996. The winter of 1995 had very little snowfall until late winter 1996 (Figure 1). November through January saw only a trace of snowfall when compared to the 30-year mean (WRCC, 1999) and it dissipated slowly. February was a snowy month and saw a total of snowfall of 52 inches. On February 10th and 11th a 13.9-inch snowfall set a 24-hour snowfall record for February. Total snowfall for the month had a water equivalent of only 2.4 inches. March snowfall was also below normal. Snow melt was slow and uniform, with much of it lost to evaporation, until the third week of March, when the remaining accumulated snow melted rapidly.

2.2.2 Variations From Design

A design document was prepared to represent a logical approach in acquiring the necessary data to achieve the goals and objectives to resolve the MOA's problem. The design included the problem and system relative to the problem, critical informational use and resolution thresholds, the process of data collection, analysis and interpretation and implementation plans. Departures from the scope and objectives of the draft assessment design were extensive due primarily to the weather. As a result of the different than normal precipitation and melt pattern, the mid-winter thaw sampling was not done, snow was sampled on only two occasions; and spring runoff sampling was of short duration and very localized thus reducing sampling opportunities.

An automatic sampler with a pressure transducer was installed in basin site B-03, but the temperature sensor was inadvertently not installed. The intent of the automatic sampler was to try to capture the first flush during spring. Owing to the unusual pattern of precipitation and melt, this objective was only partially met with the collection of two sets of runoff samples. Additional non-scheduled water quality samples were taken from alternate sites in the street deicer basins and sanding basins to help characterize runoff. These sites included standing pools at frozen storm drain intakes and an additional Chester Creek site. Fire Creek, was to be sampled as a non-urban impact stream, was found too inaccessible to fit into the necessary time frame and was not sampled. A complete list of sample sites can be found on Table 1.

Several analytical scenarios were used to determine carbonaceous oxygen demand ($CBOD_5$-nitrification inhibited) reaction rates and conversely, oxygen depletion rates for MOA waters. The first effort, using standard biological oxygen demand (BOD_5) methodology, was abandoned because the dissolved oxygen (DO) consumption rate progressed too rapidly for the laboratory to realistically measure once the bacteria reached a critical population growth. Standard laboratory analysis is conducted at 20^oC while water temperature in Anchorage creeks is near 0^oC.

In lieu of the normal method, two additional BOD_5 analytical methods were used. First, the Stirred Method (Elmore, 1955) extended the period of DO reduction by re-aerating the sample by stirring after each measurement; and second, the Orford Method (Orford, et. al., 1953), which accomplished the same end by adding fresh sample after each measurement. Both methods were used to estimate what synergistic effects might result from compounds in the melt runoff. In both methods, there were usually two sets samples (six replicates each) spiked with 50 and 500 mg/l potassium acetate. The samples were agitated while being held at approximately 5^o C. Dissolved oxygen was monitored and samples aerated in cases where dissolved oxygen levels were close to or lower than 1 mg/l. Samples that were spiked with 500-mg/l level of potassium acetate were re-aerated seven times before samples were allowed to progress to oxygen depletion. The methods were done at lower temperatures than normal 20° C methodology, varying concentrations (spike volumes) of deicer and different methods of sample re-aeration. In addition, to investigate the possibility of synergistic effects, each of these methods was tried using a spike formulated from runoff water. The methods were used on samples from Chester Creek (CC-03) and from Campbell Creek (Cam-01). The Campbell Creek site was included for background comparison.

Synergistic effects were mimicked adding additional potassium acetate. Samples of runoff water were collected at 5th Avenue and C Street and analyzed for potassium and acetate. An equal amount of potassium acetate, in the ratio found, was added to several $CBOD_5$ analytical runs to approximate synergistic effects, or an increased in-stream nutrient level. Modeling was not conducted because all spiked samples indicated substantial growth lag-phase time in laboratory tests. These tests were conducted at higher temperatures than normally found in Anchorage creeks suggesting a growth lag-phase even longer than seen in the laboratory which is consistent with rates found by Gordon, 1970.

2.3 Data Quality

Field instruments were checked and calibrated as described in the draft Assessment Design. No anomalies were found, equipment was maintained within factory specifications. Sampling was carried out using standard methodologies and protocols indicated in the Assessment Design. Laboratory data was reviewed for missing data and anomalies.

Several duplicate samples were taken during sampling for analysis and comparison for quality control. Duplicate samples were used for a representative indication of the percent difference between the two samplings. Duplicates were discrete samples, not split samples, which were taken at approximately the same time but in different containers. Some variability was expected between the samples. The reason for relatively large differences in the B-01 $CBOD_5$ is unknown (Table 2). The difference may be an error due to sample contamination or an error in analysis and reporting, or the values may lie within the $CBOD_5$ range if the sampling size was larger. Suspect data can be found on Table 3.

Data that was gathered during the monitoring period was statistically reviewed using MINITAB statistical computer software. Temperature and flow at stations B-01 and B-02 was measured continuously. All other data was from instantaneous measurement and grab samples. It was assumed that data was normally distributed. The same laboratory did all chemical analysis. Minimum analytical detection limits for analytes remained constant during the sampling period. The few values reported as less than a detection limit were given a value of one-half of their respective analytical detection limit and included in the statistical database.

Three different $CBOD_5$ analytical methods were employed to investigate $CBOD_5$ reaction rates. Further, each of the three methods was altered by temperature changes, deicer spikes and methods and timing of re-aeration. A number of tests were discarded and most tests had some alteration in methodology before completion. The most common problem was a difficulty in maintaining constant temperatures during analysis. Conversations with laboratory personnel suggest any given analysis temperature varied between 2-14 degrees Celsius. Therefore, it is likely that $CBOD_5$ reaction rate data has a greater than normal built in degree of error.

Deicer use records maintained by the MOA/DPW, Street Maintenance Department were incomplete by both applicators (drivers) record keeping and office processing and storage. Records were limited to data gathered on 3 dates in 1994, 4 dates in 1995 and 10 dates in 1996. A summary of the records and calculated deicer application and usage can be found in Appendix B.

3.0 DATA SUMMARY

HDR, Alaska, Inc., Anchorage, conducted all sampling. Sampling methodology outlined in the draft Assessment Design was followed, however, sampling schedule varied greatly. All data is appended in tabular form in Appendix A.

3.1 Sampling Site Descriptions

This section describes the sampling locations (Table 1), frequency, and parameters collected. Sampling included characterization of discharge and water quality from basin out falls, streams, hauled snow, and impoundments. Descriptive statistics for selected basin and stream variables can be found on Table 4 and 5 and graphically on Figures 9 through Figure 24.

3.1.1 Basins

The 5th Avenue Basin (B-01) is in the heart of the central business district (CBD) of Anchorage (Figure 2). Its storm drain system outfall is located west of the western end of 5th Avenue near Cook Inlet. Access to the outfall is a manhole located on the north side of the coastal trail just west of the Elderberry Park tunnel entrance. The site is reached by parking in the lot near Elderberry Park and walking through the bike path tunnel that crosses under the Alaska Railroad. The sampling site is the manhole located approximately 50 feet northwest of the manhole amidst boulders immediately to the left after emerging from the tunnel. This basin received potassium acetate deicer during the study period. A pressure transducer and thermistor linked to a continuous data logger was also installed in the manhole to monitor flow and water temperature. A sharp-crested, rectangular weir was installed in the storm drain discharging to this manhole from the east to facilitate flow monitoring. This manhole is approximately 5 feet deep.

West Fairview Basin (B-02) samples and measurements were taken from a manhole located in the north bound lane of Denali Street just north of the intersection of Denali Street and 15th Avenue (Figure 2). This is a commercial/residential basin, which also received potassium acetate deicer during the study period. A sharp-crested, v-notched weir, pressure transducer, and thermistor have been installed in this manhole to monitor flow and air temperature. The thermistor and pressure transducers were linked to a continuous data logger attached to the wall of the manhole. This manhole is approximately 10 feet deep.

The Northern Lights Basin (B-03) is a commercial use basin, which was to have received only sand to improve road traction rather than deicer (Figure 3). Samples were to be taken from a manhole located in the southbound lane of Arctic Boulevard just south of the intersection of Arctic Boulevard and West 27th Avenue. Samples were to be collected by an automated sampler from the 18" storm drain discharging to this manhole from the south. A pressure transducer, integral to the automatic sampler, and a thermistor linked to a continuous data logger were installed in this pipe to monitor flow and water and air temperature. This manhole is approximately 17 feet deep.

The West 23rd Basin (B-04) is a residential basin (Figure 3). This basin received sand instead of chemical deicer. Water samples and field measurements for the West 23rd Basin were taken from a manhole located in the center of West 23rd Avenue near the eastern terminus of the street. Samples were taken from the storm drain discharging to this manhole from the west. This manhole is approximately 15 feet deep.

3.1.2 Hauled Snow

Random samples of snow hauled from within the 5th Avenue (B-01) and the West Fairview (B-02) Basins were sampled. Samples were collected from snow that was plowed into furrows for hauling from intersection areas, designated as SI, and non-intersection areas, designated as SN, within each of the two basins (Figure 2). Snow samples from plowed furrows were assumed to be well mixed, with reference to spatial distribution of deicer material.

Intersection areas were defined as the 100-foot approach to intersections and the intersections themselves. Samples (10 each) from each of the two intersections were combined to create one composite intersection sample. Approximately one-half of the sample was from each intersection.

Non-intersection areas were defined as that section of roadway greater than 100 feet but less than 300 feet from an intersection. Samples were again collected from furrows plowed from non-intersection and combined to form a composite sample. Samples were collected from snow along 5th Avenue, representing the 5th Avenue Basin and along East 13th and East 14 Avenues representing the West Fairview Basin.

3.1.3 Impoundments

University Lake (UL-01, 02) and Westchester Lagoon (WC-01, 02), in the Chester Creek drainage, were sampled to characterize water quality before, during, and after any potential influx of potassium acetate. In University Lake the sites were in each of the two bays (Figure 4). In Westchester Lagoon both sample sites were in the large bay, one site in the old stream channel and one site in a shallower area (Figure 5). All samples were two-meter composite grab samples.

3.1.4 Chester and Campbell Creeks

Chester Creek (Figures 3, 4 and 6) will be sampled (grab) at 3 sites. The first site (CC-1) was located approximately 50 feet upstream from the University Lake inlet footbridge. This site was used for the $CBOD_5$ decay rate determination and for water quality characterization. The second site (CC-2) is approximately 50 feet upstream from the Lake Otis Parkway culverts and the third site (CC-3) is at the Aurora Street foot bridge. Both the second and third sites were for water quality characterization. Water samples from a fourth Chester Creek site (CC-Upper) and one Campbell Creek (Cam-1) site were used as background water quality sites because of the reduced possibility of deicer contamination at the site (Figure 7 & 8).

3.2 Flow Data

Continuous flow data were remotely monitored in predetermined basin manholes. All the manholes, except B-04, were equipped with pressure transducers to measure water depth. Flows were manually checked in B-04 by measuring the depth and water velocity in the outflow conduit. The configuration of inflow conduits at B-04 precluded the construction of a weir and placement of a pressure transducer at which to measure flow. Continuous flow was determined, using water depth and conduit area calculations. Flow data was then summarized into daily mean flow.

Due to the reduced runoff, flow in the B-02 storm drain was intermittent and reduced to almost nothing but seepage around the weir. Flow in B-02 averaged 0.005 CFS. Flow data from site B-02 is incomplete, and flow in B-03 and B-04 were almost non-existent until late March and averaged 0.12 CFS and 0.008 CFS, respectively. Station B-01 was the only flow station to receive groundwater base flow and, therefore, continuous flow during the monitoring period. Flow in B-01 averaged 0.57 CFS.

3.3 Carbonaceous Oxygen Demand ($CBOD_5$) Data

Numerous water samples were collected by field personnel to ascertain $CBOD_5$ concentrations in basin runoff, lakes, streams (both before and after runoff) and for use in laboratory assessment of $CBOD_5$ growth rates in cold water streams. Snow samples were also collected from the 5th Avenue Basin (B-01) and West Fairview Basin (B-02) and analyzed for $CBOD_5$ to assess the oxygen demand in snow removed from MOA streets and deposited in the snow dump.

Sanding basin samples (B-03 & B-04) had median $CBOD_5$ concentrations of 170mg/l and 32.5mg/l, respectively. While, basins where deicer was applied (B-01 & B-02) had $CBOD_5$ concentrations of 180mg/l and 250mg/l. Since one might assume the sanding basins (where deicer was not applied) would have lower $CBOD_5$ concentrations than in basins where deicer was used, the reason for the elevated concentration at the Northern Lights Basin (B-03) may be from either direct deicer usage or contamination from vehicular traffic.

Snow and ice plowed to the center of the roadway by MOA maintenance crews in the 5th Avenue and West Fairview Basins were sampled before removal to snow dumps. Samples from 5th Avenue and West Fairview intersections were found to have $CBOD_5$ concentrations of 420mg/l and 150mg/l, respectively. Non-intersection samples from the respective basins and traffic lanes leading to the intersections had concentrations of 391mg/l and 127mg/l. Several additional samples were taken from pooled melted snow at frozen storm drain culverts in the deicer basins to help characterize the deicer. $CBOD_5$ concentrations in these melt pools were between 220mg/l–2,000mg/l.

All $CBOD_5$ concentrations were below minimum detection limits (MDL) in samples from both Westchester Lagoon and University Lake. Samples taken in January 1996 from Chester Creek were also all found to be below MDL. Samples taken from Chester Creek in mid March 1996 had $CBOD_5$ concentrations ranging from <MDL to 6mg/l at the University Lake inlet (CC-03) to <MDL to 23mg/l at Lake Otis Parkway (CC-02), to <MDL to 48mg/l at C Street (CC-01).

A summary of the $CBOD_5$ reaction rate analysis using the Stirred and Orford methods can be found on. Figures 25 and 26. The Figures show both $CBOD_5$ growth rates and oxygen depletion rates for varying analyses. Samples from Chester Creek and spiked with 50 mg/l deicer (stirred method) took on the average, 90 hours to go to complete oxygen depletion. All other analyses, samples and methods had higher rates of oxygen consumption and $CBOD_5$ growth rates. Analytical $CBOD_5$ tests were run in multiples of six replicates. Curve-fitting analysis was performed on the mean of each set of replicates. $CBOD_5$ growth rates were calculated to be within a range from 0.25mg/l to 4.16mg per liter per hour and oxygen depletion rates between 0.08 and 0.41mg per liter per hour.

Data from the first incubation interval of Chester Creek and Campbell Creek analyzed using the Orford method appear to be the most consistent. Regression analysis (curve fitting) of the 1st interval data (Figures 27 and 28) yields CBOD5 growth rates of from 1.37mg/l/hr to 1.74mg/l/hr and oxygen depletion rates of 0.48mg/l/hr and 0.49mg/l/hr, respectively.

3.4 Dissolved Oxygen Data

During the sampling period, dissolved oxygen (DO) concentrations in each of the 4 basins were between 10mg/l and 15.8mg/l and in-stream DO concentrations were between 12.2mg/l and 15.4mg/l. Westchester Lagoon and University Lake were found to have surface (0.5 meters) DO concentrations usually at or near saturation. Metalimnetic zone (1-2 meters deep) in the lakes were in the 8mg/l to 10mg/l range and hypolimnetic (bottom waters, $Z_{max+0.5meters}$) averaged about 4mg/l. Both lakes had similar DO concentration-depth profiles.

3.5 Temperature Data

All the manholes, except B-03, were equipped with sensors to monitor water temperature. The temperature sensor in B-03 was inadvertently not installed and thus no temperature data was gathered. Continuous temperature data was down-loaded to a computer and summarized into daily mean water temperature and air temperature, depending on whether or not there was water in each of the manholes. Temperatures in the manholes ranged from -3.4°C to 5.9°C. Lake and stream water temperatures were between 0°C and 3.0°C

3.6 Conductivity and pH Data

Conductivity (specific conductance) and pH were measured in the field. Conductivity was highest at basin stations and in snow samples. The only base flow conductivity, which was measured at B-01, was 223umhos/cm^2. Basin and snow sample conductivity during the melt period in March 1996 ranged from 438umhos/cm^2 to 6,643umhos/cm^2. One sample from a melt pool at 9th and G Street was measured at 9,903umhos/cm^2.

Stream conductivity increased progressively at each station down stream. Average conductivity was 255umhos/cm^2, 360umhos/cm^2 and 485umohs/cm^2 at Chester Creek sampling stations 01, 02, and 03, respectively. Lake samples averaged 196umhos/cm2 in University Lake and 278umohs/cm2 in Westchester Lagoon.

All water samples, except for one each in Westchester Lagoon and University Lake on 1/17/96, which measured 7.8, had a pH range of 6 to 7.5. Snow samples had a pH range from 7.5 to 8.3.

3.7 Deicer, Nutrient and Bacteria Data

A sample of deicer, from a batch being used by MOA, was analyzed and found to be 145,000mg/l potassium and 264,000mg/l acetate. A sample from 5th Avenue and C Street was found to have potassium and acetate concentrations of 201 mg/l and 306mg/l, respectively. Samples from CC-03 and X-5 had concentrations of potassium between 0.1 and 2.67mg/l and acetate concentrations of 0.03 and 0.63mg/l. Each of the water samples was also analyzed for bacteria. Bacteria ultimately consume the potassium acetate. Bacteria counts were between 30 and 200 colonies per milliliter in Chester Creek samples and 1400 colonies per milliliter in the 5th Avenue and C Street sample.

Grab samples of surface water and bottom waters were taken from both University Lake and Westchester Lagoon and analyzed for total (TP) and ortho- (OP) phosphorus. University Lake TP concentrations ranged from less than the minimum detection limit (<MDL) to .5mg/l (n=3) in surface waters and a single bottom sample was 2.35mg/l. Likewise in Westchester Lagoon, surface water TP concentrations ranged from <MDL to 0.43mg/l (n=2) and 0.49mg/l at the bottom. Ortho-phosphorus was below analytical detection limits in all samples.

Water samples from Chester Creek showed, as with conductivity, an incremental increase in TP at downstream stations. However, OP remained at or near minimum detection limits at each station. Total phosphorus concentrations averaged 0.7mg/l, 1.0mg/l and 1.3mg/l at CC-01, CC-02, and CC-03, respectively.

Water samples from basins and pools at culvert intakes had TP ranging from 0.01 – 19.8mg/l and OP from 0.01mg/l to 1.15mg/l. Snow samples from the basins had TP and OP concentrations ranging from 0.60mg/l to 1.48mg/l and 0.03mg/l to 0.16mg/l, respectively.

3.8 Settleable Solids Data

Grab samples from basins, pools at culvert intakes and composite snow samples were analyzed for settleable solids (SS). All samples except for several from the West Fairview Basin (B-02) were below 2.5mg/l. Samples from B-02 had SS concentrations as high as 6mg/l. Samples from Chester Creek were only above minimum detection limits on four occasions (range 0.2mg/l to 0.4mg/l).

3.9 Deicer Application Data

In 1996, the MOA supervisor of each maintenance shift patrolled the Central Business District (CBD) and monitored road and weather conditions. The decision to use deicer is made by the supervisor, but deicer application is at the discretion of the truck operator. Deicer truck operators were given some guidelines for deicer application. Guidelines included; applying deicer preventatively when the weather forecast predicted temperatures to drop below 32° F and precipitation or if snow is forecast; and deicer application should be between 1gal/1000 ft^2 and 3gal/1000 ft^2. The amount of deicer that was applied varied with the operator and conditions. Deicer was applied to approximately the last 20 feet of each traffic lane approaching an intersection and recorded.

The Street Department's computer records indicated that the total deicer applied between January 1994 and April 1996 (total purchased minus total on hand) was 54,316 gallons. The application per intersection data represents less than 18 percent (9,671 gallons) of the total deicer applied. Less than 6 percent (3,247 gallons) of the total was calculated to have been used in the 5th Avenue and West Fairview Basins. Using driver application records, estimates of the amount of deicer applied at each intersection lane and amount of deicer applied at intersections within the two basins being studied was calculated. Results indicate deicer applications, both spatial and temporal, varied widely. Records indicate that between 49 and 520 intersections were treated daily. Daily deicer use varied from 12gal to 1,005gal per day and at rates between 0.46gal and 16.33gal per intersection. A summary of available deicer application records can be found in Appendix B.

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TABLES

Table 1: 1996 Sampling Stations

Station no.	Station ID.	Location	Water type	US Water	Structure	Notes
1	B-01	5th Avenue Basin	Snow melt runoff		Manhole	West end of 5th near Cook Inlet, north of coastal trail
2	B-02	West Fairview Basin	Snow melt runoff		Manhole	Northbound lane of Denali St. at 15th Ave
3	B-03	Northern Lights Basin	Snow melt runoff		Manhole	Southbound lane of Arctic Blvd., south of W27th Ave
4	B-04	West 23rd Basin	Snow melt runoff		Manhole	Eastern terminus of West 23rd Ave
5	X-1	14th & Fairbanks Street	Snow melt runoff		Paved Street	Pool at storm drain intake at SW corner of intersection
6	X-2	9th & G Street	Snow melt runoff		Paved Street	Pool at storm drain intake at NW corner of intersection
7	X-3	5th & C Street	Snow melt runoff		Paved Street	Pool at storm drain intake at SW corner of intersection
8	X-4	Northern Lights & Benson	Snow melt runoff		Paved Street	Pool at storm drain intake at N side of Benson (near Godfathers Pizza sign)
9	CC-01	Chester Creek	Stream	Chester Creek		Inlet to University Lake
10	CC-02	Chester Creek	Stream	Chester Creek		East of Lake Otis Parkway
11	CC-03	Chester Creek	Stream	Chester Creek		East of Aurora Street pedestrian bridge
12	X-5	Chester Creek	Stream	Chester Creek		Approximately 50ft upstream from Reach Tag SFC-26-1-96
13	UL-01	University Lake	Lake	University Lake		Eastern bay
14	UL-02	University Lake	Lake	University Lake		Western bay
15	WC-01	Westchester Lagoon	Lake	Westchester Lagoon		South east main bay near Minnesota Drive
16	WC-02	Westchester Lagoon	Lake	Westchester Lagoon		North west main bay near Lagoon outlet
17	Cam-01	Campbell Creek	Stream	Campbell Creek		Campbell Creek at east 72nd Street
18	SBI-01	5th Ave. Basin	Snow		Paved Street	Intersections of 5th Ave. & I St. and 5th Ave. & A St. (intersection and 100-foot approach to intersection)
19	SBN-01	5th Ave. Basin	Snow		Paved Street	Non-intersections at 5th Ave. & I St. and 5th Ave. & A St. (>100 feet but < 300 feet from an intersection)
20	SBI-02	West Fairview Basin	Snow		Paved Street	Intersections of 13th & Eagle St. and 14th & Fairbanks St. (intersection and 100-foot approach to intersection)
21	SBN-02	West Fairview Basin	Snow		Paved Street	Non-intersection at 13th & Eagle St. and 14th & Fairbanks St. (>100 feet but < 300 feet from an intersection)

Table 4 Descriptive Statistics for Basin Variables

Site	Site ID	Variable	N	Mean	Median	TrMean	StDev	SEMean	Min	Max	Q1	Q3
1	B-01	DO	13	13.238	13.000	13.209	1.040	0.290	11.5	15.3	12.55	14.000
2	B-02	DO	11	13.264	14.000	13.344	1.704	0.514	10.0	15.8	11.70	14.200
3	B-03	DO	4	12.725	12.850	12.725	1.365	0.682	11.0	14.2	11.35	13.975
4	B-04	DO	9	13.089	13.800	13.089	1.496	0.499	10.0	14.8	12.00	13.950
1	B-01	Cond.	13	2044	1638	1790	1823	505	233	6643	719	2745
2	B-02	Cond.	11	1821	1943	1787	898	271	530	3417	1045	2341
3	B-03	Cond.	4	2656	2705	2656	897	449	1762	3450	1823	3439
4	B-04	Cond.	9	1018	632	1018	667	222	438	2302	468	1496
1	B-01	pH	13	7.131	7.300	7.155	0.448	0.124	6.4	7.6	6.65	7.50
2	B-02	pH	11	7.146	7.2000	7.200	0.291	0.088	6.4	7.4	7.10	7.40
3	B-03	pH	4	6.875	6.850	6.875	0.330	0.165	6.5	7.3	6.58	7.20
4	B-04	pH	9	6.989	7.100	6.989	0.392	0.131	6.0	7.3	6.95	7.20
1	B-01	TP	15	2.935	1.880	2.393	3.552	0.917	0.010	12.900	0.030	5.280
2	B-02	TP	11	6.095	5.800	5.917	2.637	0.795	2.800	11.000	3.750	7.180
3	B-03	TP	10	6.160	5.740	5.930	3.950	1.250	1.130	13.000	1.650	9.210
4	B-04	TP	10	2.478	2.530	2.447	1.788	0.565	0.100	5.100	0.795	4.280
1	B-01	OP	15	0.245	0.070	0.194	0.342	0.088	0.010	1.150	0.010	0.340
2	B-02	OP	11	0.109	0.030	0.098	0.120	0.036	0.010	0.310	0.010	0.230
3	B-03	OP	10	0.243	0.120	0.205	0.294	0.093	0.010	0.780	0.010	0.515
4	B-04	OP	10	0.040	0.035	0.035	0.031	0.010	0.010	0.110	0.010	0.053
1	B-01	$CBOD_5$	17	187.7	180.0	151.3	230.8	56.0	1.0	920.0	2.5	245.0
2	B-02	$CBOD_5$	11	258.5	250.0	247.0	208.9	63.0	1.0	620.0	60.0	420.0
3	B-03	$CBOD_5$	10	424.0	170.0	257.0	621.0	196.0	86.0	2100.0	112.0	510.0
4	B-04	$CBOD_5$	10	41.8	32.5	37.1	39.7	12.5	1.0	120.0	6.8	80.5
1	B-01	SS	13	0.253	0.010	0.071	0.682	0.189	0.010	2.500	0.010	0.200
2	B-02	SS	11	2.341	1.000	2.193	2.721	0.820	0.010	6.000	0.010	5.500
3	B-03	SS	10	0.215	0.105	0.180	0.260	0.082	0.010	0.700	0.0100	0.375
4	B-04	SS	9	0.031	0.010	0.031	0.063	0.021	0.010	0.200	0.010	0.010
1	B-01	Flow	124	0.572	0.490	0.554	0.275	0.025	0.190	1.440	0.410	0.810
2	B-02	Flow	103	0.005	0.000	0.000	0.039	0.004	0.000	0.380	0.000	0.000
1	B-01	Temp	76	3.89	3.50	3.84	0.78	0.09	3.00	5.50	3.50	4.28
2	B-02	Temp	105	-0.32	-1.00	-0.41	2.44	0.24	-3.40	4.80	-2.50	1.60
4	B-04	Temp	76	3.89	4.00	3.85	0.59	0.067	2.80	5.90	3.50	4.00

Abbreviations

$CBOD_5$=Oxygen demand (5 day), mg/l; DO=Dissolved Oxygen, mg/l; TP=Total phosphorus, mg/l; OP=Ortho-phosphorus, mg/l, SS=Settleable Solids, mg/; pH=pH, unit
EC 25=Specific conductance, umhos/cm^2; Temp=Surface water or air temperature, C^o; Flow=Instantaneous streamflow, cfs; N=Number of samples; Mean=Arithmetic average
Median=Arithmetic middle; TrMean=Trimmed mean = smallest and largest 5% removed and the rest averaged; StDev=Standard deviation (σ); SEMean=Standard error of the mean = $\sigma/\sqrt{n}$
Min=Minimum value; Max=Maximum value; Q1=1st quartile - Q1 = (N+1)/4; Q3=3rd quartile - Q3 = 3(N+1)/4

Table 5 Summary of Lake, Stream and Snow Water Quality Data

(Mean and Ranges of Measured Parameters

Site	Site ID	Temp. Celsius	pH	Dissolved Oxygen mg/l	Conductivity umohs/cm^2	Total Phosphorus mg/l	Ortho-Phosphorus mg/l	$CBOD_5$ mg/l	Settleable Solids mg/l
9	**CC-01**	1.7 0 - 2.5	6.9 6.3-7.2	13.3 12.5-14.2	255.4 202-321	0.7 0.02-1.4	0.04 0.02-0.08	6.0 6.0	0.2 0.2
10	**CC-02**	1.9 0 - 2.9	6.9 6.0-7.5	13.6 12.4-14.5	359.9 228-588	1.0 0.6-2.35	0.02 0.01-0.03	9.9 1.5-23	<MDL <MDL
11	**CC-03**	1.7 0 - 2.6	6.9 6.1-7.3	13.8 12.2-15.4	484.8 230-805	1.3 0.02-3.35	0.02 0.01-0.06	16.5 2.0-48	0.3 0.2-0.4
13&14	**UL**	1 0 - 3	7.2 6.0-7.8	11.8* 4.0-sat.	196 144-222	0.66 <MDL-2.35	0.01 0-0.02	<MDL <MDL	-
15&16	**WC**	0.5 0 - 1.5	6.8 6.7-6.8	9.6* 3.5-sat	278 185-324	0.34 <MDL-0.49	0.01 <MDL-0.02	<MDL <MDL	-
18&19	**SB-01**	-	8 8	-	1500 1400-1600	1.09 1.03-1.15	0.03 0.03	406 391-420	2.75 2.5-3.0
20&21	**SB-02**	-	7.8 7.5-8.3	-	1070 600-1279	1 0.6-1.48	0.14 0.12-0.16	139 73-201	2 1.5-2.5

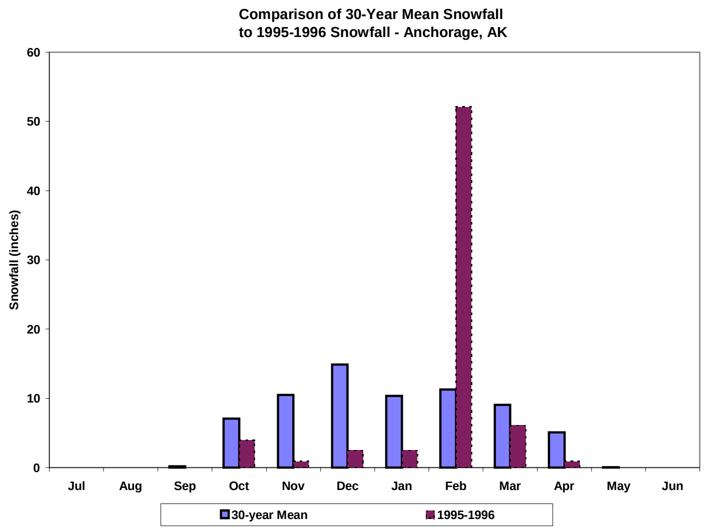
* Average of Dissolved Oxygen at transects depth; MDL - Method detection limit; sat.- Dissolved oxygen saturated water

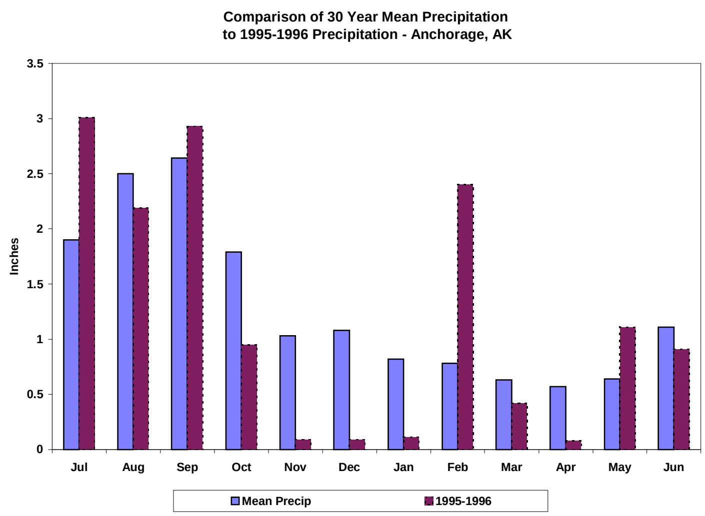
Table 2 Comparison of Quality Assurance Sample Sets

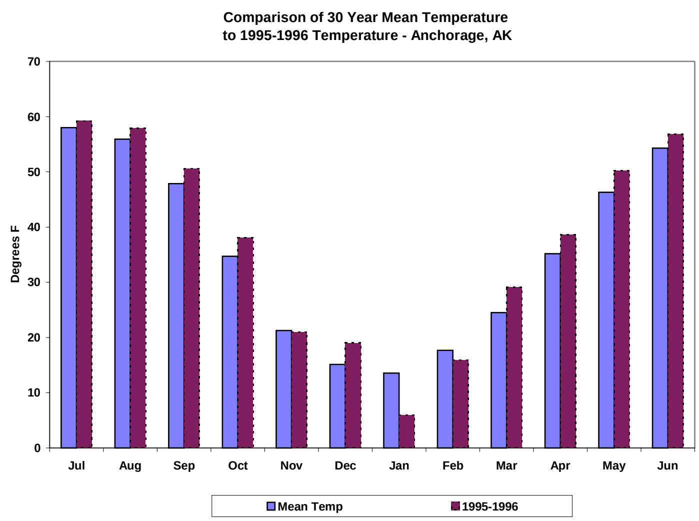
Site	Date 1996	TP mg/l	Duplicate TP mg/l	Difference %	OP mg/l	Duplicate OP mg/l	Difference %	$CBOD_5$ mg/l	Duplicate $CBOD_5$ mg/l	Difference %
B-01	3/15/	3.15	2.25	29	.34	.34	0	240	480	50
B-02	3/15	4.53	4.25	6	.11	.11	0	520	530	2
B-04	3/15	2.88	2.88	0	.06	.06	0	120	110	8
CC-02	3/15	.62	.60	3	<MDL	<MDL	0	1.5	1.5	0
CC-03	3/15	1.11	1.28	13	.01	.01	0	20	21	5
UL-01	4/4	.5	.44	12	<MDL	<MDL	0	<MDL	<MDL	0
WC-01	4/4	.43	.44	2	<MDL	<MDL	0	<MDL	<MDL	0

FIGURES

Figure 1 Study Period Climate and 30-Year Averages







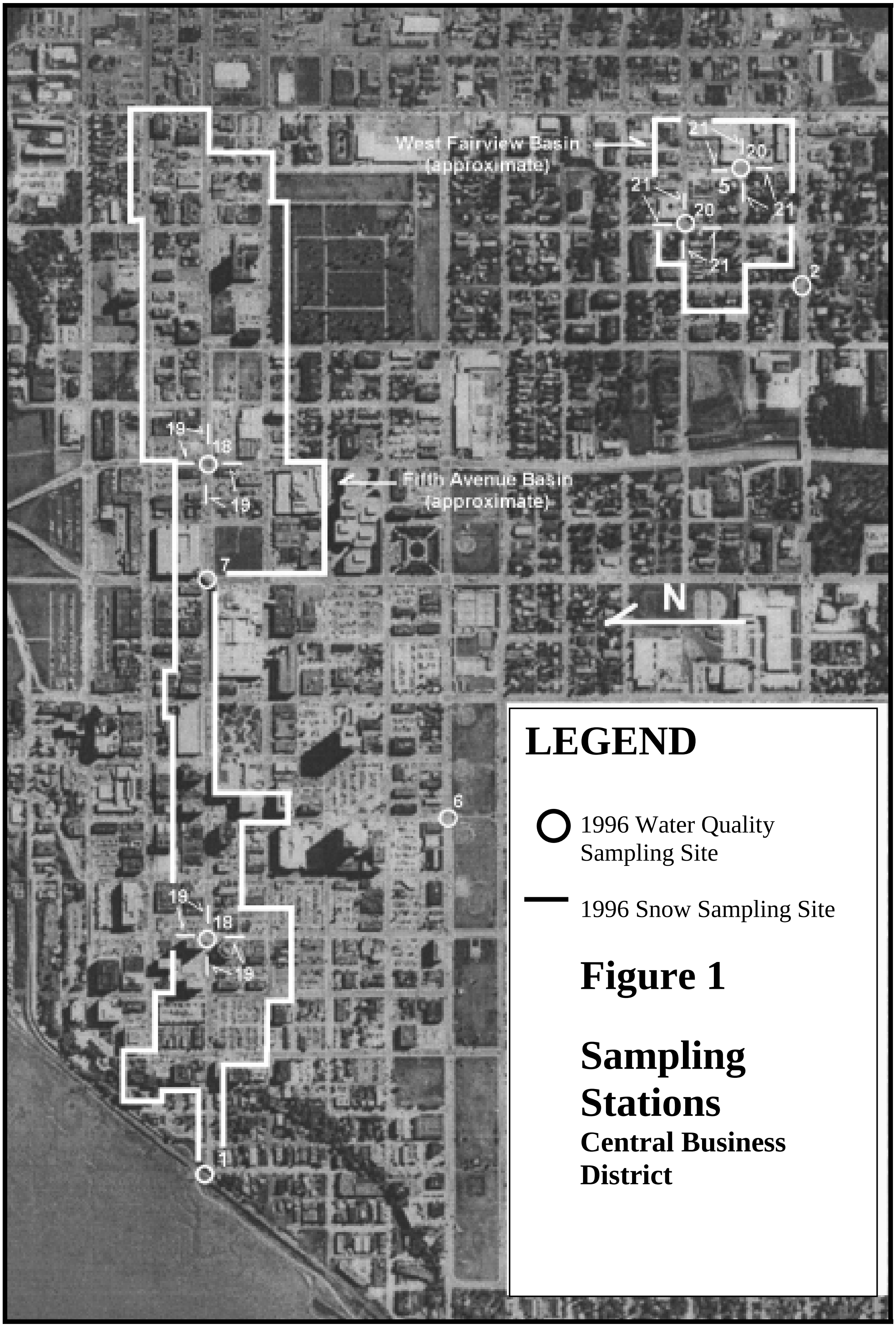


Figure 1

Sampling Stations
Central Business District

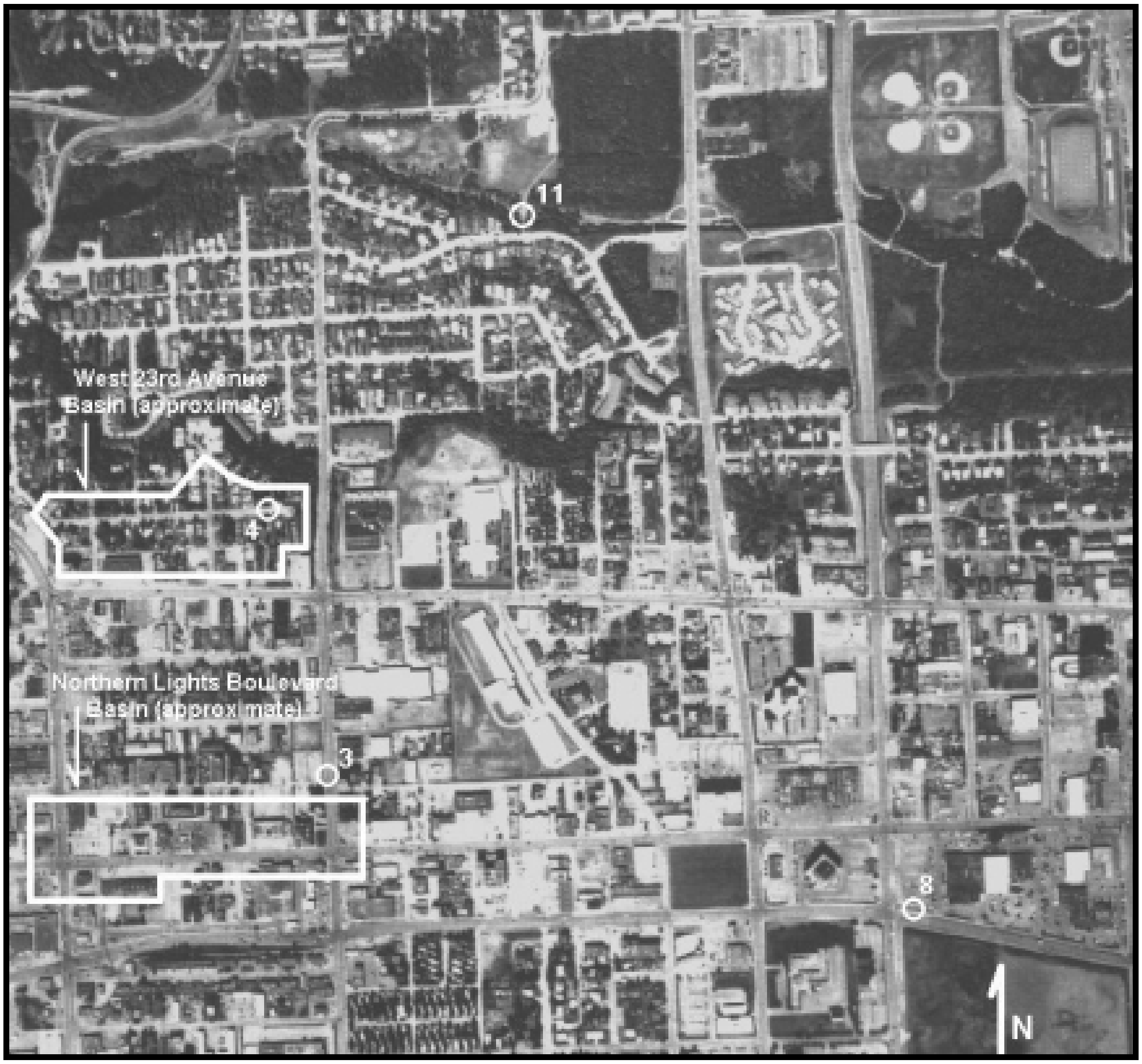


Figure 3

○ 1996 Water Quality Sampling Sites

Sampling Stations
West 23rd Avenue Basin & Northern Lights Boulevard Basin

Figure 5

○ 1996 Water Quality Sampling Sites

Sampling Stations
Westchester Lagoon

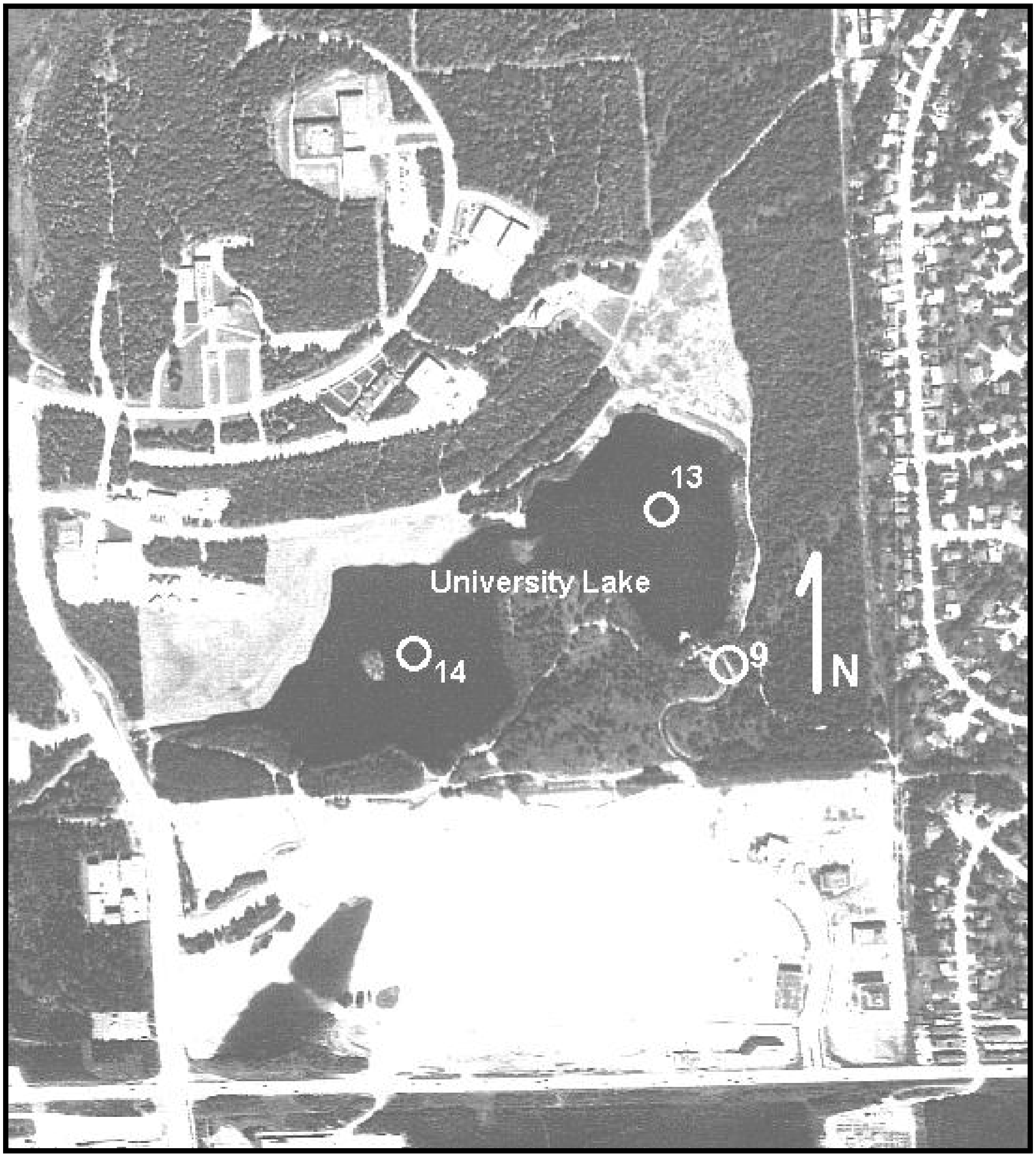


Figure 4

○ 1996 Water Quality Sampling Sites

Sampling Stations
University Lake

Figure 6

○ 1996 Water Quality Sampling Sites

Sampling Stations
Chester Creek (CC-02)

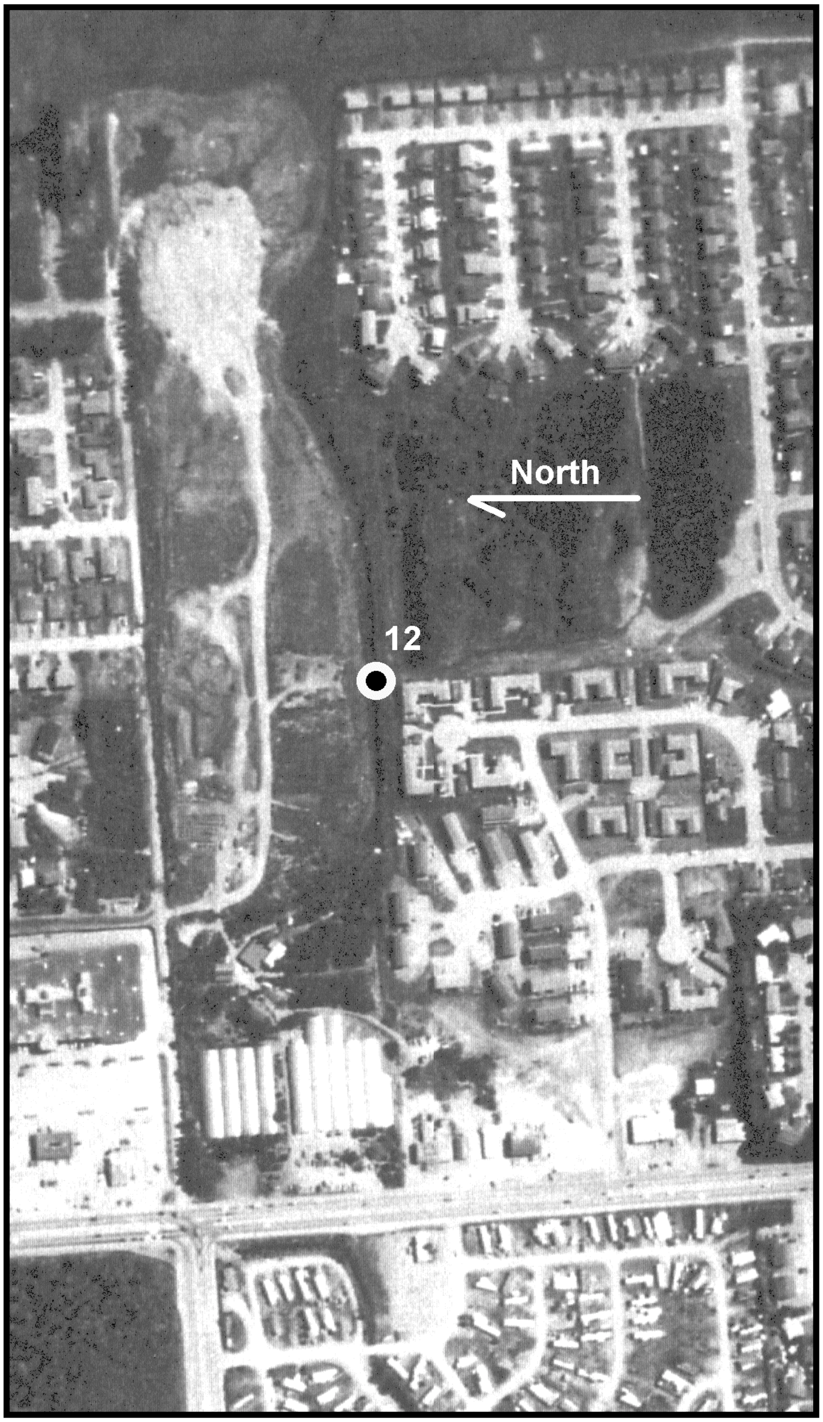


Figure 7

○ 1996 Water Quality Sampling Sites

Sampling Stations **Chester Creek (CC-Upper)**

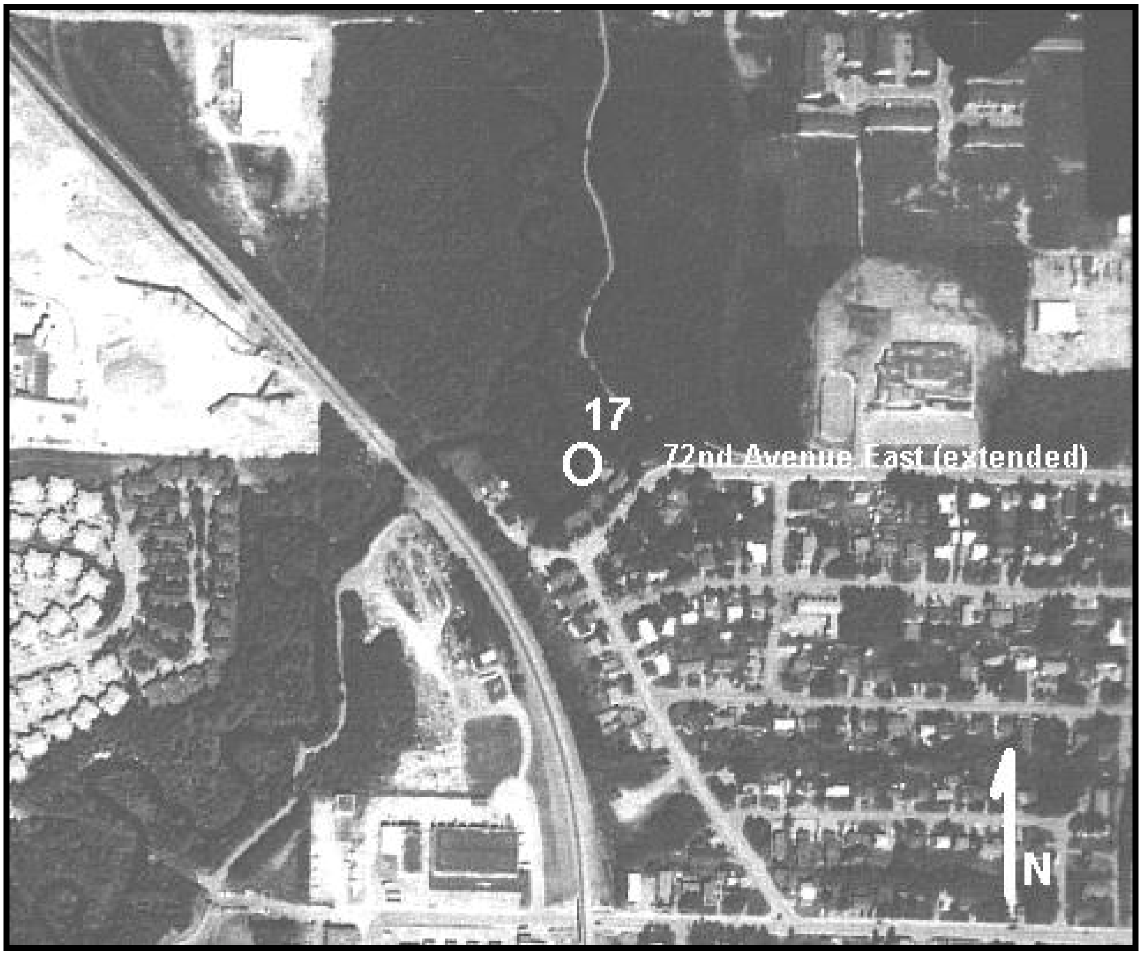


Figure 8

○ 1996 Water Quality Sampling Sites

Sampling Stations
Campbell Creek (Cam-01)

Descriptive Statistics

The following descriptive statistics of the 1995-1996 data are graphically represented:

- Mean
- Median
- Trimmed mean - smallest and largest 5% removed and the rest averaged
- Standard deviation (σ)
- Standard error of the mean - $\sigma/\sqrt{n}$
- Minimum value
- Maximum value
- 1st quartile - Q1 = (N+1)/4
- 3rd quartile - Q3 = 3(N+1)/4
- Box Plot - median, 1st and 3rd quartiles, probable outliers and possible outliers

KEY TO BOX PLOTS

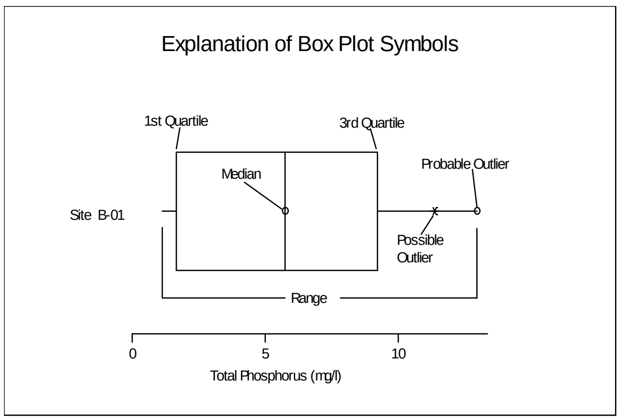


Figure 9 Flow Data from Basin Sample Sites

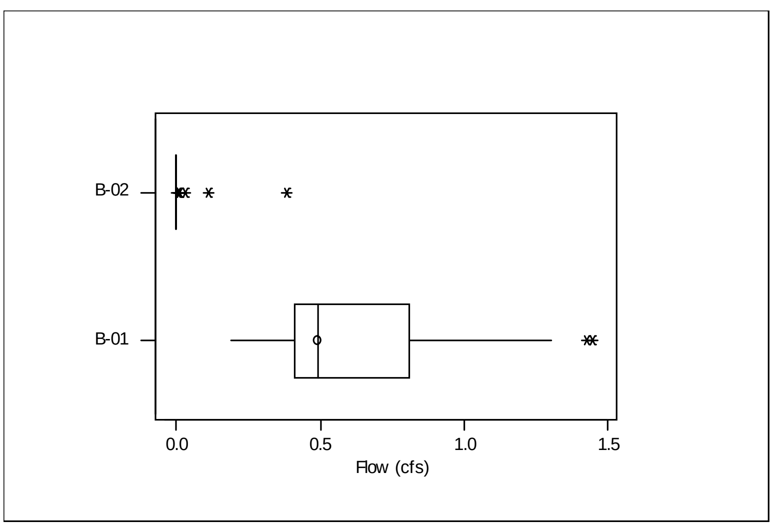


Figure 10 CBOD Data From Basin Sample Sites

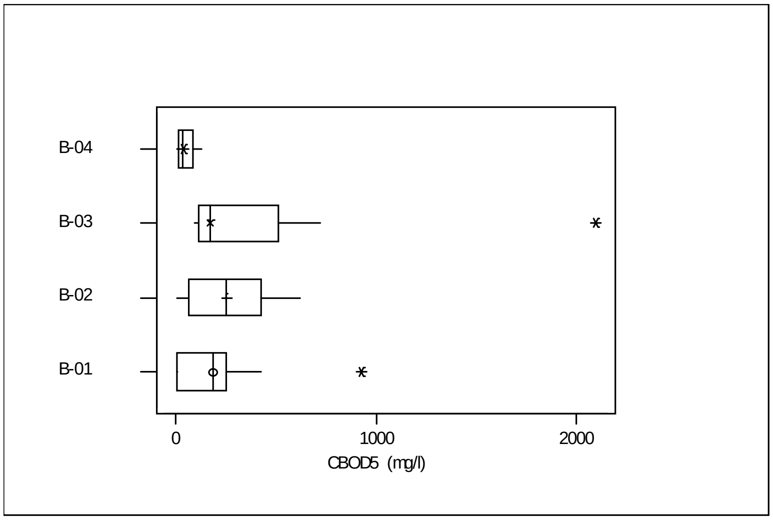


Figure 11 CBOD Data From Chester Creek Sample Sites

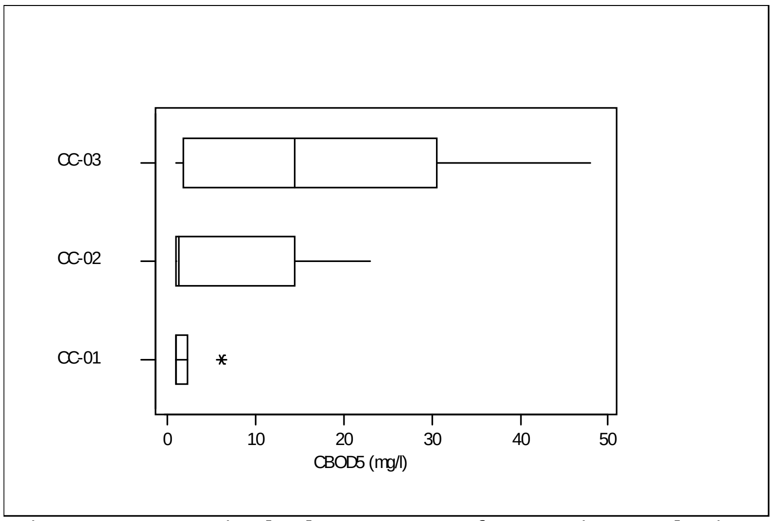


Figure 12 Dissolved Oxygen Data from Basin Sample Sites

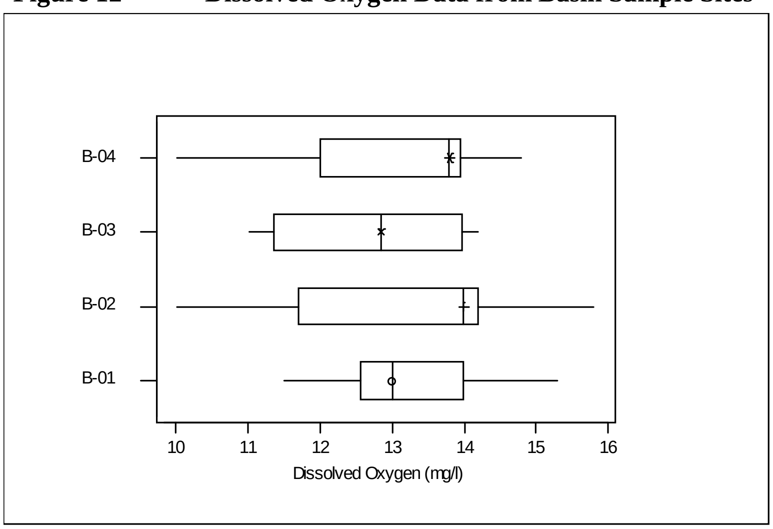


Figure 13 Dissolved Oxygen Data from Chester Creek Sample Sites

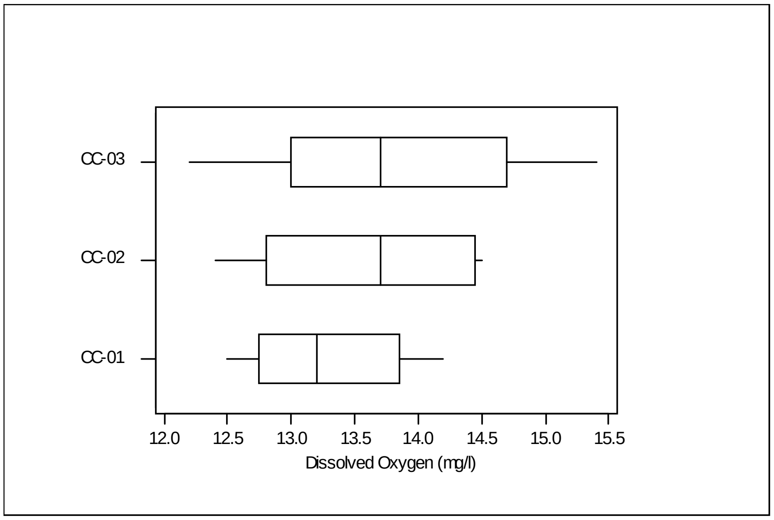


Figure 14 Total Phosphorus Data from Basin Sample Sites

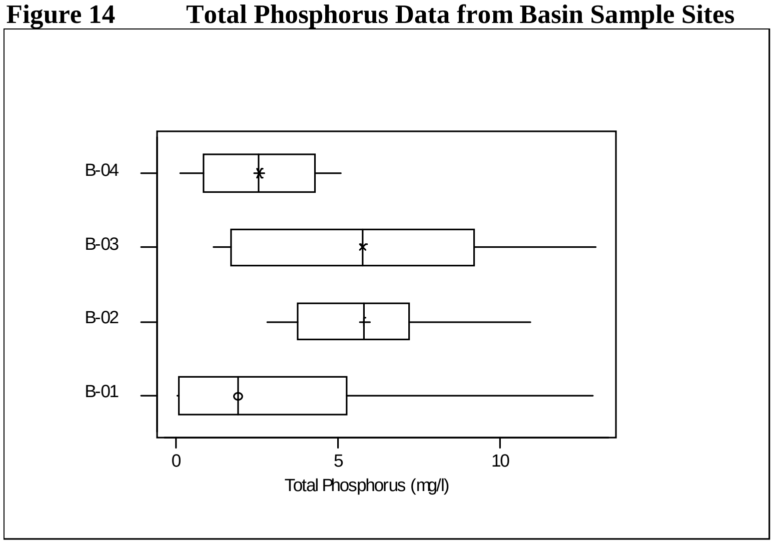


Figure 15 Total Phosphorus Data from Chester Creek Sample Sites

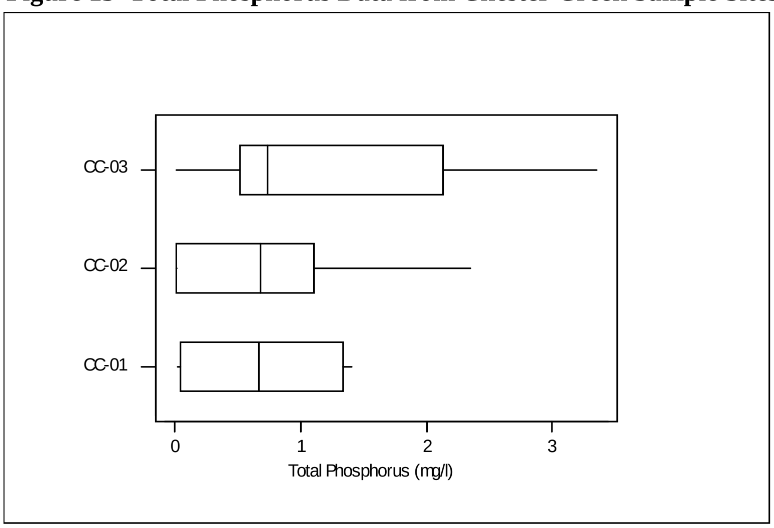


Figure 16 Ortho-Phosphorus Data from Basin Sample Sites

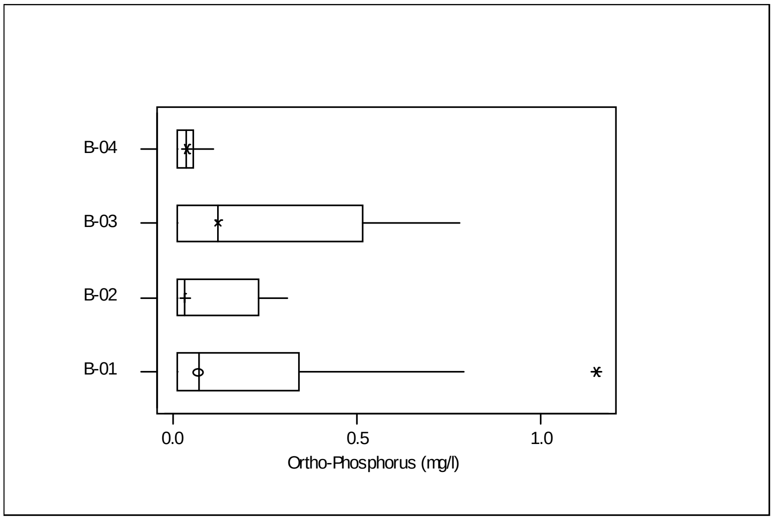


Figure 17 Ortho-Phosphorus Data from Chester Creek Sample Sites

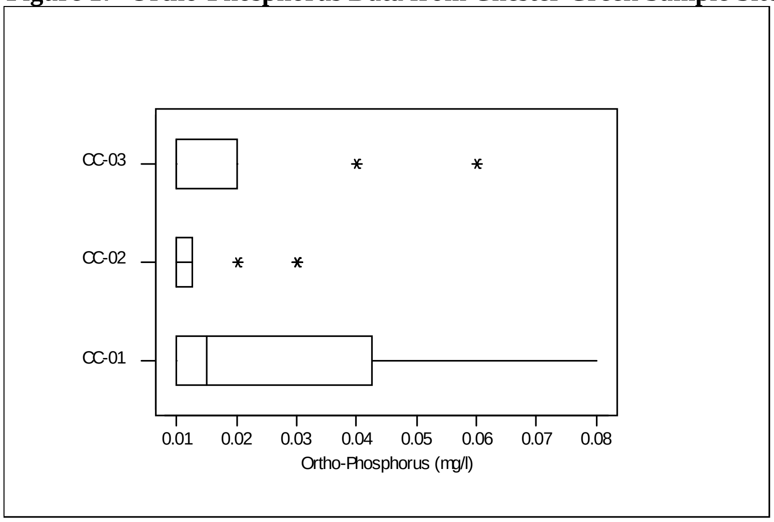


Figure 18 Conductivity Data from Basin Sample Sites

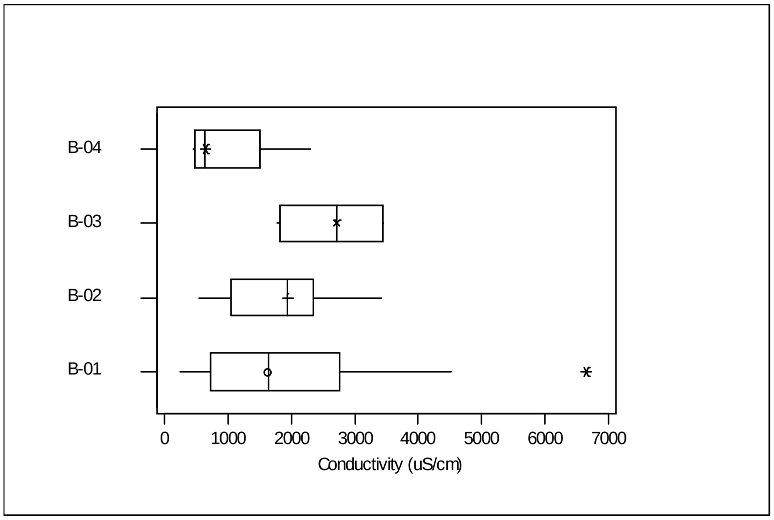


Figure 19 Conductivity Data from Chester Creek Sample Sites

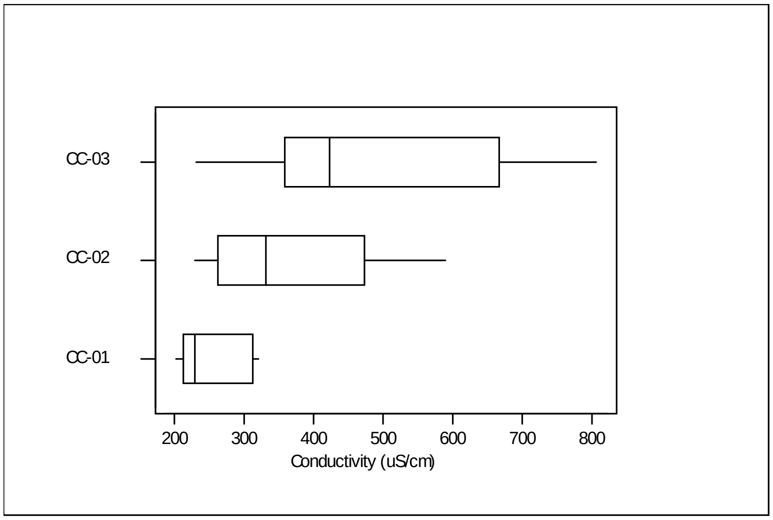


Figure 20 pH Data from Basin Sample Sites

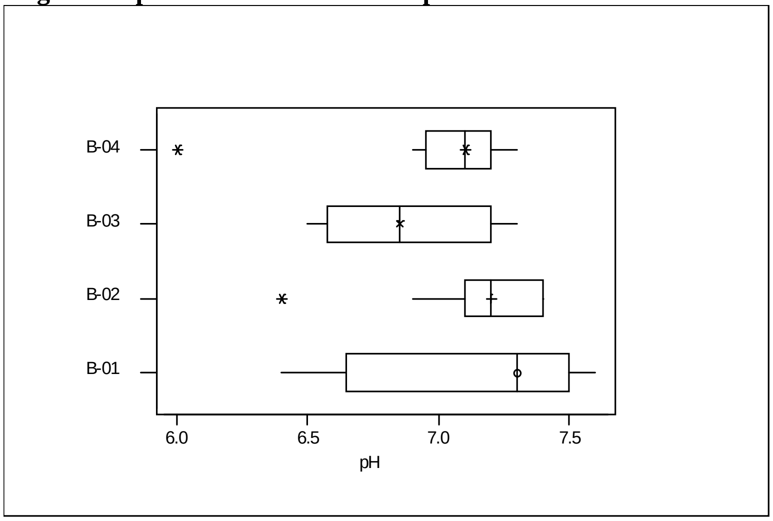


Figure 21 pH Data from Chester Creek Sample Sites

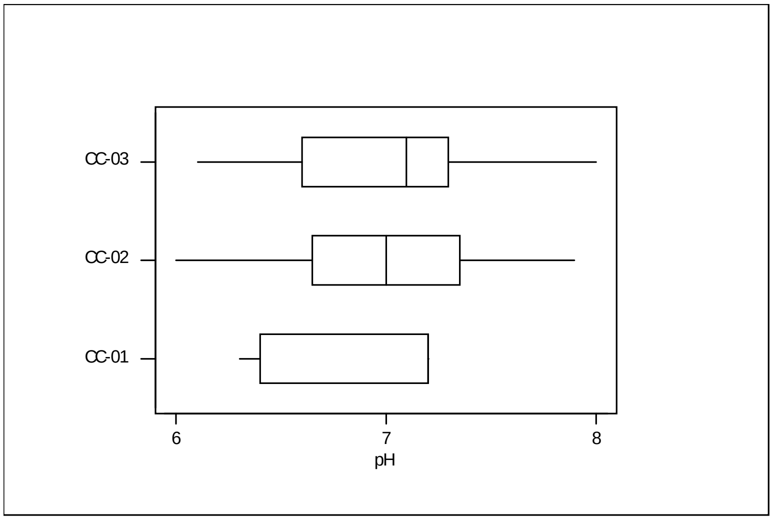


Figure 22 Suspended Solids Data from Basin Sample Sites

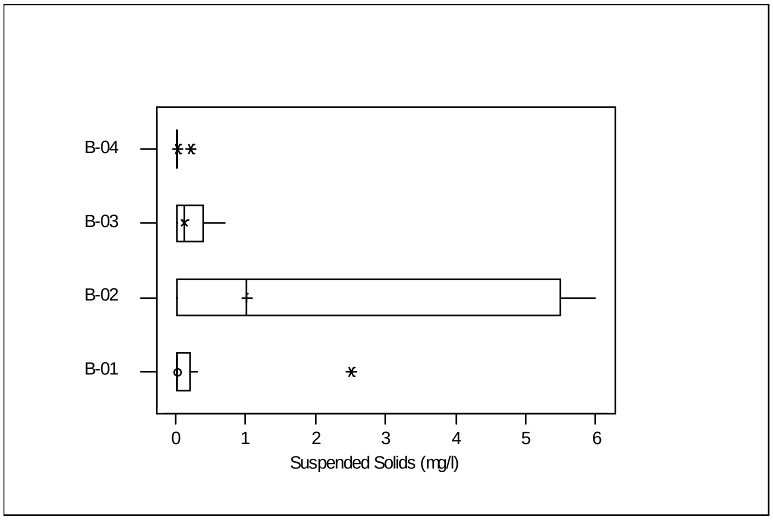


Figure 23 Suspended Solids Data from Chester Creek Sample Sites

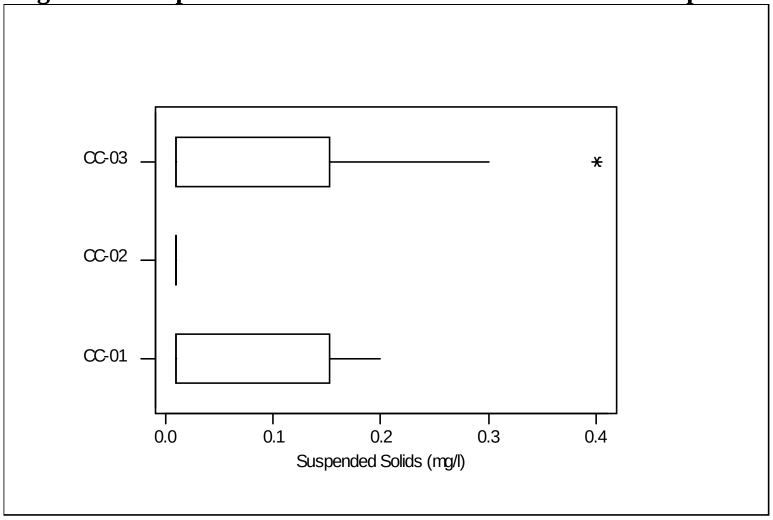


Figure 24 Temperature Data from Basin Sample Sites

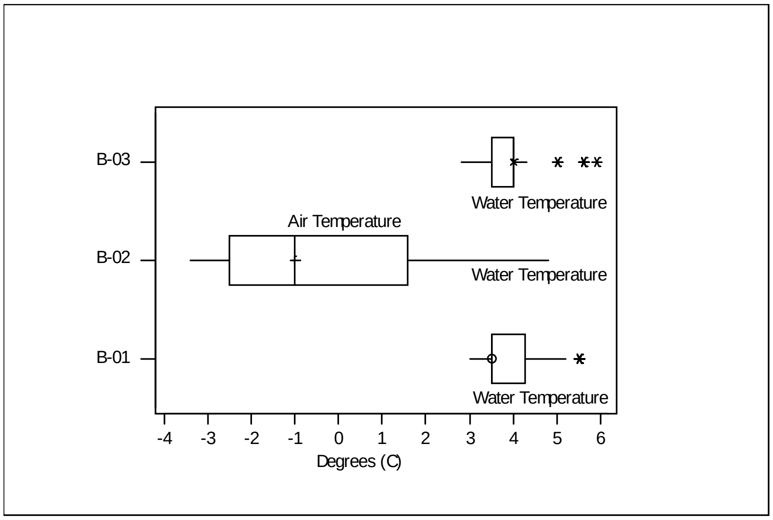


Figure 25. Oxygen Depletion Rates for Different Analytical Methods, Sources of Water and Deicer Spikes (trend lines are average of 6 replicates each)

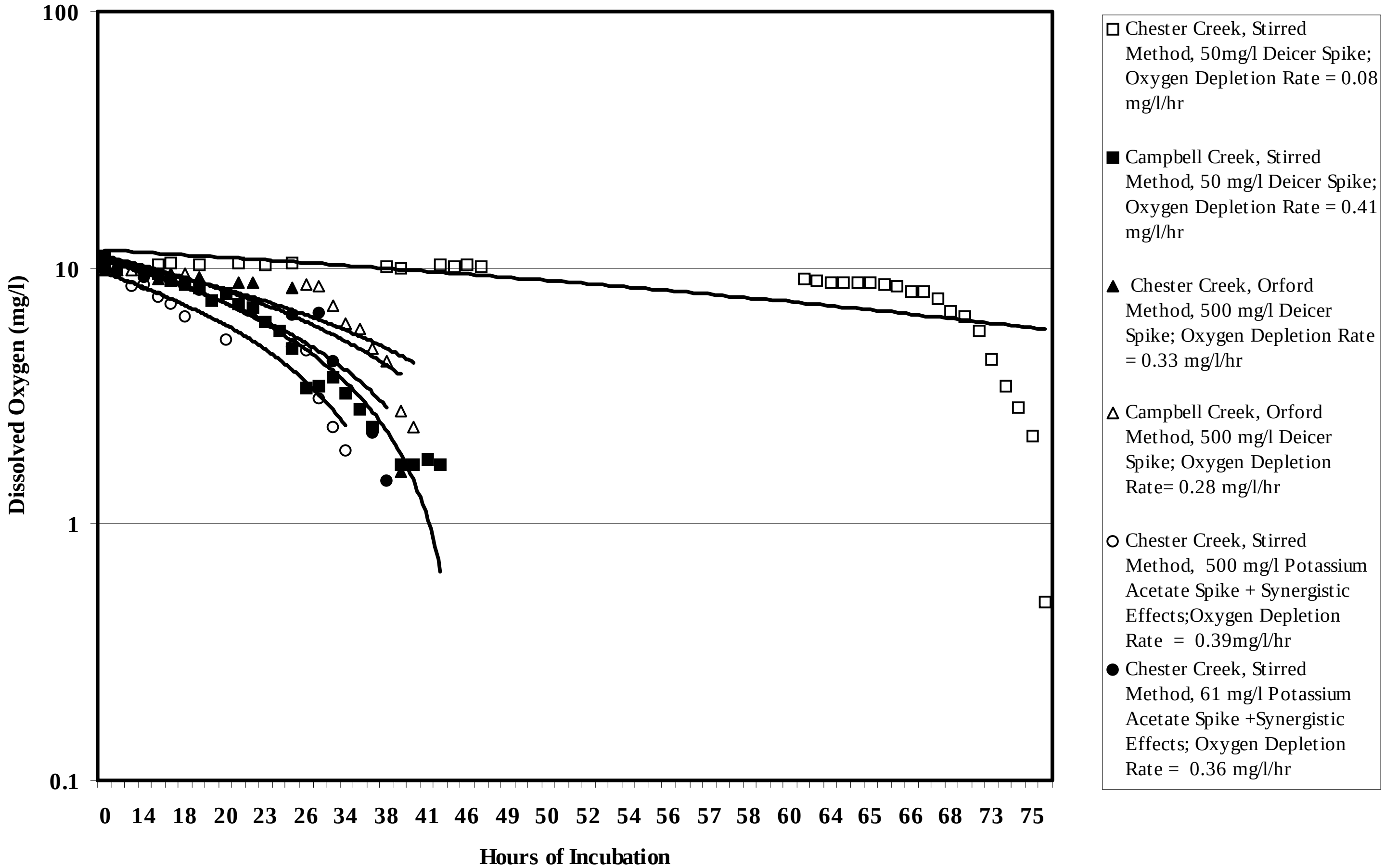


Figure 26 CBOD5 Rates for Different Analytical Methods, Water Sources and Deicer Spikes (trend lines are the average of 6 replicates each)

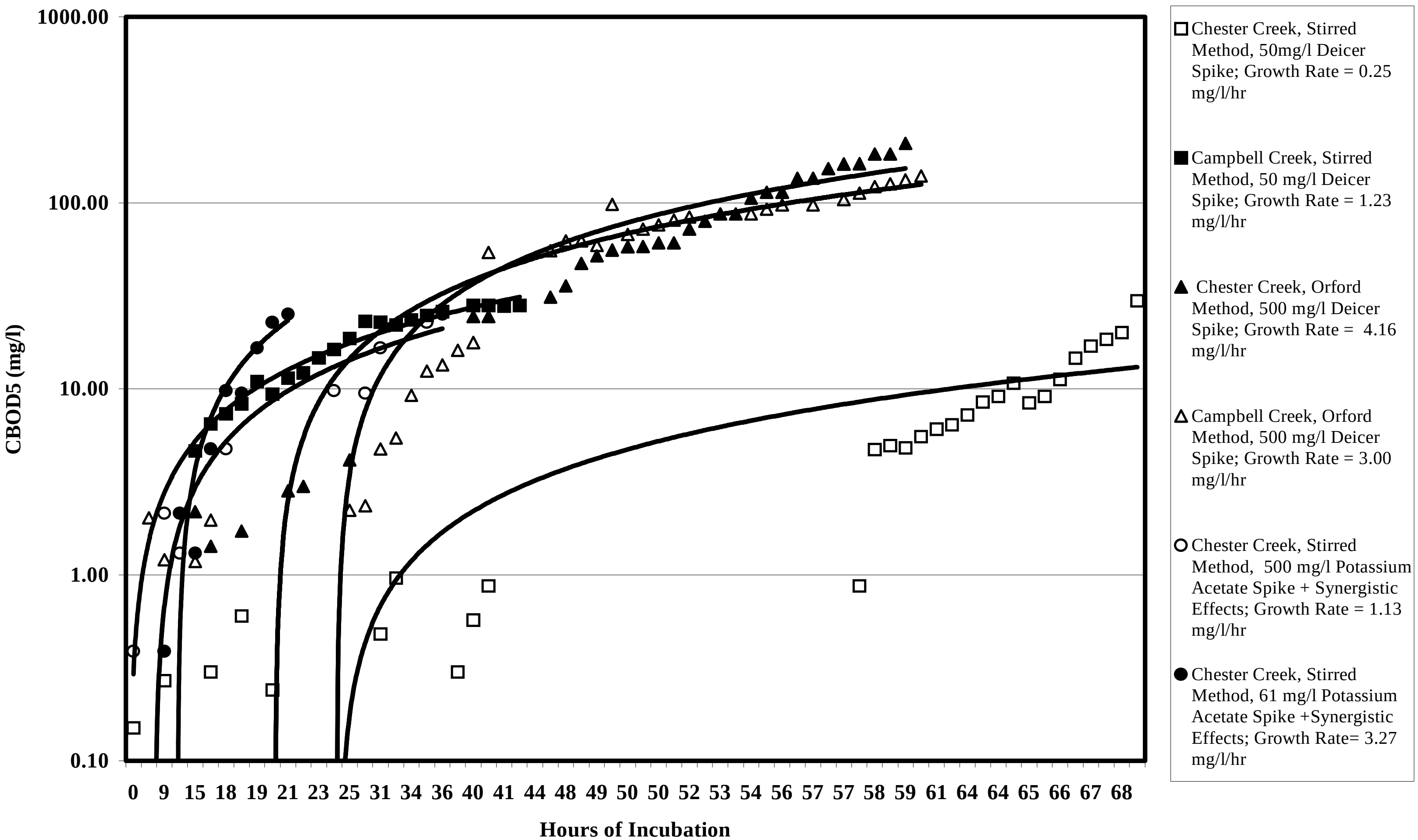


Figure 27. Dissolved Oxygen Use Rates During Orford Method - First Interval (trend lines are average of 6 replicates each)

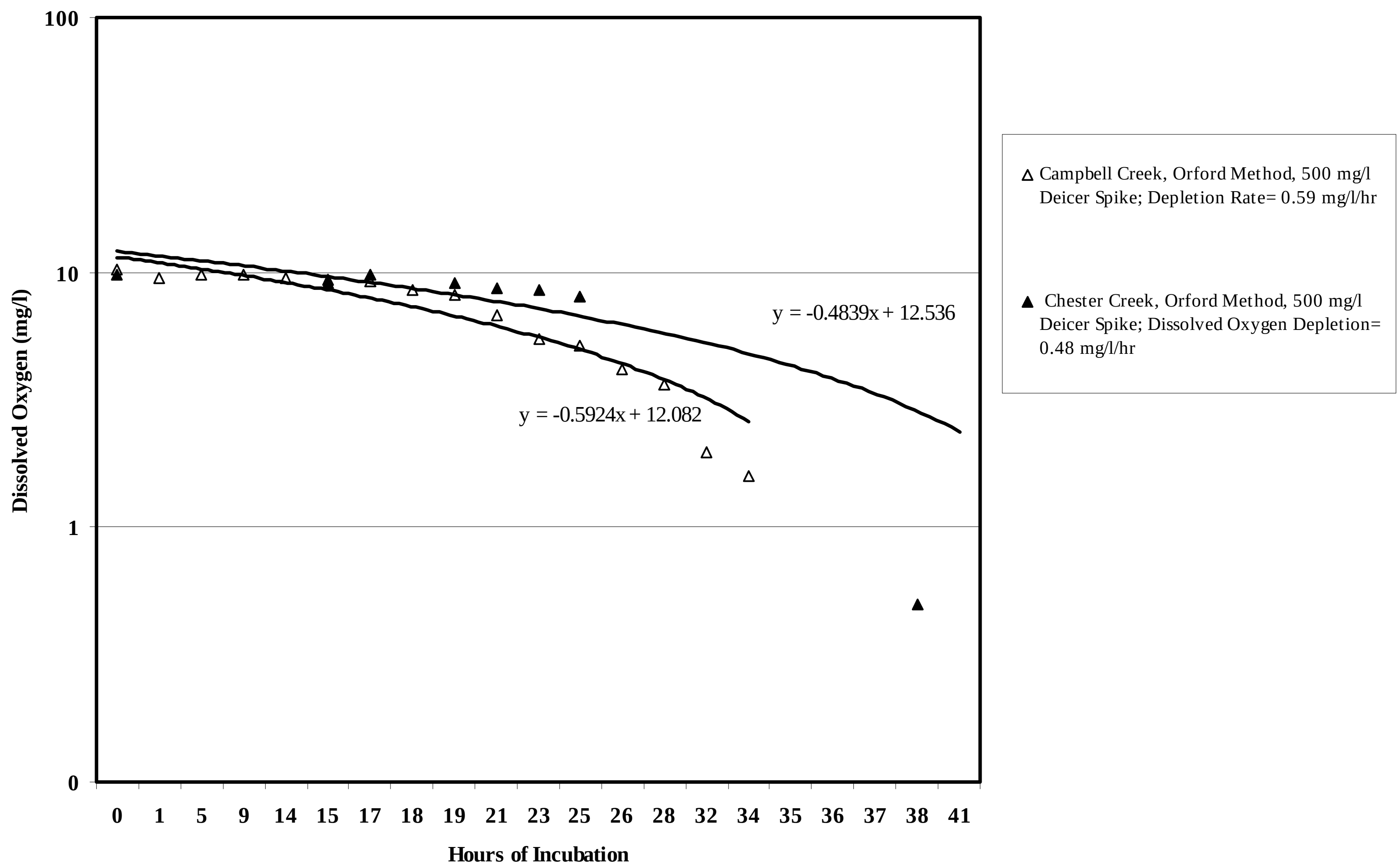
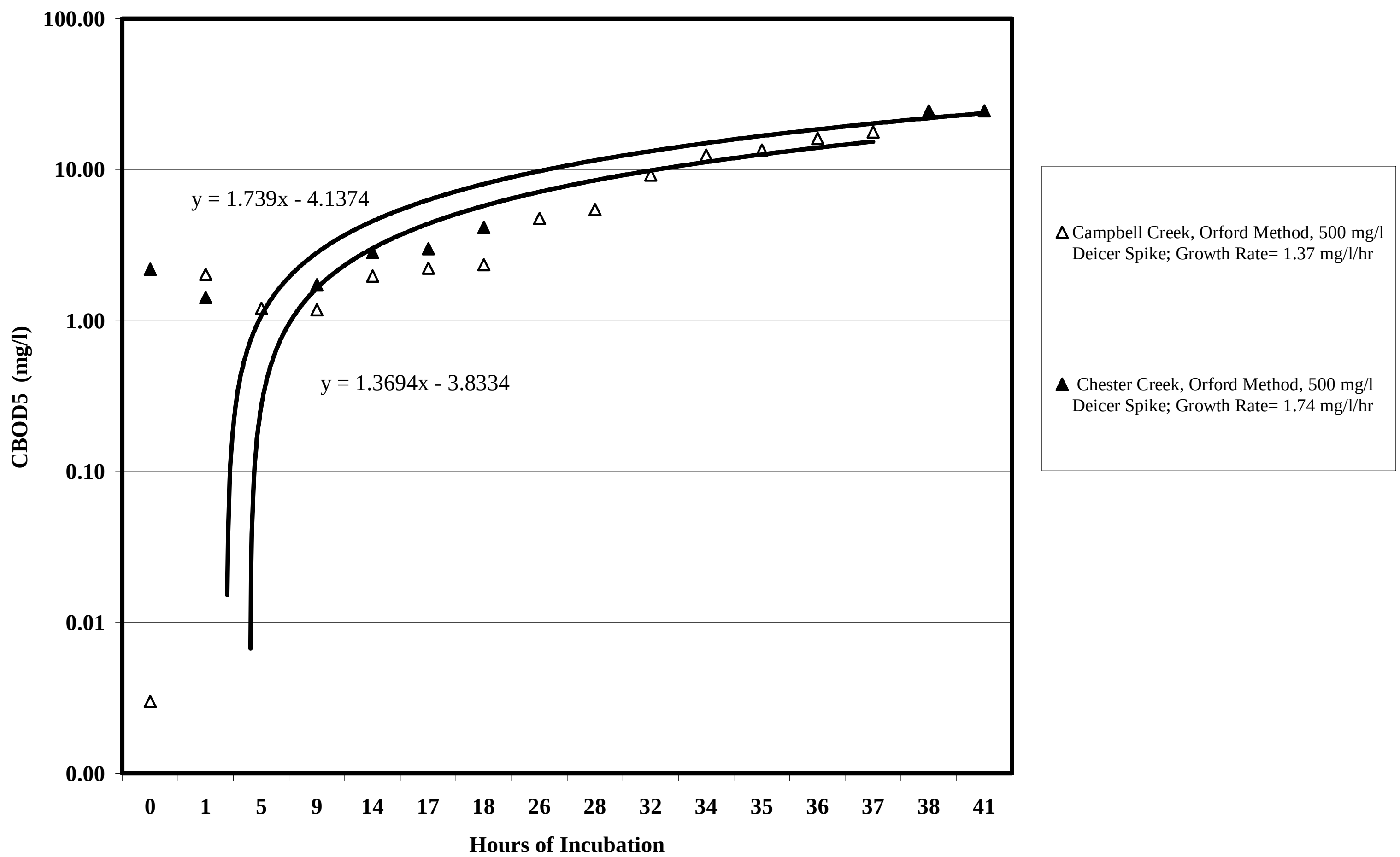


Figure 28. CBOD Growth Rates During Orford Method - First Interval (trend lines are average of 6 replicates each)



APPENDIX A:
1996 Validated Data Tabulation

Data set compiled and validated by:

Tim Chmielewski, Limnologist
Water Research & Management, Inc.
Sauk Rapids, Minnesota 56379

March 1999

APPENDIX B:
Deicer Application Data Summary

Data set compiled by:

Sally Boggs, Staff Scientist
HDR Alaska, Inc.
Anchorage, Alaska

March 1996

Summary of Available Street Deicer Application Records 1994 Through 1996

Date	Total Recorded Used (gal)	Number of Intersections Treated			Calculated Quantity used per Intersection (gal)	Amount Used Per Basin	
		Total (gal)	W. Fairview Basin	5th Ave. Basin		5th Ave. Basin	W. Fairview Basin
10/24/94	95	130	0	61	0.73	44.34	0.00
12/10/94	882	373	0	122	2.36	288.42	0.00
12/27/94	344	441	0	122	0.78	95.17	0.00
10/28/95	132	197	0	23	0.67	15.41	0.00
10/29/95	80	-	0	0	-	-	-
12/6/95	291	363	0	71	0.80	56.98	0.00
12/16/95	473	318	0	91	1.49	135.47	0.00
1/9/96	755	435	0	122	1.74	211.75	0.00
1/9/96	12	65	0	33	0.18	5.84	0.00
1/10/96	305	435	0	122	0.70	85.54	0.00
1/10/96	678	520	0	103	1.30	134.24	0.00
1/10/96	800	49	12	37	16.33	604.08	195.92
1/12/96	160	193	0	89	0.83	73.78	0.00
1/13/96	200	435	0	122	0.46	56.09	0.00
1/15/96	?	-	-	-	-	-	-
1/16/96	200	206	0	72	0.97	69.90	0.00
1/16/96	190	?	-	-	-	0.00	0.00
1/17/96	148	224	0	98	0.66	64.58	0.00
1/17/96	622	227	0	107	2.74	293.14	0.00
1/18/96	284	373	0	90	0.76	68.57	0.00
1/19/96	981	517	12	122	1.90	231.42	22.76
1/19/96	12	?	0	44	-	-	-
1/20/96	100	112	0	11	0.89	9.82	0.00
1/20/96	1005	517	12	122	1.94	237.20	23.33
1/20/96	958	300	12	58	3.19	185.21	38.32