

## **5.0 AIR QUALITY MODELLING**

### **5.1 MODEL SELECTION**

The CALPUFF modelling system (Scire et al., 2000a,b) was used in the modelling analysis. CALPUFF and its meteorological model CALMET are designed to handle complexities posed by the complex terrain, long source receptor distances, and chemical transformation and deposition. The CALPUFF modelling system has been recommended by the U.S. Environmental Protection Agency (EPA) as a Guideline Model for source-receptor distances greater than 50 km, and for use on a case-by-case basis in complex flow situations for shorter distances (Federal Register, April 21, 2000). CALPUFF is recommended for Class I impact assessments by the Federal Land Managers Workgroup (FLAG, 2000) and the Interagency Workgroup on Air Quality Modelling (IWAQM, 1998).

Regulatory models such as the Industrial Source Complex Short Term (ISCST3) and AERMOD models have several important limitations rendering them not suitable for this study. One critical limitation of ISCST3 is that it is a steady-state, straight line plume model that cannot respond to the terrain-induced spatial variability in wind fields or to changes in dispersion conditions resulting from changes in surface characteristics. ISCST3 and AERMOD use spatially invariant wind fields based on single-station wind observations. Also, the steady-state formulation does not account for causality effects (i.e. the transport time required for pollutants to reach receptors), which can be important for source-receptor distances greater than a few kilometres. Lastly, ISCST3 and AERMOD cannot calculate concentrations during calm hours.

CALMET is a diagnostic meteorological model that produces three-dimensional wind and temperature fields and two-dimensional fields of mixing heights and other meteorological variables. It contains options to parameterize slope flow effects and terrain channelling of winds. CALPUFF is a non-steady-state Gaussian puff model. It includes algorithms for chemical transformation, wet deposition, and dry deposition. CALPUFF contains algorithms for assessing the impact of primary and secondary particulate matter on visibility as well as for computing deposition fluxes. One capability of CALPUFF not found in many specialized models is the ability to treat the combined effects of multiple processes (e.g., building downwash effects in complex terrain, dry deposition and chemical transformation). It is designed for assessing the impacts of multiple sources within a spatially varying meteorological field. The EPA has formally proposed CALPUFF as an Appendix A Guideline model for this type of application (Federal Register, April 21, 2000). A complete summary of the capabilities and features of CALMET and CALPUFF is provided in Appendix D.

As stated above, a one-year (1996) hourly meteorological data set was used to drive the CALMET/CALPUFF models rather than a five-year data set based on one station which is used in less sophisticated models such as ISCST. As referenced in the US Federal Register, at least one year of site specific data are acceptable for dispersion modelling purposes. Given that the CALMET data set is a gridded dataset using multiple stations and MM5 data, the use of a one year data set is **considered** to be acceptable.

## **5.2 CALMET SET-UP**

The CALMET computational domain extended from Oakville, to Ajax and to just north of Stouffville. The entire modelling domain covers an area of 70 km by 64 km (Figure 5-1). A resolution of 1000 m in the horizontal was used to resolve the variations of the terrain elevations in the area. The United States Geological Survey (USGS) elevation records located within each grid cell in the computational domain were averaged to produce a mean elevation at each grid point. A 1 km resolution produces a workable number of grid cells (70 x 64) at the widest and longest section of the domain and allows adequate representation of the terrain features (Figure 5-2). In the vertical, a stretched grid was used with a fine resolution in the lower layers to resolve the mixed layer and a somewhat coarser resolution aloft. The eight (8) vertical levels are at 20, 50, 100, 250, 500, 1000, 1850, and 3000 meters.

Land use data available from the USGS and Natural Resources Canada were processed to generate a gridded field of dominant land use categories and land-use weighted values of surface and vegetation properties for each grid cell. The land use data from the USGS were obtained in Composite Theme Grid (CTG) format, with a resolution of 1000 m. The land use data from Natural Resources Canada were provided in maps with a scale of 1:50,000. Figure 5-3 presents the dominant landuse in the CALMET domain.

Appendix D presents the CALMET computational parameters and switches used in this analysis.

## **5.3 CALPUFF SET-UP**

The CALPUFF computational domain extends out 15 kilometers from ABTP, reaching to Finch Avenue in the north, Royal York Road to the west and Morningside Drive to the east. The computational domain includes a buffer zone east, west and north of the source area. This minimizes edge effects and allows pollutants involved in flow reversals to be brought back into the ABTP airshed. The two study areas (Beaches and South Riverdale) were analyzed separately to allow individual impacts to be evaluated. The CALPUFF computational domain is presented in Figure 5-4.

Appendix D presents the CALPUFF computational parameters and switches used in this analysis.

Figure 5-1 CALMET Computation Domain

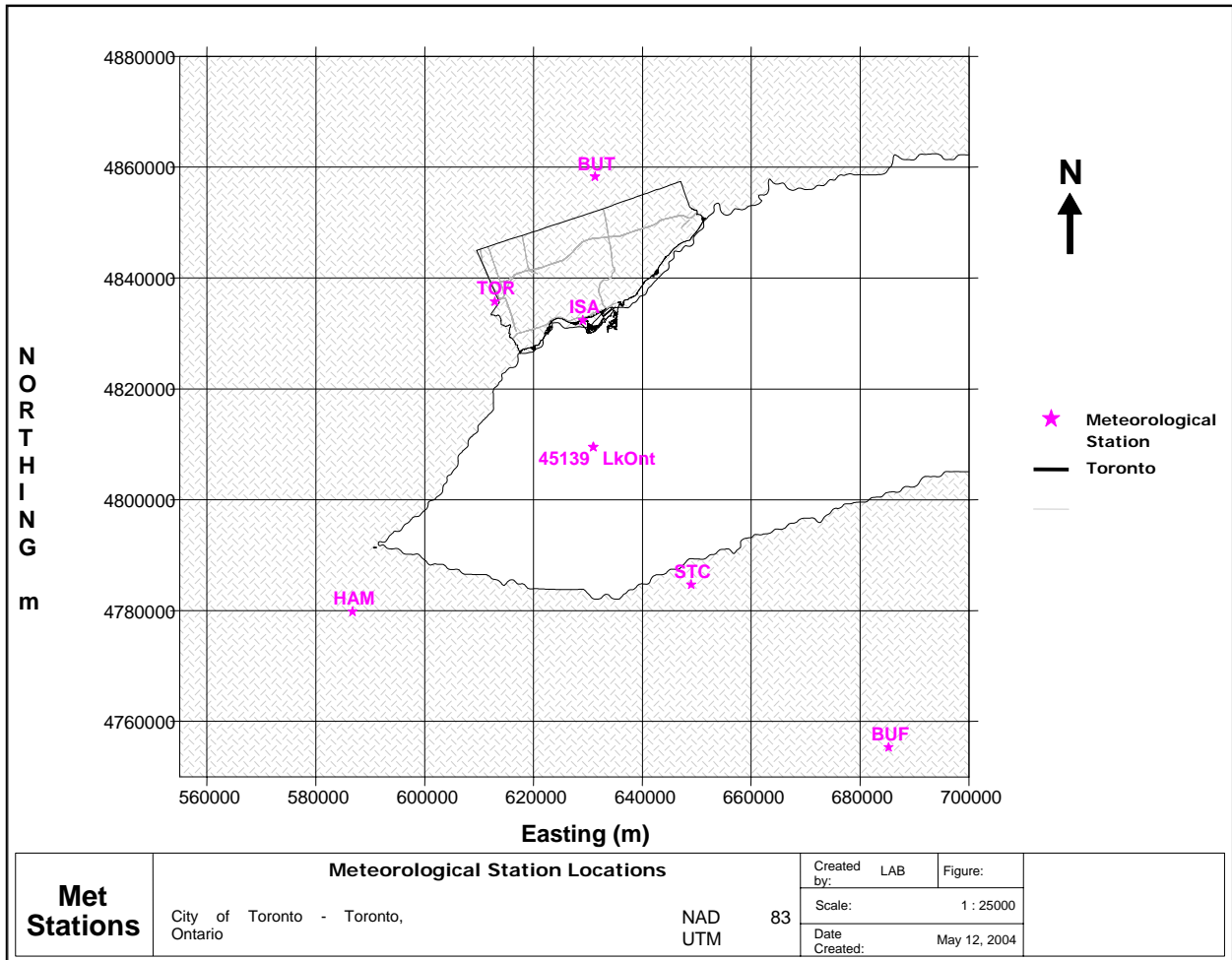


Figure 5-2 Terrain Features

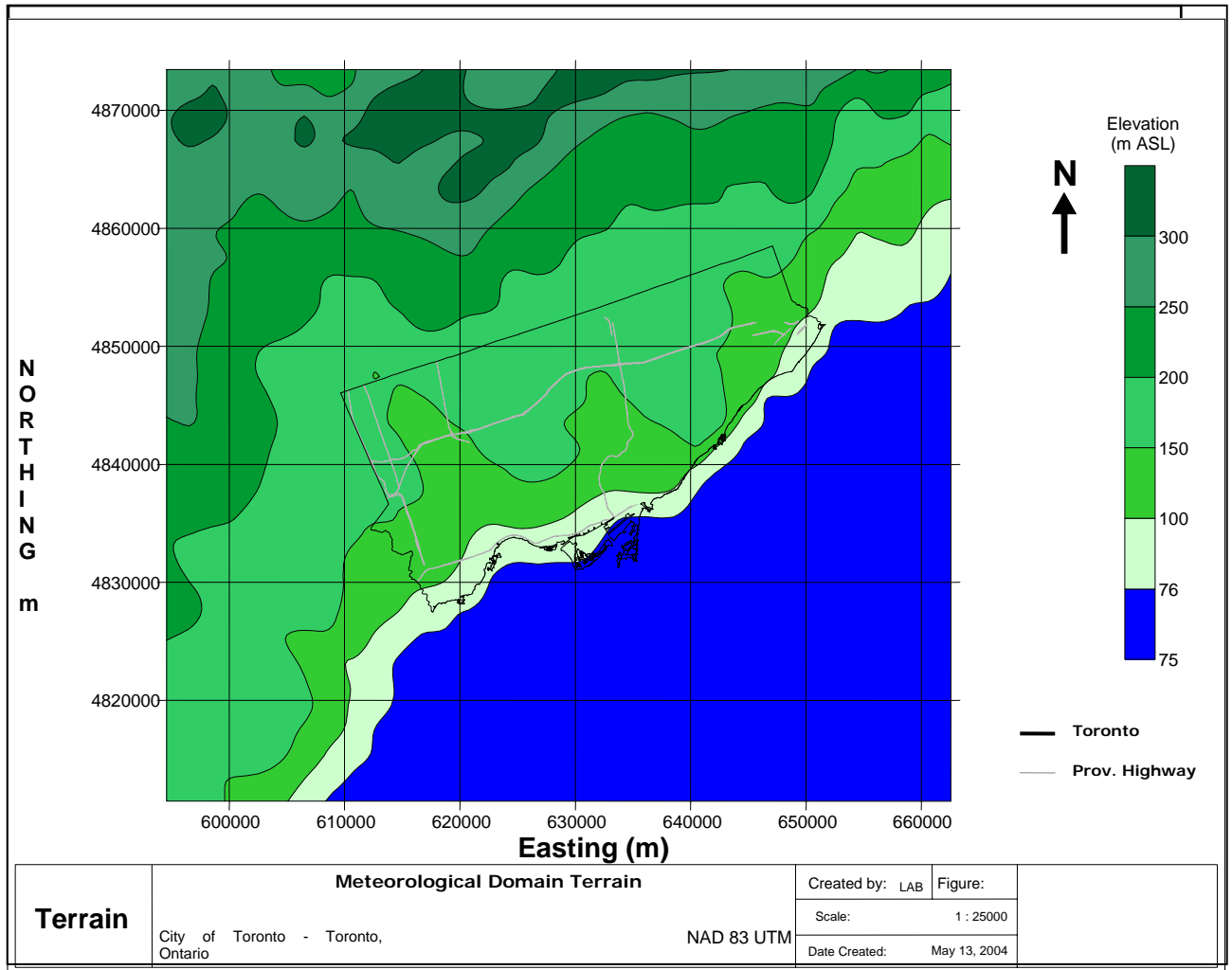
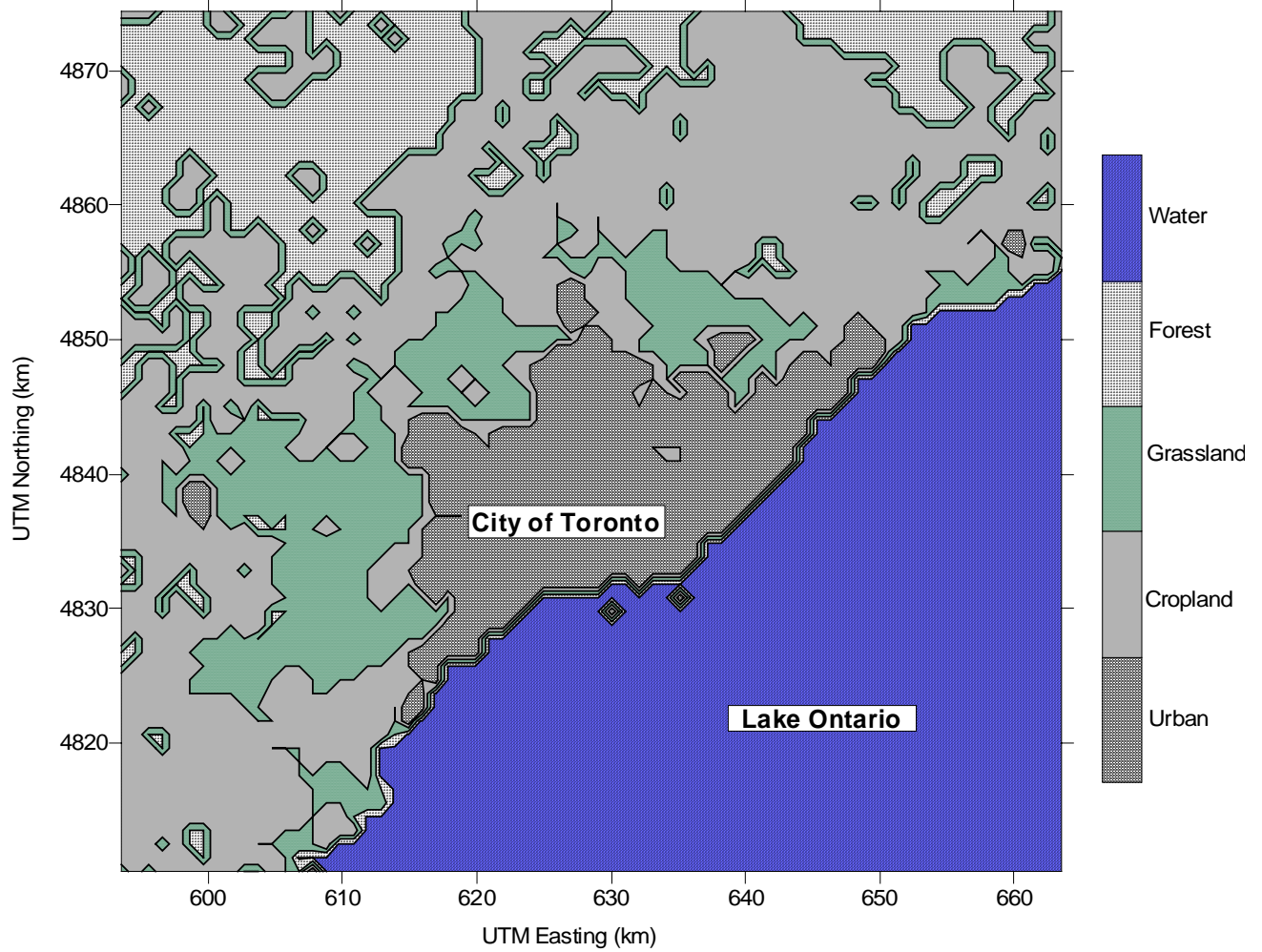
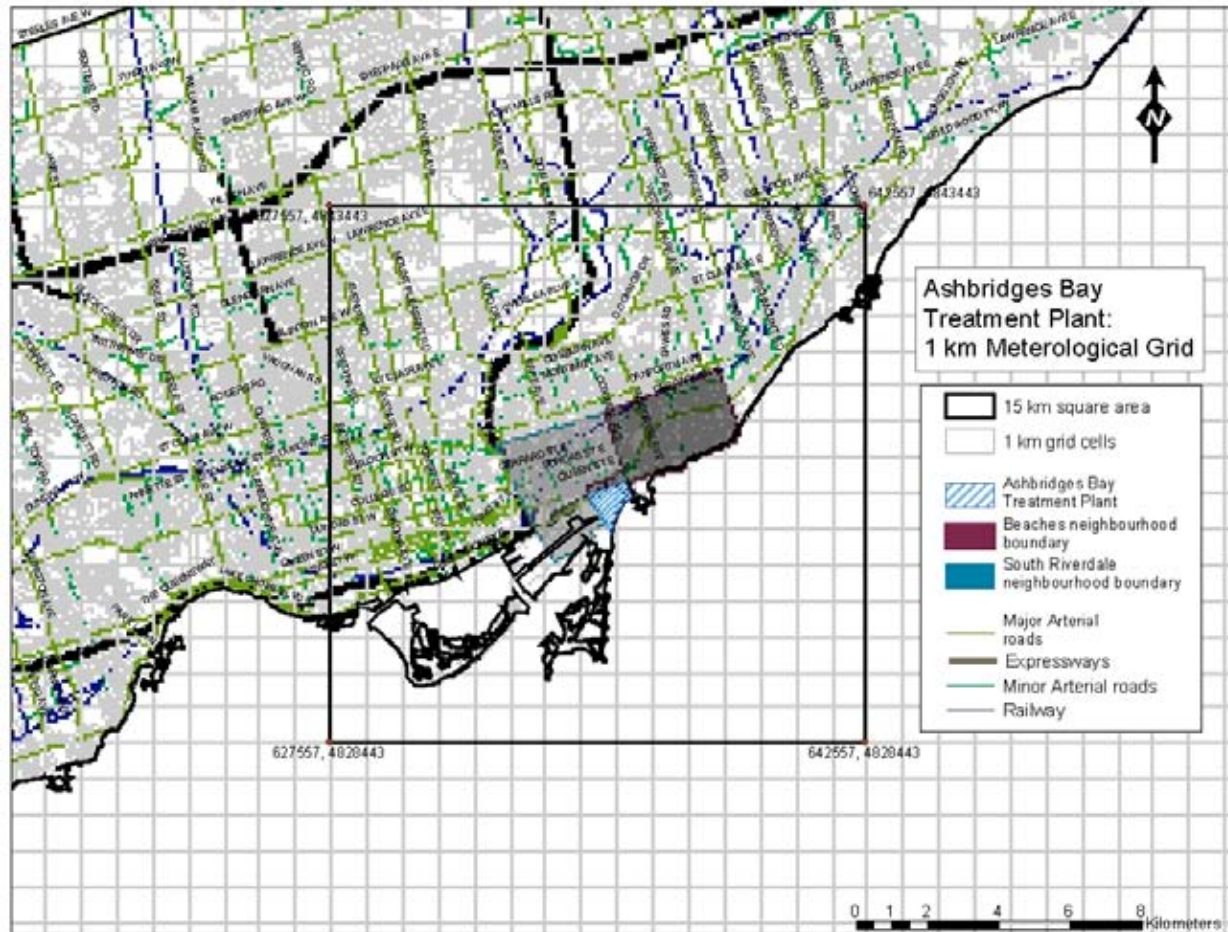


Figure 5-3 Dominant Land Use in the CALMET/CALPUFF Domain



1 km by 1 km

Figure 5-4 CALPUFF Computational Domain Around ABTP



### 5.3.1 BUILDING DOWNWASH

CALPUFF contains the PRIME algorithms for near-source effects from building downwash. The Building Profile Input Program (BPIP) PRIME that calculates building heights and projected building widths for simple multi-tiered and group structures was used to set-up building downwash effects for each modelling scenario (i.e., a separate BPIP file was created for each scenario to account for changes in the ABTP configuration). For example, the truck loading facility and the “New” boiler building was not included in Scenario #1 as they were not built yet, but they were included in Scenarios 2, 3 and 4. Another example would be in Scenario #4 where a building over Primary Tanks 7 to 9 was included.

#### 5.3.1.1 IMPACTS OF BUILDING DOWNWASH ON AREA SOURCES

At ABTP, the low release area sources are surrounded by obstacles (e.g., buildings, tanks) which increase the mechanically generated turbulence above and around these area sources. In addition, these sources act as blockage when the winds blow in certain directions (i.e., towards the Beaches or South Riverdale).

These obstacles will tend to enhance the degree of mixing and subsequently the dispersion and transport of the emissions.

To better approximate the manner by which the emissions would be dispersed from the area sources, the building wakes and cavities around and over the area sources were calculated using PRIME model equations (Schulman, Strimaitis and Scire, 2000). The maximum extent of the near cavity was calculated to determine if area source emissions would be caught in the cavity created by the surrounding structures. The height of the wake from each building was calculated at the geometric midpoint of each area source (see Appendix E for tabulated results). The average wake height calculated for each area source was used to calculate initial spread of the sources ( $\sigma_z$ ) independent of wind direction (refer to Appendix E for the Building Wake Analysis).

CALPUFF, like AERMOD-PRIME and others, only allows for one spread to be used in all directions. The average height of each building generated wake was applied. The resultant wake was transformed to an initial  $\sigma_z$ , as per the following

$$\sigma_{zi} = \frac{\sum H_{wji}}{N} \times \frac{1}{2.15} \quad \text{Equation 5-1}$$

where

$\sigma_{zi}$	=	Initial spread over area source i;
$H_{wji}$	=	Height of wake above area source i due to building/obstacle j and
$N$	=	Number of building obstacles affecting source i

Although the above is not exact, it does account for mechanical turbulence/blockage around the area sources.

### **5.3.2 TREATMENT OF CHEMICAL TRANSFORMATIONS**

Chemical transformations of  $\text{SO}_x$  to  $\text{SO}_4$  and  $\text{NO}$  to  $\text{NO}_3$  were used following the MESOPUFF II method. Sulphates and nitrates contribute to  $\text{PM}_{2.5}$  concentrations which were added to the direct emissions of  $\text{PM}_{2.5}$  (primarily combustion sources). Ozone data from the nearest station was used by CALPUFF and the chemical transformations were calculated for all four (4) scenarios. Background ammonia concentrations were assumed to be 10 ppb as there are no measured data available. This background level is high as compared to measurements in other urban areas which range between 2 to 6.5 ppb (Bari, et al, 2003). A high ammonia value will tend to maximize the potential for the formation of ammonia sulphates and ammonia nitrates.

### **5.3.3 DEPOSITION**

Deposition of chemicals was not considered in the modelling. The use of deposition will reduce the amount of available airborne concentrations.

#### **5.3.4 AVERAGING PERIODS**

Concentrations were predicted on an hourly, 24-hour (daily) and annual average basis for the seventeen (17) chemicals selected.

#### **5.3.5 LAKE SHORE EFFECTS**

CALPUFF includes a sub-grid Thermal Internal Boundary Layer (TIBL) module for cases where the position of the coastal boundary within a grid cell and growth of a TIBL must be modelled with a greater special resolution. Given the height of the incinerator and its vicinity to the shoreline, this option was activated within CALPUFF.

#### **5.3.6 TREATMENT OF TERRAIN**

For the meteorological modelling via CALMET, gridded terrain elevations derived from three (3) USGS produced arc-second digital elevation models (DEMs) were used. The USGS data are provided in files covering 1 degree by 1 degree blocks of latitude and longitude. The 1-degree DEMs are produced by the Defence Mapping Agency using cartographic and photographic sources. USGS 1:250,000 scale topographic maps are the primary source of 1-degree DEMs.

One degree DEM data consists of an array of 1201 by 1201 elevations referenced on the geographic (latitude/longitude) coordinate system of the World Geodetic System 1972 Datum. Elevations are in meters relative to mean sea level, and the spacing of the elevations along each profile is 3 arc-seconds, which corresponds to a spacing of approximately 90 meters.

### **5.4 RECEPTOR NETWORK**

#### **5.4.1 DESCRIPTION OF RECEPTOR GRIDS**

The receptor grid consisted of both gridded receptors and discrete receptors. Discrete receptors spaced at 200 m apart covered both of the two (2) study areas. This resulted in 186 discrete receptors over the Beaches and 207 discrete receptors in South Riverdale (Figure 5-5). The elevation of each receptor was determined from USGS DEM files covering the area.

A gridded field of receptors was also located within the two (2) study areas at a grid resolution of 200 m.

Figure 5-5 Study Areas and Location of Discrete Receptors – The Beaches and South Riverdale

