Depositional Modeling Results from the Russell City Energy Center Operation Critical Habitat Areas

The Russell City Energy Center (RCEC) will utilize two (2) combined cycle natural gas-fired combustion turbines. The resulting exhaust gases will discharge to the atmosphere through 145-foot-tall exhaust stacks. Emissions of criteria pollutants from the two (2) exhaust stacks will include nitrogen oxides (NO_x) sulfur oxides (SO_x), and particulate matter with an aerodynamic diameter of 10 and 2.5 microns or less (PM10/2.5). In addition, emissions of ammonia (NH_3) will occur as a byproduct of the Selective Catalytic Reduction (SCR) technology used to limit emissions of NO_x.

Nitrogen deposition resulting from the emissions of nitrogen compounds could increase the growth of non-native vegetation, particularly grasses, and as a result, could potentially have an adverse cumulative impact on the existing plant communities and endemic species in the area. This section assesses that potential.

Serpentine soil plant communities occur within certain areas of the East Bay Regional Park District (EBRPD) and are known to be particularly sensitive to nitrogen deposition. Serpentine-derived soils in the San Francisco Bay Area support native grassland plant communities that provide habitat for rare and endemic species that are adapted to nutrient-poor soils. Increased nitrogen levels may encourage non-native annual grasses to out-compete native species (Weiss 1999, as cited in CEC 2007).

The modeling analysis focused on areas of interest to the EPA within the Hayward Regional Shoreline, Garin/Dry Creek Pioneer Regional Park, Redwood Regional Park, and Lake Chabot Regional Park.

The potential for impacts from nitrogen deposition in serpentine soil plant communities and the associated plant and animal resources that they support depends on the following:

- Nitrogen deposition rates
- Response of non-native species to nitrogen fertilization

To assess the potential for nitrogen deposition in the identified habitats of the EBRPD, two Environmental Protection Agency (EPA) Gaussian dispersion models were used to assess nitrogen deposition: the AERMIC Model (AERMOD) and CALPUFF. Both models and the associated input data are discussed below.

Nitrogen Deposition Rates

Chemical Transformation of NO_x Emissions

The oxidation of nitrogen oxides is a complicated process that can include a large variety of nitrogen species, such as nitrogen dioxide (NO_2), nitric acid (HNO_3) and organic nitrates (RNO_3) such as peroxyacetylnitrate (PAN). Atmospheric chemical reactions that occur in sunlight result in the formation of ozone and other compounds. Depending on atmospheric conditions, these reactions can start to occur within several hundred meters of the original NO_X source, or after the pollutants have been carried tens of kilometers downwind. Ultimately, some nitrogen oxides are converted to nitric acid vapor or particulate nitrates. Precipitation is one mechanism that removes these pollutants from the air. Forms of atmospherically derived nitrogen are removed from the atmosphere by both wet deposition (rain) or dry deposition (direct uptake by vegetation and surfaces).

Ammonia and ammonium are other forms in which nitrogen occurs. Ammonia is a gas that becomes ammonium when dissolved in water, or when present in soils or airborne particles. Unlike NO_X, which forms during combustion, soil microorganisms naturally form ammonia and ammonium compounds of nitrogen and hydrogen.

In urban atmospheres, the oxidation rate of NO_X to HNO_3 is estimated to be approximately 20 percent per hour, with a range of 10 to 30 percent per hour (CARB, 1986). Aerosol nitrates (NO_3) are present, mainly in the form of ammonium nitrate (NH_4NO_3). Nitrate and ammonium (NH_4) are the predominant forms by which plants absorb nitrogen. In California, ammonium nitrate is the predominant airborne nitrate-bearing particle in the atmosphere (CARB, 1986).

To assess the potential for nitrogen deposition, both AERMOD and CALPUFF were used. While both models contain deposition algorithms, the treatment of the complex chemistry that transforms NO_x emissions into nitrogen are handled very differently between the two models. As discussed below, no chemistry was used in the AERMOD analysis. Instead, all emissions of NO_x and ammonia were assumed to instantaneously form depositional nitrogen in stack, thus being immediately available for deposition. CALPUFF, by comparison, contains the MESOPUFF II chemical scheme which has been widely used to assess the conversion of the various species of NO_x into nitrogen. Thus, the assumption used in AERMOD was not used in the CALPUFF modeling analysis. The description of the two EPA models along with the input data used in the modeling analysis are present below.

Description of the AERMOD Model

The purpose of the AERMOD model is to assess regional scale air quality impacts from combustion sources. Given source strength, meteorology, site geometry, and site characteristics, the model can predict pollutant concentrations for locations (receptors) located within 50 kilometers of the site.

AERMOD is called a Gaussian model because the pollutant mass within a plume calculated by AERMOD is assumed to follow a bell-shaped curve, called the normal distribution in the horizontal and vertical planes for stable conditions. A normal, or Gaussian, distribution is one in which the maximum concentrations occur in the middle of the plume and taper exponentially to almost zero at the edges. The edge of the plume is defined by the point where the concentration drops to 10% of the centerline value. For unstable atmospheric conditions, AERMOD uses a non-Gaussian probability density function in the vertical which is a more accurate portrayal of actual conditions.

This major assumption incorporates a number of other supporting assumptions called boundary conditions. The major boundary conditions in AERMOD are:

1. Steady state
2. No removal
3. No downwind stretching
4. Stable pollutant
5. Average wind

The first supporting assumption is that the atmosphere and source are in steady state. This means that the atmosphere and source conditions are constant over a period of time. With the AERMOD model, meteorology and emission conditions are assumed to be invariant for a 1-hour period. Therefore, this is not an instantaneous picture of conditions. Since in reality, both the atmosphere and source are variable over periods of time, an average must be taken that uses many instantaneous pictures.

The second supporting assumption is that no pollutant mass is lost from the plume through chemical reaction or physical deposition on a surface. This is called conservation of mass.

The third supporting assumption is that the plume does not stretch in the downwind direction. This means that the pollutant material through any slice, or cross section, of the plume is the same as any other cross section of the plume: distance from the source does not matter.

The fourth assumption is that the material in the plume does not undergo chemical or physical change. The material from the source remains in the same state at which it was released.

The last supporting assumption is that an average wind speed and direction can be identified for a 1-hour period, and that they are typical for the atmospheric layer that will disperse the pollutants.

Boundary conditions limit the model's ability to fully describe the physical conditions of the source and the atmosphere. This means that models using the Gaussian distribution may not estimate pollutant concentrations accurately. The assumptions are the reasons that Gaussian model results are conservative. This is, the estimates of downwind concentrations are larger than may be observed at a real receptor. Using AERMOD model, a calculation for a new source will overestimate the source’s effect on air quality.

AERMOD Modeling Assumptions

AERMOD, which was used in the air quality permitting analysis to evaluate the project’s air quality impacts, was also used in the deposition analysis. As described previously, AERMOD is a steady-state, mass-conserving, nonreactive (i.e., no chemistry) plume dispersion model. The ability of AERMOD to overestimate impacts was expanded on by including several other assumptions with regards to nitrogen formation and deposition, in order to assess the potential for impacts from the RCEC. These assumptions include:

- 100 percent conversion of oxides of nitrogen (NO_x) and ammonia (NH_3) into atmospherically derived nitrogen (ADN) within the turbine stack(s) rather than allowing the conversion of NO_x and NH_3 to occur over distance and time within the atmosphere
- Depositional rates and parameters were based upon nitric acid (HNO_3) which, of all the depositional species, has the most affinity for impacts to soils and vegetation and the most tendency to "stick" to what it is deposited upon
- Maximum settling velocities to produce maximum deposition rates
- Maximum potential emissions were used rather than actual emissions in the calculation of nitrogen deposition
- And, once it leaves the turbine stack, nitrogen immediately begins to deposit in the surrounding lands.

To produce conservative results (overestimates), modeling assumptions regarding the complex chemistry that occurs to produce nitrogen from NO_x, ammonia, and other pollutants were not used in this modeling analysis. As one example, it was assumed that the pollutants leaving the stack(s) would already be in the form of depositional nitrogen (nitrate and ammonium ions). To do this, the emissions of NO_x and ammonia were summed and then adjusted for the molecular weight of nitrogen. Thus, all impacts would represent 100 percent conversion of combustion emissions into depositional nitrogen. This assumption leads to an exceedingly conservative estimation of nitrogen deposition, because areas with the highest nitrogen emissions do not necessarily experience the greatest deposition effects, which usually occur far from the original nitrogen source. In addition, since mass is conserved in the model, all downwind calculations of nitrogen deposition, regardless of distance and formation rates, are overestimated by the model.

The AERMOD model calculates atmospheric deposition of nitrogen by calculating the wet and dry fluxes of total nitrogen. This deposition is accomplished by using a resistance model for the dry deposition part, and by assigning particle phase washout coefficients for the wet removal process from rainout. As discussed below, depositional parameters are input into the model in order to calculate the deposition of nitrogen. Again, depositional parameters were based on HNO_3, which is consistent with the conservative modeling assumptions that overestimate the amounts of nitrogen deposition from the proposed project. Nitric acid tends to deposit more readily than most other compounds.

No chemical conversion (which takes place over distance and time) was allowed to occur. In reality, the nitrate aerosol cannot be considered a stable product, such as sulfate typically is. Also, unlike sulfate, the ambient concentration of atmospherically derived nitrogen is limited by the availability of ammonia, which is preferentially scavenged by sulfate. Because of the preferential scavenging of ammonia by sulfate, the available ammonia in the atmosphere is often computed as total ammonia minus sulfate. These effects were not included in the analysis.

The assumption that atmospherically derived nitrogen forms instantaneously in stack and immediately begins to deposit in the surrounding areas leads to an estimation of nitrogen deposition that is unrealistically high, and would likely be several orders of magnitude higher than the actual process itself. This is especially true in the immediate area(s) surrounding the project site.

The other assumptions listed above, along with those inherent in AERMOD, add to the conservative nature of the modeling analysis. All these factors were combined into one modeling study to produce much higher impacts than would be modeled using less conservative assumptions. The goal of the analysis was to combine many conservative assumptions into one modeling analysis in order to overestimate the potential impact from operation of the RCEC.

Description of the CALPUFF Model

Significant terrain features and large distances (> 20 km) separate the location of the proposed project site and some of the surrounding critical habitats. The use of a single plume, steady state Gaussian model (AERMOD), to represent mesoscale conditions in complex terrain can produce conservatively unrealistic results. Traditional Gaussian models cannot take into account the complex dispersion and deposition conditions that could arise over large mesoscale domains in complex terrain.

As part of an Interagency Workgroup on Air Quality Modeling (IWAQM) study to design and develop a generalized non-steady-state air quality modeling system for regulatory use in situations where long range transport is involved, the CALPUFF dispersion model was developed. The original design specifications for the modeling system included: (1) the capability to treat time-varying point and area sources, (2) suitability for modeling domains from tens of meters to hundreds of kilometers from a source, (3) concentrations for averaging times ranging from one-hour to one year, (4) applicability to inert pollutants and those subject to linear removal and chemical conversion mechanisms, and, (5) applicability for rough or complex terrain situations.

The modeling system developed to meet these objectives consisted of three components: (1) a meteorological modeling package with both diagnostic and prognostic wind field generators, (2) a Gaussian puff dispersion model with chemical removal, wet and dry deposition, complex terrain algorithms, building downwash, plume fumigation, and other effects, and (3) post-processing programs for the output fields of meteorological data, concentrations and deposition fluxes.

CALPUFF is a multi-layer, multi-species, multi-source, non-steady-state puff dispersion model which can simulate the effects of time- and space-varying meteorological conditions on pollutant transport, transformation, and removal. CALPUFF can use the three dimensional meteorological fields developed by the CALMET model, or simple, single station winds in a format consistent with the meteorological files used to drive the AERMOD steady-state Gaussian model. For this analysis, the single-station meteorological data set was used.

CALPUFF Modeling Assumptions

A screening mode of the CALPUFF modeling system was run for the proposed project in order to calculate potential impacts to critical habitats. This modeling analysis focused on the potential nitrogen depositional impacts to protected areas in the vicinity of the project. The modeling followed screening guidance as provided by the Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 Summary Report. The modeling procedures also incorporate comments provided by the Federal Land Managers' Air Quality Related Values workgroup (FLAG) Final Phase I report (December 2000).

The assumption used in the AERMOD modeling analysis where all emissions of NO_x and ammonia were converted in-stack into depositional nitrogen was not used in the CALPUFF modeling analysis. Unlike AERMOD, CALPUFF incorporates a chemical algorithm which calculates the atmospheric transformation of NO_x (and its associated species) along with ammonia into depositional nitrogen. The chemical scheme used in CALPUFF was the MESOPUFF II algorithm, as recommended by the IWAQM Phase 2 Summary Report.

The screening mode of the CALPUFF modeling system requires hourly, single-station meteorological data as input, both surface and upper air. Based on the guidance contained in the IWAQM Phase 2 Summary Report, CALPUFF was used in a screening mode, which required five years of single station meteorology. Five years of surface data were obtained for San Francisco International Airport (1986-1990). The upper air data was collected for the same time period from Oakland International Airport.

The PCRAMMET meteorological preprocessor, as recommended by the IWAQM Phase 2 Report, was used to process the surface, precipitation, and upper air data. PCRAMMET requires complete data sets of the following variables: wind speed, wind direction, temperature, ceiling height, opaque cloud cover or total cloud cover, surface pressure, relative humidity, and precipitation type. The five years of upper air data includes twice-daily mixing heights.

PCRAMMET was run with wet deposition options as required in the Phase 2 Report. As such, the following domain averaged variables are required and were based on values expected in the modeling region:

- Precipitation data
- Minimum Obukhov length = 2 meters
- Surface roughness length = 0.25 meters (at both measurement and application site)
- Noon time albedo = 0.15
- Bowen ratio = 0.1
- Fraction of net radiation absorbed by ground = 0.15

- Anthropogenic heat flux = 57 W/m^2

Five years of data was preprocessed with PCRAMMET, which was then used as input into CALPUFF.

CALPUFF also requires domain averaged background ozone (O3) and ammonia (NH3) concentrations for the Mesopuff II chemistry algorithm. For O3, a domain-averaged value of 80 ppb was used, which was based on background O3 data collected in the project region by the Bay Area Air Quality Monitoring District. For NH3, a domain average value of 0.8 ppb was selected and was based on results of using the AERMOD model to calculate background NH3 from the proposed project.

A CALPUFF control file was generated that included IWAQM recommended defaults for the model options. This included rural dispersion coefficients, default wind speed profile exponents, and default vertical potential temperature gradient. Model options are listed in the CALPUFF model output, which is included on compact disk. A brief summary of the options used in the modeling analysis are listed below:

- Number of X grid cells = 2
- Number of Y grid cells = 2
- Number of vertical layers = 1
- Grid spacing = 210 km
- Cell face heights = 5000 meters
- Minimum mixing height = 50 meters
- Maximum mixing height = 5000 meters (based on observational data)
- Minimum wind speed allowed for non-calm conditions = 0.5 m/s
- Vertical distribution used in the near field = gaussian
- Terrain adjustment method = partial plume path adjustment
- No puff splitting allowed
- Chemical mechanism = Mesopuff II
- Wet and dry removal modeled
- Dispersion coefficients = PG dispersion coefficients
- PG sigma-y and z not adjusted for roughness
- Partial plume penetration of elevated inversion allowed
- Lateral turbulence not used

The computational grid extended 50 kilometers beyond the furthest receptor point.

Nitrogen Deposition Mechanisms

The AERMOD wet and dry deposition modeling for gaseous pollutants is based on the algorithm contained in the CALPUFF dispersion model (USEPA, 1995), which Moore, et al., reviewed and evaluated (1995). The deposition flux, F_d, is calculated as the product of the concentration, χ_d, and a deposition velocity, v_d, computed at a reference height z_d:

$$F_d = \chi_d \bullet v_d$$

The dry deposition algorithm is based on an approach that expresses the deposition velocity as the inverse sum of total resistance. The resistance represents the opposition to transporting the pollutant through the atmosphere to the surface. AERMOD incorporates several resistance models that include aerodynamic resistance, canopy resistance, cuticle resistance, deposition layer resistance, mesophyll resistance, and stomatal action.

With wet deposition, gaseous pollutants are scavenged by dissolution into cloud droplets and precipitation. A scavenging ratio approach was used to model the deposition of gases through wet removal. In this approach, the flux of material to the surface through wet deposition (Fw) is the product of a scavenging ratio times the concentration, integrated in the vertical direction. Because the precipitation is assumed to initiate above the plume height, a wet deposition flux is calculated, even if the plume height exceeds the mixing height.

Model Inputs

In order to model gaseous deposition, the model requires land use characteristics and gas deposition resistance terms based on five seasonal categories. The seasonal categories are input into AERMOD on a month by month basis, corresponding to each summer, fall, winter, and spring seasons. Additionally, land use data is input based on wind direction.

For both wet and dry deposition, AERMOD requires the following additional inputs:

- The molecular diffusivity (D_a) for the pollutant being modeled [cubic centimeters per second (cm^2/s)]
- The diffusivity in water (D_w) for the pollutant being modeled [cubic centimeters per second (cm^2/s)]
- The cuticular resistance to uptake by lipids for individual leaves (rcl) for the pollutant (s/cm),
- The Henry's Law coefficient (Pa) for the parameter (m^3/mol)

For this analysis, it was assumed that the deposition parameters would be based on gaseous nitric acid. Nitric acid was chosen to represent total nitrogen deposition since nitric acid has the greatest potential for depositional effects. The deposition parameters were obtained from a draft Argonne National Laboratory report (Wesely, et. al., 2002).

In addition to the above inputs, the dry and wet deposition algorithm also requires surface roughness length (cm), friction velocity (meters per second), Monin-Obukhov length (meters), surface pressure, precipitation type, and precipitation rate. For AERMOD, the meteorology used in this analysis was based on the 2003-2007 data set collected at the Oakland International Airport. This is the same meteorological data set that was used for the air quality permit application.

Each EBRP critical habitat was assigned a unique vegetative and land use type. With the exception of the Hayward Regional Shoreline, the EBRPD critical habitat areas are in forested hillsides, so land use characteristics based on rangeland were defined to model deposition, including the surface roughness length, leaf-area index, and plant-growth state. For roughness lengths, domain-averaged values for rangeland for both an active growing season and an inactive season were identified. Leaf area indices were also based on domain-averaged values for an active growing season and an inactive/dormant season. To calculate nitrogen deposition velocities, the state of the vegetation must also be specified and included both active and stressed active an unstressed.

This approach was used to develop conservative, worst-case scenarios to evaluate potential nitrogen deposition on the EBRPD critical habitats. The following scenarios were used in the assessment of nitrogen depositional fluxes:

Hayward Regional Seashore

- Land use: non-forested wetlands
- Vegetation state: active and stressed
- Roughness length = 0.2 meter
- Leaf area index = 1.0
- Diffusivity in air = 0.14E-04 (cm^2/s)
- Diffusivity in water = 0.30E-08 (cm^2/s)
- Leaf Lipid Resistance = 0.18E+04 (s/cm)
- Henry's Law Coefficient = 0.80E-07 (m^3/mol)

Lake Chabot Regional Park

- Land use: Forrest
- Vegetation state: active and unstressed
- Roughness length = 1.0 meter
- Leaf area index = 7.0
- Diffusivity in air = 0.14E-04 (cm^2/s)
- Diffusivity in water = 0.30E-08 (cm^2/s)
- Leaf Lipid Resistance = 0.18E+04 (s/cm)
- Henry's Law Coefficient = 0.80E-07 (m^3/mol)

Garin/Dry Creek Pioneer Regional Park

- Land use: Forrest and Rangeland
- Vegetation state: active and stressed
- Roughness length = 0.5 meter (rangeland) and 1.0 (forest)
- Leaf area index = 0.5 (rangeland) and 7.0 (forest)
- Diffusivity in air = 0.14E-04 (cm^2/s)
- Diffusivity in water = 0.30E-08 (cm^2/s)

- Leaf Lipid Resistance = 0.18E+04 (s/cm)
- Henry's Law Coefficient = 0.80E-07 (m^3/mol)

Redwood Regional Park

- Land use: Forest
- Vegetation state: active and unstressed
- Roughness length = 1.0 meter
- Leaf area index = 7.0
- Diffusivity in air = 0.14E-04 (cm^2/s)
- Diffusivity in water = 0.30E-08 (cm^2/s)
- Leaf Lipid Resistance = 0.18E+04 (s/cm)
- Henry's Law Coefficient = 0.80E-07 (m^3/mol)

AERMOD and CALPUFF calculate depositional flux at user-specified locations, called receptors. Receptors were placed at 90-meter intervals in within each critical habitat. The receptors used in the modeling analysis are presented in Figure 1.

Nitrogen Deposition Modeling Results

Results of the wet and dry nitrogen deposition modeling were summed to produce annual deposition rates in units of kilograms per hectare per year (kg/ha-yr). As the critical habitats cover a wide variety of elevations and distances, the deposition rate calculated for each area was averaged over the entire habitat area(s). Additionally, the maximum depositional impact was also calculated for each critical habitat.

Table 1 presents the worst-case AERMOD modeled potential averaged annual deposition rates resulting from operation of the proposed project. Potential deposition rates in all the habitat areas are extremely small (see Table 1). Figure 2 displays the deposition contours for each of the four habitat areas. Table 2 presents the worst-case Calpuff maximum modeled potential annual deposition rates resulting from operation of the proposed project. Based upon the relatively short distances to each habitat from the project site, the depositional impacts from CALPUFF are approximately two orders of magnitude less than the AERMOD results. Figure 3 displays the CALPUFF derived deposition contours for each critical habitat.

TABLE 1
Modeled Annual Nitrogen Deposition at Critical Habitat Locations
Impact Analysis for NO_x and NH_3 Emissions

Location	**Averaged Modeled Deposition from RCEC Over Each Critical Habitat Area**			**Maximum Deposition Rate (kg/ha-yr)**
	Number of Receptors	*Landuse*	*Mean Annual*	*Maximum Annual*
AERMOD			(kg/ha-yr)	(kg/ha-yr)
Hayward Regional Seashore	8,138	Un-forested Wetlands	0.1474	0.3903
Lake Chabot Regional Park	2,955	Forest	0.02847	0.0487
Garin/Dry Creek Regional Park	1,433	Rangeland/ Forest	0.23194	0.3208
Redwood Regional Park	1,346	Forest	0.01653	0.0223

TABLE 2
Modeled Annual Nitrogen Deposition at Critical Habitat Locations
Impact Analysis for all species of NO_x Emissions Using MESOPUFF II

Location	**Averaged Modeled Deposition from RCEC Over Each Critical Habitat Area**			**Maximum Deposition Rate (kg/ha-yr)**
	Number of Receptors	*Landuse*	*Mean Annual*	*Maximum Annual*
CALPUFF			(kg/ha-yr)	(kg/ha-yr)
Hayward Regional Seashore	8,138	Un-forested Wetlands	0.00339	0.01096
Lake Chabot Regional Park	2,955	Forest	0.01097	0.0171
Garin/Dry Creek Regional Park	1,433	Rangeland/ Forest	0.01883	0.02415
Redwood Regional Park	1,346	Forest	0.00634	0.009117

The maximum potential nitrogen deposition rates that have been estimated for critical habitat areas (Tables 1 and 2) are small compared to the nutritional nitrogen requirement of non-native grasses. Therefore, the small incremental impact of the proposed operation is insignificant given the small increase in depositional species.

References Cited

CARB (Air Resources Board). 1986. The Effects of Oxides of Nitrogen on California Air Quality. By Technical Support Division State of California Air Resources Board. Report Number: TSD-85-01. March

Environmental Protection Agency, 1995a. A User's Guide for the CALPUFF Dispersion Model. EPA-454/B-95-006. U.S. Environmental Protection Agency, Research Triangle Park, NC.

Environmental Protection Agency, 2003: AERMOD Deposition Algorithms - Science Document (Revised Draft). U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711.

Environmental Protection Agency, 2004a: User's Guide for the AMS/EPA Regulatory Model -AERMOD. EPA-454/B-03-001. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711.

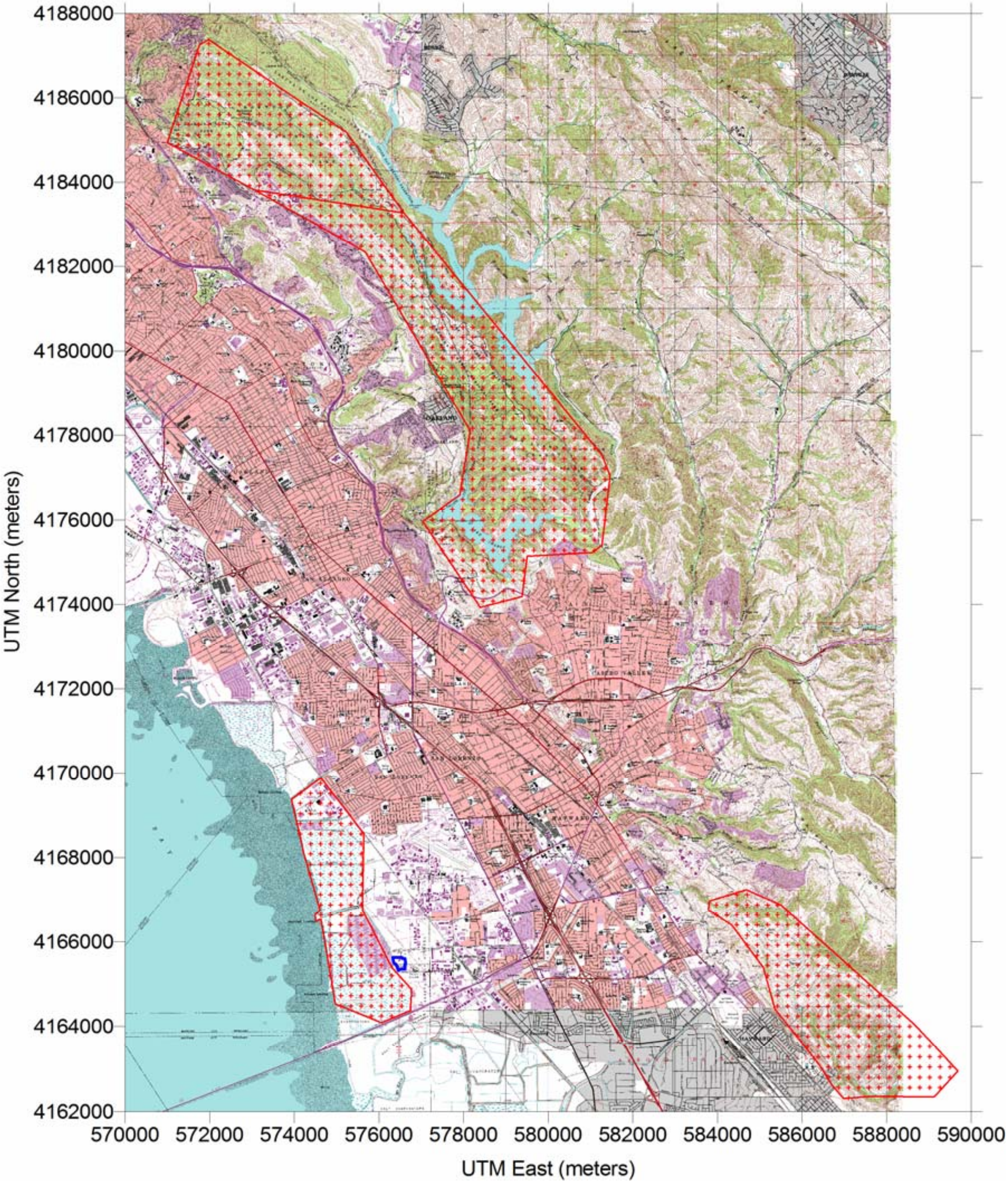
Environmental Protection Agency, 2004b: User's Guide for the AERMOD Meteorological Processor (AERMET). EPA-454/B-03-002. U.S. Environmental Protection Agency, ResearchTriangle Park, North Carolina 27711.

M.L. Wesely, P.V. Diskey, and J.D. Shannon, 2002: Deposition Parameterization for the Industrial Source Complex (ISC3) Model. Environmental Research Division, Argonne National Laboratory. Argonne, Illinois. June 2002.

Marschner, H. 1995. Mineral nutrition of higher plants. Academic press. New York, NY.

Moore, G., P. Ryan, D. Schwede, and D. Strimaitis, 1995: Model performance evaluation of gaseous dry deposition algorithms. Paper 95-TA34.02, 88th Annual Meeting & Exhibition of the Air and Waste Management Association, San Antonio, Texas, June 18-23, 1995.

Figure 1
Russell City Energy Center
Receptors used for Depositional Modeling



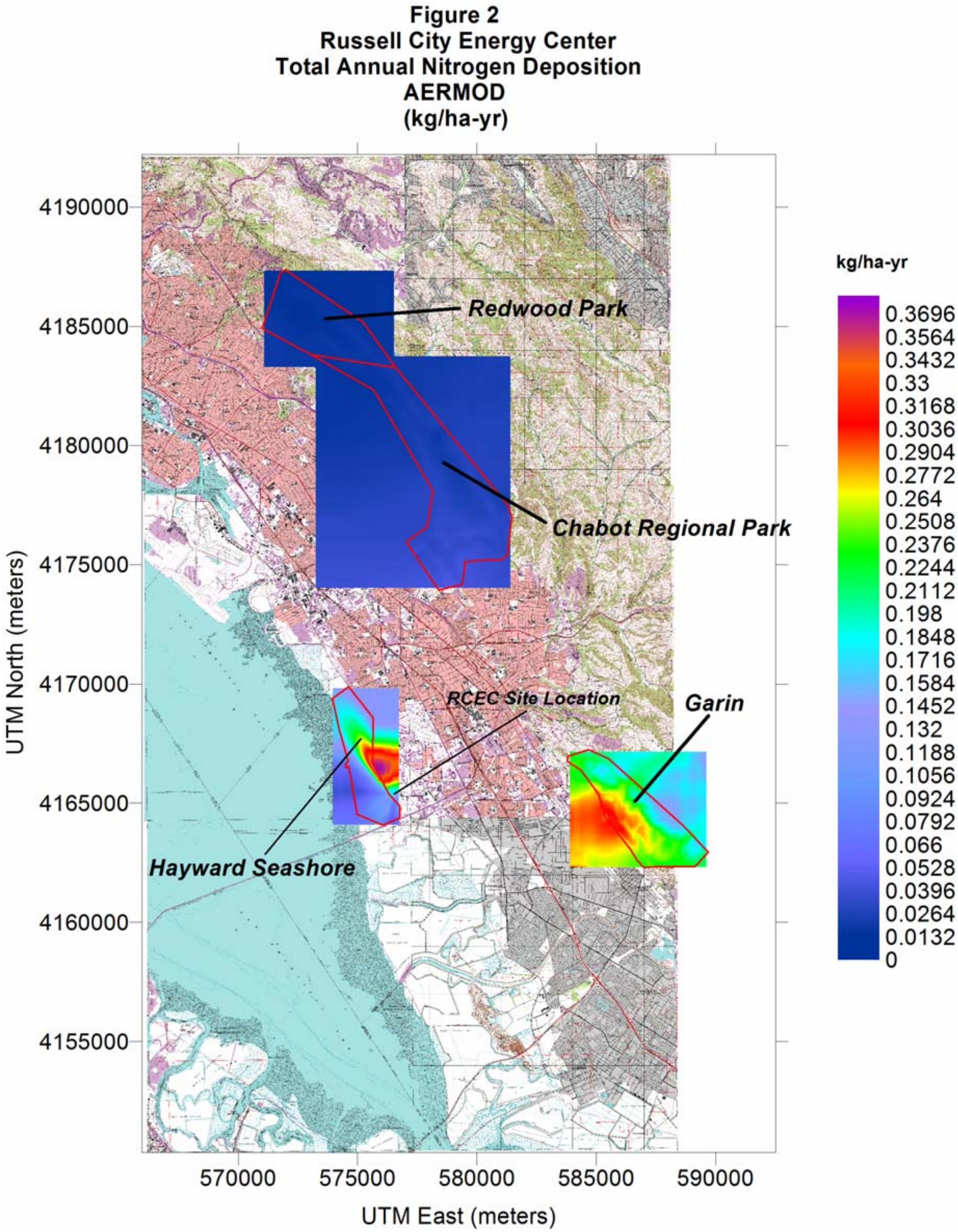


Figure 2
Russell City Energy Center
Total Annual Nitrogen Deposition
AERMOD
(kg/ha-yr)
UTM North (meters)
UTM East (meters)
4190000
4185000
4180000
4175000
4170000
4165000
4160000
4155000
570000
575000
580000
585000
590000
Redwood Park
Chabot Regional Park
RCEC Site Location
Garin
Hayward Seashore
kg/ha-yr
0.3696
0.3564
0.3432
0.33
0.3168
0.3036
0.2904
0.2772
0.264
0.2508
0.2376
0.2244
0.2112
0.198
0.1848
0.1716
0.1584
0.1452
0.132
0.1188
0.1056
0.0924
0.0792
0.066
0.0528
0.0396
0.0264
0.0132
0

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Figure 3
Russell City Energy Center
Total Annual Nitrogen Deposition
CALPUFF
(kg/ha-yr)