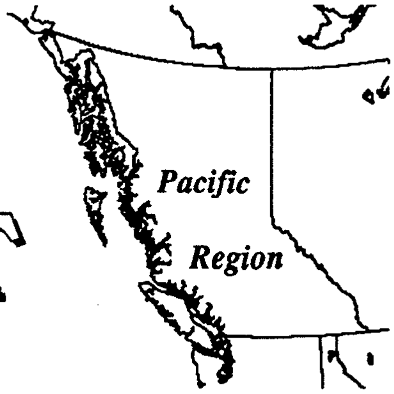
ATMOSPHERIC
ISSUES &
SERVICES
BRANCH

REPORT



Forecasting Daily Maximum Ground-Level Ozone Concentrations In Greater Vancouver and the Lower Fraser Valley

E. R. Lord
Atmospheric Issues & Services Branch
Atmospheric Environment Service
Pacific Region

February, 1993
Report PAES-93-3a

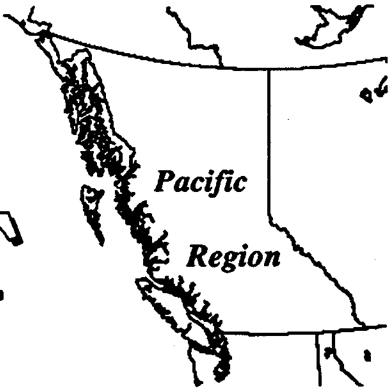
Forecasting daily maximum ground-level ozone concentrations in Greater Vancouver and the Lower Fraser Valley.

REF
PAES
93-3a

Forecasting daily maximum ground-level ozone concentrations in Greater Vancouver and the Lower Fraser Valley.

ATMOSPHERIC ISSUES & SERVICES BRANCH

REPORT



Forecasting Daily Maximum Ground-Level Ozone Concentrations In Greater Vancouver and the Lower Fraser Valley

E. R. Lord
Atmospheric Issues & Services Branch
Atmospheric Environment Service
Pacific Region

February, 1993
Report PAES-93-3a

FORECASTING DAILY MAXIMUM GROUND-LEVEL OZONE CONCENTRATIONS IN GREATER VANCOUVER AND THE LOWER FRASER VALLEY

by

E. R. Lord
Operational Meteorologist in Charge
Pacific Weather Centre

During the summer of 1992 an experiment in forecasting daily maximum concentrations of ground-level ozone in Greater Vancouver and the Lower Fraser Valley was conducted. The purpose of this experiment was to test operating procedures for the production of air quality advisories for ground-level ozone concentrations in the region in excess of the maximum acceptable air quality objective of 82 parts per billion set by the federal government of Canada. This advisory program, scheduled to begin in May 1993, is an objective of the government's Green Plan and will be produced by the Pacific Weather Centre of the Atmospheric Environment Service, the government's principle Weather Services Office in the region.

The experiment consisted of generating site-specific forecasts of daily maximum ozone concentrations within the Greater Vancouver and Lower Fraser Valley area valid for the following day. These forecasts were written by a project meteorologist specifically assigned to this task and were based on several objective models developed under contract. The experiment ran from June 30 th to September 11th 1992, during which time 44 forecasts were issued. Verification results showed that there were no operationally significant differences in accuracy between the subjective forecasts and the objective guidance. In general, biases in the forecasts were positive but small and mean absolute errors ranged from 22 to 33 percent of observed values. Most forecasts showed positive skill with respect to chance and climatology, however, neither the meteorologist nor the objective models were able to accurately predict, with a 24 hour lead time, the occurrence of days when ozone concentrations would exceed the maximum acceptable threshold. This indicates that the objective models in their current form cannot be relied upon as guidance for the issuing of air quality advisories without corroboration from forecasters trained in air quality meteorology.

1. INTRODUCTION

In 1988 the Canadian Council of Ministers of the Environment identified increases in the concentration of ground-level ozone in populated areas as the primary air quality problem in Canada (CCME Report, 1990). The Lower Fraser Valley of BC which includes portions of Greater Vancouver was singled out as one of three non-attainment areas in Canada where ozone concentrations exceed the maximum acceptable air quality objective of 82 ppb during summer months. It has been shown that levels in excess of this threshold adversely affect human health and reduce the yield and vitality of crops and forest ecosystems. For these reasons the Government of Canada included in its Green Plan a proposal to provide air quality advisories which would give 24 hour notice of the expected occurrence of high concentrations of ground-level ozone in excess of the maximum acceptable threshold to citizens living in non-attainment areas.

The Atmospheric Environment Service (AES) is the federal government agency which is responsible for providing the air quality advisory service to Canadians. For residents of the Lower Fraser Valley, the Pacific Weather Centre in Vancouver will be the Weather Services Office from which advisories will be issued. This service is due to begin in the spring of 1993. It will advise the public of the possibility of ozone levels exceeding 82 ppb with a 24 hour lead time. The advisory will be written by operational meteorologists at the Pacific Weather Centre after consultation with ambient air quality analysts in the Air Quality and Source Control Department of the Greater Vancouver Regional District (GVRD).

To prepare for this advisory service, a project meteorologist was assigned to the Air Quality Unit of the Atmospheric Issues and Services Branch (AISB) of AES Pacific Region and tasked to develop and test operating procedures for the production and dissemination of air quality advisories. In particular, previous work by Taylor (1991) on forecasting ozone in the region and the results of two projects commissioned by AISB (Robertson, 1992; Ciccone et. al., 1992) to develop statistical forecast models were to be evaluated. The procedures developed were then tested in an ozone forecasting experiment run during the summer of 1992. The purpose of this paper is to present the results of this experiment and to make recommendations for the proposed advisory service based on the findings.

2. BACKGROUND

The southwestern portion of British Columbia, generally referred to as the Lower Mainland, comprises the Greater Vancouver region and the western portions of the Lower Fraser Valley. Shown schematically in figure 1, it is bounded by the Coast Mountains on the north, the Cascades on the east and south, and the Strait of Georgia on the west. It is transected east to west by the Fraser River and the Canada-US. border. During the summer months, stationary high pressure systems form over the area which lead to hot stagnant weather conditions. A strong temperature inversion develops in the lower levels of the atmosphere which traps air pollutants in the valley. Under these conditions, concentrations of ground-level ozone can rise episodically to levels in excess of the maximum acceptable threshold of 82 ppb.

The Lower Mainland is home to nearly 1.6 million people. It is the fastest growing metropolitan area in Canada and the fourth fastest growing metropolitan area in North America with a projected population of 2.9 million people by the year 2021. The western portion of the area, the most heavily populated, is governed regionally by the Greater Vancouver Regional District (GVRD), a confederation of 21 municipalities, cities, and electoral areas. The eastern, more rural part of the area is generally referred to as the Lower Fraser Valley and is governed regionally by 3 separate districts.

The GVRD is responsible for air quality management within its boundaries, while air quality management in the Lower Fraser Valley is the responsibility of the BC Ministry of Environment, Lands and Parks (MOELP). Through agreement with the MOELP, the GVRD monitors ambient air quality throughout the entire region, acting as the lead agency in the collection, validation, publication, and dissemination of air quality information throughout the Lower Mainland of BC.

The GVRD gathers air quality information from an extensive real-time interactive air quality monitoring network . There are approximately 200 monitors in the network located at 47 monitoring stations. Twenty-one of these stations have sensors which measure concentrations of ground-level ozone. These sites are shown in figure 2. In addition, the network has sensors which measure air temperature, wind speed and direction, and rainfall amounts. Recently, AES Pacific Region added meteorological sensors to upgrade the network so that it could be used by the PWC as a mesoscale network of automated surface observations in support of their forecast program. This network is shown in figure 3.

The PWC obtains information from the GVRD network by direct computer to computer communication. Every 15 minutes a computer within the PWC telephones the GVRD air quality central computer and downloads a special bulletin composed by the GVRD computer which contains the latest weather and ozone readings from the network. This bulletin is then posted to the AES communications computer system for access by PWC meteorologists. An example of this bulletin is shown in figure 4.

3. METEOROLOGY AND THE CHEMISTRY OF OZONE FORMATION

Ground-level ozone is formed by a photochemical reaction between nitrogen oxides (NO_x) and volatile organic compounds (VOCs). The three basic reactions are (CCME Report, 1990):

$$NO_2 + h\nu = NO + O \qquad (1)$$
$$O + O_2 + M = O_3 + M \qquad (2)$$
$$NO + O_3 = NO_2 + O_2 \qquad (3)$$

where NO is nitrogen oxide, NO_2 is nitrogen dioxide, O is atomic oxygen, O_2 is the oxygen molecule, O_3 is ozone, M is an energy absorbing molecule, and $h\nu$ is the energy of a photon of light. The concentration of ozone at a particular site depends on the ratio of the reaction rates of reactions 1 and 3 and the ratio of the concentration of NO_2 to NO. The former ratio is determined primarily by the intensity of sunlight while the latter ratio is sensitive to the presence of VOCs. The VOCs react with nitrogen oxide and make it unavailable for ozone destruction.

There is a clear diurnal cycle to the hourly measurements of ozone at a site with concentrations increasing during the day due to the increase in temperature and sunlight and decreasing overnight as darkness descends and the temperature falls. Figure 5 shows this cycle for a 48 hour period in July at T9-Rocky Point Park. Notice that ozone concentrations rise rapidly during the day as the sun angle increases and fall rapidly during the evening as the sun angle decreases. In the case shown, the ozone concentration fell to zero overnight, but this does not always occur. Notice also that the time of occurrence of the peak concentration varies by a few hours from day to day. When weather conditions change dramatically, as for example, after the passage of a cold front, the ozone concentration at a site can exhibit an abnormal diurnal trend, where the maximum for the day occurs at midnight and a secondary maximum occurs the following afternoon. Figure 6 shows an example of an event of this type which occurred at T16-Pitt Meadows on July 21, 1992. Other monitoring sites recorded a similar trend on that day.

On occasion, when the atmosphere is stable and the weather is sunny and hot, concentrations of ozone can increase rapidly at a site as hot temperatures accelerate the reaction rates and a stable atmosphere prevents precursor pollutants from dispersing. Taylor (1991) has investigated the atmospheric conditions associated with high ozone concentrations in Greater Vancouver and the Lower Fraser Valley. He discovered that ozone concentrations rose when the synoptic weather pattern in the Pacific Northwest developed a strong upper ridge over the region, a low level thermal trough along the Washington and southern BC coast, and a sharp low level inversion over the Lower Fraser Valley airshed. This flow pattern allows hot, dry sub-tropical air to move northwards into the region from the southwestern United States along the back side of the upper ridge. The hot air lowers pressures over the coast resulting in a thermal trough. This trough shuts off the normal mesoscale sea breeze that develops each afternoon on warm summer days and, combined with the inversion that is formed and the trapping effect of the mountains surrounding the Fraser Valley, prevents the air from being flushed of pollutants. If this flow pattern is stationary, stagnant conditions can persist for several days allowing ozone and its precursor chemicals to increase until they exceed the maximum acceptable threshold. The episode usually ends when the upper ridge passes and the thermal trough moves inland. Then, either mid cloud invades or a cold front poised offshore sweeps eastward through the area and flushes out the valley.

4. THE 1992 OZONE SEASON

The ozone season in the Lower Mainland coincides with the summer season which typically begins in early May and ends in late September. During this period, the Pacific anticyclone regime extends into the mid-latitudes resulting in the predominance of high pressure systems over the region and warm dry weather. This pattern can be very persistent and it is during these times that the airmass can stagnate allowing an accumulation of air pollutants to develop which increases the potential for an ozone exceedance to occur (an exceedance occurs whenever the hourly ozone concentration at a monitoring site exceeds the maximum acceptable level of 82 ppb).

Figure 7 shows the daily maximum ozone concentrations measured by the network during the 153 days of the 1992 ozone season (May 1st through September 30th). The average daily maximum for the region was 47 ppb with a maximum of 101 ppb measured at T12-Chilliwack on July 30th and a minimum of 20 ppb which occurred at T3-Marpole and T17-Richmond South on July 23rd and again at T14-Burnaby Mountain on August 6th. The distribution of these measurements is shown in figure 8. The skewing to the left with a hint of a tail to the right suggests that the distribution approximates a log-normal probability distribution function. This is consistent with the distribution observed in past years.

Daily maximum concentrations of ground-level ozone can also be categorized in terms of air quality. In accordance with the standard definitions for the air quality categories used in the Air Quality Index , a good air quality day with respect to ground-level ozone is defined as one during which the measured ozone concentration does not exceed the maximum desirable threshold of 51 ppb; a fair air quality day is one during which the ozone concentration does not exceed the maximum acceptable threshold of 82 ppb; and a poor air quality day is one during which the ozone concentration exceeds 82 ppb. In 1992 there were 104 days in which the air quality in Greater Vancouver and the Lower Fraser Valley was measured to be good with respect to ground-level ozone, 45 days were fair, and 4 days were poor. In terms of relative frequencies, 68% of the days were good, 29% were fair, and 4% were poor. For comparison, the relative frequency distribution for the same period in 1991 was 74% good, 25% fair, and 1% poor; while the distribution for the same time period for the 5 years from 1985 to 1989 on which the statistical forecast models were developed was 55% good, 36% fair, and 8% poor. It should be noted that these distributions are not formally comparable since the observing network changed over the years as monitoring stations were added, removed, and relocated.

Figure 9 shows an analysis of the daily maximum ozone concentrations measured in Greater Vancouver and the Lower Fraser Valley on July 26, 1992, a day typical of many summer days in the area. The analysis shows a maximum in concentrations over the eastern portion of the region with a ridge extending northwestwards to a secondary maximum over the North Shore. A trough of low concentrations extends eastwards and southeastwards from a minimum over Downtown Vancouver. This pattern is typical of what is observed in the region each day. Although values of the measured concentrations change from day to day, the basic shape of the analysis changes very little. This feature during the ozone forecasting experiment as will be described later on in the paper.

5. THE DEVELOPMENT OF STATISTICAL OZONE FORECASTING MODELS

The first attempt to forecast daily 1 hour maximum ozone concentrations in Greater Vancouver and the Lower Fraser Valley was made by Taylor (1991). In this experiment, forecasts of daily maximum concentrations for days 1, 2, and 3 were made on the morning of day-1 based on a subjective interpretation of current and predicted weather patterns for the region. The probability of the maximum acceptable threshold being exceeded each day was also forecast. An objective verification of these forecasts was not conducted, however, it was concluded from this experiment that the correct trend in daily maximum ozone concentrations was captured by the forecaster and that errors in the predictions were due mainly to inaccuracies in forecasting the meteorological conditions.

Based on this work, the Air Quality Unit of AISB Pacific Region developed a set of multiple linear regression (MLR) equations which linked daily maximum ozone concentrations to temperature, yesterday's maximum ozone concentrations, precipitation, and pressure differences between coast and interior regions in BC. The specific variables used in the development of these equations is shown in Appendix 1. The data were stratified into 4 subsets according to:

1) days when precipitation occurred and yesterday's ozone did not exceed 60 ppb,
2) days when precipitation occurred and yesterday's ozone exceeded 60 ppb,
3) days when precipitation did not occur and yesterday's ozone did not exceed 60 ppb, and
4) days when precipitation did not occur and yesterday's ozone exceeded 60 ppb,

Using this stratification, four equations were derived for six monitoring sites: T1-Robson Square, T9-Rocky Point Park, T12-Chilliwack, T15-Surrey East, T17-Richmond South, and T28-Abbotsford. A forward stepping MLR procedure was employed. This procedure selected 13 predictors for the 24 equations. Referring to Appendix 1, these predictors were P2, P4, P5, P6, P27, P28, P29, P30, P31, P32, P33, P34, and P36.

Subsequent to this work, AISB let two contracts for the development of statistical ozone forecasting models using the same five year data set . The first contractor, Emily Robertson, developed a set of predictive equations based on MLR techniques and Multiple Discriminant Analysis (MDA) techniques. Robertson first reduced the original data set by examining the correlation between the variables in the set, then derived new variables from the remaining data in an attempt to contribute information about the previous day's conditions and to reduce some of the noise in the original data. The final data set consisted of 24 variables: P9, P11, P12, P27, P28, P29, P30, P31, P32, P33, P35, and P36 from the original set (see Appendix 1), plus two canonical variates derived from the pressure difference variables, three temperature change variables, three variables which combined temperature change with temperature anomalies, three variables which described the occurrence of precipitation and its most recent trend, and a variable which combined precipitation occurrence with maximum temperature. The reader is referred to Robertson (1992) for a detailed discussion of these variables.

For the two western monitoring sites, T1-Robson Square and T17-Richmond South, a forward stepping MLR procedure was used to develop a predictive equation for the daily 1 hour maximum ozone concentration at each of these sites. For the four eastern monitoring sites, T9-Rocky Point Park, T12-Chilliwack, T15-Surrey East, and T28-Abbotsford, MDA was used to develop a discriminant function for each site which would determine the air quality category. Then a forward stepping MLR procedure was used to develop a predictive equation for the numerical value of the ozone concentration for each air quality category. In total, Robertson delivered 14 regression equations and 4 discriminant functions to be used as statistical forecast models.

The second contractor, Concord Environmental Corporation, investigated several variations of the following model (Ciccone et al., 1992):

$$\mathrm{Log}(Oz_{tda}) = a + b\,\mathrm{Log}(Oz_{yda}) + c\,T_{max} + d\,\delta_r + e\,\delta_p + f\,J + g\,(J^2/10000) \qquad (4)$$

where Oz_{tda} is today's maximum ozone reading at the site, Oz_{yda} is yesterday's maximum ozone reading, T_{max} is the maximum temperature, δ_r is a binary variable which equals 0 if rain occurs and 1 if it doesn't, δ_r is a second binary variable which equals 0 if the pressure difference between Vancouver and the site is positive and 1 if it is negative, J is the Julian day, and a, b, c, d, e, f, and g are numerical constants determined by regression. This model is based on the following assumptions:

1) that the daily maximum 1-hr ozone concentration at a site is generally dependent on the maximum temperature at the site that day and yesterday's maximum ozone concentration at the site (Robeson and Steyn, 1989),
2) that the distribution of maximum ozone concentrations at a site is approximately log-normal,
3) that these concentrations are influenced by the occurrence of precipitation and the advection of wind (Taylor, 1991),
4) and that these concentrations are proportional to the amount of solar radiation at the site.

Concord developed models for six sites plus one which would predict the daily maximum ozone concentration within the entire region. The models were regressed on the 5 year data set to determine the value of the constants and delivered to AISB for implementation.

All the statistical models delivered under contract were validated against data from 1990. Details of their performance can be found in Robertson (1992) and Ciccone et al. (1992). As expected, the models performed reasonably well when ozone concentrations were below 82 ppb, but performed poorly when concentrations rose above this threshold. The poor performance was generally attributed to the nature of the distribution of daily maximum ozone values and the difficulty which statistical techniques have in forecasting extremes.

6. THE 1992 GROUND-LEVEL OZONE FORECASTING EXPERIMENT

The Government of Canada is committed to providing advisories for poor air quality due to ground-level ozone in Greater Vancouver and the Lower Fraser Valley beginning in 1993. To prepare for this service, an experiment was conducted during the summer of 1992 in which a dedicated meteorologist issued forecasts of the daily 1 hour maximum ozone concentration at ten sites in the Greater Vancouver and Lower Fraser Valley plus a regional maximum. These forecasts were based on the meteorologist's assessment of current and predicted weather patterns for the region and guidance from the statistical models described in the previous section. The forecasts were issued at 3 PM in the afternoon and valid for the following day providing users a 24 hour lead time. If ozone concentrations were predicted to exceed 82 ppb anywhere in the region, the forecast was accompanied by an air quality advisory. Consultation and agreement with the air quality analysts in the GVRD was required before an advisory was included.

Since this was an experiment to test various models and procedures, neither the forecasts nor the advisories were disseminated to the general public. However, the Head of the Air Quality and Source Control Department of the Greater Vancouver Regional District (GVRD) received a copy by fax for that department's planning purposes and a copy was also sent by fax to the Geography Department at the University of British Columbia to support their research.

Ten sites were chosen for the experiment: the six stations for which statistical models were developed, T1-Robson Square, T9-Rocky Point Park, T12-Chilliwack, T15-Surrey East, T17-Richmond South, and T28-Abbotsford, plus T4-Kensington Park, T16-Pitt Meadows, T26-Mahon Park (North Shore), and T27-Langley. The latter four were added to give better coverage over the region. A forecast of the maximum ozone concentration in the region was also made.

The experiment ran from June 30, 1992 to September 11, 1992, Monday to Friday, excluding statutory holidays. During this time 44 forecasts were issued. An example of the forecast is shown in figure 10.

Figure 11 shows the procedures that were executed by the project meteorologist to prepare for each day's forecast. Time was spent each morning analyzing the maximum ozone concentrations from the previous day to determine patterns within the region and to maintain an archive for the summer. The maximum concentration in the region was also recorded on a time series graph to determine day-to-day changes and identify trends. Time was also spent verifying previously issued forecasts to determine the errors generated by the statistical models. These errors were used to help assess the quality of the objective guidance for the next forecast.

The forecast production phase began each day about an hour and 40 minutes prior to the issue time of the forecast. The current and forecast meteorological conditions were examined in consultation with PWC forecasters. The latest Quillayute tephigram was examined to determine the stability of the airmass and the available numerical models were looked at to determine possible weather patterns over the region for the following day. In almost all instances of importance in the formation of high levels of ground-level ozone, the weather forecast of the project meteorologist agreed with the PWC forecast. On the few occasions where there was a disagreement, the project meteorologist deferred to the PWC forecasters in order to maintain consistency among forecast products. Once the meteorological conditions were decided, the latest ozone concentrations in the region were examined and a forecast of the maximum ozone concentration for the day at the six monitoring sites for which the statistical forecasting models were developed was made using observed trends in daily maximums at each site and by extrapolating the hourly readings from each site. Normally, this was only a two to three hour forecast. However, it was found that errors of 10 to 20 ppb could occur when ozone levels were rising rapidly during the afternoon.

At this point, values for all the predictors used by the statistical forecast models were available. Since the regression equations shared many of the predictors, it was possible to implement the equations using 35 inputs. These inputs are shown in figure 12. The Julian day and the average maximum temperatures were input automatically from previously prepared files; values for the eight pressure variables were abstracted from the PWC 24 hour and 36 hour subjective prognoses issued each morning; values for the maximum temperature variables were obtained from the public forecast; the occurrence of precipitation on the previous day was determined from observation; values for the occurrence of precipitation for today and tomorrow were deduced from the probability of precipitation forecast in the public forecast using a threshold of 50%; and, as described above, the maximum ozone concentration values were forecast subjectively by extrapolation from current trends.

The input form constituted the first of a series of linked spreadsheets which were used to produce the forecast. After completing this form, a second spreadsheet evaluated the statistical forecast models and presented the results in a third spreadsheet which was in a form that could be used to compare the results from the models and enter a subjective forecast. This form is shown in figure 13. The subjective forecast created by the project meteorologist was based primarily on the weather pattern that was forecast for the next day and the output from the objective guidance. Verification results from recent forecasts were used to monitor current model performance and this was used to subjectively weight the objective guidance for each monitoring site. Forecasts for the four intermediate sites were obtained by pattern recognition and interpolation.

Once the forecasts were entered, a fourth spreadsheet generated the forecast message. All dates, times, and notices of advisories were edited manually. If ozone concentrations were forecast to be in excess of 82 ppb, the GVRD was called and a consultation took place with the air quality analyst on the appropriateness of the advisory. This occurred four times during the experiment and the GVRD concurred with the meteorologist's forecast on all of those occasions. Once finalized, all forecast values were stored in the fifth and last spreadsheet for later verification and the forecast message was faxed to the GVRD and to UBC. The final step was to update a diary which kept a summary of the reasoning that went into the forecast each day.

7. VERIFICATION RESULTS

7.1 The forecast sample

The forecast sample was constructed from the 44 messages issued during the period of the experiment. Each message contained 11 subjective forecasts of daily maximum 1 hour ozone concentrations (for 10 monitoring sites plus a regional maximum) which were based in part on 23 objective forecasts from the statistical forecast models. This created 34 sets of forecasts. Thirty of these sets contained 44 cases; four contained only 34 cases because of a sensor breakdown at T17- Richmond South at the beginning of the experiment.

7.2 Representativeness of the forecast sample

Before any inferences can be drawn from the verification results, it must be shown that the sample, comprised of the 44 days for which forecasts were written, was representative of the 153 days of the 1992 ozone forecasting season. Since this particular sample was not chosen randomly, there is no a priori guarantee that this is so. Proof of the representativeness of the sample must rest on a comparison of the distribution of ozone observations within the sample with that for the 1992 ozone season. Such a comparison is made in figure 14 which shows differences in the average value of daily maximum ozone observations at each of the forecast sites between the 44 day sample and the 153 day season. The figure also shows the differences in the distributions of the maximum ozone observations into good, fair, and poor air quality categories at each site. At most monitoring sites the differences are small. In particular, note the very close agreement in the observations of regional daily maximum ozone between sample and season. These comparisons show fairly convincingly that this particular subset of 44 days for which forecasts were written was representative of the 1992 ozone forecasting season.

7.3 Verification procedures

Forecasts were verified against their matching observations in two ways. First, all the numerical forecasts were verified using continuous variable verification statistics. Average forecast error or bias, variance and standard deviation of forecast errors, mean absolute error, root mean square error, and reduction of variance were computed. Secondly, Robertson's MDA forecasts, and the numerical forecasts and their matching observations were categorized into good, fair, and poor air quality, and verified using 3 x 3 contingency table statistics. Percent correct, post agreement, prefigurance, and bias for each category, and the Heidke skill scores with respect to chance and climatology were computed. Definitions and formulae for these statistics can be found in Stanski, Wilson, and Burrows (1989).

7.4 Verification results for individual stations

A complete set of verification results is collected together in Appendix 2. The reader is referred to this appendix in the following discussion of the results for individual stations.

7.4.1 T1-Robson Square

Three statistical models and a subjective forecast were verified. The continuous variable verification statistics and the 3 x 3 contingency table statistics showed that there was very little difference in performance between them. Biases ranged from -2 ppb to +1 ppb, mean absolute errors were 6 ppb, root mean square errors were 8 ppb, and the reduction of variance (RV) was zero or slightly negative. The contingency table shows that all the observations fell into the good air quality category and that all were correctly forecast by the statistical models and the forecaster. The fact that air quality measured at T1-Robson Square is almost always good suggests that forecasting ozone concentrations for this site is not a problem.

7.4.2 T4-Kensington Park

There were no statistical models to guide a forecast for this site. Subjective forecast were written using the interpolation and pattern recognition techniques described previously. The forecasts exhibited a small positive bias of 4 ppb, a mean absolute error of 9 ppb, and a root mean square error of 11 ppb. The RV was slightly negative showing that the forecast was essentially equivalent to one based on climatology. The forecast correctly predicted 40 out of the 42 good air quality days, but failed to predict the 2 fair days. The 2 days that were predicted to be fair turned out to be good. There were no predictions of poor air quality days and none were observed during the experiment. Skill scores with respect to both chance and climatology generated negative values indicating that the forecast did not add value to a basic climatological forecast.

7.4.3 T9-Rocky Point Park

Four statistical models and a subjective forecast were verified.

Robertson's MDA Model - This categorical forecast model correctly predicted all 36 good days, but missed all 8 of the fair days which it forecast as good. There were no predictions of poor air quality days and none were observed at this site. Skill scores indicated that this model was not better than one based on chance or climatology.

Robertson's MLR Model - This model exhibited a positive bias of 6 ppb, a mean absolute error of 10 ppb, and a root mean square error of 13 ppb. An RV of 0.40 showed that this model performed better than a climatological forecast. The model correctly predicted 33 of 36 good air quality days and 7 of 8 fair days. It incorrectly forecast 3 of the good days as fair and 1 of the fair days as good. There were no predictions of poor air quality days. Skill scores showed that this model was much better than both chance and climatology and was the best of all the models for the site.

Concord's Model - This model exhibited a positive bias of 9 ppb, a mean absolute error of 12 ppb, and a root mean square error of 15 ppb. An RV of 0.12 showed that this model performed slightly better than climatology. The model correctly predicted 31 of 36 good air quality days and 7 of 8 fair days. It incorrectly forecast 5 of the good days as fair and 1 of the fair days as good. There were no predictions of poor air quality days. Skill scores showed that this model was better than both chance and climatology.

Taylor's MLR Model - The performance of this model was the same as Concord's.

Subjective Forecasts - These forecasts exhibited a positive bias of 8 ppb, a mean absolute error of 12 ppb, and a root mean square error of 16 ppb. An RV of 0.07 showed that these forecasts were only slightly better than climatology. The forecasts correctly predicted 32 of 36 good air quality days and 6 of 8 fair days. They incorrectly forecast 4 of the good days as fair, 1 of the fair days as good and 1 as poor. Skill scores suggest that, when treated as a categorical forecast, these forecasts were better than both chance and climatology. However, they did not improve on the best of the statistical guidance.

7.4.4 T12-Chilliwack

Four statistical models and a subjective forecast were verified.

Robertson's MDA Model - This model correctly predicted 29 of the 34 good days and 4 of the 9 fair days. It incorrectly forecast 4 of the good days as fair and 1 as poor, 3 of the fair days as good and 2 as poor, and it incorrectly forecast the poor day which occurred as fair. Skill scores indicated that this model was better than chance, but not better than climatology.

Robertson's MLR Model - This model exhibited a slight positive bias of 2 ppb, a mean absolute error of 12 ppb, and a root mean square error of 16 ppb. An RV of 0.40 showed that this model performed better than climatology. The model correctly predicted 29 of 34 good air quality days and 4 of 9 fair days. It incorrectly forecast 5 of the good days as fair, 4 of the fair days as good and 1 as poor, and it incorrectly forecast the only poor day which occurred as fair. Skill scores indicate that this model was better than chance, but not better than climatology.

Concord's Model - This model exhibited a slight positive bias of 2 ppb, a mean absolute error of 11 ppb, and a root mean square error of 15 ppb. An RV of 0.48 showed that this model performed better than climatology. The model correctly predicted 30 of 34 good air quality days and 6 of 9 fair days. It incorrectly forecast 4 of the good days as fair, 3 of the fair days as good, and it incorrectly forecast the poor day which occurred as fair. Skill scores indicate that this model was better than both chance and climatology and was the best of all the models for the site.

Taylor's MLR Model - This model exhibited a positive bias of 6 ppb, a mean absolute error of 14 ppb, and a root mean square error of 17 ppb. An RV of 0.35 showed that this model performed better than climatology. The model correctly predicted 25 of 34 good air quality days and 7 of 9 fair days. It incorrectly forecast 9 of the good days as fair, 2 of the fair days as good, and it incorrectly forecast the only poor day which occurred as fair. Skill scores indicate that this model was better than chance, but not better than climatology.

Subjective Forecasts - These forecasts exhibited a positive bias of 5 ppb, a mean absolute error of 13 ppb, and a root mean square error of 17 ppb. An RV of 0.30 showed that these forecasts were better than climatology. The forecasts correctly predicted 29 of 34 good air quality days and 4 of 9 fair days. They incorrectly forecast 3 of the good days as fair and 2 as poor, 2 of the fair days as good and 3 as poor, and the only poor day that occurred was incorrectly forecast as a fair day. Skill scores suggest that, when treated as a categorical forecast, these forecasts were better than chance, but not better than climatology. However, they did not improve on the best of the objective guidance.

7.4.5 T15-Surrey East

Four statistical models and a subjective forecast were verified.

Robertson's MDA Model - This model correctly predicted 30 of the 35 good days and 6 of the 9 fair days. It incorrectly forecast 5 of the good days as fair and 3 of the fair days as good. There were no poor air quality days and none were predicted by the model . Skill scores indicated that this model was better than both chance and climatology.

Robertson's MLR Model - This model exhibited a slight positive bias of 4 ppb, a mean absolute error of 9 ppb, and a root mean square error of 11 ppb. An RV of 0.33 showed that the model also performed better than climatology. The model correctly predicted 33 of 35 good air quality days and 6 of 9 fair days. It incorrectly forecast 2 of the good days as fair and 3 of the fair days as good. There were no predictions of poor air quality days. Skill scores indicate that this model was better than both chance and climatology and was the best of all the models for the site.

Concord's Model - This model exhibited a positive bias of 7 ppb, a mean absolute error of 11 ppb, and a root mean square error of 13 ppb. An RV of 0.01 showed that this model was equivalent to a climatological forecast. The model correctly predicted 29 of 35 good air quality days and 7 of 9 fair days. It incorrectly forecast 6 of the good days as fair and 2 of the fair days as good. There were no predictions of poor air quality days. Skill scores indicate that the forecasts from this model, when treated categorically, were better than both chance and climatology.

Taylor's MLR Model - This model exhibited a positive bias of 8 ppb, a mean absolute error of 11 ppb, and a root mean square error of 13 ppb. An RV of 0.04 showed that this model performed little better than climatology. The model correctly predicted 27 of 35 good air quality days and 7 of 9 fair days. It incorrectly forecast 8 of the good days as fair and 2 of the fair days as good. There were no predictions of poor air quality days. Skill scores indicate that this model was better than chance, but not better than climatology.

Subjective Forecasts - These forecasts exhibited a positive bias of 6 ppb, a mean absolute error of 11 ppb, and a root mean square error of 14 ppb. An RV of -0.02 showed that these forecasts were equivalent to a climatological forecast. The forecasts correctly predicted 31 of 35 good air quality days and 7 of 9 fair days. They incorrectly forecast 4 of the good days as fair and 2 of the fair days as good. There were no predictions of poor air quality days. Skill scores indicate that, when treated categorically, these forecasts were better than both chance and climatology. However, they did not improve on the best of the objective guidance.

7.4.6 T16-Pitt Meadows

This was the second of four stations for which there were no statistical models to use as objective guidance. Subjective forecast were written using interpolation and pattern recognition techniques. The forecasts exhibited a positive bias of 8 ppb, a mean absolute error of 12 ppb, and a root mean square error of 15 ppb. The RV score of -0.05 indicated little difference from climatology. The forecasts correctly predicted 29 out of 35 good air quality days and 7 out of 9 fair days. There were 6 incorrect forecasts of good days as fair, 1 incorrectly forecast of a fair day as good and 1 incorrectly forecast of a fair day as poor. There was 1 forecast of poor air quality day, but no occurrences. The forecast was better than both chance and climatology.

7.4.7 T17-Richmond South

Three statistical models and a subjective forecast were verified. Note that only 34 forecasts were made for this site. On the other 10 forecast days, the ozone measuring sensor at T17 was inoperative.

Robertson's MLR Model - This model exhibited a slight positive bias of 2 ppb, a mean absolute error of 9 ppb, and a root mean square error of 10 ppb. An RV of 0.19 showed that this model performed better than climatology. The model correctly predicted all 30 good air quality days, but incorrectly forecast the 4 fair days which occurred as good. There were no predictions of poor air quality days and none occurred. Skill scores indicated that the model was equivalent to climatology.

Concord's Model - This model exhibited no bias, a mean absolute error of 9 ppb, and a root mean square error of 11 ppb. An RV of 0.10 showed that this model was slightly better than climatology. In all other respects, the performance of this model matched that of Robertson's.

Taylor's MLR Model - This model exhibited a small positive bias of 4 ppb, a mean absolute error of 8 ppb, and a root mean square error of 10 ppb. An RV of 0.20 showed that this model performed better than climatology. The model correctly predicted all 30 good air quality days and 1 of the 4 fair days. It incorrectly forecast 3 of the 4 fair days as good. There were no predictions of poor air quality days. Skill scores indicate that this model was better than both chance and climatology and was the best of all the models for the site.

Subjective Forecasts - These forecasts exhibited a small positive bias of 3 ppb, a mean absolute error of 9 ppb, and a root mean square error of 11 ppb. An RV of 0.01 showed that these forecasts were little different from a climatological forecast. The forecasts correctly predicted 29 of 30 good air quality days, but incorrectly forecast 1 good day as fair and the 4 fair days which occurred as good. There were no predictions of poor air quality days. Skill scores indicate that these forecasts were not better than either chance or climatology and they made no improvements on the objective guidance.

7.4.8 T26-Mahon Park (North Shore)

This was the third of four stations for which there were no statistical models to use as objective guidance. Subjective forecast were written using interpolation and pattern recognition techniques. The forecasts exhibited a small positive bias of 3 ppb, a mean absolute error of 11 ppb, and a root mean square error of 13 ppb. The RV score of -0.16 indicated the forecasts were not better than climatology. The forecasts correctly predicted 38 out of 41 good air quality days and 2 out of 3 fair days. There were 3 incorrect forecasts of good days as fair and 1 incorrectly forecast of a fair day as good. There were no forecasts of poor air quality days and none occurred. The forecast was better than chance but not better than climatology.

7.4.9 T27-Langley

This was the last of four stations for which there were no statistical models to use as objective guidance. Subjective forecast were written using interpolation and pattern recognition techniques. The forecasts exhibited a positive bias of 6 ppb, a mean absolute error of 10 ppb, and a root mean square error of 14 ppb. The RV score of 0.13 indicated the forecasts were better than climatology. The forecasts correctly predicted 28 out of 31 good air quality days and 9 out of 13 fair days. There were 3 incorrect forecasts of good days as fair, 3 incorrect forecasts of a fair day as good, and 1 incorrectly forecast of a fair day as poor. There were no forecasts of poor air quality days and none occurred. The forecast was much better than both chance and climatology.

7.4.10 T28-Downtown Abbotsford

Four statistical models and a subjective forecast were verified. It should be noted that the statistical models were developed on data obtained at Abbotsford Airport, whereas the models were applied to a site in Downtown Abbotsford. This appears to have had little effect on the accuracy of the model as verification results compare well with those at other sites.

Robertson's MDA Model - This model correctly predicted 29 of the 33 good days and 6 of the 10 fair days. It incorrectly forecast 3 of the good days as fair and 1 as poor, 2 of the fair days as good and 2 as poor, and it incorrectly forecast the poor day which occurred as fair. Skill scores indicated that this model was better than both chance and climatology.

Robertson's MLR Model - This model exhibited a positive bias of 7 ppb, a mean absolute error of 12 ppb, and a root mean square error of 15 ppb. An RV of 0.29 showed that this model performed better than climatology. The model correctly predicted 29 of 33 good air quality days and 7 of 10 fair days. It incorrectly forecast 4 of the good days as fair, 3 of the fair days as good, and it incorrectly forecast the only poor day which occurred as fair. Skill scores indicate that this model was better than both chance and climatology.

Concord's Model - This model exhibited a positive bias of 6 ppb, a mean absolute error of 11 ppb, and a root mean square error of 14 ppb. An RV of 0.42 showed that this model performed better than climatology. The model correctly predicted 30 of 33 good air quality days and 8 of 10 fair days. It incorrectly forecast 3 of the good days as fair, 2 of the fair days as good, and it incorrectly forecast the poor day which occurred as fair. Skill scores indicate that this model was better than both chance and climatology and was the best of all the models for the site.

Taylor's MLR Model - This model exhibited a positive bias of 9 ppb, a mean absolute error of 13 ppb, and a root mean square error of 16 ppb. An RV of 0.24 showed that this model performed better than climatology. The model correctly predicted 27 of 33 good air quality days and 9 of 10 fair days. It incorrectly forecast 6 of the good days as fair, 1 of the fair days as good, and it incorrectly forecast the only poor day which occurred as fair. Skill scores indicate that this model was better than both chance and climatology.

Subjective Forecasts - These forecasts exhibited a positive bias of 8 ppb, a mean absolute error of 13 ppb, and a root mean square error of 16 ppb. An RV of 0.20 showed that these forecasts were better than climatology. The forecasts correctly predicted 30 of 33 good air quality days and 6 of 10 fair days. They incorrectly forecast 3 of the good days as fair, 2 of the fair days as good and 2 as poor, and the only poor day that occurred was incorrectly forecast as fair. Skill scores suggest that, when treated as a categorical forecast, these forecasts were better than both chance and climatology. However, they did not improve on the best of the objective guidance.

7.4.11 Regional Models

One statistical model and a subjective forecast were verified.

Concord's Regional Model - This model exhibited a positive bias of 7 ppb, a mean absolute error of 11 ppb, and a root mean square error of 14 ppb. An RV of 0.39 showed that the model performed better than climatology. The model correctly predicted 21 of 30 good air quality days and 8 of 13 fair days. It incorrectly forecast 9 of the good days as fair, 3 of the fair days as good and 2 as poor, and it incorrectly forecast the poor day which occurred as fair. Skill scores indicate that this model was better than chance, but not better than climatology.

Subjective Forecasts - These forecasts exhibited a positive bias of 6 ppb, a mean absolute error of 11 ppb, and a root mean square error of 15 ppb. An RV of 0.33 showed that these forecasts were better than climatology. The forecasts correctly predicted 21 of 30 good air quality days and 6 of 13 fair days. They incorrectly forecast 8 of the good days as fair and 1 as poor, 3 of the fair days as good and 4 as poor, and the only poor day that occurred was incorrectly forecast as fair. Skill scores suggest that, when treated as a categorical forecast, these forecasts were better than chance, but not better than climatology. However, they did not improve on the best of the objective guidance.

7.4.12 Differences between models and their significance

A summary of the continuous variable verification statistics for all the forecasts is given in figure 15. An examination of these statistics show that differences in the biases and mean absolute errors between the models were small in comparison with the standard deviations of their error distributions. In fact, the largest of these differences was 4 ppb. When a standard paired difference test was applied to these differences, it showed that differences were not statistically significant at the $\alpha = 0.05$ level until they exceeded 3 ppb. Therefore, statistically, it cannot be argued that one of the forecast models at a site was more accurate than another at this level of significance. Operationally, the guidance forecasts from the statistical models were considered equivalent if the differences were less than 5 ppb, as this was generally regarded as the level of precision used when the subjective forecast was written.

7.4.13 Evaluation of the air quality advisories issued during the experiment

Air quality advisories were issued on 5 occasions during the experiment. On 4 of these occasions, the air quality was observed to be fair and on one occasion the air quality was good. There was only one day on which the air quality was poor, July 30th, and the forecast for that day was for fair air quality. Forecast errors on those days when an advisory was in effect ranged between 8 and 42 ppb with an average error of

20 ppb. A detailed study of the meteorological conditions in the region on these 5 days has not as yet been investigated.

8. DISCUSSION OF ERRORS

Errors in the output from the statistical models can be traced to two sources; errors in the values of the predictors supplied to the regression equation and the error of the regression equation itself. As discussed in section 6, values for 35 input parameters were required in order to generate the objective guidance. Of these, 28 were themselves forecast values containing their own errors. The sensitivity of the model output as a function of predictor error has not been investigated in this paper. However, this sensitivity could be determined by setting these predictor variables to observed values and rerunning the experiment in an a posterior manner. The difference in the verification results so obtained could then be used to separate out the meteorological component of the error from the regression component. This would determine the percentage contribution of the input forecast error to the overall error.

Periodically missing ozone observations at monitoring sites also contributed to the error. The daily maximum ozone concentrations on the day prior to the valid day was an important predictor in all the regression equations. Values for these had to be forecast at 6 stations and when observations were missing, it made these values much more difficult to predict with any degree of accuracy. The problem was most severe for the Robertson and Taylor MLR models which used more that one station observation in the predictor set. For those models, one station with missing observations could impact the forecast for a number of other stations. The problem was not as acute for the Concord models as these models used only the maximum ozone concentration on the previous day at the forecast site as a predictor and were not dependent on observations from other stations.

9. CONCLUSIONS

This experiment has shown that it is feasible for the PWC to forecast daily 1 hour maximum ground-level ozone concentrations in Greater Vancouver and the Lower Fraser Valley during the period May through September. It showed that these forecasts could be based on statistical ozone forecasting models currently available and could be as good as or better than a forecast based on climatology. Biases could be expected to be less than 10 ppb and root mean square errors could expect to range between 8 and 17 ppb depending on the site being forecast for.

The experiment also showed that there is little difference in accuracy between the statistical models used for objective guidance. None of the four models tested stood out clearly as the best model. For some sites Robertson's MLR model was the best, at other sites Concord's model was the best. However, statistically, at the $\alpha = 0.05$ level of significance, there was no significant difference between them.

An unexpected finding was that the project meteorologist did not improve on the objective guidance. It is the nature of the ozone forecasting problem in the region that good days are relatively frequent and fairly easy to forecast while poor days are infrequent and difficult to forecast. Since it is well known that statistical methods do not handle this type of forecast problem well, it was expected that the project meteorologist would improve on the guidance on poor days by applying his knowledge of the synoptic pattern associated with high ozone levels and therefore outperform the guidance on those occasions. Unfortunately, there was only one day during the experiment when ozone levels exceeded 82 ppb and this was too few to demonstrate the improvement that the meteorologist could make.

10. FORECAST OPTIONS

The experiment has shown that the PWC can support several different air quality service options. The cheapest option would be for the PWC to issue air quality advisories only. This would require forecasting the air quality category with respect to ground-level ozone in the region each day and issuing an advisory when the forecast was for a poor air quality day. Based on climatology, this would happen approximately 6 to 12 times during the year with each occasion consuming about 90 minutes of the forecaster's time. On fair and good days, the assessment would take less than 20 minutes. This option would fulfill AES' basic responsibility with respect to air quality services and provide sufficient information for the public and other government agencies to take appropriate action. Another option is for the PWC to issue forecasts of air quality each day for the region. This would add another 10 minutes to the production time as a product would have to be issued every day. This would be a more useful service to the public and to agencies like the GVRD as it would provide an ongoing forecast service in addition to the advisory service which would allow them to make daily plans. The most expensive option would be to provide a site specific forecast of ozone concentrations each day. This could be done in a text or graphics format and would take approximately 40 minutes per day on good and fair days, but at least 90 minutes on poor days. An investment in data management and display would also be required. This high end option would allow users to make decisions based on their geographic location within the airshed.

11. RECOMMENDATIONS FOR FUTURE WORK

There are several areas that require further research. It is very important for our understanding of the specific meteorological conditions that lead to ozone exceedances in the Lower Fraser Valley that an investigation be made of the weather conditions on the four days during 1992 when maximum ozone concentrations exceeded 82 ppb and compare them to the weather conditions on the five days when an exceedance was forecast but did not occur.

As discussed in section 8, the experiment should be repeated in an a posterior fashion using observed weather and ozone values as inputs in order to separate out the component of the error due to uncertainties in the weather and ozone inputs from the error residing in the regression equations themselves. This will place a lower limit on the accuracy that can be obtained with the current models.

The experiment should also be repeated in an a posterior fashion using inputs from available objective guidance. A comparison of the errors obtained in this way with those generated by human inputs would enable us to determine the increase in value of the forecasts made by meteorologists.

The experiment should be repeated in an a posterior fashion a third time using inputs obtained from data available during the evening. By this time, several of the input parameters to the models are known and so do not need to be forecast. This should reduce the error in the models forecasts. A knowledge of the amount of error reduction would allow us to decide whether an evening issue time for the forecast is preferable to an afternoon issue time.

Significant work must be done on data analysis and display before the production of air quality forecasts can be transferred from research to operations. The experiment used prototype production methods; manual extraction and plotting of data, hand analyses, and spreadsheet calculations. In order to save on production time it is recommended that these procedures be improved through automation. In particular, computer programs must be written to generate trends in hourly data, plot data on demand, and objectively analyze fields of data.

Finally, new methods of generating objective ozone forecasts should be investigated. One of these new methods is called CART which stands for Classification And Regression Trees. Another is Neural Networks. Both these methods have an advantage over classical statistical methods in that they are not limited by non-normal data distributions. Since ozone exceedances are a rare event in the Lower Fraser Valley, it is possible that these methods will generate better results than the statistical models employed in this experiment. Other methods in the realm of Artificial Intelligence are Case Based Reasoning and Expert Systems. Case Based Reasoning may tell us which are the most important predictors of ozone exceedances. These predictors could then be used to develop an Expert System for predicting exceedances.

12. ACKNOWLEDGMENTS

I would like to thank the following people for their assistance in this project: Kirk Johnstone of AISB for funding the project, Ken Stubbs of the GVRD for his cooperation with AES Pacific Region and many useful suggestions, Les Fraser and Al Percival also of the GVRD for their help in acquiring the data, Carol Evans of AISB for drawing many of the illustrations in the report, and Bruce Thomson of AISB and Kelsey Spring of PWC for their supervision.

13. REFERENCES

CCME-EPC/TRE-31E, 1990: Management Plan for Nitrogen Oxides (NO_X) and Volatile Organic Compounds (VOCs) Phase I, November 1990.

Ciccone, A., et al., 1992: A Statistical Ozone Forecasting Model for the Lower Fraser Valley. Consultant's report prepared for the Air Quality Unit of AISB, Pacific Region, April 1992.

Robertson, E., 1992: Statistical Approaches to Forecasting Ground-Level Ozone. Consultant's report prepared for the Air Quality Unit of AISB, Pacific Region, March 1992.

Robeson, S.M. and Steyn, D.G., 1990: Evaluation and Comparison of Statistical Forecast Models for Daily Maximum Ozone Concentrations. Atmospheric Environment, 24B:2, pp. 303-312.

Stanski, H.R., Wilson, L.J. and Burrows, W.R., 1989: Survey of Common Verification Methods in Meteorology. Meteorological Services Research Branch Research Report No. 89-5, July 1989.

Taylor, E., 1991: Forecasting Ground-Level Ozone in Vancouver and the Lower Fraser Valley of British Columbia. Pacific Region Scientific Services Division Report PAES-91-3, November 22, 1991.

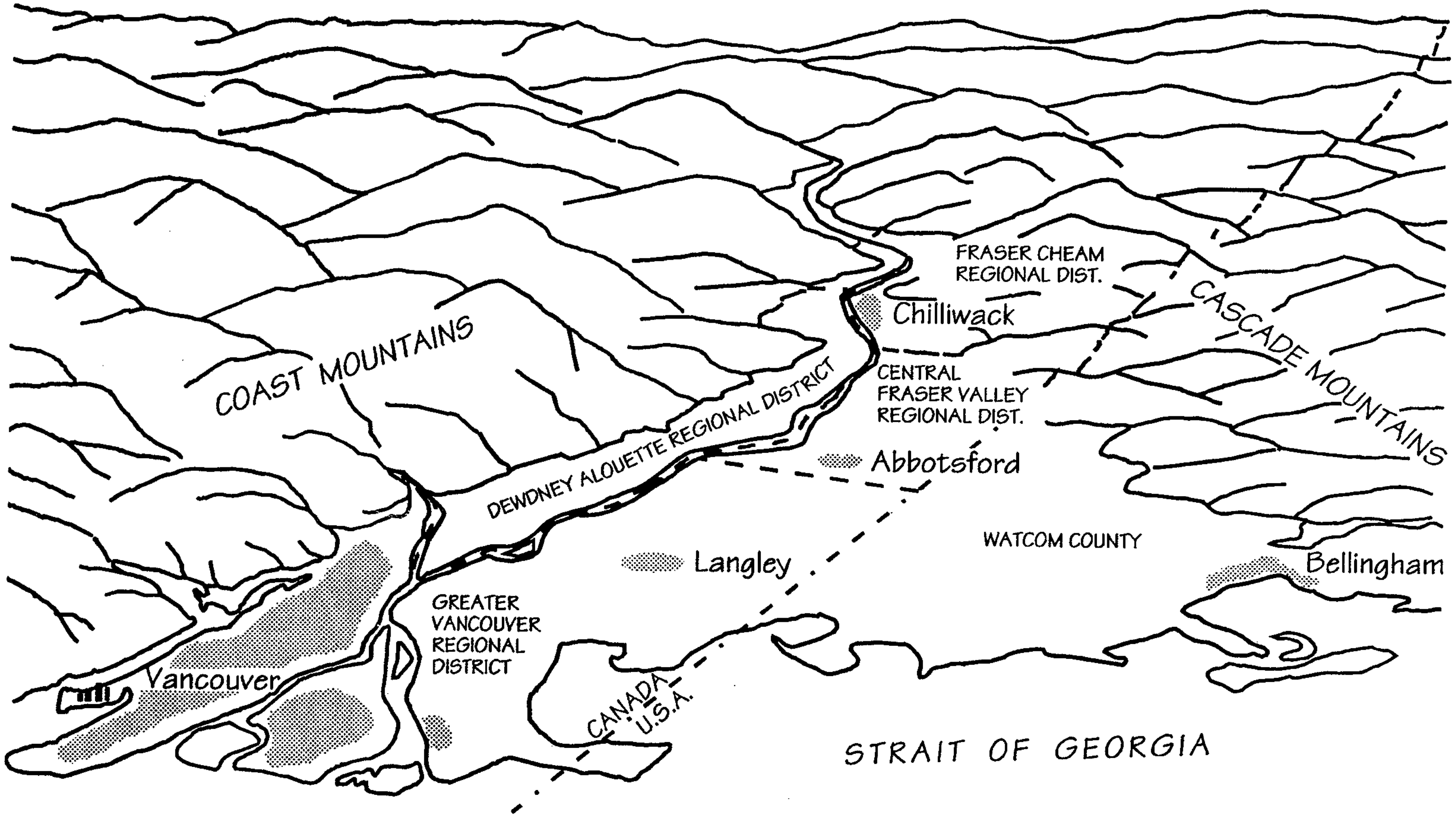
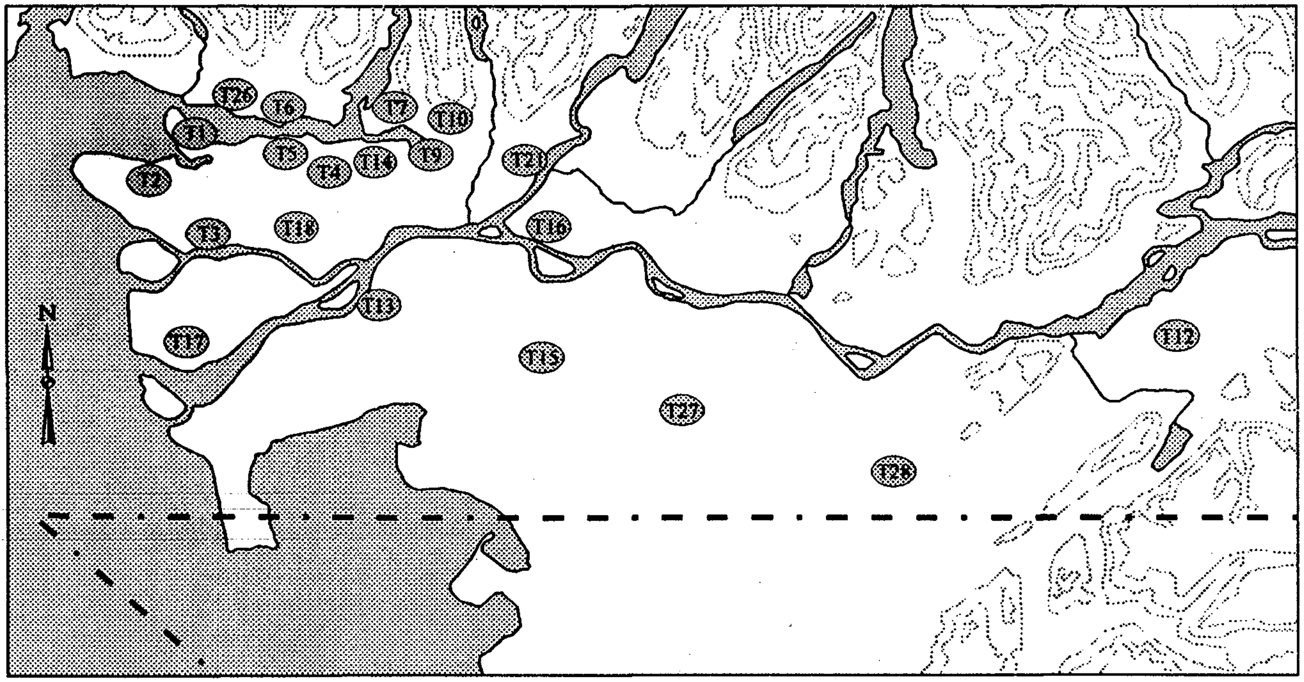


Figure 1.

Schematic diagram of the Lower Mainland showing the Greater Vancouver region and the western portions of the Lower Fraser Valley.



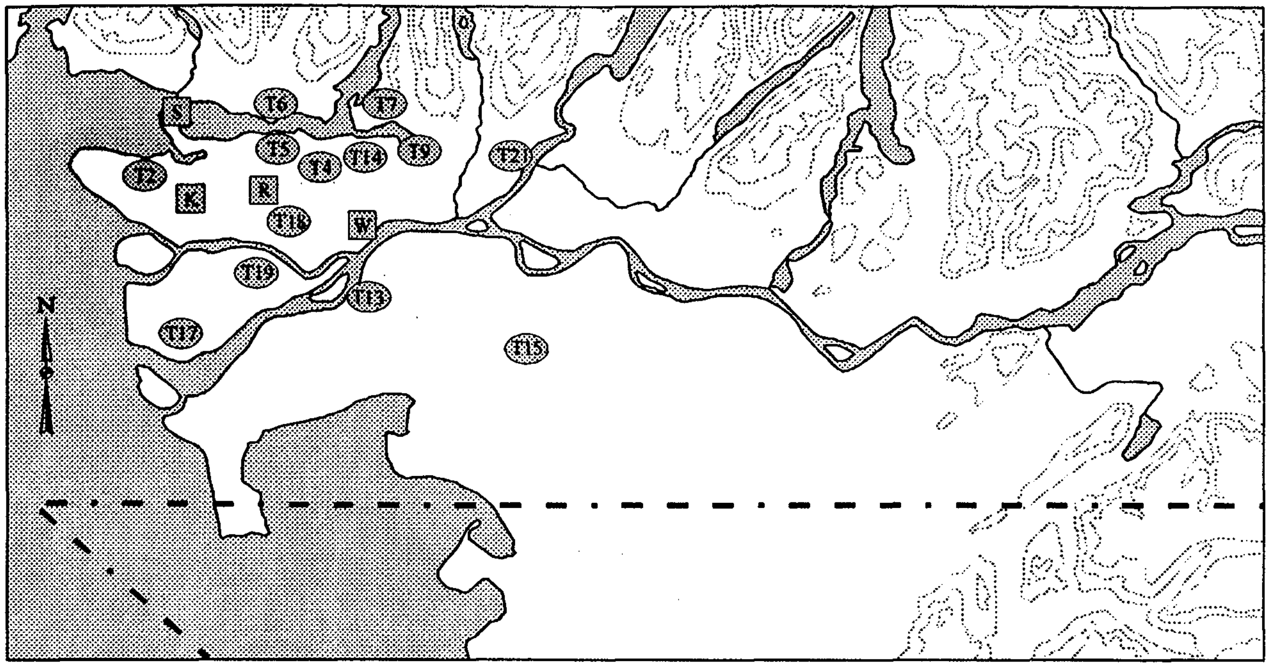
LEGEND

T1	Robson Square
T2	Kitsilano
T3	Marpole
T4	Kensington Park
T5	Confederation Park
T6	Second Narrows
T7	Anmore
T9	Rocky Point Park
T10	Eagle Ridge
T12	Chilliwack Works Yard
T13	North Delta
T14	Burnaby Mountain
T15	Surrey East
T16	Pitt Meadows
T17	Richmond South
T18	Burnaby South
T21	Port Coquitlam North
T26	Mahon Park
T27	Langley
T28	Downtown Abbotsford

Contour Interval = 300 metres

0 10 20 km

Figure 2.
A map of the GVRD air quality monitoring network showing the location of stations which measure ground-level ozone.



LEGEND

S	Stanley Park (R)
R	Renfrew (R)
K	Kersland (R)
W	Westburnco Reservoir (R)
T2	Kitsilano (W R)
T4	Kensington Park (W)
T5	Confederation Park (T W R)
T6	Second Narrows (W R)
T7	Anmore (T W)
T9	Rocky Point Park (T W R)
T13	North Delta (T W R)
T14	Burnaby Mountain (T W R)
T15	Surrey East (T W R)
T17	Richmond South (T W)
T18	Burnaby South (T W)
T19	Richmond East (T W)
T27	Langley (T W)

T = Temperature
W = Wind
R = Rain Gauge

Contour Interval = 300 metres

0 10 20 km

Figure 3.

A map of the GVRD air quality monitoring network showing the location of stations which measure air temperature wind speed and direction and rainfall amounts

SXCN33 GVRD 282220

GVRD **1st QUARTER HOUR**

Location	DateTime (GMT)	T (Cel)	WD (Deg)	WSS (km/h)	Gust (km/h)	RF (mm)	
Stanley Park	282215					0.0	
Kitsilano	282215		176	005	005	0.0	
Kensington Park	282215		167	001	003		
Confederation Park	282215	21.0	114	002	005	0.0	
Renfrew	282215					0.0	
Second Narrows	282215		125	003	005	0.0	
Kersland	282215					0.0	
Westburnco Reservoir	282215					0.0	
Anmore	282215	20.4	225	000	001		
Rocky Point Park	282215	19.7	201	000	005	0.0	
North Delta	282215	19.2	155	000	007	0.0	
Burnaby Mountain	282215	21.4	135	007	011	0.0	
Surrey East	282215	17.8	141	002	005	0.0	
Richmond South	282215	19.3	095	004	004		
Burnaby South	282215	20.3	183	002	003		
Richmond East	282215	19.8	360	000	000		
Langley	282215	19.4	215	003	006		

\\

METEOROLOGICAL REPORT
HOURLY

Location	DateTime (GMT)	T (Cel)	WD (Deg)	WSS (km/h)	Gust (km/h)	RF (mm)	OZ (ppb)
Robson Square	282200						2
Stanley Park	282200					0.0	
Kitsilano	282200		212	005	006	0.0	3
Marpole	282200					0.0	6
Kensington Park	282200		133	004	006		14
Confederation Park	282200	20.5	090	004	010	0.0	31
Renfrew	282200					0.0	
Second Narrows	282200		112	001	011	0.0	16
Kersland	282200					0.0	
Westburnco Reservoir	282200					0.0	
Anmore	282200	20.1	225	000	005		15
Rocky Point Park	282200	20.5	275	000	004	0.0	14
Eagle Ridge	282200						7
Chilliwack Works Yard	282200						21
North Delta	282200	18.8	113	001	005	0.0	12
Burnaby Mountain	282200	21.4	108	002	011	0.0	22
Surrey East	282200	17.4	128	002	005	0.0	***
Pitt Meadows	282200						24
Richmond South	282200	19.2	178	001	006		16
Burnaby South	282200	20.3	215	001	006		11
Richmond East	282200	19.6	227	000	005		
Port Coquitlam North	282200						22
Mahon Park	282200						30
Langley	282200	19.7	116	004	008		27
Downtown Abbotsford	282200						13

//

*** Indicates data unavailable

Data accumulation based on less than 100% of available data

Figure 4.

GVRD Meteorological Bulletin with quarterly hour weather reports and hourly weather and ozone reports.

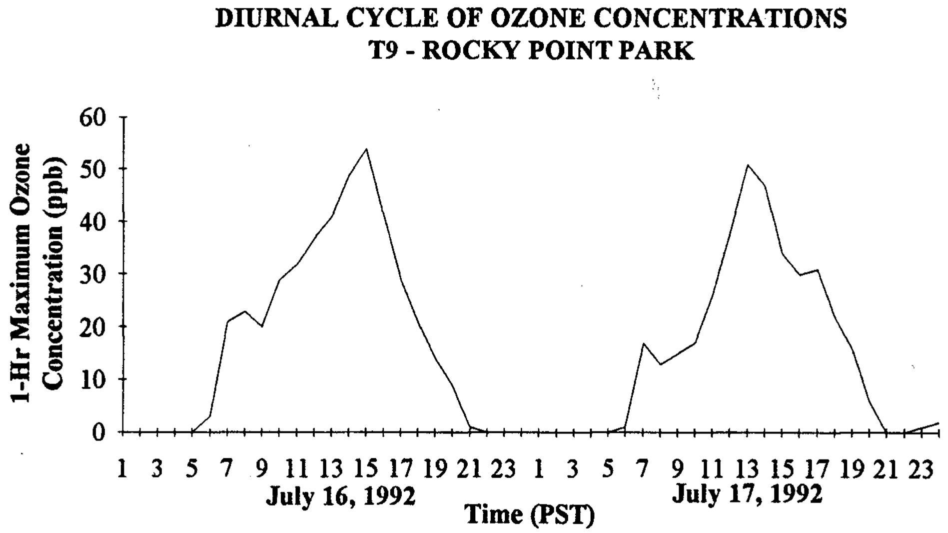


Figure 5.
Example of a normal diurnal cycle of ozone concentrations. This example was taken from measurements made at T9-Rocky Point Park between 0100 PST 16 July 1992 and 2400 PST 17 July 1992.

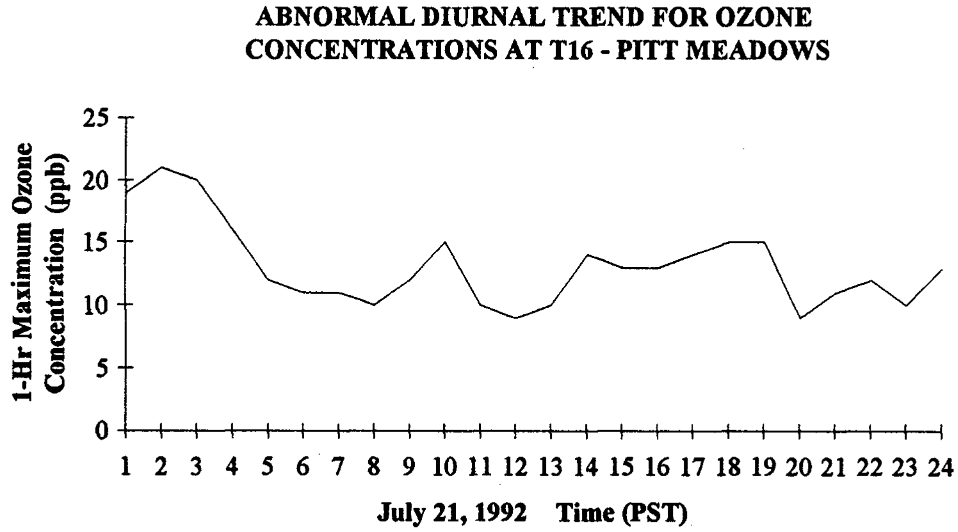


Figure 6.
Example of an abnormal diurnal trend for ozone concentrations. This example was taken from measurements made at T16-Pitt Meadows between 0100 PST and 2400 PST on 21 July 1992.

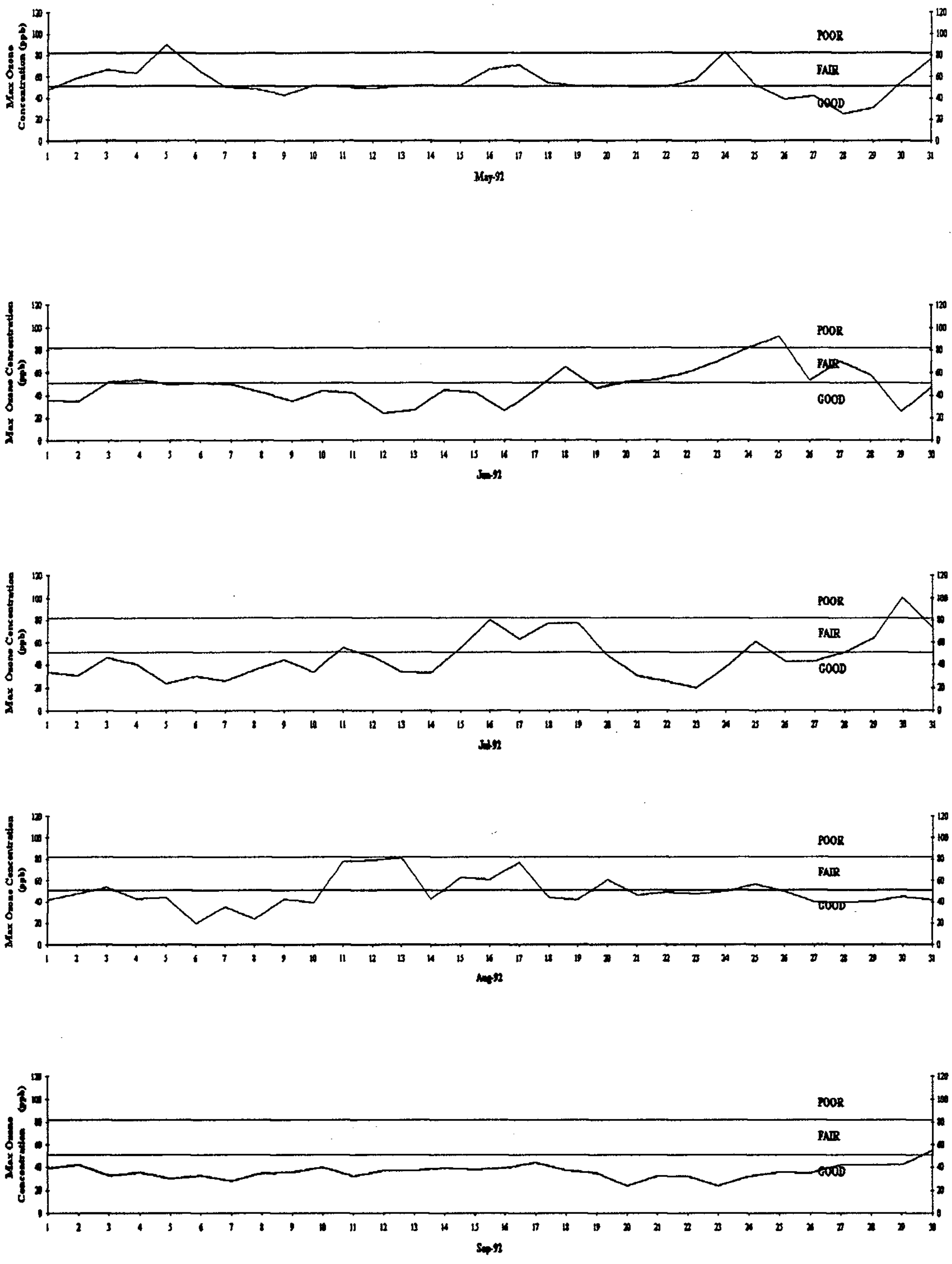


Figure 7.
Chart of the daily 1 hour maximum ozone concentrations measured within Greater Vancouver and the Lower Fraser Valley during the 1992 ozone forecasting season which occurred between May 1st and September 30th.

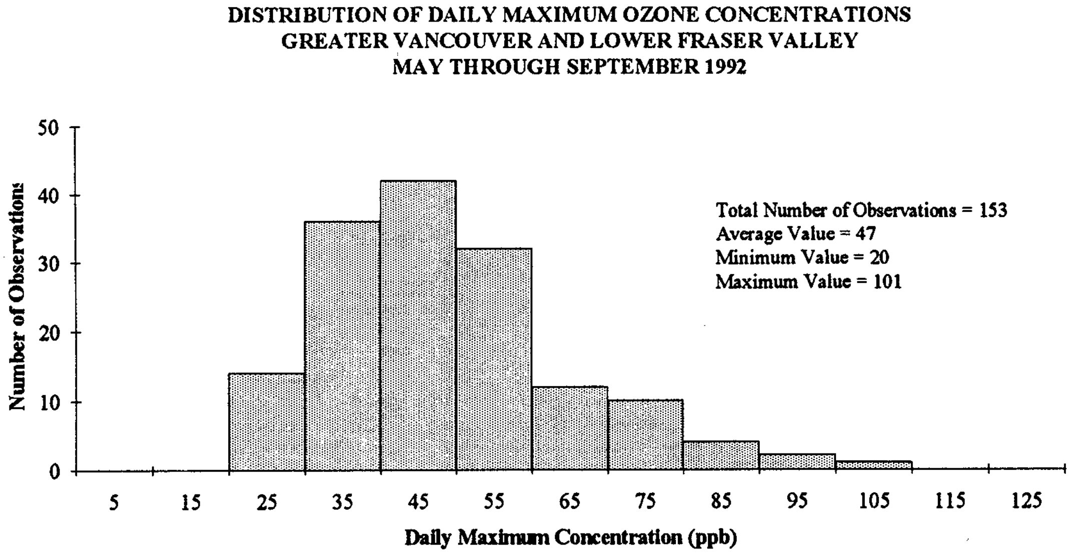
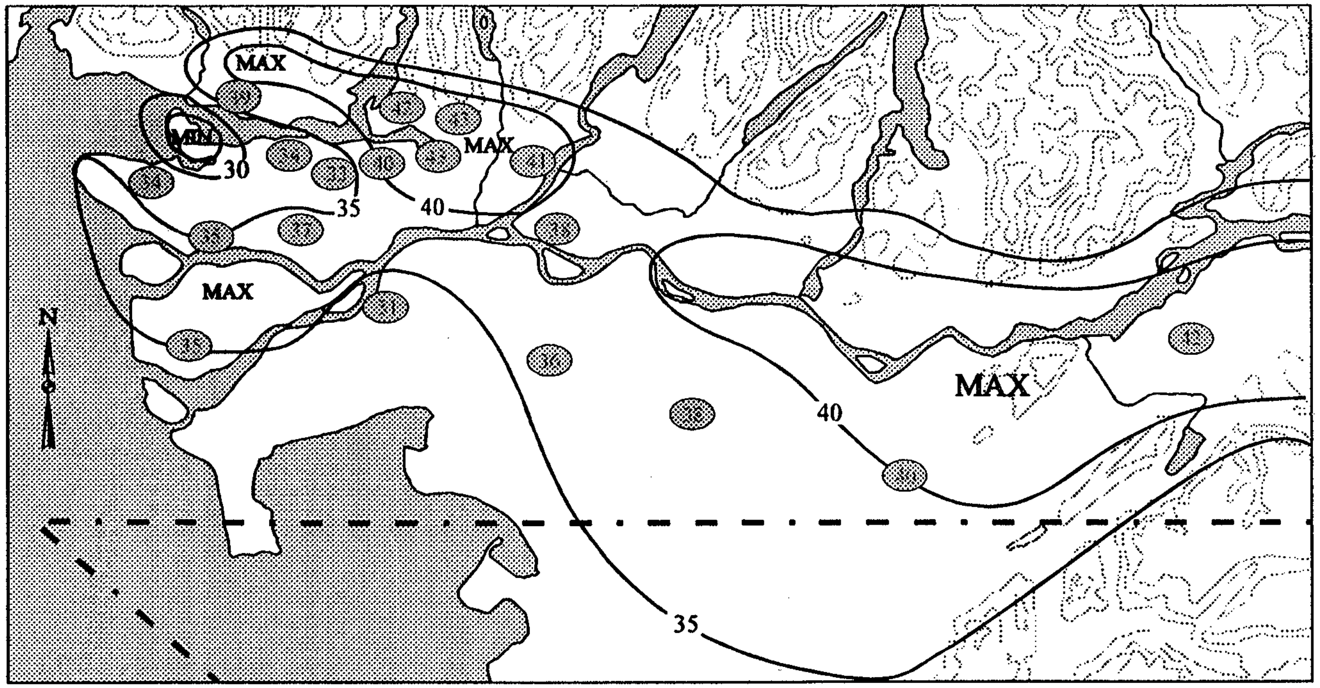


Figure 8.
Distribution of the daily 1 hour maximum ozone concentrations measured in Greater Vancouver and the Lower Fraser Valley during 1992. The class interval is 10 ppb.



MAXIMUM DAILY OZONE CONCENTRATIONS (ppb)
July 26, 1992

Values at Stations   Maximum 1 hour ozone concentration (ppb)

Maximum Ozone Concentration Contour Interval   5 ppb

Height Contour Interval   300 metres

0   10   20 km

Figure 9.
An analysis of the daily 1 hour maximum ozone concentrations measured in Greater Vancouver and the Lower Fraser Valley on July 26th, 1992

FACSIMILE TRANSMISSION
FROM
PACIFIC WEATHER CENTRE
ATMOSPHERIC ENVIRONMENT SERVICE
PACIFIC REGION

DATE:	THURSDAY	JULY 30, 1992		
TO:	KEN STUBBS	GVRD	FAX 555-5000	PHONE 555-5001
	DAN CIARNIELLO	UBC	FAX 555-5555	PHONE 555-5554
FROM:	TED LORD	AES	FAX 555-9999	PHONE 555-9998

EXPERIMENTAL GROUND LEVEL OZONE CONCENTRATION FORECAST FOR GREATER VANCOUVER AND THE LOWER FRASER VALLEY ISSUED BY THE PACIFIC WEATHER CENTRE OF ENVIRONMENT CANADA AT 3 PM PDT THURSDAY 30 JULY 1992 FOR FRIDAY. THE NEXT SCHEDULED FORECAST WILL BE ISSUED AT 3 PM FRIDAY 31 JULY 1992.

ALL OZONE CONCENTRATIONS ARE IN PARTS PER BILLION.
THE FORECAST IS FOR THE MAXIMUM ONE-HOURLY CONCENTRATION EXPECTED FOR THE DAY.

STATION		FORECAST
T1	ROBSON SQUARE	20
T26	NORTH SHORE	55
T4	KENSINGTON PARK	55
T17	RICHMOND SOUTH	50
T9	ROCKY POINT PARK	85
T15	SURREY EAST	80
T16	PITT MEADOWS	90
T27	LANGLEY	90
T28	ABBOTSFORD	90
T12	CHILLIWACK	90
REGIONAL MAXIMUM		95

NOTE: AN ADVISORY FOR CONCENTRATIONS OF GROUND LEVEL OZONE IN EXCESS OF 82 PPB HAS BEEN ISSUED FOR FRIDAY.

END/LORD
$$$$

Figure 10.
Example of experimental ozone forecast message with an air quality advisory included.

OZONE FORECAST TASK LIST

(all times are PDT)

TIME	TASK
0800	Plot map of yesterday's maximum ozone concentrations in region and analyze.
0830	Chart yesterday's daily maximum ozone concentration in region on time series graph.
0845	Enter yesterday's observed maximum ozone concentrations in verification data base.
0900	Verify forecast from two days ago that was valid yesterday.
1300	Assess stability of airmass using 12Z Quillayute tephigram.
1315	Assess NWP models for next 24 to 36 hour weather pattern.
1330	Consult with PWC staff regarding current weather elements and the forecast for tomorrow.
1400	Access latest hourly ozone data from GVRD and make trend forecast to determine today's maximum ozone concentrations in the region.
1415	Complete input form and generate objective forecasts for tomorrow's maximum ozone concentration from statistical models.
1420	Make forecast of tomorrow's maximum ozone concentrations at the ten sites plus the regional maximum based on your assessment of the latest trends in ozone concentrations
1430	Phone GVRD to consult on possible air quality advisory if forecast values exceed 82 ppb.
1440	Fax forecast to GVRD and UBC.
1445	Store all input
1450	Write summary describing the reasoning that went into the forecast.

Figure 11.

Tasks performed daily by meteorologist to prepare ozone forecasts.

INPUTS FOR TOMORROW'S FORECAST OF MAXIMUM GROUND-LEVEL OZONE

DESCRIPTION	VALUE
JULIAN DAY	254
AVERAGE MAXIMUM TEMPERATURE AT VANCOUVER	19.1 ° C
AVERAGE MAXIMUM TEMPERATURE AT ABBOTSFORD	21.3 ° C
AVERAGE MAXIMUM TEMPERATURE AT HOPE	22.1 ° C
FORECAST 12Z MSL PRESSURE AT VANCOUVER	1015.0 mb
FORECAST 12Z MSL PRESSURE AT TOFINO	1016.0 mb
FORECAST 12Z MSL PRESSURE AT ABBOTSFORD	1014.5 mb
FORECAST 12Z MSL PRESSURE AT HOPE	1014.0 mb
FORECAST 12Z MSL PRESSURE AT PENTICTON	1013.5 mb
FORECAST 00Z MSL PRESSURE AT VANCOUVER	1016.0 mb
FORECAST 00Z MSL PRESSURE AT TOFINO	1019.0 mb
FORECAST 00Z MSL PRESSURE AT ABBOTSFORD	1015.0 mb
FORECAST 00Z MSL PRESSURE AT HOPE	1014.5 mb
FORECAST 00Z MSL PRESSURE AT PENTICTON	1013.5 mb
TODAY'S MAXIMUM TEMPERATURE AT VANCOUVER	19 ° C
TODAY'S MAXIMUM TEMPERATURE AT ABBOTSFORD	23 ° C
TODAY'S MAXIMUM TEMPERATURE AT HOPE	24 ° C
TOMORROW'S MAXIMUM TEMPERATURE AT VANCOUVER	18 ° C
TOMORROW'S MAXIMUM TEMPERATURE AT ABBOTSFORD	20 ° C
TOMORROW'S MAXIMUM TEMPERATURE AT HOPE	21 ° C
OCCURRENCE OF MEASURABLE RAIN AT VANCOUVER YESTERDAY	NO
OCCURRENCE OF MEASURABLE RAIN AT ABBOTSFORD YESTERDAY	NO
OCCURRENCE OF MEASURABLE RAIN AT HOPE YESTERDAY	NO
OCCURRENCE OF MEASURABLE RAIN AT VANCOUVER TODAY	NO
OCCURRENCE OF MEASURABLE RAIN AT ABBOTSFORD TODAY	NO
OCCURRENCE OF MEASURABLE RAIN AT HOPE TODAY	NO
OCCURRENCE OF MEASURABLE RAIN AT VANCOUVER TOMORROW	YES
OCCURRENCE OF MEASURABLE RAIN AT ABBOTSFORD TOMORROW	YES
OCCURRENCE OF MEASURABLE RAIN AT HOPE TOMORROW	YES
TODAY'S MAXIMUM OZONE CONCENTRATION AT T1-ROBSON SQUARE	10 ppb
TODAY'S MAXIMUM OZONE CONCENTRATION AT T17-RICHMOND SOUTH	35 ppb
TODAY'S MAXIMUM OZONE CONCENTRATION AT T9-ROCKY POINT PARK	30 ppb
TODAY'S MAXIMUM OZONE CONCENTRATION AT T15-SURREY EAST	35 ppb
TODAY'S MAXIMUM OZONE CONCENTRATION AT T28-ABBOTSFORD	30 ppb
TODAY'S MAXIMUM OZONE CONCENTRATION AT T12-CHILLIWACK	30 ppb

Figure 12.
Form used to enter values for the 35 shared predictors used by the statistical forecast models.

SUBJECTIVE FORECAST INPUT FORM

	LOCATION	ROB	ROB	CON	TAY	SUBJ
ID	NAME	CAT	PPB	PPB	PPB	PPB
T1	ROBSON SQUARE	-	17	10	19	10
T26	NORTH SHORE	-	-	-	-	30
T4	KENSINGTON PARK	-	-	-	-	25
T17	RICHMOND SOUTH	-	36	26	39	30
T9	ROCKY POINT PARK	GOOD	32	30	42	25
T15	SURREY EAST	GOOD	38	34	43	30
T16	PITT MEADOWS	-	-	-	-	35
T27	LANGLEY	-	-	-	-	30
T28	ABBOTSFORD	GOOD	37	33	43	30
T12	CHILLIWACK	GOOD	31	29	44	25
	REGIONAL MAXIMUM	-	-	38	-	35

Figure 13.
Subjective forecast input form showing objective forecasts for each station for comparison.

STATION	T1	T4	T9	T12	T15	T16	T17	T26	T27	T28	RGN
POPULATION											
# OBSERVATIONS	153	151	153	142	152	152	108	152	121	153	153
AVERAGE VALUE	19	32	38	40	40	42	36	36	41	39	47
# GOOD	152	144	131	116	130	121	99	143	98	127	104
# FAIR	1	7	22	24	22	29	9	8	23	25	45
# POOR	0	0	0	2	0	2	0	1	0	1	4
% GOOD	99	95	86	82	86	80	92	94	81	83	68
% FAIR	1	5	14	17	14	19	08	5	19	16	29
% POOR	0	0	0	1	0	01	0	1	0	1	3
SAMPLE											
# OBSERVATIONS	44	44	44	44	44	44	34	44	44	44	44
AVERAGE VALUE	18	30	36	41	39	39	34	34	42	40	48
# GOOD	44	42	36	34	35	35	30	41	31	33	30
# FAIR	0	2	8	9	9	9	4	3	13	10	13
# POOR	0	0	0	1	0	0	0	0	0	1	1
% GOOD	100	95	82	78	80	80	88	93	70	75	68
% FAIR	0	5	18	20	20	20	12	7	30	23	30
% POOR	0	0	0	2	0	0	0	0	0	2	2

Figure 14.

A comparison of the distribution of maximum ozone concentrations within Greater Vancouver and the Lower Fraser Valley between the 153 days of the ozone forecasting season and the 44 days during which ozone forecasts were produced.

SUMMARY OF CONTINUOUS VARIABLE VERIFICATION STATISTICS

LOCATION	FCST MODEL	MEAN	BIAS	SD	MAE	RMSE	RV
T1-Robson Sq.	Robertson's MLR	18	0	8	6	8	-0.06
	Concord's		-2	8	6	8	-0.05
	Taylor's MLR		1	8	6	8	0
	Subjective		-1	8	6	8	-0.08
T4-Kens. Pk.	Subjective	30	4	11	9	11	-0.05
T9-Rocky Pt. Pk.	Robertson's MLR	36	6	11	10	13	0.40
	Concord's		9	13	12	15	0.12
	Taylor's MLR		10	12	12	15	0.12
	Subjective		8	14	12	16	0.07
T12-Chilliwack	Robertson's MLR	42	2	16	12	16	0.40
	Concord's		2	15	11	15	0.48
	Taylor's MLR		6	15	14	17	0.35
	Subjective		5	17	13	17	0.30
T15-Surrey East	Robertson's MLR	40	4	10	9	11	0.33
	Concord's		7	12	11	13	0.01
	Taylor's MLR		8	11	11	13	0.04
	Subjective		6	12	11	14	-0.02
T16-Pitt Meadws.	Subjective	40	8	13	12	15	-0.05
T17-Richmond S.	Robertson's MLR	34	2	10	9	10	0.19
	Concord's		0	11	9	11	0.10
	Taylor's MLR		4	10	8	10	0.20
	Subjective		3	11	9	11	0.01
T26-Mahon Park	Subjective	34	3	13	11	13	-0.16
T27-Langley	Subjective	42	6	13	10	14	0.13
T28-Abbotsford	Robertson's MLR	40	7	13	12	15	0.29
	Concord's		6	12	11	14	0.42
	Taylor's MLR		9	13	13	16	0.24
	Subjective		8	14	13	16	0.20
Regional	Concord's	49	7	13	11	14	0.39
	Subjective		6	14	11	15	0.33

Figure 15.

A summary of the continous variable verification statistics for all the models and the subjective forecasts. The statistics shown are as follows: the MEAN is the average observed daily 1 hour maximum ozone concentration observed at the site during the 44 forecast days of the experiment, the BIAS is the average error in the forecast, SD is the standard deviation of the errors, the MAE is the mean absolute error, the RMSE is the root mean square error, and the RV is the reduction of variance of the errors. All numbers are recorded to the nearest ppb.

APPENDIX 1

Following is a list of the parameters which E. Taylor, Emily Robertson, and Concord Environmental used to derive their statistical ozone forecasting models. The data base consisted of 5 years of data from 1985 through 1989 (765 days) with a record for each day containing observed values for the following 38 parameters:

P1	12Z Pressure differential between Vancouver and Abbotsford
P2	12Z Pressure differential between Vancouver and Tofino
P3	12Z Pressure differential between Vancouver and Hope
P4	12Z Pressure differential between Vancouver and Penticton
P5	00Z Pressure differential between Vancouver and Abbotsford
P6	00Z Pressure differential between Vancouver and Tofino
P7	00Z Pressure differential between Vancouver and Hope
P8	00Z Pressure differential between Vancouver and Penticton
P9	Maximum daily temperature for Vancouver International Airport
P10	Maximum daily temperature for Agassis
P11	Maximum daily temperature for Hope
P12	Maximum daily temperature for Abbotsford Airport
P13	Maximum daily temperature for Haney
P14	Maximum daily temperature for Chilliwack
P15	24-hour precipitation amount for Vancouver International Airport
P16	24-hour precipitation amount for Agassiz
P17	24-hour precipitation amount for Hope
P18	24-hour precipitation amount for Abbotsford Airport
P19	24-hour precipitation amount for Haney
P20	24-hour precipitation amount for Chilliwack
P21	Daily 1-hr maximum ozone concentration for T1-Robson Square
P22	Daily 1-hr maximum ozone concentration for T9-Rocky Point Park
P23	Daily 1-hr maximum ozone concentration for T17-Richmond South
P24	Daily 1-hr maximum ozone concentration for T15-Surrey East
P25	Daily 1-hr maximum ozone concentration for T11-Abbotsford Airport
P26	Daily 1-hr maximum ozone concentration for T12-Chilliwack
P27	Yesterday's daily 1-hr maximum ozone concentration for T1-Robson Square
P28	Yesterday's daily 1-hr maximum ozone concentration for T9-Rocky Point Park
P29	Yesterday's daily 1-hr maximum ozone concentration for T17-Richmond South
P30	Yesterday's daily 1-hr maximum ozone concentration for T15-Surrey East
P31	Yesterday's daily 1-hr maximum ozone concentration for T11-Abbotsford Airport
P32	Yesterday's daily 1-hr maximum ozone concentration for T12-Chilliwack
P33	Daily temperature anomoly for Vancouver International Airport
P34	Daily temperature anomoly for Agassiz
P35	Daily temperature anomoly for Hope
P36	Daily temperature anomoly for Abbotsford Airport
P37	Daily temperature anomoly for Haney
P38	Daily temperature anomoly for Chilliwack.

Note that the ozone monitoring site T11-Abbotsford Airport was changed to T28-Downtown Abbotsford in 1992. There were only small differences in the measured ozone concentrations between the two sites in 1992 and the error in applying the regression equations developed on data from T11 using current measurements from T28 was negligible.

APPENDIX 2

Following is a complete set of verification statistics covering all 34 sets of forecasts.

VERIFICATION STATISTICS

FORECAST MODEL: Robertson's MLR
LOCATION: T1-Robson Square

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	18
Bias:	0
Error variance:	62
Standard deviation of errors:	8
Mean absolute error:	6
Root mean square error:	8
Reduction of variance:	-0.06

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

O		GOOD (0-51 ppb)	FAIR (52-82 ppb)	POOR (>82 ppb)	TOTAL
B S	**GOOD (0-51 ppb)**	44	0	0	44
E R	**FAIR (52-82 ppb)**	0	0	0	0
V E	**POOR (>82 ppb)**	0	0	0	0
D	**TOTAL**	44	0	0	44

Percent correct:	100
Post agreement of "Good" category:	1.00
Post agreement of "Fair" category:	-
Post agreement of "Poor" category:	-
Prefigurance of "Good" category:	1.00
Prefigurance of "Fair" category:	-
Prefigurance of "Poor" category:	-
Bias of "Good" category:	1.00
Bias of "Fair" category:	-
Bias of "Poor" category:	-

Heidke skill score w.r.t. chance:	-
Heidke skill score w.r.t. sample climatology:	-

VERIFICATION STATISTICS

FORECAST MODEL:	Concord's
LOCATION:	T1-Robson Square

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	18
Bias:	-2
Error variance:	57
Standard deviation of errors:	8
Mean absolute error:	6
Root mean square error:	8
Reduction of variance:	-0.05

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	**FAIR (52-82 ppb)**	**POOR (>82 ppb)**	**TOTAL**
OBSERVED	**GOOD (0-51 ppb)**	44	0	0	44
	FAIR (52-82 ppb)	0	0	0	0
	POOR (>82 ppb)	0	0	0	0
	TOTAL	44	0	0	44

Percent correct:	100
Post agreement of "Good" category:	1.00
Post agreement of "Fair" category:	-
Post agreement of "Poor" category:	-
Prefigurance of "Good" category:	1.00
Prefigurance of "Fair" category:	-
Prefigurance of "Poor" category:	-
Bias of "Good" category:	1.00
Bias of "Fair" category:	-
Bias of "Poor" category:	-
Heidke skill score w.r.t. chance:	-
Heidke skill score w.r.t. sample climatology:	-

VERIFICATION STATISTICS

FORECAST MODEL: Taylor's MLR
LOCATION: T1-Robson Square

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified: 44
Observed sample mean: 18
Bias: 1
Error variance: 58
Standard deviation of errors: 8
Mean absolute error: 6
Root mean square error: 8
Reduction of variance: 0

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	FAIR (52-82 ppb)	POOR (>82 ppb)	TOTAL
OBSERVED	**GOOD (0-51 ppb)**	44	0	0	44
	FAIR (52-82 ppb)	0	0	0	0
	POOR (>82 ppb)	0	0	0	0
	TOTAL	44	0	0	44

Percent correct: 100
Post agreement of "Good" category: 1.00
Post agreement of "Fair" category: -
Post agreement of "Poor" category: -
Prefigurance of "Good" category: 1.00
Prefigurance of "Fair" category: -
Prefigurance of "Poor" category: -
Bias of "Good" category: 1.00
Bias of "Fair" category: -
Bias of "Poor" category: -
Heidke skill score w.r.t. chance: -
Heidke skill score w.r.t. sample climatology: -

VERIFICATION STATISTICS

FORECAST MODEL:	Subjective
LOCATION:	T1-Robson Square

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	18
Bias:	-1
Error variance:	63
Standard deviation of errors:	8
Mean absolute error:	6
Root mean square error:	8
Reduction of variance:	-0.08

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

O		**GOOD (0-51 ppb)**	**FAIR (52-82 ppb)**	**POOR (>82 ppb)**	**TOTAL**
B S	**GOOD (0-51 ppb)**	44	0	0	44
E R	**FAIR (52-82 ppb)**	0	0	0	0
V E	**POOR (>82 ppb)**	0	0	0	0
D	**TOTAL**	44	0	0	44

Percent correct:	100
Post agreement of "Good" category:	1.00
Post agreement of "Fair" category:	-
Post agreement of "Poor" category:	-
Prefigurance of "Good" category:	1.00
Prefigurance of "Fair" category:	-
Prefigurance of "Poor" category:	-
Bias of "Good" category:	1.00
Bias of "Fair" category:	-
Bias of "Poor" category:	-
Heidke skill score w.r.t. chance:	-
Heidke skill score w.r.t. sample climatology:	-

VERIFICATION STATISTICS

FORECAST MODEL:	Subjective
LOCATION:	T4-Kensington Park

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	30
Bias:	4
Error variance:	115
Standard deviation of errors:	11
Mean absolute error:	9
Root mean square error:	11
Reduction of variance:	-0.05

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	**FAIR (52-82 ppb)**	**POOR (>82 ppb)**	**TOTAL**
OBSERVED	**GOOD (0-51 ppb)**	40	2	0	42
	FAIR (52-82 ppb)	2	0	0	2
	POOR (>82 ppb)	0	0	0	0
	TOTAL	42	2	0	44

Percent correct:	91
Post agreement of "Good" category:	0.95
Post agreement of "Fair" category:	0
Post agreement of "Poor" category:	-
Prefigurance of "Good" category:	0.95
Prefigurance of "Fair" category:	0
Prefigurance of "Poor" category:	-
Bias of "Good" category:	1.00
Bias of "Fair" category:	1.00
Bias of "Poor" category:	-
Heidke skill score w.r.t. chance:	-0.05
Heidke skill score w.r.t. sample climatology:	-1.00

VERIFICATION STATISTICS

FORECAST MODEL:	Robertson's MDA
LOCATION:	T9-Rocky Point Park

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	36
Bias:	-
Error variance:	-
Standard deviation of errors:	-
Mean absolute error:	-
Root mean square error:	-
Reduction of variance:	-

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	FAIR (52-82 ppb)	POOR (>82 ppb)	TOTAL
OBSERVED	**GOOD (0-51 ppb)**	36	0	0	36
	FAIR (52-82 ppb)	8	0	0	8
	POOR (>82 ppb)	0	0	0	0
	TOTAL	44	0	0	44

Percent correct:	82
Post agreement of "Good" category:	0.82
Post agreement of "Fair" category:	-
Post agreement of "Poor" category:	-
Prefigurance of "Good" category:	1.00
Prefigurance of "Fair" category:	0
Prefigurance of "Poor" category:	-
Bias of "Good" category:	1.22
Bias of "Fair" category:	0
Bias of "Poor" category:	-
Heidke skill score w.r.t. chance:	0
Heidke skill score w.r.t. sample climatology:	0

VERIFICATION STATISTICS

FORECAST MODEL: Robertson's MLR
LOCATION: T9-Rocky Point Park

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified: 44
Observed sample mean: 36
Bias: 6
Error variance: 121
Standard deviation of errors: 11
Mean absolute error: 10
Root mean square error: 13
Reduction of variance: 0.40

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	**FAIR (52-82 ppb)**	**POOR (>82 ppb)**	**TOTAL**
OBSERVED	**GOOD (0-51 ppb)**	33	3	0	36
	FAIR (52-82 ppb)	1	7	0	8
	POOR (>82 ppb)	0	0	0	0
	TOTAL	34	10	0	44

Percent correct: 91
Post agreement of "Good" category: 0.97
Post agreement of "Fair" category: 0.70
Post agreement of "Poor" category: -
Prefigurance of "Good" category: 0.92
Prefigurance of "Fair" category: 0.88
Prefigurance of "Poor" category: -
Bias of "Good" category: 0.94
Bias of "Fair" category: 1.25
Bias of "Poor" category: -
Heidke skill score w.r.t. chance: 0.72
Heidke skill score w.r.t. sample climatology: 0.50

VERIFICATION STATISTICS

FORECAST MODEL:	Concord's
LOCATION:	T9-Rocky Point Park

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	36
Bias:	9
Error variance:	157
Standard deviation of errors:	13
Mean absolute error:	12
Root mean square error:	15
Reduction of variance:	0.12

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

O		GOOD (0-51 ppb)	FAIR (52-82 ppb)	POOR (>82 ppb)	TOTAL
B S	GOOD (0-51 ppb)	31	5	0	36
E R	FAIR (52-82 ppb)	1	7	0	8
V E	POOR (>82 ppb)	0	0	0	0
D	TOTAL	32	12	0	44

Percent correct:	86
Post agreement of "Good" category:	0.97
Post agreement of "Fair" category:	0.58
Post agreement of "Poor" category:	-
Prefigurance of "Good" category:	0.86
Prefigurance of "Fair" category:	0.88
Prefigurance of "Poor" category:	-
Bias of "Good" category:	0.89
Bias of "Fair" category:	1.50
Bias of "Poor" category:	-
Heidke skill score w.r.t. chance:	0.62
Heidke skill score w.r.t. sample climatology:	0.25

VERIFICATION STATISTICS

FORECAST MODEL:	Taylor's MLR
LOCATION:	T9-Rocky Point Park

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	36
Bias:	10
Error variance:	134
Standard deviation of errors:	12
Mean absolute error:	12
Root mean square error:	15
Reduction of variance:	0.12

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	FAIR (52-82 ppb)	POOR (>82 ppb)	TOTAL
OBSERVED	**GOOD (0-51 ppb)**	31	5	0	36
	FAIR (52-82 ppb)	1	7	0	8
	POOR (>82 ppb)	0	0	0	0
	TOTAL	32	12	0	44

Percent correct:	86
Post agreement of "Good" category:	0.97
Post agreement of "Fair" category:	0.58
Post agreement of "Poor" category:	-
Prefigurance of "Good" category:	0.86
Prefigurance of "Fair" category:	0.88
Prefigurance of "Poor" category:	-
Bias of "Good" category:	0.89
Bias of "Fair" category:	1.50
Bias of "Poor" category:	-
Heidke skill score w.r.t. chance:	0.62
Heidke skill score w.r.t. sample climatology:	0.25

VERIFICATION STATISTICS

FORECAST MODEL: Subjective
LOCATION: T9-Rocky Point Park

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified: 44
Observed sample mean: 36
Bias: 8
Error variance: 182
Standard deviation of errors: 14
Mean absolute error: 12
Root mean square error: 16
Reduction of variance: 0.07

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	**FAIR (52-82 ppb)**	**POOR (>82 ppb)**	**TOTAL**
OBSERVED	**GOOD (0-51 ppb)**	32	4	0	36
	FAIR (52-82 ppb)	1	6	1	8
	POOR (>82 ppb)	0	0	0	0
	TOTAL	33	10	1	44

Percent correct: 86
Post agreement of "Good" category: 0.97
Post agreement of "Fair" category: 0.60
Post agreement of "Poor" category: 0
Prefigurance of "Good" category: 0.89
Prefigurance of "Fair" category: 0.75
Prefigurance of "Poor" category: -
Bias of "Good" category: 0.92
Bias of "Fair" category: 1.25
Bias of "Poor" category: -
Heidke skill score w.r.t. chance: 0.60
Heidke skill score w.r.t. sample climatology: 0.25

VERIFICATION STATISTICS

FORECAST MODEL:	Robertson's MDA
LOCATION:	T12-Chilliwack

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	41
Bias:	-
Error variance:	-
Standard deviation of errors:	-
Mean absolute error:	-
Root mean square error:	-
Reduction of variance:	-

3x3 CONTINGENCY TABLE STATISTICS

		FORECAST			
		GOOD (0-51 ppb)	**FAIR (52-82 ppb)**	**POOR (>82 ppb)**	**TOTAL**
OBSERVED	**GOOD (0-51 ppb)**	29	4	1	34
	FAIR (52-82 ppb)	3	4	2	9
	POOR (>82 ppb)	0	1	0	1
	TOTAL	32	9	3	44

Percent correct:	75
Post agreement of "Good" category:	0.91
Post agreement of "Fair" category:	0.44
Post agreement of "Poor" category:	0
Prefigurance of "Good" category:	0.85
Prefigurance of "Fair" category:	0.44
Prefigurance of "Poor" category:	0
Bias of "Good" category:	0.94
Bias of "Fair" category:	1.00
Bias of "Poor" category:	3.00
Heidke skill score w.r.t. chance:	0.37
Heidke skill score w.r.t. sample climatology:	-0.10

VERIFICATION STATISTICS

FORECAST MODEL:	Robertson's MLR
LOCATION:	T12-Chilliwack

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	41
Bias:	2
Error variance:	257
Standard deviation of errors:	16
Mean absolute error:	12
Root mean square error:	16
Reduction of variance:	0.40

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	FAIR (52-82 ppb)	POOR (>82 ppb)	TOTAL
OBSERVED	GOOD (0-51 ppb)	29	5	0	34
	FAIR (52-82 ppb)	4	4	1	9
	POOR (>82 ppb)	0	1	0	1
	TOTAL	33	10	1	44

Percent correct:	75
Post agreement of "Good" category:	0.88
Post agreement of "Fair" category:	0.40
Post agreement of "Poor" category:	0
Prefigurance of "Good" category:	0.85
Prefigurance of "Fair" category:	0.44
Prefigurance of "Poor" category:	0
Bias of "Good" category:	0.97
Bias of "Fair" category:	1.11
Bias of "Poor" category:	1.00
Heidke skill score w.r.t. chance:	0.33
Heidke skill score w.r.t. sample climatology:	-0.10

VERIFICATION STATISTICS

FORECAST MODEL: Concord's
LOCATION: T12-Chilliwack

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	41
Bias:	2
Error variance:	218
Standard deviation of errors:	15
Mean absolute error:	11
Root mean square error:	15
Reduction of variance:	0.48

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

OBSERVED

	GOOD (0-51 ppb)	**FAIR (52-82 ppb)**	**POOR (>82 ppb)**	**TOTAL**
GOOD (0-51 ppb)	30	4	0	34
FAIR (52-82 ppb)	3	6	0	9
POOR (>82 ppb)	0	1	0	1
TOTAL	33	11	0	44

Percent correct:	82
Post agreement of "Good" category:	0.91
Post agreement of "Fair" category:	0.55
Post agreement of "Poor" category:	-
Prefigurance of "Good" category:	0.88
Prefigurance of "Fair" category:	0.67
Prefigurance of "Poor" category:	0
Bias of "Good" category:	0.97
Bias of "Fair" category:	1.22
Bias of "Poor" category:	0
Heidke skill score w.r.t. chance:	0.51
Heidke skill score w.r.t. sample climatology:	0.20

VERIFICATION STATISTICS

FORECAST MODEL:	Taylor's MLR
LOCATION:	T12-Chilliwack

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	41
Bias:	6
Error variance:	238
Standard deviation of errors:	15
Mean absolute error:	14
Root mean square error:	17
Reduction of variance:	0.35

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

OBSERVED		GOOD (0-51 ppb)	FAIR (52-82 ppb)	POOR (>82 ppb)	TOTAL
	GOOD (0-51 ppb)	25	9	0	34
	FAIR (52-82 ppb)	2	7	0	9
	POOR (>82 ppb)	0	1	0	1
	TOTAL	27	17	0	44

Percent correct:	73
Post agreement of "Good" category:	0.93
Post agreement of "Fair" category:	0.41
Post agreement of "Poor" category:	-
Prefigurance of "Good" category:	0.74
Prefigurance of "Fair" category:	0.78
Prefigurance of "Poor" category:	0
Bias of "Good" category:	0.79
Bias of "Fair" category:	1.89
Bias of "Poor" category:	0
Heidke skill score w.r.t. chance:	0.39
Heidke skill score w.r.t. sample climatology:	-0.20

VERIFICATION STATISTICS

FORECAST MODEL:	Subjective
LOCATION:	T12-Chilliwack

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	41
Bias:	5
Error variance:	276
Standard deviation of errors:	17
Mean absolute error:	13
Root mean square error:	17
Reduction of variance:	0.30

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

OBSERVED

	GOOD (0-51 ppb)	**FAIR (52-82 ppb)**	**POOR (>82 ppb)**	**TOTAL**
GOOD (0-51 ppb)	29	3	2	34
FAIR (52-82 ppb)	2	4	3	9
POOR (>82 ppb)	0	1	0	1
TOTAL	31	8	5	44

Percent correct:	75
Post agreement of "Good" category:	0.94
Post agreement of "Fair" category:	0.50
Post agreement of "Poor" category:	0
Prefigurance of "Good" category:	0.85
Prefigurance of "Fair" category:	0.44
Prefigurance of "Poor" category:	0
Bias of "Good" category:	0.91
Bias of "Fair" category:	0.89
Bias of "Poor" category:	5.00
Heidke skill score w.r.t. chance:	0.40
Heidke skill score w.r.t. sample climatology:	-0.10

VERIFICATION STATISTICS

FORECAST MODEL:	Robertson's MDA
LOCATION:	T15-Surrey East

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	39
Bias:	-
Error variance:	-
Standard deviation of errors:	-
Mean absolute error:	-
Root mean square error:	-
Reduction of variance:	-

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	**FAIR (52-82 ppb)**	**POOR (>82 ppb)**	**TOTAL**
OBSERVED	**GOOD (0-51 ppb)**	30	5	0	35
	FAIR (52-82 ppb)	3	6	0	9
	POOR (>82 ppb)	0	0	0	0
	TOTAL	33	11	0	44

Percent correct:	82
Post agreement of "Good" category:	0.91
Post agreement of "Fair" category:	0.55
Post agreement of "Poor" category:	-
Prefigurance of "Good" category:	0.86
Prefigurance of "Fair" category:	0.67
Prefigurance of "Poor" category:	-
Bias of "Good" category:	0.94
Bias of "Fair" category:	1.22
Bias of "Poor" category:	-
Heidke skill score w.r.t. chance:	0.48
Heidke skill score w.r.t. sample climatology:	0.11

VERIFICATION STATISTICS

FORECAST MODEL:	Robertson's MLR
LOCATION:	T15-Surrey East

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	39
Bias:	4
Error variance:	109
Standard deviation of errors:	10
Mean absolute error:	9
Root mean square error:	11
Reduction of variance:	0.33

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	**FAIR (52-82 ppb)**	**POOR (>82 ppb)**	**TOTAL**
OBSERVED	**GOOD (0-51 ppb)**	33	2	0	35
	FAIR (52-82 ppb)	3	6	0	9
	POOR (>82 ppb)	0	0	0	0
	TOTAL	36	8	0	44

Percent correct:	89
Post agreement of "Good" category:	0.92
Post agreement of "Fair" category:	0.75
Post agreement of "Poor" category:	-
Prefigurance of "Good" category:	0.94
Prefigurance of "Fair" category:	0.67
Prefigurance of "Poor" category:	-
Bias of "Good" category:	1.03
Bias of "Fair" category:	0.89
Bias of "Poor" category:	-
Heidke skill score w.r.t. chance:	0.64
Heidke skill score w.r.t. sample climatology:	0.44

VERIFICATION STATISTICS

FORECAST MODEL:	Concord's
LOCATION:	T15-Surrey East

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	39
Bias:	7
Error variance:	132
Standard deviation of errors:	12
Mean absolute error:	11
Root mean square error:	13
Reduction of variance:	0.01

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

OBSERVED		GOOD (0-51 ppb)	FAIR (52-82 ppb)	POOR (>82 ppb)	TOTAL
	GOOD (0-51 ppb)	29	6	0	35
	FAIR (52-82 ppb)	2	7	0	9
	POOR (>82 ppb)	0	0	0	0
	TOTAL	31	13	0	44

Percent correct:	82
Post agreement of "Good" category:	0.94
Post agreement of "Fair" category:	0.54
Post agreement of "Poor" category:	-
Prefigurance of "Good" category:	0.83
Prefigurance of "Fair" category:	0.78
Prefigurance of "Poor" category:	-
Bias of "Good" category:	0.89
Bias of "Fair" category:	1.44
Bias of "Poor" category:	-
Heidke skill score w.r.t. chance:	0.52
Heidke skill score w.r.t. sample climatology:	0.11

VERIFICATION STATISTICS

FORECAST MODEL: Taylor's MLR
LOCATION: T15-Surrey East

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified: 44
Observed sample mean: 39
Bias: 8
Error variance: 114
Standard deviation of errors: 11
Mean absolute error: 11
Root mean square error: 13
Reduction of variance: 0.04

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	**FAIR (52-82 ppb)**	**POOR (>82 ppb)**	**TOTAL**
OBSERVED	**GOOD (0-51 ppb)**	27	8	0	35
	FAIR (52-82 ppb)	2	7	0	9
	POOR (>82 ppb)	0	0	0	0
	TOTAL	29	15	0	44

Percent correct: 77
Post agreement of "Good" category: 0.93
Post agreement of "Fair" category: 0.47
Post agreement of "Poor" category: -
Prefigurance of "Good" category: 0.77
Prefigurance of "Fair" category: 0.78
Prefigurance of "Poor" category: -
Bias of "Good" category: 0.83
Bias of "Fair" category: 1.67
Bias of "Poor" category: -
Heidke skill score w.r.t. chance: 0.44
Heidke skill score w.r.t. sample climatology: -0.11

VERIFICATION STATISTICS

FORECAST MODEL:	Subjective
LOCATION:	T15-Surrey East

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	39
Bias:	6
Error variance:	148
Standard deviation of errors:	12
Mean absolute error:	11
Root mean square error:	14
Reduction of variance:	-0.02

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	FAIR (52-82 ppb)	POOR (>82 ppb)	TOTAL
OBSERVED	**GOOD (0-51 ppb)**	31	4	0	35
	FAIR (52-82 ppb)	2	7	0	9
	POOR (>82 ppb)	0	0	0	0
	TOTAL	33	11	0	44

Percent correct:	86
Post agreement of "Good" category:	0.94
Post agreement of "Fair" category:	0.64
Post agreement of "Poor" category:	-
Prefigurance of "Good" category:	0.89
Prefigurance of "Fair" category:	0.78
Prefigurance of "Poor" category:	-
Bias of "Good" category:	0.94
Bias of "Fair" category:	1.22
Bias of "Poor" category:	-
Heidke skill score w.r.t. chance:	0.61
Heidke skill score w.r.t. sample climatology:	0.33

VERIFICATION STATISTICS

FORECAST MODEL: Subjective
LOCATION: T16-Pitt Meadows

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	40
Bias:	8
Error variance:	158
Standard deviation of errors:	13
Mean absolute error:	12
Root mean square error:	15
Reduction of variance:	-0.05

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

OBSERVED

	GOOD (0-51 ppb)	**FAIR (52-82 ppb)**	**POOR (>82 ppb)**	**TOTAL**
GOOD (0-51 ppb)	29	6	0	35
FAIR (52-82 ppb)	1	7	1	9
POOR (>82 ppb)	0	0	0	0
TOTAL	30	13	1	44

Percent correct:	82
Post agreement of "Good" category:	0.97
Post agreement of "Fair" category:	0.54
Post agreement of "Poor" category:	0
Prefigurance of "Good" category:	0.83
Prefigurance of "Fair" category:	0.78
Prefigurance of "Poor" category:	-
Bias of "Good" category:	0.86
Bias of "Fair" category:	1.44
Bias of "Poor" category:	-
Heidke skill score w.r.t. chance:	0.54
Heidke skill score w.r.t. sample climatology:	0.11

VERIFICATION STATISTICS

FORECAST MODEL:	Robertson's MLR
LOCATION:	T17-Richmond South

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	34
Observed sample mean:	34
Bias:	2
Error variance:	100
Standard deviation of errors:	10
Mean absolute error:	9
Root mean square error:	10
Reduction of variance:	0.19

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	FAIR (52-82 ppb)	POOR (>82 ppb)	TOTAL
OBSERVED	**GOOD (0-51 ppb)**	30	0	0	30
	FAIR (52-82 ppb)	4	0	0	4
	POOR (>82 ppb)	0	0	0	0
	TOTAL	34	0	0	34

Percent correct:	88
Post agreement of "Good" category:	0.88
Post agreement of "Fair" category:	-
Post agreement of "Poor" category:	-
Prefigurance of "Good" category:	1.00
Prefigurance of "Fair" category:	0
Prefigurance of "Poor" category:	-
Bias of "Good" category:	1.13
Bias of "Fair" category:	0
Bias of "Poor" category:	-
Heidke skill score w.r.t. chance:	0
Heidke skill score w.r.t. sample climatology:	0

VERIFICATION STATISTICS

FORECAST MODEL:	Concord's
LOCATION:	T17-Richmond South

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	34
Observed sample mean:	34
Bias:	0
Error variance:	117
Standard deviation of errors:	11
Mean absolute error:	9
Root mean square error:	11
Reduction of variance:	0.10

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	FAIR (52-82 ppb)	POOR (>82 ppb)	TOTAL
OBSERVED	**GOOD (0-51 ppb)**	30	0	0	30
	FAIR (52-82 ppb)	4	0	0	4
	POOR (>82 ppb)	0	0	0	0
	TOTAL	34	0	0	34

Percent correct:	88
Post agreement of "Good" category:	0.88
Post agreement of "Fair" category:	-
Post agreement of "Poor" category:	-
Prefigurance of "Good" category:	1.00
Prefigurance of "Fair" category:	0
Prefigurance of "Poor" category:	-
Bias of "Good" category:	1.13
Bias of "Fair" category:	0
Bias of "Poor" category:	-
Heidke skill score w.r.t. chance:	0
Heidke skill score w.r.t. sample climatology:	0

VERIFICATION STATISTICS

FORECAST MODEL:	Taylor's MLR
LOCATION:	T17-Richmond South

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	34
Observed sample mean:	34
Bias:	4
Error variance:	91
Standard deviation of errors:	10
Mean absolute error:	8
Root mean square error:	10
Reduction of variance:	0.20

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	FAIR (52-82 ppb)	POOR (>82 ppb)	TOTAL
OBSERVED	**GOOD (0-51 ppb)**	30	0	0	30
	FAIR (52-82 ppb)	3	1	0	4
	POOR (>82 ppb)	0	0	0	0
	TOTAL	33	1	0	34

Percent correct:	91
Post agreement of "Good" category:	0.91
Post agreement of "Fair" category:	1.00
Post agreement of "Poor" category:	-
Prefigurance of "Good" category:	1.00
Prefigurance of "Fair" category:	0.25
Prefigurance of "Poor" category:	-
Bias of "Good" category:	1.10
Bias of "Fair" category:	0.25
Bias of "Poor" category:	-
Heidke skill score w.r.t. chance:	0.37
Heidke skill score w.r.t. sample climatology:	0.25

VERIFICATION STATISTICS

FORECAST MODEL:	Subjective
LOCATION:	T17-Richmond South

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	34
Observed sample mean:	34
Bias:	3
Error variance:	120
Standard deviation of errors:	11
Mean absolute error:	9
Root mean square error:	11
Reduction of variance:	0.01

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	FAIR (52-82 ppb)	POOR (>82 ppb)	TOTAL
OBSERVED	**GOOD (0-51 ppb)**	29	1	0	30
	FAIR (52-82 ppb)	4	0	0	4
	POOR (>82 ppb)	0	0	0	0
	TOTAL	33	1	0	34

Percent correct:	85
Post agreement of "Good" category:	0.88
Post agreement of "Fair" category:	0
Post agreement of "Poor" category:	-
Prefigurance of "Good" category:	0.97
Prefigurance of "Fair" category:	0
Prefigurance of "Poor" category:	-
Bias of "Good" category:	1.10
Bias of "Fair" category:	0.25
Bias of "Poor" category:	-
Heidke skill score w.r.t. chance:	-0.05
Heidke skill score w.r.t. sample climatology:	-0.25

VERIFICATION STATISTICS

FORECAST MODEL:	Subjective
LOCATION:	T26-Mahon Park (North Shore)

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	34
Bias:	3
Error variance:	172
Standard deviation of errors:	13
Mean absolute error:	11
Root mean square error:	13
Reduction of variance:	-0.16

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	FAIR (52-82 ppb)	POOR (>82 ppb)	TOTAL
OBSERVED	**GOOD (0-51 ppb)**	38	3	0	41
	FAIR (52-82 ppb)	1	2	0	3
	POOR (>82 ppb)	0	0	0	0
	TOTAL	39	5	0	44

Percent correct:	91
Post agreement of "Good" category:	0.97
Post agreement of "Fair" category:	0.40
Post agreement of "Poor" category:	-
Prefigurance of "Good" category:	0.93
Prefigurance of "Fair" category:	0.67
Prefigurance of "Poor" category:	-
Bias of "Good" category:	0.95
Bias of "Fair" category:	1.67
Bias of "Poor" category:	-
Heidke skill score w.r.t. chance:	0.45
Heidke skill score w.r.t. sample climatology:	-0.33

VERIFICATION STATISTICS

FORECAST MODEL:	Subjective
LOCATION:	T27-Langley

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	42
Bias:	6
Error variance:	163
Standard deviation of errors:	13
Mean absolute error:	10
Root mean square error:	14
Reduction of variance:	0.13

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	**FAIR (52-82 ppb)**	**POOR (>82 ppb)**	**TOTAL**
OBSERVED	**GOOD (0-51 ppb)**	28	3	0	31
	FAIR (52-82 ppb)	3	9	1	13
	POOR (>82 ppb)	0	0	0	0
	TOTAL	31	12	1	44

Percent correct:	84
Post agreement of "Good" category:	0.90
Post agreement of "Fair" category:	0.75
Post agreement of "Poor" category:	0
Prefigurance of "Good" category:	0.90
Prefigurance of "Fair" category:	0.69
Prefigurance of "Poor" category:	-
Bias of "Good" category:	1.00
Bias of "Fair" category:	0.92
Bias of "Poor" category:	-
Heidke skill score w.r.t. chance:	0.62
Heidke skill score w.r.t. sample climatology:	0.46

VERIFICATION STATISTICS

FORECAST MODEL:	Robertson's MDA
LOCATION:	T28-Abbotsford

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	40
Bias:	-
Error variance:	-
Standard deviation of errors:	-
Mean absolute error:	-
Root mean square error:	-
Reduction of variance:	-

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	FAIR (52-82 ppb)	POOR (>82 ppb)	TOTAL
OBSERVED	GOOD (0-51 ppb)	29	3	1	33
	FAIR (52-82 ppb)	2	6	2	10
	POOR (>82 ppb)	0	1	0	1
	TOTAL	31	10	3	44

Percent correct:	80
Post agreement of "Good" category:	0.94
Post agreement of "Fair" category:	0.60
Post agreement of "Poor" category:	0
Prefigurance of "Good" category:	0.88
Prefigurance of "Fair" category:	0.60
Prefigurance of "Poor" category:	0
Bias of "Good" category:	0.94
Bias of "Fair" category:	1.00
Bias of "Poor" category:	3.00
Heidke skill score w.r.t. chance:	0.51
Heidke skill score w.r.t. sample climatology:	0.18

VERIFICATION STATISTICS

FORECAST MODEL:	Robertson's MLR
LOCATION:	T28-Abbotsford

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	40
Bias:	7
Error variance:	180
Standard deviation of errors:	13
Mean absolute error:	12
Root mean square error:	15
Reduction of variance:	0.29

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	**FAIR (52-82 ppb)**	**POOR (>82 ppb)**	**TOTAL**
OBSERVED	**GOOD (0-51 ppb)**	29	4	0	33
	FAIR (52-82 ppb)	3	7	0	10
	POOR (>82 ppb)	0	1	0	1
	TOTAL	32	12	0	44

Percent correct:	82
Post agreement of "Good" category:	0.91
Post agreement of "Fair" category:	0.58
Post agreement of "Poor" category:	-
Prefigurance of "Good" category:	0.88
Prefigurance of "Fair" category:	0.70
Prefigurance of "Poor" category:	0
Bias of "Good" category:	0.97
Bias of "Fair" category:	1.20
Bias of "Poor" category:	0
Heidke skill score w.r.t. chance:	0.54
Heidke skill score w.r.t. sample climatology:	0.27

VERIFICATION STATISTICS

FORECAST MODEL:	Concord's
LOCATION:	T28-Abbotsford

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	40
Bias:	6
Error variance:	153
Standard deviation of errors:	12
Mean absolute error:	11
Root mean square error:	14
Reduction of variance:	0.42

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

OBSERVED		GOOD (0-51 ppb)	FAIR (52-82 ppb)	POOR (>82 ppb)	TOTAL
	GOOD (0-51 ppb)	30	3	0	33
	FAIR (52-82 ppb)	2	8	0	10
	POOR (>82 ppb)	0	1	0	1
	TOTAL	32	12	0	44

Percent correct:	86
Post agreement of "Good" category:	0.94
Post agreement of "Fair" category:	0.67
Post agreement of "Poor" category:	-
Prefigurance of "Good" category:	0.91
Prefigurance of "Fair" category:	0.80
Prefigurance of "Poor" category:	0
Bias of "Good" category:	0.97
Bias of "Fair" category:	1.20
Bias of "Poor" category:	0
Heidke skill score w.r.t. chance:	0.65
Heidke skill score w.r.t. sample climatology:	0.45

VERIFICATION STATISTICS

FORECAST MODEL: Taylor's MLR
LOCATION: T28-Abbotsford

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified: 44
Observed sample mean: 40
Bias: 9
Error variance: 162
Standard deviation of errors: 13
Mean absolute error: 13
Root mean square error: 16
Reduction of variance: 0.24

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

OBSERVED

	GOOD (0-51 ppb)	**FAIR (52-82 ppb)**	**POOR (>82 ppb)**	**TOTAL**
GOOD (0-51 ppb)	27	6	0	33
FAIR (52-82 ppb)	1	9	0	10
POOR (>82 ppb)	0	1	0	1
TOTAL	28	16	0	44

Percent correct: 82
Post agreement of "Good" category: 0.96
Post agreement of "Fair" category: 0.56
Post agreement of "Poor" category: -
Prefigurance of "Good" category: 0.82
Prefigurance of "Fair" category: 0.90
Prefigurance of "Poor" category: 0
Bias of "Good" category: 0.85
Bias of "Fair" category: 1.60
Bias of "Poor" category: 0
Heidke skill score w.r.t. chance: 0.59
Heidke skill score w.r.t. sample climatology: 0.27

VERIFICATION STATISTICS

FORECAST MODEL: Subjective
LOCATION: T28-Abbotsford

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	40
Bias:	8
Error variance:	191
Standard deviation of errors:	14
Mean absolute error:	13
Root mean square error:	16
Reduction of variance:	0.20

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	**FAIR (52-82 ppb)**	**POOR (>82 ppb)**	**TOTAL**
OBSERVED	**GOOD (0-51 ppb)**	30	3	0	33
	FAIR (52-82 ppb)	2	6	2	10
	POOR (>82 ppb)	0	1	0	1
	TOTAL	32	10	2	44

Percent correct:	82
Post agreement of "Good" category:	0.94
Post agreement of "Fair" category:	0.60
Post agreement of "Poor" category:	0
Prefigurance of "Good" category:	0.91
Prefigurance of "Fair" category:	0.60
Prefigurance of "Poor" category:	0
Bias of "Good" category:	0.97
Bias of "Fair" category:	1.00
Bias of "Poor" category:	2.00
Heidke skill score w.r.t. chance:	0.55
Heidke skill score w.r.t. sample climatology:	0.27

VERIFICATION STATISTICS

FORECAST MODEL:	Concord's
LOCATION:	Regional

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	48
Bias:	7
Error variance:	167
Standard deviation of errors:	13
Mean absolute error:	11
Root mean square error:	14
Reduction of variance:	0.39

3x3 CONTINGENCY TABLE STATISTICS

		FORECAST			
		GOOD (0-51 ppb)	**FAIR (52-82 ppb)**	**POOR (>82 ppb)**	**TOTAL**
OBSERVED	**GOOD (0-51 ppb)**	21	9	0	30
	FAIR (52-82 ppb)	3	8	2	13
	POOR (>82 ppb)	0	1	0	1
	TOTAL	24	18	2	44

Percent correct:	66
Post agreement of "Good" category:	0.88
Post agreement of "Fair" category:	0.44
Post agreement of "Poor" category:	0
Prefigurance of "Good" category:	0.70
Prefigurance of "Fair" category:	0.62
Prefigurance of "Poor" category:	0
Bias of "Good" category:	0.80
Bias of "Fair" category:	1.38
Bias of "Poor" category:	2.00
Heidke skill score w.r.t. chance:	0.33
Heidke skill score w.r.t. sample climatology:	-0.07

VERIFICATION STATISTICS

FORECAST MODEL:	Subjective
LOCATION:	Regional

CONTINUOUS VARIABLE STATISTICS

Number of forecasts verified:	44
Observed sample mean:	48
Bias:	6
Error variance:	199
Standard deviation of errors:	14
Mean absolute error:	11
Root mean square error:	15
Reduction of variance:	0.33

3x3 CONTINGENCY TABLE STATISTICS

FORECAST

		GOOD (0-51 ppb)	FAIR (52-82 ppb)	POOR (>82 ppb)	TOTAL
OBSERVED	**GOOD (0-51 ppb)**	21	8	1	30
	FAIR (52-82 ppb)	3	6	4	13
	POOR (>82 ppb)	0	1	0	1
	TOTAL	24	15	5	44

Percent correct:	61
Post agreement of "Good" category:	0.88
Post agreement of "Fair" category:	0.40
Post agreement of "Poor" category:	0
Prefigurance of "Good" category:	0.70
Prefigurance of "Fair" category:	0.46
Prefigurance of "Poor" category:	0
Bias of "Good" category:	0.80
Bias of "Fair" category:	1.15
Bias of "Poor" category:	5.00
Heidke skill score w.r.t. chance:	0.26
Heidke skill score w.r.t. sample climatology:	-0.21