SECTION 5 - DISPERSION MODELING

5.1 Introduction

The Mono Basin Planning Area is in violation of the 24-hour PM-10 Standard for ambient air quality as measured at the Simis Ranch and Warm Springs monitoring sites during the period of January 1988 to May 1993. Episodes that result in exceedances of the Standard are accompanied by high winds and the source area responsible for windblown dust emissions is the exposed lake shore of Mono Lake. In order to implement effective control measures that reduce emissions, it is essential to develop techniques (1) to predict the distribution and concentration of windblown PM-10 from the source area, (2) to evaluate the variables that contribute to episodes with serious air quality impacts, and (3) to validate modeled predictions with observed data.

This section describes the application of dispersion modeling techniques to fulfill these objectives. In addition to predicting PM-10 concentrations downwind of exposed lake shore areas, modeling results are used to examine change in predictions based on different lake levels or source elevations. Understanding the correlation between emission concentrations and differing lake levels is germane to strategies for attaining and maintaining the federal PM-10 Standard.

5.2 Dispersion Modeling Overview

Predicting ambient air quality impacts requires an understanding of the transport, dispersion, chemical transformation, and removal processes that affect pollutant emissions after their release into the atmosphere. Computer models provide the most practical method for developing quantitative air quality assessments for multiple scenarios of possible future conditions. Air pollution problems at Mono Lake are dominated by physical processes, rather than by chemical transformations. Gaussian dispersion models are best suited for the analysis of such physical processes and are the logical choice for this setting. Dispersion modeling techniques were utilized by the TRC Environmental Corporation and McCulley, Frick & Gilman, Inc. (1992-1993) in studies designed to predict ambient PM-10 levels at Mono Lake. A summary of the modeling methods, inputs, and results are presented later in this section. The complete report of findings is included in Appendix 5 - *Final Mono Lake Air Quality Modeling Study*.

Dispersion models calculate pollutant concentrations at particular receptor locations by applying appropriate horizontal and vertical dispersion factor equations to the initial pollutant concentration. The proper dispersion factor equations are determined from the position of the receptor relative to both the emission source and the center line of the pollution plume, extending downwind from the emission source. Gaussian dispersion models assume pollutant emissions to be carried downwind in a defined plume that is subject to horizontal and vertical mixing with the surrounding atmosphere. As the plume spreads horizontally and vertically, pollutant concentrations diminish downwind from the emission source. Pollutant mixing with the surrounding atmosphere is greatest at the edge of the plume, resulting in lower pollutant concentrations outward in all directions from the center of the plume. This decrease in concentrations outward from the center is assumed to follow a Gaussian or "normal" statistical distribution. Horizontal and vertical mixing generally occur at different respective rates. Because turbulence in the atmosphere occurs on a variety of spatial and temporal scales, mixing also varies with distance downwind from the emission source.

Gaussian dispersion models estimate the net effect of atmospheric dispersion processes on emissions, but do not mathematically simulate the physical process of turbulent dispersion. These models are generally structured as a series of mathematical terms multiplied together. The initial term in the equation represents the concentration at the plume center line of the emission source. This term is multiplied by a series of three factors that reduce the initial concentration value to account for distance downwind from the emission source, lateral offset from the plume center line, and vertical offset from the plume center line.[22]

5.3 Industrial Source Complex Model (ISC2)

The *Mono Lake Air Quality Modeling Study* investigated two dispersion models--the Industrial Source Complex Short-Term (ISCST) model[23] and the Fugitive Dust Model (FDM).[24] The EPA recently released restructured versions of the original ISC models called ISC2.[25] The ISC models have historically been the regulatory preferred models for assessments associated with fugitive dust.[26] ISC models are also preferred by CARB for calculations of ground level area sources of fine particles or gaseous pollutants.[27] The ISC2 model was selected based on regulatory precedence and proven performance in predicting PM-10 concentrations at Mono Lake.

The ISC2 model is based on the steady-state Gaussian plume formulation. For fugitive dust problems, the ISC2 model is often applied because it includes routines both to simulate area sources and to account for removal of mass at the surface caused by gravitational settling and dry deposition. In addition to prediction of ground level concentrations, the model can be applied to estimate deposition fluxes.

5.4 Emission Factor

Windblown PM-10 emissions from the exposed lake shore areas of Mono Lake are estimated using an empirical emissions factor developed by the District. This mathematical relationship is based on interpretations from a series of wind tunnel tests conducted at Mono Lake during 1990 with a portable wind tunnel erected over characteristic erodible surfaces. During those tests, it was observed that PM-10 emissions are a strong function of wind speed with the velocity threshold value in the range of 16 to 20 mph as measured at a height of 10 meters. It also noted that surface crusting influences the threshold value.

Observations from the wind tunnel tests resulted in the following PM-10 emissions factor:

$$q_a = 2.6 \times 10^{-5} \exp(0.11u)$$

where: q_a is the area source PM_{10} emission factor or vertical flux ($g/m^2/sec$), and u is wind speed (mph).[28]

The emission factor assumes "worst case" conditions for PM-10 emissions from the lake bed, including the availability of a continuous supply of PM-10 sized particles during the storm period. This worst case emission factor is used to simulate the worst storms, specifically those that may violate the PM-10 Standard, and not to simulate every storm. Seasonal and daily changes in the surface crust strength result in conditions that are less erosive than the worst case emissions algorithm and, therefore, the model produces higher average predictions for the five years of modeling results than is observed from the ambient data.

5.5 ISC2 Modeling Input Data

Operation of the ISC2 model requires the following input data files: (1) emission inventory for lake shore windblown dust, (2) meteorological data, (3) background PM-10 concentration estimates, and (4) receptor configuration. This section briefly describes the preparation of these requisite data sets.

Emission Inventory

Emission inventory data for lake shore windblown dust is obtained from the air quality monitoring sites discussed in Section 3.3. (Detailed sampling data is contained in Appendix 4.)

Windblown PM-10 emissions at Mono Lake vary with season due to crust formation, snow cover, and precipitation. As presented later in this section, in order to account for the effect of seasonal variables on actual source area conditions, the modeling predictions are segregated into two basic groupings. These groupings are determined by the input data sets. The first data set includes all days with the potential for nonzero windblown emissions using the criterion that at least one hour of winds exceeds the 16 mph threshold. The second data set includes only those days meeting the wind threshold criterion and falling within the "dust season." For the purposes of this modeling study, the dust season refers to the months of April, May, June, November, and December. Developing the two groupings of modeling results provides a qualitative framework for analyzing conditions which inhibit the erodibility of the lake shore.

The location of emissive source areas is shown in Figure 5-1. The irregular lake shore area, delineated by the contours in the figure, is organized into a series of square source areas aligned in an east-west direction for each designated lake level or source elevation. The modeling study simulates windblown PM-10 emissions from these source areas with lower elevation bounds of 6,375', 6,377', 6,381', 6,387', and 6,393'. It is important to note that the lower limits of the modeled source areas will be somewhat higher in elevation than the actual lake level due to a one vertical foot stable band which has been observed to form above the water line. For example, a modeled lower source elevation of 6,393' will correspond to an actual lake level at about 6,392'.

Meteorological Data

Hourly meteorological data files have been constructed using observations from the Simis Ranch site during 1988 to 1992. The meteorological station located at Simis Ranch collects wind, temperature, and precipitation data. The data set includes only those days with the potential for nonzero windblown emissions. Days with significant gaps in the key meteorological variables have also been eliminated from the simulations.

In addition to wind speed, wind direction, and temperature data, the ISC2 model requires hourly estimates of atmospheric stability class and the depth of the well-mixed layer. Hourly values have been estimated from the average morning and afternoon mixing height using interpolation routines employed by both the EPA's MPRM and RAMNET meteorological pre-processors (with a minimum mixing depth of 100 meters).[29]

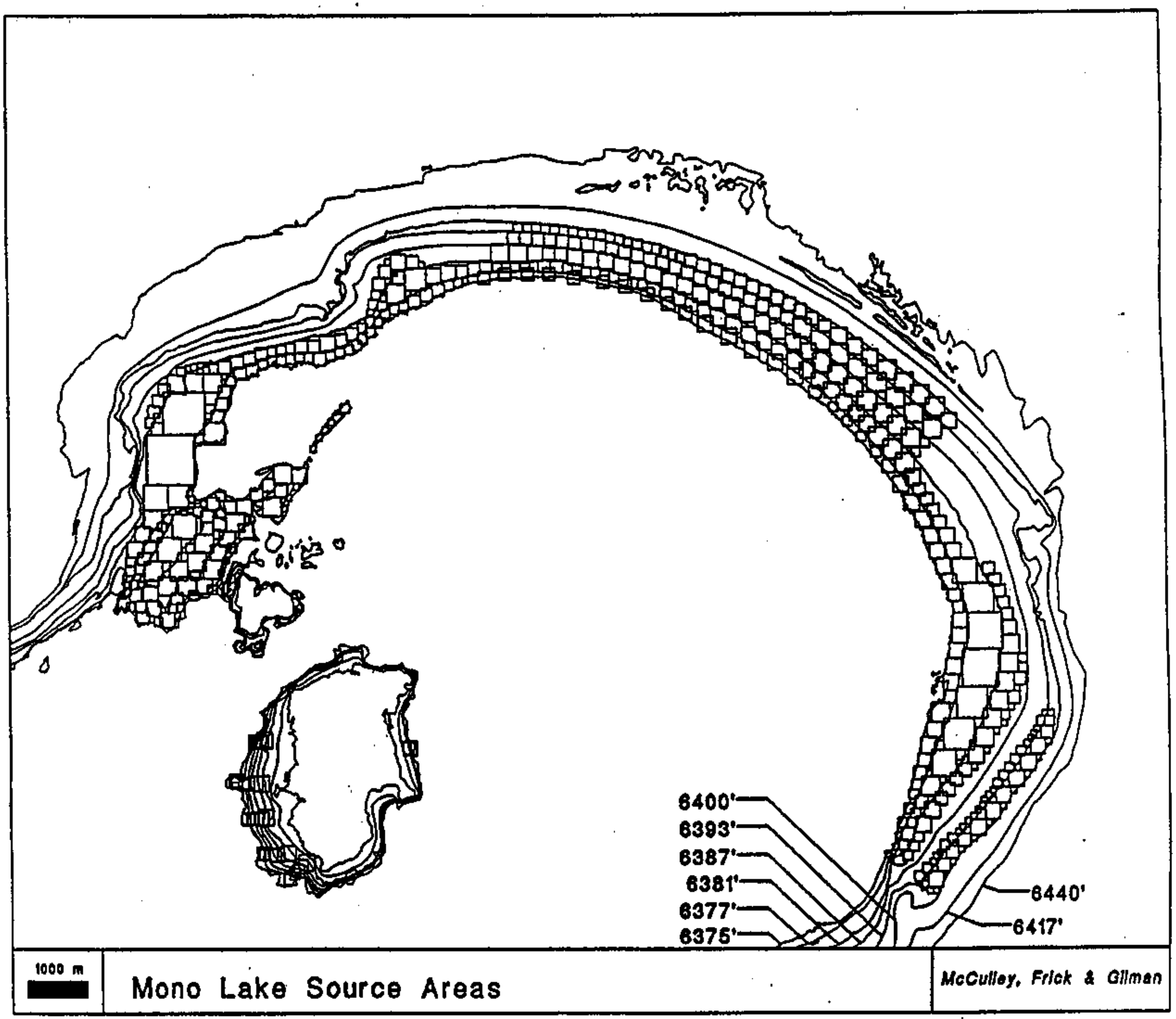


Figure 5-1 Mono Lake Source Areas

Background PM-10 Concentration Estimates

Estimates of background PM-10 levels have been obtained from the Lee Vining site. Examination of wind patterns during periods of high wind velocity indicates that Lee Vining is generally upwind of the dust source areas and the other monitoring stations. Daily values observed at Lee Vining have been added to all model predictions, when available. When data is not available for a specific episode, background PM-10 is assumed to be 13.1 $\mu g/m^3$.[30]

Receptor Configuration

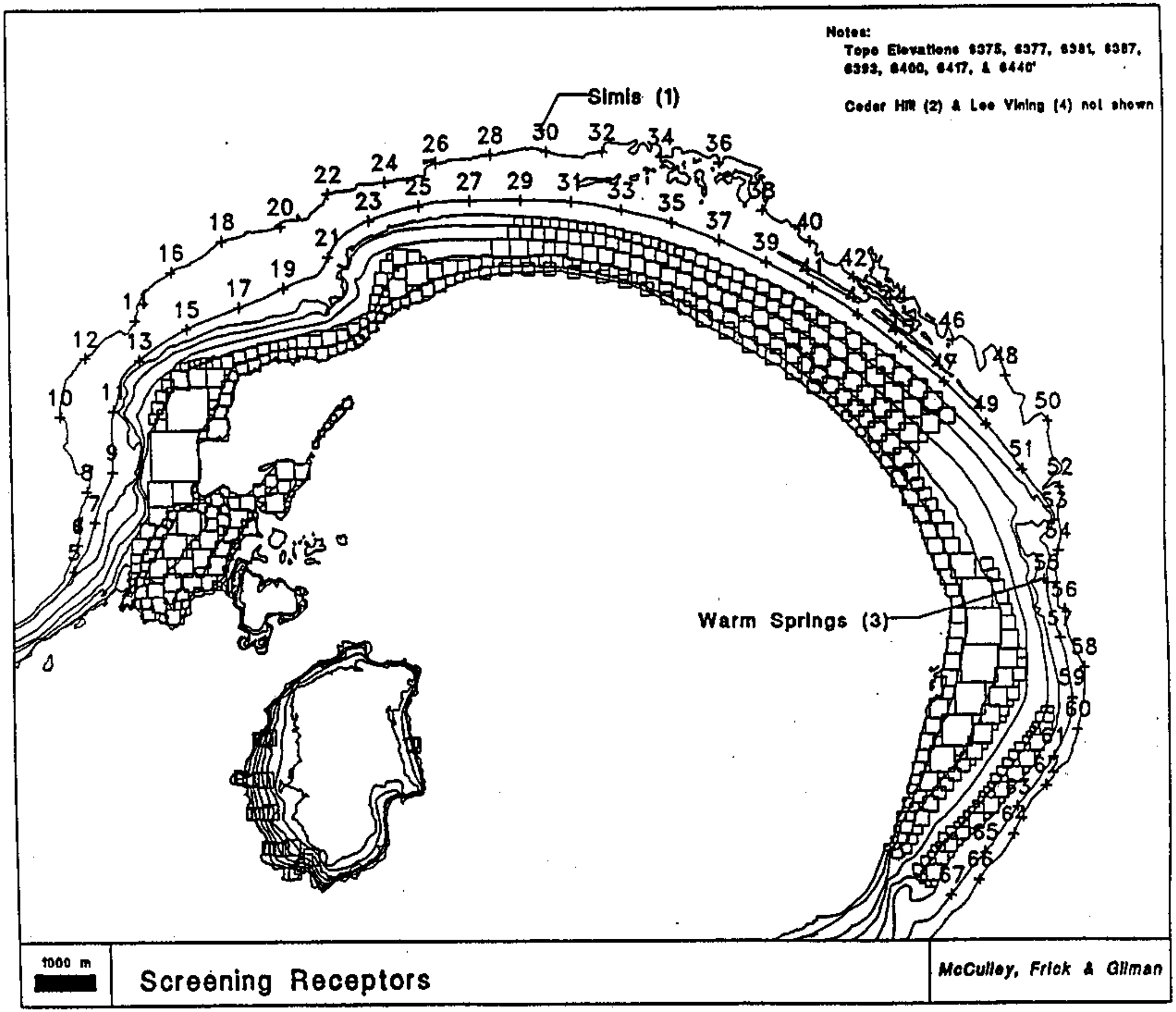
The magnitude of the concentration predictions is significantly influenced by the placement of the receptor grid. Sensitivity tests indicate that concentration predictions drop considerably downwind of the eroding area sources. Based on District consultation, a ring of screening receptors was placed at the 6,417' and 6,440' elevations along the northern shore of Mono Lake and at the monitoring stations at Simis Ranch, Warm Springs, and Cedar Hill (Figure 5-2). At their closest point, these receptors are within about 150 meters of the eroding lake shore. The full receptor network includes the screening receptors plus receptors placed on a one kilometer rectangular grid outside the 6,440' elevation and inside the 6,375' elevation. Additional receptors are also placed on nongrid positions to improve accuracy of the contour plots. The full receptor network set includes 482 receptors. (Figure 5-3)

5.6 Performance Evaluation of ISC2 Modeling Approach

The *Final Mono Lake Air Quality Modeling Study* includes a performance evaluation which compares ISC2 modeled predictions (using the empirical emission factor and programmed source area definitions) with actual ambient PM-10 data. EPA's *Interim Procedures for Evaluating Air Quality Models*[31] was used along with recommended guidelines from CARB. The primary objective of the performance evaluation is to assess whether the modeling methods and approach produce results that adequately simulate measured emissions.

The modeled results are found to overpredict average PM-10 concentrations by about a factor-of-two or more. However, performance of the modeling approach improves significantly when days outside the dust season are excluded from the analysis. The evaluation indicates that the simulations contained in the *Final Mono Lake Air Quality Modeling Study* "[f]orm a conservative basis for assessing the effects of differing lake levels. However, the degree of conservatism is well within recognized guidelines for acceptable model performance in a regulatory application."[32]

Figure 5-2 Screening Receptors



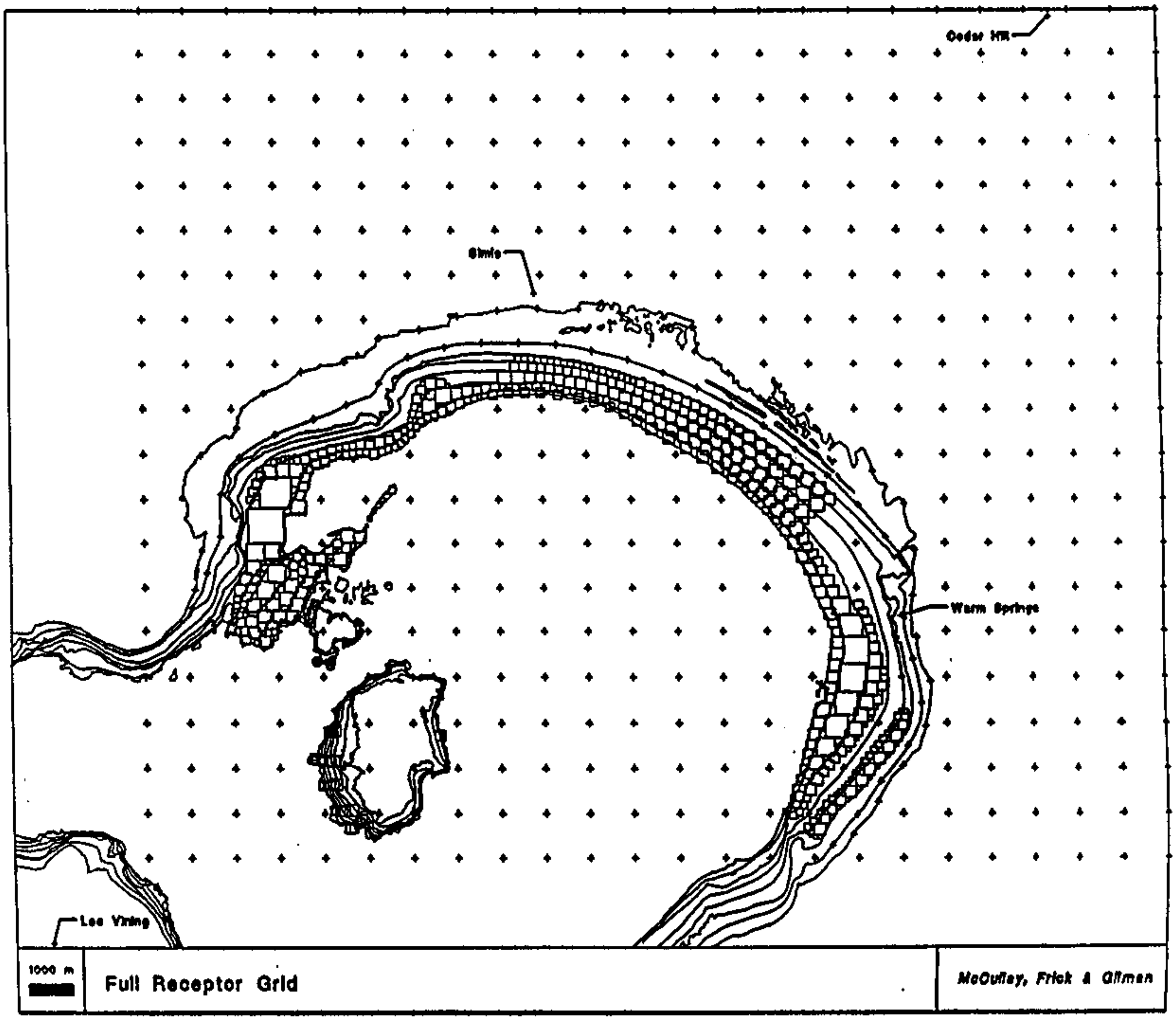


Figure 5-3 Full Receptor Grid

5.7 Dispersion Modeling Results

Dispersion modeling techniques have been applied to predict PM-10 concentrations downwind of exposed lake shore areas for different lower lake levels or source elevations. Predictions for each screening receptor are modeled for every day of the five year meteorological data set where wind velocity exceeded the 16 mph threshold at the Simis Ranch monitoring site. This results in the simulation of 451 days. The highest potential daily emissions range from 708,648 Kg/day to 81,301 Kg/day and occur on June 4, 1988. (Table 7, Appendix 5). This is for lake surface elevations of 6,375' and 6,393' respectively. The measured wind velocity at the Simis Ranch monitoring site for this episode averaged 22 mph and 22 hours were above the entrainment threshold of 16 mph.

Using the same meteorological data set, the highest predicted 24-hour PM-10 concentrations for each of the 67 screening receptors in the network are calculated. The location and date of the top six predictions for all source elevations are shown in
Table 5-1 below.

Receptor site 45, located on the 6,417' topographic contour, experiences the highest 24-hour PM-10 predictions for all but one source elevation. High predictions at this receptor site can be attributed to the close proximity of the eroding lake shore and the exposure of this receptor to wide bands of upwind source areas. Also, this receptor is potentially exposed to emissions under a wide variety of wind directions ranging from south-southeasterly to westerly.

It is important to note that several of the highest predictions in Table 5-1 occur on days outside of the dust season. As discussed earlier, crust formation or other conditions which inhibit erosion would normally be present during these periods and that the model overpredicts the potential impacts based on meteorological data only.

Table 5-1

TOP SIX PM-10 PREDICTIONS
SCREENING RECEPTOR SET

		MODELED ELEVATIONS				
		6,375'	6,377'	6,381'	6,387'	6,393'
Max PM-10	(µg/m³) Receptor Date	1,588 45 10/23/89	1,446 45 10/23/89	1,127 45 10/23/89	846 45 10/23/89	550 59 8/26/91
Max 2nd Hi PM-10	(µg/m³) Receptor Date	1,417 45 6/4/88	1,304 45 6/4/88	1,054 45 6/4/88	784 45 6/4/88	510 45 4/21/89
Max 3rd Hi PM-10	(µg/m³) Receptor Date	1,212 45 4/21/89	1,143 45 4/21/89	960 45 4/21/89	734 45 4/21/89	509 45 6/4/88
Max 4th Hi PM-10	(µg/m³) Receptor Date	1,182 45 2/16/90	1,100 45 2/16/90	921 45 2/16/90	696 45 2/16/90	467 45 2/16/90
Max 5th Hi PM-10	(µg/m³) Receptor Date	1,077 45 9/26/89	961 45 9/26/89	762 45 4/19/88	584 45 5/23/90	409 45 5/23/90
Max 6th Hi PM-10	(µg/m³) Receptor Date	1,013 45 4/19/88	914 45 4/19/88	762 45 5/23/90	578 45 4/19/88	408 45 4/19/88
Receptor locations are shown in Figure 5-2						

In order to obtain more realistic predictions that account for actual source area conditions at Mono Lake, the highest predicted 24-hour PM-10 concentrations for all receptors are calculated for days in the dust season only. Applying the new criterion, the location and date of the top six predictions for all source elevations are presented in Table 5-2.

Table 5-2

TOP SIX PM-10 PREDICTIONS
SCREENING RECEPTOR SET
Dust Season Only

		MODELED ELEVATIONS				
		6,375'	6,377'	6,381'	6,387'	6,393'
Max PM-10	(μg/m³) Receptor Date	1,417 45 6/4/88	1,304 45 6/4/88	1,054 45 6/4/88	784 45 6/4/88	510 45 4/21/89
Max 2nd Hi PM-10	(μg/m³) Receptor Date	1,294 17 6/4/88	1,143 45 4/21/89	960 45 4/21/89	734 45 4/21/89	509 45 6/4/88
Max 3rd Hi PM-10	(μg/m³) Receptor Date	1,021 17 11/13/88	914 45 4/19/88	762 45 4/19/88	589 47 5/8/91	409 45 5/23/90
Max 4th Hi PM-10	(μg/m³) Receptor Date	1,016 17 5/23/90	897 45 5/23/90	762 45 5/23/90	578 45 4/19/88	408 45 4/19/88
Max 5th Hi PM-10	(μg/m³) Receptor Date	903 45 6/28/92	848 45 5/8/91	727 45 5/8/91	558 45 5/8/91	391 45 6/28/92
Max 6th Hi PM-10	(μg/m³) Receptor Date	895 45 5/8/91	831 45 6/28/92	700 45 6/28/92	540 45 6/28/92	356 45 5/8/91

Receptor locations are shown in Figure 5-2

Table 5-2 shows that several of the high episodes previously predicted in Table 5-1 are eliminated when the qualitative effects of seasonal crust formation, snow cover, and precipitation are considered in the analysis. Notice again that receptor site 45 is the predominant location for predicted high PM-10 episodes at all source elevations.

"Attainment of the 24-hour PM-10 NAAQS [Standard] is demonstrated when the sixth highest concentration at any receptor over a five year period is less than 150 $\mu g/m^3$. While the top five episodes over five years are of interest, due to the probabilistic nature of the NAAQS the focus of most regulatory analyses is on the sixth highest or design concentration. The highest-sixth highest concentration for the screening receptor grid excluding days outside of the dust season ranged from 895 to 356 $\mu g/m^3$ for the lower source elevations of 6,375' to 6,393', respectively. . . . The majority of the receptors located at the 6,417' and 6,440' levels were predicted to exceed the 150 $\mu g/m^3$ NAAQS until the lower source elevation rose to 6,387'. . . . However even when the lower source elevation was 6,393', large areas along the northeastern and eastern shores remained above 150 $\mu g/m^3$."[33]

Contour plots have been constructed from the May 8, 1991 design day receptor grid concentrations for the 6,393' source elevation (Figure 5-4). The patterns in the contour plots display the areas downwind of the lake shore to about the 6,440' elevation that still exceed the PM-10 Standard (Figure 5-5).

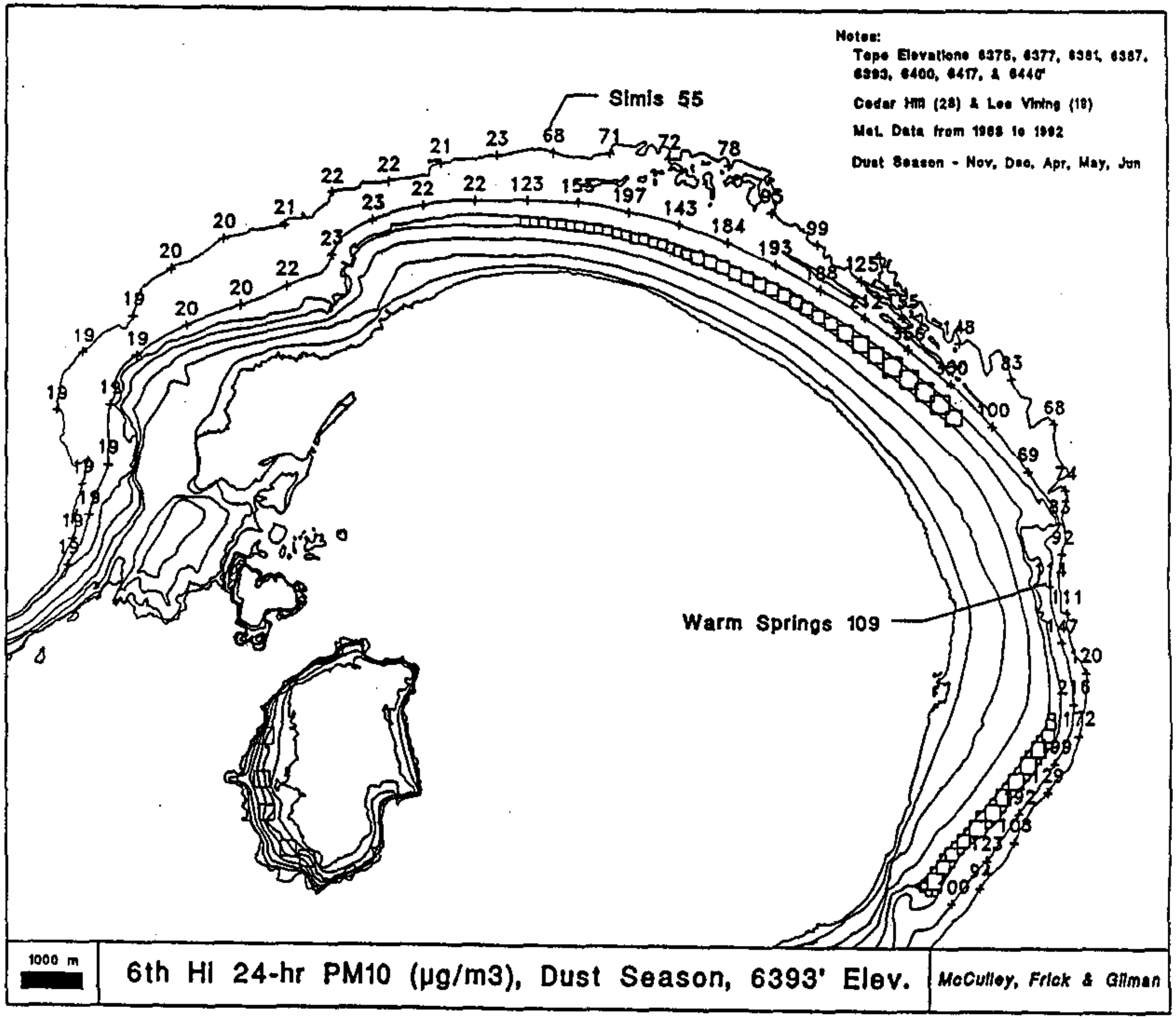


Figure 5-4 Design Day Receptor Grid Concentrations: 6,393' Elevation

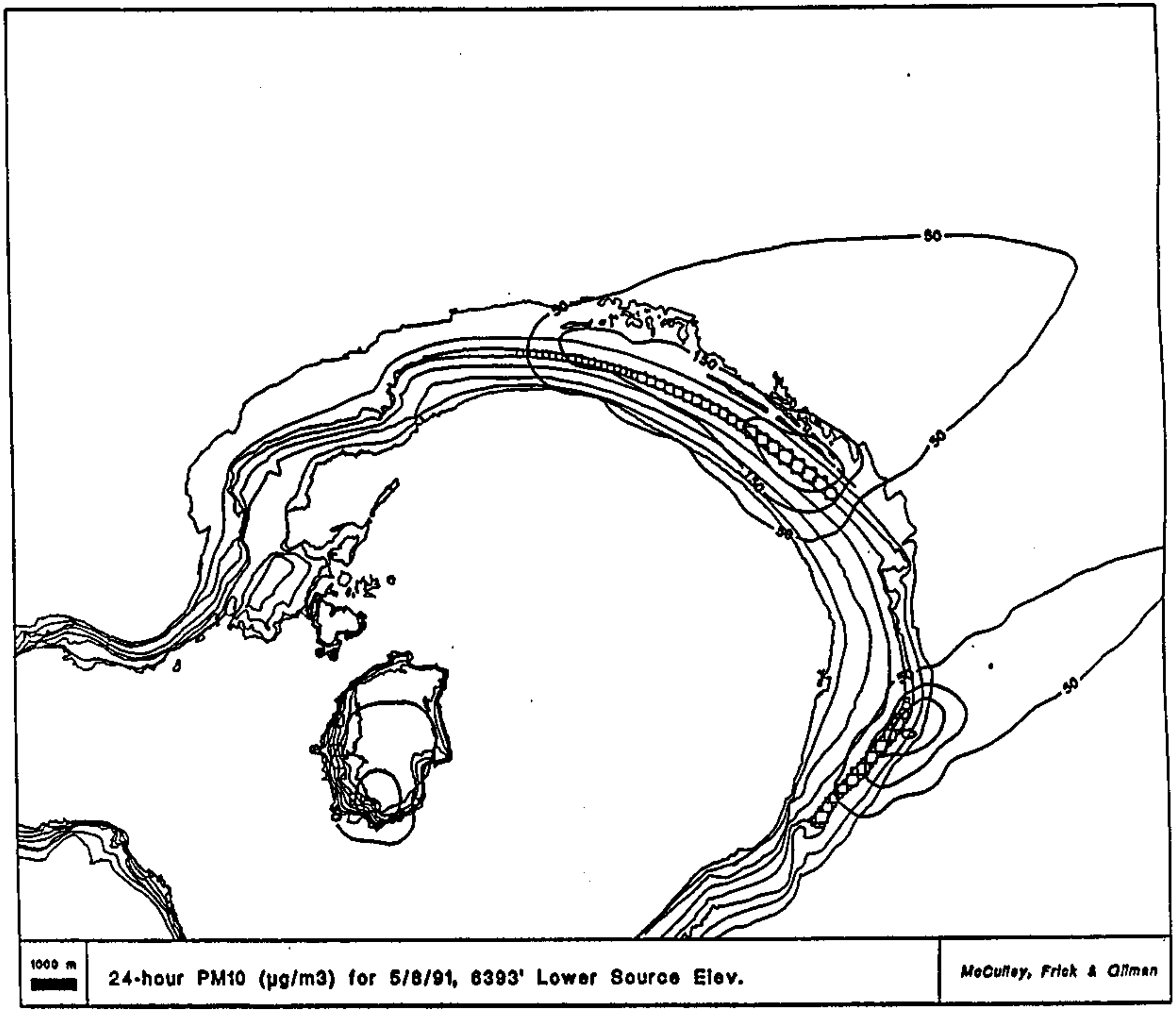


Figure 5-5 Contour Plots for Design Day: 6,393' Elevation