Appendix 9c - LADCO's "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis Document (July 18, 2007)"

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LADCO's "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis" (July 18, 2007) addresses factor analysis to establish a reasonable progress goal toward achieving natural visibility conditions in mandatory Class 1 areas. While Indiana does not have any Class 1 areas within the state, it may potentially impact visibility at nearby Class 1 areas. This factor analysis will address sulfur dioxides (SO2) and nitrogen oxides (NOx) emissions at several source categories, including electric generating units (EGUs), industrial, commercial and institutional (ICI) boilers, ammonia from agricultural operations, NOx emissions from onroad and nonroad mobile sources and reciprocating engines and turbines.

Indiana has reviewed the information contained in the "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis" and has listed emissions and visibility impact tables to show Indiana's contributions. Additional analyses related to each source category will be referenced but not shown in this appendix.

EGU – Page 22-38 of LADCO's "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis"

Indiana's emissions were based on LADCO's Base K emissions for 2002 and projected to 2018 and are shown below in Table 1. Indiana's emission contribution to the 9-state northern Midwest region (including the states of Michigan, Minnesota, Wisconsin, Illinois, Iowa, Missouri, North Dakota and South Dakota) was 33% of SO2 emissions and 24% of NOx emissions for 2002. Indiana's contribution is projected to drop to 21% for SO2 emissions and 17% of NOx by 2018.

Table 1. Estimated Baseline Emissions from EGUs

	Emissions in 2002 (1000 tons/year)		Projected emissions in 2018 (1000 tons/year)	
	SO2	**Nox**	**SO2**	**Nox**
Michigan	403	164	399	100
Minnesota	116	99	86	42
Wisconsin	220	107	155	46
3-State Subtotal	*739*	*370*	*641*	*188*
Illinois	478	260	241	73
Indiana	**912**	**303**	**377**	**95**
Iowa	150	93	147	51
Missouri	305	167	281	78
North Dakota	137	72	109	72
South Dakota	13	16	12	15
9-State Total	*2,734*	*1,280*	*1,808*	*571*

Table 5.1-2 "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis" (July 18, 2007)

Two sets of possible caps have been evaluated, which are termed EGU1 and EGU2:

EGU1 would establish a regional emissions cap for SO2 and NOX based on projected fuel Consumption:

- SO2 limited to 0.15 pounds per million British thermal units (lb/million-BTU) of fossil fuel consumption in the region
- NOX limited to 0.10 lb/million-BTU

EGU2 would establish regional emission caps for SO2 and NOX based on projected fuel consumption:

- SO2 limited to 0.10 lb/million-BTU
- NOX limited to 0.07 lb/million-BTU

Estimated costs for SO2 and NOx controls for each of the possible cap scenarios for the 9-State region is listed in Tables 5.1-3 and 5.1-4 of the "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis" document. The estimated energy and non-air environmental impacts of EGU control strategies can be found in Table 5.1-8 and estimated annual health benefits applied to the 5-state Midwest Regional Planning Organization can be found in Table 5.1-9.

Based on these possible caps, visibility impacts were determined and improvements were shown for 2018. Indiana emission reductions were combined with the other 8 state region emission reductions to determine the visibility improvements and are shown below in Table 2. Significant visibility improvements were modeled with both emission cap scenarios.

Table 2. Estimated Visibility Impacts of EGU Control Strategies

	Estimated Visibility Improvement in 2018 (DV)				
Strategy and region	**Boundary Waters**	**Voyageurs**	**Isle Royale**	**Seney**	**Average**
EGU1 Emission Caps: 9-State Region					
SO2	0.77	0.35	0.84	1.01	0.74
NOX	0.18	0.24	0.15	0.12	0.17
Total	0.95	0.59	1	1.13	0.92
EGU2 Emission Caps: 9-State Region					
SO2	0.87	0.4	0.96	1.18	0.85
NOX	0.26	0.3	0.23	0.19	0.24
Total	1.13	0.69	1.18	1.37	1.09

Table 5.1-10 "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis" (July 18, 2007)

Cost effectiveness of EGU control strategies for the 9-State region can be found in Table 5.1-11.

ICI– Page 39-52 of LADCO's "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis"

Non-EGU point sources, such as Industrial, Commercial and Institutional (ICI) boilers was identified by source apportionment as the second largest contributor to visibility impairment to the northern Class 1 areas. Two control strategies have been constructed to address non-EGU/ICI boiler emissions. The first strategy, referred to as the ICI1, requires 40% SO2 reduction and 60% NOx reduction from 2018 baseline emissions. The second strategy was created by an ICI Workgroup and identifies SO2 and NOx emission limitations based on boiler type, size and fuel type consumed. This strategy would result in approximately 77% SO2 emission reductions and 70% reduction in NOx emissions. Table 5.2-3 of the "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis" document outlines the ICI Workgroup proposed emission caps for NOx and SO2 for different boiler and fuel types.

Indiana's emissions were based on LADCO's Base K emissions for 2002 and projected to 2018 and are shown below in Table 6. Indiana's emission contribution to the 9-state northern Midwest region (including the states of Michigan, Minnesota, Wisconsin, Illinois, Iowa, Missouri, North Dakota and South Dakota) was 28.4% of SO2 emissions and 21% of NOx emissions for 2002. Indiana's contribution is projected to drop to 28.3% for SO2 emissions and 20.7% of NOx by 2018.

Table 3 Estimated Point and Area Emissions from ICI Boilers				
	Emissions from ICI sources in 2002 (1000 tons/year)		**Projected emissions from ICI sources in 2018 (1000 tons/year)**	
	SO2	**Nox**	**SO2**	**Nox**
Michigan	44.2	27	42.8	26.5
Minnesota	20.2	52.9	19.7	52.7
Wisconsin	57	34.5	54.8	33.9
3-State Subtotal	*121.5*	*114.4*	*117.2*	*113.1*
Illinois	58.9	49.5	59	48
Indiana	**108.9**	**54.2**	**105.2**	**52.5**
Iowa	32.2	16.3	30.6	16.2
Missouri	53	18.8	52.5	18.7
North Dakota	7.6	5.1	7.2	5.1
South Dakota	0.7	0.3	0.7	0.3
9-State Total	*382.8*	*258.7*	*372.3*	*253.9*

Table 5.2-1 "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis" (July 18, 2007)

Estimated cost of ICI1 SO2 and NOx controls for the 9-state region can be found in Tables 5.2-5 and 5.2-6 of the "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis" document with the estimated cost of ICI Workgroup SO2 and NOx controls for the 9-state region can be found in Tables 5.2-7 and 5.2-8. The estimated energy and non-air environmental impact of ICI control strategies for the 9-state region can be found in Table 5.2-10 with cost effectiveness of the ICI controls found in Table 5.2-12.

Visibility improvements at nearby Class 1 areas are realized with emission reductions from ICI point and area sources, however these improvements are an order of magnitude less that those achieved from EGU emission reductions. Impacts are shown below in Table 4.

Table 4. Estimated Visibility Impacts of ICI Control Strategies							
			Estimated Visibility Improvement in 2018 (DV)				
			Boundary Waters	Voyageurs	Isle Royale	Seney	Average
ICI1	3-State	SO2	0.07	0.03	0.07	0.05	0.06
		NOX	0.07	0.05	0.03	0.02	0.04
	9-State	SO2	0.09	0.05	0.09	0.11	0.08
		NOX	0.1	0.07	0.05	0.06	0.07
ICI Workgroup	3-State	SO2	0.1	0.06	0.11	0.09	0.09
		NOX	0.1	0.06	0.03	0.03	0.05
	9-State	SO2	0.15	0.08	0.15	0.18	0.14
		NOX	0.11	0.08	0.06	0.07	0.08

Table 5.2-11 "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis" (July 18, 2007)

Reciprocating Engines and Turbines – Page 53-60 of LADCO's "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis"

Indiana's reciprocating engines and turbine emissions were based on LADCO's Base K emissions for 2002 and projected to 2018 and are listed below in Table 5. Indiana's emission contribution to the 9-state northern Midwest region (including the states of Michigan, Minnesota, Wisconsin, Illinois, Iowa, Missouri, North Dakota and South Dakota) was 9% of NOx emissions for 2002. Indiana's contribution is projected to drop to 8% of NOx emissions by 2018. Stationary internal combustion engines are projected to represent 11 % of all non-EGU point sources in 2018.

Table 5. Estimated Emissions from Reciprocating Engines and Turbines in Non-EGU Emissions in 2018						
	Nox Emissions from stationary internal Combustion sources in 2002 (tons/day)			Projected Nox from stationary internal Combustion sources in 2018 (tons/day)		
	Reciprocating Engines	Turbines	Total	Reciprocating Engines	Turbines	Total
Michigan	44.1	11.4	55.5	41.4	11.5	52.9
Minnesota	18.3	5.9	24.3	17.6	6.3	23.9
Wisconsin	8.1	1.9	10	7.2	1.9	9.2
3-State Subtotal	*70.5*	*19.2*	*89.8*	*66.2*	*19.7*	*85.9*
Illinois	112.5	14.3	126.8	110.6	15.9	126.4
Indiana	**25.1**	**1.7**	**26.8**	**23**	**1.8**	**24.7**
Iowa	26.3	1.6	27.9	25.2	1.7	26.9
Missouri	21	3.2	24.3	20.2	3.4	23.6
North Dakota	8.7	1.3	10	8.3	1.4	9.7
South Dakota	0	1	1	0	1.1	1.1
9-State Total	*264.1*	*42.5*	*306.6*	*253.6*	*44.9*	*298.4*

Table 5.3-1 "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis" (July 18, 2007)

Emission reductions for candidate internal combustion control measures are found in Table 5.3-2 of the "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis" document. Indiana's sources with emissions of 100 tons/year or more could realize emission reductions up to 88.5% with sources with emission of 10 tons/year or more up to 87.7%. Estimated cost effectiveness of controls for internal combustion sources are found in Table 5.3-3 with cost effectiveness in terms of visibility improvement found in Table 5.3-5.

Indiana emission reductions were combined with the other 8 state region emission reductions to determine the visibility improvements and are shown below in Table 6. Visibility improvements were modeled with larger improvements seen from emission reductions from the reciprocating engines.

Table 6. Estimated Visibility Improvements from Internal Combustion Control Measures					
9-State region					
Control of sources emitting over 100 tons/year	**Boundary Waters**	**Voyageurs**	**Isle Royale**	**Seney**	**Average**
Reciprocating engines	0.074	0.053	0.036	0.044	0.052
Turbines	0.01	0.007	0.005	0.006	0.007
Total	0.084	0.06	0.041	0.05	0.059
9-State region					
Control of sources emitting over 10 tons/year	**Boundary Waters**	**Voyageurs**	**Isle Royale**	**Seney**	**Average**
Reciprocating engines	0.105	0.075	0.051	0.062	0.073
Turbines	0.017	0.012	0.008	0.01	0.012
Total	0.121	0.087	0.059	0.072	0.085

Table 5.3-4 "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis" (July 18, 2007)

Ammonia from Agricultural Sources – Page 61-67 of LADCO's "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis"

Agricultural sources account for an estimated 97% of ammonia emissions in the nine-state region with most of those emissions coming from livestock. Cost effectiveness for control measures for agricultural ammonia emissions in the study region is found in Table 5.4-1 of the "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis" document with the estimated energy and non-air environmental impact located in Table 5.4-2. Cost effectiveness in terms of visibility improvement from agricultural ammonia emission reductions from the 9-state region can be found in Table 5.4-4.

Visibility improvements at nearby Class 1 areas are realized with 10% and 15% ammonia emission reductions and are shown below in Table 7. Indiana would not be expected to significantly impact nearby Class 1 areas due to the ground-level releases of ammonia being dispersed before reaching the surrounding Class 1 areas.

Table 7. Estimated Visibility Impacts of Agricultural Ammonia Emission Control Measures.					
Estimated visibility Improvement in 2018 (DV)					
	Boundary Waters	**Voyageurs**	**Isle Royale**	**Seney**	**Average**
10% Ammonia Reduction in the 9-state region	0.15	0.18	0.15	0.17	0.16
15% Ammonia Reduction in the 9-state region	0.23	0.27	0.23	0.26	0.25

Table 5.4-3 "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis" (July 18, 2007)

Mobile Sources – Page 68-76 of LADCO's "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis"

Source apportionment modeling show that mobile sources contribute significantly to visibility impairment in 2018 in the northern Midwest Class I areas, despite projected NOX reductions from on-the-books Federal and state-wide programs targeting on- and non-road mobile source sectors as well as locomotives and marine engines. Potential additional control strategies were identified that could be applied on a regional level.

For on-road engines:

- Low-NOX Reflash
- Anti-Idling
- Midwest Clean Diesel Initiative (MCDI)
- Cetane Additive Program

For non-road and locomotive engines:

- Anti-Idling
- Cetane Additive Program
- MCDI

Estimated cost effectiveness and emission reduction potential from mobile sources in the 9-state region are found in Table 5.5-1. The estimated energy and non-air environmental impacts from mobile source control strategies are listed in Table 5.5-2. Cost effectiveness of mobile source controls in terms of visibility improvement can be found in Table 5.5-4.

Emission reductions resulting from the above mobile emission control strategies for the 9-state region will average less than 2% for 2012 emission projections and just over 2 % for 2018 emission projections. Resulting visibility improvements as a result of each of the emission reductions will only improve visibility by less than 0.005 deciviews with visibility impacts from the cumulative mobile emission reductions resulting in 0.04 deciview improvement.

SUMMARY

Tables 8 and 9 show the 2002 and 2018 emission summaries for the nine state region for NOx and SO2. Table 10 shows a summary of the estimate visibility impacted from each of the source category emission reductions strategies. All Class 1 areas see a bigger benefit for visibility with emission controls on EGUs followed by ammonia reduction from agricultural sources. This analysis takes into account emission reductions from sources in all nine states within the study region so visibility improvement represents a cumulative impact from the states of Indiana, Michigan, Minnesota, Wisconsin, Illinois, Iowa, Missouri, North Dakota and South Dakota.

Table 8. Summary of Current (2002) Emissions in the Nine States in the Study Region										
	EGU	ICI Boilers	Reciprocating Engines	Turbines	Other Point	Area Sources	Onroad Mobile Sources	Nonroad Mobile Sources	Marine, Aircraft, Railroad	Total
SO2 in 2002										
Michigan	1,103	55			107	71		19	1	1,355
Minnesota	318	23			36	33		19	8	437
Wisconsin	602	149			14	9		13	13	800
3-State Subtotal	2,023	227			156	113		51	21	2,592
Illinois	1,310	161			213	11		31	0	1,725
Indiana	**2,499**	**148**			**144**	**158**		**17**	**0**	**2,966**
Iowa	412	88			50	2		12	8	571
Missouri	835	28			227	117		12	12	1,231
North Dakota	376	21			22	142		0	3	564
South Dakota	35	1			3	50		0	1	90
9-State Total	7,489	676			813	594		123	44	9,739
NOx in 2002										
Michigan	448	45	44	11	116	49	926	205	114	1,959
Minnesota	271	26	18	6	117	126	455	208	100	1,327
Wisconsin	294	65	8	2	24	32	481	145	79	1,129
3-State Subtotal	1,013	136	71	19	256	208	1,862	557	294	4,416
Illinois	712	101	112	14	129	62	890	324	277	2,622
Indiana	**830**	**105**	**25**	**2**	**106**	**63**	**703**	**178**	**123**	**2,133**
Iowa	254	45	26	2	39	7	304	174	89	941
Missouri	458	12	21	3	63	64	602	199	133	1,555
North Dakota	196	14	9	1	7	45	75	2	46	395
South Dakota	44	1	0	1	14	14	92	2	8	176
9-State Total	3,507	413	264	42	616	462	4,529	1,437	969	12,239

Table A-1.1 “Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis” (July 18, 2007)

Table 9. Summary of Projected (2018) Emissions in the Nine States in the Study Region										
	EGU	ICI Boilers	Reciprocating Engines	Turbines	Other Point	Area Sources	Onroad Mobile Sources	Nonroad Mobile Sources	Marine, Aircraft, Railroad	Total
SO2 in 2018										
Michigan	1,093	51			134	68		0	1	1,347
Minnesota	236	22			48	34		4	2	346
Wisconsin	426	142			15	10		0	9	601
3-State Subtotal	1,755	215			196	112		4	11	2,294
Illinois	661	155			94	13		0	0	923
Indiana	**1,033**	**138**			**152**	**153**		**3**	**0**	**1,479**
Iowa	404	83			74	3		1	2	567
Missouri	770	26			395	120		3	7	1,321
North	298	20			32	137		4	0	491
South	33	2			4	51		3	0	94
9-State Total	4,952	641			948	588		19	20	7,168
NOx in 2018										
Michigan	273	43	41	11	133	54	385	94	110	1,145
Minnesota	115	25	18	6	134	136	205	175	54	867
Wisconsin	126	64	7	2	21	35	118	69	57	500
3-State Subtotal	514	132	66	20	287	225	708	338	222	2,512
Illinois	199	96	111	16	121	73	176	154	186	1,131
Indiana	**262**	**100**	**23**	**2**	**101**	**69**	**105**	**141**	**84**	**887**
Iowa	140	44	25	2	50	9	67	141	47	525
Missouri	213	12	20	3	75	74	119	161	99	777
North Dakota	196	14	8	1	12	50	34	204	24	545
South Dakota	40	1	0	1	22	15	42	148	5	273
9-State Total	1,564	400	254	45	669	515	1,250	1,288	666	6,650

Table A-1.2 “Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis” (July 18, 2007)

Table 10. Estimated Visibility Impacts of Potential Control Strategies								
				Estimated visibility improvement on the 20% worst-visibility days in 2018 (deciviews)				
Strategy and Region				Boundary Waters	Voyageurs	Isle Royale	Seney	Average
EGU	EGU1	9-State	SO2	0.77	0.35	0.84	1.01	0.74
			NOX	0.18	0.24	0.15	0.12	0.17
	EGU2	9-State	SO2	0.87	0.4	0.96	1.18	0.85
			NOX	0.26	0.3	0.23	0.19	0.24
ICI boilers	ICI1	9-State	SO2	0.09	0.047	0.092	0.109	0.084
			NOX	0.098	0.07	0.048	0.058	0.068
	ICI Workgroup	9-State	SO2	0.145	0.075	0.148	0.176	0.136
			NOX	0.114	0.082	0.056	0.067	0.08
Reciprocating Engines and Turbines	Reciprocating engines emitting 100 tons/year or more	9-State	NOX	0.074	0.053	0.036	0.044	0.052
	Turbines emitting 100 tons/year or more	9-State	NOX	0.01	0.007	0.005	0.006	0.007
	Reciprocating engines emitting 10 tons/year or more	9-State	NOX	0.105	0.075	0.051	0.062	0.073
	Turbines emitting 10 tons/year or more	9-State	NOX	0.017	0.012	0.008	0.01	0.012
Agricultural Sources	10% reduction	9-State	NH3	0.15	0.18	0.15	0.17	0.16
	15% reduction	9-State	NH3	0.23	0.27	0.23	0.26	0.25
Mobile Sources	Low-NOX Reflash	9-State	NOX	0.008	0.009	0.012	0.012	0.01
	MCDI	9-State	NOX	0.014	0.018	0.013	0.013	0.015
	Anti-Idling	9-State	NOX	0.005	0.007	0.006	0.006	0.006
	Cetane Additive Program	9-State	NOX	0.006	0.007	0.009	0.01	0.008

Table 6.5-2 "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis" (July 18, 2007)

References:

LADCO's "Reasonable Progress for Class 1 Areas in the Northern Midwest – Factor Analysis" (July 18, 2007)
http://www.ladco.org/reports/rpo/consultation/products/reasonable_progress_for_class_i_areas_in_the_northern_midwest-factor_analysis_draft_final_technical_memo_july_18_2007.pdf