Prevention of Significant Deterioration (PSD) Permit Application

Canal Unit 3

Canal Generating Station
Sandwich, MA

Application Addendum

July 15, 2017

Prepared for:

NRG Canal 3 Development LLC
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TETRA TECH

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July 15, 2017

Mr. Thomas Cushing
Chief, Permit Section,
Bureau of Air &Waste Prevention
MassDEP Southeast Region
20 Riverside Drive
Lakeville, MA 02347

Subject: NRG Canal 3 Development LLC
PSD Application Addendum

Dear Mr. Cushing:

Tetra Tech is providing this PSD Application Addendum on behalf of NRG Canal 3 Development LLC (Canal 3) to provide dispersion modeling results for a revised combustion turbine stack height of 250 feet, as approved by the Massachusetts Energy Facilities Siting Board on June 30, 2017. The updated dispersion modeling also incorporates a revision in the design SCR attemperated flue gas temperature from 900 to 850 degrees F, and an increase in the design stack exit temperature from 750 to 835 degrees F. The stack exit diameter is increased from 25' to 25'4". The stack will now be insulated so the stack temperature loss has significantly decreased. The decrease in the design SCR attemperated flue gas temperature will allow more effective operation of the SCR system and more flexibility in SCR catalyst selection. The revised modeling now also incorporates prior changes in the PM_{10}/$PM_{2.5}$ and CO emission rates as well as the annual limit on ULSD operation.

This addendum includes revised text for Section 5 up through subsection 5.8.8. (Subsections 5.8.9 and 5.8.10 have not changed and are not included.) Also included are a revised version of Figure 5-6 (Significant Impact Areas). Revised text is in bold/italics.

Please contact me 617-443-7545 or by email at george.lipka@tetratech.com if you have any questions.

Very truly yours,

George S. Lipka, P.E.
Senior Consultant I

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5.0 AIR QUALITY IMPACT ANALYSIS

As described in Section 3.1, the Project will be a major modification under PSD rules for NO_x, $PM/PM_{10}/PM_{2.5}$, H_2SO_4, and GHGs. As such, the Project is required to demonstrate compliance with NAAQS and PSD Increments. As there are no NAAQS for H_2SO_4, it is evaluated as an air toxic. All applicable air toxics, including H_2SO_4, have been evaluated per MassDEP's air toxics policy. SO_2 will also be evaluated to demonstrate compliance with the NAAQS and for use in the impacts to soils and vegetation analysis. There are no air quality modeling requirements for GHGs.

Air quality dispersion modeling uses mathematical formulations to simulate how a pollutant emitted by a source will disperse in the atmosphere to predict concentrations at downwind receptor locations. An evaluation of the potential impacts of the proposed Project's air emissions on ambient air quality has been conducted using USEPA's regulatory model, AERMOD (***16216r***). The air quality dispersion modeling analyses for the Project have been conducted as specified in the Air Quality Dispersion Modeling Protocol, submitted to and approved by MassDEP. These procedures are in accordance with 40 CFR 51 Appendix W USEPA's *Guideline on Air Quality Models* (USEPA, 2005), *Modeling Guidance for Significant Stationary Sources of Air Pollution* (MassDEP, 2011), the AERMOD Implementation Guide (USEPA, 2015), and supplemented by additional agency guidance.

The dispersion modeling for the Project evaluates worst-case operating conditions to predict the appropriate maximum ground-level concentration for each pollutant and averaging period. The appropriate maximum concentrations from the worst-case scenarios are compared to the corresponding SILs. If the maximum concentration is below the corresponding SIL, then compliance is demonstrated and no additional analysis is necessary. However, if any maximum predicted concentration is equal to or greater than its corresponding SIL, a cumulative impact analysis must be conducted with other major emission sources in the area, as identified by the MassDEP.

As discussed in the following sections, the modeling analysis demonstrates that the proposed Project will not cause or significantly contribute to an exceedance of any NAAQS, PSD Increment, or MassDEP non-criteria pollutant threshold.

5.1 SOURCE PARAMETERS AND EMISSION RATES

The proposed Project will include one new combustion turbine and ancillary equipment (specifically, one new emergency generator and one new fire water pump). In addition to modeling impacts from the Project, the modeling analysis includes consideration of cumulative impacts from the existing Station sources. Table 5-1 lists the physical stack characteristics for each source that was included in the modeling.

Table 5-1: Stack Characteristics for the Proposed Project and the Existing Canal Generating Station

Source	Status	UTM E[1] (m)	UTM N[1] (m)	Base Elevation (m)	Stack Height (ft)	Stack Diameter (ft)
Canal 3 CTG	Proposed	374,636.75	4,625,364.08	4.88	***250***	***25.33***
Emergency Gen.	Proposed	374,636.50	4,625,375.45	4.88	25	0.75
Fire Water Pump	Proposed	374,802.48	4,625,326.75	4.88	25	0.33
Canal Unit 1,2	Existing	374,565.91	4,625,318.96	3.66	498	25.5
Emergency Gen 1	Existing	374,393.38	4,625,435.85	3.66	14.4	0.66
Emergency Gen 2	Existing	374,608.72	4,625,460.22	3.66	14.4	0.66
Fire Water Pump	Existing	374,397.46	4,625,433.02	3.66	14.1	0.33
Gas Heater	Existing	373,685.91	4,625,564.01	3.66	15	1.6

[1] Universal Transverse Mercator Zone 19, based on North American Datum 83.

Modeling for the Project was conducted in a manner that utilizes the worst-case operating conditions for the proposed new combustion turbine in combination with the ancillary sources impacts in an effort to predict the highest impact for each averaging period. The Project is requesting a permit that will allow up to 4,380 hours per year of operation for the new simple-cycle turbine. Turbine operation could range from up to 4,380 hours per year on natural gas alone to 3,660 hours per year on natural gas and 720 hours per year on ULSD. The proposed GE 7HA.02 turbine is rated at a maximum capacity of 3,425 MMBtu/hr at 0°F while firing natural gas and 3,471 MMBtu/hr at 0°F while firing ULSD. The emissions will exit to the atmosphere through a ***250***-foot tall stack with an inside exit diameter of ***25.33*** feet. Since proposed new combustion turbine emission rates and flue gas characteristics for a given turbine load vary as a function of ambient temperature, data were derived for the following ambient temperatures and load scenarios:

- three operating loads (Base [100%], Mid [~75%], and Min [30-40%]); and,
- five ambient temperatures (90°F, 59°F, 50°F, 20°F, and 0°F).

In order to calculate conservatively ground-level concentrations, a composite "worst-case" set of emission parameters was used in the modeling. For each turbine load, the highest pollutant-specific emission rate coupled with the lowest exhaust temperature and exhaust flow rate was selected. Tables 5-2 and 5-3 summarize the worst-case emission parameters over the three operating loads for natural gas and ULSD firing, respectively.

Table 5-2: Worst-Case Operational Data for the Proposed Simple-Cycle CTG firing Natural Gas

Parameter		Load Value		
		Base	Mid	Min
Exit Temperature (°F)		***835.0***	***835.0***	***835.0***
Exit Velocity (feet/sec)		***146.84***	***122.81***	***85.35***
Pollutant Emissions (lb/hr)	SO_2	5.14	4.11	2.80
	PM_{10}	18.10	***18.10***	***18.10***
	$PM_{2.5}$	18.10	***18.10***	***18.10***
	NO_X	31.51	25.24	17.19
	CO	***27.06***	***21.67***	***14.77***

Table 5-3: Worst-Case Operational Data for the Proposed Simple-Cycle CTG firing ULSD

Parameter		Load Value		
		Base	Mid	Min
Exit Temperature (°F)		***835.0***	***835.0***	***835.0***
Exit Velocity (feet/sec)		***140.94***	***119.23***	***80.42***
Pollutant Emissions (lb/hr)	SO_2	5.21	4.17	2.66
	PM_{10}	***65.8***	***65.8***	***65.8***
	$PM_{2.5}$	***65.8***	***65.8***	***65.8***
	NO_X	67.35	53.96	34.34
	CO	40.96	32.82	20.89
	Pb	1.1E-02	8.7E-03	5.5E-03

The proposed combustion turbine will be operated as a peaking unit; therefore, in addition to estimating the steady-state operational impacts, the proposed new combustion turbine's SUSD conditions were also included in the AERMOD operating scenario modeling for the pollutants that have short-term standards (SO_2, PM_{10}, $PM_{2.5}$, NO_2, and CO). SUSD modeling was not conducted for annual averaging periods. The vendor data suggest that startup events will last only 10-30 minutes and shutdown events will last only 8-14 minutes, depending on the fuel. Therefore, the modeling for SUSD is composed of a representative hourly profile of emissions that accounts for a startup or shutdown within 1 hour. For longer averaging periods (i.e., 24-hour) a limited number of startups and shutdowns were considered in a day as it is unreasonable to expect that the turbine will startup and shutdown 24 hours per day. Since the SUSD emissions occur under different exhaust parameters (which are different from exhaust parameters for steady-state operations), the hourly profile of emissions for a SUSD hour was modeled assuming co-located stacks.

For the 1-hour, 3-hour, and 8-hour averaging periods, two co-located stacks were used. (This is just a calculation technique and does not mean two or three stacks are being constructed, as discussed below; only a single physical stack for the new CTG is being constructed.) Stack 1 consists of the startup stack and is modeled with the total emissions from a single startup event. Stack 2 consists of the normal operation stack representing the balance of the hour that the turbine is not operating in startup mode. The emissions for Stack 2 are scaled based on the portion of the hour that the turbine is operating under normal conditions. With the exception of CO during shutdown from natural gas firing, startup emissions are always higher with lower plume rise, as shown in Table 5-4. Therefore, for CO, natural gas startup, the shutdown emission rate was conservatively used with the startup stack parameters.

For the 24-hour averaging period, three co-located stacks were used in the modeling. Stack 1 consists of the startup stack and is modeled with the total emissions from a single startup event. Stack 2 consists of the shutdown stack and is modeled with the total emissions from a single shutdown event. Stack 3 consists of the normal operation stack representing the balance of the hour that the turbine is not operating in startup or shutdown mode. The emissions for Stack 3 are scaled based on the portion of the hour that the turbine is operating under normal conditions (both minimum and maximum load conditions were evaluated). As noted above, since the turbine will not be starting up and shutting down every hour of the day, the modeling assumed a maximum of six startup and six shutdown events per day. The daily emissions were scaled accordingly to account for this assumption. For the remainder of the day, it was assumed the turbine is at normal load operations.

For all averaging periods (except annual), the modeled concentrations from all three stacks are combined to determine the total hourly modeled concentration.

Table 5-4: Startup/Shutdown Data for the Proposed Simple-Cycle Combustion Turbine

Parameter		Natural Gas		ULSD	
		Startup	Shutdown	Startup	Shutdown
Exit Temperature (°F)		***785.0***	***785.0***	***785.0***	***785.0***
Exit Velocity (feet/sec)		***37.88***	***37.88***	***37.88***	***37.88***
Pollutant Emissions (lb/hr)	SO_2	0.25	***0.21***	0.24	***0.18***
	PM_{10}	2.28	1.05	12.05	3.20
	$PM_{2.5}$	2.28	1.05	12.05	3.20
	NO_X	151.0	7.0	219.0	8.0
	CO	130.0	133.0	163.0	25.0

The Project will also include a ULSD-fired emergency generator and a ULSD-fired emergency fire pump, which are each expected to operate approximately 1 hour/week per unit for maintenance and 300 hours/year per unit. Therefore, the modeled short-term emissions (24-hour or less) were normalized to reflect 1 hour of operation within the averaging period for the assessment of short-term modeled averaging periods. The modeled annual emission rates for these emergency sources were normalized based on the 300 hours per year for the assessment of annual modeled averaging periods. Additionally, for the 1-hour NO_2 and SO_2 modeling, per USEPA guidance for modeling intermittent sources (USEPA, 2011), these emission rates are annualized (i.e., based on 300 hours per year). Source parameters and emissions rates for the ancillary equipment are provided in Table 5-5.

No modifications of the existing Station sources are proposed. The source parameters and emission rates for the existing combustion equipment are presented in Table 5-6. Emission rates are based on the existing permit limits, i.e., maximum allowable emissions.

Worst-case turbine operating conditions were determined based on AERMOD-predicted concentrations for comparison with the SILs, which included the Project emission sources. The worst-case operating condition was based on the operating scenario that results in the highest predicted ground-level air quality impacts. The operating scenarios resulting in the highest predicted concentrations for each pollutant for each averaging period are summarized in Table 5-7.

5.2 AIR QUALITY MODEL SELECTION AND OPTIONS

The USEPA-recommended AERMOD modeling system was used to conduct the dispersion modeling for this analysis. The current versions of the models (AERMOD v***16216r***, AERMET v***16216***, and AERMAP v11103) were used to model both criteria pollutants and air toxics.

The AERMOD model is a steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts. AERMOD includes the treatment of both surface and elevated emission sources in areas of simple and complex terrain. The model can assess sources in either rural or urban settings and calculate concentrations for every hour of meteorological data at user-defined receptors that are allowed to vary with terrain. The AERMOD model has incorporated the latest USEPA building downwash algorithm, the Plume Rise Model Enhancements (PRIME), for the improved treatment of building downwash. PRIME can also account for the stack placement relative to the building, thereby allowing the estimation of impacts in the cavity region near the stack.

AERMOD is designed to operate with two preprocessor executables: AERMET processes meteorological data for input to AERMOD, and AERMAP processes terrain elevation data and generates receptor information for input to AERMOD. The AERMOD model was selected for the air quality modeling analysis because of several model features that properly simulate the proposed Project dispersion environments, including the following:

- ability to model multiple sources;
- ability to calculate simple, complex, and intermediate terrain concentrations;
- ability to estimate cavity impacts;
- use of representative historical hourly average meteorological data; and,
- processing for concentration averaging periods ranging from one hour to one year, as well as 5-year averaging (which is necessary for comparison with the NAAQS).

A complete technical description of the AERMOD model may be found in the User's Guide for AERMOD (USEPA, 2004a). Modeling was performed with all regulatory default options in AERMOD set. The chemical conversion of NO_X into NO_2 is an important factor when assessing NO_2 concentrations. The Ambient Ratio Method (ARM) in AERMOD was used to determine the NO_2 impacts for the Project. Specifically, the USEPA Tier 2 methodology for estimating NO_2 concentrations from total NO_x emissions was implemented. ARM assumes a 75% conversion of NO_x to NO_2 on an annual basis and an 80% conversion of NO_x to NO_2 on a 1-hour basis.

Table 5-5: Source Parameters and Emission Rates for the Proposed Ancillary Equipment

Source	Exit Temp. (°F)	Exit Velocity (fps)	Emission Rates (lb/hr)												
			NO_X		CO		PM_{10}		$PM_{2.5}$		SO_2				Pb
			1-hr	Ann	1-hr	8-hr	24-hr	Ann	24-hr	Ann	1-hr	3-hr	24-hr	Ann	24-hr
Emergency Engine[1]	887.1	139.3	0.154	0.154	4.49	0.561	0.007	0.0058	0.007	0.0058	0.00026	0.0025	0.00031	0.00026	1.60e-5
Fire Water Pump[1]	809.0	127.0	0.031	0.031	1.11	0.139	0.0031	0.0025	0.0031	0.0025	6.18e-5	0.0006	7.53e-5	6.18e-5	3.75e-6

[1]For the emergency engine and fire water pump the short-term modeled emission rates are normalized to operate 1 hour within the averaging period. For 1-hour NO_2, 1-hour SO_2 and other pollutant's annual averaging periods, the modeled emission rates were normalized based on 300 hours per year.

Table 5-6. Source Parameters and Emission Rates for the Existing Canal Generating Station Equipment

Source	Exit Temp. (°F)	Exit Velocity (fps)	Emission Rates (lb/hr)												
			NO_X		CO		PM_{10}		$PM_{2.5}$		SO_2				Pb
			1-hr	Ann	1-hr	8-hr	24-hr	Ann	24-hr	Ann	1-hr	3-hr	24-hr	Ann	24-hr
Canal Unit 1, 2	338.5	116	3112.1	3112.1	10859.3	10859.3	333.2	333.2	333.2	333.2	6728.7	6728.7	6728.7	6728.7	0.109
Emergency Gen 1[1]	900	152	0.60	0.60	3.81	0.48	0.05	0.044	0.05	0.044	0.0002	0.0021	0.0003	0.0002	1.28e-5
Emergency Gen 2[1]	900	152	0.60	0.60	3.81	0.48	0.05	0.044	0.05	0.044	0.0002	0.0021	0.0003	0.0002	1.28e-5
Emerg. Fire Pump[1]	900	267	0.27	0.27	1.75	0.22	0.02	0.019	0.02	0.019	0.0031	0.0299	0.0037	0.0031	5.63e-6
Gas Heater	600	8.5	0.64	0.64	0.48	0.48	0.079	0.079	0.079	0.079	0.033	0.033	0.033	0.033	2.94e-6

[1]For the emergency engine and fire water pump the short-term modeled emission rates are normalized to operate 1 hour within the averaging period. For 1-hour NO_2, 1-hour SO_2 and other pollutant's annual averaging periods, the modeled emission rates were normalized based on 300 hours per year.

Table 5-7: Results of Proposed Turbine Operating Condition Analysis

Pollutant	Averaging Period	Fuel	Worst-Case Operating Condition(1)
SO_2	1-hr[2,3]	ULSD	Base Load
	3-hr[3]	ULSD	Base Load
	24-hr[4]	ULSD	Base Load
	Annual[2,5]	***3660*** hours NG ***720*** hours ULSD	Minimum Load
PM_{10}	24-hr[4]	ULSD	Startup/shutdown to minimum load
	Annual[5]	***3660*** hours NG ***720*** hours ULSD	Minimum Load
$PM_{2.5}$	24-hr[4]	ULSD	Startup/shutdown to minimum load
	Annual[5]	***3660*** hours NG ***720*** hours ULSD	Minimum Load
NO_2	1-hr[2,3]	ULSD	Startup/shutdown to base load
	Annual[5]	***3660*** hours NG ***720*** hours ULSD	Minimum Load
CO	1-hr[3]	ULSD	***Base Load***
	8-hr[3]	ULSD	Startup/shutdown to base load
Pb	Rolling 3-month[6]	ULSD	Base Load

[1]Worst-case operating conditions were determined based on AERMOD modeled concentrations for SILs analysis, which include the project emission sources: simple cycle turbine; fire pump; and, emergency generator, unless noted.
[2]Emergency equipment was included using modeled emission rates that were normalized based on 300 hours per year.
[3]Startup/shutdown conditions for 1-hr, 3-hr, and 8-hr model runs are conservatively defined as 30-min startup and 30-min of normal operations (minimum load for 1-hr NO_2, 8-hr CO and base load for 1-hr CO).
[4]Startup/shutdown conditions for 24-hr model runs refine emissions to six 30-minute startups, six 8-minute shutdowns, and 22-minute minimum load.
[5] Annual average modeling does not evaluate startup/shutdown conditions.
[6] Rolling 3-month average modeling does not evaluate startup/shutdown conditions.

5.3 URBAN/RURAL CLASSIFICATION FOR MODELING

One of the factors affecting input parameters to dispersion models is the presence of either a rural or urban setting near the Project site. Use of the urban options in AERMOD (URBANOPT) depends upon the land use characteristics within 3 kilometers (km) of the source being modeled (Appendix W to 40 CFR Part 51) (USEPA, 2005). Factors that affect the decision if an area is urban, and thus the use of the URBANOPT options in AERMOD, include the extent of vegetated surface area, the water surface area, types of industry and commerce, and building types and heights within this area. Per USEPA guidance, the Auer method of meteorological land use typing scheme was applied to determine whether urban or rural dispersion should be used in the modeling. The Auer land use types are defined in Table 5-8 (Auer, 1978). If the land use types I1, I2, C1, R2 and R3 account for 50% or more of the area within 3 km of the source, then the URBANOPT option could be used in the modeling analysis.

Figure 5-1 shows the 3-km radius around the Project. Observation of the aerial map shows that the area within a 3-km radius of the Project is predominantly rural; therefore, the URBANOPT options were not used in the AERMOD modeling.

Table 5-8: Identification and Classification of Land Use

Type	Use and Structures	Vegetation
I1	Heavy Industrial Major chemical, steel and fabrication industries; generally 3-5 story buildings, flat roofs	Grass and tree growth extremely rare; <5% vegetation
I2	Light-Moderate Industrial Rail yards, truck depots, warehouses, industrial parks, minor fabrications; generally 1-3 story buildings, flat roofs	Very limited grass, trees almost absent; <5% vegetation
C1	Commercial Office and apartment buildings, hotels; >10 story heights, flat roofs	Limited grass and trees; < 15% vegetation
R1	Common Residential Single family dwellings with normal easements; generally one story, pitched roof structures; frequent driveways	Abundant grass lawns and light-moderately wooded; >70% vegetation
R2	Compact Residential Single, some multiple, family dwellings with close spacing; generally <2 story, pitched roof structures; garages (via alley), no driveways	Limited lawn sizes and shade trees; < 30% vegetation
R3	Compact Residential Old multi-family dwellings with close (<2m) lateral separation; generally 2 story, flat roof structures; garages (via alley) and ashpits, no driveways	Limited lawn sizes, old established shade trees; < 35% vegetation
R4	Estate Residential Expansive family dwellings on multi-acre tracts	Abundant grass lawns and lightly wooded; > 95% vegetation
A1	Metropolitan Natural Major municipal, state or federal parks, golf courses, cemeteries, campuses, occasional single story structures	Nearly total grass and lightly wooded; > 95% vegetation
A2	Agricultural; Rural	Local crops (e.g.,corn, soybean); > 95% vegetation
A3	Undeveloped; Uncultivated; wasteland	Mostly wild grasses and weeds, lightly wooded; > 90% vegetation
A4	Undeveloped Rural	Heavily wooded; > 95% vegetation
A5	Water Surfaces: Rivers, lakes	

5.4 GOOD ENGINEERING PRACTICE STACK HEIGHT ANALYSIS

A Good Engineering Practice (GEP) stack height analysis was performed based on the proposed Project design to determine the potential for building-induced aerodynamic downwash for all modeled stacks. The analysis procedures described in USEPA's *Guidelines for Determination of Good Engineering Practice*

Stack Height (USEPA, 1985), Stack Height Regulations (40 CFR 51), and current USEPA Model Clearinghouse guidance were used.

The GEP formula height is based on the observed phenomena of disturbed atmospheric flow in the immediate vicinity of a structure resulting in higher ground-level concentrations at a closer proximity to the building than would otherwise occur. It identifies the minimum stack height at which significant aerodynamic downwash is avoided.

GEP stack height is defined as the greater of 65 meters or the formula height. The formula height, as defined by USEPA, is:

$$H_{GEP} = H_b + 1.5L$$

where:

H_{GEP} = GEP formula height;

H_b = Height of adjacent or nearby building or structure; and

L = Lesser of height or maximum projected width of adjacent or nearby building or structure, i.e., the critical dimension.

A structure is determined to be “nearby” if the stack is within 5L from the edge of the structure.

The latest version of the USEPA Building Profile Input Program (BPIP-PRIME) was run for all stacks and buildings in the vicinity of the Project to create the building parameter inputs to AERMOD. BPIP-PRIME addresses the entire structure of the wake, from the cavity immediately downwind of the building, to the far wake. Figure 5-2 shows the stack locations as well as the structure footprints and heights input into BPIP-PRIME. A GEP formula height of 491.4 feet (149.8 meters) was calculated for the new turbine stack with the combined structure of the boiler buildings #1 and #2 at the existing Station as the controlling structure. Stack heights for each source modeled are provided in Table 5-1. Each of the stacks modeled are equal to or below its GEP height and, therefore, exhaust emissions have the potential to experience the aerodynamic effects of downwash. As such, wind-direction-specific building parameters generated by BPIP-PRIME were input into AERMOD to account for potential downwash from nearby structures in the dispersion calculations.

5.5 RECEPTOR LOCATIONS FOR MODELING

The receptor grid selected for the AERMOD modeling is sufficient to capture maximum modeled impacts. A nested Cartesian grid was extended out from the Property fence line based on the following spacing and distances:

- at 25-meter intervals along the fence line;
- at 50-meter intervals extending out to 1 km;
- at 100-meter intervals from 1 km to 3 km;
- at 250-meter intervals from 3 km to 5 km;
- at 500-meter intervals from 5 km to 10 km; and,
- at 1,000-meter intervals from 10 km to 20 km.

In addition to the gridded receptors, discrete receptors are placed at locations of schools, daycare centers, hospitals, and nursing homes within 5 km of the Project. Specifically those locations include:

Three identifiable sensitive receptors within 1 km of Canal Generating Station:

1. Dieu's Daycare - Day Care Center (14 Moody Dr. Sandwich, MA)
2. Radius HealthCare Center - Nursing Home (37 MA-6A Sandwich, MA)
3. Sandwich Schoolhouse Preschool (38 Route 6A, Sandwich, MA)

Between 1 km and 5 km from Canal Generating Station, there are 11 identifiable sensitive receptors:

1. Bridgeview Montessori School (885 Sandwich Rd. Sagamore, MA).
2. Ella F Hoxie School (30 Williston Rd. Sagamore Beach, MA)
3. Henry T. Wing School (33 Water St. Sandwich, MA)
4. Sandwich Community School-Early Learning (4 Beale Ave. Sandwich, MA)
5. Little Owl Day Care - Day Care Center (67 Main St. Sandwich, MA)
6. Sandwich Village Preschool - Preschool (159 Main St. Sandwich, MA)
7. Cape Winds Rest Home - Retirement Home (125 Main St. Sandwich, MA)
8. Decatur House Inc - Assisted Living Facility (176 Main St. Sandwich, MA)
9. Joyful Noise Preschool (136 Main St, Sandwich, MA)
10. Rainbow Preschool (80 Old Plymouth Rd, Sagamore Beach)
11. Bourne/Sandwich I Preschool and Borne Sandwich II Preschool (90 Adams St, Sagamore, MA)

The receptor coordinates used in the modeling analysis are in Universal Transverse Mercator (UTM) Zone 19, based on North American Datum (NAD) 83. A total of 8,589 receptors were included in the modeling. The full receptor network is depicted in Figure 5-3 and a close-up of the near field receptors is shown in Figure 5-4.

AERMAP (version 11103) (USEPA, 2004b), AERMOD's terrain preprocessor program, was used to calculate terrain elevations and critical hill heights for each model receptor using National Elevation Data (NED). The 1 arc-second (~30-meter resolution) NED dataset was downloaded from the United States Geological Service (USGS) website (http://seamless.usgs.gov/).

5.6 METEOROLOGICAL DATA FOR MODELING

The meteorological data utilized in the modeling analysis were described in detail in the Modeling Protocol approved by MassDEP. Meteorological data required for AERMOD include hourly values of wind speed, wind direction, and ambient temperature. Five years (2008-2012) of site-specific meteorological data from the nearby Telegraph Hill monitor (approximately 2.9 miles to the south-southeast of the proposed Project) were used in the modeling analyses, along with concurrent surface observations from Barnstable Municipal Airport and upper air data from Chatham Municipal Airport. The meteorological data were processed with AERMET (USEPA, 2004c), the meteorological preprocessor for AERMOD, based on USEPA guidance (USEPA, 2013a), 40 CFR Part 51 Appendix W, the AERSURFACE user's guide (USEPA, 2013b), and other USEPA publications.

The five-year data period selected for this analysis spans the calendar years 2008-2012 because the latest five years (through 2014) from Telegraph Hill had periods that were well below the data completeness requirements for modeling. In particular, data recovery of wind direction for the first quarter of 2013 was less than 60% due to an outage at the tower. However, data for the five consecutive years of 2008–2012 meets data completeness requirements and, therefore, were chosen for this modeling analysis.

The Telegraph Hill monitor records some key measurements at a height much higher than the typical airport 10-m (33-ft) level:

- wind speed at 145 feet;
- wind direction at 145 feet;
- sigma theta at 145 feet;
- temperature at 10 feet; and,
- relative humidity at 10 feet.

The Telegraph Hill data were supplemented, as appropriate, with concurrent surface observations (not including wind data) from Barnstable Municipal Airport (to substitute for missing data) and upper air observations from Chatham Municipal Airport (for upper air data as required by the AERMOD modeling system). The Telegraph Hill Station base of 64.3 meters was used for the potential temperature profile.

AERMET requires specification of site land use characteristics including surface roughness (z_o), albedo (r), and Bowen ratio (B_o). USEPA has developed the AERSURFACE (v13016) tool to determine the site characteristics based on digitized land cover data. AERSURFACE supports the use of land cover data from the USGS National Land Cover Data 1992 archives (NLCD92) (http://edcftp.cr.usgs.gov/pub/data/landcover/states/). The NLCD92 archive provides data at a spatial resolution of 30 meter based on a 21-category classification scheme applied over the continental United States.

AERSURFACE was applied for surface roughness, based on the 1-km radius circular area centered at the Telegraph Hill monitor. The 1-km radius was divided into sectors for the AERSURFACE analysis; each chosen sector has a mix of land uses that is different from that of other selected sectors. Three sectors used for this analysis are: 80˚ – 170˚, 170˚ – 345˚, and 345˚ – 80˚. The determination of the Bowen ratio and albedo are based on a mean value (i.e., no direction or distance dependency) for a representative domain defined by a 10 km by 10 km region centered on the measurement site. For Bowen ratio, the land use values are linked to three categories of surface moisture corresponding to average, wet, and dry conditions. The surface moisture condition for the site may vary depending on the meteorological data period for which the surface characteristics are applied. AERSURFACE applies the surface moisture condition for the entire data period. Therefore, if the surface moisture condition varies significantly across the data period, then AERSURFACE can be applied multiple times to account for those variations. The surface moisture condition for each month was determined by comparing precipitation for the period of data to be processed to the 30-year climatological record, selecting “wet” conditions if precipitation is in the upper 30th-percentile, “dry” conditions if precipitation is in the lower 30th-percentile, and “average” conditions if precipitation is in the middle 40th-percentile. The 30-year precipitation data set used in this modeling was taken from the National Climatic Data Center for Chatham, MA (USC00191386). The monthly designations of surface moisture input to AERSURFACE are summarized in Table 5-9.

Table 5-9: AERSURFACE Bowen Ratio Moisture Condition Designations

Month	Bowen Ratio Category				
	2008	2009	2010	2011	2012
January	Average	Average	Average	Wet	Average
February	Wet	Dry	Average	Average	Dry
March	Average	Average	Wet	Dry	Dry
April	Average	Average	Dry	Average	Dry
May	Wet	Average	Average	Dry	Wet
June	Dry	Average	Average	Average	Dry
July	Average	Wet	Average	Wet	Average
August	Average	Wet	Wet	Average	Average
September	Wet	Average	Wet	Dry	Average
October	Average	Wet	Wet	Wet	Average
November	Average	Dry	Average	Average	Dry
December	Wet	Average	Average	Dry	Wet

There were no months during the 2008-2012 time period in which there was measurable snow depth on the ground for more than 50% of the winter months. As such, all winter months were modeled as “winter no snow.”

A composite wind rose for the five years of meteorological data used in the modeling analysis is presented in Figure 5-5. The winds are predominantly from the southwest.

5.7 BACKGROUND AIR QUALITY DATA

Air quality data collected from the closest, representative, available monitoring stations to the Project site were used to characterize ambient air quality conditions near the proposed Project. Background air quality levels characterize the existing ambient air quality in the vicinity of the proposed Project. NRG operates an ambient air quality monitoring station, Shawme Crowell Monitoring Station, in Shawme Crowell State Park located approximately 1 mile southwest of the Project site. This monitoring site was put into operation to provide data of the existing air quality conditions in the vicinity of the Station. This monitor measures concentrations of SO_2, NO_2, PM_{10}, and $PM_{2.5}$. For background concentrations of CO and Pb (lead), the Francis School monitor in East Providence (EPA AQS ID 440071010), which is located 43.6 miles to the west-northwest of the Project site, was used. Data from both of these monitoring sites represent conservative estimates of the existing ambient air quality. The Shawme-Crowell monitor is a source-specific location designed to capture impacts from the existing Station, which was cumulatively modeled with the Project. The East Providence site is conservative because it is affected by more development, since it is located in a more urban environment than Sandwich. A summary of the background air quality concentrations based on the latest three years (2012-2014) of existing monitoring data is presented in Table 5-10. The Pb (lead) data are for 2013–2015.

As shown in Table 5-10, ambient concentrations of SO_2, NO_2, PM_{10}, and $PM_{2.5}$ measured at the Shawme-Crowell monitor are well below the NAAQS. Ambient concentrations of CO at the closest measurement location in East Providence are also well below the NAAQS.

Table 5-10: Monitored Ambient Air Quality Concentrations and Selected Background Levels

Pollutant	Averaging Period	2012	2013	2014	Background Air Quality (µg/m^3)	NAAQS/MAAQS (µg/m^3)
SO_2 (ppb)	1-Hour	11	9	5	22	196
	3-Hour	22	14	5	58	1,300
	24-Hour	5	4	5	12	365
	Annual	1	2	2	5	80
NO_2 (ppb)	1-Hour	22	20	22	40	188
	Annual	8	8	7	15	100
CO (ppm)	1-Hour	1.5	2.0	1.6	2,346	40,000
	8-Hour	1.0	1.3	1.2	1,495	10,000
PM_{10} (µg/m^3)	24-Hour	23	18	20	23	150
	Annual	9	9	9	9	50
$PM_{2.5}$ (µg/m^3)	24-Hour	12	10	10	11	35
	Annual	5	5	4	5	12
Lead (Pb) (µg/m^3)	3-Month	0.01	0.01	0.01	0.01	0.15

In January 2013, a Court ruling held that use of the $PM_{2.5}$ SIL alone cannot be used to demonstrate compliance with NAAQS. The Court decision does not preclude the use of the SILs for $PM_{2.5}$ entirely, but requires that monitoring data be evaluated to ensure that predicted impacts that are less than the SIL do not result in total concentrations (existing ambient plus project-related contributions) that exceed the NAAQS. Therefore, if there is a sufficient margin (greater than the SIL value) between the representative monitored background concentration in the area and the $PM_{2.5}$ NAAQS, then USEPA believes it would be sufficient to conclude that a proposed source with an impact less than the SIL value will not cause or contribute to a violation of the NAAQS and to forego a more comprehensive modeling analysis for that pollutant for that averaging period (USEPA, 2014). MassDEP believes that this methodology can be extended to all NAAQS pollutants and averaging periods. Table 5-11 presents the difference between the NAAQS and the representative monitored background concentration, compared to the SILs. As shown in Table 5-11, all averaging periods for each pollutant have a margin between the monitored value and the NAAQS that is greater than the respective SIL; therefore, use of the SILs as *de minimis* levels for all pollutants is appropriate.

Table 5-11: Margin between the Monitored Air Quality Concentrations and the NAAQS Compared to the SILs

Pollutant	Averaging Period	Background Concentration ($\mu g/m^3$)	NAAQS ($\mu g/m^3$)	Delta Concentration (NAAQS –Background) ($\mu g/m^3$)	Significant Impact Level ($\mu g/m^3$)
SO_2	1-Hour	22	196	174	7.8
	3-Hour	58	1,300	1,242	25
	24-Hour	12	365	353	5
	Annual	5	80	75	1
NO_2	1-Hour	40	188	148	7.5
	Annual	15	100	85	1
CO	1-Hour	2,346	40,000	37,654	2,000
	8-Hour	1,495	10,000	8,505	500
PM_{10}	24-Hour	23	150	127	5
	Annual	9	50	41	1
$PM_{2.5}$	24-Hour	11	35	24	1.2
	Annual	5	12	7	***0.2***

(Note: Pb does not have a Significant Impact Level so it is not listed in the Table.)

5.8 AIR QUALITY MODELING RESULTS

5.8.1 Significant Impact Level Analysis

The modeled concentrations for criteria pollutants predicted using AERMOD for the proposed Project sources were compared to the applicable SILs. The modeling evaluated a range of operating loads (including SUSD) to assess the proposed Project's impact. SUSD conditions were not evaluated for annual average modeling because these conditions are only expected to last for a short amount of time (less than 30 minutes). The maximum modeled criteria pollutant concentrations are compared to the SILs in Table 5-12. All maximum impacts are predicted at the Station fence-line or within ***1000*** meters of the fence-line for a few pollutants/averaging periods. The results show that maximum modeled concentrations of SO_2, ***PM_{10}*** and CO for all averaging periods, and annual NO_2, ***and*** $PM_{2.5}$ are below their corresponding SILs. Maximum modeled concentrations of 24-hour average $PM_{2.5}$ and 1-hour NO_2 are above their corresponding SILs (shown in bold in Table 5-12). Therefore, cumulative modeling (see Section 5.8.2) was required for these pollutants/averaging period combinations. Figure 5-6 presents the Significant Impact Area (SIA) for 24-hr $PM_{2.5}$ and 1-hr NO_2. The SIA: for 24-hour $PM_{2.5}$ extends to ***1,715*** meters; and, for 1-hour NO_2 extends to ***4,255*** meters from the Project stack location.

Table 5-12: Proposed Canal 3 Project Maximum AERMOD Modeled Results Compared to Significant Impact Levels

Pollutant	Avg. Period	Form	Max. Modeled Conc. (µg/m³)	SIL (µg/m³)	% of SIL	Period	Receptor Location[4] (m) (UTME, UTMN, Elev.)
SO_2	1-hr	H1H[1]	***0.34***	7.8	***4%***	2008-2012	***375300.00, 4626200.00, 2.46***
	3-hr	H1H	***0.32***	25.0	***1%***	***12/10/08 hr 06***	***374750.00, 4625650.00, 0.00***
	24-hr	H1H	***0.18***	5.0	***4%***	***124/10/08 hr 24***	***374750.00, 4625650.00, 0.00***
	Annual	H1H	***0.0026***	1.0	***<0%***	2011	***375300.00, 4626100.00, 4.85***
PM_{10}	24-hr	H1H	***4.18***	5.0	***84%***	04/28/11 hr 24	***374615.32, 4625525.14, 3.16***
	Annual	H1H	***0.02***	1.0	***2%***	2011	***375300.00, 4626100.00, 4.85***
$PM_{2.5}$	24-hr	H1H[2]	***2.77***	1.2	***231%***	2008-2012	***374593.22, 4625523.12, 3.09***
	Ann.	H1H[3]	***0.02***	0.2	***10%***	2008-2012	***375300.00, 4626100.00, 4.85***
NO_2 [5]	1-hr	H1H[1]	***28.26***	7.5	***377%***	2008-2012	***374500.00, 4625000.00, 12.06***
	Annual	H1H	***0.33***	1.0	***33%***	2009	***374603.87, 4625282.00, 3.62***
CO	1-hr	H1H	***197.67***	2000.0	***10%***	07/18/10 hr 22	***374900.00, 4625300.00, 4.71***
	8-hr	H1H	***24.51***	500.0	***5%***	***12/10/08 hr 08***	***374750.00, 4625700.00, 0.00***

Note: Impacts denoted in bold font are above the SILs.
[1] High 1st High daily maximum 1-hr concentrations averaged over 5 years.
[2] High 1st High maximum 24-hour concentrations averaged over 5 years.
[3] Maximum annual concentrations averaged over 5 years.
[4] All modeled concentrations depicted in this table occur on the facility fence line or within 1000-meters of the facility fence line.
[5] NO_2 estimated by assuming 75% conversion of NO_X to NO_2 for annual concentrations and 80% conversion of NO_X to NO_2 for 1-hour concentrations.
Note: Pb does not have a Significant Impact Level so it is not listed in the Table.

5.8.2 NAAQS Compliance Demonstration

Since the proposed Project is a modification of the existing Station, a compliance demonstration was conducted to ensure that the combined emissions from the existing Station and the proposed new Project will not cause or contribute to a NAAQS violation (MassDEP, 2011).

For the pollutants and averaging periods that have maximum predicted impacts greater than the SILs (24-hour $PM_{2.5}$ and 1-hour NO_2), cumulative modeling is required. MassDEP modeling guidance indicates that sources within 10 km of the Station that emit significant $PM_{2.5}$, and NO_x emissions (i.e., > 10 tpy $PM_{2.5}$, >40 tpy NO_x, based on actual emissions) should be included in the cumulative modeling. A search for facilities was conducted using these criteria and no sources were found within 10 km that satisfy the criteria. Therefore, there are no nearby sources beyond those existing sources at the Canal Generating Station to include in a cumulative modeling analysis. MassDEP has concurred with the finding of no additional sources required for a cumulative NAAQS modeling analysis.

The cumulative design value modeled concentrations of the new Project and existing Station were combined with appropriate ambient background concentrations and then compared with the NAAQS. Table 5-13 demonstrates that the predicted total ambient criteria pollutant concentrations (modeled plus background) are below the NAAQS for all pollutants. For reference, the maximum impact from the new sources and existing sources are also shown separately in Table 5-13. Note that these individual concentrations represent their relative maximum impact (in the form of the standard) and are not paired in time and space; therefore, these concentrations do not sum to the “AERMOD Total Modeled Concentration” shown in the table, which reflects the maximum in the form of the standard of the combined impacts (new plus existing) paired in time and space.

5.8.3 PSD Increment Analysis

To ensure that air quality in areas that are in attainment of the NAAQS is not allowed to be significantly degraded from existing levels, USEPA has established PSD Increments. PSD Increments reflect the maximum increase in pollutant concentrations that is allowed to occur above a baseline concentration for a subject pollutant. The baseline concentration for each pollutant and averaging period is defined as the ambient concentration existing at the time that the first complete PSD permit application affecting the area is submitted to the regulatory agency. Significant deterioration is said to occur when the amount of new pollution would exceed the applicable PSD Increment. Modeling to demonstrate that allowable increments are not exceeded must include existing sources that are both within the baseline area and were constructed after the PSD baseline date (consume increment). In addition, credit may be taken for sources that have added controls or stopped operating after the PSD baseline date (expand increment). The existing Station sources do not consume increment because they were in operation prior to the baseline dates and are considered part of the baseline concentration.

If the maximum modeled concentration of a pollutant due to the emission increase from the proposed Project are below the applicable SILs, the predicted emissions from the proposed modifications are considered to be in compliance with the PSD Increments for that pollutant. Therefore, for this Project, PSD Increment modeling is required for short-term particulates (24-hour $PM_{2.5}$). A PSD Increment has not been established for 1-hour NO_2.

Canal 3 has conferred with MassDEP to determine that the $PM_{2.5}$ minor source baseline date has not yet been established for the baseline area (Barnstable County). The PSD Permit application for this Project will establish the baseline date for $PM_{2.5}$ when it is determined to be complete. Therefore, because the baseline has not been previously established for $PM_{2.5}$, there are no other $PM_{2.5}$ increment-consuming sources in the baseline area to include in the $PM_{2.5}$ PSD Increment modeling.

Table 5-14 presents the results of the PSD Increment analysis for $PM_{2.5}$. The analysis includes impacts from the new turbine, emergency generator and the fire water pump. The results indicate that the operation of the proposed Project is protective of the PSD Increments.

Table 5-13: AERMOD Model Results for the New Project and Existing Station Compared to the NAAQS

Pollutant	Avg. Period	Form	AERMOD Modeled Max. Concentration (µg/m³) (6)		AERMOD Total Modeled Conc. (µg/m³)	Back-ground Conc. (µg/m³)	Total Ambient Conc. (µg/m³)	NAAQS (µg/m3)	% of NAAQS	Period (7)	Receptor Location (m) (7)
			New Sources	Existing Sources							(UTME, UTMN, Elev.)
SO_2	1-hr	H4H[1]	***0.29***	128.20	***128.29***	22	***150.29***	196	77%	2008-2012	375700.00, 4626300.00, 4.35
	3-hr	H2H	***0.31***	133.70	***133.77***	58	***191.77***	1300	15%	06/26/08 hr 12	375400.00, 4626300.00, 4.01
	24-hr	H2H	***0.14***	45.87	***45.90***	12	***57.90***	365	16%	07/08/08 hr 24	375800.00, 4626300.00, 0.51
	Annual	H1H	***0.003***	4.20	4.20	5	9.20	80	12%	2011	376000.00, 4626700.00, 0.00
PM_{10}	24-hr	H2H	***3.71***	6.40	***6.40***	23	***29.40***	150	20%	***06/21/09 hr 24***	***373682.47, 4625526.98, 3.77***
	Annual	H1H	***0.02***	1.00	***1.00***	9	***10.00***	50	20%	2009	373682.47, 4625526.98, 3.77
$PM_{2.5}$	24-hr	H8H[2]	***1.05***	3.87	3.87	11	14.87	35	42%	2008-2012	373682.47, 4625526.98, 3.77
	Annual	H1H[3]	***0.02***	0.79	0.79	5	5.79	12	48%	2008-2012	373713.42, 4625597.92, 4.23
NO_2(5)	1-hr	H8H[4]	***21.02***	91.23	91.23	40	131.33	188	70%	2008-2012	373682.47, 4625526.98, 3.77
	Annual	H1H	***0.33***	10.03	10.04	15	25.04	100	25%	2009	373682.47, 4625526.98, 3.77
CO	1-hr	H2H	***195.26***	666.81	***678.81***	2,346	***3,024.81***	40,000	8%	04/11/08 hr 11	374300.00, 4626700.00, 1.71
	8-hr	H2H	***21.18***	159.51	***166.62***	1,495	***1,661.62***	10,000	17%	09/22/10 hr 16	375900.00, 4626400.00, 0.00
Pb[8]	3-month	H1H	***4.15E-04***	1.43E-03	***1.84E-03***	0.01	0.012	0.15	8%	03/08/12	376500.00, 4627100.00, 0.00

1 High 4st High daily maximum 1-hr concentrations averaged over 5 years.
2 High 8th High 24-hour concentrations averaged over 5 years.
3 Maximum annual concentration averaged over 5 years.
4 High 8th High daily maximum 1-hr concentrations averaged over 5 years.
5 NO_2 estimated by assuming 75% conversion of NO_X to NO_2 for annual concentrations and 80% conversion of NO_X to NO_2 for 1-hour concentrations.
6 Modeled concentrations depict impacts from New Sources and Existing Sources relative to their own maximum modeled concentrations. Therefore the total of the New Sources + Existing Sources does not add up to the "AERMOD Total Modeled Concentration" depicted in this table.
7 The period and receptor location correspond to the AERMOD Total Modeled Concentration value.
8 Pb impacts are conservatively based on the maximum 24-hr AERMOD modeled concentrations. The "AERMOD Total Modeled Concentration" for Pb is conservatively the sum of the maximum concentrations for the New and Existing source, and the period and receptor are based on the existing source impact.

Table 5-14: AERMOD Model Results Compared to the PSD Increments

Pollutant	Avg. Period	Form	Modeled Conc. ($\mu g/m^3$)	PSD Increment ($\mu g/m^3$)	% of Increment	Period	Receptor Location (m) (UTME, UTMN, Elev.)
$PM_{2.5}$	24-hr	H2H[1]	***3.71***	9	***41%***	***12/10/08 hr 24***	***374800.00, 4625700.00, 0.00***
[1] High 2nd High concentration over 5 years.							

5.8.4 Secondary $PM_{2.5}$ Assessment

In May 2014, USEPA released "*Guidance for $PM_{2.5}$ Permit Modeling*" (the Guidance), which provides guidance on demonstrating compliance with the NAAQS and PSD Increment for $PM_{2.5}$ specifically with regard to consideration of the secondarily formed $PM_{2.5}$. In the Guidance, USEPA has defined four "Assessment Case" categories based on a project's potential emissions of direct $PM_{2.5}$ and precursors for potential secondary formation, NO_x and SO_2 (in tpy). The Assessment Case categories identify assessment approaches that are available and appropriate for each case.

The current USEPA dispersion model recommended for near-field $PM_{2.5}$ modeling, AERMOD, does not explicitly account for potential secondary formation of $PM_{2.5}$. Therefore, in addition to the direct $PM_{2.5}$ dispersion modeling analysis, the potential for secondary formation of $PM_{2.5}$ from significant precursor emissions should be assessed in accordance with the Guidance.

Based on the information in Table III-1 of the Guidance, the Project falls into Assessment Case 3[6]. Accordingly, a Case 3 hybrid qualitative/quantitative assessment of potential secondary formation of $PM_{2.5}$ is appropriate.

Based upon the Guidance, a hybrid qualitative/quantitative assessment is deemed appropriate for evaluation of the Project's potential secondary $PM_{2.5}$ because the underlying refined air quality modeling provides a well-developed analysis of both the current background concentrations and the Project's primary $PM_{2.5}$ emissions. Accordingly, a hybrid qualitative/quantitative assessment of the emission source and the atmospheric environment in which the source is located is presented.

A quantitative estimate of the projected secondary formation of $PM_{2.5}$ is developed based on the approach described in Appendix D of the Guidance, which incorporates a regional average offset ratio. This assessment supports a determination that secondary $PM_{2.5}$ impacts associated with the source's precursor emissions will not cause or contribute to a violation of the 24-hour or annual $PM_{2.5}$ NAAQS.

Regional $PM_{2.5}$

Particulate matter in the atmosphere is made up of different chemical species (nitrates, sulfates, organic matter, elemental carbon, etc.). NO_x as a gas is considered a precursor pollutant because NO_x emissions can convert to nitrates, a particulate, in the atmosphere. Similarly, SO_2 as a gas can be converted to sulfates in the atmosphere. These conversions involve highly complex shifting between gaseous, liquid and solid phases. They are dependent on atmospheric conditions such as temperature, sunlight, relative humidity, and the presence of reactive gases such as O_3, hydrogen peroxide, and NH_3. The formation of secondary $PM_{2.5}$ takes time to occur and, therefore, generally materializes considerably downwind of the precursor emission source. The sulfate formation is considered a stable product; however, the nitrate process is reversible. Equilibrium is established between nitric acid, NH_3 and ammonium nitrate.

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[6] Assessment Case 3 applies when direct $PM_{2.5}$ emissions are ≥ 10 tpy and NO_x and/or SO_2 emissions are ≥ 40 tpy.

As a general matter, the composition of $PM_{2.5}$ varies by season and location across the United States. Nitrates make up a small fraction of the $PM_{2.5}$ in the Northeast. The percentage of nitrates in $PM_{2.5}$ is almost negligible during the summer, increases somewhat in the spring and fall, with the highest percentage of nitrates seen during the winter season. Even during the winter, sulfates and organic matter dominate the $PM_{2.5}$ composition in the Northeast.

For the proposed Project, the background $PM_{2.5}$ monitoring data considered in the air quality analysis are from the Shawme Crowell Monitoring Station located in Shawme Crowell State Park. This monitoring station was specifically established to characterize air quality in the vicinity of the Station. There are co-located $PM_{2.5}$ monitors operating at that monitoring station. Figures 5-7 and 5-8 show a seven-year trend of measured annual $PM_{2.5}$ at the Shawme Crowell site and a 10-year trend at other monitoring locations across the state, respectively. The $PM_{2.5}$ monitoring data show improvement in the ambient air quality on an annual basis over recent years. The same trend is found at other monitoring locations throughout Massachusetts.

A recent Harvard School of Public Health study (Masri, et al., 2015) found that regional sources accounted for 48% of the $PM_{2.5}$ measured at a Boston monitoring site. Hence, the representative background monitoring data for $PM_{2.5}$ used in the modeling analysis adequately accounts for secondary contribution from background sources in the region. On the basis of measured data, there is no indication that secondary formation of $PM_{2.5}$ from existing sources in the region is currently causing or contributing to an exceedance of the $PM_{2.5}$ NAAQS on a short-term or annual basis.

Figure 5-9 presents the recent trend of annual NO_2 measurement from Shawme Crowell monitor. The long-term trend of annual NO_2 monitoring data across Massachusetts, as presented on Figure 5-10, shows a pronounced downward trend in concentrations over time. However, as concentrations have decreased to low levels, the trend has stabilized over the past few years across the state as well as at the Shawme Crowell site.

Summary of Primary $PM_{2.5}$ Emissions and Modeling

AERMOD air quality modeling of the primary $PM_{2.5}$ emissions from the proposed Project demonstrates that the predicted 24-hour and annual impacts plus ambient background concentrations are well below the respective NAAQS.

Air quality modeling of the direct $PM_{2.5}$ emissions from the Project plus the ambient background concentration results in a total 24-hour concentration that is approximately 34% of the 24-hour $PM_{2.5}$ NAAQS. The modeled 24-hour impact from the Project represents only approximately 3% of the NAAQS, while the monitored background alone comprises 31% of the NAAQS. On an annual basis, the annual average direct $PM_{2.5}$ modeled impact plus the monitored background accounts for approximately 42% of the annual NAAQS. The modeled concentration attributable to the Project alone accounts for less than 1% of the NAAQS, while the monitored background accounts for more than 41% of the NAAQS.

Therefore, for both the 24-hour standard and the annual standard, there is a very considerable margin allowing for the formation of secondary $PM_{2.5}$ from precursor emissions before an exceedance of the NAAQS would be predicted.

A cumulative modeling analysis was also conducted for direct $PM_{2.5}$ impacts including the proposed Project as well as sources at the existing Station. Air quality modeling of the direct $PM_{2.5}$ emissions from the future Canal Generating Station (new and existing sources) plus the ambient background concentration results in 24-hour impacts that are approximately 42% of the 24-hour $PM_{2.5}$ NAAQS and 48% of the annual $PM_{2.5}$ NAAQS. The monitored background data may also already include the impacts of the existing Station that was also explicitly modeled, so there is some degree of conservative double counting in the analysis. Even with the addition of the direct impacts from the existing Station, there is still a substantial margin available to accommodate any potential secondary formation of $PM_{2.5}$ without approaching the health-protective NAAQS.

Assessment of Secondary $PM_{2.5}$ Emissions

Because the Project is subject to NNSR, it must apply LAER for NO_x. The proposed Project's NO_x emissions are minimized through the use of DLN burners and SCR. SO_2, PM_{10}, and $PM_{2.5}$ emissions will be controlled through the use of clean-burning fuels.

An estimate of the projected secondary formation of $PM_{2.5}$ was developed based on the example described in Appendix D of the Guidance, which incorporates a regional average offset ratio. The method divides the projected emissions by a national ratio of 40 for SO_2 and 200 (eastern states value) for NO_x to determine the total equivalent $PM_{2.5}$ emissions. Then, the ratio of the total equivalent $PM_{2.5}$ emissions is divided by the primary $PM_{2.5}$ emissions and the result is used to scale the total modeled primary $PM_{2.5}$ impact to account for the secondary formation of $PM_{2.5}$.

Hence, for the proposed Project:

Total Equivalent $PM_{2.5}$ (tpy) = $PM_{2.5}$ + SO_2/40 + NO_x/200

Total Equivalent $PM_{2.5}$ (tpy) = ***60.5*** + ***11.1***/40 + ***104.3***/200 = ***61.3*** tpy Total Equivalent

$PM_{2.5}$ /Primary $PM_{2.5}$ ratio = 61.3 tpy / 60.5 tpy = 1.01

Table 5-15 presents the total $PM_{2.5}$ impacts (24-hour and annual) including the primary modeled $PM_{2.5}$ (from Table 5-13), the estimated secondary $PM_{2.5}$ formed from precursor emissions, and the ambient monitored background. Using the estimation technique provided by USEPA, the secondary formation of $PM_{2.5}$ (from SO_2 and NO_x) is approximately ***0.01*** μg/m^3 on a 24-hour basis, or approximately ***0.03***% of the 24-hour NAAQS, and ***0.0002*** μg/m^3 on an annual average basis, or approximately ***0.002***% of the annual NAAQS.

Also presented in Table 5-15 is a comparison of the total $PM_{2.5}$ impacts (24-hour and annual) including the primary modeled $PM_{2.5}$ and the estimated secondary $PM_{2.5}$ formed from precursor emissions compared to the PSD Increments. The total $PM_{2.5}$ impacts demonstrate compliance with both the 24-hour and annual average NAAQS and the 24-hour and annual average PSD Increments.

Table 5-15: Total $PM_{2.5}$ (Primary + Secondary) Impacts Comparison to the NAAQS and PSD Increments

Avg. Period	New Source Modeled Primary $PM_{2.5}$ Conc. (μg/m^3)	Equivalent Ratio	Primary plus Secondary $PM_{2.5}$ Conc. (μg/m^3)	Monitored Back-ground (μg/m^3)	Existing Source Contrib.[1] (μg/m^3)	Total $PM_{2.5}$ Impact (μg/m^3)	Standard (μg/m^3)	% of Standard
NAAQS								
24-Hour	***1.05***	1.01	***1.06***	11	3.87	***15.93***	35	***45.5%***
Annual	***0.02***	1.01	***0.02***	5	0.79	***5.81***	12	***48.4%***
[1] includes existing Station units								
PSD Increments								
24-Hour	3.71	1.01	***3.75***	N/A	N/A	***3.75***	9	***41.7%***
Annual	0.02	1.01	***0.02***	N/A	N/A	***0.02***	4	***0.5%***

It should be noted that this analysis is very conservative because the maximum secondary $PM_{2.5}$ impacts will not occur at the same location and time as the maximum direct $PM_{2.5}$ impacts. This is due to the fact that the secondary chemical reactions take time to occur, so the secondary $PM_{2.5}$ impacts would be expected to occur at a greater distance away from the Project than the predicted direct $PM_{2.5}$ impacts.

Based on these factors, the above assessment, which has been made in accordance with USEPA Guidance, demonstrates that the $PM_{2.5}$ NAAQS and PSD Increments will be protected, taking into account both primary $PM_{2.5}$ impacts and potential contributions from secondary $PM_{2.5}$ due to precursor emissions from the proposed Project.

5.8.5 PSD Pre-Construction Monitoring Requirements

The PSD regulations require that a PSD permit application establish existing air quality levels. The determination of existing air quality levels can be satisfied by air measurements from an existing representative monitor, by an on-site monitoring program, or by demonstrating that modeled impacts are *de minimis,* as defined by Significant Monitoring Concentrations (SMC). Due to its proximity to the Project, data from the Shawme Crowell Monitoring Station can be used to fulfill the PSD pre-construction monitoring requirement for PM_{10}, $PM_{2.5}$, SO_2, and NO_2.

O_3 is a secondary, regional-scale pollutant and not modeled for single-source applications. As such, regional monitoring data are considered sufficient to establish existing O_3 levels without the need for pre-construction monitoring.

5.8.6 Air Toxics Analysis

An air quality impact assessment of the non-criteria pollutants (air toxics) emitted from the proposed Project and existing Station sources was conducted. The highest 24-hour and annual normalized AERMOD predicted concentrations were determined across all operating loads and then scaled by the appropriate pollutant emission rates to obtain the predicted concentration of each pollutant. The worst-case impacts were then compared to applicable thresholds. Table 5-16 presents the maximum predicted non-criteria pollutant air quality impacts for those pollutants for which MassDEP has a guideline 24-hour Threshold Effects Exposure Limit (TEL). The modeled impacts from the proposed Project alone as well as the combined impacts from the proposed Project plus the existing Station are presented. Similarly, Table 5-17 presents the maximum predicted non-criteria pollutant air quality impacts for those pollutants for which MassDEP has a guideline annual Allowable Ambient Limit (AAL). The results show that air quality impacts from the non-criteria emissions are well below the threshold levels of the corresponding MassDEP AALs and TELs.

Table 5-16: Non-Criteria Pollutant Modeled Concentrations from Proposed Project and Existing Canal Sources for Comparison to Massachusetts TELs

Pollutant	AERMOD Maximum 24-Hr Concentration (µg/m³)		MassDEP 24-hr TEL (µg/m³)	Proposed Project % of TEL	Proposed Project plus Existing % of TEL
	Proposed Project Only(1)	Proposed Project plus Existing(2)			
Acetaldehyde	***6.70E-03***	***1.88E-02***	30	0%	0%
Acrolein	***9.94E-04***	***2.46E-03***	0.07	***1%***	4%
Ammonia	***8.45E-01***	***1.07E+00***	100	***1%***	***1%***
Antimony	**0**.00E+00	3.28E-03	0.02	0%	16%
Arsenic	***5.67E-06***	***1.00E-03***	0.003	0%	***33%***
Benzene	***1.12E-02***	***2.79E-02***	0.6	***2%***	***5%***
Beryllium	0.00E+00	2.78E-05	0.001	0%	3%
1,3-Butadiene	***1.99E-03***	***2.61E-03***	1.2	0%	0%
Cadmium	***6.30E-07***	1.20E-03	0.002	0%	60%
Chromium (metal)	***2.54E-03***	***4.64E-03***	1.36	0%	***0%***
Chromium (VI) Compounds	***4.41E-07***	2.43E-0***4***	0.003	0%	8%
Copper	0.00E+00	1.84E-03	0.54	0%	0%
o-Dichlorobenzene	0.00E+00	1.04E-03	81.74	0%	0%
p-Dichlorobenzene	0.00E+00	1.04E-03	122.61	0%	0%
Ethylbenzene	***3.52E-03***	***3.56E-03***	300	0%	0%
Formaldehyde	***3.07E-02***	***1.35E-01***	2	***2%***	***7%***
Hydrogen Chloride	0.00E+00	2.26E-01	7	0%	3%
Hydrogen Fluoride	***0***.00E+00	2.49E-02	0.68	0%	4%
Lead	***3.84E-04***	***1.81E-03***	0.14	***0%***	***1%***
Mercury (elemental)	***1.26E-06***	***2.97E-04***	0.14	0%	0%
Mercury (inorganic)	***1.26E-06***	***2.97E-04***	0.14	0%	0%
Naphthalene (including 2-methylnaphthalene)	***4.69E-03***	***7.27E-03***	14.25	0%	0%
Nickel (metal)	***1.16E-03***	***5.59E-02***	0.27	***0%***	21%
Nickel Oxide	***1.48E-03***	***7.11E-02***	0.27	1%	***26%***
Phosphoric Acid	0.00E+00	1.90E-02	0.27	0%	7%
Propylene Oxide	***2.35E-02***	***7.98E-02***	6	0%	1%
Selenium	***3.15E-05***	***4.83E-04***	0.54	0%	0%
Sulfuric Acid	***2.12E-01***	***2.41E+00***	2.72	***8%***	89%
Toluene	***1.62E-02***	***2.96E-02***	80	0%	0%
1,1,1-Trichloroethane	0.00E+0***0***	1.50E-04	1038.37	0%	0%
Vanadium	***0***.00E+***00***	2.18E-02	0.27	0%	8%
Vanadium Pentoxide	0.00E+00	3.90E-02	0.14	0%	28%
Xylenes (m-,o-,p- isomers)	***8.36E-03***	***1.29E-02***	11.8	0%	0%

[1] Proposed project alone impacts were based on either 24-hrs/day of operation on gas or ULSD for CT3, plus 1-hr/day for the emergency engine and fire water pump.

[2] Project impacts were then also combined with existing sources assuming oil firing in Canal Units 1 and 2.

Table 5-17: Non-Criteria Pollutant Modeled Concentrations from Proposed Project and Existing Canal Sources for Comparison to Massachusetts AALs

Pollutant	AERMOD Annual Concentrations (µg/m³)				MassDEP Annual AAL (µg/m³)	Proposed Project % of AAL	Proposed Project plus Existing % of AAL
	Proposed Project Only(1)		Proposed Project plus Existing(2)				
	NG Only	NG + Oil	NG Only	NG + Oil			
Acetaldehyde	***2.83E-04***	***2.72E-04***	***1.47E-03***	***1.46E-03***	0.4	0%	0%
Acrolein	***3.91E-05***	***3.73E-05***	***1.82E-04***	***1.80E-04***	0.07	0%	0%
Ammonia	***1.13E-02***	***1.14E-02***	***2.74E-02***	***2.75E-02***	100	0%	0%
Antimony	0.00E+00	0.00E+00	2.35E-04	2.35E-04	0.02	0%	1%
Arsenic	3.47E-08	***4.73E-08***	8.37E-05	8.37E-05	0.0003	0%	28%
Benzene	***6.44E-04***	***6.56E-04***	***2.35E-03***	***2.37E-03***	0.1	1%	2%
Beryllium	0.00E+00	0.00E+00	2.71E-06	2.71E-06	0.0004	0%	1%
1,3-Butadiene	***1.11E-05***	***1.54E-05***	***7.16E-05***	***7.59E-05***	0.003	1%	3%
Cadmium	***3.85E-09***	***5.26E-09***	1.53E-04	1.53E-04	0.0002	0%	76%
Chromium (metal)	1.55E-05	***2.12E-05***	2.59E-04	***2.65E-04***	0.68	0%	0%
Chromium (VI) Compounds	2.70E-09	***3.68E-09***	2.35E-05	2.35E-05	0.0001	0%	23%
Copper	0.00E+00	0.00E+00	1.83E-04	1.83E-04	0.54	0%	0%
o-Dichlorobenzene	0.00E+00	0.00E+00	1.47E-04	1.47E-04	81.74	0%	0%
p-Dichlorobenzene	0.00E+00	0.00E+00	1.47E-04	1.47E-04	0.18	0%	0%
Ethylbenzene	***5.31E-05***	***4.43E-05***	***5.59E-05***	***4.72E-05***	300	0%	0%
Formaldehyde	***7.15E-04***	***7.19E-04***	***1.32E-02***	***1.32E-02***	0.08	1%	17%
Hydrogen Chloride	0.00E+00	0.00E+00	1.62E-02	1.62E-02	7	0%	0%
Hydrogen Fluoride	0.00E+00	0.00E+00	1.79E-03	1.79E-03	0.34	0%	1%
Lead	2.35E-06	***3.21E-06***	1.36E-04	***1.37E-04***	0.07	0%	0%
Mercury (elemental)	7.70E-09	***1.05E-08***	3.69E-05	3.69E-05	0.07	0%	0%
Mercury (inorganic)	7.70E-09	***1.05E-08***	3.69E-05	3.69E-05	0.01	0%	0%
Naphthalene (including 2-methylnaphthalene)	***8.77E-05***	***9.70E-05***	***3.45E-04***	***3.54E-04***	14.25	0%	0%
Nickel (metal)	7.11E-06	***9.71E-06***	4.06E-03	***4.06E-03***	0.18	0%	2%
Nickel Oxide	9.05E-06	***1.24E-05***	5.17E-03	***5.17E-03***	0.01	0%	52%
Phosphoric Acid	0.00E+00	0.00E+00	1.36E-03	1.36E-03	0.27	0%	1%
Propylene Oxide	***2.86E-03***	***2.85E-03***	***8.37E-03***	***8.36E-03***	0.3	1%	3%
Selenium	1.93E-07	***2.63E-07***	3.41E-05	***3.42E-05***	0.54	0%	0%
Sulfuric Acid	***2.74E-03***	***2.80E-03***	***1.72E-01***	***1.72E-01***	2.72	0%	***6%***
Toluene	***4.61E-04***	***4.25E-04***	***1.79E-03***	***1.76E-03***	20	0%	0%
1,1,1-Trichloroethane	0.00E+00	0.00E+00	1.07E-05	1.07E-05	1038.37	0%	0%
Vanadium	0.00E+00	0.00E+00	1.71E-03	1.71E-03	0.27	0%	1%
Vanadium Pentoxide	0.00E+00	0.00E+00	3.04E-03	3.04E-03	0.03	0%	10%
Xylenes (m-,o-,p- isomers)	***2.76E-04***	***2.58E-04***	***7.21E-04***	***7.04E-04***	11.8	0%	0%

1 Annual Project impacts includes the greater of either 4,380 hours of gas firing or ***3,660*** hours gas firing and ***720*** hours ULSD firing for the CT plus 300 hours for the emergency engine and fire water pump.

2 For these two cases, annual Project impacts were then also combined with existing sources assuming oil firing in Units 1 and 2.

5.8.7 PSD Class I Area Analyses

PSD Class I Areas are specifically designated pristine locations (e.g., National Parks, Wildlife Refuges, and Wilderness Areas) that are afforded additional protection by the Clean Air Act. The closest PSD Class I area is more than 250 km from the Station. The Federal Land Managers (FLMs) recommend a screening approach to determine if a proposed source will potentially have an adverse impact on a Class I area, described in the *Federal Land Managers' Air Quality Related Values Work Group Phase 1 Report – Revised* (NPS, 2010).

The guidance references an emissions/distance (Q/D) ratio of 10, below which a proposed source will likely not have an adverse impact on a Class I Area and, therefore, a full Class I Area impact analysis is not warranted. The "Q" in the Q/D is the sum of SO_2, NO_X, H_2SO_4, and PM emissions expressed in tpy, based on maximum short-term (24-hour) emission levels. Conservatively, the total sum of these short-term emissions, based on firing ULSD, is ***317*** tpy ***for 4,380 hours of operation***. The "D" in the Q/D is the distance from the source to the closest Class I area in km. The closest Class I area is Lye Brook Wilderness Area, located in southern Vermont just over 250 km northwest of the Station. The resulting Q/D ratio is ***1.3***, well below the recommended screening ratio of 10. As a result, no further Class I Area analyses have been conducted.

Canal 3 sent a request to the FLM requesting a Class I Area analysis determination. The FLM is in agreement with screening analysis Canal 3 presented above. The form submitted and response email confirming that a Class I Area analysis is not required for this Project are presented in Appendix C.

5.8.8 Impacts to Soils and Vegetation

The USEPA guidance document for soils and vegetation, *A Screening Procedure for the Impacts of Air Pollution Sources on Plants, Soils, and Animals* (USEPA, 1980) and related technical publications established a screening methodology for comparing air quality modeling impacts to vegetation sensitivity thresholds.

For assessing impacts to soils, the USEPA provides a method that evaluates trace element contamination of soils. Since plant and animal communities can be affected before noticeable accumulation occur in the soils, the approach used here evaluates the way soil acts as an intermediary in the transfer of a deposited trace element to plants. For trace elements, the concentration deposited in the soil is calculated from the maximum predicted annual ground-level concentrations, conservatively assuming that all deposited material is soluble and available for uptake by plants. The amount of trace element potentially taken up by plants is calculated using average plant to soil concentration ratios. The calculated soil and plant concentrations are compared to screening concentrations designed to assess potential adverse effects to soils and plants.

Table 5-19 presents the results of the potential soil and plant concentrations (based on maximum annual concentrations) and compares them to the corresponding screening concentration criteria. Only pollutants that will be emitted from the Project and that have a screening concentration are presented. A calculated concentration in excess of either of the screening concentration criteria is an indication that a more detailed evaluation may be required. However, as shown in Table 5-18, calculated concentrations as a result of operation of the Project are all well below the screening criteria.

As an indication of whether emissions from the proposed Project will significantly impact (i.e., cause acute or chronic exposure to each evaluated pollutant) any surrounding vegetation with commercial or recreational value, the modeled emission concentrations are compared against both a range of injury thresholds found in the guidance and appropriate literature, as well as those established by the NAAQS secondary standards. Since the NAAQS secondary standards were set to protect public welfare, including protection against damage to crops and vegetation, comparing modeled emissions to these standards will provide some indication if potential impacts are likely to be significant. Tables 5-19 through 5-22 list the Project impact concentrations of NO_2, CO, SO_2, PM_{10}, and formaldehyde and compare them to the vegetation sensitivity thresholds and NAAQS secondary standards. For averaging periods for which concentrations were not predicted, the concentration for the next shortest averaging period is conservatively used. All pollutant concentrations are well below the vegetation sensitivity thresholds.

Table 5-1*8*: Soils Impact Screening Assessment

Pollutant	Maximum Project Deposited Soil Concentration (ppmw[a])	Soil Screening Criteria (ppmw)	Percent of Soil Screening Criteria	Plant Tissue Concentration (ppmw)	Plant Screening Criteria (ppmw)	Percent of Plant Screening Criteria
Arsenic	***1.36E-05***	3	***0.0005%***	***1.90E-06***	0.25	***0.0008%***
Cadmium	***1.51E-06***	2.5	0.0001%	***1.61E-05***	3	***0.0005%***
Chromium	***6.08E-03***	8.4	***0.0723%***	***1.22E-04***	1	***0.0122%***
Lead	***9.20E-04***	1,000	0.0001%	***4.14E-04***	126	***0.0003%***
Mercury	***3.01E-06***	455	0.0000%	***1.51E-06***	NA	NA
Nickel	***2.78E-03***	500	***0.0006%***	***1.25E-04***	60	***0.0002***%
Selenium	***7.54E-05***	13	***0.0006%***	***7.54E-05***	100	0.0001%

[a] ppmw = parts per million wet

Note: Based on screening procedures described in Chapter 5 of the USEPA guidance document for soils and vegetation, *A Screening Procedure for the Impacts of Air Pollution Sources on Plants, Soils, and Animals*.

Table 5-*19*: Predicted Air Quality Impacts Compared to NO_2 Vegetation Impact Thresholds

Averaging Period	Maximum Project Impacts (µg/m³)	Threshold for Impact to Vegetation (µg/m³)	Applicability
1-hour	***28.26***	66,000[a]	Leaf Injury to plant
2-hour		1,130[b]	Affects to alfalfa
4-hour		3,760[c]	Protects all vegetation
8-hour		3,760[c]	Protects all vegetation
1-month		564[c]	Protects all vegetation
Annual	***0.33***	94[c], 100[d]	Protects all vegetation
		190[e]	Metabolic and growth impact to plants

[a] "Diagnosing Injury Caused by Air Pollution", EPA-68-02-1344, Prepared by Applied Science Associates, Inc. under contract to the Air Pollution Training Institute, Research Triangle Park, North Carolina. 1976.

[b] "Synergistic Inhibition of Apparent Photosynthesis Rate of Alfalfa by Combinations of SO_2 and NO_2" Environmental Science and Technology, vol. 8(6): p.574-576, 1975. The limit is based on a concentration in ambient air of 0.6 ppm NO_2 (1,130 µg/m³) which was found to depress the photosynthesis rate of alfalfa during a 2-hour exposure.

[c] *A Screening Procedure for the Impacts of Air Pollution Sources on Plants, Soils, and Animals,* EPA 450/2-81-078, Research Triangle Park, NC. 1980.

[d] Secondary National Ambient Air Quality Standard (µg/m³) which is a limit set to avoid damage to vegetation resulting in economic losses in commercial crops, aesthetic damage to cultivated trees, shrubs, and other ornamentals, and reductions in productivity, species richness, and diversity in natural ecosystems to protect public welfare (Section 109 of the Clean Air Act). These thresholds are the most stringent of those found in the literature survey.

[e] "Air Quality Criteria for Oxides of Nitrogen," EPA/600/8-91/049aF-cF.3v, Office of Health and Environment Assessment, Environmental Criteria and Assessment Office, USEPA, Research Triangle Park, NC. 1993.

Table 5-*20*: Predicted Air Quality Impacts Compared to CO Vegetation Impact Thresholds

Averaging Period	Maximum Project Impacts (µg/m^3)	Threshold for Impact to Vegetation (µg/m^3)	Applicability
1-hour	***197.67***	40,000[a]	Protects all vegetation
8-hour	***24.51***	10,000[a]	Protects all vegetation
Multiple day		10,000[b]	No known effects to vegetation
1-week		115,000[c]	Effects to some vegetation
Multiple week		115,000[d]	No effect on various plant species

[a] Secondary NAAQS (µg/m^3) which is a limit set to avoid damage to vegetation resulting in economic losses in commercial crops, aesthetic damage to cultivated trees, shrubs, and other ornamentals, and reductions in productivity, species richness, and diversity in natural ecosystems to protect public welfare (Section 109 of the Clean Air Act). These thresholds are the most stringent of those found in the literature survey.

[b] "Air Quality Criteria for Carbon Monoxide," EPA/600/8-90/045F (NTIS PB93-167492), Office of Health and Environment Assessment, Environmental Criteria and Assessment Office, USEPA, Research Triangle Park, NC. 1991. Various CO concentrations were examined the lowest of these was 10,000 µg/m^3. Concentrations this low had no effects to various plant species. For many plant species, concentrations as high as 230,000 µg/m^3 caused no effects. The exception was legume seedlings which were found to experience abnormal leaf growth when exposed to CO concentrations of only 27,000 µg/m^3. Also related to this family of plants, CO concentrations in the soil of 113,000 µg/m^3 were found to inhibit nitrogen fixation. It is clear that ambient CO concentrations as low as 10,000 µg/m^3 will not affect vegetation.

[c] "Diagnosing Injury Caused by Air Pollution," EPA-68-02-1344, Prepared by Applied Science Associates, Inc. under contract to the Air Pollution Training Institute, Research Triangle Park, North Carolina. 1976. A CO concentration of 115,000 µg/m^3 was found to affect certain plant species.

[d] "Polymorphic Regions in Plant Genomes Detected by an M13 Probe," Zimmerman, P.A., et al. 1989. Genome 32: 824-828. 115,000 µg/m^3 was the lowest CO concentration included in this study. This concentration was not found to cause a reduction in growth rate to a variety of plant species.

Table 5-*21*: Predicted Air Quality Impacts Compared to SO_2 and PM_{10} Vegetation Impact Thresholds

Averaging Period	Maximum Project Impacts (µg/m³)	Threshold for Impact to Vegetation (µg/m³)	Applicability
SO_2			
1-hour SO_2	***0.34***	131[a]	Suggested worst-case limit
3-hour SO_2	***0.32***	390[b]	Protects SO_2 sensitive species
3-hour SO_2		1,300[c]	Protects all vegetation
24-hour SO_2	***0.18***	63[d]	Insignificant effect to wheat and barley
Annual SO_2	***0.0026***	130[b]	Protects SO_2 sensitive species
Annual SO_2		18 [e]	Protects all vegetation
PM_{10}			
24-hour PM_{10}	***4.18***	150[c]	Protects all vegetation
Annual PM_{10}	***0.02***	50[c]	Protects all vegetation
Annual PM_{10}		579[f]	Damage to sensitive species (fir tree)

a. "Crop and Forest Losses due to Current and Projected Emissions from Coal-Fired Power Plants in the Ohio River Basin," Loucks, O.L., R.W. Miller, et al. 1980. The Institute of Ecology. In this publication, the authors propose 1-hour thresholds from 131 to 262 µg/m³.

b. "Impacts of Coal-fired Power Plants on Fish, Wildlife, and their Habitats," Dvorak, A.J., et al. Argonne National Laboratory. Argonne, Illinois. Fish and Wildlife Service Publication No. FWS/OBS-78/29. March 1978. This document indicates the lowest 3-hour SO_2 concentration expected to cause injury to sensitive plants growing under compromised conditions is approximately 390 µg/m³. Similarly, a threshold of 130 µg/m³ is suggested for chronic exposure.

c. Secondary National Ambient Air Quality Standard (µg/m³) which is a limit set to avoid damage to vegetation resulting in economic losses in commercial crops, aesthetic damage to cultivated trees, shrubs, and other ornamentals, and reductions in productivity, species richness, and diversity in natural ecosystems to protect public welfare (Section 109 of the Clean Air Act). These thresholds are the most stringent of those found in the literature survey.

d. "Concurrent Exposure to SO_2 and/or NO_2 Alters Growth and Yield Responses of Wheat and Barley to Low Concentrations of O_3," (New Phytologist, 118 (4). 1991. pp. 581-592). This paper indicates exposure to 63 µg/m³ of SO_2 during the growing season had insignificant effects to wheat but did affect the weight of barley seeds.

e. *A Screening Procedure for the Impacts of Air Pollution Sources on Plants, Soils, and Animals,* EPA 450/2-81-078, Research Triangle Park, NC. 1980

f. "Responses of Plants to Air Pollution," Lerman, S.L., and E.F. Darley. 1975. "Particulates," pp. 141-158 (Chap. 7). In J.B. Mudd and T.T. Kozlowski (eds.). Academic Press. New York, NY. Results of studies conducted indicated concluded that particulate deposition rates of 365 grams per square meter per year (g/m²/yr) caused damage to fir trees, but rates of 274 g/m²/year and 400 to 600 g/m²/yr did not cause damage to vegetation. 365 g/m²/yr translates to W579 µg/m³, using a worst-case deposition velocity of 2 cm/s.

Table 5-*22*: Predicted Air Quality Impacts Compared to Formaldehyde Vegetation Impact Thresholds

Averaging Period	Maximum Project Impacts (µg/m³)	Threshold for Impact to Vegetation (µg/m³)	Applicability
Repeated 4.5 hour	***0.297*** [a]	18 [b]	Sensitive species affected
5-hour		840 [c]	Signs of injury to sensitive species (alfalfa)
5-hour		367 [d]	Signs of injury to pollen tube length (lily)
Repeated 7-hour		78 [e]	Stimulated shoot growth (beans)

[a] The maximum 1-hour predicted formaldehyde concentration is used as a conservative surrogate for the longer averaging periods.

[b] "Formaldehyde-Contaminated Fog Effects on Plant Growth," Barker J.R. & Shimabuku R.A. (1992). In Proceedings of the 85th Annual Meeting and Exhibition, Air and Waste Management Association, pp. 113. 92150.01. Pittsburgh, PA. The authors examined the effects on vegetation grown in fog with formaldehyde concentrations of 18 and 54 µg/m³. Exposure rates were 4.5 hours per night, 3 nights/week, for 40 days. The growth rate of rapeseed was found to be affected in this study. However, slash pine grown under the same conditions showed a significant increase in needle and stem growth. No effects were observed in wheat or aspen at test concentrations.

[c] "Investigation on Injury to Plants from Air Pollution in the Los Angeles Area," Haagen-Smit AJ, Darley EE, Zaitlin M, Hull H, Noble WM (1952). Plant physiology, 27:18–34. The authors found a 5-hour exposure to 700 ppb caused mild atypical signs of injury in alfalfa, but no injury to spinach, beets, or oats.

[d] "Effects of Exposure to Various Injurious Gases on Germination of Lily Pollen," Masaru N, Syozo F, Saburo K (1976). Environmental Pollution, 11:181–188. The authors fund a significant reduction of the pollen tube length of lily following a 5-hour exposure to ambient formaldehyde concentrations of 367 ppb.

[e] "Formaldehyde exposure affects growth and metabolism of common bean," Mutters RG, Madore M, Bytnerowicz A (1993). Journal of the Air and Waste Management Association, 43:113–116. The authors found that repeated exposure of sensitive plants to ambient formaldehyde concentrations of 78 µg/m³ could cause plant shoots to grow faster than the roots. It is pointed out that this effect would not be a problem except for crops growing in a water starved condition.

Locator Map

Legend

- NO2 1-hour SIA
- PM2.5 24-hour SIA
- Canal Generating Station

Figure 5-6
Extent of SIA for 24-hour $PM_{2.5}$, and 1-hour NO_2

nrg

AECOM

Scale: 0 – 1 – 2 – 4 Miles; 0 – 1.5 – 3 – 6 Kilometers