CHAPTER 6

Air Quality Modeling

FIGURES

6

Air Quality Modeling

6.1 INTRODUCTION

An air quality model was used to help identify air pollution sources that contributed to PM_{10} violations, and to evaluate control strategies to bring the area into attainment. The CALPUFF modeling system was selected for use in the Owens Valley State Implementation Plan (SIP). CALPUFF is an approved United States Environmental Protection Agency (USEPA) guideline model that is used for evaluating SIP control strategies and for other regulatory purposes (Scire, *et al*., 2000). It was previously used to support the attainment demonstration in the 2003 Owens Valley PM_{10} SIP (2003 SIP). The modeling analysis contained in this SIP revision updates the 2003 SIP modeling studies with more recent observations collected from July 2002 to June 2006. This section describes the sources of data that were used to support the CALPUFF model and explains how the model was run. Further details are provided in the Modeling Report included in this 2008 SIP as Appendix B.

The model is an important tool that is used to help quantify the PM_{10} impacts caused by dust source areas at Owens Lake. Data to support the air quality model are collected as part of the Owens Lake Dust Source Identification (Dust ID) Program. The Dust ID Program is a long-term monitoring program that is intended to identify dust source areas for control under the provisions of the Supplemental Control Requirements (SCR) in the 2003 SIP and the 2006 Owens Lake Settlement Agreement entered into between the District and the City on December 4, 2006 (Settlement Agreement) (GBUAPCD, 2006b).

In the modeling analysis emissions from individual dust source areas are simulated to assess whether they caused or contributed to an exceedance or violation of the National Ambient Air Quality Standards (NAAQS) for PM_{10}. The Owens Valley planning area is currently designated as a federal nonattainment area for the 24-hour PM_{10} standard, which is set at 150 $\mu g/m^3$. Attainment of the 24-hour PM_{10} NAAQS is achieved when predicted concentrations are not above 150 $\mu g/m^3$ more than once per year on average. In the current study, the model attainment demonstration is performed for a four-year period with special attention to receptors locations that are at or above the 3,600 foot contour of Owens Lake.

6.2 OVERVIEW OF THE DUST ID PROGRAM

The District started a field monitoring program at Owens Lake in January 2000 to identify PM_{10} emission source areas, and to estimate their PM_{10} emissions and impacts on air quality at the shoreline. The data used in the 2008 SIP was collected during July 2002 through June 2006 using the methods described in the Owens Lake Dust ID Field Manual (GBUAPCD, 2007). The field program was designed based on previous observations and field studies that suggest PM_{10} emissions are related to the flux of saltating sand-sized particles.

Figure 6.1 is a map of Owens Lake showing the locations of the meteorological and PM_{10} monitoring stations. Figure 6.2 shows the locations of the sand flux monitoring network for the period from July 2005 through June 2006. Features of the Dust ID Program are as follows:

- Co-located Sensits and Cox Sand Catchers (CSCs) were used to estimate hourly sand flux rates at each lake bed monitor site shown in Figure 6.2. Sensits measure the kinetic energy and the particle counts of sand-sized particles as they saltate (bounce) across the surface. CSCs are passive instruments used to collect sand-sized particles blown across the surface during a dust event. For a given period, the total mass of saltating sand was based on the CSC catch. The Sensits were then used to time-resolve the horizontal sand flux (Ono, *et al*., 2003a, Gillette, *et al.*, 2004).
- Hourly PM_{10} concentration data were collected at seven sites around Owens Lake using Tapered Element Oscillating Microbalance (TEOM) PM_{10} monitors. TEOMs are a USEPA-designated equivalent method for measurement of PM_{10} concentration.
- Hourly surface meteorological data were collected at 13 District stations within the domain shown in Figure 6.1. These data were augmented by an additional two District sites south of the domain and up to three sites operated by the City during periods of the four year study.
- A 915 MHz Radar Wind Profiler and Radio Acoustic Sounding System (RASS) were used to collect upper level wind and temperature measurements. The Wind Profiler was located at the Mill Site until it was removed during June 2004.
- To help verify the location of dust source areas, time-lapse video cameras were installed at three sites to continuously record dust events during daylight hours and three human observers mapped dust source areas and plumes during the storms on regular workdays. In addition, the erosion boundaries of some source areas were mapped with the aid of a field crew using a Global Positioning System (GPS) after a storm.

A large Geographic Information System (GIS) database was constructed using observations collected during the Dust ID Program. Using the GIS database, the District prepared maps displaying hourly sand movement, winds, visually observed plume and source area boundaries, and PM_{10} concentrations for dust events at Owens Lake during the study period. Owens Lake Dust ID Field Manual provides further detail (GBUAPCD, 2007).

6.3 DISPERSION MODELING TECHNIQUES

The CALPUFF modeling system was selected for assessing source contributions to observed PM_{10} concentrations and for the development of control strategies for the 2008 SIP. CALPUFF is the USEPA recommended modeling approach for long-range transport studies (40 CFR Part 51, Appendix W). USEPA also recommends application of the modeling system on a case-by-case basis to near-field dispersion problems where the three-dimensional qualities of the wind field are of interest. Observations during the Dust ID Program indicate dust events on Owens Lake are sometimes influenced by complex wind patterns, with plumes from the North Sand Sheet traveling in different directions than plumes from the South Sand Sheet. Both CARB and the USEPA approved the application of CALPUFF during their review of the modeling protocol for the 2003 SIP.

6.3.1 Preparation of the Meteorological Data

Three-dimensional wind fields for CALPUFF were constructed from surface and upper air observations using the CALMET meteorological preprocessor program. CALMET combines surface observations, upper air observations, terrain elevations, and land use data into the format required by CALPUFF. In addition to specifying the three-dimensional wind field, CALMET also estimates the boundary layer parameters used to characterize diffusion and deposition by the CALPUFF dispersion model.

The model domain shown in Figure 6.3 is a 34 km-by-48 km (21 by 30 mile) area centered on Owens Lake. The extent of the model domain was selected to include the "data rich" study area, terrain features that act to channel winds, and receptor areas of interest. The meteorological grid used a one-kilometer horizontal mesh size with ten vertical levels ranging geometrically from the surface to four kilometers aloft.

The majority of the necessary surface meteorological data came from the District's network of ten-meter towers shown in Figure 6.1 and two District stations south of the domain. In addition to the District's network, surface data from the City's field programs at Owens Lake were used when available. Cloud cover and ceiling height observations were also obtained from the Bishop Airport and China Lake. Cloud cover is a variable used to estimate the surface energy fluxes and, along with ceiling height, is used to calculate the Pasquill stability class (a classification of atmospheric stability).

The upper air data for construction of the wind fields and estimation of mixing heights with CALMET included local hourly observations from the Mill Site Wind Profiler and regional twice-daily upper air soundings from Desert Rock Airport (Mercury, Nevada) and China Lake Naval Air Station. The Wind Profiler with RASS samples wind and temperature from 300 ft, up to 15,000 ft with a vertical resolution as low as 200 ft. The Wind Profiler data were used until the instrument was removed in June 2004.

The China Lake and Desert Rock twice daily soundings were used to extend the profiles aloft near the profiler and, following removal of the Wind Profiler, for upper level temperature lapse rates. Upper level winds within the domain depend on either actual Wind Profiler measurements or extrapolation of the local surface wind measurements using the wind profile characteristics derived from the Wind Profiler studies

6.3.2 PM_{10} Emissions and Source Characterization

This section provides an overview of the methods discussed in Section 4.3, which were used to calculate hourly wind-blown PM_{10} emissions for dispersion model simulations at Owens Lake. PM_{10} emission fluxes from source areas at Owens Lake were calculated using hourly sand flux activity data and the following simple relationship:

Equation 6.1

$$PM_{10} = K_f \times q$$

Where:

PM_{10} = the vertical PM_{10} emission flux ($g/cm^2/hr$)
K_f = an empirical constant (referred to as the K-factor)
q = the horizontal sand flux measured at 15 cm above the surface ($g/cm^2/hr$)

Field data at Owens Lake suggest the horizontal sand flux at a single measurement height is proportional to the total horizontal sand flux and is a good indicator of wind erosion processes generating PM_{10} emissions. The total horizontal sand flux is a strong function of both the surface shear stress and the properties of the soil at the time of the event. Rather than trying to predict the horizontal sand flux using wind speed and properties of the soil, sand movement on the lake was parameterized using the network of paired Sensit and CSC measurements.

Experimental and theoretical evidence suggest K_f is a property associated with the binding energies of the soil and is relatively independent of the surface stress induced by wind speed. On Owens Lake this empirical constant appears to vary by season, due to the presence or absence of protective salt crusts, and by source areas grouped together by surface soil textures. In the Dust ID Program K_f was inferred using the modeling practices described by Ono, *et al*. (2003a). Simulations were performed using a first guess for K_f and the measured hourly sand flux data. Following a screening analysis, predictions were then compared to observed PM_{10} concentrations and a revised estimate for K_f was obtained. The screening criteria were selected to ensure a strong relationship existed between the source area and the downwind PM_{10} monitoring site. The source-to-receptor relationship was established using wind direction data, sand flux data for the source area, the maps generated from visual observations, and source contribution matrices based on the modeling.

The screened estimates for K_f were then grouped together by period and source area. Four K-factor areas were selected based on common surface soil properties. These source areas are identified as: the Keeler dunes, North area, Central area and the South area (see the maps in Figures 4.3 and 4.4). The periods were subjectively based on inspection of the variability exhibited in time series plots and considerations of the precipitation-temperature history thought to affect surface crusting, surface erodibility, and the formation of efflorescent salts on the surface. For each period and source area with nine or more hourly K_f estimates remaining after the screening process, a revised K_f was derived based on the 75th percentile of the ensemble. During periods and for source areas where nine data pairs were not available, the seasonal 2003 SIP K_f defaults for the areas were used

Table 4.1 lists the K_f estimates used in the 2008 SIP from the data collected during the four year period and the methods outlined above. Figures 4.10 through Figure 4.13 show the temporal variability of the K_f estimates assigned to each of the four general source areas. The hourly K_f plots show the seasonality of the data and provide an indication of the uncertainty of the estimates used in the 2008 SIP.

The CALPUFF simulations at Owens Lake are sensitive to source area configuration. Emissions were varied hourly according to Equation 6.1. The paired Sensit and CSC measurements were assumed to be representative of the horizontal sand flux for irregularly shaped source areas near the sand flux site. The following general rules were used to characterize and map source areas on the lake bed:

- Actual source boundaries were used when available to delineate emission sources in the simulations. Actual source boundaries were determined using a weight-of-evidence approach considering visual observations, GPS mapping, and surface erosive characteristics. Erosive characteristics that were considered when defining a source boundary include properties of the soil, surface crusting, wetlands, and the proximity of the brine pool.
- Source boundaries were also defined based on the DCM locations. For example, sand flux measurements outside the DCM were assumed to apply up to the boundary of the DCM. Sand flux measurements inside the DCM were assumed to apply to the area inside the DCM.
- Source areas were represented by a series of rectangular cells that generally conform to the actual shape of the source area and share the same hourly sand flux rates as the sand flux site representing that source area. Smaller rectangles were used as the active areas became smaller during the study period and in some instances near the shoreline to better represent source areas where predicted concentrations are expected to be particularly sensitive to the source area configuration.

Figure 6.4 shows the annual source configurations used in the 2008 SIP attainment demonstration for the period from July 2005 through June 2006. The location, size, Sensit, and general source area assignments for each source cell during the four annual periods are shown in Appendix B. The number of individual sources simulated varied from 1500 to over 2000 depending on the year of the simulation. The total simulated area ranged from 77 to 130 square kilometers.

With the exception of the Keeler dunes, PM_{10} emissions from non-Owens Lake PM_{10} windblown sources are not included in the model as individual sources. Due to the difficult nature of accurately estimating emissions from these much smaller, sporadic sources, non-Owens Lake PM_{10} emissions are included as contributors to the background concentration (see Section 6.3.4). This also includes contributions from upwind sources that may be outside the modeling domain.

6.3.3 CALPUFF Options and Application

The application of CALPUFF involves the selection of options controlling dispersion. Although the simulations are primarily driven by the meteorological data, emission fluxes, and source characterization, the dispersion options also affect predicted PM_{10} concentrations. In this study, the following options were selected for the simulations:

- Dispersion according to the conventional Pasquill-Gifford dispersion curves.
- Near-field puffs modeled as Gaussian puffs, not elongated “slugs.
- Consideration of dry deposition and depletion of mass from the plume.

Dry deposition and subsequent depletion of mass from the dust plumes depend on the particle size distribution. Several field studies have collected particle size distributions within dust plumes at Owens Lake. Based on results from Niemeyer, the CALPUFF simulations assumed a lognormal distribution with a geometric mean diameter of 3.5 µm and a geometric standard deviation of 2.2 (Niemeyer, *et al.*, 1999). These variables are based on the average of 13 dust plume size distributions reported by Niemeyer between June 1995 and March 1996 at different locations within the Airshed.

6.3.4 Background PM_{10} Concentrations

The dispersion model simulations include only wind-blown emissions from the source areas with sand flux activity shown in Figure 6.4 and in Appendix B. During high wind events other local and regional sources of fugitive dust also contribute to the PM_{10} concentrations observed at the monitoring locations. A constant background concentration of 20 $\mu g/m^3$ was added to all predictions to account for background sources. The constant background was calculated from the average of the lowest observed PM_{10} concentrations for each dust event when 24-hour PM_{10} concentrations at any of the sites were above 150 $\mu g/m^3$. To avoid including impacts from lake bed dust source areas in the background estimate, the procedures used a simple wind direction filter to exclude hours when the lake bed may have directly influenced observed PM_{10} concentrations. Such hours were removed and daily average background concentrations were recalculated based on the remaining data (Ono, 2002).

6.4 ATTAINMENT DEMONSTRATION

The CALPUFF modeling techniques described in previous sections and in Appendix B were applied to assess control strategies proposed for the 2008 Owens Valley PM_{10} SIP. These control strategies are described in Chapters 7 and 8. This section of the report describes the methods used to demonstrate attainment of the 24-hour PM_{10} NAAQS and presents the results of the analysis.

PM_{10} emissions were simulated using the hourly sand flux data collected during July 2002 through June 2006 based on the area source configuration shown in Figure 6.4 and Appendix B. The characterization of PM_{10} emissions follows the general techniques discussed above described more fully in Section 4.3.

Emissions from the Keeler dunes were excluded from the simulations to assess attainment. The District believes emissions from the Keeler dunes and several other off-lake sources are primarily caused by deposition from the lake bed sources. As discussed in more detail in Section 7.5, the District will work with the City and other federal, state and local agencies to develop a plan to control dust emissions from the Keeler dunes. Any PM_{10} control measures necessary for the Keeler dunes will be implemented by or before December 31, 2013 in order to demonstrate attainment of the federal standard by 2017.

The influence of non-lake bed sources is included in the simulations through the use of a background concentration. As discussed in Section 6.3.4, a background concentration of 20 $\mu g/m^3$ was added to all model predictions.

Attainment of the NAAQS was assessed using concentration predictions at the historic shoreline in addition to receptors at the monitoring stations. Attainment of the 24-hour NAAQS is achieved when the fifth highest 24-hour PM_{10} concentration in four years at each receptor is less than 150 $\mu g/m^3$. Predictions were obtained at more than 460 receptor locations placed at the historic shoreline (approximately at the 3600 foot elevation) of Owens Lake.

6.4.1 Control Strategy Analysis

The control strategy assessed in this study was developed as part of the 2006 Settlement Agreement between the District and the City. The location of 2003 SIP DCAs and the additional areas for control from the Settlement Agreement are shown in Figure 7.1. The 2003 SIP attainment demonstration evaluated controls for the existing DCAs. The Supplemental Dust Control Areas were identified through the Supplemental Control Requirement provision of the 2003 SIP. The 2008 SIP attainment demonstration evaluates these additional areas: Channel Areas, Supplemental DCAs, and Study Areas.

For the 2008 SIP and the controls in the 2006 Settlement Agreement, the City developed a customized spreadsheet containing the source-receptor contributions for every predicted concentration greater than 50 $\mu g/m^3$. Control efficiencies were assigned based on control type, but allowed to vary within certain DCAs. The spreadsheet starts with the controls specified in the 2003 SIP and then adds controls to new areas identified in the Settlement Agreement. These additional areas begin with no control and then are repetitively increased until all shoreline receptors are predicted to have PM_{10} concentrations less than 150 $\mu g/m^3$. The District then checks the resulting set of controls by re-applying the CALPUFF modeling system.

Control efficiencies for the 2008 SIP attainment demonstration are discussed in Section 7.3. Areas with variable levels of control in the Settlement Agreement are shown in Figure 7.2. These same efficiencies were used in the 2008 attainment demonstration, except for the Study Areas (S1, S2, S3, and S4 in Figure 7.1). The Study Areas were assumed to have no controls as none are required by the Settlement Agreement.

PM_{10} emissions from the Keeler dunes (see discussion above) and the 2003 SIP DCAs were not considered in the 2008 attainment demonstration. Dust control measures were not fully implemented in the 29.8 square mile 2003 SIP DCAs during the modeling period from July 2002 through June 2006. Thus it was not known whether emissions from these areas would be representative of future controlled conditions. For the purpose of the 2008 SIP to establish control levels for the supplemental DCAs in the Settlement Agreement, it was assumed that no emissions were coming from the 2003 DCAs. Controls for these 2003 SIP DCAs were considered in the 2003 attainment demonstration.

6.4.2 Attainment Demonstration Results

The predicted fifth highest 24-hour PM_{10} concentrations at receptors located along the shoreline are shown in Figure 6.5 based on a CALPUFF simulation of the control strategy discussed above. The numbers of times the PM_{10} predictions are above 150 $\mu g/m^3$ at shoreline receptors are displayed in Figure 6.6**.** Although four predictions are above the 24-hour NAAQS, the design or fifth highest concentration at the same receptor was 147 $\mu g/m^3$ for the four-year simulation. The modeling analysis demonstrates attainment of the 24-hour PM_{10} NAAQS using the Settlement Agreement control strategy.

The highest concentrations are along the shoreline at locations influenced by the Study Areas. These areas are being investigated, but there are currently no plans to control these areas. The Study Areas have relatively high emissions for a few days in the four-year simulations.

However, the frequency of such events from these areas is not high enough to cause violations of the 24-hour PM_{10} NAAQS.

6.5 REFERENCES

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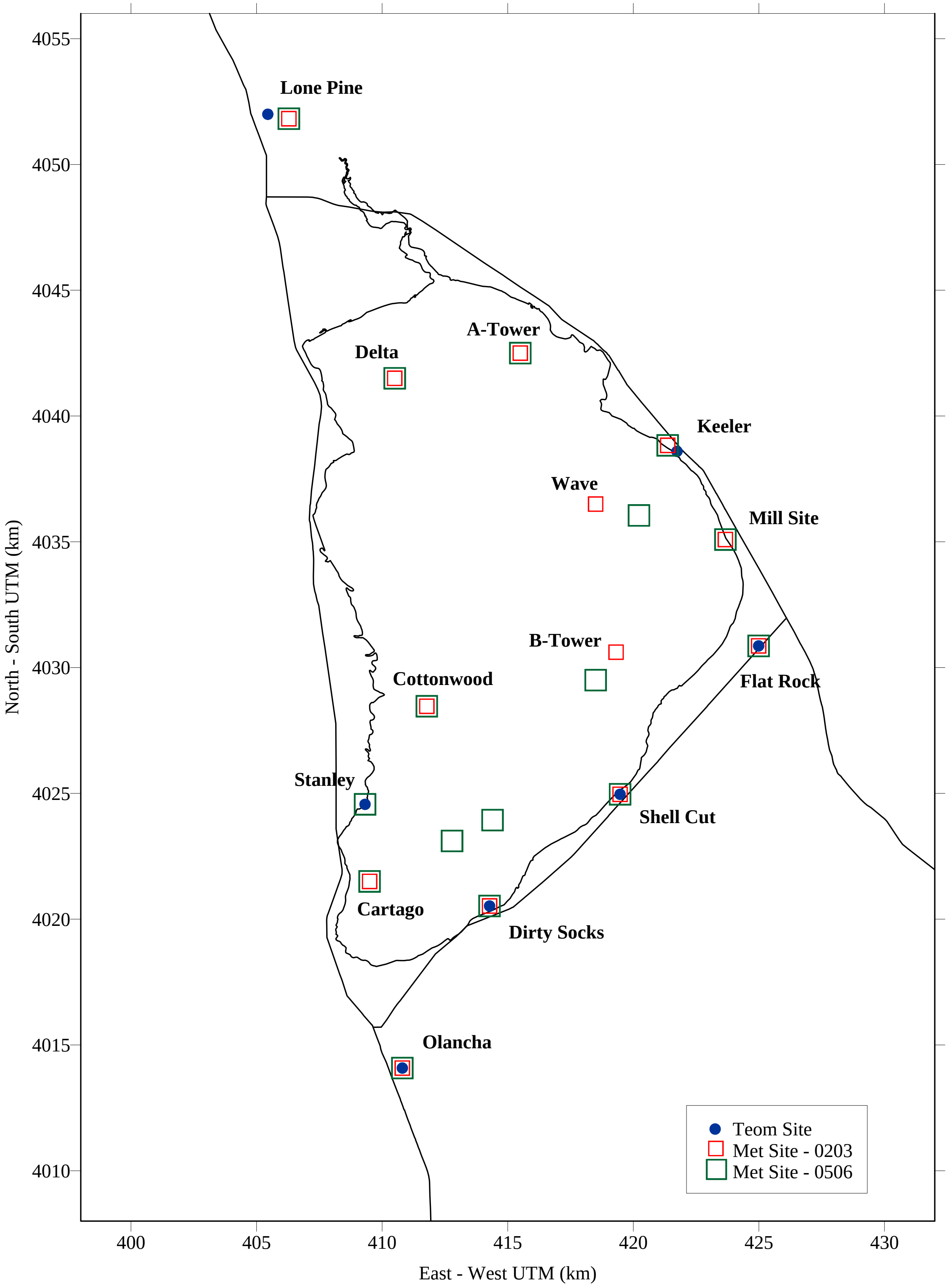

Figure 6.1 - Owens Lake PM_{10} and meteorological monitoring network

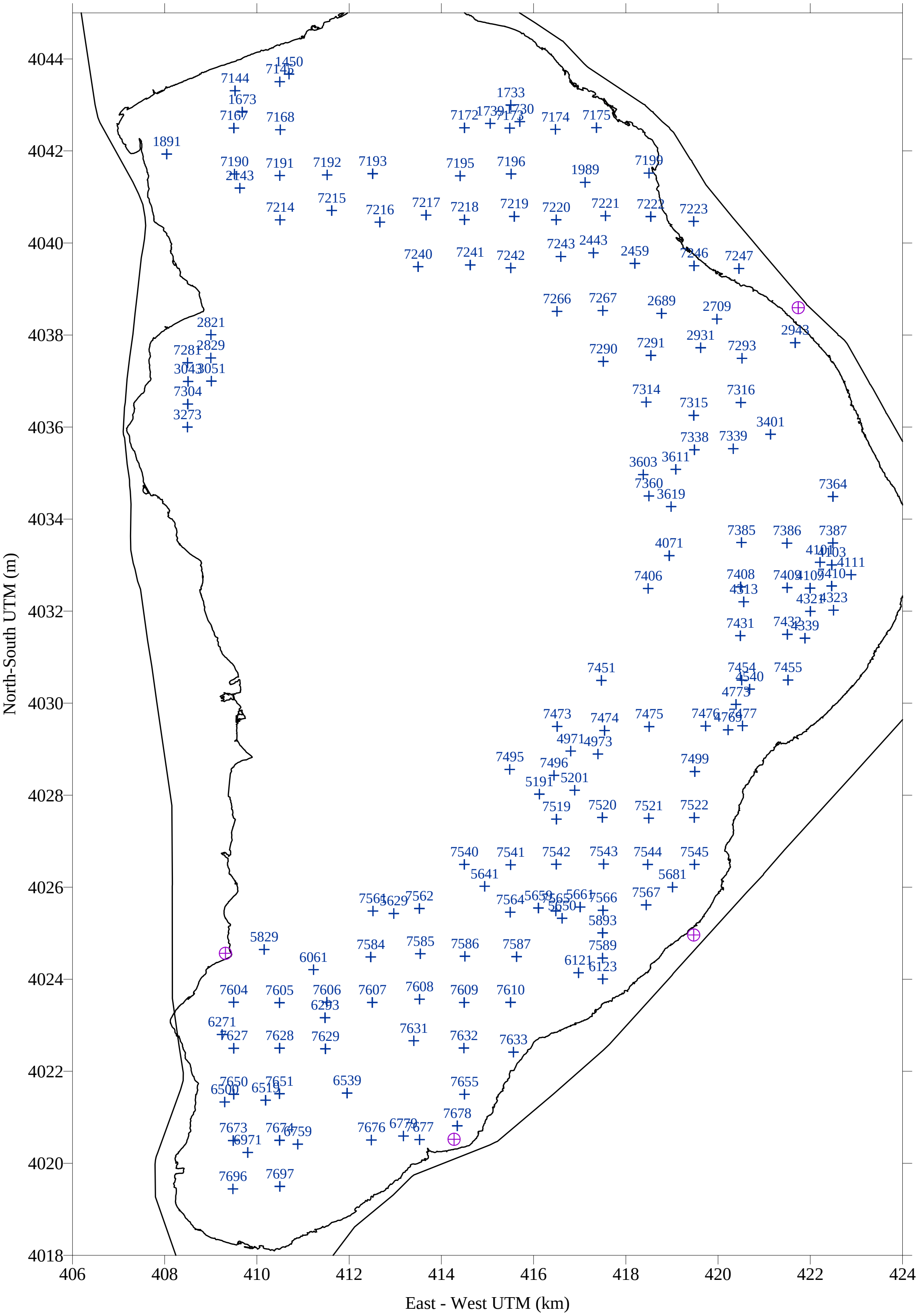

Figure 6.2 - Owens Lake sensit network for July 2005 through June 2006

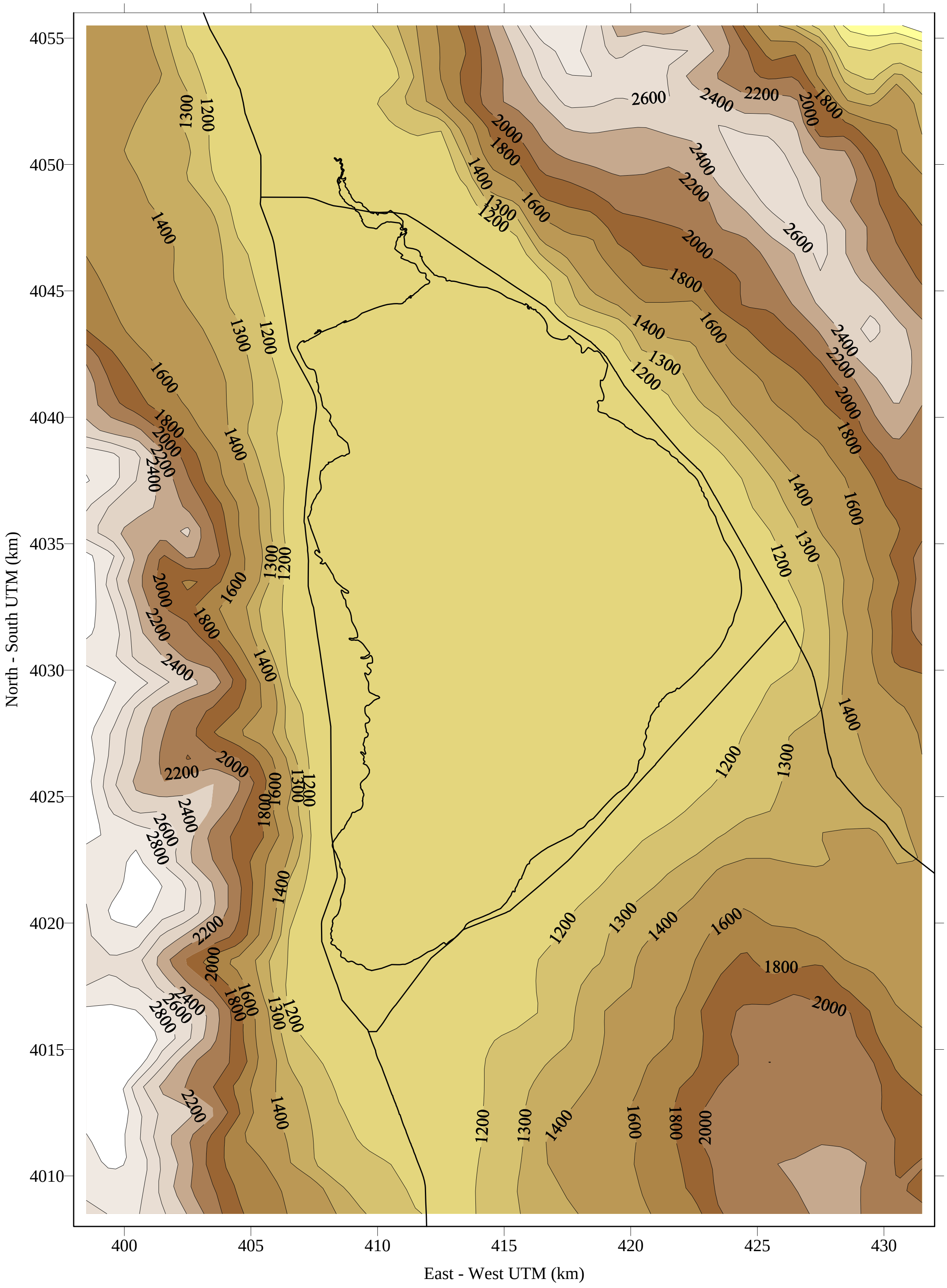

Figure 6.3 - Model domain and one-km mesh size terrain (m)

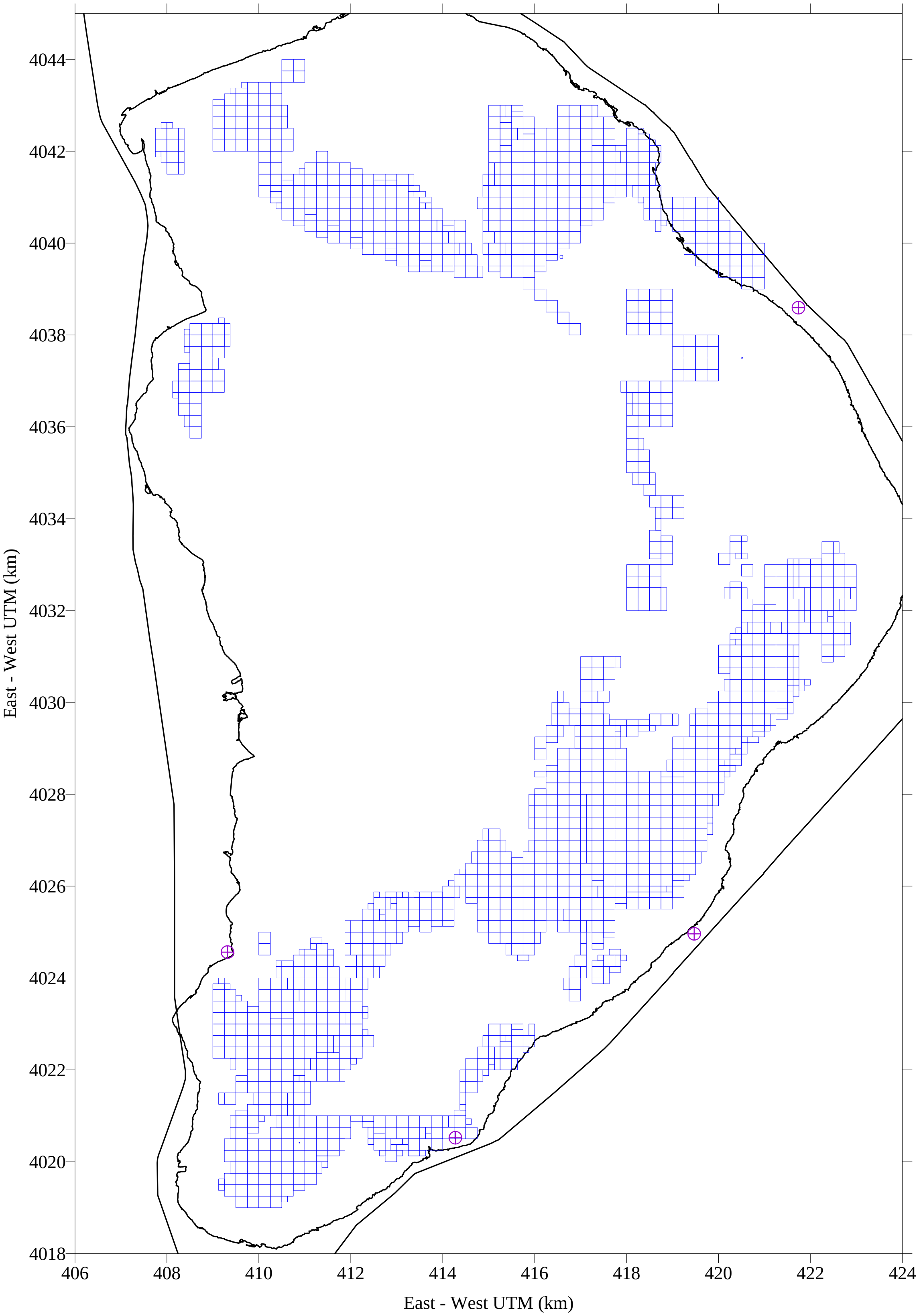

Figure 6.4 - Area source configuration for July 2005 through June 2006

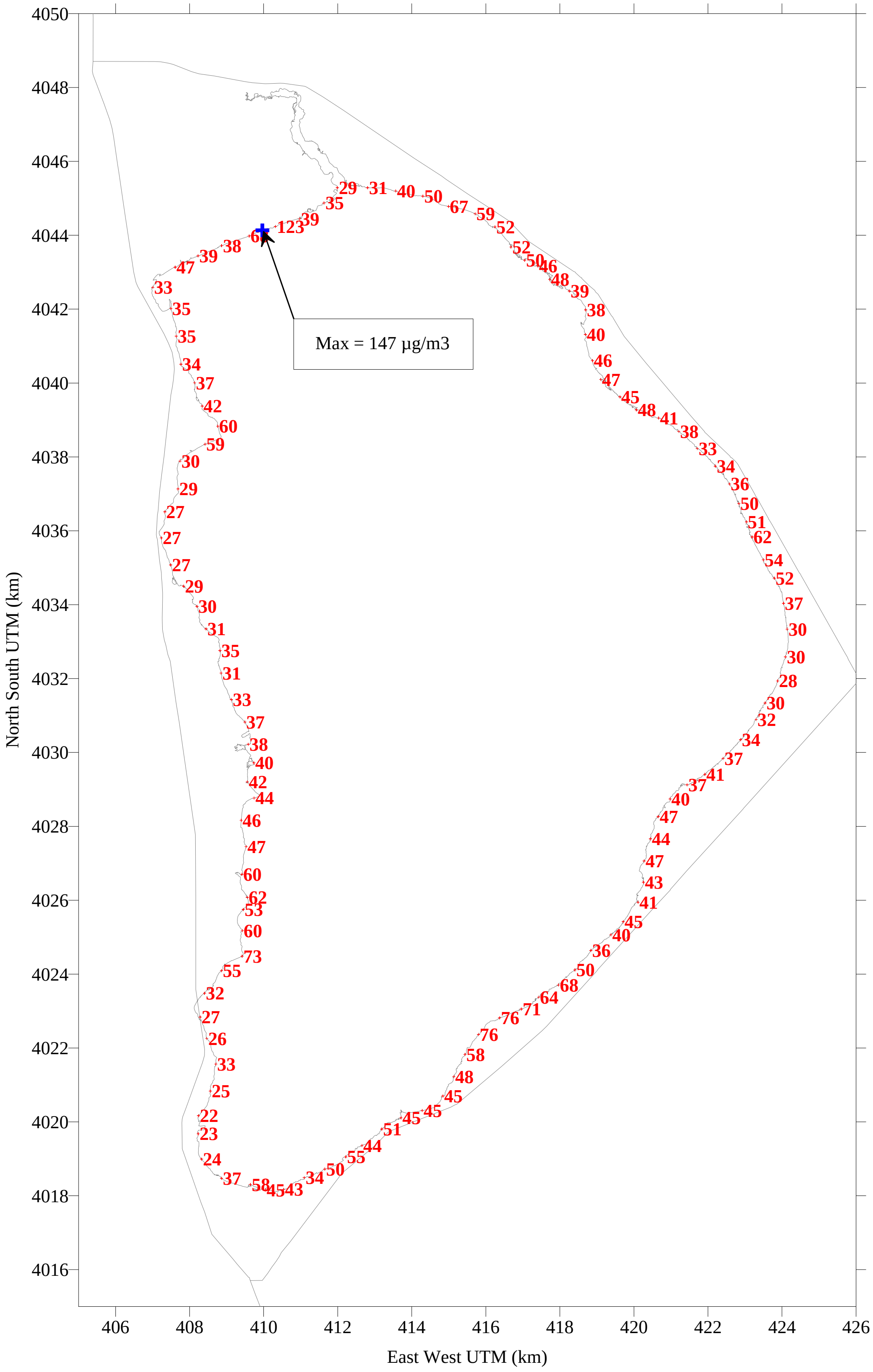

Figure 6.5 - Fifth highest 24-hour PM_{10} ($\mu g/m^3$) at shoreline receptors, no Keeler dunes, after controls (every 4th plotted)

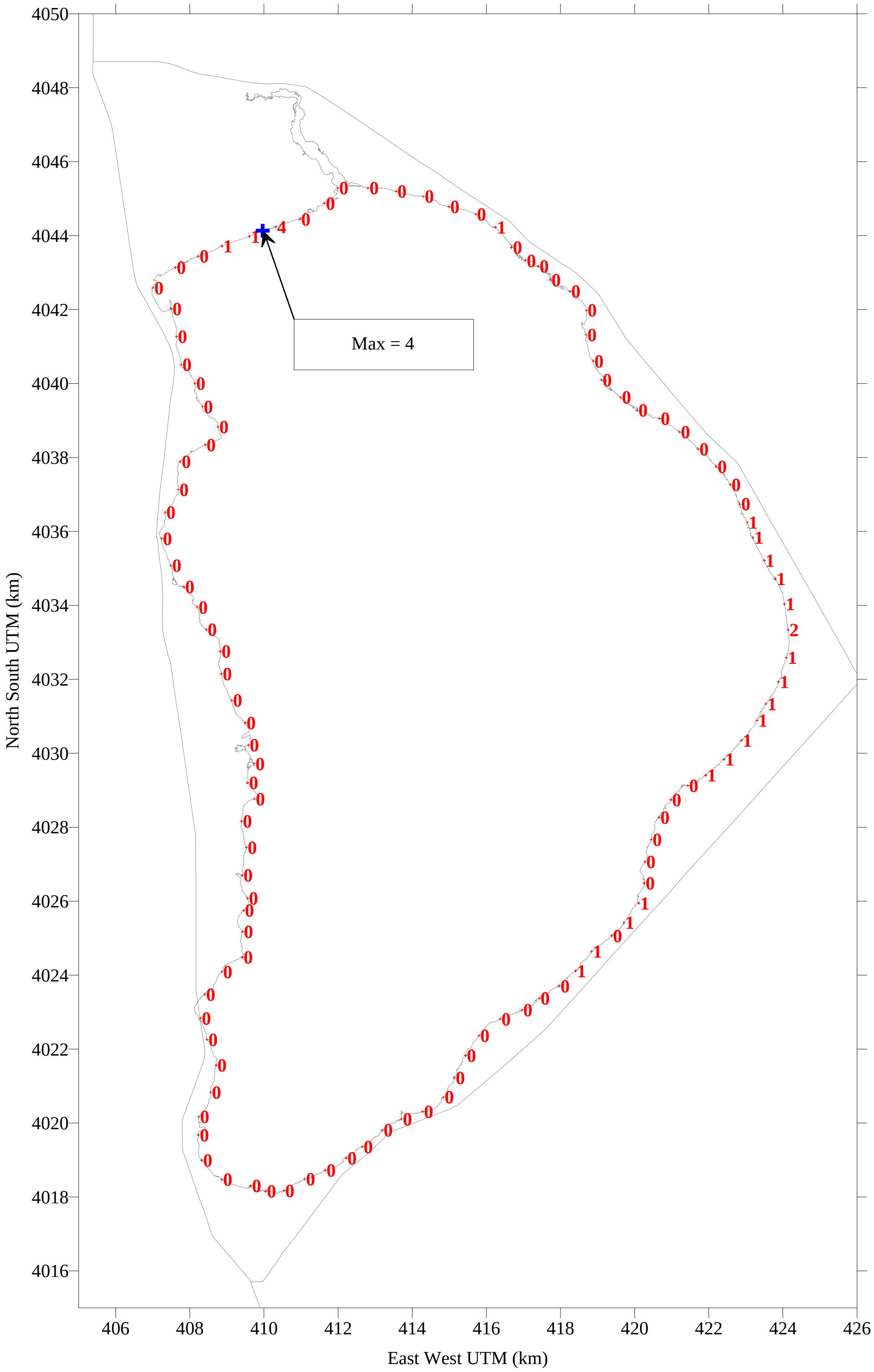

Figure 6.6 - Number of 24-hour PM_{10} predictions greater than 150 µg/m^3 at shoreline receptors, no Keeler dunes, after controls (every 4th plotted)