Chesapeake Bay Water Quality Goal Implementation Team
Attachment E - Briefing Paper for the September 21, 2009 Call
UPDATED September 22nd, 2009

THE CHESAPEAKE BAY AIRSHED MODEL: STRUCTURE, SCENARIOS, APPROACH FOR ALLOCATING AIR LOADS, AND ADJUSTMENT OF OCEAN BOUNDARY CONDITIONS DUE TO REDUCED NITROGEN DEPOSITION IN COATAL WATERS

Background

The CBP Airshed Model is comprised of two models, the Community Multiscale Air Quality Model (CMAQ) and a sophisticated regression model of wet deposition loads developed by Penn State. The CMAQ Model provides dry deposition estimates of nitrogen loads, as well as providing our air scenario capability. Advantages of CMAQ are an improved resolution and quantification of atmospheric deposition, as well as increased opportunities for integration of State and Federal water and air programs.

CMAQ Model

The Community Multiscale Air Quality Model (CMAQ) is a next generation airshed model that's replaced the RADM model used by the CBP since 1990. The CMAQ Model has several advantages over RADM. CMAQ has a more advanced "one atmosphere" model design, meaning most of the air and water quality constituents are simulated, providing better coordination between air and water programs. The CMAQ simulation capabilities include all wet and dry species of nitrogen deposition, particulate matter (PM 2.5), acid deposition, ozone, and visibility. Plans are underway to add to CMAQ the simulation of mercury deposition in 2011.

The new CMAQ simulation improves resolution of hot spots like metropolitan areas and along with recent refinements to the wet deposition regression model, greatly improves our understanding of agricultural sources of ammonia. Estimates of nitrogen deposition to tidal waters were further improved in 2008 by the use of a 12 km CMAQ grid, as well as the incorporation of sea salt in the simulation which significantly modified deposition in tidal areas.

CMAQ Scenarios

The CMAQ Model also provides estimates of nitrogen deposition resulting from changes in emissions from utility, mobile, and industrial sources due to management actions or growth. For the CMAQ Model the base deposition year is 2002 and scenarios include the management actions required by the Clean Air Act in 2010, 2020, and 2030. The future year 2010, 2020, and 2030 scenarios reflect emissions reductions from national control programs for both stationary and mobile sources, including the Clean Air Interstate Rule, the Tier-2 Vehicle Rule, the Nonroad Engine Rule, the Heavy-Duty Diesel Engine Rule, and the Locomotive/Marine Engine Rule. Although the Clean Air Interstate Rule has been remanded to EPA, it will remain in place pending a rulemaking to replace it. At this point, it unclear how the replacement rule will compare to the remanded rule. However, EPA anticipates that NOx emissions reductions close to those originally projected will occur.

To develop a Watershed Model scenario using one of the CMAQ Model air scenarios below, a monthly factor is determined by CMAQ by comparing the CMAQ atmospheric deposition loads in the scenario year to the CMAQ 2002 Base year. The CMAQ scenario factor is then used to adjust the base atmospheric deposition conditions in Phase 5 over the 1991 to 2000 scenario years.

2010 Scenario
The 2010 Scenario represents emission reductions due to regulations implemented through the Clean Air Act authority to meet National Ambient Air Quality standards for criteria pollutants in 2010. This includes National/Regional and available State Implementation Plans (SIPs) for NOx reductions*. Other components of the 2010 Scenario include: Tier 1 vehicle emission standards reaching high penetration in the vehicle fleet for on-road light duty mobile sources along with Tier 2 vehicle emission standards which were fully phased in by the 2006 model year and will in 2010 begin to show an impact. For Electric Generating Units, also called EGUs, the 2010 controls assume that the NOx SIP call, NOx Budget Trading Program (NBP), and the CAIR program that regulates the ozone season NOx are all in place and that the CAIR program is designed for annual NOx reductions to match the ozone season reductions under the 2010 CAIR first phase conditions.

2020 Scenario
The 2020 Scenario has all components of the 2010 Scenario and includes the Clean Air Mercury Rule (CAMR), the Best Available Retrofit Technology (BART) used for reducing regional haze and the off-road diesel and heavy duty diesel regulations. The 2020 Scenario represents emission reductions due to regulations implemented through the Clean Air Act authority to meet National Ambient Air Quality standards for criteria pollutants in 2020. These include:
<u>On-Road mobile sources</u>: For On-Road Light Duty Mobile Sources this includes Tier 2 vehicle emissions standards and the Gasoline Sulfur Program which affects SUV's pickups, and vans which are now subject to same national emission standards as cars.
<u>On-Road Heavy Duty Diesel Rule – Tier 4</u>: New emission standards on diesel engines starting with the 2010 model year for NOx, plus some diesel engine retrofits.
<u>Clean Air Non-Road Diesel Rule</u>: Off-road diesel engine vehicle rule, commercial marine diesels, and locomotive diesels (phased in by 2014) require controls on new engines. Off-road large spark ignition engine rules affect recreational vehicles (marine and land based).
<u>EGUs</u>: CAIR second phase in place (in coordination with earlier NOx SIP call); Regional Haze Rule and guidelines for Best Available Retrofit Technology (BART) for reducing regional haze; Clean Air Mercury Rule (CAMR) all in place.
<u>Non-EGUs</u>: Solid Waste Rules (Hospital/Medical Waste Incinerator Regulations).

**Note: All CBP CMAQ runs use the actual State Implementation Plans as submitted to EPA in 2008 (2008 SIP Call) if available at the time of the scenario run, but EPA's Office of Air Quality Planning and Standards (OAQPS) does not expect to receive and compile all the SIP plans until about December 2009.*

2020 Maximum Feasible Scenario
The 2020 Maximum Feasible Scenario includes additional aggressive EGU, industry, and mobile source controls. Emissions projections were developed that represented incremental improvements and control options (beyond 2020 CAIR) that might be available to States for application by 2020 to meet a more stringent ozone standard (stricter than 0.08 ppm, i.e., the new 0.075 ppm ozone standard of March 2008). Incremental control measures for 5 sectors were developed:
EGUs: lower ozone season nested emission caps in OTC states; targeting use of maximum controls for coal fired power plants in or near non-attainment areas.
Non-EGU point sources: new supplemental controls, such as low NOx burners, plus increased control measure efficiencies on planned controls and step up of controls to maximum efficiency measures, e.g., replacing SNCRs (Selective Non-Catalytic Reduction) with SCRs (Selective Catalytic Reduction) control technology.
Area (nonpoint area) sources: switching to natural gas and low sulfur fuel.
On-Road mobile sources: increased penetration of diesel retrofits and continuous inspection and maintenance using remote onboard diagnostic systems.
Non-Road mobile sources: increased penetration of diesel retrofits and engine rebuilds. Reduced NOx emissions from marine vessels in coastal shipping lanes.

2030 Scenario
The 2030 scenario is in some areas a further decrease in emissions beyond the 2020 Scenario due to continuing fleet replacement of heavy diesels, off road diesels, and of mobile sources of all types. These emission decreases are offset by continued growth in the Chesapeake region. The emissions projections assume continued stringent controls are in place, such as:
Tier 2 vehicle emissions standards fully penetrated in the fleet.
Heavy Duty Diesel vehicle fleet fully replaced with newer heavy-duty vehicle that comply with new standards.
On-Road mobile sources: Increased penetration of diesel retrofits maintained.
Non-Road mobile sources capped at 2020 Maximum Feasible Scenario levels.
EGUs and Non-EGUs emissions capped at 2020 Maximum Feasible Scenario levels.
Area sources emissions capped at 2020 Maximum Feasible Scenario levels, assuming energy efficiency and control efficiencies keep up with growth.
Further reductions in NOx emissions from marine vessels in coastal shipping lanes.

CMAQ Scenario Results
Table 1 lists the loads delivered to the Bay from the key scenarios, in millions of pounds, using the Phase 5.2 - August 2009 Version of the Watershed Model. All of the scenarios in Table 1 use 2002 as their base year. The point sources, human and animal populations, septic systems, etc. are the same 2002 levels in all of these scenarios, only the atmospheric deposition changes. Table 2 lists the atmospheric deposition loads of nitrogen to the Chesapeake watershed for key scenarios by State in units of millions of pounds as N. The regression and CMAQ models provide estimates of direct deposition to the tidal waters of the Chesapeake. Table 3 lists the estimates of direct deposition to the tidal Bay for key scenarios.

Table 1. Atmospheric Deposition Nitrogen Delivered to the Bay Under Key Scenarios Units in millions of pounds as N (Phase 5.2 - August 2009 Version).

Basins	1985 Scenario	2002 Scenario	2010 Scenario	2020 Scenario	2020 Maximum Feasible Scenario	2030 Scenario
Susquehanna	160.43	148.09	141.44	138.68	137.60	139.28
West Shore	15.72	15.30	15.07	14.98	14.94	14.99
Potomac	77.00	72.15	69.41	68.34	67.87	68.58
Patuxent	4.82	4.54	4.38	4.32	4.29	4.31
Rappahannock	10.96	9.83	9.99	9.83	9.77	9.81
James	37.89	36.67	35.61	35.15	35.01	35.11
York	9.33	8.88	8.55	8.41	8.36	8.39
East Shore MD-DE	31.57	29.77	29.19	29.18	29.06	29.69
East Shore VA	3.01	2.91	2.84	2.83	2.81	2.83
Total	**350.74**	**328.13**	**316.50**	**311.71**	**309.72**	**312.98**

Table 2. Atmospheric deposition loads of nitrogen to the Chesapeake watershed for key scenarios by State Units in millions of pounds as N (Phase 5.2 - August 2009 Version).

	STATE							
Total Nitrogen	**DE**	**DC**	**MD**	**NY**	**PA**	**WV**	**VA**	**Chesapeake Watershed**
1985 Scenario	7.8	0.8	97.4	53.7	221.7	30.6	179.8	591.8
1985-2000 Calibration	7.1	0.7	84.0	46.0	192.2	26.2	159.3	515.4
2002 Scenario	6.5	0.6	73.0	39.5	167.3	22.5	142.3	451.6
2010 Scenario	6.3	0.5	59.6	30.6	133.3	17.2	112.8	360.2
2020 Scenario	6.6	0.4	54.6	26.2	117.6	15.3	99.9	320.6
2020 Maximum Feasible	6.5	0.4	51.9	24.8	111.2	14.5	95.0	304.3
2030 Scenario	7.4	0.4	56.9	26.1	121.4	15.4	100.0	327.6
Dry NOx Deposition								
1985 Scenario	3.1	0.5	51.0	23.1	102.1	15.7	97.5	293.0
1985-2000 Calibration	2.6	0.4	42.2	19.2	84.9	13.1	83.2	245.4
2002 Scenario	2.2	0.3	35.2	16.2	71.3	10.9	71.8	207.8
2010 Scenario	1.6	0.2	23.1	10.8	46.2	6.7	46.7	135.4
2020 Scenario	1.3	0.1	16.6	7.9	32.5	4.8	33.3	96.5
2020 Maximum Feasible	1.1	0.1	14.3	6.9	28.2	4.2	29.6	84.5
2030 Scenario	1.0	0.1	13.7	6.7	27.0	4.1	28.9	81.6
Dry NH_3 Deposition								
1985 Scenario	2.1	0.1	12.2	5.0	25.3	2.9	18.2	65.8
1985-2000 Calibration	2.2	0.1	12.1	4.7	25.3	2.8	18.5	65.7
2002 Scenario	2.3	0.1	12.1	4.5	25.4	2.8	18.7	65.7
2010 Scenario	3.0	0.1	15.8	5.3	32.0	3.7	24.8	84.7
2020 Scenario	3.7	0.1	18.7	5.6	36.5	4.4	29.2	98.3
2020 Maximum Feasible	3.9	0.1	19.4	5.8	37.2	4.5	29.8	100.7
2030 Scenario	4.8	0.1	23.9	6.6	45.5	5.2	34.0	120.3
Wet NOx Deposition								
1985 Scenario	1.6	0.1	22.2	17.0	63.4	8.1	42.0	154.4
1985-2000 Calibration	1.3	0.1	17.9	13.9	51.7	6.6	35.4	126.9
2002 Scenario	1.1	0.1	14.1	11.0	40.9	5.2	29.4	101.8
2010 Scenario	0.7	0.1	9.4	7.3	26.7	3.4	19.6	67.2
2020 Scenario	0.6	0.0	7.2	5.3	19.3	2.5	14.7	49.6
2020 Maximum Feasible	0.5	0.0	6.4	4.7	16.9	2.2	13.3	44.1
2030 Scenario	0.5	0.0	6.2	4.6	16.7	2.2	13.0	43.3
Wet NH_3 Deposition								
1985 Scenario	0.9	0.1	12.0	8.7	30.9	3.9	22.0	78.6
1985-2000 Calibration	1.0	0.1	11.8	8.2	30.3	3.7	22.3	77.4
2002 Scenario	1.0	0.1	11.7	7.8	29.7	3.6	22.5	76.4
2010 Scenario	1.0	0.1	11.3	7.3	28.3	3.5	21.7	73.0
2020 Scenario	1.0	0.1	12.0	7.4	29.2	3.6	22.7	76.1
2020 Maximum Feasible	1.0	0.1	11.8	7.4	28.9	3.6	22.4	75.1
2030 Scenario	1.1	0.1	13.0	8.1	32.2	3.9	24.1	82.4

Table 3. Direct atmospheric deposition loads of nitrogen to the tidal Chesapeake Bay for key scenarios. Units in millions of pounds as N.

SCENARIO	Wet NO_x Deposition	Dry NO_x Deposition	Wet NH_3 Deposition	Dry NH_3 Deposition	Total Inorganic Nitrogen Deposition	Wet Organic Nitrogen Deposition	Total Nitrogen Deposition	Wet PO_4 Deposition	Wet Organic Phosphorus Deposition	Total Phosphorus Deposition
1985 Scenario	6.57	13.15	3.34	1.97	25.03	1.05	26.08	0.33	0.98	1.30
2002 Scenario	4.81	10.04	3.57	2.12	20.54	1.05	21.60	0.33	0.98	1.30
2010 Scenario	3.27	6.85	3.49	2.76	16.36	1.05	17.42	0.33	0.98	1.30
2020 Scenario	2.56	5.11	3.72	3.24	14.63	1.05	15.68	0.33	0.98	1.30
2020 Maximum Feasible	2.30	4.48	3.64	3.41	13.84	1.05	14.89	0.33	0.98	1.30
2030 Scenario	2.22	4.30	3.96	4.08	14.56	1.05	15.61	0.33	0.98	1.30

Atmospheric Deposition Cap Load Allocations

Atmospheric deposition loads to the Chesapeake are from the watershed (indirect atmospheric loads), from direct deposition to Chesapeake tidal waters, and from deposition to coastal waters with subsequent exchange between Bay and adjacent coastal waters.

In the 2003 Assessment, EPA had an 8 million pound allocation for atmospheric deposition. This allocation was counted as what was deposited on the watershed and delivered to the Bay due to the Clean Air Interstate Rule (CAIR). This was possible because the CAIR were newly proposed regulations that provided load reductions over and above what we were tracking in our key air scenarios at the time.

Currently, the consensus within the Bay Program is that the precedent that EPA set in the 2003 Allocations should be continued, and that an atmospheric deposition allocation to EPA should be made. The draft 202A Executive Order Report provides the direction that “EPA would establish air deposition allocations as part of the load allocations for the Bay TMDL” as well as analyzing “whether additional reductions are needed to meet the air deposition load allocations developed under the Bay TMDL”. An assessment of the need for additional atmospheric deposition reductions would be made through “the establishment and adoption of each new set of federal 2-year milestones, EPA would reevaluate ongoing and planned regulations and actions for reducing nitrogen emissions and deposition and consider whether additional actions are warranted”.

Direct Deposition Loads Are A Direct Allocation to EPA

The watershed loads are only a portion of the total loads to the Chesapeake, and there is a growing recognition that the atmospheric deposition to tidal waters should be a part of the overall allocations. Accordingly, direct deposition loads to the tidal Chesapeake are proposed as a direct allocation to EPA. This would increase the total allocation loads to the Chesapeake but would more correctly quantify the total loads to the Chesapeake influencing water quality.

The potential also exists for the direct deposition to the coastal waters to also be a part of the EPA allocation, but the potential for the quantification of the coastal ocean loads on the overall allocation has yet to be demonstrated.

Indirect Atmospheric Deposition Loads Are An Assumed Load Allocation to EPA
A separate allocation for watershed (indirect) atmospheric loads are infeasible to account for directly due to the computational burden imposed. For example, a computation of indirect atmospheric deposition loads to a land use must track the total nutrients including the mix with fertilizer and manure loads at every time step, the uptake and transformation by crops, grass, or woodland trees, the amelioration by BMPs, and the transport to the Bay. However, EPA could established assumed allocations for atmospheric loads delivered to the watershed, in which allocations to the states would assume some reduction in atmospheric deposition. EPA would be responsible for meeting these assumed reductions, and progress would be tracked through 2-year milestones.

Reductions by CBP States Beyond the CAA
In cases where implementation of air emission reductions go beyond the federally mandated Clean Air Act air quality standards, the States will be able to take credit in their nutrient allocations for atmospheric deposition both to their State, and in the Chesapeake watershed beyond their State. Atmospheric deposition loads that go beyond achieving the CAA air quality Standards would be those air emission reduction not counted in the CAA 2008 State Implementation Plan or in the subsequent SIP calls required for CAA compliance.

Adjusting the Ocean Boundary Conditions for Reductions in Atmospheric Deposition to Coastal Waters

The CMAQ Model allows us to estimate atmospheric deposition loads to the coastal ocean. The estimated distribution of 2001 atmospheric deposition loads to North America and adjacent coastal ocean is shown in Figure 1. A mass balance of nitrogen in coastal ocean waters (Howarth,1998) are that atmospheric deposition loads are roughly equivalent to watershed loads in the Northeast U.S. The Northeast includes all watersheds from Maine to Virginia draining to the Atlantic. Howarth estimates that the watershed inputs of nitrogen to the Northeast coastal waters to be 0.27 teragrams (10^{12} grams). Inputs from direct atmospheric deposition to coastal waters are 0.21 teragrams, and inputs from deep ocean upwelling are 1.54 teragrams.

This has implications for the fixed ocean boundary condition used in the Water Quality Sediment Transport Model (WQSTM). Atmospheric deposition total nitrogen loads to the tidal Bay are estimated to be 21.6 million pounds in the Base Case 2002 Scenario and 14.89 million pounds in the 2020 Maximum Feasible Scenario, a reduction of 31%. If we extrapolate this same reduction to the coastal ocean the direct atmospheric inputs to the coastal ocean would decrease to 0.15 teragrams. Assuming the watershed loads discharged to the ocean and the and deep upwelling pelagic loads are constant, that would give a combined watershed, direct deposition, and uncontrollable deep upwelling load of 1.96 teragrams, a decrease of 3% relative to the estimated current ocean boundary condition.

To determine CMAQ estimates of atmospheric deposition to the coastal ocean region effecting nitrogen loads through the ocean boundary we arbitrarily assigned boundaries as shown in Figure 2. This boundary is adjacent to the shore, and is inside, or west, of the Gulf Stream. To account for the prevailing north to south current along the coast, the coastal ocean boundary includes more of the coastal waters north of the Chesapeake mouth.

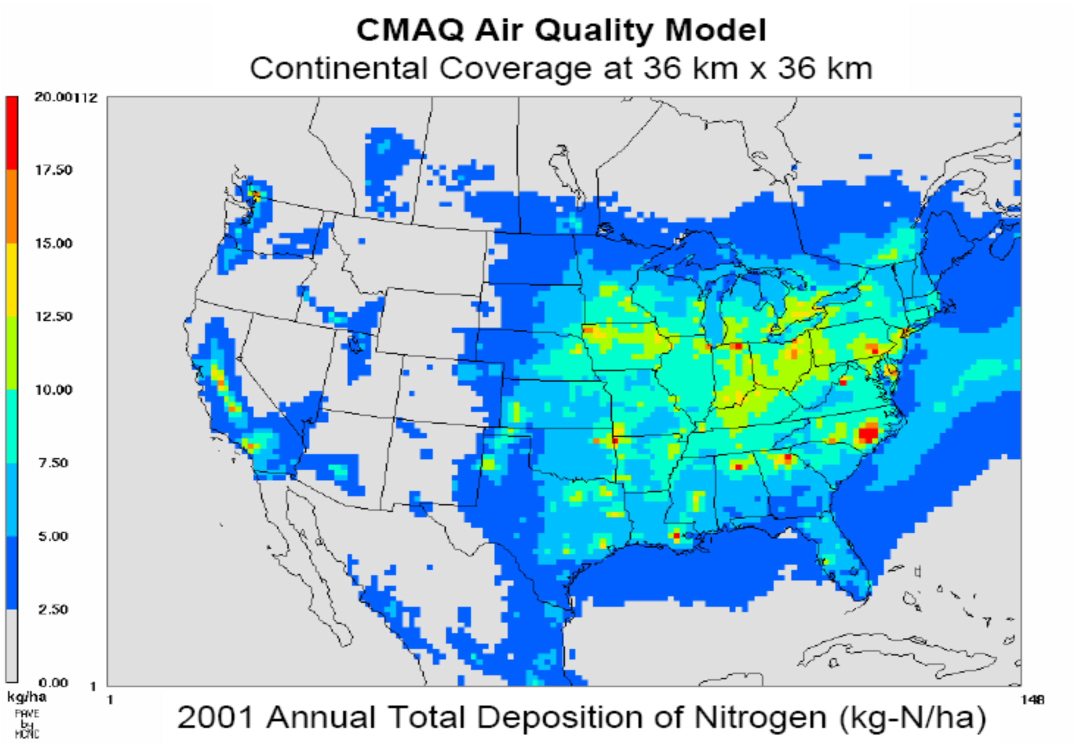

Figure 1. Estimated CMAQ atmospheric deposition loads to North America and adjacent coastal ocean. Atmospheric deposition loads are approximately equal to watershed loads in the Northeast U.S. (Howarth, 1998).

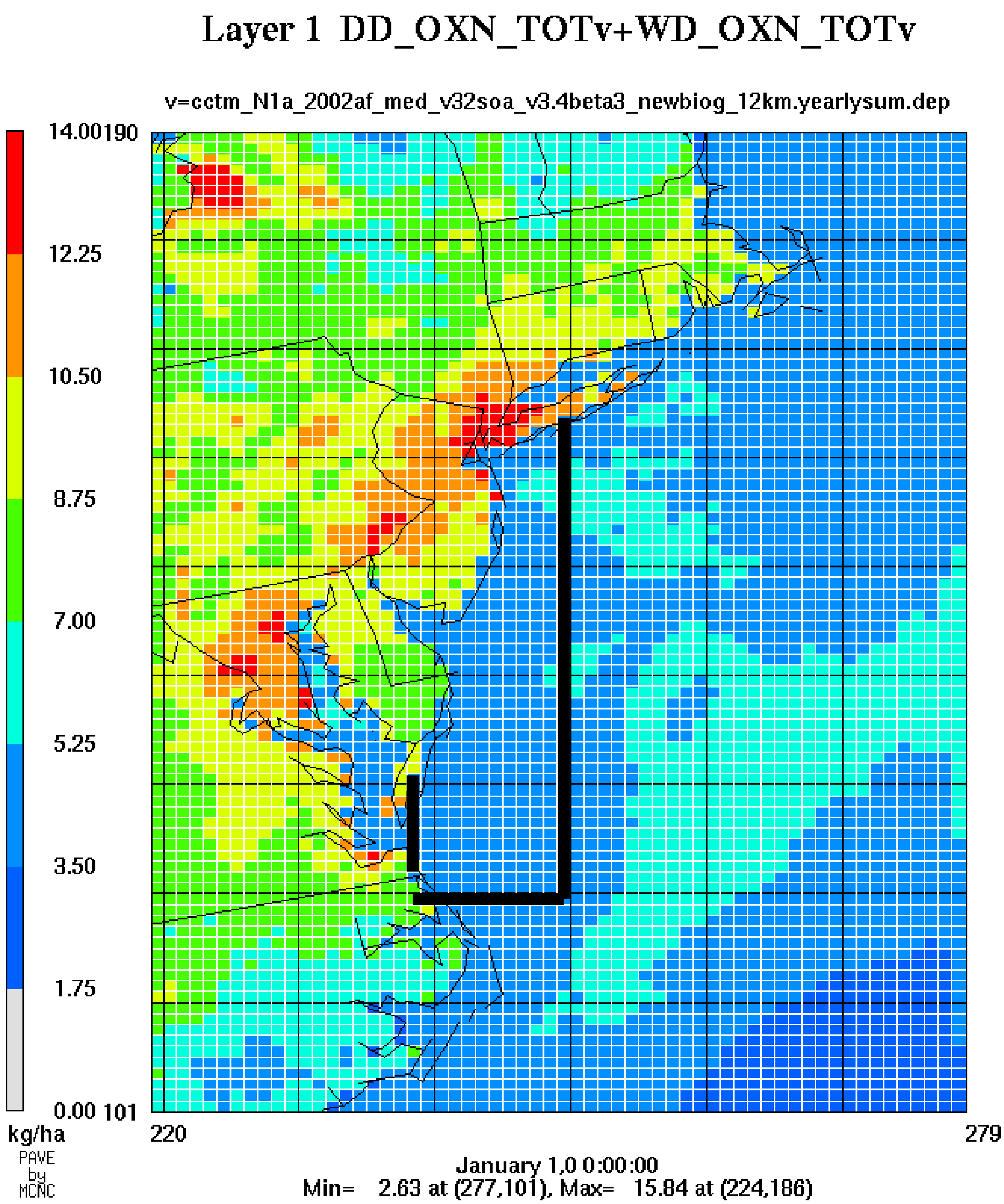

Figure 2. Boundaries of the coastal ocean region used to adjust the ocean boundary conditions in the WQSTM.

KEY POINTS

- Watershed atmospheric deposition loads (indirect loads) are proposed to be an assumed EPA allocation.
- Direct atmospheric deposition loads to the tidal Bay are proposed to a direct allocation to the EPA.

- Only air emission reductions beyond what’s needed to comply with CAA air quality standards are eligible to count toward meeting the CBP basin-state allocations.

- The potential for estimates of atmospheric deposition loads to coastal waters adjacent to the Chesapeake will be explored for the adjustment of model boundary conditions for nitrogen in the Water Quality and Sediment Transport Model as appropriate.