Recent Air Pollution Control and Permit Experience in the Lime Industry

Control #1029

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Prepared for the Annual Meeting of the Air & Waste Management Association, June 2007.

ABSTRACT

An air quality permit was issued for a new coal-fired lime kiln in Superior, Wisconsin. This project included a new preheater lime kiln and handling and storage operations for limestone, coal, lime and fines. It was subject to the Prevention of Significant Deterioration air quality regulations including an evaluation of Best Available Control Technology (BACT) and air quality impacts. All air pollutants were controlled using BACT or state-of-the-art air pollution control methods based on recent projects in the U.S. lime industry. These methods included the use of a fabric filter baghouse for the capture of dust from the kiln and materials handling operations, and use of low sulfur coal and a preheater type kiln to neutralize sulfur dioxide emissions by 92%. Combustion related air pollutants including nitrogen oxides and carbon monoxide were controlled by the use of a preheater lime kiln which reduced both energy usage and resulting stack discharges by 30% compared to the conventional lime kilns. The project was designed to assure local, near-field air quality impacts were insignificant for all air pollutants. Approval was also obtained from the U.S. Forest Service after demonstrating that far-field impacts on Class I Air Quality Areas within 200 kilometers of the project were insignificant. These areas included the Boundary Waters Canoe Area Wilderness in Minnesota and the Rainbow Lake Wilderness in Wisconsin. The requirements and analyses for this Wisconsin project are presented along with those for recent lime kiln projects in the U.S.

INTRODUCTION

In 2006, an air quality permit was issued for a new coal-fired lime kiln in Superior, Wisconsin.[1] This project included a new preheater lime kiln and associated handling and storage operations for limestone, coal, lime and fines. The kiln had a production capacity of 600 tons per day of lime while burning a maximum of 135 mmbtu/hr of coal. The location of the project on Lake Superior is shown in Figure 1.

Prior to the start of construction, the project required issuance of an air quality permit from the Wisconsin Department of Natural Resources. Due to the proximity of two Class I air quality areas, the Boundary Waters Canoe Area Wilderness in Minnesota and the Rainbow Lake Wilderness in Wisconsin, the project also required approval from the U.S. Forest Service.

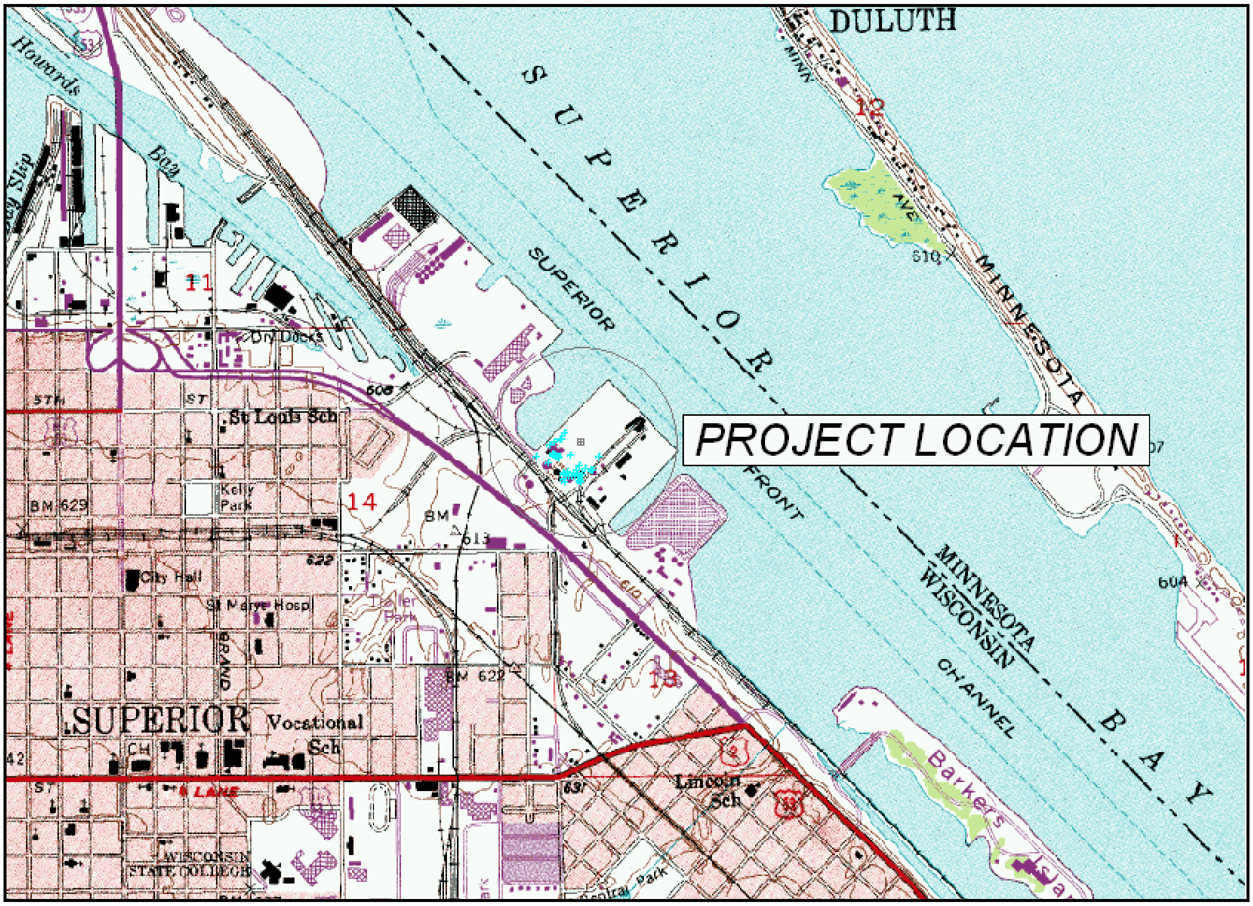

Figure 1 - Project Location in Superior, Wisconsin

Project air pollution emissions exceeded major source thresholds at which it was subject to the Prevention of Significant Deterioration requirements under Chapter NR 405, Wis. Adm. Code, and 40 CFR Part 51.21. The PSD rules required that the permit application include the following analyses:

BACT Analysis	Determination of Best Available Control Technology or state-of-the-art air pollution control methods used in U.S. lime industry.
Near-field Air Quality Impact Analysis	An air quality modeling analysis to estimate impacts on the area immediately surrounding the project site, and verify compliance with the National Ambient Air Quality Standards, PSD increments and Ambient Air Standards for hazardous air pollutants.
Far-field Air Quality Impact Analysis	An air quality modeling analysis to estimate impacts on more distant Class I air quality areas verify compliance with the PSD increments and protection of Air Quality Related Values.

Additional Impact Analysis	An analysis of impacts on regional growth, soils and vegetation, and plume visibility.

The project was also subject to the recently promulgated National Emission Standards for Hazardous Air Pollutants for Lime Manufacturing Plants under 40 CFR Part 63, Subpart AAAAA. These regulations were adopted by USEPA on January 5, 2004.

The requirements and analyses for this project are presented along with those for recent lime kiln projects in the U.S. This is based on the permit application submitted on behalf of the lime manufacturing plant and the permit technical support document prepared by the state agency, the Wisconsin Department of Natural Resources.[2,3]

PROJECT DESCRIPTION

Lime is the high-temperature product of the calcination or burning of limestone. Lime is used in many industries including metallurgy, steel products manufacture, pulp and paper, chemicals manufacture, water treatment, sewage treatment, air pollution control, ceramic products, building materials, protective coatings, food and food by-products.

It is produced in various types of kilns by the following reaction:

$$CaCO_3 \text{ (limestone)} + \text{heat} = CO_2 + CaO \text{ (lime)}$$

A modern lime kiln is a long, cylindrical, inclined, refractory-lined furnace, through which the limestone and hot combustion gases from the fuels pass counter-currently. The project facility had four conventional horizontal rotary lime kilns. The proposed fifth kiln was a preheater design which uses the hot exhaust gases to preheat the incoming limestone. This reduces the fuel usage and fuel generated emissions by approximately 30% compared to a conventional rotary kiln. Proposed fuels were natural gas to be used for start-up, and coal and petroleum coke as primary fuels.

The new kiln would be equipped with a fabric filter baghouse control system to capture dust or PM emissions. SO_2 emissions would be controlled by limiting the sulfur content of the fuels, use of a preheater type kiln, and the neutralizing ability of the kiln and baghouse. Combustion-related air pollutants such as CO and NO_x would be controlled by the use of the preheater type kiln.

Ancillary operations include the storage and handling of limestone, coal and lime. Non-fugitive, enclosed sources include handling, screening, and bin storage. These dust generation points were to be controlled using fabric filter baghouses. Fugitive emissions would be generated by operations including limestone and coal storage piles, travel on unpaved roads and raw material handling equipment. Fugitive emissions would continue to be controlled as specified in the Dust Control Plan developed for the facility's Title V operation permit.

Project operations and emission control methods are summarized in Table 1.

Table 1 - Project Operations and Air Pollution Control Methods		
Operation	*Air Pollutant*	*Control Method*
P50 - Kiln 5	SO_2	92% removal by kiln and baghouse, 2.0% Sulfur Fuel,
	NO_x	30% reduction by use of preheater-type kiln
	CO	30% reduction by use of preheater-type kiln
	Pb	Pulse Jet Baghouse; 3.5:1 Air to Cloth Ratio
	TSP/PM_{10}	Pulse Jet Baghouse; 5.0:1 Air to Cloth Ratio
P51 - Lime Crushing & Handling	TSP/PM_{10}	Pulse Jet Baghouse; 5.0:1 Air to Cloth Ratio
P52 - Lime Storage & Handling	TSP/PM_{10}	Pulse Jet Baghouse; 5.0:1 Air to Cloth Ratio
P53 - Small Silo Truck Loading	TSP/PM_{10}	Pulse Jet Baghouse; 5.0:1 Air to Cloth Ratio
P54 - Large Silo Truck Loading	TSP/PM_{10}	Pulse Jet Baghouse; 5.0:1 Air to Cloth Ratio
P55 - Coal Storage & Handling	TSP/PM_{10}	Pulse Jet Baghouse; 5.0:1 Air to Cloth Ratio
P56 - Fines Storage	TSP/PM_{10}	Pulse Jet Baghouse; 5.0:1 Air to Cloth Ratio

PROJECT EMISSIONS - CRITERIA AIR POLLUTANTS

Project operations and approved criteria air pollutant emissions are summarized in Table 2. The existing lime manufacturing plant included four coal-fired conventional rotary lime kilns and was considered a major source with respect to Prevention of Significant Deterioration (PSD) regulations. The project emissions of TSP/PM_{10}, SO_2, NO_x and CO exceeded the significant emission increase thresholds at which the project was subject to the additional requirements of the PSD regulations.

PROJECT EMISSIONS - HAZARDOUS AIR POLLUTANTS

Compliance with State Requirements

Hazardous air pollutant (HAP) emissions included inorganic HAP contained in the raw materials and fuels, and organic HAP generated by combustion. These emissions were regulated by both state and federal regulations.

In Wisconsin, HAP are regulated under Chapter NR 445, Wis. Adm. Code. Total facility emissions from both existing and the proposed operations were compared with the applicable thresholds under Table A of NR 445. HAP with emissions below the NR 445 thresholds require no further analysis. HAP which exceeded their respective thresholds include the following: hydrogen chloride (HCl), calcium oxide (CaO), calcium hydroxide (CaOH), sulfuric acid (H_2SO_4) and TCDD Equivalents. The TCDD Equivalents are derived from the total emissions of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans.

Table 2 - Project Potential Emissions					
Operation	*Air Pollutant*	*Control Method*	*Emissions (lbs per unit)*	*Emissions (lbs per hour)*	*Emissions (tons per year)*
P50 - Kiln 5	SO_2	92% Removal	0.62 lbs/tsf	44.8	196.3
	NO_x	Preheater Kiln	1.83 lbs/tsf	98.8	432.8
	CO	Preheater Kiln	1.56 lbs/tsf	84.2	369.0
	Pb	Baghouse	646 ppm in PM	0.0035	0.02
	TSP/PM_{10}	Baghouse	0.1 lbs/tsf	5.40	23.65
P51 - Lime Crushing & Handling	TSP/PM_{10}	Baghouse	0.005 gr/dscf	0.58	2.54
P52 - Lime Storage & Handling	TSP/PM_{10}	Baghouse	0.005 gr/dscf	0.56	2.45
P53 - Small Silo Truck Loading	TSP/PM_{10}	Baghouse	0.005 gr/dscf	0.06	0.26
P54 - Large Silo Truck Loading	TSP/PM_{10}	Baghouse	0.005 gr/dscf	0.06	0.26
P55 - Coal Storage & Handling	TSP/PM_{10}	Baghouse	0.005 gr/dscf	0.04	0.18
P56 - Fines Storage	TSP/PM_{10}	Baghouse	0.005 gr/dscf	0.17	0.74
Project Total	TSP/PM_{10}			6.87	30.09

HCl, CaO, CaOH and H_2SO_4 have an Ambient Air Standards or AAS under Table A of NR 445. A facility-wide air quality modeling analysis was conducted for facility emissions of these HAP. TCDD Equivalents are a class of carcinogenic contaminants which have a control technology requirement under Table A of NR 445. If the lime kilns only burned coal, this requirement would not apply since coal emissions are exempt from NR 445 due to the use of a virgin fossil fuel. Facility kilns also burn a mixture of coal and petroleum coke. The state agency did not consider coke to be a virgin fossil fuel so the organic HAP emissions such as TCDD Equivalents are not exempt from NR 445 requirements.

In lieu of conducting a control technology determination for TCDD Equivalent emissions from the facility, a modeling analysis was conducted to determine if the maximum risk is less than 1×10^{-6}. This is an alternative compliance method for HAP subject to BACT or LAER requirements under the state regulations.

From the facility modeling analysis, the maximum predicted annual average TCDD Equivalents concentration was 0.013 $\mu g/m^3$. Based on a unit risk value of 33 ($\mu g/m^3)^{-1}$, the maximum predicted risk was 0.4 x 10^{-6}. This complied with the NR 445 compliance threshold of 1 x 10^{-6} so no further analysis or control requirement was necessary.

Compliance with Federal MACT Requirements

The EPA has identified the lime manufacturing industry as a major source of hazardous air pollutant (HAP) emissions notably hydrogen chloride (HCl). On January 5, 2004, USEPA adopted the National Emission Standards for Hazardous Air Pollutants for Lime Manufacturing Plants under 40 CFR Part 63, Subpart AAAAA, simply referred to the Maximum Available Control Technology or MACT requirement.

The existing facility has HCl emission from the combustion of coal by the lime kilns which are greater than 10 tons per year. Therefore, the facility was considered a major source and subject to the MACT requirements. Existing sources must comply with the MACT requirements by January 5, 2007. New sources, including the proposed preheater lime kiln, must comply with the MACT requirements upon start-up.

MACT required that the new preheater lime kiln be equipped with a baghouse control system to meet the new source limitation for PM of 0.1 lbs/tsf (ton stone feed). This limitation is based on front-half, filterable emissions.

BACT ANALYSIS

BACT Procedures

Any major stationary source or major modification subject to PSD must conduct an analysis to ensure the application of best available control technology (BACT). For this project, air pollutants which required a BACT analysis included TSP/PM_{10}, SO_2, NO_x and CO.

The requirement to conduct a BACT analysis and determination is set forth in section 165(a)(4) of the Clean Air Act (Act), in federal regulations at 40 CFR 52.21(j), in regulations setting forth the requirements for State implementation plan approval of a State PSD program at 40 CFR 51.166(j), and in the SIP's of the various States at 40 CFR Part 52, Subpart A - Subpart FFF. In Wisconsin, the BACT requirement is required under s. NR 405.08, Wis. Adm. Code. An explanation of the BACT analysis procedures is provided in Chapter B of the October 1990 USEPA document, *New Source Review Workshop Manual*: [4]

For this project, the USEPA "top-down" method originally established 1987 was required. In brief, the top-down process provides that all available control technologies be ranked in descending order of control effectiveness. The PSD applicant first examines the most stringent--or "top"--alternative. That alternative is established as BACT unless the applicant demonstrates, and the permitting authority in its informed judgment agrees, that technical considerations, or energy, environmental, or economic impacts justify a conclusion that the most stringent technology is not "achievable" in that case. If the most stringent technology is eliminated in this fashion, then the next most stringent alternative is considered, and so on.

Table B-1 of the New Source Review Workshop Manual identifies the key steps necessary for a "Top-Down" BACT analysis. These are as follows:

1. Identify All Control Technologies
2. Eliminate Technically Infeasible Options
3. Rank Remaining Control Technologies by Control Effectiveness
4. Evaluate Most Effective Controls and Document Results
5. Select BACT

Prior BACT Determinations

To assure this project will control its emissions as effectively as similar projects in the U.S., recent BACT determinations for lime manufacturing operations (Process Type 90.019) were obtained from the BACT/LAER Clearinghouse at the USEPA web site.[5] In addition, contact was made with industrial representatives, such as the National Lime Association, to identify additional projects not yet entered into the BACT/LAER Clearinghouse.

Recent kiln projects in the U.S. included the following:

Arkansas Lime Co., Batesville, AK
687 TPD Preheater Lime Kiln #3
Permit issued August 30, 2005

Western Lime & Cement, Gulliver, MI
900 TPD Preheater Lime Kiln #1
Permit issued August 9, 2005

Chemical Lime Co., Calera, AL
1,500 TPD Preheater Lime Kiln #2
Permit issued March 23, 2005

Graymont (PA), Inc., Bellefonte, PA
1,200 TPD Preheater Lime Kiln #6
Permit issued July 9, 2004

Carmeuse Lime Co., Maple Grove, OH
Two 650 TPD Conventional Lime Kilns
Permit issued October 14, 2003

The USEPA Clearinghouse provided the control methods and emission limitations for each of these projects. The procedures used to evaluate and approve these projects were obtained from the technical support documents prepared by the state agency.[6,7,8,9]

BACT Analysis for TSP/PM_{10}

The following control methods for TSP/PM_{10} were considered:

- Cartridge Collectors
- Fabric Filters
- Electrostatic Precipitators
- Venturi Scrubbers
- Gravel Bed Filters
- Cyclones

The only option considered technically infeasible was cartridge collectors. This was due to the high flow rate and dust loading associated with the lime kiln. Of the remaining operations, a fabric filter baghouse was concluded to be the most effective control method and was determined to represent BACT, similar to prior lime kiln projects.

While the control method for the lime kiln was easily determined, establishing a suitable emission limitation required additional debate. One issue was inclusion of back-half, condensible PM. Historically, PM limitations adopted for lime kilns have only addressed front-half emissions as measured with USEPA Method 5. These limitations include the New Source Performance Standard for lime manufacturing of 0.60 lbs per ton of stone feed, and the recently adopted MACT requirement of 0.10 lbs per ton stone feed. The BACT limitation for the proposed kiln included back-half, condensible emissions. PM limitations for recently approved lime kiln projects are summarized in Table 3.

The inclusion of back-half PM created uncertainty about future compliance with the BACT limitation. Reasons for uncertainty were the fact that the baghouse would not control these emissions, there was lack of lime kiln test results for predicting the emissions, and the USEPA test procedures for condensible PM were under review. The Emissions Measurement Branch of USEPA is evaluating changes to Method 202 for more accurate measurement of condensible PM. It has been found that the water-filled impingers used for Method 202 encourages SO_2, NO_2, and soluble organic compounds in the flue gas to form artifacts such as sulfates and nitrates which are measured as condensible PM, though these are not actually emitted by the tested operation.[10] Current discussion on proposed changes to Method 202 is available on the Technology Transfer Network (TTN) of the USEPA web page.[11]

A second issue for BACT determination was developing a limitation using units of "gr/dscf" in addition to a limitation in units of "lbs/ton of stone feed". Not all earlier BACT determinations established concentration limitations. Those which did set limits of 0.01 gr/dscf or higher. This format allowed emissions of 0.014 gr/dscf to be considered in compliance. Establishing a limitation to the thousands decimal place did not allow emissions up to 0.014 gr/dscf and required an accurate estimate of the expected exhaust flow rate from the lime kiln. Based on the anticipated exhaust flow rate of 49,212 dscf/tsf, the proposed limitation of 0.012 gr/dscf would require emissions of 0.08 lbs/tsf, which would be more stringent that the MACT limitation of 0.10 lbs/tsf.

Compliance with the PM limitations would be demonstrated by a stack test during initial operation, monitoring and recording of the baghouse pressure drop every 8-hours, and installation, certification, and operation of a continuous emissions monitor for visible emissions.

Similar control methods evaluated for the lime kiln were evaluated as BACT for the ancillary operations. The baghouse was concluded to represent the most effective methods with an emission limitation of 0.005 gr/dscf. The control method and emission limitation was equivalent or more stringent than prior BACT determinations.

Table 3 - BACT Determinations for TSP/PM_{10}

Facility	*Lime Kiln*		*Ancillary Operations*	
	Control Method	Limitation	Control Method	Limitation
Project	Baghouse	0.1 lbs/tsf 0.012 gr/dscf	Baghouse	0.005 gr/dscf
Arkansas Lime Co. Batesville, AK	Baghouse	0.1 lb/tsf	Baghouse	0.010 - 0.015 gr/dscf
Western Lime & Cement Gulliver, MI	Baghouse	0.1 lbs/tsf	Baghouse	0.003 - 0.01 gr/dscf
Chemical Lime Co. Calera, AL	Baghouse	0.1 lb/tsf 0.01 gr/dscf	Baghouse	0.005 - 0.01 gr/dscf
Graymont (PA), Inc. Bellefonte, PA	Baghouse	0.10 lb/tsf 0.01 gr/dscf	Baghouse	0.01 gr/dscf
Carmeuse Lime Co. Maple Grove, OH	Baghouse	0.021 gr/dscf 0.26 lb/tsf	Baghouse	0.01 gr/dscf
Lime Mfg MACT	Baghouse	0.10 lbs/tsf	Baghouse or Scrubber	0.02 gr/dscf

BACT Analysis for SO_2

SO_2 was to be generated by the combustion of the coal and coke mixture in the lime kiln and the oxidation of fuel sulfur into SO_2. The following control methods for SO_2 were considered:

1. Wet Scrubbers
2. Preheater Kiln Design with Baghouse
3. Low-Sulfur Fuel
4. Emerging Technologies

All of these control options were considered technically feasible for controlling lime kiln SO_2 emissions. Consideration as BACT depended on the cost effectiveness for SO_2 removal.

Recent lime kiln BACT determinations had approved coal / solid fuel sulfur contents ranging from 2 to 5.5%. The 2.0% sulfur fuel proposed for the project was concluded to represent BACT.

The preheater kiln followed by a baghouse was expected to reduce uncontrolled SO_2 by 92% from 421 to 34 lbs/hr. With this initial reduction in emissions, there were much less emissions to control and the cost effectiveness of any additional control method was significantly higher.

A wet scrubber located after a baghouse had been required for the a conventional rotary kiln at Graymont Inc. in Pennsylvania. However, this kiln was larger (1,050 tpd versus 650 tpd), burned higher sulfur fuel (i.e. 3% versus 2%), and used a conventional kiln type with lower SO_2 retention than the proposed preheater kiln type (i.e. 40% verus 90%).

Various wet scrubber configurations were evaluated including use of municipal water supply, water withdrawl direct from Lake Superior, wastewater discharge to the municipal sanitary sewer, and on-site wastewater treatment with discharge to Lake Superior. The least expensive wet scrubber option had a cost effectiveness of $10,686 per ton of SO_2 removed and was found to not represent BACT.

Several emerging control technologies for SO_2 were also evaluated. These had not been used on existing lime kiln operations. These included the following:

A semi-wet scrubber manufactured by *Solios* was evaluated. This control system removed 90% of the SO_2 by injecting hydrated lime and water in a venturi reactor. The reaction product (i.e. $CaSO_4$) is collected downstream in the baghouse with the PM emissions. The vendor considered this application to be technically feasible. However, the estimated cost effectiveness was $11,880 per ton of SO_2 removed so this control system was considered economically infeasible.

Two systems were evaluated using a combination wet scrubber and oxidation / reduction chemistry to control both SO_2 and NO_x. Vendors of these systems were the *Comply 2000 System* manufactured by ECO Power Solutions and the *TriNO$_x$ Multi-chem System* manufactured by the Tri-Mer Corporation. Similar to the semi-wet scrubber, these sysetms were not considered cost effective with the cost of SO_2 control exceeding $16,000 per ton of SO_2 removed.

The lime kiln BACT determination for SO_2 required the following:

- Use of a preheater lime kiln that achieves 92% collection of fuel sulfur.
- Maximum fuel sulfur content of 2.0% while burning coal, or a coal/petroleum coke blend.
- An emission limitation of 0.62 lbs per ton of stone feed, 24-hour rolling average and not more than 33.7 lbs/hr (3-hour average).

Compliance with the SO_2 emission limitation would be demonstrated by recording limestone consumption and the installation, calibration and operation of a continuous emissions monitor, and fuel sampling (for quarterly sulfur content average and sulfur collection).

BACT Analysis for NO_x

NOx was to be generated by the combustion of the coal and coke mixture in the lime kiln and the oxidation of combustion air nitrogen into NO_x. The following control methods for NOx were considered:

- Selective Catalytic Reduction (SCR)
- Selective Non-Catalytic Reduction (SNCR)
- Wet Scrubbing Oxidation / Reduction system
- Combustion Modifications
- Low-NO_x Burners
- Efficient Combustion
- Preheater Kiln Design

There were no current applications of the add-on control methods on a lime kiln. These included SCR, SNCR, wet scrubber oxidation/reduction systems, combustion modifications or low-NOx burners. Based on a review of the operating conditions within a lime kiln, the use of SNCR, combustion modifications, and low-NOx burners were considered technically infeasible.

No SCR vendor would provide a cost estimate for the lime kiln project. They did not consider the project cost effective. This was borne out by order-of-magnitude estimates. Based on a removal efficiency of 80%, the estimated cost effectiveness was $10,441 per ton of NO_x removed, so that the use of SCR was considered economically infeasible.

Wet scrubbing based oxidation / reduction systems considered were the aforementioned *Comply 2000 System* and the *Tri-NO_x System*. The cost effectiveness of the *Comply 2000 System* was $5,681 per ton of NO_x controlled and for the *Tri-NO_x System* was $6,755 per ton. These were control systems designed to control both SO_2 and NO_x. Their cost effectiveness for SO_2 emissions control was beyond the range considered reasonable for BACT. The estimated cost effectiveness for NO_x emissions was within the range that could be considered economically feasible. However, based on the lack of experience with these systems on lime kilns or comparable operations, these were not considered for BACT.

The remaining control methods were: 1) use of a preheater type lime kiln which reduced fuel usage and the resulting NO_x emissions by 30% compared to a conventional kiln, and 2) monitoring of kiln combustion to efficiently burn the fuel. Both these methods were considered feasible and cost effective.

The lime kiln BACT determination for NO_x required the following:

- Maintain efficient combustion conditions
- Install, calibrate and operate an oxygen monitor for combustion gases.
- Use of a preheater lime kiln.
- Emissions of 1.83 lbs per ton of stone feed, 24 hour rolling average.

Compliance with the NO_x emission limitation would be demonstrated by recording limestone consumption and the installation, calibration and operation of a continuous emissions monitor.

BACT Analysis for CO

CO was to be generated by the combustion of the coal and coke mixture in the lime kiln and the created of products of incomplete combustion such as CO. The following control methods for CO were considered:

- Thermal Oxidation
- Catalytic Incineration
- Efficient Combustion
- Preheater Kiln Design

There were no current applications of the add-on control methods on a lime kiln. These include thermal oxidation and catalytic incineration. A regenerative thermal incinerator was evaluated using CO emissions of 1.56 lbs/tsf and 100,700 acfm. This resulted in a cost effectiveness of approximately $5,000 per ton of CO controlled. This was within the range of costs considered economically feasible. However, the use of an add-on incineration was not considered as BACT for the following reasons: lack of experience on a comparable installation; large fuel consumption; and increased Nox emissions.

The remaining control methods were: 1) use of a preheater type lime kiln which reduced fuel usage and the resulting CO emissions by 30% compared to a conventional kiln, and 2) monitoring of kiln combustion to efficiently burn the fuel. Both these methods were considered feasible and cost effective.

The lime kiln BACT determination for CO required the following:

- Maintain efficient combustion conditions.
- Install, calibrate and operate an oxygen monitor for combustion gases.
- Preheater kiln design.
- An emission limitation of 1.56 lbs per ton of stone feed, 24-hour rolling average.

Compliance with the CO emission limitation would be demonstrated by recording limestone consumption and the installation, calibration and operation of a continuous emissions monitor.

AIR QUALITY IMPACT ANALYSIS

Required Analyses

As required by the PSD air quality regulations, three air quality impact analysis were necessary:

1. Near-field analysis to evaluated compliance with the National Ambient Air Quality Standards (NAAQS), PSD increments and state Ambient Air Standards for hazardous air pollutants.

2. Far-field analysis to evaluate impacts on Class I air quality areas located within 200 kilometers of the project site in Superior, Wisconsin.

3. Additional impacts analysis to address impacts on growth, visibility, and soils and vegetation.

Near-field Air Quality Impact Analysis

Near-field Modeling Procedures

Key features of the near-field air quality impact modeling analysis were as follows:

1. Evaluation of PM, SO_2, NO_x and CO emissions from the proposed lime kiln, proposed ancillary operations, and existing emission sources at the lime manufacturing plant. A total of 37 stacks were included in the modeling analysis.

2. Building downwash information was derived from the Building Profile Input Program (BPIP) using measurements taken from facility plot plans.

3. The Industrial Source Complex Short Term 3 (ISCST3) model was also used in the analysis. The model used rural dispersion coefficients with the regulatory default options. These allow for calm wind correction, buoyancy induced dispersion, and building downwash. The permit application was submitted prior to January 1, 2006 use the recently approved AERMOD dispersion modeling system was not required.

4. Five years (1982-1986) of preprocessed meteorological data was used in this analysis. The surface data was collected in Duluth, and the upper air meteorological data originated in St. Cloud, MN.

5. A rectangular grid centered on the facility and consisting of approximately 4,090 points was used in the analysis. The receptors were placed every 25 meters around the property fence line of the facility and in a 100 meter spaced grid extending to 2,000 meters.

6. Surrounding the facility receptor grid were points spaced every 100 meters in a polar grid extending to 10 kilometers.

7. Terrain is a factor in the immediate area, so receptor elevations were considered in this analysis.

Figure 2 shows the receptor grid extending out to 10 kilometers

Figure 3 shows the receptor grid near the facility.

Figure 4 shows the stack locations at the facility.

Near-field Modeling Results

Based on the near-field modeling analysis, the project was shown to compliance with the following air quality standards:

- NAAQS for TSP, PM_{10}, SO_2, NO_x and CO
- PSD Increments for PM_{10}, SO_2 and NO_x
- AAS for CaO, CaOH, HCl and H_2SO_4.

NAAQS compliance results are presented in Table 4. PSD increment consumption results are presented in Table 5. AAS compliance results are presented in Table 6. The air quality impacts of the project itself were below the significant impact levels or SIL for Class II areas. For this reason, only the facility emission sources were included in the NAAQS and increment analyses.

If project impacts were above the SIL, a regional inventory of emission sources would have been required. Maintaining project impacts below the SIL simplified the near-field modeling analysis and time required to prepare and review the permit application.

Table 4 - NAAQS Compliance Results					
Air Pollutant	*Averaging Period (hours)*	*Predicted Concentration (µg/m³)*	*Background Concentration (µg/m³)*	*Total Concentration (µg/m³)*	*NAAQS (µg/m³)*
TSP	24	60.5	67.0	127.5	150
PM_{10}	24	60.5	27.4	87.9	150
	Annual	3.1	9.2	12.3	50
SO_2	3	436.3	128.3	564.6	50
	24	233.9	33.5	267.4	50
	Annual	26.1	7.9	34.0	50
NO_x	Annual	6.3	4.7	11.0	50
CO	1	127.0	3188.0	3315.0	50
	8	57.1	890.4	947.5	50

Table 5 - Increment Consumption Results			
Air Pollutant	*Averaging Period (hours)*	*Predicted Concentration (µg/m³)*	*Class II PSD Increment (µg/m³)*
PM_{10}	24	21.9	30
	Annual	3.1	17
SO_2	3	93.1	512
	24	49.4	91
	Annual	2.3	20
NO_x	Annual	1.1	25

Table 6 - AAS Compliance Analysis Results				
HAP	*Averaging Period (hours)*	*Maximum Concentration (µg/m3)*	*AAS (µg/m3)*	*Complies with AAS?*
HCl	1	60	746	YES
	Annual	2	20	YES
CaO	24	44	48	YES
CaOH	24	44	120	YES
H_2SO_4	24	2.8	24	YES

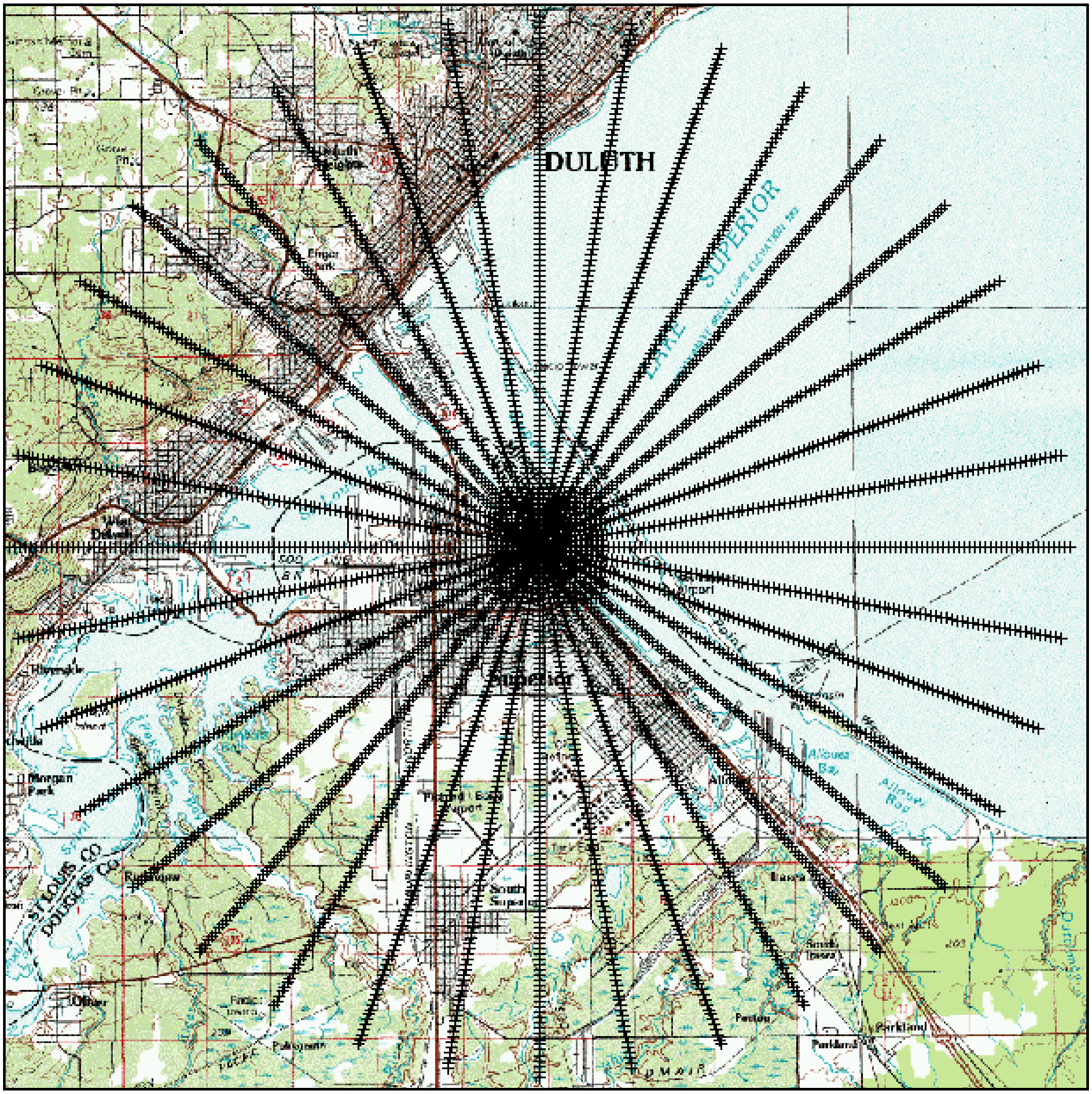

Figure 2 - Project 10-km Modeling Receptor Grid

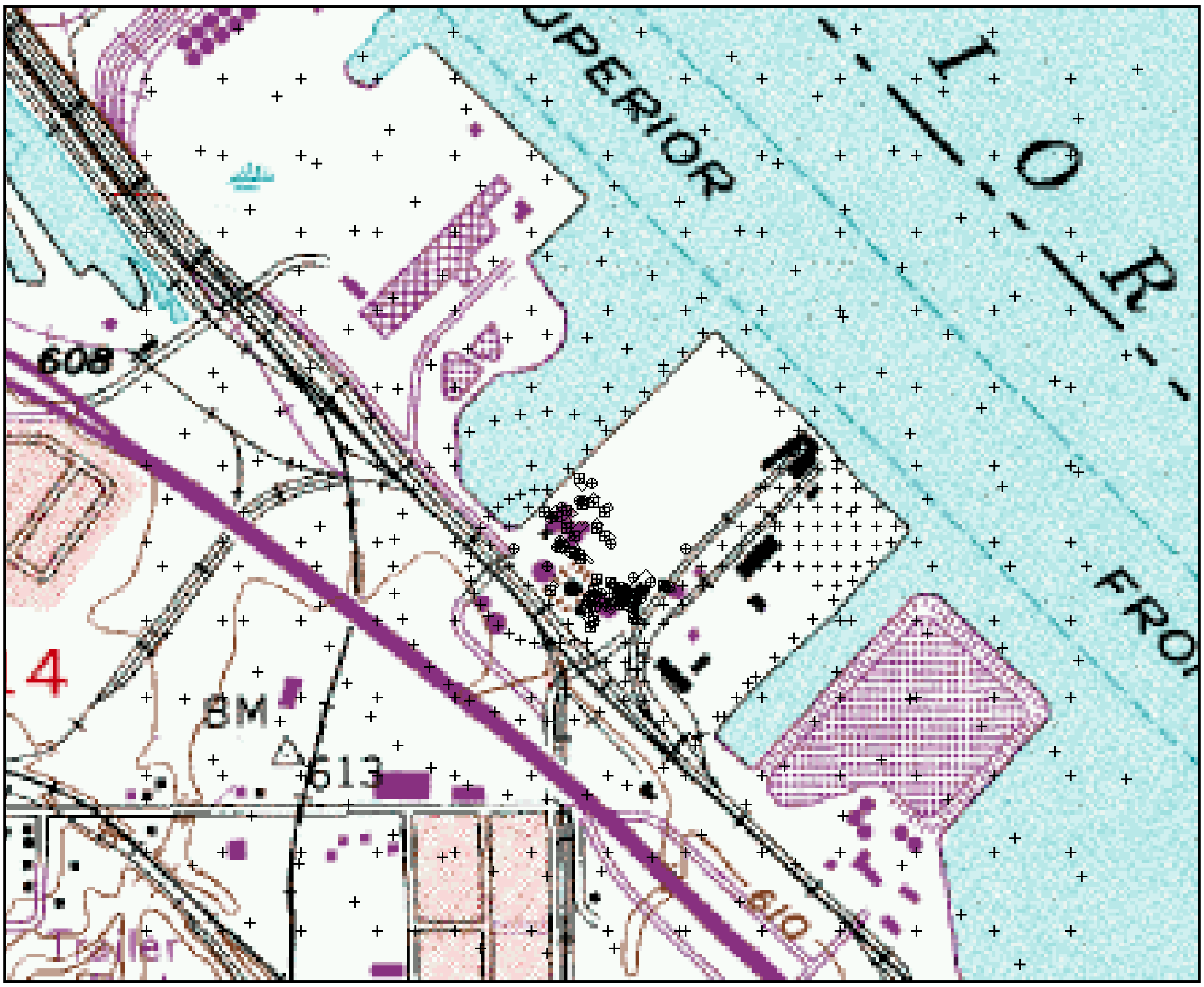

Figure 3 - Facility Modeling Receptor Grid

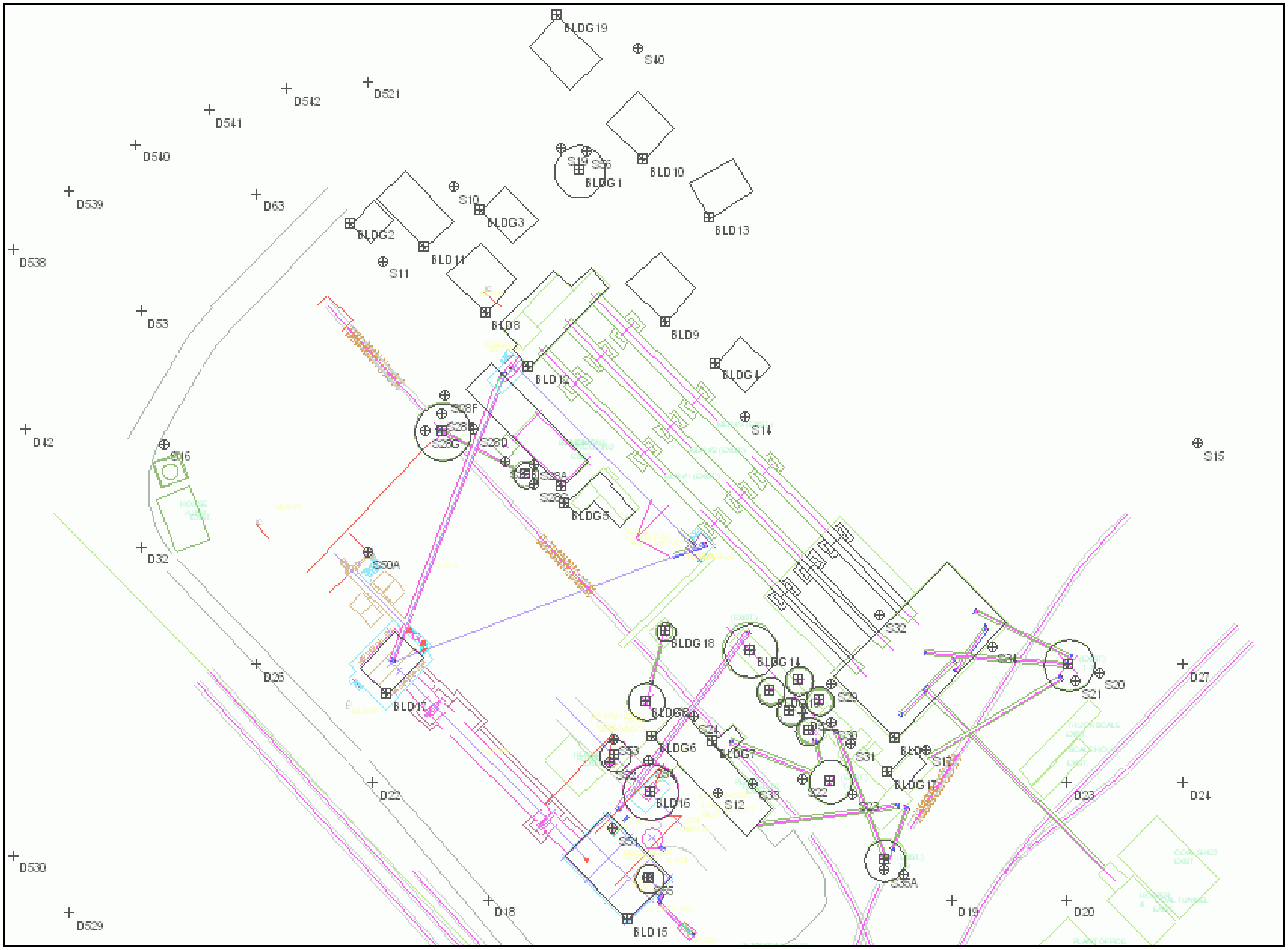

Figure 4 - Stack and Building Locations

Far-field Air Quality Impact Analysis

Far-field Modeling Procedures

Under the PSD regulations, federal land managers (FLM) for nearby Class I areas must review the project to evaluate its impacts on the PSD increments and Air Quality Related Values or AQRV. Evaluation of AQRV typically require consideration of impacts on acidic deposition and regional haze. In the past, Class I areas within 100 km were considered for this analysis. More recently, 200 km has become the distance when the federal land managers should be contacted to determine if an analysis may be necessary. Class I areas within 200 km of the project site in Superior, Wisconsin included the following:

- Rainbow Lake NWA (~68 km)
- Boundary Waters Canoe Area (~128 km)
- Voyageurs National Park (~179 km)

The next two closest Class I areas, Isle Royale National Park and the Seney National Wildlife Refuge, were located over 200 km from the project site and no evaluation is typically required.

Figure 5 shows the location of Class I areas relative to the project.

The FLM for these Class I areas are within the National Park Service and the U.S. Forest Service. Both agencies were contacted to clarify the procedures for evaluating air quality impacts. Based on project emissions and distances no further review of the project was required by the National Park Service for Voyageurs or Isle Royale National Parks. The U.S. Forest Service required that impacts on PSD increments and AQRV be conducted for the closest Class I areas, Rainbow Lake National Wilderness Area and Boundary Waters Canoe Area.

Air quality impacts on the Class I areas were predicted using the CALPUFF screening analysis, also known as a CALPUFF-Lite.[12] This analysis typically provides conservative estimates of impacts on nearby Class I area compared to a more extensive refined CALPUFF analysis. If impacts are predicted to be significant, then the more time consuming and accurate refined CALPUFF analysis would be conducted. The refined analysis uses 3-years of meterological data for the region derived from the CALMET program, while the screening analysis uses the same meteorological data which is used by the near-field modeling with ISC3. This was five years of hourly surface and twice-daily mixing height data from Duluth and St. Cloud, respectively for the years 1982-1986. The meteorological record included additional non-ISC3 parameters that are required by the CALPUFF model. These additional parameters include surface roughness, Monin-Obukov length, solar radiation, relative humidity and precipitation.[13]

Figure 5 - Location of Class I Areas

While the refined analysis uses discrete receptors, the screening analysis predicts impacts using a polar receptor grid, with rings of receptors with radii equal to the respective minimum distance to each class I area. There were 360 receptors per ring, spaced at 1-degree intervals. Three rings were used for each Class I area to represent the minimum, maximum and average elevations of a respective Class I area. The predicted impacts for a given Class I area are based on the highest impacts anywhere on the receptor ring for that Class I area, regardless if the direction is towards the area or away. Project emissions were be modeled each year to evaluate the potential impacts on pollutant concentrations, annual total nitrogen and sulfur deposition levels, and on visibility impairment in the form of regional haze. The visibility analysis was not performed for the Rainbow Lake Wilderness Area since visibility is not an AQRV for this area.

Far-Field Modeling Results

SIL and Increment - Project impacts near the facility were compared with the Class II area significant impact levels and PSD increments. For the more distance Class I areas, there are separate and more stringent significant impact levels and PSD increments. A comparison of predicted impacts with the SIL is presented in Table 7. Project impacts were below all Class I SIL. SO_2 was just under its 24-hour average SIL. Had a SIL been exceeded, then a refined CALPUFF would have been necessary and potential a cumulative increment consumption analysis incorporating other SO_2 sources in the region.

Table 7 - Predicted Air Pollutant Concentrations at Class I Areas (μg/m^3)

Air Pollutant	*Period*	Maximum	SIL
Rainbow Lake National Wilderness Area			
SO_2	3 Hour	0.683	1.0
	24 Hour	0.198	0.2
	Annual	0.010	0.1
PM_{10}	24 Hour	0.041	0.3
	Annual	0.002	0.2
NO_x	Annual	0.022	0.1
Boundary Waters Canoe Wilderness Area			
SO_2	3 Hour	0.345	1.0
	24 Hour	0.083	0.2
	Annual	0.004	0.1
PM_{10}	24 Hour	0.018	0.3
	Annual	0.001	0.2
NO_x	Annual	0.007	0.1

Regional Visibility - To assess impacts on regional visibility, the percent change in light extinction was calculated at each of the areas due to project emissions only. This analysis included the emissions of PM, SO_2 and NO_x. The current significant impact level used by the NPS and USFS is a 0.5 change in deciview haze index (▲dv) over background extinction levels. Results are presented in Table 8. Project impacts were slightly below the significant impact level for visibility.

Table 8 - Predicted Regional Haze Impacts at Class I Areas (▲dv)							
AQRV	*Period*	*1982*	*1983*	*1984*	*1985*	*1986*	SIL
Boundary Waters Canoe Wilderness Area							
▲dv	24-hour	0.43	0.41	0.39	0.43	0.49	0.5

Sulfur and Nitrogen Deposition - Total annual nitrogen and sulfur depositions due to project emissions were evaluated. For the eastern U.S., the current significant impact level or Deposition Analysis Threshold (DAT) used by the NPS and USFS for either total nitrogen and sulfur is 0.01 kilogram per hectare per year (kg/ha/yr).[14] A comparison of project impacts and the DAT is provided in Table 9. The highest predicted impact was 53% of the DAT for nitrogen deposition.

Table 9 - Predicted Sulfur and Nitrogen Deposition at Class I Areas (kg/ha/yr)							
AQRV	*Period*	*1982*	*1983*	*1984*	*1985*	*1986*	DAT
Rainbow Lake Wilderness (RLW)							
Sulfur	Annual	0.0039	0.0039	0.0040	0.0041	**0.0047**	0.01
Nitrogen	Annual	0.0049	0.0050	0.0047	0.0050	**0.0053**	0.01
Boundary Waters Canoe Wilderness Area (BWCWA)							
Sulfur	Annual	0.0016	0.0016	0.0016	**0.0018**	0.0017	0.01
Nitrogen	Annual	0.0019	0.0020	0.0018	**0.0022**	0.0020	0.01

The USFS also required that predicted sulfur and nitrogen deposition rates be added to background deposition, and the compared with the USFS green and red line values.[15,16]

The green and red line value comparison for the Rainblow Lake Wilderness is presented in Table 10. Background deposition rates are based on five years of measurements from the monitoring site at Perkinstown, Wisconsin. Project emissions were predicted to increase background deposition of sulfur and sulfur + 20% nitrogen by 0.1% or less. After this project, total sulfur deposition, based on the five-year average, will slightly exceed the green line values but be less than the red line values. Recent years (i.e. 2003 and 2004) have shown background deposition within the green lines values. After this project, total sulfur + 20% nitrogen, based on the five-year average, will exceed the green line values but be less than the red line values. As with total sulfur, recent years have lower sulfur and nitrogen deposition rates than the five-year average, and are within the green line values.

Table 10 - RLW Comparison with USFS Green and Red Line Values (kg/ha/yr)						
Year	*Background Sulfur*	*Background Nitrogen*	*Project Sulfur*	*Project Nitrogen*	*Total Sulfur*	*Total Sulfur +20% N*
2000	4.5	8.6	-	-	-	-
2001	4.9	8.4	-	-	-	-
2002	4.4	8.2	-	-	-	-
2003	3.6	6.4	-	-	-	-
2004	3.7	6.9	-	-	-	-
Average	4.6	8.4	0.0047	0.0053	4.605	6.286
Project Increase over 5-Year Average Background (%)					0.1%	0.1%
USFS Green Line Values					3.5 to 4.5	4.5 to 5.5
USFS Red Line Values					7.5 to 8.5	9.0 to 10.5

The green and red line value comparison for the Boundary Waters National Canoe Wilderness is presented in Table 11. Background deposition rates are based on five years of measurements from the monitoring site at Voyageurs National Park. Project emissions were predicted to increase background deposition of sulfur and sulfur + 20% nitrogen by 0.1% or less. After this project, both total sulfur deposition and total sulfur + 20% nitrogen will continue to be well below their green line values.

USFS staff also requested that we compare the proposed project emissions with existing emissions in the region. Table 12 summarizes the historical SO_2 and NO_x emissions from the two counties closest to project, Douglas County in Wisconsin and St. Louis County in Minnesota. Annual emissions from point and areas sources were obtained for 1997, 1999 and 2001.[17]

The average emissions for these years were compared with the proposed allowable emissions from the Kiln #5 project. This shows that the project has the potential to increase the total emissions of SO_2 and NO_x from these two counties by approximately 1.1% and 0.8%, respectively. Actual project emissions will be less than the allowable, so the actual increase will be less.

Table 11 - BWCAW Comparison with USFS Green and Red Line Values (kg/ha/yr)						
Year	*Background Sulfur*	*Background Nitrogen*	*Project Sulfur*	*Project Nitrogen*	*Total Sulfur*	*Total Sulfur+20 % N*
2000	2.9	5.2	-	-	-	-
2001	2.4	4.6	-	-	-	-
2002	2.2	4.8	-	-	-	-
2003	1.5	3.3	-	-	-	-
2004	2.2	4.5	-	-	-	-
Average	2.5	4.9	0.0018	0.0022	2.502	3.482
Project Increase over 5-Year Average Background (%)					0.1%	0.1%
USFS Green Line Values					7.5 to 8.0	9 to 10
USFS Red Line Values					10 to 11	12 to 13

Table 12 - Comparison of Project and Regional Emissions (tons per year)							
Air Pollutant	*County*	*1997*	*1999*	*2001*	*Average*	*Project*	Increase
SO_2	Douglas, WI	3,603	3,235	3,420	3,419	-	-
	St. Louis, MN	7,885	11,625	11,905	10,472	-	-
	Total	11,488	14,860	15,325	13,891	148	1.1%
NO_x	Douglas, WI	3,960	3,251	3,263	3,491	-	-
	St. Louis, MN	42,249	52,303	50,911	48,488	-	-
	Total	46,209	55,554	54,174	51,979	433	0.8%

Additional Impact Analysis

Modeling Procedures

The PSD regulations also required that a permit applicant must provide an analysis of impairment to visibility, soils and vegetation, and general commercial, residential, and industrial and other growth resulting from the operation of the project. An interpretation of this Additional Impacts Analysis requirement is described in Chapter D of the USEPA *New Source Review Workshop Manual*.[4]

The required analyses for this project are provided in four sections as suggested by USEPA in the workshop manual. These sections are as follows: Growth Analysis; Ambient Air Quality Impact Analysis; Soils and Vegetation Impacts Analysis; and Visibility Impairment Analysis.

Growth Analysis

While the proposed lime kiln project would increase facility production capacity, there would be little change in growth of non-air pollution related impacts.The existing lime manufacturing plant had operated at its current site for over 50 years. The first kiln was installed in 1946. The typical operating schedule is 24 hours per day, 7 days per week, 270 days per year. This schedule is not expected to change as a result of this project. There will be a minor increase in the number of employees resulting from the addition of the new lime kiln. Truck traffic for the hauling of lime product will increase proportionally with the increase in actual production from the new lime kiln.

Ambient Air Quality Impact Analysis

The near-field dispersion modeling analysis demonstrated that no exceedence of the National Ambient Air Quality Standards is anticipated due to this project. This project is expected to have a minor impact on air quality below significant impact levels for criteria air pollutants.

To characterize the air quality impacts of this project, a comparison was made between the project emissions and existing emissions in the surrounding county. Existing emissions are contributed by industrial sources and mobile sources. Table 13 compares an estimate of actual emissions released in Douglas County in 1999 with the potential or allowable emissions from the Kiln #5 project. This was the most recent year for which both stationary and mobile source emissions were available.

Soil and Vegetation Impacts Analysis

The PSD regulations require that a soils and vegetation impact analysis be conducted for the project.Procedures for this analysis are described in the 1990 USEPA draft, *New Source Workshop Manual*. For this project, emissions of SO_2 and NO_x are phytotoxic and capable of damaging vegetation. Predicted air pollutant concentrations are typically compared with the thresholds for vegetation damage. These thresholds were obtained from the USEPA publication, *A Screening Procedure for the Impacts of Air Pollution Sources on Plants, Soils and Animals*.[18]

Table 13 - Comparison of Kiln #5 Project and Douglas County Emissions				
Air Pollution Source Category	*PM10* (TPY)	*SO_2* (TPY)	*NO_x* (TPY)	*CO* (TPY)
Fuel Combustion - Industrial	51.8	1,522.7	436.4	1,959.1
Fuel Combustion - Other	149.5	209.6	179.8	389.4
Petroleum & Related Industries	49.0	1,382.8	212.5	1,595.3
Other Industrial Processes	282.0	-	218.6	218.6
Storage & Transport	711.0	-	-	-
Waste Disposal & Recycling	114.8	3.1	43.1	-
Highway Vehicles	37.1	47.5	1,267.5	46.1
Off-Highway	58.2	66.6	888.8	1,315.1
Miscellaneous	1,385.4	2.6	4.5	955.3
Total	2,838.8	3,234.9	3,251.2	6,479.0
Kiln #5 Project	30.1	196.3	432.8	369.0
Kiln #5 Project Contribution (%)	1.1	6.1	13.3	5.7

A comparison of maximum downwind concentrations due to total facility emissions after the project is presented in Table 14. This comparison demonstrated that NO_x concentrations will be less than the thresholds for damage to sensitive vegetation.

For the 1-hour and annual averaging periods, SO_2 concentrations were predicted to exceed the thresholds. Further evaluation was necessary to show no significant impact. The specific locations were identified where the higher SO_2 concentrations would occur. Since these were in developed and industrialized areas, was concluded that sensitive plant species such as lichens and mosses on which the screening thresholds would not be present in these areas.

It was also argued that predicted SO_2 concentrations were less than the NAAQS, including the secondary standards designed to protect the human welfare and the environment. The secondary standard was established by USEPA to protect vascular plants such as cultivated crops, trees, ferns and flowering plants during sensitive periods of the day when they are most vulnerable.[19]There was insufficient information for USEPA to establish a long-term averaging period standard. USEPA recognized that non-vascular plants such as lichens and mosses are more sensitive than vascular plants, but did not establish an air quality standard for them. It instead recommended using programs aimed at visibility and acidic deposition to protect non-vascular plants.

Finally, emissions from the new kiln project itself were estimated to contribute air quality impacts below the significant impact thresholds , or far less than the vegetation screening concentrations.

Visibility Impairment Analysis

This project was subject to PSD approval for TSP/$PM_{10.}$ These emissions may result in a plume which influences visibility due to atmospheric discoloration or reduction of visual range. However, the facility is more than 50 km from the nearest Class I area. Beyond this distance, coherent plume visibility impacts on Class I areas are expected to be negligible and no analysis are required.

Visible impacts near the facility were also expected to be small. The air pollution control systems used on the process equipment (i.e. fabric filter baghouse systems) will collect TSP/PM_{10} significantly reducing these pollutants. Based on similar air pollution control equipment at the facility, the plumes leaving project stacks are not expected to be visible.

Under certain meteorological conditions, the facility stacks may emit a visible steam plume. Factors influencing the formation of a steam plume include ambient temperatures and humidity. Any steam plume will eventually dissipate by dispersion and evaporation.

Table 14 - Sensitive Vegetation Screening Analysis

Air Pollutant	*Averaging Period*	*Maximum Facility Concentration ($\mu g/m^3$)*	*Background Concentration [a] ($\mu g/m^3$)*	*Total Concentration ($\mu g/m^3$)*	*Vegetation Screening Concentration ($\mu g/m^3$)*	*Screening Criteria Exceeded?*
SO_2	1-hour	759.9	223.5	990	917	Yes
	3-hour	463.0	128.3	591	786	No
	Annual	26.1	7.9	34	18	Yes
NO_x	4-hour	130.8	97.6	228	3760	No
	8-hour	91.0	67.9	159	3760	No
	1-month	14.4	10.7	25	564	No
	Annual	6.3	4.7	11	94 - 188	No

CONCLUSIONS

The requirements for obtaining an air quality permit for the lime kiln project were extensive, but similar to those for kilns approved in other states. While applicability of the PSD regulations was common to all lime kiln projects in the U.S., site-specific interpretations of these regulations by local regulatory agencies influenced permit issuance and emission control requirements. These included:

1. - The emission control options to be evaluated for the BACT analysis.

The need to evaluate innovative emission control methods and in some instances obtain quotations led to unanticipated delays. During the pre-application phase, control options for the BACT analysis should be clarified with the regulatory agency.

2. - The cost effectiveness threshold at which a control option was considered infeasible.

For this project, the state used a cost effectiveness threshold of approximately $10,000 per ton of pollutant controlled before deeming a control option to be economically infeasible for the BACT analysis.[3] This was higher than other states where lime kilns were approved. For instance, the reviewing agency in Arkansas considered a CE of $4,200 per ton excessive for wet scrubbing and the agency in Pennsylvania considered a CE of $5,000 per ton to be excessive for scrubbing.[6,20] Being aware of the CE threshold assures the project BACT analysis is complete and approvable. While most states don't publish an acceptable CE threshold, this might be determined by reviewing prior permits and BACT analyses issued by the state.

3. - The modeling procedures to evaluate Class I area impacts.

The Class I area evaluation for this project required several additional analyses not typically used for other projects in the U.S. These included establishing background sulfur and nitrogen deposition raters, a comparison of U.S. Forest Service green and red line values, and a comparison of emissions from the project and within the region. These additional requirements can be clarified during the pre-application phase to assure a complete and approvable permit application.

The schedule for obtaining the permit was as follows:

Month	Action
0	Pre-application meeting with state and federal regulatory agencies.
1	Submit permit application.
2-8	Respond to agency questions and comments.
8	Draft permit and public comment period.
9	Final permit issued and construction begins.

The time required to obtain a permit was shortened by incorporating several goals in the project design:

1. Anticipate and demonstrate compliance with all emission limitations and requirements.
2. Review and compare requirements for similar projects.
3. Design the project so air quality impacts were less than significant impact thresholds.

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KEY WORDS

lime, limestone, kiln, PSD, permit, emissions, modeling, coal, BACT