Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus and Sediment

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Appendix A.
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Tetra Tech, Inc.

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Appendix B.
Index of Documents Supporting the Chesapeake Bay TMDL

This index of documents (with URL links for direct electronic access) includes materials EPA and its seven watershed jurisdictional partners relied upon during development of the Chesapeake Bay TMDL. These documents include but are not limited to data, analyses, computer programs, computer model code, scientific/technical references used or cited in the main Bay TMDL document, correspondence, agreements, directives, strategies, plans, independent peer reviews, workshop proceedings, and other supporting materials. Access to advance briefing materials, presentations, issue papers, and summaries of relevant partnership meetings and conference calls related to development of the Bay TMDL are fully cataloged in Appendix C.

The listed documents are organized by subcategories by date of publication to assist the reader in locating documents of interest. For each listed document, full reference citation (in the case of a formal publication) and URL address for direct web-based electronic access to the document are provided. In the case of reference to data, the data repository and the URL address for direct electric access to the data are provided. Some of the individual documents are listed in multiple categories to aid the readers to get access the correct documents.

The ultimate objective of this appendix is to ensure direct public access to the full array of data, documentation, models, tools, and computer programming that supported development of the Chesapeake Bay TMDL.

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Appendix C.
Record of Chesapeake Bay TMDL Related Chesapeake Bay Program Committee, Team and Workgroup and Partner/Stakeholder Meetings

This appendix presents the dates of Chesapeake Bay Program (CBP) committee, team, and workgroup meetings since 2005 where the Chesapeake Bay TMDL or a directly related topic was on the agenda (Table C-1). A URL is provided to access the Chesapeake Bay Program website's calendar of events and each meeting's respective agenda, advance briefing materials, presentations or meeting summary.

This appendix also documents the record of Chesapeake Bay Program committee/workgroup and stakeholder meetings since 2008 where the Chesapeake Bay TMDL was a principal topic of the meeting (Table C-2). The abbreviations used in Table C-2 are explained in Tables C-3 (EPA staff names) and C-4 (organizations).

Table C-1. Record of CBP Office committee, team, and workgroup meetings/conference calls where the Chesapeake Bay TMDL or a directly related topic was on the meeting/conference call agenda

Date	Group	URL
January 10, 2005	Executive Council	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5851&DefaultView=all&RequestDate=01/17/2005
January 11, 2005	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5937&DefaultView=all&RequestDate=01/17/2005
January 12, 2005	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5858&DefaultView=all&RequestDate=01/17/2005
January 25, 2005	Sediment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5802&DefaultView=all&RequestDate=01/17/2005
February 15, 2005	Urban Stormwater Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5749&DefaultView=all&RequestDate=02/17/2005
February 17, 2005	Implementation Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5507&DefaultView=all&RequestDate=02/17/2005
February 22, 2005	Sediment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5755&DefaultView=all&RequestDate=02/17/2005
February 23, 2005	Nutrient Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5721&DefaultView=all&RequestDate=02/17/2005
April 4, 2005	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5932&DefaultView=all&RequestDate=04/17/2005
April 5, 2005	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5933&DefaultView=all&RequestDate=04/17/2005
April 28, 2005	Sediment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5803&DefaultView=all&RequestDate=04/17/2005
May 3, 2005	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5934&DefaultView=all&RequestDate=05/17/2005
May 5, 2005	Water-Quality Criteria Assessment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6366&DefaultView=all&RequestDate=05/17/2005
June 7, 2005	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5935&DefaultView=all&RequestDate=06/17/2005
June 21, 2005	Sediment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5756&DefaultView=all&RequestDate=06/17/2005
June 22, 2005	Principals' Staff Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6371&DefaultView=all&RequestDate=06/17/2005
July 12, 2005	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5976&DefaultView=all&RequestDate=07/17/2005
July 13, 2005	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5977&DefaultView=all&RequestDate=07/17/2005
July 14, 2005	Water-Quality Criteria Assessment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6363&DefaultView=all&RequestDate=07/17/2005
July 21, 2005	Implementation Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5512&DefaultView=all&RequestDate=07/17/2005
July 21, 2005	Water-Quality Criteria Assessment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6393&DefaultView=all&RequestDate=07/17/2005
July 28, 2005	Water-Quality Criteria Assessment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6480&DefaultView=all&RequestDate=07/17/2005
August 3, 2005	Water-Quality Criteria Assessment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6483&DefaultView=all&RequestDate=08/17/2005
August 18, 2005	Water-Quality Criteria Assessment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6527&DefaultView=all&RequestDate=08/17/2005
August 24, 2005	Nutrient Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5728&DefaultView=all&RequestDate=08/17/2005

Table C-2. Record of CBP Office committee, team, and workgroup meetings/conference calls where the Chesapeake Bay TMDL or a directly related topic was on the meeting/conference call agenda (continued)

Date	Group	URL
September 13-14, 2005	Scientific and Technical Advisory Committee	http://www.chesapeake.org/stac/MeetInfo/Sept05Mins.pdf
September 28, 2005	Nutrient Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5729&DefaultView=all&RequestDate=09/17/2005
October 3, 2005	Principals' Staff Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6619&DefaultView=all&RequestDate=10/17/2005
October 11, 2005	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5980&DefaultView=all&RequestDate=10/17/2005
October 13, 2005	Agricultural Nutrient Reduction Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5672&DefaultView=all&RequestDate=10/17/2005
October 26, 2005	Nutrient Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5730&DefaultView=all&RequestDate=10/17/2005
October 27, 2005	Sediment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5806&DefaultView=all&RequestDate=10/17/2005
November 21, 2005	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6844&DefaultView=all&RequestDate=11/17/2005
December 7, 2005	Nutrient Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=5950&DefaultView=all&RequestDate=12/17/2005
December 13-14, 2005	Scientific and Technical Advisory Committee	http://www.chesapeake.org/stac/MeetInfo/Dec05Mins.pdf
December 19, 2005	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6845&DefaultView=all&RequestDate=12/17/2005
December 21, 2005	Urban Stormwater Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6957&DefaultView=all&RequestDate=12/17/2005
January 9, 2006	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6934&DefaultView=all&RequestDate=01/17/2006
January 19, 2006	Sediment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6832&DefaultView=all&RequestDate=01/17/2006
January 23, 2006	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6935&DefaultView=all&RequestDate=01/17/2006
January 24-25, 2006	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6940&DefaultView=all&RequestDate=01/17/2006
February 23, 2006	Sediment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6985&DefaultView=all&RequestDate=02/21/2006
February 27, 2006	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6936&DefaultView=all&RequestDate=02/17/2006
March 14-15, 2006	Scientific and Technical Advisory Committee	http://www.chesapeake.org/stac/MeetInfo/Mar06Mins.pdf
March 20, 2006	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6937&DefaultView=all&RequestDate=03/17/2006
April 4-5, 2006	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=7065&DefaultView=all&RequestDate=4/17/2006
April 17, 2006	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6938&DefaultView=all&RequestDate=04/01/2006

Table C-2. Record of CBP Office committee, team, and workgroup meetings/conference calls where the Chesapeake Bay TMDL or a directly related topic was on the meeting/conference call agenda (continued)

Date	Group	URL
April 25, 2006	Water Quality Assessment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=7293&DefaultView=all&RequestDate=04/21/2006
April 27, 2006	Sediment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6986&DefaultView=all&RequestDate=04/21/2006
May 16, 2006	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=7072&DefaultView=all&RequestDate=05/21/2006
May 22, 2006	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=7290&DefaultView=all&RequestDate=05/21/2006
May 24, 2006	Nutrient Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6848&DefaultView=all&RequestDate=05/21/2006
June 7-8, 2006	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=7081&DefaultView=all&RequestDate=06/21/2006
June 29, 2006	Sediment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6987&DefaultView=all&RequestDate=06/21/2006
July 18-19, 2006	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=7066&DefaultView=all&RequestDate=07/21/2006
July 27, 2006	Water Quality Assessment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=7453&DefaultView=all&RequestDate=07/21/2006
August 21, 2006	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=7455&DefaultView=all&RequestDate=08/21/2006
August 28, 2006	Sediment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=7569&DefaultView=all&RequestDate=08/21/2006
August 30, 2006	Nutrient Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=7450&DefaultView=all&RequestDate=08/01/2006
September 6, 2006	Tributary Strategy Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=7460&DefaultView=all&RequestDate=09/01/2006
September 18, 2006	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=7456&DefaultView=all&RequestDate=09/01/2006
September 27, 2006	Nutrient Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6896&DefaultView=all&RequestDate=09/01/2006
October 2, 2006	Tributary Strategy Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6776&DefaultView=all&RequestDate=10/01/2006
October 16, 2006	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=7457&DefaultView=all&RequestDate=10/01/2006
October 17-18, 2006	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=7067&DefaultView=all&RequestDate=10/01/2006
October 26, 2006	Sediment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6988&DefaultView=all&RequestDate=10/21/2006
November 2, 2006	Nutrient Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6777&DefaultView=all&RequestDate=11/01/2006
November 6, 2006	Tributary Strategy Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6777&DefaultView=all&RequestDate=11/01/2006
November 14-15, 2006	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=7684&DefaultView=all&RequestDate=11/01/2006
December 12, 2006	Sediment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6989&DefaultView=all&RequestDate=12/01/2006
December 13, 2006	Nutrient Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=6763&DefaultView=all&RequestDate=12/21/2006
January 9-10, 2007	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=7849&DefaultView=all&RequestDate=01/01/2007

Table C-2. Record of CBP Office committee, team, and workgroup meetings/conference calls where the Chesapeake Bay TMDL or a directly related topic was on the meeting/conference call agenda (continued)

Date	Group	URL
January 16, 2007	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=8083&DefaultView=all&RequestDate=01/01/2007
March 1, 2007	Sediment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=8045&DefaultView=all&RequestDate=03/01/2007
March 5, 2007	Tributary Strategy Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=7819&DefaultView=all&RequestDate=03/01/2007
March 6-7, 2007	Scientific and Technical Advisory Committee	http://www.chesapeake.org/stac/MeetInfo/March07Minutes.pdf
March 8, 2007	Agricultural Nutrient Reduction Workshop	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=7896&DefaultView=all&RequestDate=03/11/2007
March 26, 2007	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=8087&DefaultView=all&RequestDate=03/01/2007
March 30, 2007	Urban Stormwater Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=8269&DefaultView=all&RequestDate=03/18/2007
April 3-4, 2007	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=8028&DefaultView=all&RequestDate=04/18/2007
June 4, 2007	Tributary Strategy Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=7823&DefaultView=all&RequestDate=06/18/2007
June 6, 2007	Nutrient Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=8255&DefaultView=all&RequestDate=06/18/2007
June 12-13, 2007	Scientific and Technical Advisory Committee	http://www.chesapeake.org/stac/MeetInfo/Jun07Minutes.pdf
June 20-21, 2007	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=8501&DefaultView=all&RequestDate=06/18/2007
July 10-11, 2007	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=8678&DefaultView=all&RequestDate=07/18/2007
July 23, 2007	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=8823&DefaultView=all&RequestDate=07/18/2007
July 24, 2007	Wastewater Treatment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=8813&DefaultView=all&RequestDate=07/18/2007
August 6, 2007	Tributary Strategy Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=8816&DefaultView=all&RequestDate=08/18/2007
August 27, 2007	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=8824&DefaultView=all&RequestDate=08/18/2007
September 11, 2007	Scientific and Technical Advisory Committee	http://www.chesapeake.org/stac/meetings
September 17, 2007	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=8825&DefaultView=all&RequestDate=09/18/2007
October 1, 2007	Principals' Staff Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9029&DefaultView=all&RequestDate=10/18/2007
October 9, 2007	Sediment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9034&DefaultView=all&RequestDate=10/18/2007

Table C-2. Record of CBP Office committee, team, and workgroup meetings/conference calls where the Chesapeake Bay TMDL or a directly related topic was on the meeting/conference call agenda (continued)

Date	Group	URL
October 15, 2007	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=8030&DefaultView=all&RequestDate=10/18/2007
October 15, 2007	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=8826&DefaultView=all&RequestDate=10/18/2007
October 25, 2007	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9098&DefaultView=all&RequestDate=10/18/2007
November 16, 2007	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9194&DefaultView=all&RequestDate=11/18/2007
November 19, 2007	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=8827&DefaultView=all&RequestDate=11/18/2007
December 11-12, 2007	Scientific and Technical Advisory Committee	http://www.chesapeake.org/stac/December2007quarterly.html
December 17, 2007	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9246&DefaultView=all&RequestDate=12/18/2007
December 17, 2007	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=8829&DefaultView=all&RequestDate=12/18/2007
December 18, 2007	Tributary Strategy Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9212&DefaultView=all&RequestDate=12/18/2007
January 8, 2008	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9046&DefaultView=all&RequestDate=01/18/2008
January 10, 2008	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9301&DefaultView=all&RequestDate=01/18/2008
January 22, 2008	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9043&DefaultView=all&RequestDate=01/18/2008
January 23, 2008	Nutrient Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9159&DefaultView=all&RequestDate=01/18/2008
January 24, 2008	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9302&DefaultView=all&RequestDate=01/18/2008
January 31, 2008	Wastewater Treatment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9296&DefaultView=all&RequestDate=01/18/2008
February 7, 2008	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9356&DefaultView=all&RequestDate=02/18/2008
February 28, 2008	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9369&DefaultView=all&RequestDate=02/18/2008
March 5, 2008	Wastewater Treatment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9374&DefaultView=all&RequestDate=03/18/2008
March 13, 2008	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9370&DefaultView=all&RequestDate=03/18/2008
March 17, 2008	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9377&DefaultView=all&RequestDate=03/18/2008

Table C-2. Record of CBP Office committee, team, and workgroup meetings/conference calls where the Chesapeake Bay TMDL or a directly related topic was on the meeting/conference call agenda (continued)

Date	Group	URL
March 19, 2008	Principals' Staff Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9413&DefaultView=all&RequestDate=03/18/2008
March 25-26, 2008	Scientific and Technical Advisory Committee	http://www.chesapeake.org/stac/march2008quarterly.html
March 26, 2008	Nutrient Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9161&DefaultView=all&RequestDate=03/18/2008
March 27, 2008	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9422&DefaultView=all&RequestDate=03/18/2008
April 8, 2008	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9414&DefaultView=all&RequestDate=04/18/2008
April 10, 2008	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9471&DefaultView=all&RequestDate=04/18/2008
April 22-23, 2008	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9376&DefaultView=all&RequestDate=04/18/2008
April 28-29, 2008	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9316&DefaultView=all&RequestDate=04/18/2008
May 19, 2008	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9486&DefaultView=all&RequestDate=05/20/2008
May 27, 2008	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9537&DefaultView=all&RequestDate=05/20/2008
June 2, 2008	Tributary Strategy Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9155&DefaultView=all&RequestDate=06/20/2008
June 3, 2008	Scientific and Technical Advisory Committee	http://www.chesapeake.org/stac/june2008quarterly.html
June 5, 2008	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9538&DefaultView=all&RequestDate=06/20/2008
June 18-19, 2008	Principals' Staff Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9553&DefaultView=all&RequestDate=06/20/2008
June 19, 2008	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9539&DefaultView=all&RequestDate=06/20/2008
June 24, 2008	Urban Stormwater Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9233&DefaultView=all&RequestDate=06/20/2008
July 2, 2008	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9048&DefaultView=all&RequestDate=07/20/2008
July 3, 2008	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9540&DefaultView=all&RequestDate=07/20/2008
July 14, 2008	Urban Stormwater Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9639&DefaultView=all&RequestDate=07/20/2008
July 17, 2008	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9541&DefaultView=all&RequestDate=07/20/2008

Table C-2. Record of CBP Office committee, team, and workgroup meetings/conference calls where the Chesapeake Bay TMDL or a directly related topic was on the meeting/conference call agenda (continued)

Date	Group	URL
July 21, 2008	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9534&DefaultView=all&RequestDate=07/20/2008
July 23, 2008	Reasonable Assurance Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9734&DefaultView=all&RequestDate=07/20/2008
August 4, 2008	Watershed Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9725&DefaultView=all&RequestDate=08/20/2008
August 6, 2008	Reasonable Assurance Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9735&DefaultView=all&RequestDate=08/20/2008
August 14, 2008	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9543&DefaultView=all&RequestDate=08/20/2008
August 19, 2008	Agricultural Nutrient Reduction Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9619&DefaultView=all&RequestDate=08/20/2008
August 19, 2008	Reasonable Assurance Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9736&DefaultView=all&RequestDate=08/20/2008
August 21-22, 2008	Citizens Advisory Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9299&DefaultView=all&RequestDate=08/20/2008
September 8-9, 2008	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9721&DefaultView=all&RequestDate=09/20/2008
September 12, 2008	Reasonable Assurance Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9733&DefaultView=all&RequestDate=09/20/2008
September 16-17, 2008	Scientific and Technical Advisory Committee	http://www.chesapeake.org/stac/september2008quarterly.html
September 18, 2008	Urban Stormwater Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9728&DefaultView=all&RequestDate=09/20/2008
September 22, 2008	Principals' Staff Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9784&DefaultView=all&RequestDate=09/20/2008
September 25, 2008	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9546&DefaultView=all&RequestDate=09/20/2008
September 29, 2008	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9536&DefaultView=all&RequestDate=09/20/2008
October 6, 2008	Tributary Strategy Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9157&DefaultView=all&RequestDate=10/20/2008
October 9, 2008	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9547&DefaultView=all&RequestDate=10/20/2008
October 20, 2008	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9780&DefaultView=all&RequestDate=10/20/2008
October 20, 2008	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9773&DefaultView=all&RequestDate=10/20/2008

Table C-2. Record of CBP Office committee, team, and workgroup meetings/conference calls where the Chesapeake Bay TMDL or a directly related topic was on the meeting/conference call agenda (continued)

Date	Group	URL
October 22, 2008	Nutrient Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9168&DefaultView=all&RequestDate=10/20/2008
October 23, 2008	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9548&DefaultView=all&RequestDate=10/20/2008
October 30, 2008	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9775&DefaultView=all&RequestDate=10/20/2008
October 31, 2008	Principals' Staff Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9865&DefaultView=all&RequestDate=10/20/2008
November 6-7, 2008	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9795&DefaultView=all&RequestDate=11/20/2008
November 19, 2008	Agricultural Nutrient Reduction Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9922&DefaultView=all&RequestDate=11/20/2008
November 20, 2008	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9777&DefaultView=all&RequestDate=11/28/2008
November 20, 2008	Chesapeake Executive Council	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9923&DefaultView=all&RequestDate=11/20/2008
November 21, 2008	Sediment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9800&DefaultView=all&RequestDate=11/28/2008
November 26, 2008	Wastewater Treatment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9916&DefaultView=all&RequestDate=11/28/2008
December 4, 2008	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9778&DefaultView=all&RequestDate=12/28/2008
December 8, 2008	Tributary Strategy Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9158&DefaultView=all&RequestDate=12/28/2008
December 9-10, 2008	Scientific and Technical Advisory Committee	http://www.chesapeake.org/stac/december08quarterly.html
December 11, 2008	Agricultural Nutrient Reduction Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9226&DefaultView=all&RequestDate=12/28/2008
December 11, 2008	Watershed Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9981&DefaultView=all&RequestDate=12/28/2008
December 15, 2008	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9774&DefaultView=all&RequestDate=12/28/2008
December 18, 2008	Chesapeake Action Plan Partners Meeting	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9211&DefaultView=all&RequestDate=12/19/2008
December 18, 2008	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9779&DefaultView=all&RequestDate=12/28/2008
January 6-7, 2009	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9964&DefaultView=all&RequestDate=01/28/2009
January 8, 2009	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9895&DefaultView=all&RequestDate=01/28/2009

Table C-2. Record of CBP Office committee, team, and workgroup meetings/conference calls where the Chesapeake Bay TMDL or a directly related topic was on the meeting/conference call agenda (continued)

Date	Group	URL
January 12, 2009	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9901&DefaultView=all&RequestDate=01/28/2009
January 13, 2009	Sediment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9980&DefaultView=all&RequestDate=01/28/2009
January 13, 2009	Principals' Staff Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10020&DefaultView=all&RequestDate=01/28/2009
January 14, 2009	Wastewater Treatment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10091&DefaultView=all&RequestDate=01/28/2009
January 15, 2009	Agricultural Nutrient Reduction Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9983&DefaultView=all&RequestDate=01/11/2009
January 22, 2009	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9896&DefaultView=all&RequestDate=01/28/2009
January 26, 2009	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9903&DefaultView=all&RequestDate=01/28/2009
February 2, 2009	Watershed Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9913&DefaultView=all&RequestDate=02/28/2009
February 5, 2009	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9897&DefaultView=all&RequestDate=02/28/2009
February 9, 2009	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9904&DefaultView=all&RequestDate=02/28/2009
February 17, 2009	Agricultural Nutrient Reduction Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9984&DefaultView=all&RequestDate=02/28/2009
February 17, 2009	Urban Stormwater Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10119&DefaultView=all&RequestDate=02/28/2009
February 18, 2009	Urban Stormwater Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10149&DefaultView=all&RequestDate=02/28/2009
February 19-20, 2009	Citizens Advisory Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9867&DefaultView=all&RequestDate=02/28/2009
February 23, 2009	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9920&DefaultView=all&RequestDate=02/28/2009
February 24, 2009	Urban Stormwater Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9955&DefaultView=all&RequestDate=02/28/2009
February 25, 2009	Nutrient Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9817&DefaultView=all&RequestDate=02/28/2009
February 26, 2009	Local Government Advisory Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9872&DefaultView=all&RequestDate=02/28/2009
March 9, 2009	Water Quality Steering Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9921&DefaultView=all&RequestDate=03/30/2009

Table C-2. Record of CBP Office committee, team, and workgroup meetings/conference calls where the Chesapeake Bay TMDL or a directly related topic was on the meeting/conference call agenda (continued)

Date	Group	URL
March 10-11, 2009	Scientific and Technical Advisory Committee	http://www.chesapeake.org/stac/march09quarterly.html
March 16, 2009	Water Quality Criteria Assessment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10153&DefaultView=all&RequestDate=03/30/2009
April 6, 2009	Watershed Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9914&DefaultView=all&RequestDate=04/30/2009
April 6, 2009	Water Quality Steering	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10096&DefaultView=all&RequestDate=04/30/2009
April 7-8, 2009	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9965&DefaultView=all&RequestDate=04/30/2009
April 15-16, 2009	Water Quality Steering	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10097&DefaultView=all&RequestDate=04/30/2009
April 16-17, 2009	Citizens Advisory Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9868&DefaultView=all&RequestDate=04/30/2009
April 20-21, 2009	Principals' Staff Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10103&DefaultView=all&RequestDate=04/30/2009
April 23-24, 2009	Local Government Advisory Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9991&DefaultView=all&RequestDate=04/30/2009
April 24, 2009	Water Quality Criteria Assessment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10238&DefaultView=all&RequestDate=04/11/2009
May 18, 2009	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10241&DefaultView=all&RequestDate=05/30/2009
June 1, 2009	Watershed Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9915&DefaultView=all&RequestDate=06/30/2009
June 9, 2009	Wastewater Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10305&DefaultView=all&RequestDate=06/30/2009
June 9, 2009	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10319&DefaultView=all&RequestDate=06/11/2009
June 16, 2009	Scientific and Technical Advisory Committee	http://www.chesapeake.org/stac/june09quarterly.html
June 22, 2009	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10242&DefaultView=all&RequestDate=06/30/2009
June 23, 2009	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10335&DefaultView=all&RequestDate=06/30/2009
July 6, 2009	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10345&DefaultView=all&RequestDate=07/30/2009
July 8, 2009	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9966&DefaultView=all&RequestDate=07/30/2009
July 20, 2009	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10243&DefaultView=all&RequestDate=07/30/2009
July 22, 2009	Principals' Staff Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10348&DefaultView=all&RequestDate=07/30/2009

Table C-2. Record of CBP Office committee, team, and workgroup meetings/conference calls where the Chesapeake Bay TMDL or a directly related topic was on the meeting/conference call agenda (continued)

Date	Group	URL
August 24, 2009	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10403&DefaultView=all&RequestDate=08/30/2009
September 3, 2009	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10406&DefaultView=all&RequestDate=09/30/2009
September 8-9, 2009	Scientific and Technical Advisory Committee	http://www.chesapeake.org/stac/sept09quarterly.html
September 9, 2009	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10244&DefaultView=all&RequestDate=09/30/2009
September 10, 2009	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10402&DefaultView=all&RequestDate=08/30/2009
September 14, 2009	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10458&DefaultView=all&RequestDate=09/30/2009
September 15, 2009	Urban Stormwater Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10408&DefaultView=all&RequestDate=09/30/2009
September 17-18, 2009	Citizens Advisory Committee/Local Government Advisory Committee	http://archive.chesapeakebay.net/calendar.cfm?eventdetails=9874
September 19, 2009	Watershed Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10193&DefaultView=all&RequestDate=08/30/2009
September 21, 2009	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10412&DefaultView=all&RequestDate=09/30/2009
September 29-30, 2009	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10404&DefaultView=all&RequestDate=09/30/2009
October 5, 2009	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10491&DefaultView=all&RequestDate=10/31/2009
October 6-7, 2009	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9967&DefaultView=all&RequestDate=10/31/2009
October 8, 2009	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10476&DefaultView=all&RequestDate=10/31/2009
October 9, 2009	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10492&DefaultView=all&RequestDate=10/31/2009
October 19, 2009	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10245&DefaultView=all&RequestDate=10/31/2009
October 22, 2009	Sediment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10526&DefaultView=all&RequestDate=10/26/2009
October 23, 2009	Principals' Staff Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10431&DefaultView=all&RequestDate=10/26/2009
October 27, 2009	Urban Stormwater Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9959&DefaultView=all&RequestDate=10/26/2009

Table C-2. Record of CBP Office committee, team, and workgroup meetings/conference calls where the Chesapeake Bay TMDL or a directly related topic was on the meeting/conference call agenda (continued)

Date	Group	URL
November 2, 2009	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10527&DefaultView=all&RequestDate=11/26/2009
November 5-6, 2009	Citizens Advisory Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9871&DefaultView=all&RequestDate=11/26/2009
November 18, 2009	Wastewater Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10547&DefaultView=all&RequestDate=11/26/2009
November 20, 2009	CAP-TMDL Tech call	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10554&DefaultView=all&RequestDate=11/26/2009
November 30, 2009	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10558&DefaultView=all&RequestDate=11/26/2009
December 8-9, 2009	Scientific and Technical Advisory Committee	http://www.chesapeake.org/stac/dec09quarterly.html
December 14, 2009	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10572&DefaultView=all&RequestDate=12/26/2009
December 15, 2009	Nonpoint BMP Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10573&DefaultView=all&RequestDate=12/26/2009
December 18, 2009	Sediment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10537&DefaultView=all&RequestDate=12/26/2009
December 18, 2009	Urban Stormwater Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=9962&DefaultView=all&RequestDate=12/26/2009
January 11, 2010	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10248&DefaultView=all&RequestDate=01/26/2010
February 1, 2010	Watershed Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10589&DefaultView=all&RequestDate=02/26/2010
February 5, 2010	Local Government Advisory Committee	http://archive.chesapeakebay.net/calendar.cfm?eventdetails=10636
February 12, 2010	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10249&DefaultView=all&RequestDate=02/26/2010
February 17, 2010	Reevaluation Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10113&DefaultView=all&RequestDate=02/28/2009
March 11, 2010	Citizens Advisory Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10555&DefaultView=all&RequestDate=03/26/2010
March 15, 2010	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10251&DefaultView=all&RequestDate=03/26/2010
March 23, 2010	Management Board	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10619&DefaultView=all&RequestDate=03/26/2010
March 29, 2010	Agriculture Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10714&DefaultView=all&RequestDate=03/26/2010
March 29, 2010	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10679&DefaultView=all&RequestDate=03/26/2010
March 31-April 1, 2010	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10657&DefaultView=all&RequestDate=04/26/2010

Table C-2. Record of CBP Office committee, team, and workgroup meetings/conference calls where the Chesapeake Bay TMDL or a directly related topic was on the meeting/conference call agenda (continued)

Date	Group	URL
April 5-6, 2010	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10559&DefaultView=all&RequestDate=04/26/2010
April 7, 2010	Forestry Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10715&DefaultView=all&RequestDate=04/26/2010
April 8, 2010	Citizens Advisory Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10556&DefaultView=all&RequestDate=04/26/2010
April 12, 2010	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10736&DefaultView=all&RequestDate=04/26/2010
April 19, 2010	Management Board	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10620&DefaultView=all&RequestDate=04/26/2010
April 19, 2010	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10738&DefaultView=all&RequestDate=04/26/2010
April 21, 2010	Watershed Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10590&DefaultView=all&RequestDate=04/26/2010
April 22, 2010	Wastewater Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10746&DefaultView=all&RequestDate=04/26/2010
April 22-24, 2010	Local Government Advisory Committee	http://archive.chesapeakebay.net/calendar.cfm?eventdetails=10637
April 26, 2010	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10737&DefaultView=all&RequestDate=04/26/2010
April 27, 2010	Agriculture Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10747&DefaultView=all&RequestDate=04/26/2010
April 28, 2010	Stormwater Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10775&DefaultView=all&RequestDate=04/26/2010
April 29-30, 2010	Principals' Staff Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10740&DefaultView=all&RequestDate=04/26/2010
May 3, 2010	Watershed Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10609&DefaultView=all&RequestDate=05/26/2010
May 5, 2010	Forestry Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10778&DefaultView=all&RequestDate=05/26/2010
May 10, 2010	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10776&DefaultView=all&RequestDate=05/26/2010
May 17, 2010	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10252&DefaultView=all&RequestDate=05/26/2010
May 21, 2010	CB Atmospheric Deposition Meeting	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10859&DefaultView=all&RequestDate=05/26/2010
May 24, 2010	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10851&DefaultView=all&RequestDate=05/26/2010
May 26, 2010	Urban/Suburban Stormwater Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10858&DefaultView=all&RequestDate=05/26/2010
May 27, 2010	Agriculture Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10862&DefaultView=all&RequestDate=05/26/2010
June 1, 2010	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10850&DefaultView=all&RequestDate=06/26/2010

Table C-2. Record of CBP Office committee, team, and workgroup meetings/conference calls where the Chesapeake Bay TMDL or a directly related topic was on the meeting/conference call agenda (continued)

Date	Group	URL
June 7, 2010	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10852&DefaultView=all&RequestDate=06/26/2010
June 8-9, 2010	Scientific and Technical Advisory Committee	http://www.chesapeake.org/stac/june10quarterly.html
June 17, 2010	Management Board	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10866&DefaultView=all&RequestDate=06/26/2010
June 21, 2010	Wastewater Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10879&DefaultView=all&RequestDate=06/26/2010
July 6, 2010	Water Quality GIT	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10933&DefaultView=all&RequestDate=07/26/2010
July 12, 2010	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10929&DefaultView=all&RequestDate=07/26/2010
July 13, 2010	Modeling Subcommittee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10658&DefaultView=all&RequestDate=07/26/2010
July 15-16, 2010	Citizen Advisory Meeting	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10562&DefaultView=all&RequestDate=07/26/2010
July 20, 2010	Management Board	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10929&DefaultView=all&RequestDate=07/26/2010
July 21, 2010	Wastewater Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10941&DefaultView=all&RequestDate=07/26/2010
July 22, 2010	Sediment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10939&DefaultView=all&RequestDate=07/26/2010
August 5-6, 2010	Local Government Advisory Committee	http://archive.chesapeakebay.net/calendar.cfm?eventdetails=10861
August 16, 2010	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10936&DefaultView=all&RequestDate=08/20/2010
September 13, 2010	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10937&DefaultView=all&RequestDate=09/20/2010
October 13, 2010	Sediment Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=11023&DefaultView=all&RequestDate=10/20/2010
October 21, 2010	Principals' Staff Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=11035&DefaultView=all&RequestDate=10/20/2010
October 25, 2010	Water Quality Goal Implementation Team	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10254&DefaultView=all&RequestDate=10/20/2010
November 4, 2010	Point Source Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=11080&DefaultView=all&RequestDate=11/20/2010
November 18-19, 2010	Citizens Advisory Committee	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=10557&DefaultView=all&RequestDate=11/20/2010
December 3, 2010	Local Government Advisory Committee	http://archive.chesapeakebay.net/calendar.cfm?eventdetails=10986
December 1, 2010	Watershed Technical Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=11111&DefaultView=all&RequestDate=12/20/2010
December 9, 2010	Analytical Methods and Quality Assurance Workgroup	http://archive.chesapeakebay.net/calendar.cfm?EventDetails=11113&DefaultView=all&RequestDate=12/20/2010
December 14-15, 2010	Scientific and Technical Advisory Committee	http://www.chesapeake.org/stac/dec10quarterly.html

Table C-3. Record of CBP committee/workgroup and stakeholder meetings since 2008 where the Chesapeake Bay TMDL was a principal topic of the meeting

Date	Meeting	Location	EPA/CBPO staff
January 9, 2008	VA DEQ	Richmond, VA	RB
January 10, 2008	DE DNREC	Dover, DE	RB
January 15, 2008	WVDEP, WVDA, WVCA	Charleston, WV	RB
January 18, 2008	PA DEP	Harrisburg, PA	RB
January 23, 2008	CBP STAC	Annapolis, MD	RB, LL
February 21, 2008	CBP CAC	Annapolis, MD	RB
March 10, 2008	Bay Funders Network	Washington, D.C.	RB
March 19, 2008	CBP PSC	Annapolis, MD	RB
March 21, 2008	Chesapeake Bay Foundation	Annapolis, MD	RB
March 28, 2008	MDE	Baltimore, MD	RB, JS
April 10, 2008	CBP RTWG	Annapolis, MD	RB, JS
April 11, 2008	PA DEP	Williamsport, PA	RB, BK
April 22-23, 2008	CBP WQSC	Fairfield, PA	BK, RB, JS, etc.
May 3, 2008	CBP STAC	Annapolis, MD	RB
June 6, 2008	EPA HQs briefing with Ben Grumbles	Washington, D.C.	BK, JS, JC, DW, etc.
June 16, 2008	Chesapeake Bay Foundation	Annapolis, MD	DE, BK, RB, JS
June 19, 2008	CBP PSC	Montross, VA	RB
August 19, 2008	Reasonable Assurance Action Team	Annapolis, MD	CD, JS
August 21, 2008	CBP LGAC	Annandale, VA	RB
August 26, 2008	Congressional Staff Bay Briefing and Boat Tour	Edgewater, MD	RB
September 17, 2008	CBP STAC	Ashburn, VA	JS
September 18, 2008	CBP USWG	Annapolis, MD	JS, AD, RP, KA
September 29, 2008	CBP WQSC	Conference Call	BK, RB, KA, JS, etc.
October 7, 2008	PA Public Television	State College, PA	RB
October 17, 2008	Society of Environmental Journalists	Roanoke, VA	RB
October 20, 2008	CBP WQSC	Conference Call	BK, RB, KA, JS, etc.
October 24, 2008	MDE and MDNR	Baltimore, MD	BK, RB, KA, JS
October 30, 2009	CBP RTWG	Rockville, MD	RB, JS
November 6-7, 2008	CBP WQSC	Shepherdstown, WV	BK, RB, KA, JS, etc.
November 18, 2008	Harrisburg Homebuilders	Harrisburg, PA	BK
November 19, 2008	Susquehanna River Basin Commission	Harrisburg, PA	RB

Table C-4. Record of CBP committee/workgroup and stakeholder meetings since 2008 where the Chesapeake Bay TMDL was a principal topic of the meeting (continued)

Date	Meeting	Location	EPA/CBPO staff
November 20, 2008	CBP Executive Council	Washington, D.C.	RB
December 15, 2008	CBP WQSC	Conference Call	BK, RB, KA, JS, etc.
January 6, 2009	VA DEQ, DCR	Richmond, VA	RB, BK
January 6, 2009	CBP Modeling Subcommittee	Annapolis, MD	LL, JS
January 12, 2009	CBP WQSC	Conference Call	BK, RB, KA, JS, etc.
January 23, 2009	PA Chamber of Commerce	Harrisburg, PA	BK
January 26, 2009	CBP WQSC	Conference Call	BK, RB, KA, JS, etc.
February 4, 2009	NYSDEC	Albany, NY	RB, BK
February 7, 2009	MD Tributary Teams Annual Meeting	Baltimore, MD	RB
February 9, 2009	CBP WQSC	Conference Call	BK, RB, KA, JS, etc.
February 11, 2009	Metropolitan Washington Council of Governments	Washington, D.C.	BK, RB, JS
February 11, 2009	DC DOE	Washington, D.C.	BK, RB, JS
February 13, 2009	PA DEP	Harrisburg, PA	BK
February 19, 2009	Chesapeake Bay Foundation	Philadelphia, PA	RB, BK, CD
February 20, 2009	CBP CAC	Annapolis, MD	RB
February 23, 2009	CBP WQSC	Conference Call	BK, RB, KA, JS, etc.
February 26, 2009	CBP LGAC	Annapolis, MD	RB
February 27, 2009	DE DNREC	Dover, DE	BK, RB, JS
March 5, 2009	PA Chesapeake Bay Advisory Committee	Harrisburg, PA	BK
March 9, 2009	CBP WQSC	Conference Call	BK, RB, KA, JS, etc.
March 12, 2009	WV DEP	Charleston, WV	RB
March 18, 2009	MDNR	Annapolis, MD	RB
March 23, 2009	Senator Brubaker (PA)	Harrisburg, PA	BK
March 24, 2009	CBP LGAC	Washington, D.C.	RB
April 1, 2009	VA Environmental Forum	Lexington, VA	BK
April 6, 2009	CBP WQSC	Conference Call	BK, RB, KA, JS, etc.
April 7, 2009	CBP Modeling Subcommittee	Annapolis, MD	LL, JS
April 14-15, 2009	CBP WQSC	Lancaster, PA	BK, RB, KA, JS, etc.
April 20, 2009	CBP PSC	Montross, VA	BK, RB, KA, etc.
April 30, 2009	Bay TMDL/Stormwater Webinar	Charlottesville, VA	AD, JS
May 8, 2009	Chesapeake Bay Commission	Washington, D.C.	BK

Table C-4. Record of CBP committee/workgroup and stakeholder meetings since 2008 where the Chesapeake Bay TMDL was a principal topic of the meeting (continued)

Date	Meeting	Location	EPA/CBPO staff
May 12, 2009	CBP Executive Council	Mount Vernon, VA	BK, RB, etc.
May 13, 2009	TMDL/NPS/WQS States Meeting	Martinsburg, WV	JS
May 15, 2009	Bay Funders Network	Washington, D.C.	RB
May 18, 2009	CBP WQSC	Conference Call	BK, RB, KA, JS, etc.
May 20, 2009	Senator Brubaker (PA)	Lancaster, PA	BK
May 21, 2009	NPDES States Meeting	Gettysburg, PA	JS
May 28-29, 2009	CBP STAC	Annapolis, MD	RB
June 1, 2009	Bay Executive Order Meeting	Arlington, VA	BK
June 9, 2009	Harrisburg Chamber of Commerce	Harrisburg, PA	BK
June 16, 2009	CBP STAC	Annapolis, MD	RB
June 22, 2009	CBP WQSC	Conference Call	BK, RB, KA, JS, etc.
July 1, 2009	WEF 2009 Nutrient Removal Conference	Washington, D.C.	BK
July 6, 2009	CBP WQSC	Conference Call	BK, RB, KA, JS, etc.
July 7, 2009	Municipal Water Quality Meeting	Washington, D.C.	BK
July 9, 2009	PA DEP - Executive Order	Harrisburg, PA	BK
July 9, 2009	Metropolitan Washington Council of Governments Water Resources Technical Committee	Washington, D.C.	KA
July 10, 2009	PA Transportation and Agricultural Group (Legacy Sediments)	Lancaster, PA	BK, JS
July 20, 2009	CBP WQSC	Conference Call	BK, RB, KA, JS, etc.
July 22, 2009	CBP PSC	Washington, D.C.	BK, RB, KA
August 4, 2009	USDA NRCS	Annapolis, MD	BK, RB, KA, JS, SH
August 4, 2009	Environmental Defense Fund	Annapolis, MD	BK, RB, KA, JS, SH
August 4, 2009	CBP LGAC webinar	Annapolis, MD	BK, RB
August 6, 2009	Hampton Roads Planning District Commission	Chesapeake, VA	KA
August 10, 2009	CBP WQSC	Conference Call	BK, RB, KA, JS, etc.
August 11, 2009	Chesapeake Bay Commission	Annapolis, MD	BK
August 12, 2009	Maryland Association of Counties	Ocean City, MD	BK
August 20, 2009	Lancaster Chamber of Commerce	Lancaster, PA	JS
August 24, 2009	CBP WQSC	Conference Call	BK, RB, KA, JS, etc.
August 25, 2009	Congressional Staff Bay Briefing and Boat Tour	Mason Neck, VA	RB
August 27, 2009	VA House of Delegates Natural Resources Committee - Chesapeake Bay Subcommittee	Gloucester, VA	RB

Table C-4. Record of CBP committee/workgroup and stakeholder meetings since 2008 where the Chesapeake Bay TMDL was a principal topic of the meeting (continued)

Date	Meeting	Location	EPA/CBPO staff
August 27, 2009	U.S. Department of Defense Chesapeake Quality Management Board	Aberdeen Proving Ground, MD	KA
September 3, 2009	PA Chesapeake Bay Advisory Committee	Harrisburg, PA	BK
September 8-9, 2009	CBP STAC	Annapolis, MD	RB
September 9, 2009	CBP WQSC	Conference Call	BK, RB, KA, JS, etc.
September 9, 2009	Chesapeake Bay Commission	Williamsburg, VA	BK
September 10, 2009	Metropolitan Washington Council of Governments Water Resources Technical Committee	Washington, D.C.	RB
September 14, 2009	CBP WQSC	Conference Call	BK, RB, KA, JS, etc.
September 17-18, 2009	CBP LGAC & CAC	Lancaster, PA	KA, RB
September 21, 2009	CBP WQSC	Conference Call	BK, RB, KA, JS, etc.
September 23, 2009	Susquehanna River Basin Commission Water Quality Advisory Committee	Harrisburg, PA	RB
September 29-30, 2009	CBP WQSC	Lancaster, PA	BK, RB, KA, etc.
October 2, 2009	Bay TMDL Public Meeting & Webinar	Richmond, VA	BK, RB
October 5, 2009	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
October 5, 2009	Mid-Atlantic Regional Air Management Association, Inc.	Towson, MD	RB
October 9, 2009	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
October 9-10, 2009	Chesapeake Watershed Forum	Shepherdstown, WV	BK
October 16, 2009	Pennsylvania State Senate/House members	Harrisburg, PA	RB
October 19, 2009	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
October 21, 2009	Lancaster County Agriculture Forum	Bird-in-Hand, PA	JS, KZ
October 22, 2009	Regulatory Update: Water Pollution Controls	Richmond, VA	RP
October 23, 2009	CBP PSC	Washington, D.C.	BK, RB, KA
October 27, 2009	USGS Chesapeake Bay Science Workshop	Shepherdstown, WV	RB
October 28, 2009	Anne Arundel County, MD	Annapolis, MD	RB, KS
November 2, 2009	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
November 2, 2009	National TMDL Conference	Washington, D.C.	JS
November 4, 2009	WV Region 9, local officials for planning, stormwater, wastewater, and economic development	Martinsburg, WV	BK, RB, JS, etc.
November 4, 2009	Eastern Panhandle Home Builders Association	Martinsburg, WV	BK, RB, JS, etc.
November 4, 2009	Bay TMDL Public Meeting & Webinar	Martinsburg, WV	BK, RB, JS, etc.

Table C-4. Record of CBP committee/workgroup and stakeholder meetings since 2008 where the Chesapeake Bay TMDL was a principal topic of the meeting (continued)

Date	Meeting	Location	EPA/CBPO staff
November 5, 2009	WV environmental and watershed groups at Freshwater Institute	Shepherdstown, WV	BK, RB, JS, etc.
November 5, 2009	Planning and utility directors at USDA offices	Martinsburg, WV	BK, RB, JS, etc.
November 5, 2009	Agricultural representatives at the WV Department of Agriculture	Moorefield, WV	BK, RB, JS, etc.
November 5, 2009	Bay TMDL Public Meeting	Moorefield, WV	BK, RB, JS
November 6, 2009	CBP CAC	Washington, D.C.	RB
November 16, 2009	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
November 16, 2009	Bay TMDL Public Meeting & Webinar	Washington, D.C.	BK, KA, JS
November 17, 2009	Bay TMDL Public Meeting	Wilkes-Barre, PA	BK, RB, JS
November 18, 2009	Pennsylvania Builders Association	Lemoyne, PA	BK, RB, JS
November 18, 2009	Environmental/conservation groups at Chesapeake Bay Foundation office	Harrisburg, PA	BK, RB, JS
November 18, 2009	Pennsylvania Municipal Authority Association	Wormleysburg, PA	BK, RB, JS
November 18, 2009	Bay TMDL Public Meeting	Williamsport, PA	BK, RB, JS
November 19, 2009	Lycoming County officials	Williamsport, PA	BK, RB, JS
November 19, 2009	NRCS State Technical Committee meeting	State College, PA	BK, RB, JS
November 19, 2009	Bay TMDL Public Meeting	State College, PA	BK, RB, JS
November 23, 2009	MDE, DNR, MDA, MDP Meeting on Bay TMDL and WIPs for Counties and Conservation Districts	Baltimore, MD	KA
November 23, 2009	Lancaster County government officials	Lancaster, PA	BK, RB, JS, SH
November 23, 2009	Bay TMDL Public Meeting & Webinar	Lancaster, PA	BK, RB, JS
November 30, 2009	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
December 1, 2009	Bay TMDL Public Meeting & Webinar	Binghamton, NY	BK, KA, TD
December 1, 2009	NY wastewater treatment operators	Binghamton, NY	BK, KA, TD
December 2, 2009	Rappahannock River Basin Comm.	Richmond, VA	RB
December 2, 2009	Upper Susquehanna Coalition	Owego, NY	BK, KA, TD
December 4, 2009	Water Resources Planning in MD: Hosted by CBF, MACo, MD Municipal League	Annapolis, MD	KA
December 4, 2009	CBP LGAC	Annapolis, MD	RB
December 8, 2009	CBP STAC	Annapolis, MD	RB
December 8, 2009	PA Chesapeake Bay Advisory Committee	Harrisburg, PA	BK
December 8, 2009	Bay TMDL Public Meeting & Webinar	Baltimore, MD	BK, RB, JS
December 9, 2009	Rappahannock River Symposium	Fredericksburg, VA	BK

Table C-4. Record of CBP committee/workgroup and stakeholder meetings since 2008 where the Chesapeake Bay TMDL was a principal topic of the meeting (continued)

Date	Meeting	Location	EPA/CBPO staff
December 10, 2009	Delaware and Maryland Homebuilders	Grasonville, MD	BK, KA, JS
December 10, 2009	Seaford, DE local officials and wastewater treatment plant operators	Seaford, DE	BK, KA, JS
December 10, 2009	Delaware and Maryland agricultural representatives at Delaware Poultry Industry office	Georgetown, DE	BK, KA, JS, HZ
December 10, 2009	Bay TMDL Public Meeting & Webinar	Laurel, DE	BK, KA, JS
December 11, 2009	Maryland and Delaware environmental/watershed/conservation groups	Annapolis, MD	BK, RB, JS, HZ
December 11, 2009	Bay TMDL Public Meeting	Wye Mills, MD	BK, RB, JS
December 14, 2009	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
December 14, 2009	Virginia environmental/watershed/conservation groups at CBF office	Richmond, VA	BK, RB, TD
December 14, 2009	Prince William County staff, planning commissioners, Board members, nonprofit conservation groups, Northern Virginia Industry	Prince William, VA	BK, RB, TD
December 14, 2009	Bay TMDL Public Meeting	Falls Church, VA	BK, RB, TD
December 15, 2009	Bay TMDL Public Meeting	Chesapeake, VA	BK, RB, TD
December 15, 2009	Virginia Farm Bureau and other agricultural organizations	Williamsburg, VA	BK, RB, TD
December 15, 2009	Bay TMDL Public Meeting	Williamsburg, VA	BK, RB, TD
December 16, 2009	National Academy of Sciences	Washington, D.C.	BK, RB, TD
December 16, 2009	Waste Solutions Forum steering committee meeting	Harrisonburg, VA	BK, RB, TD
December 16, 2009	Bay TMDL Public Meeting	Penn Laird, VA	BK, RB, TD
December 16, 2009	Region 3 State Nonpoint Source Managers Meeting	Frederick, MD	KA
December 17, 2009	Homebuilders Association of Virginia	Richmond, VA	BK, RB, TD
December 17, 2009	VA Watershed Implementation Plan stakeholder group	Richmond, VA	BK, RB, TD
December 17, 2009	Rivanna River Basin Commission - Local government officials and environmental groups	Charlottesville, VA	BK, RB, TD
December 17, 2009	Bay TMDL Public Meeting	Fredericksburg, VA	BK, RB, TD
December 18, 2009	George Washington Regional Commission	Fredericksburg, VA	RB, TD
December 18, 2009	VAMWA	Fredericksburg, VA	RB, TD
January 7, 2010	Maryland Association of Counties	Cambridge, MD	KA
January 8, 2010	World Resources Institute	Washington, D.C.	RB, PG
January 10-12, 2010	Choose Clean Water Conference	Washington, D.C.	BK, RB
January 11, 2010	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
January 12, 2010	VA General Assembly Joint Commission on Administrative Rules	Richmond, VA	RB

Table C-4. Record of CBP committee/workgroup and stakeholder meetings since 2008 where the Chesapeake Bay TMDL was a principal topic of the meeting (continued)

Date	Meeting	Location	EPA/CBPO staff
January 20, 2010	VA House of Delegates Natural Resources, Chesapeake Bay, and Agriculture Committee/Senate Natural Resources, Conservation and Agriculture Committee	Richmond, VA	RB
January 20, 2010	Symposium on Integrated Modeling and Analysis to Support the Management and Restoration of Large Aquatic Ecosystems	Washington, D.C.	MH, LL, GS
January 29, 2010	American Academy of Environmental Engineering	Washington, D.C.	RB
February 2, 2010	CBP Modeling Subcommittee	Annapolis, MD	LL
February 5, 2010	CBP LGAC	Annapolis, MD	JL
February 9, 2010	MDE Meeting on Bay TMDL and WIPs	Baltimore, MD	KA
February 12, 2010	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
February 18, 2010	Virginia Polytechnic Institute and State University	Blacksburg, VA	RB
February 19, 2010	Waste Solutions Forum steering committee meeting	Charlottesville, VA	RB
February 22, 2010	University of Maryland	College Park, MD	RB
February 23, 2010	Chesapeake Bay Commission	Annapolis, MD	BK, RB
February 24, 2010	MDE and MDNR meeting on WIP	Baltimore, MD	MF
February 25, 2010	Bay TMDL Monthly Webinar	Webinar	RB, BK, TD
March 1, 2010	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
March 3, 2010	Maryland Association of Counties	Annapolis, MD	KA
March 3, 2010	Conewago Watershed Advisory Team Meeting webinar	Webinar	KA
March 4, 2010	Pennsylvania General Assembly Legislators Retreat	Bedford Springs, PA	RB
March 4, 2010	WIP Pilots with Anne Arundel and Caroline Counties	Annapolis, MD	MF
March 6, 2010	Public engagement with Tributary Teams	Annapolis, MD	MF and JL
March 9, 2010	PA Senate Ag & Rural Affairs and Environmental Resources & Energy Committees	Harrisburg, PA	BK
March 9-10, 2010	CBP STAC	Annapolis, MD	RB, LL, GS
March 11, 2010	CBP CAC	Annapolis, MD	RB
March 12, 2010	Metropolitan Council of Governments	Washington, D.C.	KA
March 13, 2010	State of Our Watersheds Conference	Baltimore, MD	JL
March 15, 2010	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
March 17, 2010	PA Senate Ag & Rural Affairs and Environmental Resources & Energy Committees	Harrisburg, PA	BK, JC
March 22, 2010	Bay TMDL Webinar for the Agricultural Community	Washington, D.C.	RB, BK, etc

Table C-4. Record of CBP committee/workgroup and stakeholder meetings since 2008 where the Chesapeake Bay TMDL was a principal topic of the meeting (continued)

Date	Meeting	Location	EPA/CBPO staff
March 25, 2010	WIP Pilot with Anne Arundel County	Annapolis, MD	MF
March 25, 2010	Bay TMDL Monthly Webinar	Webinar	RB, BK, TD
March 25, 2010	PA Association of Environmental Professionals - Eastern & Central Divisions	Fort Washington, PA	BK
March 29, 2010	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
March 29 -30, 2010	Farm Pilot Project Coordination (FPPC) Regional Summit	Annapolis, MD	MD
March 31, 2010	PA WIP Stakeholder meeting	Harrisburg, PA	SH, BK
March 31 - April 1, 2010	CBP Modeling Subcommittee	Annapolis, MD	LL, GS, etc
April 5-6, 2010	CBP WQGIT	Gettysburg, PA	BK, RB, JS, etc.
April 7, 2010	WIP Pilot with Anne Arundel County	Annapolis, MD	MF
April 7, 2010	VA Environmental Forum	Lexington, VA	BK
April 9, 2010	USDA/EPA Chesapeake Bay Models Meeting	Annapolis, MD	BK, LL, GS, etc
April 9, 2010	Draft Chesapeake Bay Federal Land Management Guidance Document (Section 502 Guidance)	Webinar	KA
April 12, 2010	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
April 19, 2010	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
April 23, 2010	CBP LGAC	Washington, D.C.	JS
April 26, 2010	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
April 27, 2010	WIP Pilot with Anne Arundel County	Annapolis, MD	MF
May 3-5, 2010	American Planning Association (Virginia Chapter) Conference	Norfolk	KA
May 3, 2010	PA Chesapeake Bay Advisory Committee	Harrisburg, PA	SH
May 6, 2010	American Planning Association (DE/MD Chapter) Conference	Dover, DE	KA
May 6, 2010	Bay TMDL Webinar for the Homebuilders/Developers Community	Annapolis, MD	BK, RB, etc.
May 6, 2010	PA Chesapeake Bay WIP Urban/Suburban/Rural Workgroup	Harrisburg, PA	SH
May 7, 2010	Choose Clean Water Coalition Roundtable	Washington, D.C.	JeffC
May 10, 2010	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
May 10, 2010	PA Chesapeake Bay WIP Agriculture Workgroup	Harrisburg, PA	SH
May 11, 2010	PA Water Resources Advisory Committee	Harrisburg, PA	SH
May 11-13, 2010	Region 3 NPS/TMDL/WQM/WQS/NPDES Annual Meeting	Gettysburg, PA	JS
May 12, 2010	Positive Growth Alliance - DE congressional meeting	Conference Call	BK, JM
May 13, 2010	WIP Pilot with Caroline County	Denton, MD	MF
May 13, 2010	LGAC/STAC Stormwater Meeting	Washington, D.C.	BK

Table C-4. Record of CBP committee/workgroup and stakeholder meetings since 2008 where the Chesapeake Bay TMDL was a principal topic of the meeting (continued)

Date	Meeting	Location	EPA/CBPO staff
May 13, 2010	PA Chesapeake Bay WIP Management Team	Harrisburg, PA	SH
May 13, 2010	ASIWPCA Watershed Ad Hoc Committee	Conference Call	BK
May 14, 2010	Western Maryland Local Government Exchange	Hagerstown, MD	KA or MF
May 17, 2010	Bay TMDL Webinar	Webinar	BK, RB, etc.
May 17, 2010	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
May 24, 2010	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
May 25, 2010	USDA/EPA meeting on Nutrient Trading Tool/Comet-VR and Chesapeake Bay Watershed Model	Washington, D.C.	RB
May 25, 2010	PA Chesapeake Bay WIP Management Team	Harrisburg, PA	SH
June 1, 2010	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
June 2, 2010	VA Association of Counties Environmental Policy Committee	Charlottesville, VA	RB or KA
June 3, 2010	CBP Executive Council	Baltimore, MD	SG
June 7, 2010	Bay TMDL Webinar	Webinar	BK, RB, etc.
June 7, 2010	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
June 8-9, 2010	CBP STAC	Kent Island, MD	RB
June 10, 2010	WIP Pilot with Anne Arundel County	Annapolis, MD	MF
June 10, 2010	Rappahannock Nutrient Cooperative Business Advisory Council	Fredericksburg, VA	KA
June 10, 2010	LEAD Maryland Panel	Solomons, MD	MF
June 11, 2010	Tidal States Call with MDNR, MDE, VADEQ, VADCR, and DC DoE	Conference Call	BK, RB
June 14, 2010	CBP WQGIT: co-regulators only	Conference Call	BK, RB, KA, JS, etc.
June 15, 2010	EPA Region 3 State/Interstate Water Directors Meeting	Stauton, VA	RB, MM, TD
June 15, 2010	VA Stakeholders Advisory Group	Richmond, VA	KA, Jeff C
June 15, 2010	MD Public Meeting on WIP	Hagerstown, MD	MF
June 16, 2010	Center for Watershed Protection Watershed Treatment Model	Webinar	Staff
June 16, 2010	Tri-County Council for Southern Maryland	Waldorf, MD	KA
June 17, 2010	Beyond Water Quality in the Chesapeake Bay: Lowering Barriers to Achieving Multiple Environmental Goals,	Washington, D.C.	KA
June 17, 2010	CBP Management Board	Annapolis, MD	RB
June 18, 2010	MD Public Meeting on WIP	Baltimore, MD	MF
June 21, 2010	TMDL Seminar for USDA Undersecretary	Washington, D.C.	BK
June 23, 2010	MD Public Meeting on WIP	Denton, MD	MF
July 6, 2010	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.

Table C-4. Record of CBP committee/workgroup and stakeholder meetings since 2008 where the Chesapeake Bay TMDL was a principal topic of the meeting (continued)

Date	Meeting	Location	EPA/CBPO staff
July 8, 2010	Bay TMDL Webinar	Webinar	BK, RB, etc.
July 9, 2010	WIP Pilot with Anne Arundel County	Annapolis, MD	MF
July 12, 2010	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
July 12, 2010	NYSDEC, NYSDA, USDA, USC meeting on WIP	NY	RI
July 13, 2010	CBP Modeling Subcommittee	Annapolis, MD	LL
July 14, 2010	PA DEP meeting on WIP	Harrisburg, PA	KS, SH
July 19, 2010	USDA Leadership Conference	Washington, D.C.	RB
July 20, 2010	CBP Management Board	Annapolis, MD	BK
July 20, 2010	MDE and MDNR meeting on WIP	Baltimore, MD	MF, KA,
July 20, 2010	Virginia Legislature - House Agriculture, Natural Resrouces and Chesapeake Committee	Richmond, VA	JeffC
July 21, 2010	Industry Coffee with EPA HQs	Washington, D.C.	BK
July 26, 2010	CBP WQGIT: co-regulators only	Conference Call	BK, RB, KA, JS, etc.
July 29, 2010	WIP Pilot discussion with Anne Arundel County	Annapolis, MD	MF
July 30, 2010	Metropolitan Washington Council of Governments Water Resources Technical Committee	Washington, D.C.	JE
July 30, 2010	WIP Pilot with Caroline County	Denton, MD	MF
August 4, 2010	PA DEP meeting on WIP	Harrisburg, PA	SH
August 5, 2010	PA DEP meeting on WIP	Harrisburg, PA	SH
August 9, 2010	CBP WQGIT: co-regulators only	Conference Call	BK, RB, KA, JS, etc.
August 10, 2010	MDE meeting on stormwater/WIP	Conference Call	MF, JM
August 11, 2010	PA DEP meeting on WIP	Harrisburg, PA	SH
August 11, 2010	VA DEQ/DCR WIP discussion	Richmond, VA	JeffC, KA, AC, MD, JM, etc.
August 11, 2010	Patuxent River Commission, Tributary Team for the Patuxent River	Annapolis, MD	MF
August 16, 2010	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
August 18, 2010	MDE and MDNR meeting on WIP	Annapolis, MD	KA, MF. KS
August 19, 2010	Bay TMDL Webinar	Webinar	BK, RB, etc.
August 19, 2010	DE DNREC meeting on WIP	Annapolis, MD	KA, KS, MD
August 23, 2010	CBP WQGIT: co-regulators only	Conference Call	BK, RB, KA, JS, etc.
August 24, 2010	VA DCR and DEQ meeting on WIP	Richmond, VA	KA, MD
August 25, 2010	Annual Army Chesapeake Bay Meeting	Fort A.P. Hill, VA	GS

Table C-4. Record of CBP committee/workgroup and stakeholder meetings since 2008 where the Chesapeake Bay TMDL was a principal topic of the meeting (continued)

Date	Meeting	Location	EPA/CBPO staff
August 26, 2010	MDE, DNR, MDA meeting on input decks/WIP	Annapolis, MD	MF, MD
August 26, 2010	WIP Pilot discussion with Anne Arundel County	Annapolis, MD	MF
August 26, 2010	Congressional Staff Bay Briefing and Boat Tour	Annapolis, MD	RB, JE, TL, JeffC
September 8, 2010	National Academy of Sciences - Independent Evaluator Panel	Washington, D.C.	JeffC, RB, JW
September 13, 2010	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
September 14-15, 2010	CBP STAC	Annapolis, MD	RB, RW
September 15, 2010	Council on Environmental Quality/Chesapeake Bay Federal Leadship Committee	Washington, D.C.	RB, JE, CB
September 15, 2010	Sierra Club "Healling Our Waters" Public Forum	Hampton, VA	JeffC
September 16, 2010	WIP Pilots with Caroline County	Denton, MD	MF
September 18, 2010	Virginia Environmental Assembly	Virginia Beach, VA	JeffC
September 20, 2010	EPA conference call with WV to discuss high-level comments on draft WIP	Conference Call	RW, LE, KA, etc.
September 21, 2010	EPA meeting with MD to discuss high-level comments on draft WIP	Annapolis, MD	JE, MF
September 21, 2010	EPA conference call with PA to discuss high-level comments on draft WIP	Conference Call	BK, JC, KA, GwenS
September 21, 2010	EPA conference call with DE to discuss high-level comments on draft WIP	Conference Call	SG, JC, KA
September 22, 2010	CBP Management Board	Annapolis, MD	JE, RW, CB, JeffC
September 22, 2010	Virginia Water Environment Association	Hampton, VA	JeffC
September 23, 2010	EPA conference call with VA to discuss high-level comments on draft WIP	Conference Call	JeffC, AC, KA
September 23, 2010	EPA conference call with DC to discuss high-level comments on draft WIP	Conference Call	JC, RP, KA
September 23, 2010	Congressional Briefings for Environmental and Agriculture Committees	Washington, D.C.	JeffC
September 24, 2010	Bay TMDL Briefing for Environmental/Fishing Community	Conference Call	JeffC
September 24, 2010	CBP Advisory Committees	Conference Call	JE
September 28, 2010	Bay TMDL Webinar	Webinar	BK, RB, etc.
September 28, 2010	PA WIP Management Stakeholder Team meeting	Harrisburg, PA	BK, SH, GwenS
September 29, 2010	Bay TMDL Public Meeting & Webinar	Washington, D.C.	BK, RB, JS, LM, PG, SH, JimC, TL, GwenS
September 29, 2010	Metropolitan Washington Council of Governments	Washington, D.C.	BK, RB, LM, JS, RP, TL
September 30, 2010	EPA Federal Advisory Committee on Agriculture	Washington, D.C.	RB

Table C-4. Record of CBP committee/workgroup and stakeholder meetings since 2008 where the Chesapeake Bay TMDL was a principal topic of the meeting (continued)

Date	Meeting	Location	EPA/CBPO staff
September 30, 2010	EPA meeting with DE to discuss detailed comments on draft WIP	Dover, DE	SG, KA, PG, KS, MD
September 30, 2010	PA Agriculture Stakeholder Workgroup meeting	Harrisburg, PA	SH, GwenS, MD, KS
September 30, 2010	EPA conference call with WV to discuss detailed comments on draft WIP	Conference Call	LE, KA, JM, BT, EM
October 4, 2010	EPA meeting with MD to discuss detailed comments on draft WIP	Annapolis, MD	JE, MF, KA, etc.
October 4, 2010	Virginia agriculture stakeholders	Harrisonburg, VA	RB, BK, LM, PG, TL, JeffC
October 4, 2010	Virginia environmental groups/stakeholders	Harrisonburg, VA	RB, BK, LM, PG, TL, JeffC
October 4, 2010	Bay TMDL Public Meeting	Harrisonburg, VA	RB, BK, LM, PG, TL, JeffC
October 5, 2010	PA WIP Point Source Stakeholder Workgroup Meeting	Harrisburg, PA	SH, GwenS
October 5, 2010	Virginia environmental groups/stakeholders	Fairfax, VA	RB, BK, LM, PG, TL, JeffC
October 5, 2010	Virginia local government stakeholders	Fairfax, VA	RB, BK, LM, PG, TL, JeffC
October 5, 2010	Virginia developers and homebuilders	Fairfax, VA	RB, BK, LM, PG, TL, JeffC
October 5, 2010	Bay TMDL Public Meeting	Annandale, VA	RB, BK, LM, PG, TL, JeffC
October 6, 2010	Virginia wastewater treatment operators	Richmond, VA	RB, BK, LM, GwenS, GB, JeffC
October 6, 2010	Virginia developers and homebuilders	Richmond, VA	RB, BK, LM, GwenS, GB, JeffC
October 6, 2010	Virginia State Legislators	Richmond, VA	RB, BK, LM, GwenS, GB, JeffC
October 6, 2010	Bay TMDL Public Meeting	Richmond, VA	RB, BK, LM, GS, GB, JeffC
October 7, 2010	EPA meeting with PA to discuss detailed comments on draft WIP	Harrisburg, PA	KA, SH, KS, MD, JM, etc.
October 7, 2010	EPA meeting with VA to discuss detailed comments on draft WIP		AC, JeffC
October 7, 2010	Virginia environmental groups/stakeholders	Richmond, VA	RB, BK, LM, GwenS, GB, JeffC

Table C-4. Record of CBP committee/workgroup and stakeholder meetings since 2008 where the Chesapeake Bay TMDL was a principal topic of the meeting (continued)

Date	Meeting	Location	EPA/CBPO staff
October 7, 2010	Hampton Roads Planning District Commission	Chesapeake, VA	RB, BK, LM, GwenS, GB, JeffC
October 7, 2010	Bay TMDL Public Meeting & Webinar	Webinar	RB, BK, LM, GwenS, GB, JeffC
October 7, 2010	Bay TMDL Public Meeting	Hampton, VA	RB, BK, LM, GwenS, GB, JeffC
October 11, 2010	Delaware agriculture stakeholders	Georgetown, DE	RB, BK, LM, GwenS, TL
October 11, 2010	Delaware local government stakeholders	Seaford, DE	RB, BK, LM, GwenS, TL
October 11, 2010	Delaware developers and homebuilders	Seaford, DE	RB, BK, LM, GwenS, TL
October 11, 2010	Bay TMDL Public Meeting & Webinar	Georgetown, DE	RB, BK, LM, GwenS, TL
October 12, 2010	PA WIP Stormwater Stakeholder Meeting	Harrisburg, PA	SH, JM, EM
October 12, 2010	Maryland environmental groups/stakeholders	Easton, MD	RB, BK, LM, GwenS, TL
October 12, 2010	Bay TMDL Public Meeting	Easton, MD	RB, BK, LM, GwenS, TL
October 12, 2010	Chesapeake Bay Stormwater Listening Session	Richmond, VA	RH, JM, KW
October 13, 2010	EPA Call with NY to discuss detailed comments on draft WIP	Conference Call	RI, KA
October 13, 2010	Maryland developers and homebuilders	Annapolis, MD	RB, BK, LM, JS
October 13, 2010	Maryland State Legislators	Annapolis, MD	RB, BK, LM, JS, CF
October 13, 2010	Bay TMDL Public Meeting	Annapolis, MD	RB, BK, LM, JS, TL
October 14, 2010	EPA conference call with PA to discuss stormwater - WIP	Conference Call	JC, KA, SH, JM, EM
October 14, 2010	EPA conference call with MD, DC, and VA to discuss Blue Plains	Conference Call	RP, MF, BT
October 14, 2010	Maryland local government stakeholders	Annapolis, MD	RB, BK, LM, JS
October 14, 2010	Maryland agriculture stakeholders	Frederick, MD	RB, BK, LM, JS, TL
October 14, 2010	Bay TMDL Public Meeting & Webinar	Hagerstown, MD	RB, BK, LM, JS, TL
October 14, 2010	Chesapeake Bay Stormwater Listening Session	Washington, D.C.	RH, JM, KW
October 15, 2010	EPA weekly call with VA to discuss WIP	Conference Call	JeffC, AC, KA, KD, NZ, JeffS
October 18, 2010	EPA call with WV to discuss offsets/growth/trading in WIP	Conference Call	RW, KevinD
October 18, 2010	Pennsylvania local government stakeholders	Lancaster, PA	RB, BK, SH, TD
October 18, 2010	Pennsylvania agriculture stakeholders	Lancaster, PA	RB, BK, SH, TD
October 18, 2010	Bay TMDL Public Meeting	Lancaster, PA	RB, BK, SH, TD
October 18, 2010	Pennsylvania legislative delegation	Harrisburg, PA	RB, BK, SH, TD, JC
October 18, 2010	Chesapeake-Bay Focused EMS conference for Federal Facilities	Greenbelt, MD	Staff

Table C-4. Record of CBP committee/workgroup and stakeholder meetings since 2008 where the Chesapeake Bay TMDL was a principal topic of the meeting (continued)

Date	Meeting	Location	EPA/CBPO staff
October 19, 2010	Pennsylvania Municipal Authority Association	Harrisburg, PA	RB, BK, SH, TD, LM
October 19, 2010	Pennsylvania environmental groups/stakeholders	Harrisburg, PA	RB, BK, SH, TD, LM
October 19, 2010	Bay TMDL Public Meeting & Webinar	State College, PA	RB, BK, SH, TD, LM
October 19, 2010	Pennsylvania agriculture stakeholders	State College, PA	RB, BK, SH, TD, LM
October 19, 2010	Chesapeake Bay Stormwater Listening Session	Baltimore, MD	RH, JM, KW
October 20, 2010	EPA conference call with MD to discuss stormwater - WIP	Conference Call	MF, JM
October 20, 2010	EPA meeting with DC to discuss detailed comments on draft WIP	Washington, D.C.	RP, JM, BT
October 20, 2010	EPA conference call with NY to discuss agriculture - WIP	Conference Call	RI, KS, MD, KA
October 20, 2010	Richmond, VA Mayor's Office	Richmond, VA	JeffC
October 20, 2010	Pennsylvania Builders Association	Williamsport, PA	RB, BK, SH, TD, LM
October 20, 2010	Lycoming County officials	Williamsport, PA	RB, BK, SH, TD, LM
October 20, 2010	Bay TMDL Public Meeting	Williamsport, PA	RB, BK, SH, TD, LM
October 21, 2010	Bay TMDL Public Meeting	Ashley, PA	RB, BK, SH, TD, LM
October 21, 2010	Chesapeake Bay Stormwater Listening Session	Salisbury, MD	RH, JM, KW
October 21, 2010	CBP PSC	Baltimore, MD	JE, RW, CB, GS
October 22, 2010	EPA weekly call with VA to discuss WIP	Conference Call	JeffC, AC, KA
October 25, 2010	EPA conference call with NY to discuss wastewater - WIP	Conference Call	RI, BT, KA
October 25, 2010	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
October 26, 2010	EPA call with MD to discuss trading/offsets/growth	Conference Call	RW, KevinD, MF
October 26, 2010	EPA meeting with VA to discuss agriculture - WIP	Richmond, VA	JeffC, AC, KS, MD
October 26, 2010	OMB/CEQ TMDL Briefing	Washington, D.C.	CF, KA, JE
October 26, 2010	Bay Model Briefing for Senators Warner and Webb staff	Washington, D.C.	JeffC, GS, LK
October 26, 2010	New York wastewater treatment operators	Elmira, NY	RB, BK, PG, DS
October 26, 2010	Bay TMDL Public Meeting	Elmira, NY	RB, BK, PG, DS
October 26, 2010	Chesapeake Bay Stormwater Listening Session	Lancaster, PA	RH, JM, KW
October 27, 2010	Virginia Water Commission	Richmond, VA	JeffC
October 27, 2010	Chemung County Stormwater Coalition	Horseheads, NY	RB, BK, PG, DS
October 27, 2010	Upper Susquehanna Coalition	Apalachin, NY	RB, BK, PG, DS
October 27, 2010	New York Farm Bureau	Apalachin, NY	RB, BK, PG, DS
October 27, 2010	Bay TMDL Public Meeting & Webinar	Binghamton, NY	RB, BK, PG, DS
October 29, 2010	EPA meeting with VA to discuss detailed comments on draft WIP	Annapolis, MD	JeffC, AC, KA, etc.
November 1, 2010	Sierra Club TMDL/WIP Forum	Virginia Beach, VA	JeffC

Table C-4. Record of CBP committee/workgroup and stakeholder meetings since 2008 where the Chesapeake Bay TMDL was a principal topic of the meeting (continued)

Date	Meeting	Location	EPA/CBPO staff
November 1, 2010	EPA conference call with NY to discuss stormwater - WIP	Conference Call	RI, JM, KA
November 2, 2010	EPA conference call with PA on non-cost share BMPs	Conference Call	SH, KS, KA, MD
November 3, 2010	EPA "closure" meeting with PA on final WIP	Harrisburg, PA	JC, KA, SH, KS
November 3, 2010	EPA conference call with DE to discuss trading/offsets/growth - WIP	Conference Call	RW, KevinD, PG
November 3, 2010	EPA "closure" conference call with DC to discuss final WIP	Conference Call	JC, RP, KA
November 3, 2010	West Virginia environmental groups/stakeholders	Shepherdstown, WV	RB, BK, JS, JG, GB
November 3, 2010	West Virginia developers and homebuilders	Martinsburg, WV	RB, BK, JS, JG, GB
November 3, 2010	West Virginia local government stakeholders	Martinsburg, WV	RB, BK, JS, JG, GB
November 3, 2010	Bay TMDL Public Meeting	Martinsburg, WV	RB, BK, JS, JG, GB
November 4, 2010	Chesapeake Bay Commission	Montross, VA	JeffC
November 4, 2010	EPA weekly conference call with VA to discuss final WIP	Conference Call	JeffC, AC, KA, KS
November 4, 2010	West Virginia agriculture stakeholders	Romney, WV	RB, BK, JS, JG, GB, RW
November 4, 2010	West Virginia local government stakeholders	Romney, WV	RB, BK, JS, JG, GB, RW
November 4, 2010	West Virginia developers and homebuilders	Romney, WV	RB, BK, JS, JG, GB, RW
November 4, 2010	Bay TMDL Public Meeting & Webinar	Romney, WV	RB, BK, JS, JG, GB, RW
November 5, 2010	EPA "closure" conference call with WV to discuss final WIP	Conference Call	RW, LE, KA
November 8, 2010	Virginia Association of Counties Annual Conference	Hot Springs, VA	JeffC
November 8, 2010	EPA "closure" meeting with MD to discuss final WIP	Annapolis, MD	JE, MF, KA, etc.
November 8, 2010	EPA conference call with PA on non-cost share BMPs	Conference Call	KS, MD, SH, JS
November 9, 2010	PA Chesapeake Bay WIP Urban/Suburban/Rural Workgroup	Harrisburg, PA	SH, LP, LO; JS called in
November 9, 2010	PA Chesapeake Bay WIP Agriculture Workgroup	Harrisburg, PA	SH, LP, MD
November 10, 2010	EPA weekly conference call with VA to discuss final WIP	Conference Call	JeffC, AC, KA
November 10, 2010	EPA "closure" meeting with DE to discuss final WIP	Dover, DE	SG, PG, KA
November 10, 2010	EPA "closure" conference call with NY to discuss final WIP	Conference Call	RI, KA, etc.
November 10, 2010	EPA conference call with PA on non-cost share BMPs	Conference Call	KS, MD, SH, JS
November 12-13, 2010	2010 Watershed Forum	Shepherdstown, WV	Staff
November 16, 2010	CBP WQGIT	Conference Call	BK, RB, KA, JS, etc.
November 16, 2010	PA Chesapeake Bay WIP Wastewater workgroup	Harrisburg, PA	SH, BT, NZ, LP all called in
November 18, 2010	CBP CAC	Washington, D.C.	RB, JE
November 18, 2010	EPA conference call with PA on non-cost share BMPs	Conference Call	KS
November 19, 2010	EPA "closure" meeting with VA to discuss final WIP	Washington, D.C.	JeffC, KA, AC, RW, KS

Table C-4. Record of CBP committee/workgroup and stakeholder meetings since 2008 where the Chesapeake Bay TMDL was a principal topic of the meeting (continued)

Date	Meeting	Location	EPA/CBPO staff
November 23, 2010	EPA conference call with PA on non-cost share BMPs	Conference Call	MD
November 24, 2010	EPA discussion with PA on closing the gap	conference call	SH, MD, KA, CB
December 3, 2010	CBP LGAC	Annapolis, MD	RB, CB
December 14, 2010	CBP STAC	Annapolis, MD	RB, RW

Table C-5. EPA staff name abbreviations key

EPA staff abbreviation	Name
AC	Ann Carkcuff
AD	Andrew Dinsmore
BK	Bob Koroncai
BT	Brian Trulear
CB	Carin Bisland
CD	Chris Day
CF	Chuck Fox
DE	Diana Esher
DM	Dave McGuigan
DS	David Sternberg
DW	Don Welsh
EM	Evelyn MacKnight
GB	Greg Barranco
GS	Gary Shenk
GwenS	Gwen Supplee
HZ	Hank Zygmunt
JC	Jon Capacasa
JE	Jim Edward
JeffC	Jeff Corbin
JeffS	Jeff Sweeney
JimC	Jim Curtin
JG	Jessica Greathouse
JL	Jeff Lape
JM	Jenny Molloy

EPA staff abbreviation	Name
JS	Jennifer Sincock
JW	Julie Winters
KA	Katherine Antos
KD	Kevin DeBell
KS	Kelly Shenk
KW	Kevin Weiss
KZ	Kyle Zieba
LK	LaRonda Koffi
LL	Lewis Linker
LM	Linda Miller
LO	Liz Ottinger
LP	Lucinda Power
MD	Mark Dubin
MF	Mike Fritz
MH	Mike Haire
PG	Peter Gold
RB	Rich Batiuk
RH	Rachel Herbert
RI	Ruth Izraeli
RP	Reggie Parrish
RW	Rob Wood
SG	Shawn Garvin
SH	Suzanne Hall Trevena
TD	Thomas Damm
TL	Travis Loop

Table C-4. Organization abbreviations key

Abbreviations	Organization
ASWIPCA	Association of States Interstate Water Pollution Control Administrators
CAC	Citizens Advisory Committee
CBP	Chesapeake Bay Program
DC DOE	District of Columbia Department of Environment
DE DNREC	Delaware Department of Natural Resources and Environmental Control
EPA	Environmental Protection Agency
HQ	Headquarters
LGAC	Local Government Advisory Committee
MDA	Maryland Department of Agriculture
MDE	Maryland Department of Environment
MDNR	Maryland Department of Natural Resources
MDP	Maryland Department of Planning
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resources Conservation Service
NYSDA	New York State Department of Agriculture
NYSDEC	New York State Department of Environmental Conservation
PA DEP	Pennsylvania Department of Environmental Protection
PSC	Principles' Staff Committee
RTWG	Re-evaluation Technical Workgroup
STAC	Scientific and Technical Advisory Committee
USC	Upper Susquehanna Coalition
USDA	United States Department of Agriculture
USGS	United States Geological Survey
USWG	Urban Stormwater Workgroup
VA DCR	Virginia Department of Conservation and Recreation
VA DEQ	Virginia Department of Environmental Quality
VAMWA	Virginia Municipal Wastewater Authorities
WEF	Water Environmental Federation
WQGIT	Water Quality Goal Implementation Team
WQM	Water Quality Monitoring
WQS	Water Quality Standards
WQSC	Water Quality Steering Committee
WVCA	West Virginia Conservation Agency
WVDA	West Virginia Department of Agriculture
WVDEP	West Virginia Department of Environmental Protection

Appendix D.
Evaluation of the Most Protective Bay Dissolved Oxygen Criteria

As outlined in the criteria assessment documentation in Section 3.4.3 and shown in Table D-1, seven different dissolved oxygen criteria are to be assessed to determine attainment of the open-water, deep-water, and deep-channel designated uses (USEPA 2003). Using the available monitoring data, only one temporal averaging period can be assessed for each designated-use type (USEPA 2003, 2007). Because the monitoring data are not available to assess all seven criteria or an assessment protocol has not been developed by the Chesapeake Bay Program partners and published by EPA, it raises the question of whether the three assessed criteria are more or less protective of all four Chesapeake Bay designated uses than the four criteria that are not able to be assessed.

Table D-1. Chesapeake Bay dissolved oxygen criteria assessed with observed data for developing the jurisdictions' the 303(d) lists and criteria that are not evaluated because of insufficient data/lack of published assessment protocols

Designated use	Instantaneous	1-day mean	7-day mean	30-day mean
Open water	Insufficient Data	No Criterion	Insufficient Data	Assessed
Deep water	Insufficient Data	Insufficient Data	No Criterion	Assessed
Deep channel	Assessed	No Criterion	No Criterion	No Criterion

Because of insufficient monitoring data or lack of published assessment protocols or both, it is difficult to comprehensively evaluate the protectiveness of the assessed criteria strictly on the basis of monitoring data, because the unassessed criteria cannot be directly evaluated. A multi-partner effort is underway to develop criteria assessment protocols based on the available monitoring data, but those protocols will not be complete, peer reviewed, and published until 2011 at the earliest.

The full set of seven dissolved oxygen criteria can be assessed through direct evaluation of the Chesapeake Bay Water Quality and Sediment Transport Model (Bay Water Quality Model) output. The assessments will not agree precisely with the 303(d) or Bay TMDL-related criteria assessment because neither of those criteria assessments uses model outputs directly (see Section 6.2.4). However, assuming that the temporal variability of dissolved oxygen in the Chesapeake Bay is reasonably well-characterized in the Bay Water Quality model, the relative protectiveness of different criteria evaluated directly using Bay Water Quality Model output would approximate the relative protectiveness of three dissolved oxygen criteria evaluated using monitoring data.

All seven dissolved oxygen criteria were assessed using the direct outputs from a series of Bay Water Quality Model scenarios. That work was completed in November 2008 using the Phase 5.1 version of the Chesapeake Bay Watershed Model. The Bay Water Quality Model has not been modified since completion of the work described here. Because the analysis is focused on evaluating temporal variability of dissolved oxygen in the Bay Water Quality Model outputs and uses only the Bay Watershed Model for generation of different loading scenario input decks, the findings are still relevant even with use of the Phase 5.3 Bay Watershed Model in developing the Bay TMDL.

Figures D-1 and D-2 show the average dissolved oxygen criteria nonattainment of eight mainstem Chesapeake Bay segments for three scenarios for the 1996–1998 period. The moderate reduction scenario approximates 2009 loads and the large reduction scenario approximates the Bay TMDL cap loads.

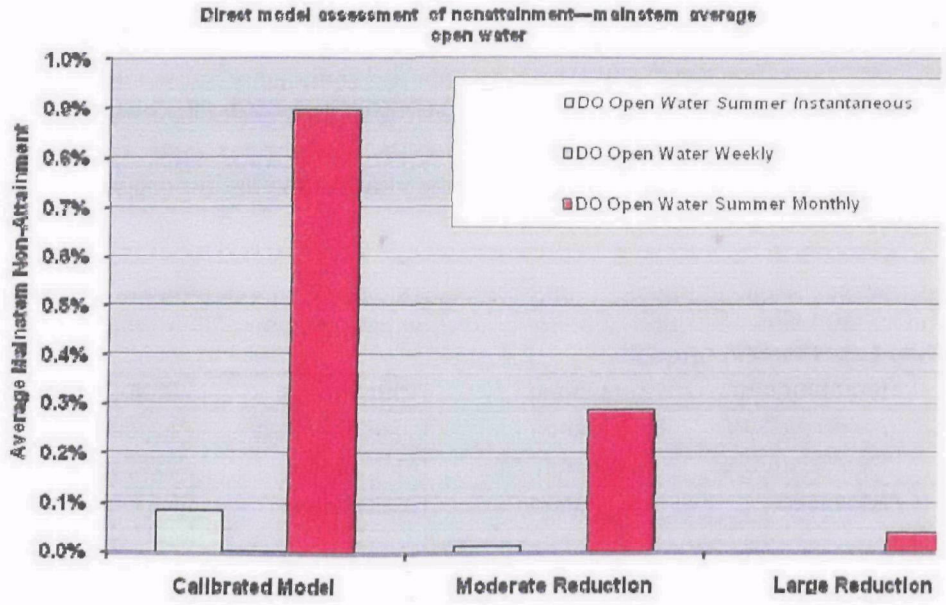


Figure D-1. Direct model assessment of open-water dissolved oxygen criteria nonattainment for the eight mainstem Chesapeake Bay segments.

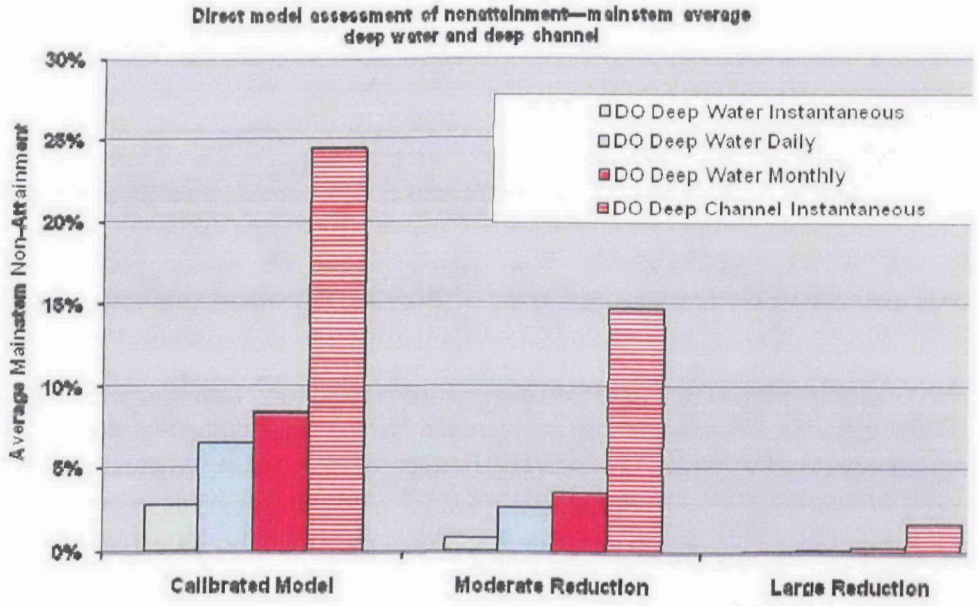


Figure D-2. Direct model assessment of deep-water and deep-channel dissolved oxygen criteria nonattainment for the eight mainstem Chesapeake Bay segments.

For both open-water and deep-water designated uses, the 30-day mean criteria had the highest nonattainment in all three scenarios (Figures D-1 and D-2). The 30-day mean open-water and deep-water criteria are, therefore, protective of the other two sets of non-assessed dissolved oxygen criteria (open-water 7-day and instantaneous minimum, deep-water 1-day mean and instantaneous minimum) on average for the eight mainstem Bay segments. Only one dissolved oxygen criterion applies to the deep-channel designated use, and it is assessed using monitoring data. The deep-channel criterion is also more protective, on the basis of the levels of nonattainment recorded in Figures D-1 and D-2, than all the other six open-water and deep-water criteria.

Looking at the results of criteria assessment of the individual designated uses strengthens those findings considerably. Using the criteria nonattainment percentages for the moderate reduction scenario and the 1996–1998 assessment period, the 30-day mean, 7-day mean, and instantaneous minimum criteria are compared across 53 of the 92 Bay segments with the open-water designated use. During the 1996–1998 assessment period, those 53 segments did not attain all three open-water criteria. In all 53 segments, the 30-day mean open-water criterion had the highest nonattainment percentage compared to the 7-day mean and 1-day mean open-water criteria (Table D-2). In the 16 Bay segments that did not attain all three deep-water criteria during the same 3-year period, the 30-day mean deep-water criterion had the highest nonattainment percentage in all 16 segments compared with the deep-water 1-day mean and instantaneous minimum criteria (Table D-3).

Because this is a direct assessment of the Bay Water Quality Model output using inputs from the Phase 5.1 Bay Watershed Model and because the water quality criteria and assessment protocols that existed in 2008, the nonattainment values will not match with nonattainment in other parts of this document.

EPA used direct assessment of Bay Water Quality Model outputs to document that the three dissolved oxygen criteria that are assessed by Maryland, Virginia, Delaware, and the District of Columbia using Bay water quality monitoring data—open-water 30-day mean, deep-water 30-day mean, and deep-channel instantaneous minimum—are the most restrictive and, therefore, most protective criteria. Those three criteria, applied during the summer period, are protective of the other four dissolved oxygen criteria across all four designated uses, across a range of nutrient reduction scenarios, and in all areas of the Chesapeake Bay and its tidal tributaries and embayments.

Table D-2. Comparison of open-water dissolved oxygen 30-day mean, 7-day mean, and instantaneous criteria for the moderate reduction scenario and the 1996–1998 assessment period across Bay segments for identification of the most protection criterion

Ches Bay segment	30-day mean	7-day mean	Instantaneous minimum	Most protective criterion
BI2MH	3.56%	0.43%	0.00%	30-day mean
C11TF	0.02%	0.00%	0.00%	30-day mean
CB1TF	0.03%	0.00%	0.00%	30-day mean
CB2OH	1.48%	0.00%	0.10%	30-day mean
CB5MH	0.01%	0.00%	0.00%	30-day mean
CB6PH	0.24%	0.00%	0.00%	30-day mean
CB7PH	0.57%	0.00%	0.00%	30-day mean
CDDOH	24.87%	20.59%	19.19%	30-day mean
CHOMH1	7.24%	1.96%	2.53%	30-day mean
CHOMH2	34.10%	28.45%	25.47%	30-day mean
CHOOH	28.04%	24.18%	23.20%	30-day mean
CHOTF	20.32%	14.31%	13.96%	30-day mean
CHSMH	0.65%	0.00%	0.12%	30-day mean
CHSOH	46.68%	36.62%	34.53%	30-day mean
CHSTF	63.24%	60.63%	57.21%	30-day mean
CMDOH	48.35%	41.64%	37.15%	30-day mean
CNDOH	35.86%	30.44%	27.75%	30-day mean
CRRMH	0.25%	0.00%	0.00%	30-day mean
DCATF	2.67%	0.09%	0.29%	30-day mean
EBEMH	1.19%	0.00%	0.00%	30-day mean
EL1OH	9.96%	3.44%	4.14%	30-day mean
ELIPH	27.51%	16.54%	13.56%	30-day mean
ELKOH	9.13%	2.93%	3.77%	30-day mean
FSBMH	8.13%	2.35%	2.83%	30-day mean
HNGMH	1.09%	0.00%	0.13%	30-day mean
JMSPH	1.07%	0.00%	0.00%	30-day mean
JMSTF	0.22%	0.00%	0.13%	30-day mean
JMSTFL	0.27%	0.00%	0.17%	30-day mean
LCHMH	10.24%	6.17%	7.01%	30-day mean
MA1MH	0.55%	0.00%	0.00%	30-day mean
MAGMH	3.74%	0.00%	0.00%	30-day mean
MANMH	0.48%	0.00%	0.00%	30-day mean
MD5MH	0.01%	0.00%	0.00%	30-day mean
MOBPH	1.26%	0.00%	0.02%	30-day mean
NANMH	5.70%	3.09%	3.95%	30-day mean
NANOH	0.04%	0.00%	0.00%	30-day mean
PAXOH	10.68%	0.49%	0.03%	30-day mean
PAXTF	0.95%	0.00%	0.00%	30-day mean
PIAMH	1.93%	0.00%	0.00%	30-day mean
PO1OH	3.83%	0.00%	0.04%	30-day mean
POCMH	1.14%	0.03%	0.41%	30-day mean
POTOH	3.55%	0.00%	0.03%	30-day mean
SA1OH	10.46%	1.28%	1.36%	30-day mean
SA2OH	8.85%	1.54%	2.19%	30-day mean
SASOH	9.95%	1.27%	1.81%	30-day mean

Ches Bay segment	30-day mean	7-day mean	Instantaneous minimum	Most protective criterion
SEVMH	4.38%	0.77%	1.54%	30-day mean
TA1MH	11.93%	6.99%	7.39%	30-day mean
TA2MH	1.20%	0.00%	0.00%	30-day mean
TAMMH	11.34%	6.50%	7.00%	30-day mean
TANMH	12.85%	6.76%	6.66%	30-day mean
TAVMH	15.43%	7.17%	5.76%	30-day mean
VPCMH	1.62%	0.08%	0.59%	30-day mean
YRKMH	7.42%	2.89%	3.19%	30-day mean

Table D-3. Comparison of deep–water dissolved oxygen 30-day mean, 1-day mean and instantaneous criteria for the moderate reduction scenario and the 1996–1998 assessment period across Bay segments for identification of the most protection criterion.

Ches Bay segment	30-day mean	1-day mean	Instantaneous minimum	Most protective criterion
CB3MH	1.86%	0.60%	0.29%	30-day mean
CB4MH	11.45%	10.21%	3.00%	30-day mean
CB5MH	2.22%	1.55%	0.01%	30-day mean
CB7PH	2.21%	0.99%	0.77%	30-day mean
CHSMH	14.31%	12.37%	6.60%	30-day mean
EASMH	18.11%	16.84%	9.91%	30-day mean
MD5MH	6.08%	5.52%	0.01%	30-day mean
PA1MH	0.11%	0.00%	0.00%	30-day mean
PA2MH	8.11%	7.82%	3.44%	30-day mean
PATMH	29.12%	27.75%	19.75%	30-day mean
PAXMH	0.63%	0.00%	0.10%	30-day mean
POMMH	0.08%	0.00%	0.00%	30-day mean
POMMH	0.08%	0.00%	0.00%	30-day mean
POTMH	0.08%	0.00%	0.00%	30-day mean
RPPMH	0.01%	0.00%	0.00%	30-day mean
SBEMH	42.50%	35.44%	22.34%	30-day mean

References

USEPA (U.S. Environmental Protection Agency). 2003. *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries*. EPA 903-R-03-002. U.S. Environmental Protection Agency Region 3 Chesapeake Bay Program Office, Annapolis, MD.

USEPA (U.S. Environmental Protection Agency). 2007. *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries–2007 Addendum*. EPA 903-R-07-003. CBP/TRS 285-07. U.S. Environmental Protection Agency Region 3 Chesapeake Bay Program Office, Annapolis, MD.

Appendix E.
Summary of Initial Climate Change Impacts on the Chesapeake Bay Watershed Flows and Loads

The potential effects of climate change have not been explicitly accounted for in the current Chesapeake Bay TMDL allocations, beyond application of a 10-year hydrologic period, because of known limitations in the current suite of Chesapeake Bay models to fully simulate the effects of climate change. A preliminary assessment of climate change impacts on the Chesapeake Bay was conducted, in parallel, using an earlier version of the Phase 5 Chesapeake Bay Watershed Model and tools developed for EPA's BASINS 4 system including the Climate Assessment Tool (CAT). Flows and associated nutrient and sediment loads were assessed in all river basins of the Chesapeake Bay with three key climate change scenarios reflecting the range of potential changes in temperature and precipitation in the year 2030. The three key scenarios came from a larger set of 42 climate change scenarios that were evaluated from 7 Global Climate Models (GCMs), 2 scenarios from the Intergovernmental Panel on Climate Change SRES (Special Report on Emissions Scenarios) storylines, and 3 assumptions about precipitation intensity in the largest events. The 42 climate change scenarios were run on the Phase 5 Watershed Model of the Monocacy River watershed, a subbasin of the Potomac River watershed in the Piedmont region, using a 2030 estimated land use based on a sophisticated land use model containing socioeconomic estimates of development throughout the watershed. The results provide an indication of likely precipitation and flow patterns under future potential climate conditions.

Downscaling of GCM temperature and precipitation data sets were provided by the Consortium for Atlantic Regional Assessment (http://www.cara.psu.edu/). Weather data reflecting each climate change scenario were created by modifying a 16-year period of historical data of precipitation and temperature from 1984 to 2000. The climate change simulation provided for low, medium, and high climate change effects projected out to 2030.

The Susquehanna River Basin covers almost half the Chesapeake watershed and has a major influence on flows and loads to the Chesapeake. The Susquehanna River responses were examined with an annual average time series of flows and loads reported as a percent difference of the 2030 climate scenarios to the 2000 Base Scenario. Generally flows were seen to decrease in the climate change scenarios despite the higher climate change precipitation inputs. Decreased flows were due to the increased estimates in temperature which, in turn, increased the simulated evapotranspiration in the Susquehanna River watershed.

In the Chesapeake Bay watershed, the 2030 estimated temperatures are about 1.5 degrees Celsius higher over the current temperatures. That estimate is relatively consistent in the different GCMs and has a high degree of certainty. Estimated precipitation increases among the seven global climate models are about 2 percent over current conditions, especially at higher rainfall events, and that is estimated with a moderate degree of certainty. How the temperature and precipitation increases affect flow and associated nutrient and sediment loads in the watershed depends on the hydrologic balance between precipitation and evapotranspiration.

Temperature increases tend to increase evapotranspiration in watersheds, and that can offset increases in precipitation. That seems to be the case in the Chesapeake Bay watershed. Current estimates of the medians of the different scenarios run have an annual average flow, nitrogen,

and phosphorus load decrease of –6.0 percent, –1.6 percent, and –2.1 percent, respectively. Because sediment loads increase with higher rainfall events, the median of the nine scenario estimates for sediment is for an increase of 4.9 percent. Figures E-1 through E-4 show annual average time series of flow, nitrogen, phosphorus, and sediment loads, respectively, for the three climate change scenarios compared to the 2000 Base Scenario.

For all three scenarios, flow is decreased in the high-flow winter period, although for two of the scenarios, summer flows are higher (Figure E-1). That could be because of the *flash 30%* and *flash 10%* precipitation conditions used in the scenarios as summer precipitation is characterized by short-term, high-precipitation thunderstorm events.

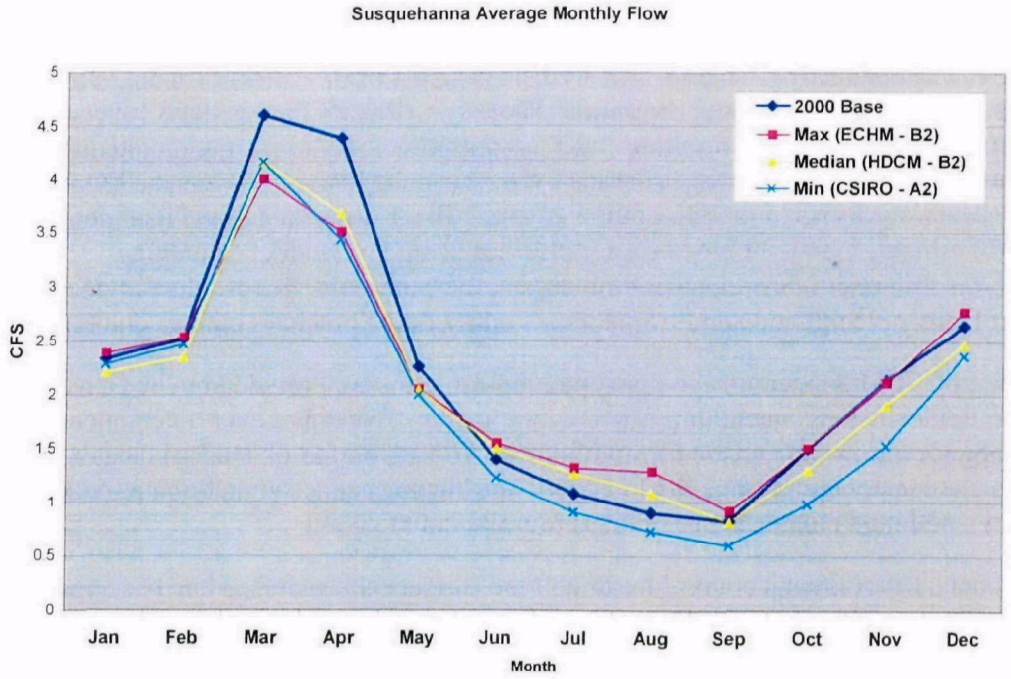


Figure E-1. Average annual time series of flow (cubic feet per second or CFS) for the 2000 Base Scenario and the maximum, median, and minimum climate change scenarios.

Total nitrogen loads follow the overall flow conditions, and they are generally depressed in the winter high-load period of nitrogen (Figure E-2).

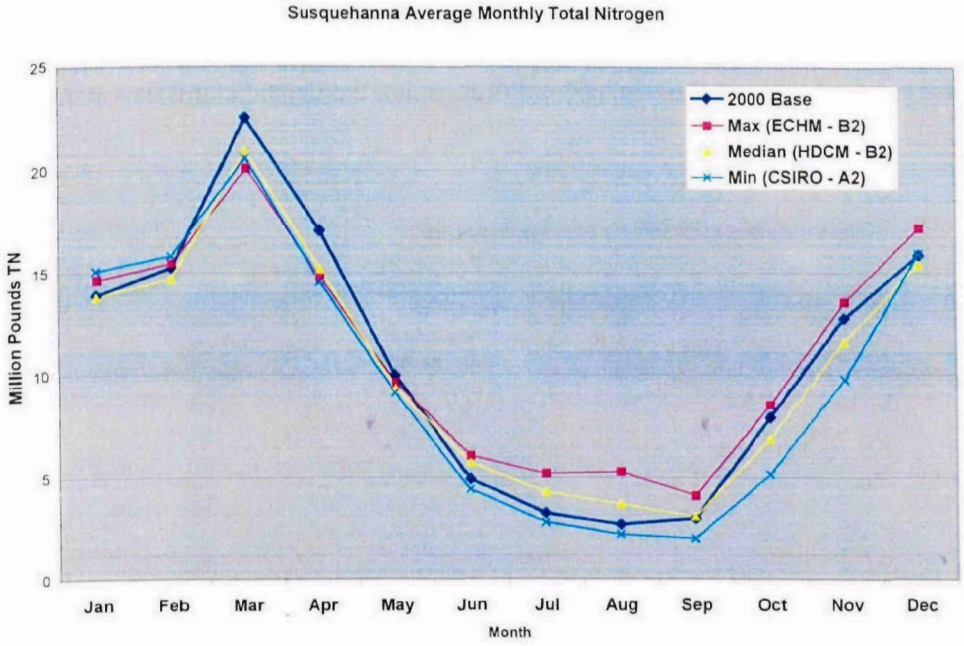


Figure E-2. Average annual time series of total nitrogen loads (millions of pounds per year) for the 2000 Base Scenario and the maximum, median, and minimum climate change scenarios.

The total phosphorus time series is similar to total nitrogen but is somewhat more responsive to episodic high flows in the two flash 10% and flash 30% precipitation conditions (Figure E-3).

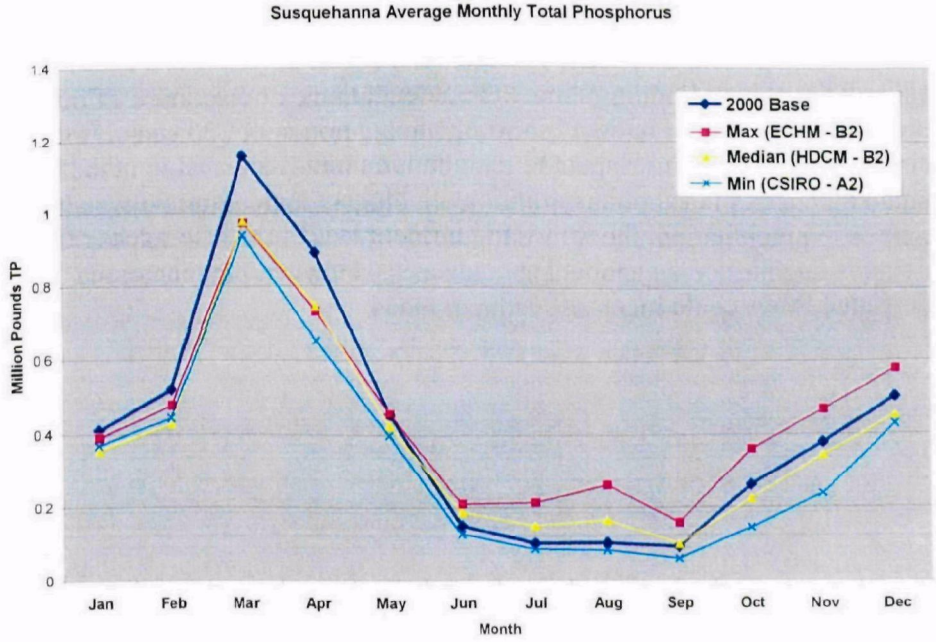


Figure E-3. Average annual time series of total phosphorus loads (millions of pounds per year) for the 2000 Base Scenario and the maximum, median, and minimum climate change scenarios.

In the Chesapeake Bay watershed, the concentration of total suspended solids (TSS) can increase three orders of magnitude from low-flow to extreme high-flow conditions, particularly in the larger rivers. Combined with higher flows, the higher TSS concentrations generate estimates of TSS loads under the flash 10% and flash 30% conditions that are episodic and flashy in nature (Figure E-4).

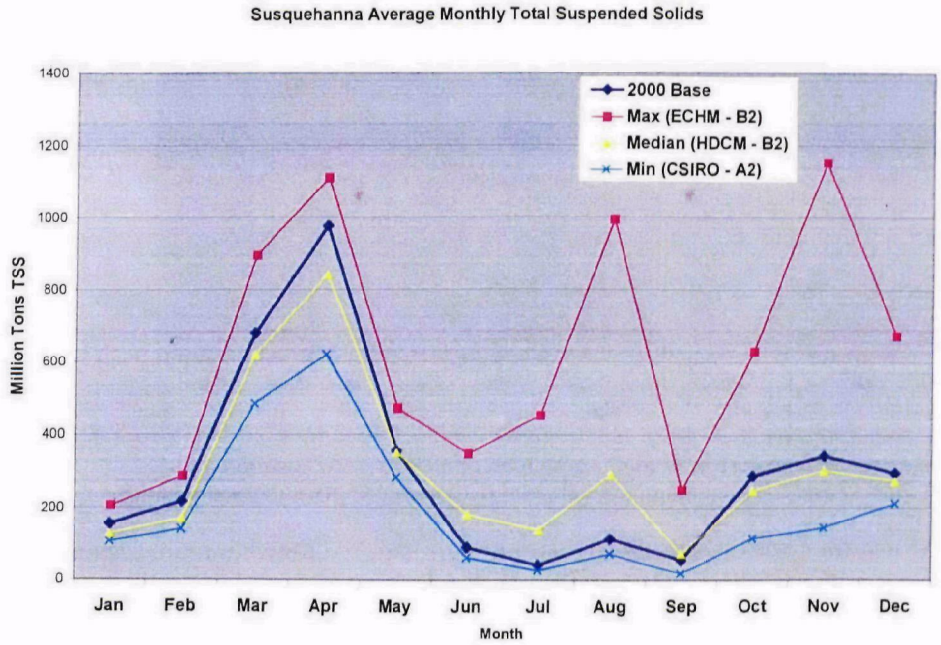


Figure E-4. Average annual time series of total suspended solids loads (millions of tons per year) of the 2000 Base Scenario and the maximum, median, and minimum climate change scenarios

Overall, the model simulation-based findings show the potential range of response of flows and loads to climate change, at least over a relatively short planning horizon of 20 years. If the historic and model trends hold true with respect to precipitation trends increasing in the larger events, and if estimated increases in evapotranspiration with higher temperature outweigh estimated 2030 increases in precipitation, the flow and nutrient loads in the Chesapeake Bay should experience relative declines on an annual average basis. However, the increased precipitation and its related flows could increase sediment loads.

Appendix F.
Determination of the Hydrologic Period for Model Application

Section 6.1.1 defined the hydrologic period for application of the suite of Chesapeake Bay models and reported that the 10-year period 1991–2000 was selected on the basis of a number of criteria. This appendix documents the analyses behind the selection of the hydrologic averaging period.

The hydrologic period for modeling purposes represents a typical or representative long-term hydrologic condition for the waterbody. The hydrologic period is used for expressing average annual loads from various sources. It is not to be confused with the critical period, which defines a period of high stress (see Sections 6.2.1 and 6.4.1 and Appendix G). It is important that the selected hydrologic period is representative of the long-term hydrology in each area of the Chesapeake Bay watershed so that no one area is modeled with a particularly high or low loading or an unrepresentative mix of point and nonpoint sources. The selection of a representative hydrologic averaging period ensures that the balance between point and nonpoint source loading and the balance between different geographic areas are appropriate.

Because of the long history of stream flow and water quality monitoring in the Chesapeake Bay watershed, the Chesapeake Bay Program partners were in the position of selecting a period for model application representative of typical hydrologic conditions from among the 21 contiguous model simulation years—1985 to 2005. The partners first selected 10 years as the appropriate number of years for the hydrologic period and then selected the best contiguous 10-year period.

Methods

Monitored stream/river flow was used exclusively as the indicator of hydrology. Three other criteria were investigated and evaluated by the Chesapeake Bay Program's Water Quality Goal Implementation Team but were not used.

1. Rainfall: Stream/river flow was judged to be a better overall indicator than rainfall as flow integrates the effects of evapotranspiration and snowpack effects of temperature. Flow is also more tractable to work with because the nine river input monitoring stations characterize flows and pollutant loads from 80 percent of the Chesapeake Bay watershed, whereas approximately 500 rainfall stations are across the entire Chesapeake Bay watershed.
2. Water quality: Observed water quality was considered as an ancillary criterion but was eventually rejected. Observed water quality is dependent, in part, on management actions taken throughout the Bay watershed. The Chesapeake Bay Program's Water Quality Goal Implementation Team decided that the criteria for selecting the hydrologic period should be independent of management actions.
3. Modeled loads: The EPA Chesapeake Bay Program Office performed an analysis of modeled loads to investigate the change in the fraction of load by major river basin and pollutant loading source sectors for different hydrologic averaging periods. This criterion was also rejected by the Water Quality Goal Implementation Team because it incorporated the effects from management actions and not just hydrology.

The objective of selecting a hydrologic period is to ensure that the period has flow statistics that were representative of the long-term flow statistics and that the representativeness held across different areas of the Bay watershed. Flow statistics for periods of different length and starting years were considered. To judge the overall representativeness, several statistics were calculated.

1. Mean flow anomaly: This statistic is the absolute value of the difference between the mean flow value for any given period and the long-term mean, divided by the long-term mean. If the mean flow value for a candidate period were equal to the long-term mean, the value of this indicator would be zero. If the mean flow value for a candidate period were either zero or twice the long-term mean, the value would be one.
2. Standard deviation anomaly: Similar to the mean anomaly, this statistic is the absolute value of the difference between the standard deviation of a candidate period and the long-term standard deviation divided by the long-term standard deviation.
3. Kolmogorov-Smirnov (K-S) test statistic: The K-S test is a common nonparametric method of comparing two distributions. The cumulative frequency distributions of two populations are plotted together, and the maximum distance between the two distributions on the probability axis is used at the test statistic, commonly known as *D*. From that test statistic, P values are generally calculated and hypothesis tests run. In the analyses for selecting the hydrologic period, a candidate period distribution is compared to a long-term distribution. For this work, the Water Quality Goal Implementation Team decided to use the D statistic. The D is monotonically related to the P value in this case because the number of observations was constant across analyses and the distribution of the D values was more suited to this work. The D statistic was calculated for the daily flow for an estimate of the agreement in short-term events and for the annual flow for an estimate of the agreement in inter-annual variability.

The nine river input stations compose the set of farthest-downstream, well-monitored flow stations on significant rivers flowing to the Chesapeake Bay, measuring river flow close to the point where the free-flowing river enters the Bay's tidally influenced waters. The analysis used a 30-year flow period that was common to all nine stations and also a long-term flow that used different flow period lengths for each major river basin (Table F-1). In both analyses, only years without missing data were used. At the time of this analysis, the last full year record of flow data was 2006, so the 30-year analysis used all data from 1977 to 2006.

Table F-1. The nine major Chesapeake Bay river flow gage stations used in the determination of the Chesapeake Bay TMDL hydrologic period

Gage ID	Flow gage station description	Full years in the 30-year record*	Full years in long-term record
1668000	Rappahannock River near Fredericksburg, VA	30	99
1646502	Potomac River (Adjusted) near Washington, DC	30	77
2037500	James River near Richmond, VA	30	72
1674500	Mattaponi River near Beulahville, VA	28	64
1673000	Pamunkey River near Hanover, VA	30	65
1491000	Choptank River near Greensboro, MD	30	60
1578310	Susquehanna River at Conowingo, MD	30	40
2041650	Appomattox River at Matoaca, VA	30	37
1594440	Patuxtent River near Bowie, MD	29	29

* The 30-year record is 1977-2006.

Selecting the Number of Years

Ten years was selected as an appropriate length of time as the following analysis showed that most of the 12 possible 10-year contiguous periods are statistically similar to the long-term flow record.

To reduce the dimensionality of the analysis, the Water Quality Goal Implementation Team recommended using a statistic that combined the mean and standard deviation of a given candidate period compared to the same statistics for the 30-year period. The combined statistic allows depiction of a single statistic rather than multiple statistics for easier interpretation. The combination statistic was simply the average of the mean flow anomaly and the standard deviation anomaly described above. The flow and standard deviation anomalies were calculated separately for each of the nine river stations and then averaged. Lower values of the combined statistic correspond to more representative periods.

Because the hydrologic period had to be within the Chesapeake Bay model simulation period of 1985–2005, only periods that fell within that 21-year window were considered. The combined statistic was calculated for each instance of each window length that occurred within the modeling period. For example, the statistic was calculated for two 20-year periods, 1985–2004 and 1986–2006 and for 16 6-year periods, 1985–1990, 1986- 1991, ... 2000–2005. For each candidate hydrologic period length, the minimum, maximum, and average values of the combined statistic were tabulated and are plotted in Figure F-1.

Figure F-1 illustrates that when using 10 or more contiguous years, all possible candidate periods are score relatively well using the combined metric. With fewer than 10 years, there is a mix of periods that score well and periods that score poorly. A 10-year period was chosen by the Water Quality Goal Implementation Team as a robust choice for the length of the hydrologic period.

Selecting the Ten-Year Period

There are 12 possible 10-year contiguous periods from 1985 to 2005. Although the above analysis suggests that any of the periods might be acceptable, a more detailed analysis showed that some regional differences and overall statistical differences exist between the candidates. As with selecting the number of years, a combined statistic reduced the dimensionality to make the analysis more tractable. For the analysis, the Water Quality Goal Implementation Team agreed on developing a statistic that combined mean anomaly, standard deviation anomaly, and the D statistic for daily and annual flow. Those four statistics were normalized by the average value of each statistical type individually and then averaged so that the overall score for all 10-year periods centered around one. The averages were plotted separately for each of the nine major river basins.

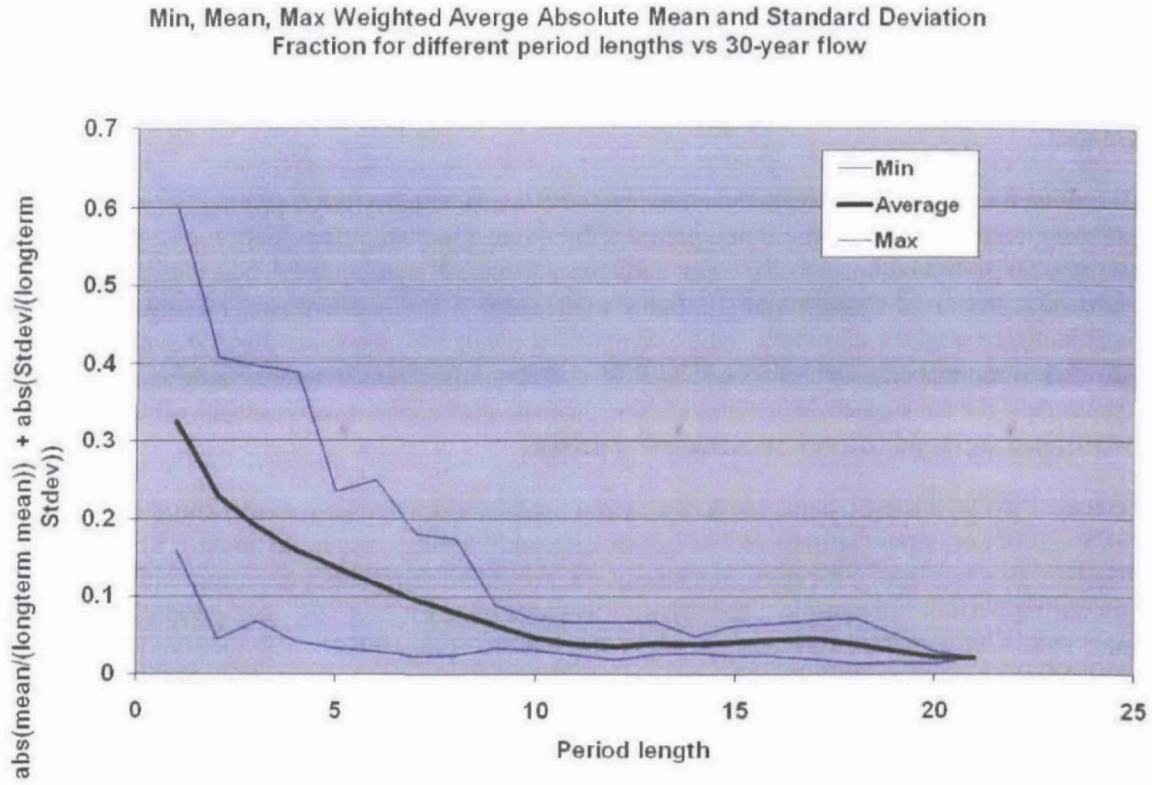
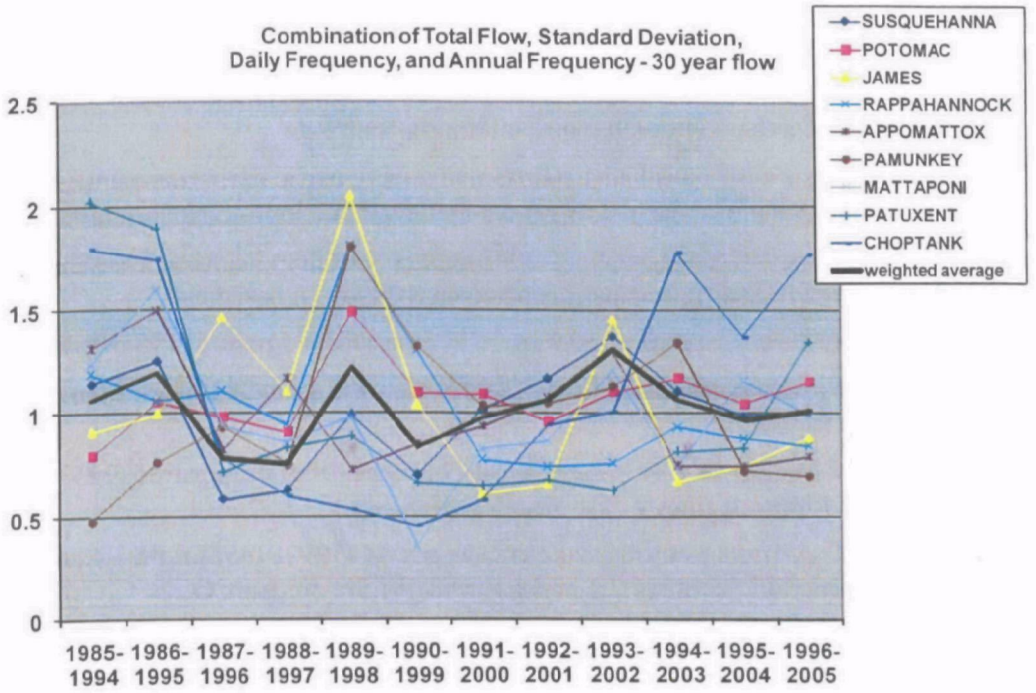


Figure F-1. Range of values of the combined flow statistic for different period lengths.

For example, the mean anomaly in the James River Basin for 1985–1994 was divided by the average mean anomaly of all twelve 10-year periods in the James River Basin. The standard deviation anomaly and D statistics for 1985–1994 were divided by the average of their counterparts for all twelve 10-year periods. The four values were averaged to get an overall score for 1985–1994 in the James River Basin. That process was repeated for each basin and for the flow-weighted average of all nine major river basins for each candidate period. Both the 30-year flow and the long-term flow were considered. The results are shown in Figure F-2.

In Figure F-2, the statistics are all compared to the average, so the average value is one. Lower values reflect better statistical fit to the long-term data set, so values below one are the better candidates for a representative hydrologic period. The thick black line in Figure F-2 is the flow-weighted average of the values for the individual major river basins and, therefore, the best overall indication of statistical fit.

Another consideration is the size of the spread around the flow-weighted average. A tighter distribution means that the good statistical fit holds across all major river basins and is not an unrepresentative hydrologic period for any major river basin. The candidate periods 1987–1996, 1988–1997, 1990–1999, and 1991–2000 are all better than average in terms of the statistical fit (Figure F-2). However, the first three candidate periods—1987–1996, 1988–1997, and 1990–1999—all have individual major river basins that are not good statistical fits. The period 1991–2000 has the tightest overall grouping meaning that it is representative across all major river basins (Figure F-2).



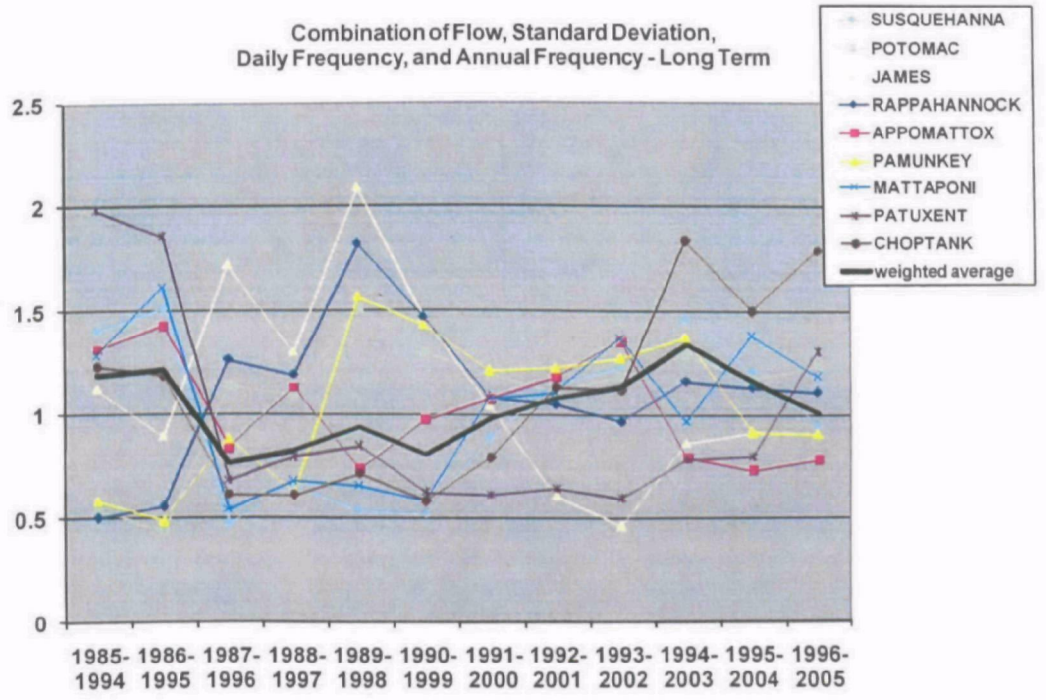


Figure F-2. The combined statistic for the candidate 10-year periods by the nine major river basins for the 30-year flow record (a) and the available long term flow record (b).

The 10-year hydrologic assessment period from 1991 to 2000 was selected by the Water Quality Goal Team for the following reasons:

- It was one of the 10-year periods within the 1985–2005 Chesapeake Bay model simulation period that was closest to an integrated metric of long-term flow.
- Each of the nine major river basins had statistics that were particularly representative of the long-term flow for both the 30-year flow record and available long-term flow record.
- It overlaps several years with the previous 2003 tributary strategy allocation assessment period (1985–1994) facilitating comparisons between the two assessments.
- It incorporates more recent years than previous 2003 assessment period (1985–1994).
- It encompasses the complete decade of 1991–2000, which is a straightforward span of time to communicate to the public,
- It overlaps with the Chesapeake Bay Water Quality Model calibration period (1993–2000), which is important for the accuracy of the model predictions.
- The 10-year period encompasses the 3-year critical period (1993–1995) for the Chesapeake Bay TMDL as explained in Section 6.2.1 and documented in Appendix G.

Appendix G.
Determination of Critical Conditions for the Chesapeake Bay TMDL

Introduction

The Chesapeake Bay TMDL must be developed to attain applicable water quality standards. Critical conditions for stream flow pollutant loading and water quality parameters must be taken into account. All approvable TMDLs must be established in a manner that reflects *Critical Conditions*. Critical conditions are represented by the combination of loading, waterbody conditions, and other environmental conditions that result in impairment and violation of water quality standards. Critical conditions for an individual TMDL typically depend on applicable water quality standards, characteristics of the observed impairments, source type and behavior, pollutant, and waterbody type. In establishing the Chesapeake Bay TMDL, it was necessary to define a *Critical Period*, a period during which hydrologic, temperature, environmental, flow, and other such conditions result in a waterbody experiencing critical conditions with respect to an identified impairment (e.g., summer low flow, winter high flow). The approach chosen in the Chesapeake Bay TMDL was to select a 3-year period as the critical period.

The Chesapeake Bay Program's Water Quality Goal Implementation Team decided that the critical period would be selected from the previously selected hydrologic period 1991–2000 because that time frame is representative of long-term hydrology, is within the model calibration period, and would facilitate modeling operations (see Sections 6.2.1 and 6.5.1 and Appendix F). A 3-year period was selected to coincide with the Chesapeake Bay water quality criteria assessment period (USEPA 2003).

The Water Quality Goal Implementation Team also agreed that the critical period should be representative of an approximate 10-year return period. The return period is defined as the average period of time expected to elapse between occurrences of events at a certain site. A 10-year event is an event of such size that over a long period, the average time between events of equal or greater magnitude is 10 years. The team believed that 10 years was a good balance between guarding against extreme events (greater than 10-year return frequency) and ensuring attainment during more frequent critical events (occurring within less than a 10-year period). The selection of a 10-year return period was also based on the commonly applied 10-year return period for application of the 7Q10 low flow conditions. Finally, the 10-year return period is also consistent with the critical periods selected for other TMDLs developed and published by the Chesapeake Bay watershed jurisdictions.

The following sections discuss the process for determining the critical period on the basis of determining the return period for each of the 3-year time frames within the selected 1991–2000 hydrologic period using various methods. A critical period was selected for assessing achievement of the jurisdictions' Chesapeake Bay dissolved oxygen (DO) and water clarity/submerged aquatic vegetation (SAV) water quality standards. As described below, there was no basis for selecting a specific 3-year critical period for assessment of achievement of the jurisdictions' numerical chlorophyll *a* water quality standard.

Approaches Used in Previous TMDLs to Select the Critical Period

To determine if there is a consistent approach to establishing a critical period among the Chesapeake Bay watershed jurisdictions, each jurisdiction's water quality standards were reviewed, the seven watershed jurisdictions were polled, and previously completed TMDLs were referenced.

Generally, the jurisdictions' water quality standards do not address a method for establishing the critical hydrologic period. Further, EPA does not have specific guidance or regulations on how to determine critical period. EPA only requires that critical conditions and seasonal variations are considered [40 CFR 130.7(c)(1)]. EPA Region 3 has not required any specific method for determining critical conditions and seasonal variations as long as the critical condition captures the *worst case* scenario or the most vulnerable environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards.

In polling the jurisdictions regarding their approaches to determining the hydrology critical period, all jurisdictions reported that the determination is dependent on the pollutant, the water quality standards, the TMDL endpoint, and the amount of flow data available. All jurisdictions reported that the critical period was determined using a representative data set capturing a range of high, low, and average flows. Maryland, the District of Columbia, and Virginia reported selecting the critical period by using a dry year, an average year, and a wet year. Maryland also indicated that in some TMDLs, time-variable models use the worst condition in the calibration period. Although, nutrient TMDLs with steady-state models use 7Q10 flows as the critical period. Delaware reported using the 7Q10 for free-flowing streams and using the monthly or seasonally average as the critical condition for the calibration period for tidal streams. Pennsylvania reported recently beginning to use the growing season average as the critical period for nutrient TMDLs. West Virginia watershed TMDLs use representative precipitation-induced flow data over a 6-year period with high, low, and average conditions.

A review of TMDLs completed for tidal influenced streams and estuaries along the Atlantic and Gulf Coasts revealed that there is no consistent method for determining the critical period. That review was not intended to be exhaustive but to reveal general patterns of methodology across the country. Most TMDLs used a critical period that was protective during low flows, rather than high flows, the condition of interest for the Chesapeake Bay TMDL.

The most commonly identified method for establishing the critical period was the use of 7Q10 flows. The *Louisiana Standard Operating Procedures for Louisiana TMDL Technical Procedures* (LDEQ 2009) specifically outlines the summer critical conditions as 7Q10 or 0.1 cubic feet per second (cfs), whichever is greater, or for tidal streams one-third of the average or typical flow averaged over one tidal cycle. Similarly, winter critical conditions are 7Q10 of 1 cfs, whichever is greater, or for tidal streams one-third of the average or typical flow averaged over one tidal cycle.

Other examples of using 7Q10 flows include the following:

- **Total Maximum Daily Load Analysis for Nanticoke River and Broad Creek, Delaware (DNREC 1998).** The model for this DO, total nitrogen, and total phosphorus TMDL was developed and calibrated using hydrologic and hydrodynamic from 1992, a dry

year. Hydrodynamic Model was run using 7Q10 flows, water quality model was run using 1992 pollutant loads.

- **Organic Enrichment/Dissolved Oxygen TMDL Rabbit Creek and Dog River, Alabama (ADEM 2005).** The hydrology of the LSPC model was calibrated for the period of record, October 1, 1996, through September 30, 2000. For the purposes of this TMDL the 2000-year was used as the critical low-flow period. 2000 was a relatively dry year and was one of the periods over which the models were calibrated, lending confidence to the simulations. The period of the model simulation was from 2000 to 2001. This period was selected on the basis of the availability and relevance of the observed data to the current conditions in the watershed. The model was calibrated for the year 2000, which represented both high- and low-flow periods. In 2000 flows were very low and near critical 7Q10 conditions, while in 2001 flows were higher.
- **TMDL Bayou Sara/Norton Creek – Mobile River Basin Organic Enrichment/DO (ADEM 1996).** Summer (May–November) TMDL critical conditions and MOS were established as 7Q10 flows and 30 degrees Celsius (°C). The winter (December–April) TMDL critical conditions and MOS were established as 7Q2 and 20 °C.
- **Total Maximum Daily Load Cooper River, Wando River, Charleston Harbor System, South Carolina (SCDHEC 2002).** Critical conditions for this DO TMDL were determined in the model by setting water quality parameters to represent 75/25 percentiles. The average spring and neap tidal conditions were evaluated with freshwater inflow set to approximate a 7Q10 recurrence, and algal processes were turned off. The model was calibrated to a 3-day period and validated on a 2-day period in 1993. The seasonal critical period was considered to be the low-flow, high-temperature conditions associated with summer and early fall.
- **Total Maximum Daily Load Ashley River, South Carolina (SCDEHC 2003).** The recommended critical flow period includes setting uncontrolled freshwater inflows to 7Q10 flows and selecting the seaward tidal boundary to represent a full lunar month including both spring and neap tides. Those conditions approach worst-case conditions for the impact of point sources on river DO levels. The wasteloads determined for the critical conditions are considered to be protective of the river DO standard when river flow is equal to or greater than 7Q10 because higher flows would provide greater dilution. Higher river flows are expected during wet weather, so the wasteloads should be protective under those conditions.

Another common method for determining the critical period was selecting a 3-year time span on the basis of precipitation, selected to include a wet year, a dry year, and a normal year. Some examples of this approach include the following:

- **Total Maximum Daily Load Analysis for Indian River, Indian River Bay and Rehoboth Bay, Delaware (DNREC 1998).** This is a nitrogen and phosphorus TMDL. The baseline period was established as 1988 through 1990. The hydrologic condition of the year 1988 was considered to represent a dry year, 1989 a wet year, and 1990 a normal year. No indication of the full data set from which the baseline period was established was given.
- **Total Maximum Daily Loads of Nitrogen and Phosphorus for Baltimore Harbor in Anne Arundel, Baltimore, Carroll, and Howard Counties and Baltimore City, Maryland (MDE 2006).** The baseline conditions scenario represents the observed

conditions of the Harbor and its tributaries 1995–1997. Simulating the system for 3 years accounts for various loading and hydrologic conditions, which represent possible critical conditions and seasonal variations of the system. For example, the 1995–1997 period includes an average year (1995), a wet year (1996) and a dry year (1997).

- **Total Maximum Daily Load Organic Enrichment/Dissolved Oxygen Threemile Creek, Alabama (ADEM 2006).** The hydrology of the LSPC model was calibrated for the period of record, October 1, 1996, through September 30, 2000. The period of the model simulation was from 2000 to 2001. That period was selected on the basis of the availability and relevance of the observed data to the current conditions in the watershed. The model was calibrated for the year 2000, which represented both high and low-flow periods. The model was simulated from May 2000 through April 2001 to account for both summer (May–November) and winter (December–April) conditions. In the natural conditions model, two critical periods were selected to establish seasonal TMDLs. A period during June 2000 was simulated under natural conditions, which resulted in a minimum DO concentration of 1.91 milligrams per liter (mg/L) at a 5-foot depth. That June event defines critical conditions in Threemile Creek during the summer season. A period during April of 2001, the model simulated natural condition is 2.26 mg/L at a 5-foot depth and defines the winter critical period. A low-flow period with high temperatures for both summer and winter seasons was used to represent the worst-case conditions.
- **Total Maximum Daily Loads of Nutrients/Biochemical Oxygen Demand for the Anacostia River Basin, Montgomery and Prince George's Counties, Maryland and the District of Columbia. (MDE and DC DOE 2008).** The critical condition and seasonality was accounted for in the TMDL analysis by the choice of simulation period, 1995–1997. That 3-year period represents a relatively dry year (1995), a wet year (1996), and an average year (1997), based on precipitation data, and accounts for various hydrological conditions including the critical condition.

Two TMDLs used the period of the worst hypoxia as the critical period. DO exceedances for Long Island Sound were dominated by point sources. Further details regarding the TMDLs follow:

- **A Total Maximum Daily Load Analysis to Achieve Water Quality Standards for Dissolved Oxygen in Long Island Sound (NYSDEC and CTDEP 2000).** Annual surveys from 1986 to 1998 and a review of historical data indicated that the 1988–1989 modeling time frame was the most severe period of hypoxia on record. As a result, model simulations of reduced nitrogen inputs were used to predict water quality conditions that would result during the same physical conditions that exist during the 1988–1989 period. The use of 1988–1989 worst-case scenario was considered an implicit margin of safety.
- **Total Maximum Daily Load for Nitrogen in the Peconic Estuary Program Study Area Including Waterbodies Currently Impaired Due to Low Dissolved Oxygen: the Lower Peconic River and Tidal Tributaries; Western Flanders Bay and Lower Sawmill Creek; and Meetinghouse Creek, Terrys Creek and Tributaries (Peconic Estuary Program 2007).** The Environmental Fluid Dynamics Code (EFDC) model was calibrated using an 8-year period from October 1, 1988, to September 30, 1996 and validated using the 6-year period from October 1, 196, through September 30, 2002. Model calibration and verification included all seasons of the year, as well as extreme wet and dry years.

Monitoring data indicated that the October 2000 to September 2002 time frame was the most severe period of hypoxia on record from 1988 to 2002. October 1, 2000, to September 30, 2002, was selected as the critical period for the TMDL model runs.

In some cases, the data set either does not contain a critical year or several years are included to capture a range of temperature and flow concentrations. The *TMDLs for The Little Assawoman Bay and Tributaries and Ponds of the Indian River, Indian River Bay, and Rehoboth Bay* (DNREC 2004) is an example of the former. There was no *worst* year for DO, nitrogen and phosphorus during the 3-year period in question, so the average over the three summers was used as the critical (design) condition. The *TMDL for Nutrients in the Lower Charles River Basin, Massachusetts* (MassDEP and USEPA 2007) is an example of the latter. A continuous, 5-year simulation was run. The 1998–2002 period was selected because it represented some of the lowest summer flows throughout the 23-year period of record. Low flows at or near the 7Q10 flow value were observed during three of the summers during the selected critical period.

Two of the TMDLs reviewed had limited data sets, so the critical period was chosen on the basis of the period with the most data available. Examples of this approach follow:

- **Total Maximum Daily Loads of Nitrogen and Phosphorus for the Upper and Middle Chester River, Kent and Queen Anne's Counties, Maryland (MDE 2006).** The models were calibrated to the period of 1997–1999, which was the most recent period for which all of the needed data were available and consistent with the Chesapeake Bay Program modeling efforts of the Tributary Strategies. Only the output from 1997 was used to investigate different nutrient loading scenarios and calculate the annual average and growing season TMDLs for the Upper and Middle Chester rivers because in 1999, the region experienced extreme weather conditions (prolonged drought followed by Hurricane Floyd) resulting in atypically high flows and loads. On the basis of the flow gauge, it was determined that the flow in 1997 was representative of the average annual flow and loads. The timeframe selected includes representative wet and dry periods, accounting for seasonality and critical conditions.
- **Total Maximum Daily Load for Dissolved Oxygen in Mill Creek, Northampton County, Virginia (VADEQ 2009).** The observations show that the instantaneous DO levels fell below the water quality criterion of 4 mg/L minimum repeatedly throughout the period of 1997–2003. Because the nutrients data in the watershed were not available, an interactive approach of calibration of watershed and in-stream water quality model was conducted using all available in-stream monitoring data. The water quality model was calibrated in Mill Creek using the observation data. A 6-year model simulation (1998–2003) was conducted. Seasonal variations involved changes in surface runoff, stream flow, and water quality condition as a result of hydrologic and climatologic patterns. Those were accounted for by using this long-term simulation to estimate the current load and reduction targets.

Initial Analysis by Malcolm Pirnie

The consulting firm Malcolm Pirnie, representing the stakeholders from the Maryland Association of Municipal Wastewater Agencies, Inc. (MAMWA) and the Virginia Association of Municipal Wastewater Agencies, Inc. (VAMWA) conducted an independent analysis of the

inflows to the Chesapeake Bay to determine whether the initially selected critical period of 1996–1998 might represent a hydrologic condition with a longer return period than 10 years (Malcolm Pirnie 2009).

Malcolm Pirnie analyzed the flows from the Potomac and Susquehanna rivers, which together contribute most of the flow to the Chesapeake Bay, for the period 1967 through 2009. The average daily inflow from January through May was calculated for each year and for each 3-year period within the 42-year period of record. January through May was selected as the period of interest because studies have indicated that the magnitude and extent of hypoxia in the Chesapeake Bay is largely controlled by freshwater and nutrient inputs during the preceding winter and spring months (freshet).

Results indicated that 1996–1998 had the highest average January through May inflow over the entire period of record and would result in a return period of 40 years. The year 1996 had January through May inflows in the 93rd percentile and 1998 had flows in the 98th percentile. High flows in 1996 were attributed to rainfall on winter snowpack in January 1996, resulting in an event know as the *Big Melt*.

On the basis of those results, Malcolm Pirnie indicated that the critical condition would be too extreme if 1996–1998 were selected as the critical period. Malcolm Pirnie recommended using 1993–1995 or 1994–1996 as the critical period because they represent return flows much closer to a 10-year return period.

Replication of Malcolm Pirnie Results

To confirm the results of the Malcolm Pirnie analysis, Tetra Tech staff replicated the approach used in the Malcolm Pirnie flow analysis. The analysis was repeated using both the flow data presented in the Malcolm Pirnie technical memo (Malcolm Pirnie 2009) and the raw flow data from the U.S. Geological Survey (USGS). Although the replicated 3-year averages based on the flows in the technical memo did not match exactly what was presented in the technical memo, the minor discrepancies did not affect the percentile calculations. Similarly, the 3-year running averages using the raw USGS data resulted in minor discrepancies from the Malcolm Pirnie results. Despite the small differences, Tetra Tech's replication yielded the same results as the Malcolm Pirnie technical memo (Malcolm Pirnie 2009).

Analysis to Support Critical Period Selection

Additional analyses were performed to further explore the options for the selection of the critical period.

Preliminary analysis included an exploration of the results of including the nine major rivers in the flow analysis and expanding the combinations of different monthly flow durations beyond January to May to include other monthly duration combinations from September through July. Data were analyzed for 1978 through 2009 because the Patuxent flow gage did not begin until 1977. Refer to Table G-1 for the gages used in the analysis and the period for which data was available. Running 3-year average flows were calculated for 25 different month combinations for the entire period of evaluation. The probability of each 3-year flow average was determined

using the Weibull Plotting Position. The return period is the inverse of the probability. That method differed from the approach in the Malcolm Pirnie analysis (Malcolm Pirnie 2009), which used percentile ranks. A regression was also performed on the 3-year flow averages to determine if there was a correlation with the DO percent exceedances. The percent DO exceedances were provided by EPA's Chesapeake Bay Program Office (CBPO) and represent volume exceedances. The analysis was run with and without the use of tributary multipliers, which the CBPO developed because flows from different tributaries do not affect conditions in the Bay equally. Those factors are the estuarine delivery factors presented in the Section 6.3.1. The CBPO multipliers were translated to a 0.0 to 1.0 scale and are included in Table G-2. Without the multipliers, the Susquehanna and Potomac rivers contribute approximately 80 percent of the flow to the Bay. With the multipliers, the two rivers contribute approximately 95 percent of the effective load.

Table G-1. Flow gages and period of available data

Gage ID	Description	Start	End
1668000	Rappahannock River near Fredericksburg, VA	9/19/1907	8/25/2009
1646502	Potomac River (Adjusted) near Washington, DC	3/1/1930	7/31/2009
2037500	James River near Richmond, VA	10/1/1934	8/25/2009
1674500	Mattaponi River near Beulahville, VA	9/19/1941	8/25/2009
1673000	Pamunkey River near Hanover, VA	10/1/1941	8/25/2009
1491000	Choptank River near Greensboro, MD	1/1/1948	8/25/2009
1578310	Susquehanna River at Conowingo, MD	10/1/1967	8/25/2009
2041650	Appomattox River at Matoaca, VA	10/1/1969	8/25/2009
1594440	Patuxtent River near Bowie, MD	6/27/1977	8/25/2009

Table G-2. Chesapeake Bay tributaries flow multiplier ratios

Major river basin	Multiplier	Adjusted ratio
Appomattox	0.533111028	0.017
Choptank	6.929861533	0.217
James	0.533111028	0.017
Mattaponi	0.798423188	0.025
Pamunkey	0.798423188	0.025
Patuxent	3.093385849	0.097
Potomac	6.188243619	0.193
Rappahannock	2.809613056	0.088
Susquehanna	10.3187158	0.322
		1.000

Source: EPA Chesapeake Bay Program Office

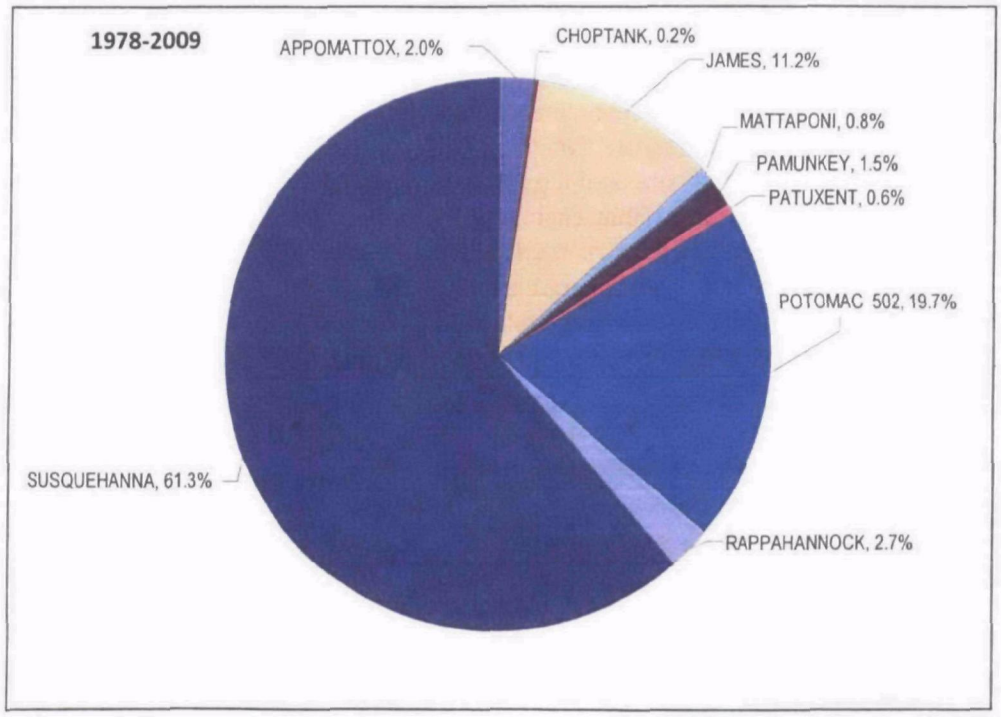


Figure G-1. Tributary flow contributions without multiplier ratios.

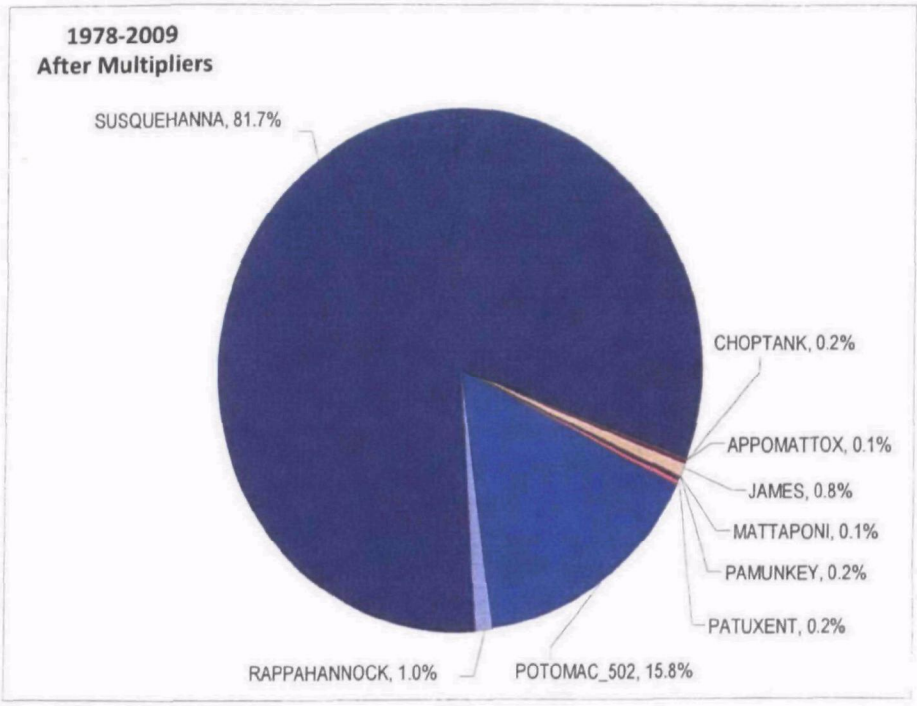


Figure G-2. Tributary flow contributions with the multiplier ratios.

Results of the analysis, as shown in Tables G-3 and G-4, indicate that the monthly span should be extended beyond the January through May period suggested in the Malcolm Pirnie analysis (Malcolm Pirnie 2009) because the 3-year flow averages with the highest correlation to DO exceedances generally included longer monthly spans. The 3-year average flow with the highest correlation to DO exceedances was September through June. Findings also suggest that 1996–1998 had closer to a 15-year return period for months when flow was more closely correlated with DO exceedances. The other possible critical periods 1992–1994 and 1993–1995 had generally lower than 10-year return periods and return periods greater than 10 years when flow was not strongly correlated with DO exceedances. Return periods greater than 6 years are highlighted in Tables G-3 and G-4, and only 3-year average flows with at least one monthly interval with a 6-year or greater return period are shown. There were no 3-year average flows with return periods greater than 6 years for any of the years between 1978 and 1991.

Table G-3. Return periods and R^2 correlation between various monthly durations and DO percent exceedances without the Tributary Multiplier Ratio.

% DO Exceedences --->		25.87%	25.92%	24.26%	27.84%	26.05%	31.11%	27.24%
Interval	R2	1992-1994	1993-1995	1994-1996	1996-1998	1997-1999	2003-2005	2004-2006
		Return Period						
SEP-JUNE	0.54	4.43	6.20	3.44	15.50	2.58	31.00	7.75
NOV-JUNE	0.53	6.20	7.75	5.17	31.00	2.07	15.50	4.43
SEP-JULY	0.53	4.43	5.17	3.44	15.50	2.58	31.00	10.33
NOV-JULY	0.52	6.20	7.75	4.43	15.50	2.07	31.00	5.17
DEC-JUNE	0.52	7.75	6.20	4.43	31.00	2.38	15.50	3.88
SEP-MAY	0.51	4.43	6.20	3.88	15.50	3.10	31.00	7.75
DEC-JULY	0.51	6.20	7.75	4.43	31.00	2.21	15.50	3.88
OCT-JUNE	0.50	5.17	6.20	4.43	15.50	2.38	31.00	7.75
OCT-JULY	0.49	5.17	6.20	4.43	15.50	2.21	31.00	7.75
NOV-MAY	0.48	6.20	7.75	5.17	31.00	3.10	15.50	4.43
SEP-APR	0.48	4.43	5.17	3.44	15.50	3.10	31.00	10.33
OCT-MAY	0.46	5.17	7.75	4.43	31.00	2.82	10.33	6.20
DEC-MAY	0.46	10.33	7.75	5.17	31.00	2.82	6.20	3.88
JAN-JUNE	0.44	10.33	6.20	4.43	31.00	2.58	5.17	2.21
JAN-JULY	0.44	6.20	5.17	4.43	31.00	2.21	7.75	2.82
NOV-APR	0.44	7.75	10.33	4.43	31.00	3.10	15.50	5.17
OCT-APR	0.42	5.17	7.75	3.44	31.00	3.10	15.50	6.20
SEP-MAR	0.42	2.82	3.44	3.88	15.50	4.43	31.00	10.33
DEC-APR	0.40	10.33	15.50	5.17	31.00	3.10	6.20	4.43
NOV-MAR	0.39	3.10	3.44	6.20	31.00	4.43	15.50	7.75
JAN-MAY	0.37	10.33	7.75	6.20	31.00	3.10	4.43	2.21
OCT-MAR	0.36	2.82	3.44	4.43	31.00	3.88	10.33	7.75
DEC-MAR	0.36	3.44	5.17	7.75	31.00	4.43	10.33	6.20
JAN-APR	0.32	31.00	15.50	6.20	10.33	3.44	3.88	2.38
JAN-MAR	0.26	5.17	6.20	10.33	31.00	7.75	3.88	2.58

Table G-4. Return periods and R^2 correlation between various monthly durations and DO percent exceedances with the Tributary Multiplier Ratio

% DO Exceedences --->		25.87%	25.92%	24.26%	27.84%	26.05%	31.11%	27.24%
Interval	R2	1992-1994	1993-1995	1994-1996	1996-1998	1997-1999	2003-2005	2004-2006
		Return Period						
SEP-JUNE	0.53	4.43	5.17	3.44	7.75	2.21	31.00	15.50
NOV-JUNE	0.53	5.17	6.20	4.43	15.50	1.94	31.00	7.75
DEC-JUNE	0.52	6.20	7.75	3.88	15.50	1.94	31.00	4.43
SEP-JULY	0.52	3.88	5.17	3.44	10.33	2.07	31.00	15.50
NOV-JULY	0.52	5.17	6.20	4.43	15.50	1.94	31.00	10.33
DEC-JULY	0.51	5.17	6.20	3.88	15.50	1.94	31.00	7.75
OCT-JUNE	0.49	5.17	6.20	3.88	15.50	2.07	31.00	7.75
SEP-MAY	0.49	4.43	5.17	3.88	7.75	2.58	31.00	15.50
OCT-JULY	0.48	5.17	6.20	3.88	15.50	1.94	31.00	10.33
NOV-MAY	0.46	6.20	7.75	4.43	31.00	2.38	15.50	5.17
SEP-APR	0.46	4.43	5.17	3.44	6.20	2.82	31.00	15.50
JAN-JULY	0.46	10.33	5.17	4.43	31.00	1.55	15.50	3.88
JAN-JUNE	0.46	10.33	6.20	4.43	31.00	1.82	5.17	2.82
DEC-MAY	0.45	7.75	10.33	5.17	31.00	2.21	6.20	4.43
OCT-MAY	0.44	5.17	6.20	3.88	15.50	2.21	10.33	7.75
NOV-APR	0.42	7.75	10.33	3.88	15.50	2.58	31.00	6.20
SEP-MAR	0.41	2.07	3.10	3.88	10.33	4.43	15.50	31.00
OCT-APR	0.41	5.17	6.20	3.44	10.33	2.58	31.00	7.75
DEC-APR	0.40	15.50	31.00	4.43	10.33	2.58	7.75	5.17
NOV-MAR	0.38	2.58	3.10	5.17	31.00	3.44	15.50	10.33
JAN-MAY	0.37	15.50	7.75	6.20	31.00	2.38	5.17	2.82
DEC-MAR	0.37	2.58	3.44	6.20	31.00	3.88	15.50	10.33
OCT-MAR	0.35	2.38	3.10	4.43	31.00	3.44	10.33	15.50
JAN-APR	0.32	31.00	15.50	6.20	10.33	2.58	5.17	3.44
JAN-MAR	0.28	2.58	3.88	10.33	31.00	7.75	6.20	2.82

Analysis of Critical Period Using the Log Pearson III Method

After determining the return period using the Weibull Plotting Position method, a second method, the Log Pearson III Method (U.S. Interagency Advisory Committee on Water Data 1982; Ponce 1989), was used to determine whether the return period changed significantly depending on the method of calculation. The Log Pearson III method provides a smooth fit through the plotting position data and in essence smoothens out the predicted values. That analysis was conducted over the same 1978 through 2009 period and focused on monthly spans with the highest correlation between flow and DO exceedances. Results in Table G-5 and Table G-6 show that there are some changes in the return periods, but the conclusion in terms of candidate years remains the same. This method of determining the return period was used in subsequent analyses.

Table G-5. Log Pearson III method for determining return period, without Tributary Multiplier Ratio.

Without Multiplier

% DO Exceedences	25.87%	25.92%	24.26%	27.84%	31.11%	27.24%
Year	1992-1994	1993-1995	1994-1996	1996-1998	2003-2005	2004-2006
Sep-June	4.38	4.90	3.77	17.99	34.80	12.37
Nov-June	7.45	7.90	5.46	20.71	19.09	5.36
Sep-July	4.16	4.79	4.05	16.77	36.03	14.15
Nov-July	6.79	7.53	6.02	18.95	20.33	6.59
Dec-June	9.19	9.11	6.68	19.70	15.89	4.24
Sep-May	4.90	5.74	3.80	17.77	23.83	11.69
Dec-July	8.39	8.66	7.26	18.14	17.24	4.97
Oct-June	5.44	6.15	4.60	19.99	21.57	7.16
Flow (Sep-June) (cfs)	81,791	83,254	80,099	95,684	101,516	92,106
Flow (Nov-June) (cfs)	97,725	98,368	94,810	108,161	107,300	94,664
Flow (Sep-July) (cfs)	76,755	78,432	76,487	89,677	96,200	88,110
Flow (Nov-July) (cfs)	89,756	90,753	88,724	99,399	100,142	89,485
Flow (Dec-June) (cfs)	104,233	104,117	100,461	111,988	109,418	95,653
Flow (Sep-May) (cfs)	86,706	88,203	83,278	100,501	103,783	96,146
Flow (Dec-July) (cfs)	94,451	94,829	92,906	101,658	101,107	89,709
Flow (Oct-June) (cfs)	88,780	89,746	87,057	101,106	101,688	91,140

Table G-6. Log Pearson III method for determining return period, with Tributary Multiplier Ratio.

With Multiplier

% DO Exceedences	25.87%	25.92%	24.26%	27.84%	31.11%	27.24%
Year	1992-1994	1993-1995	1994-1996	1996-1998	2003-2005	2004-2006
Sep-June	4.39	5.17	3.87	13.21	35.52	18.76
Nov-June	7.47	8.19	5.70	16.84	19.21	8.52
Sep-July	4.19	4.83	4.04	12.21	36.18	21.53
Nov-July	6.85	7.48	5.98	16.06	21.37	10.34
Dec-June	9.17	9.27	6.76	16.02	17.64	6.88
Sep-May	4.92	6.32	4.08	13.12	24.42	17.15
Dec-July	8.38	8.39	7.08	14.58	18.76	8.73
Oct-June	5.40	6.41	4.67	16.09	22.11	10.74
Flow (Sep-June) (cfs)	19,682	20,141	19,338	22,251	24,445	23,100
Flow (Nov-June) (cfs)	23,429	23,668	22,837	25,294	25,648	23,779
Flow (Sep-July) (cfs)	18,494	18,892	18,400	20,891	23,136	22,147
Flow (Nov-July) (cfs)	21,550	21,739	21,292	23,285	23,910	22,535
Flow (Dec-June) (cfs)	24,860	24,893	24,069	26,006	26,242	24,110
Flow (Sep-May) (cfs)	20,897	21,462	20,265	23,415	25,103	24,122
Flow (Dec-July) (cfs)	22,568	22,569	22,178	23,659	24,214	22,671
Flow (Oct-June) (cfs)	21,337	21,662	20,998	23,689	24,436	22,921

Analysis of Critical Period Using Expanded Flow Data

Given some concern that the 30-year period from 1978 through 2009 was of insufficient length to fully capture the return period over the full period of flow data and was artificially lowering the most extreme return period to 30 years, an extended analysis was performed for the years 1930 through 2009 but only included the Potomac and Susquehanna rivers. The Potomac and Susquehanna rivers account for almost 80 percent of the total flow to the Chesapeake Bay, and if the CBPO allocation multipliers are used, those two rivers account for almost 95 percent of the total inflow to the Chesapeake Bay. Hence, those two flow gages were considered sufficient for analysis purposes. The two USGS flow gages are described in Table G-1.

The Susquehanna River at Conowingo gage flow data runs from October 1, 1967, to the present. The period before October 1, 1967, was patched using data from the Susquehanna River at Harrisburg gage (01570500 – October 1, 1890, to August 25, 2009) using a simple drainage area ratio method. The daily freshwater inflow from the Potomac and Susquehanna rivers were weighed using the adjusted tributary multipliers provided by the CBPO (Table G-7).

Table G-7. Adjusted tributary flow multiplier ratios

Gage	Multiplier	Adjusted ratio
Potomac	6.188	0.375
Susquehanna	10.317	0.625

Source: EPA Chesapeake Bay Program Office

The analysis using the extended period followed the same procedure as previous analyses except that the data were extended back to 1930, only the weighted flow data based on multipliers were used, and the Log Pearson III method was used to determine the return period. Table G-8 lists the return periods for each of the monthly intervals for the extended period, with return periods greater than 6 years highlighted.

Table G-8. Extended period (1930–2009) return periods

% DO Exceedences	24.97%	25.87%	25.92%	24.26%	22.58%	27.84%	31.11%	27.24%
Year	1991-1993	1992-1994	1993-1995	1994-1996	1995-1997	1996-1998	2003-2005	2004-2006
jan-july	2.69	11.80	8.95	8.72	1.77	16.28	11.76	4.37
jan-june	3.05	13.72	9.84	8.14	1.69	17.59	9.71	3.03
jan-may	4.61	24.98	19.13	10.56	1.69	25.43	7.20	2.73
jan-apr	7.48	39.45	34.34	10.82	1.81	16.67	7.48	3.59
jan-mar	2.18	3.24	4.32	13.91	4.28	46.60	5.51	4.33
dec-july	3.03	9.20	9.15	7.92	2.69	15.66	20.18	9.88
dec-june	3.35	9.90	9.98	7.52	2.62	17.02	19.14	7.95
dec-may	4.76	16.77	17.73	9.20	2.76	23.09	16.70	8.14
dec-apr	6.96	20.14	23.89	9.10	3.01	16.01	16.48	9.99
dec-mar	2.68	3.49	5.42	9.87	7.27	31.16	13.94	13.66
nov-july	1.66	2.08	3.29	2.63	3.11	2.75	1.35	1.31
nov-june	3.39	8.92	9.67	7.10	3.18	20.60	25.44	10.69
nov-may	4.68	13.11	15.60	8.48	3.43	28.01	21.32	11.48
nov-apr	6.51	16.24	19.83	8.46	3.78	19.26	21.02	15.07
nov-mar	2.84	3.43	5.51	8.90	8.28	34.04	17.98	17.83
oct-july	3.64	6.50	7.38	6.27	3.71	18.35	32.07	18.23
oct-june	4.12	6.98	8.03	5.91	3.72	19.90	31.72	15.37
oct-may	5.69	9.02	10.95	7.06	4.09	25.80	26.88	16.45
oct-apr	7.66	10.82	14.96	7.08	4.40	18.91	26.38	19.62
oct-mar	3.42	2.92	4.50	7.25	8.82	29.23	20.77	22.25
sep-july	3.39	5.40	6.73	5.06	4.18	17.56	69.44	38.08
sep-june	3.86	5.81	7.27	4.87	4.26	18.29	62.21	30.68
sep-may	4.93	7.51	9.31	5.64	4.62	21.90	56.34	34.77
sep-apr	6.60	8.70	11.93	5.68	4.90	17.28	52.38	40.22
sep-mar	3.25	2.74	4.31	5.78	9.16	23.34	40.15	43.20

The monthly intervals with high correlations with DO exceedances are September – June, November–June, December–June, September–July, and December–July. Table G-9 highlights the return periods for the monthly intervals with high correlations with DO exceedances.

Table G-9. Return periods for monthly intervals highly correlated to Chesapeake Bay DO criteria exceedances

Interval	1992–1994	1993–1995	1994–1996	1996–1998
September–June	5.81	7.27	4.87	18.29
November–June	8.92	9.67	7.10	20.60
December–June	9.90	9.98	7.52	17.02
September – July	5.40	6.73	5.06	17.56
December – July	9.20	9.15	7.92	15.66

Analysis of Critical Period using De-Trended Flow Data

As previously noted, initial analysis of the 3-year average flows from 1978 through 2009 did not reveal any 3-year periods before 1992 with return periods greater than 6 years for the monthly intervals included in the analysis. This indicates a potential increasing trend in flow volume over the last several decades. De-trending removes any flow trends over time and allows for an equal comparison of current and historic flows. It can remove the effects of urbanization and other impacts, which are apparent in the flow data.

The first step in de-trending was to determine if there is a significant trend in the flow data. The slope of the trend line is 0.1878. The Kendall Tau ranking correlation coefficient was used to determine if this is a statistically significant trend. The Tau value can range between –1 and 1, with a positive number indicating an increasing trend and a negative number indicating a decreasing trend. The flow data from 1930 through 2009 had a positive Tau value. A p-value < 0.05 indicates a statistically significant trend. The time-series flow data had a p-value of 0.0042, which is statistically significant. Figure G-3 shows the trend line in the raw data.

After establishing that a statistically significant increasing trend exists in the flow data, a de-trended time-series was developed. Two different methods were used to fit a trend line through the time-series data—Linear Least Squares Regression, and the Locally Weighted Scatter Plot Smoothing (LOWESS) (Helsel and Hirsch 2002; NIST and SEMATECH 2006).

The linear regression trend line was estimated by fitting the time-series data using a trend line of the form $y = mx + c$ (where m is the slope, c is the intercept, y being the dependent variable, i.e., flow, and x the independent variable time). The LOWESS fit is determined by specifying a smoothening parameter, which defines the subset of data that will be used for the local fit. The LOESS technique performs a weighted least square regression fit (on a subset of points) in a moving range around the x value (time), where the values in the moving range are weighted according to their distance from this x value. For that analysis, a smoothening parameter of 0.33 was found to fit the data trend reasonably well. Details of the LOWESS computation are at: http://www.itl.nist.gov/div898/handbook/pmd/section1/dep/dep144.htm.

The residuals were then calculated for each method (i.e., the difference between the observed and predicted values along the trend line). Finally, the residuals were added to the last point in the time series (the maximum value) to generate a de-trended time series. To confirm that no trend exists in the resulting de-trended time series using the linear regression approach, the linear slope was calculated. The slope was zero, indicating that there was no remaining trend. For the

de-trended time-series using the LOWESS regression, the presence of no trend in the time-series was confirmed using a p-value. The p-value of the de-trended data was 1.2376, indicating a statistically insignificant trend (p-value < 0.05 is significant). Figure G-4 plots the de-trended data.

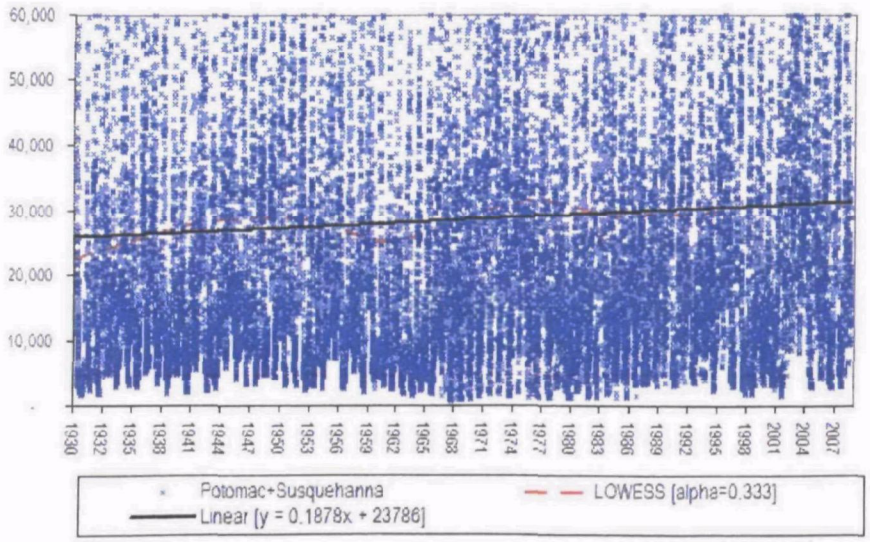


Figure G-3. Raw flow data with trend line.

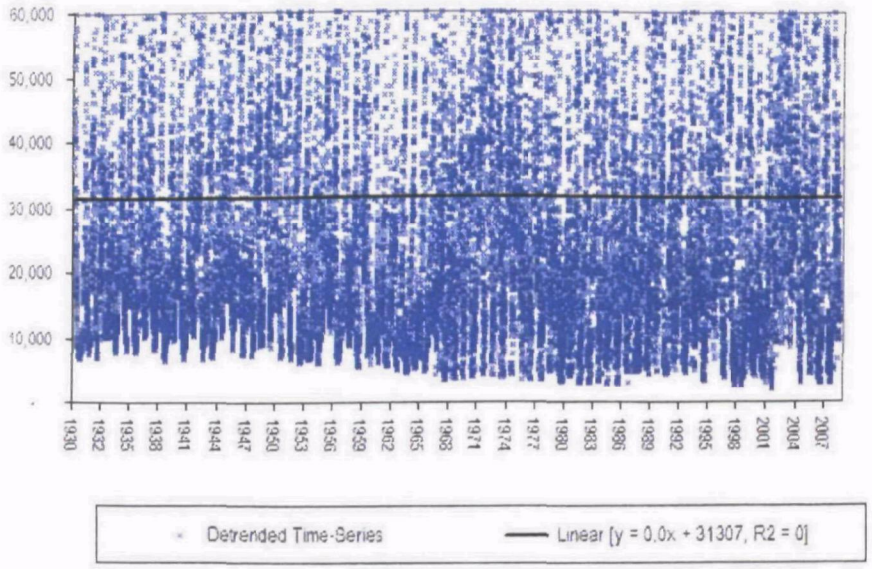


Figure G-4. De-trended data with slope of zero.

Linear Regression to Determine Return Period

Using the linear regression de-trended data yielded revised return periods, which are in Table G-10. Table G-11 highlights return periods for the monthly spans with the highest correlation to DO exceedances.

Table G-10. De-trending analysis results using linear regression

% DO Exceedences	25.87%	25.92%	24.26%	22.58%	27.84%	31.11%	27.24%
Year	1992-1994	1993-1995	1994-1996	1995-1997	1996-1998	2003-2005	2004-2006
jan-july	7.53	5.51	5.14	1.41	9.02	6.05	2.49
jan-june	8.57	6.62	4.89	1.39	9.82	5.28	1.97
jan-may	16.31	11.91	6.84	1.41	15.37	3.88	1.85
jan-apr	26.99	22.35	7.73	1.54	10.27	4.50	2.46
jan-mar	2.67	3.36	9.85	3.28	34.34	3.92	3.10
dec-july	6.52	6.34	4.95	1.95	9.54	11.75	5.74
dec-june	7.38	7.36	4.83	1.95	10.73	11.13	4.48
dec-may	11.05	11.80	6.33	2.06	15.37	9.18	4.57
dec-apr	16.93	19.29	6.92	2.28	11.43	10.39	6.93
dec-mar	2.83	4.30	8.35	5.44	26.43	9.67	9.45
nov-july	2.80	4.80	3.61	4.36	3.69	1.46	1.41
nov-june	6.35	7.03	4.60	2.29	14.35	15.47	6.38
nov-may	9.00	10.18	5.63	2.44	19.11	13.24	6.80
nov-apr	12.56	16.41	6.16	2.77	15.06	14.98	9.32
nov-mar	2.75	4.30	7.17	6.40	29.15	13.42	13.06
oct-july	4.31	4.71	4.05	2.48	12.57	19.18	9.92
oct-june	4.64	5.26	3.96	2.58	13.94	18.36	8.54
oct-may	6.42	7.83	4.53	2.79	18.18	16.63	9.13
oct-apr	8.37	10.70	4.77	3.12	14.50	18.16	13.31
oct-mar	2.29	3.42	5.25	6.88	23.92	15.97	16.78
sep-july	3.75	4.39	3.45	2.81	11.30	40.03	21.57
sep-june	4.00	4.73	3.31	2.87	13.01	42.41	18.94
sep-may	4.91	6.67	3.79	3.13	16.03	37.44	20.99
sep-apr	6.53	8.84	4.01	3.48	12.77	39.63	29.60
sep-mar	2.14	3.23	4.29	7.21	19.30	32.86	34.85

Table G-11. Return periods for monthly intervals highly correlated to Chesapeake Bay DO criteria exceedances using linear regression de-trended flow data.

Interval	1992–1994	1993–1995	1994–1996	1996–1998
September–June	4.00	4.73	3.31	13.01
November–June	6.35	7.03	4.60	14.35
December–June	7.38	7.36	4.83	10.73
September–July	3.75	4.39	3.45	11.30
December–July	6.52	6.34	4.95	9.54

LOWESS Polynomial Regression

Using LOWESS regression to de-trend the data, the 3-year return periods were recalculated (Tables G-12 and G-13).

Table G-12. De-trending analysis results using LOWESS polynomial regression

% DO Exceedences	24.97%	25.87%	25.92%	24.26%	22.58%	27.84%	31.11%	27.24%
Year	1991-1993	1992-1994	1993-1995	1994-1996	1995-1997	1996-1998	2003-2005	2004-2006
jan-july	2.25	11.24	8.10	7.33	1.42	11.81	7.30	2.60
jan-june	2.57	13.21	9.07	6.67	1.40	13.47	6.26	1.98
jan-may	3.88	23.61	17.29	8.59	1.44	18.30	4.16	1.88
jan-apr	6.54	38.98	32.42	9.11	1.58	12.20	4.73	2.53
jan-mar	1.98	3.00	3.95	13.24	3.61	44.48	4.14	3.21
dec-july	2.61	9.21	8.92	7.01	2.06	12.92	15.91	7.02
dec-june	2.99	9.92	9.82	6.55	2.05	14.52	14.78	4.95
dec-may	4.23	17.41	18.11	8.19	2.15	19.58	11.04	4.92
dec-apr	6.39	21.35	25.19	8.30	2.44	13.25	12.00	7.63
dec-mar	2.39	3.18	4.99	9.93	6.51	35.53	11.54	11.12
nov-july	1.73	2.15	3.58	2.65	3.13	2.67	1.30	1.31
nov-june	3.02	8.93	9.61	6.16	2.47	18.92	19.92	7.68
nov-may	4.13	14.14	16.91	7.59	2.62	28.85	17.34	7.96
nov-apr	5.91	17.53	22.63	7.72	3.00	17.97	17.60	10.73
nov-mar	2.47	3.08	4.99	8.85	7.67	44.25	16.87	16.58
oct-july	3.16	6.30	7.20	5.28	2.81	18.23	31.63	14.98
oct-june	3.63	6.83	7.95	4.91	2.85	20.09	30.32	11.10
oct-may	4.95	9.06	11.49	5.97	3.06	28.12	23.30	11.96
oct-apr	7.36	11.36	16.16	6.17	3.45	17.97	22.69	16.49
oct-mar	3.10	2.57	4.14	6.83	8.28	33.96	19.30	20.54
sep-july	3.00	4.97	6.38	4.44	3.18	16.66	81.73	36.71
sep-june	3.32	5.35	7.02	4.21	3.24	18.26	82.60	29.70
sep-may	4.46	7.18	9.27	4.63	3.51	22.56	73.13	34.38
sep-apr	6.09	8.59	12.46	4.76	4.01	16.11	59.30	40.07
sep-mar	2.92	2.37	3.87	5.01	8.65	25.51	44.82	48.49

Table G-13. Return periods for monthly intervals highly correlated to Chesapeake Bay DO criteria exceedances using LOWESS polynomial regression de-trended flow data

Interval	1992–1994	1993–1995	1994–1996	1996–1998
September–June	5.35	7.02	4.21	18.26
November–June	8.93	9.61	6.16	18.92
December–June	9.92	9.82	6.55	14.52
September–July	4.97	6.38	4.44	16.66
December–July	9.21	8.92	7.01	12.92

Summary of Analyses

No strict guidance exists on determining the critical period; however, the general approach is to determine the critical period for TMDLs on the basis of data availability, capturing the worst conditions in the period of record, capturing a range of flows, or 7Q10 flow. The availability of many decades of flow and water quality monitoring data in the Chesapeake Bay watershed allowed the opportunity to select a critical period from a group of candidate periods, so there is some freedom to follow a very rational approach to the selection of the period. It is EPA's best professional judgment that a 10-year return period captures a good balance between guarding against extreme events and ensuring attainment during more frequent critical events.

The analyses presented here take into account two methods of calculating probability, two methods of giving weight to more effective basins, two periods to calculate long-term probability, and two de-trending methods. All methods are more or less relevant and are considered as a group to determine the critical period most indicative of a 10-year return period. Of the candidate periods, 1996–1998 and 1993–1995 are closest to the 10-year return period. Table G-14 below summarizes the results from the two candidate periods.

Table G-14. Summary of results for 1993–1995 and 1996–1998 periods

	All tributaries (1978–2009)		Potomac + Susquehanna (1930–2009)		
	Without multiplier	With multiplier	With multiplier	With multiplier	With multiplier
	No de-trending	No de-trending	No De-trending	De-trended (Linear regression)	De-trended (LOWESS)
Year	1993–1995				
Median (High r^2)	7.53	7.48	7.27	6.34	8.92
Mean (High r^2)	6.84	6.99	7.39	5.97	8.35
Median (All monthly spans)			9.31	6.62	9.07
Mean (All monthly spans)			11.28	8.05	11.26
Overall range 1993–1995	**5.97–11.28**				
Year	1996-1998				
Median (High r^2)	18.95	16.02	17.56	11.3	16.66
Mean (High r^2)	18.82	14.87	15.24	11.78	16.26
Median (All monthly spans)			19.26	14.35	18.26
Mean (All monthly spans)			21.63	15.57	21.05
Overall range 1996–1998	**11.30–21.63**				

Using the above table to compare 1993–1995 and 1996–1998, it is clear that in all methods of determining the return period, the 1996–1998 period has a return period of greater than 10 years. The period 1993–1995 is generally evaluated to be slightly below a 10-year return period, but the overall range incorporates the 10-year period. The Water Quality Goal Implementation Team selected 1993–1995 as the most appropriate critical period for assessment of the jurisdictions' DO water quality standards because it was the most consistent with existing Chesapeake Bay watershed jurisdictions' practices.

Critical Period for Water Clarity/SAV Standards Assessment

SAV responds negatively to the same suite of environmental factors that result in low to no DO conditions -high-flow periods yielding elevated loads of nitrogen, phosphorus, and sediments (Dennison et al. 1993; Kemp 2004). High levels of nitrogen and phosphorus within the estuarine water column results in high level of algae, which block sunlight from reaching the SAV leaves. The same high concentrations of nitrogen and phosphorus also fuel the growth of epiphytes or microscopic plants on the surface of the SAV leaves, also directly blocking sunlight. Sediment in the form of total suspended solids further reduces that amount of sunlight reaching the SAV leaves. Therefore, the critical period of 1993–1995 that was selected for assessing the jurisdictions' DO water quality standards was also selected as the same critical period for assessing the water clarity/SAV water quality standards.

Critical Period for Chlorophyll a Standards Assessment

Algae, measured as chlorophyll *a*, responds to a multitude of different environmental factors, parameters, and conditions including the following:

- Nitrogen and phosphorus loads
- Water column temperature

- pH conditions
- Local nutrient conditions (e.g., fluxes of nutrients from the bottom sediments)
- River flow influences on dilution of existing algae populations
- River flow, bathymetry, and other factors influencing residence time
- Local weather conditions (e.g., wind, percentage of sunlight)
- Other conditions and parameters not well understood in the current state of the science

Some of those same factors influence DO conditions, while others are unique to algae. As documented below, by applying the same methodology used to determine the critical period for DO (and water clarity/SAV) water quality standards assessment, a specific 3-year critical period appropriate for assessing the chlorophyll *a* water quality standards was not supported by the analyses.

Using the same methodology as was used to determine the DO critical period for the entire Chesapeake Bay, a flow analysis was conducted to support the selection of a critical period for the James River on the basis of the correlation between flow and chlorophyll *a* violations.

Flow from USGS Gage 02037500 – James River near Richmond, Virginia, was analyzed for the period 1935–2009. De-trending was unnecessary because no trend was detected from the flow time series. The average annual flows and running 3-year average flows were calculated for the James River. The 3-year averages were used to determine the corresponding exceedance probabilities and return period for the flows. The exceedance probability was determined using both the Weibull Plotting Position and the Log Pearson III Method. The return period is defined as the inverse of the exceedance probability. Table G-15 summarizes the flow and return period using both the Weibull Plotting Position and Log Pearson III Method. Although the analysis includes all years between 1935 and 2009, only the years 1985 through 2006 are shown below, because those are the years with available data on water quality criteria violations.

To determine whether a correlation exists between 3-year mean annual flows and the percent violations for chlorophyll *a*, two methods were used: the R-squared value and Kendall's Tau. Chlorophyll *a* violations were tested for both the spring and summer by individual segments and for the James River as a whole for the years 1985–2006. Table G-16 summarizes the results of the analyses. Generally, a strong correlation does not exist between the percent chlorophyll *a* violations and the 3-year average flow. The two exceptions were JMSTFL – Spring and JMSTFU – Summer, which had statistically significant correlations but were shown to have an inverse relationship between flow and chlorophyll *a* violations. Because the James River did not exhibit a correlation between high flow and chlorophyll *a* violations, a critical period was not selected on the basis of those factors..

Within the selected 1991-2000 hydrologic period, the return periods for the three year assessment periods were generally four years or less for the James River, well below the 10-year return frequency selected by the Water Quality Goal Implementation Team (Table G-15). The exceptions were 1994-1996 with about an 8 year return period and 1996-1998 with a 15 year return period. These return periods were derived using both the the Weibull Plotting Position and the Log Pearson III Method. This evaluation of return periods also did not support selection of a critical period for the James River.

Table G-15. James River 3-year flow averages and return period

Assessment Period	James River flow (cfs)	Flow rank	Weibull return period (yr)	Log Pearson III return period (yr)
1985-1987	7,057	36	2.08	2.37
1986-1988	5,780	53	1.42	1.36
1987-1989	7,386	28	2.68	2.88
1988-1990	7,073	35	2.14	2.39
1989-1991	8,018	19	3.95	4.36
1990-1992	7,270	30	2.50	2.67
1991-1993	7,502	25	3.00	3.08
1992-1994	8,011	21	3.57	4.34
1993-1995	8,012	20	3.75	4.34
1994-1996	8,836	10	7.50	8.24
1995-1997	8,225	17	4.41	4.93
1996-1998	9,526	5	15.00	14.56
1997-1999	7,211	31	2.42	2.57
1998-2000	6,645	41	1.83	1.92
1999-2001	4,240	72	1.04	1.03
2000-2002	3,975	74	1.01	1.02
2001-2003	7,277	29	2.59	2.69
2002-2004	9,235	7	10.71	10.99
2003-2005	10,320	3	25.00	30.50
2004-2006	7,701	22	3.41	3.48

Because a specific 3-year critical period appropriate for assessment of the chlorophyll *a* water quality standards in the tidal James River was not supported by these analyses—e.g., no critical period was selected—EPA determined the need to evaluate all eight 3-year periods in the 1991–2000 hydrologic period to assess attainment of the chlorophyll *a* water quality standards in the tidal James River.

Table G-16. Correlation analyses for flow and chlorophyll *a* violations

Segment	p-value	Kendall Tau	Level of significance	R^2
Spring-Whole James	0.4180	−0.14	> 0.01	0.008
Summer-Whole James	0.4966	−0.12	> 0.01	0.061
Spring-JMSMH	0.7188	0.06	> 0.01	0.029
Spring-JMSOH	0.0250	−0.37	>0.01	0.274
Spring-JMSPH	0.9204	0.02	>0.01	0.084
Spring-JMSTFL	**0.0058**	**−0.45**	**<0.01**	**0.519**
Spring-JMSTFU	0.1616	−0.23	>0.01	0.117
Summer-JMSMH	0.6242	0.08	>0.01	0.027
Summer-JMSOH	0.5824	0.09	>0.01	0.004
Summer-JMSPH	0.6242	0.08	>0.01	0.015
Summer-JMSTFL	0.0644	−0.31	>0.01	0.219
Summer-JMSTFU	**0.0001**	**−0.63**	**<0.01**	**0.519**

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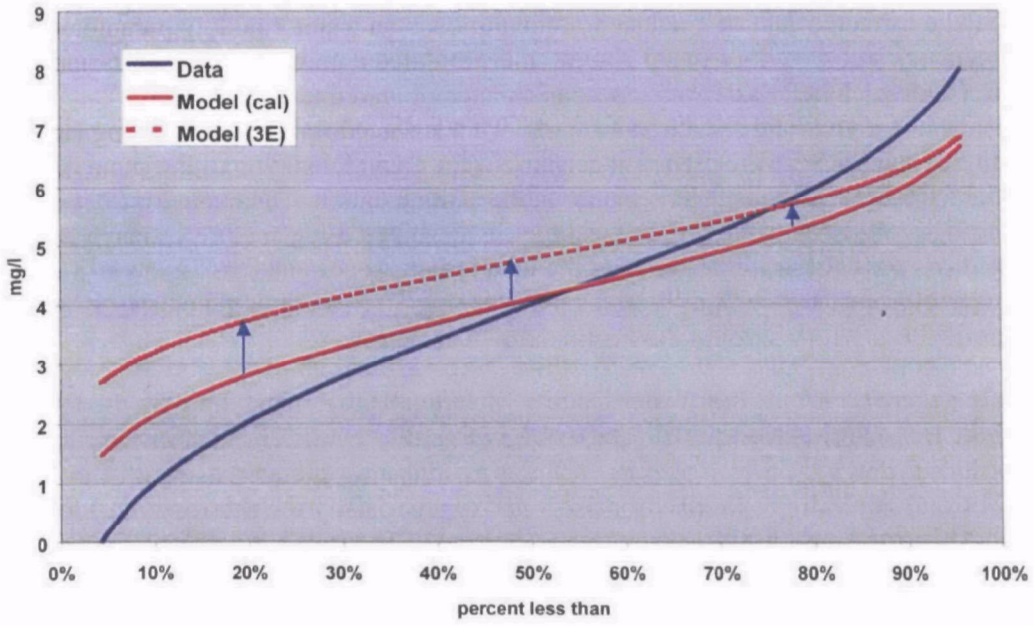
Appendix H.
Criteria Assessment Procedures using Model Scenario Output with Bay Monitoring Data

Scenarios representing different nutrient and sediment loading conditions were run using the Chesapeake Bay Phase 5.3 Watershed Model (Bay Watershed Model) and the resultant model scenario output was used as input into the Chesapeake Bay Water Quality and Sediment Transport Model (Bay Water Quality Model) to evaluate the response of critical water quality parameters, specifically dissolved oxygen, water clarity, underwater bay grasses, and chlorophyll *a*. To determine whether the loading scenarios met the applicable Bay jurisdictions' Chesapeake Bay water quality standards, the Bay Water Quality Model's simulated water quality response for each variable was used to increase/decrease the corresponding observed monitoring values collected during the same 1991–2000 hydrological period. In other words, the Bay Water Quality model was used to estimate the change in Bay water quality that would result from various loading scenarios. The model-simulated change in water quality was then used to adjust the actual Chesapeake Bay water quality monitoring data. Figure H-1 provides an example of the relationship between the calibration (cal) and scenario (E3) Bay Water Quality Model outputs described above, as well as their relationship to hypothetical monitoring observations (Data) over the same 10-year period.



Source: Linker et al. 2002

Figure H-1. Frequency distribution of hypothetical observed data (blue), model calibration (solid red) and model scenario (dashed) for a designated use.

In the simplest terms, the following steps were taken to apply the Bay Water Quality Model outputs to predict Bay water quality:

1. Calibrate the Bay Water Quality Model to actual monitoring data.
2. Run a Bay Water Quality Model simulation for a given *loading scenario* (usually a management scenario resulting in lower loads relative to the calibration scenario) through the Bay Watershed and Bay Water Quality models.
3. Determine the simulated change in water quality from the calibration scenario to the given loading scenario.
4. Apply the change in water quality as predicted by the Bay Water Quality Model to the actual historical water quality monitoring data, and evaluate attainment based on this *scenario modified* data set.

In following those steps, the scenario assessment process uses both model simulated outputs and observed water quality monitoring data.

For a more detailed description of the model calibration process (Step 1 above), and the process of constructing management scenarios to simulate reduced loads to the Bay Water Quality Model (step 2 above), see Sections 5 and 6, respectively. More detailed descriptions of Steps 3 and 4 are summarized below.

To determine the expected effect of reduced pollutant loads on a water quality parameter such as dissolved oxygen or chlorophyll *a* (Step 3 above), the simulated parameter concentrations from the Bay Water Quality Model's calibration scenario are compared to the parameter concentrations from a given load reduction scenario. This is accomplished by relating each month's worth of values from the calibration scenario for a given location to the same month's worth of values from the load reduction scenario at the same location. The resulting *linear regression* equation represents the degree of change (in dissolved oxygen or chlorophyll *a* concentration) from the calibration scenario to the load reduction scenario. In Figure H-2, a dissolved oxygen concentration of 2 milligrams per liter (mg/L) (x axis) in the calibration scenario becomes 3.6 mg/L (y axis) in the load reduction scenario.

Regressions are generated for all Bay Water Quality Model cells that match up with the long-term Chesapeake Bay mainstem and tidal tributary water quality monitoring stations and vertical sampling locations through the water column. The regressions are generated using all Bay Water Quality Model simulated values (hourly for dissolved oxygen; daily for chlorophyll *a*) for the month when the historical monitoring observation occurred. The result is a unique linear regression equation for each monitoring location and month (Figure H-3).

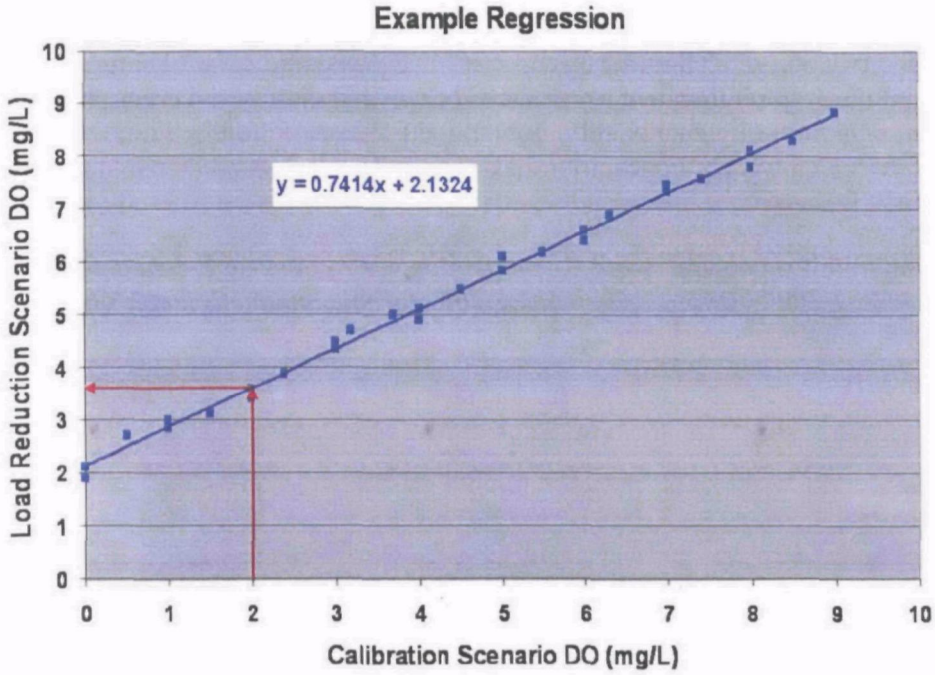


Figure H-2. Hypothetical example of a linear regression between model calibration (x axis) and scenario (y axis) data.

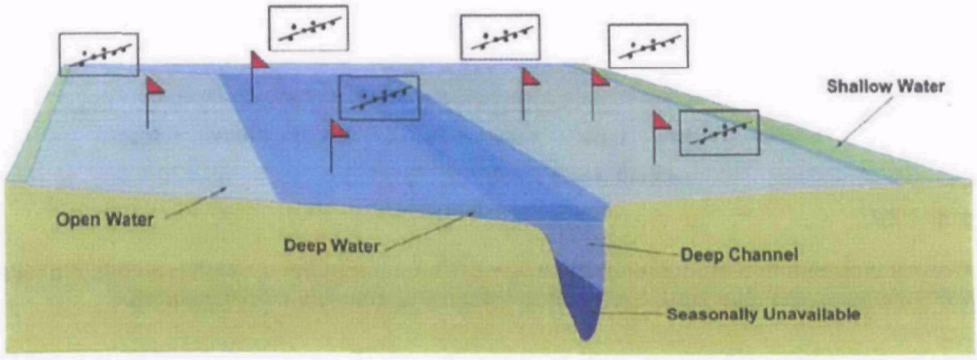
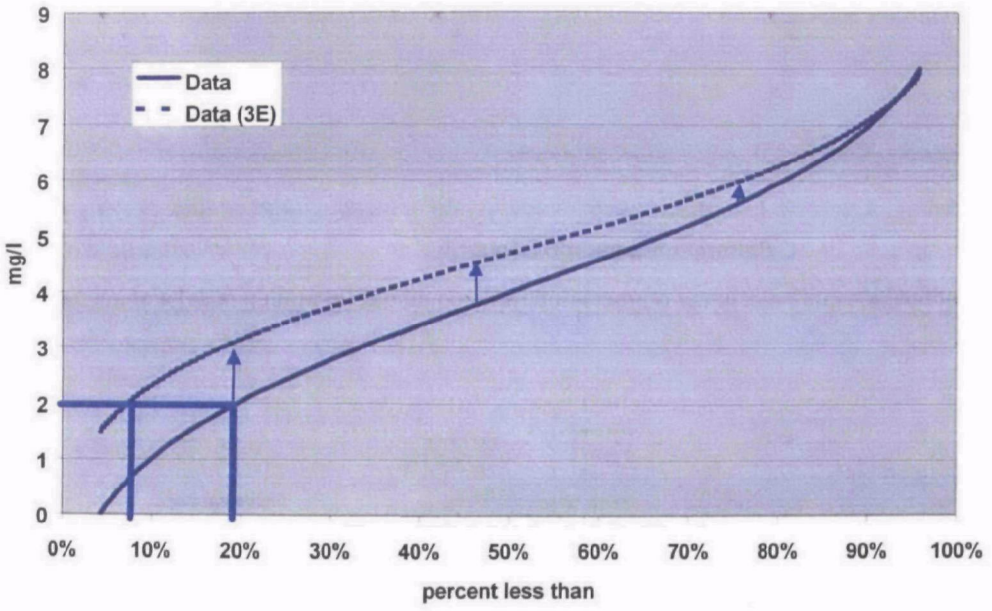


Figure H-3. Individual regression equation generated for each monitoring station location and month.

Once the relationship between the calibration and a given loading scenario is established, that relationship is used to generate a *scenario-modified* value for each observation in the historical monitoring data set spanning 1991–2000 (step 4 above). Those scenario-modified values represent an estimate of the concentration that would have been observed under the conditions of nutrient and sediment management represented by the scenario. In that manner, each observed concentration for dissolved oxygen or chlorophyll *a* in the 1991–2000 data set is replaced with a scenario-modified' concentration for the same sampling location and date.

Figure H-4 illustrates the modification of hypothetical historical monitoring data using a regression generated with the described procedure. The result is shown on a frequency plot so that changes in the prediction of attainment can be seen. The perpendicular blue lines in the lower-left portion of the graph illustrate the predicted change in dissolved oxygen from the hypothetical historical monitoring data (solid line) to the E3 scenario (dashed line). In this case, the incidence of dissolved oxygen concentrations less than 2.0 mg/L is predicted to decrease from 20 percent to 10 percent.

For a full discussion of this procedure, see *A Comparison of Chesapeake Bay Estuary Model Calibration With 1985-1994 Observed Data and Method of Application to Water Quality Criteria* (Linker et al. 2002).



Source: Linker et al. 2002

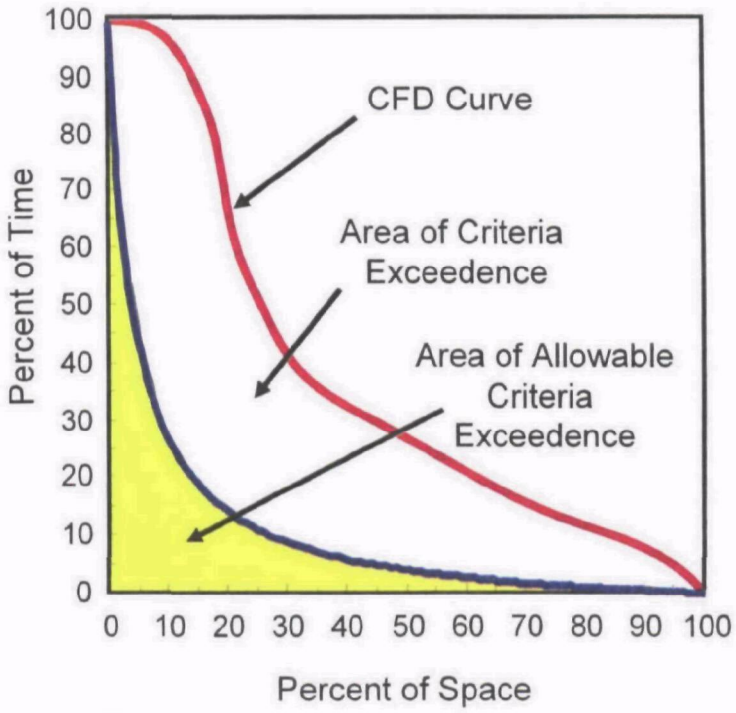
Figure H-4. Frequency distribution of hypothetical summer DO concentrations, as observed (solid blue line) and as simulated using a regression equation generated from water quality model scenarios.

Reference

Linker, L., G. Shenk, P. Wang, C. Cerco, A. Butt, P. Tango, and R. Savage. 2002. *A Comparison of Chesapeake Bay Estuary Model Calibration with 1985–1994 Observed Data and Method of Application to Water Quality Criteria*. Chesapeake Bay Program Modeling Subcommittee Report. U.S. Environmental Protection Agency, Chesapeake Bay Program Office, Annapolis, MD.

Appendix I.
Documentation of the Reduced Sensitivity to Load Reductions at Low Nonattainment Percentages

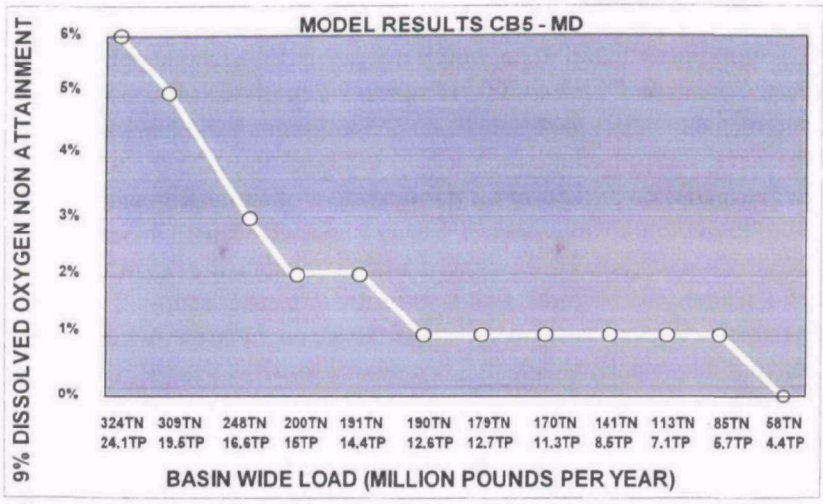
The Chesapeake Bay water quality criteria adopted by the four Bay jurisdictions into their respective water quality standards (WQS) regulations provide for allowable exceedances of each set of dissolved oxygen (DO), water clarity and chlorophyll a criteria defined through application of a biological or default reference curve (USEPA 2003). Figure I-1 depicts this concept in yellow as allowable exceedance of the criterion concentration. To compare the Chesapeake Bay Water Quality Model results with the Bay jurisdictions WQS, the model results for each scenario and for each modeled segment are analyzed to determine the percent of time and space that the modeled DO results exceed the allowable concentration. For any modeled result where the exceedance in space and time (shown in Figure I-1 as the red line) exceeds the allowable exceedance (shown in Figure I-1 as the yellow area), that segment is considered in nonattainment. That amount of nonattainment is shown in the figure as the area in white between the red line and the yellow area and is typically displayed in model results as percent of nonattainment for that segment. The amount of nonattainment is reported to the whole number percent. The yellow area below the blue reference curve reflects the amount of *allowable* criteria exceedance. The area between the blue reference curve and the red cumulative frequency distribution (CFD) curve is the amount of *unallowable* criteria exceedance, defined here as the *red area*.



Source: USEPA 2003

Figure I-1. Illustration of the application of a reference curve to the cumulative frequency distribution curve to assess Chesapeake Bay water quality criteria attainment.

Figure I-2 below displays Chesapeake Bay Water Quality Model results showing percent nonattainment of the 30-day mean open-water DO criterion of the Maryland portion of the lower central Chesapeake Bay segment CB5MH_MD for various basinwide nitrogen and phosphorus loading levels.



Source: Appendix M

Figure I-2. Example of DO criteria nonattainment results from a wide range of total nitrogen (TN) and total phosphorus (TP) loading Chesapeake Bay Water Quality Model scenarios.

As can be seen in Figure I-2, there is a notable improvement in the percent DO criterion nonattainment as the loads are reduced until approximately 1 percent nonattainment. At and below a basinwide loading level of 190 million pounds per year total nitrogen (TN) and 12.7 million pounds per year total phosphorus (TP), the 1 percent nonattainment is persistent through consecutive reductions in loading levels and remains consistent until a loading level of 58 million pounds per year TN and 4.4 million pounds per year of TP is reached. While this is one of the more extreme examples of persistent levels of 1 percent nonattainment over a wider range of reduced nitrogen and phosphorus loads, this general observation of persistent nonattainment at 1 percent is fairly common to the Bay Water Quality Model DO results as described and documented below.

Clear evidence of small, yet persistent percentage of model projected DO criteria nonattainment over a wide range of reduced nitrogen and phosphorus loads across a wide range of segments and designated uses, all of which are responding to nitrogen and phosphorus load reductions, is documented within this appendix. Given that this has been observed in a wide variety of different segments across all three designated uses—open-water, deep-water, and deep-channel—nonattainment percentages projected by the Bay Water Quality Model rounded to 1 percent were considered to be in attainment for a segment's designated use for purposes of developing the Chesapeake Bay TMDL.

A separate validation of the findings described above was undertaken to confirm that 1 percent was the correct percentage below which the designated use-segment could be considered in attainment and is provided in this appendix.

Reporting of Criteria Nonattainment Percentages

Chesapeake Bay modeling results for DO, chlorophyll *a*, and water clarity criteria nonattainment percentages are rounded to whole numbers. This is a common scientific practice and principle for conveying data to the public and is fully consistent with how many others report modeling output.

Documenting Attainment for 1 Percent Nonattainment Criteria Values

The Chesapeake Bay water quality criteria adopted by Maryland, Virginia, Delaware, and the District of Columbia into their respective WQS regulations already provides for *allowable* exceedances of each set of DO, water clarity and chlorophyll *a* criteria defined through application of a biological or default reference curve (USEPA 2003). What is being addressed here is how to address 1 percent nonattainment DO, water clarity, and chlorophyll *a* criteria values assessed using the CFD-based criteria assessment procedures in the face of clear evidence: (1) for persistence over large simulated load reductions across numerous segments and designated uses; and (2) reduced sensitivity to load reductions at and below the 1 percent nonattainment level.

Evaluation of Residual 1.499 Percent or Less DO Criteria Nonattainment Values

There is clear evidence for a *residual* of 1 percent DO criteria nonattainment across a large span of model-simulated load reductions across a number of tidal Bay segments and designated uses (Table I-1). Within the Bay TMDL document and supporting appendices, the reported criteria attainment values already account for the allowable exceedances documented in each Bay jurisdiction's respective Chesapeake Bay WQS regulations. These reported criteria attainment values also account for any restoration variances adopted by the Bay jurisdictions into their WQS regulations. All the values that are colored green denote full attainment of the respective criteria, DO in this case.

For illustration purposes only, as observed in the DO *stoplight plot* spreadsheet dated May 24, 2010, shared with members of the Chesapeake Bay Program's Water Quality Goal Implementation Team, 21 designated use-segments have the recorded model scenario-transformed monitoring data nonattainment values between 0.0 percent and 1.5 percent across a range of model scenarios. (Note that all the values reported in Table I-1 would round to 0 percent or 1 percent.) Those model scenarios had loading levels that spanned 9 to 151 million pounds of nitrogen and comparable ranges of phosphorus loading levels (Table I-1).

Table I-1. The range of DO criteria nonattainment percentages across different model simulated nitrogen load ranges for 21 Chesapeake Bay segments-designated uses

Chesapeake Bay segment	Designated use	Criteria nonattainment range[a] (%)	Model simulated nitrogen load range (million pounds/yr)
CB7	Open-water	0.5-0.0	200-141
CHOMH1	Open-water	0.1-0.0	254-179
CSHMH	Open-water	0.8-0.1	342-309
DCATF	Open-water	1.2-0.1	191-179
PAXTF	Open-water	1.0-0.6	190-179
DCPTF	Open-water	0.6-0.2	309-254
MAGMH	Open-water	1.3-0.3	342-191
MOBPH	Open-water	1.0-0.0	342-200
PIAMH	Open-water	0.1-0.1	191-179
TANMH	Open-water	1.5-0.1	342-309
YRKMH	Open-water	1.0-0.4	191-170
CB3MH	Deep-water	0.6-0.0	254-179
CB5MH	Deep-water	1.5-0.0	254-141
CHSMH	Deep-water	0.5-0.4	170-141
EASMH	Deep-water	0.8-0.2	200-170
MD5MH	Deep-water	1.5-0.1	191-141
MAGMH	Deep-water	0.5-0.5	170-141
PATMH	Deep-water	1.1-0.1	200-190
VA5MH	Deep-water	0.7-0.0	254-179
CB3MH	Deep-channel	0.2-0.1	200-190
EASMH	Deep-channel	1.3-0.0	190-170

Source: The DO criteria attainment detailed stoplight spreadsheet dated May 24, 2010 presented to the Chesapeake Bay Program's Water Quality Goal Implementation Team during the Team's May 24, 2010, conference call.
Note:
a. Each 0.0% value in this column is colored in red in the original May 24, 2010 stoplight plot spreadsheet, denoting a very low percentage of nonattainment was recorded below 0.1%.

Small, yet persistent percentage of DO criteria nonattainment are observed across a wide range of segments and designated uses, all of which are responding to nutrient load reductions. There is not comparable evidence of persistent percentages of DO criteria nonattainment above 1 percent across a wide range of segments and designated uses for segments responding to nutrient load reductions. Several open-water segments exist where the same percentage nonattainment persists across a wide set of nutrient loading reductions—e.g., Gunpowder River (GUNOH) at 5 percent from 342 TN to 85 TN, Wicomico River (WICMH) at 5 percent from 191 TN to 85 TN, several segments in Pocomoke River at 5 percent from 179 TN to 85 TN (see Appendix M). However, all those segments have been identified as having poor local responses to load reductions in the Bay Water Quality Model scenarios on the basis of poor linear regressions. Other lines of evidence, separate from the model-generated outputs were used to determine attainment and develop the respective Bay segment TMDL (see Appendix N). The cause for the persistent percentages (poor linear regressions) is different from the small, yet persistent percentages (reduced sensitivity when approaching water quality criteria attainment) being addressed in this appendix.

Analysis of DO Criteria Attainment Sensitivity to Simulated Load Reductions

A separate validation of the findings described above was undertaken to confirm that 1 percent was the correct percentage below which the designated use-segment could be considered in attainment. This analysis involves plotting the change in unallowable DO criterion exceedance or *red area* under the reference curve (see Figure I-1) per loading unit against the starting red area. The change in red area between two scenarios is divided by the change in load. For this analysis, the changes in nitrogen (N) and phosphorus (P) loads are combined into a single measure, load units, enabling the calculation of change in red area per change in load:

$$\text{load units} = (N + 10 \times P) / 2) \qquad \text{Equation I-1}$$

This single measure, when plotted against starting red area, allows a direct comparison of sensitivity of the analysis system[1] to nitrogen and phosphorus load changes across different levels of nonattainment. To get a true sensitivity, calculations involving scenarios that attained the applicable DO criteria were not included. Twelve scenarios were used with eight 3-year periods for a total of 96 possible sensitivity assessments per designated-use segment, decreased by the number of assessments that attained the applicable DO criterion.

This analysis was not amenable to tidal tributary segments as the nitrogen and phosphorus loadings are basinwide and not specific to an individual tidal tributary. Further, some of the existing scenarios used for this analysis have varying levels of nitrogen and phosphorus load reductions between different tributaries.

The CB7PH open-water segment provides a clear example of a decrease in sensitivity to nitrogen and phosphorus load reductions as criteria nonattainment approaches zero. The highest sensitivity to load reductions is with the highest red area, but there is still considerable sensitivity to nitrogen and phosphorus load reductions through approximately 0.2 percent (Figure I-3). Another example is the CB2OH open-water segment, where a sharp drop off occurs in sensitivity to nitrogen and phosphorus load reductions near 1 percent (Figure I-4).

A counter-example is the CB5MH open-water segment, where the sensitivity to load reductions is relatively constant throughout the model-simulated range of load reductions (Figure I-5).

A large number of segments could be analyzed (see Table I-1), but it is most appropriate to focus on those designated-use segments most important to the Bay TMDL—those requiring significant basinwide nutrient reductions to come in attainment with the respective DO criterion. Those designated use-segments are CB3MH, CB4MH, and CB5MH for deep-water and deep-channel and POTMH for deep-channel.

[1] The analysis system referred to here is the combination of the Chesapeake Bay Water Quality and Sediment Transport Model, the procedures for using differences in Bay model scenarios outputs to transform Bay water quality monitoring data, and the EPA-published Bay criteria assessment procedures.

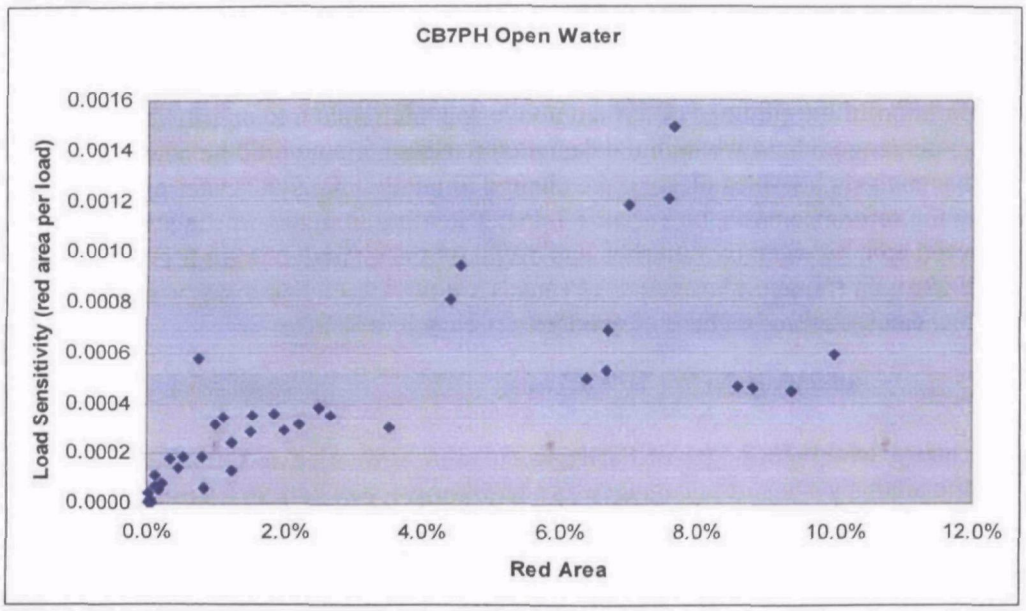


Figure I-3. Load sensitivity (unallowable DO criteria exceedances per load unit) vs. red area (unallowable DO criteria exceedances) for designated use-segment CB7PH open-water.

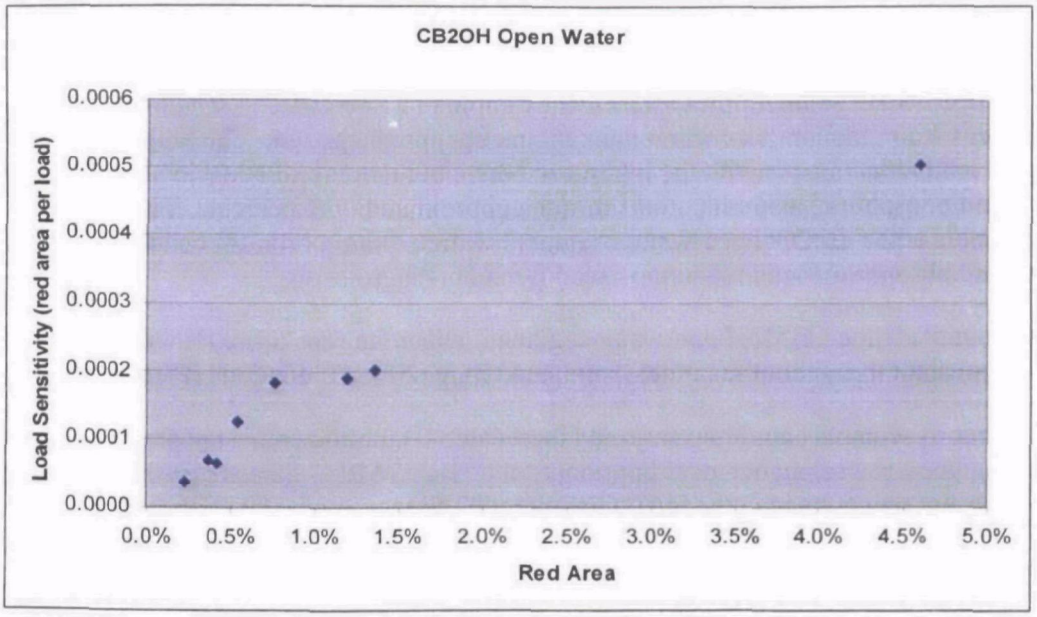


Figure I-4. Load sensitivity (unallowable DO criteria exceedances per load unit) vs. red area (unallowable DO criteria exceedances) for designated use-segment CB2OH open-water.

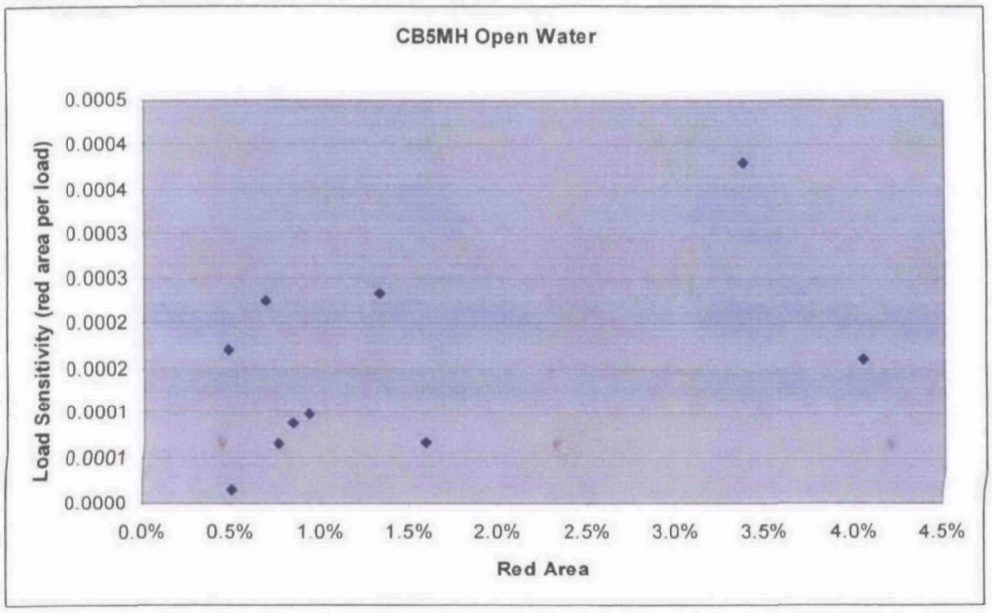


Figure I-5. Load sensitivity (unallowable DO criteria exceedances per load unit) vs. red area (unallowable DO criteria exceedances) for designated use-segment CB5MH open-water.

The CB3MH deep-water segment has consistently reducing sensitivity to nitrogen and phosphorus load reductions and no high sensitivity examples above 1 percent red area (Figure I-6). The CB4MH deep-water designated use-segment shows relatively consistent sensitivity across a wide range of red area (Figure I-7). The CB5MH deep-water designated use-segment (Figure I-8) and the POTMH deep-water designated use-segment (Figure I-9) are relatively constant across wide ranges but have a clear reduction in sensitivity to load reductions around 1 percent.

The deep-channel designated use-segment plots are similar to the deep-water designated use-segment plots. The CB3MH deep-channel designated use-segment also shows a consistent range of sensitivity throughout multiple ranges of red area but has low sensitivity to further load reductions at 1–1.5 percent red area (Figure I-10). The CB4MH deep-channel designated use-segment shows a clear drop off in sensitivity to load reductions at 1 percent (Figures I-11 and I-12). The CB5MH deep-channel designated use-segment has no basis to make the judgment because no red area values are less than 15 percent (Figure I-13).

Although there is some discretion involved in the judgment of exactly when sensitivity to further load reductions becomes low, there is a general decrease in sensitivity when the red area is low. One percent is a relatively consistent level at which sensitivity decreases significantly across many of the principal designated use-segments used for decision making in the Chesapeake Bay TMDL (Table I-2). At the nonattainment values of 1 percent (or less), there is a significant drop off in the sensitivity—further reduction in DO criteria nonattainment—of these designated use-segments to further load reductions. The analysis system is not sensitive to the effects of further load reductions at the 1 percent or less nonattainment level. This finding is fully consistent with findings from the parallel analysis summarized in Table I-1 for a wider array of designated use-segments.

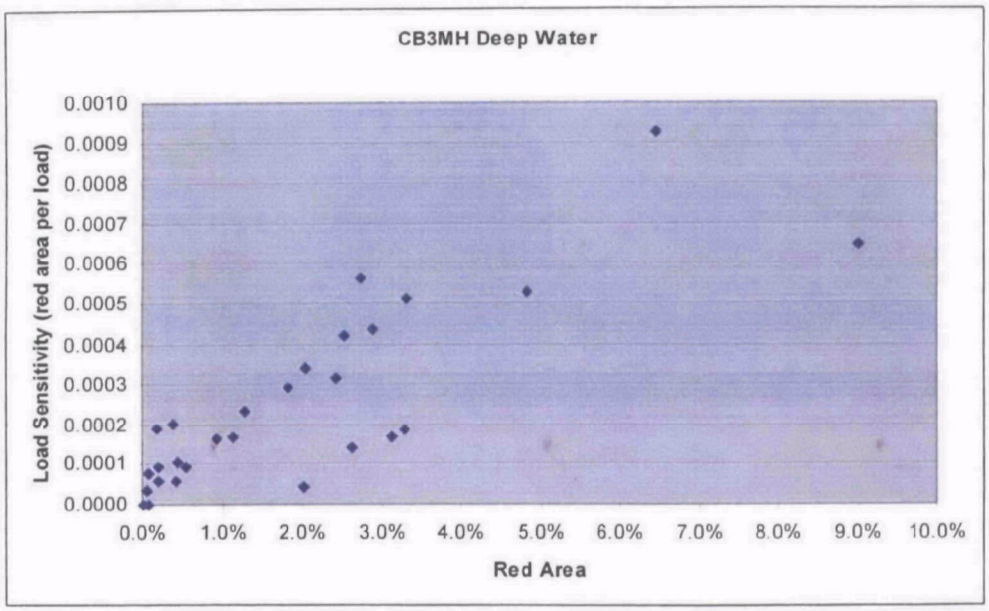


Figure I-6. Load sensitivity (unallowable DO criteria exceedances per load unit) vs. red area (unallowable DO criteria exceedances) for designated use-segment CB3MH deep-water.

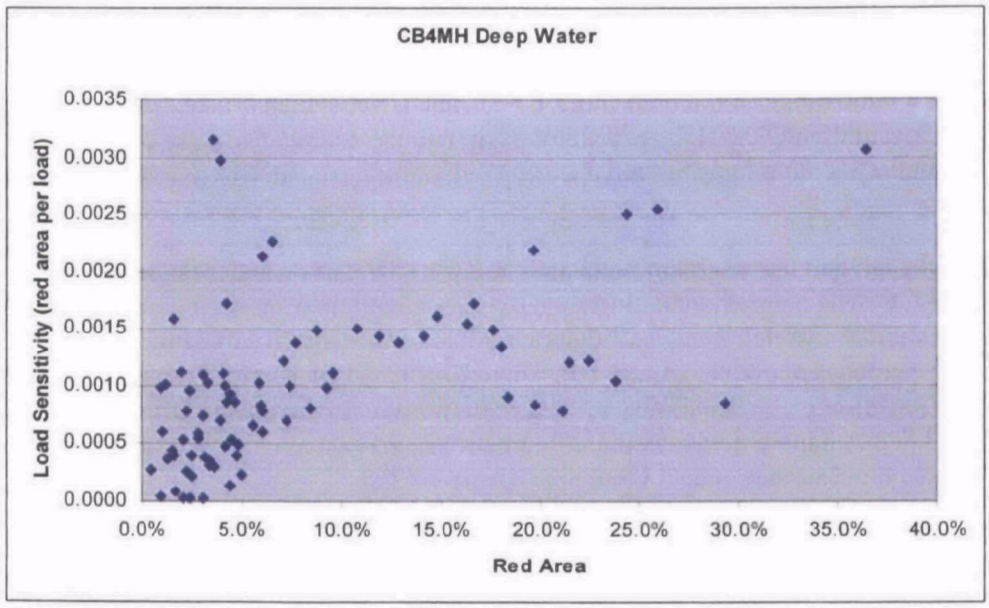


Figure I-7. Load sensitivity (unallowable DO criteria exceedances per load unit) vs. red area (unallowable DO criteria exceedances) for designated use-segment CB4MH deep-water.

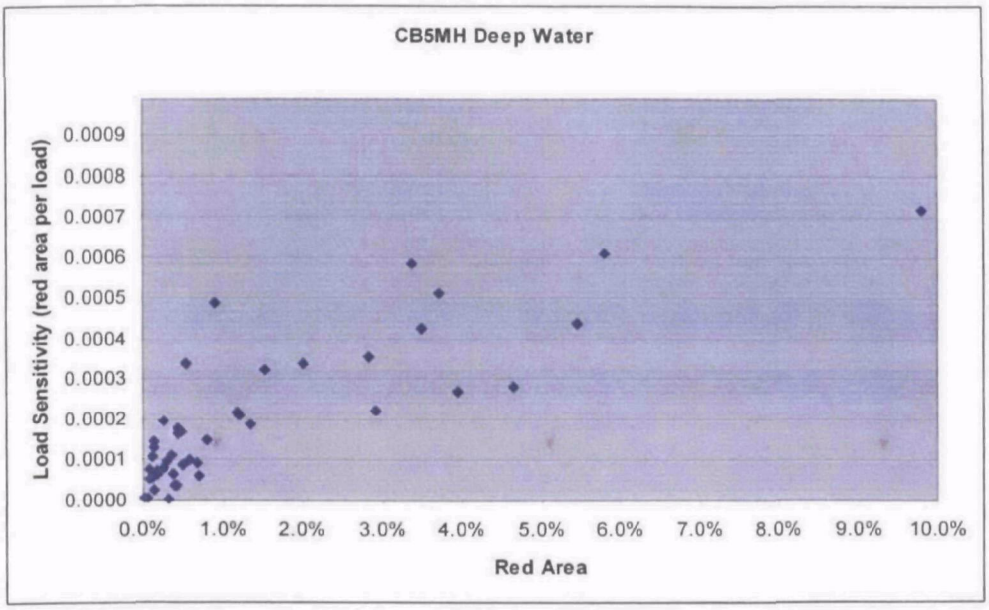


Figure I-8. Load sensitivity (unallowable DO criteria exceedances per load unit) vs. red area (unallowable DO criteria exceedances) for designated use-segment CB5MH deep-water.

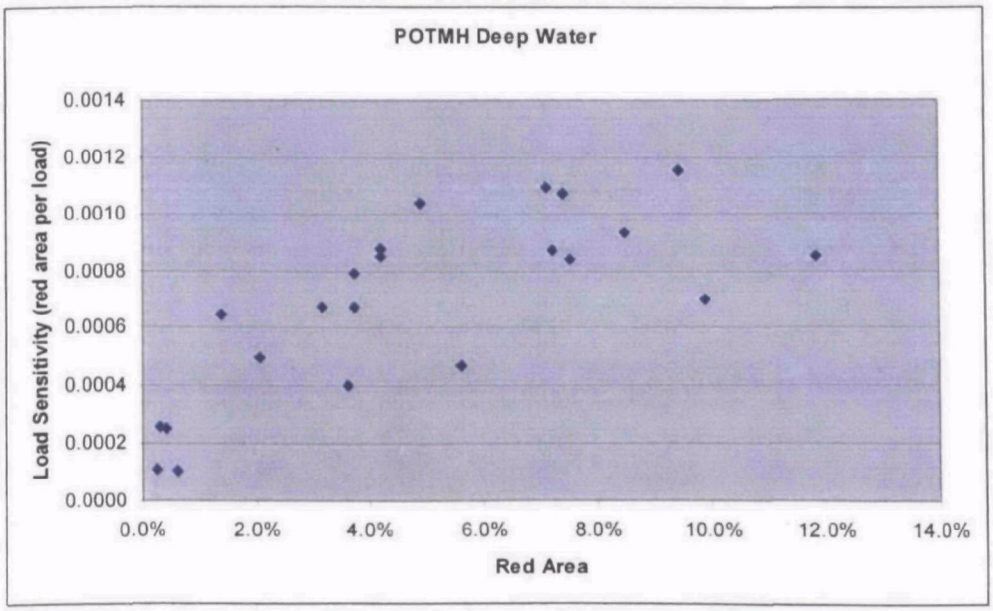


Figure I-9. Load sensitivity (unallowable DO criteria exceedances per load unit) vs. red area (unallowable DO criteria exceedances) for designated use-segment POTMH deep-water.

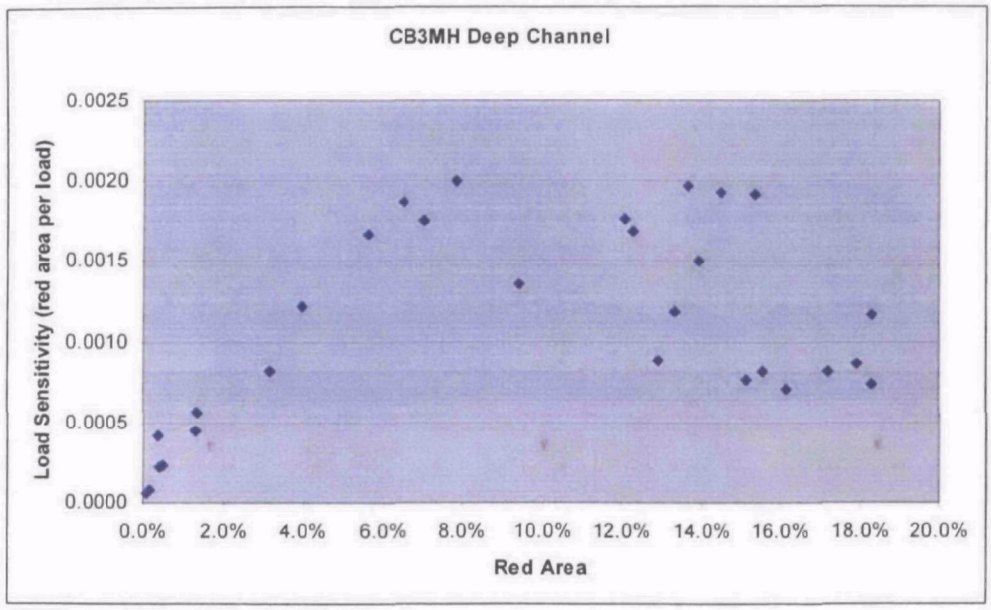


Figure I-10. Load sensitivity (unallowable DO criteria exceedances per load unit) vs. red area (unallowable DO criteria exceedances) for designated use-segment CB3MH deep-channel.

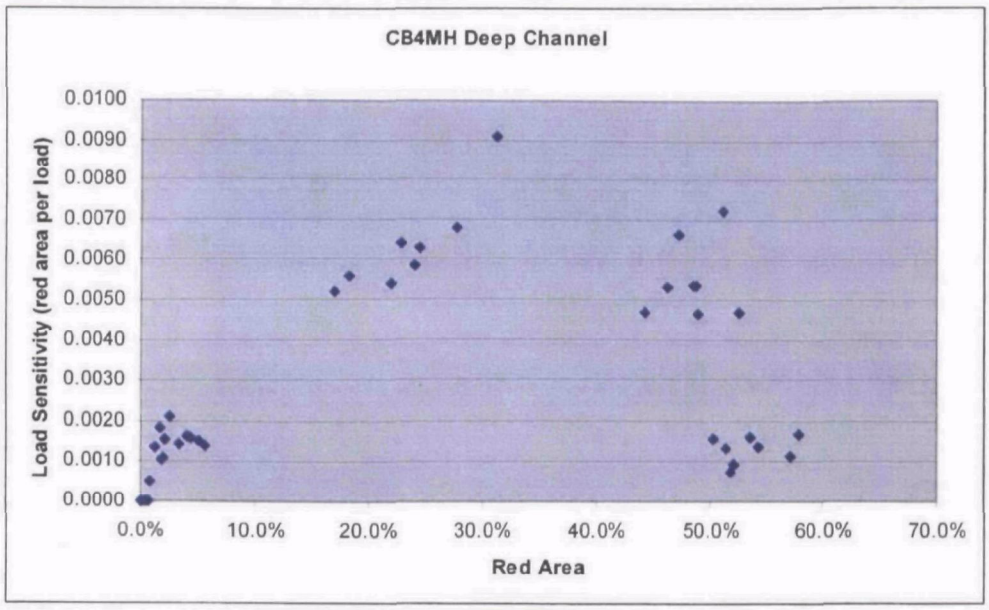


Figure I-11. Load sensitivity (unallowable DO criteria exceedances per load unit) vs. red area (unallowable DO criteria exceedances) for designated use-segment CB4MH deep-channel.

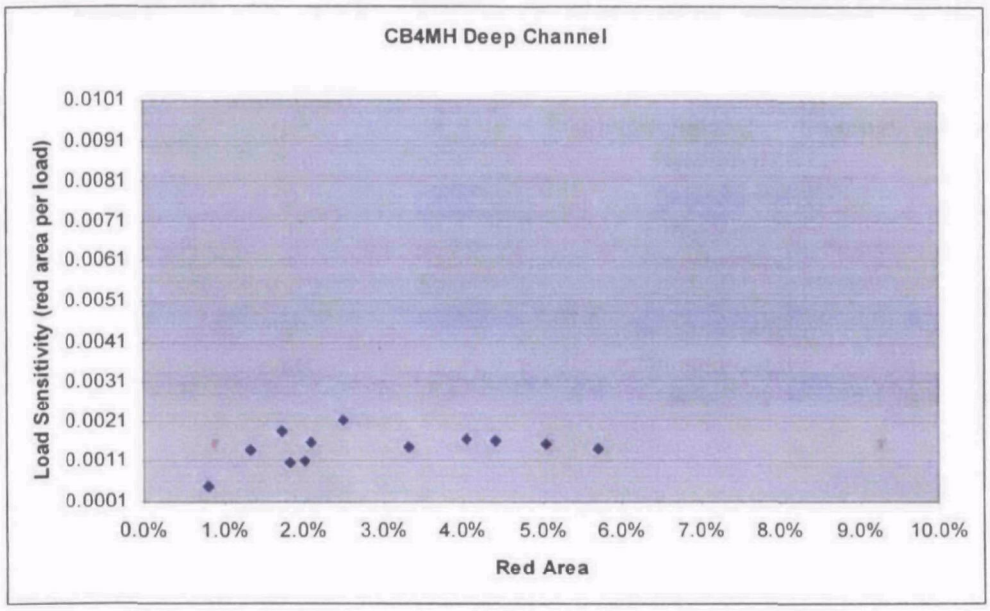


Figure I-12. Expanded view of the Figure I-11 focusing down on the 0-10% red area for segment CB4MH deep-channel to illustrate the drop off in sensitivity at the 1-1.5% of red area.

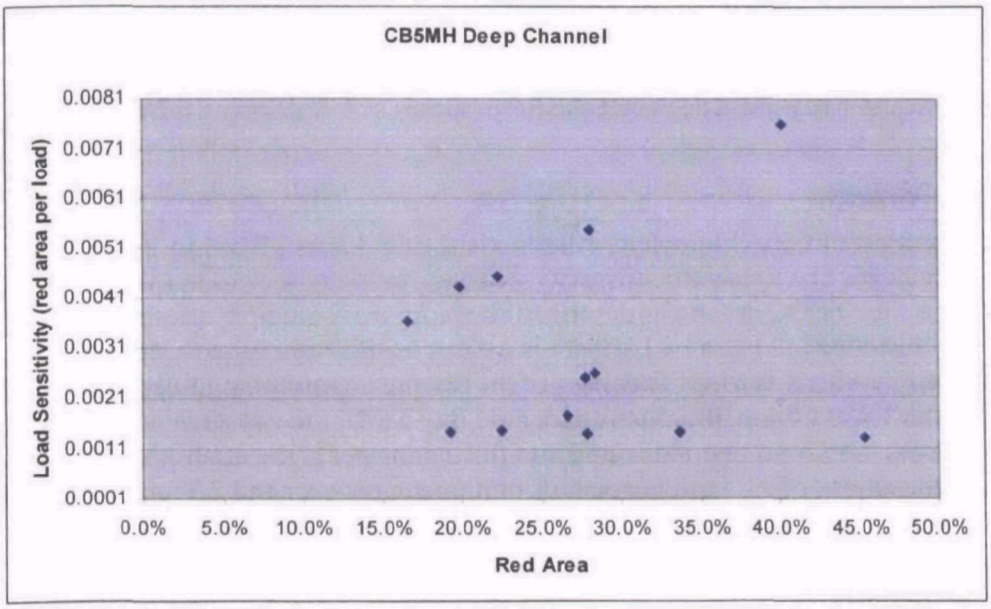


Figure I-13. Load sensitivity (unallowable DO criteria exceedances per load unit) vs. red area (unallowable DO criteria exceedances) for designated use-segment CB5MH deep-channel.

Table I-2. Summary of findings from the analysis of red area with low sensitivity to load reductions for the Chesapeake Bay designated use

Chesapeake Bay segment	Designated use	Red area with low sensitivity to load reductions (%)
CB3MH	Deep-water	0.2
CB4MH	Deep-water	0
CB5MH	Deep-water	1
POTMH	Deep-water	1
CB3MH	Deep-channel	1-1.5
CB4MH	Deep-channel	1
CB5MH	Deep-channel	N/A

Sources: Figures I-6 through I-13 in this appendix

Water Clarity Criteria

Only one segment displayed a small, yet persistent percentage of model projected water clarity/submerged aquatic vegetation (SAV) criteria nonattainment over a range of reduced nitrogen and phosphorus loads—the Appomattox River segment (APPTF) in Virginia's James River Basin. In the case of that segment, no observed SAV has been mapped since the early 1970s, but historical acreages were observed back in the 1950s. That tidal fresh segment (salinities from 0 to 0.5 ppt) was one of the very few tidal fresh segments that did not exhibit a positive response (increased water clarity, increased SAV acreage) to model simulated reductions in nitrogen, phosphorus, and sediment. For the reasons unique to this segment, EPA considered 1 percent nonattainment of the water clarity/SAV criteria in attainment for the Bay segment's shallow water bay grass designated use for purposes of developing the Bay TMDL.

Chlorophyll a Criteria

In the case of assessment of the chlorophyll *a* criteria in the tidal James River in Virginia, there was very limited evidence of a reduced sensitivity when approaching the criteria values as compared with the suite of DO criteria as described above for across multiple designated uses and segments. As illustrated in Figure I-14, there is a clear, positive response to reduced nitrogen and phosphorus loads, with a stepwise flattening of the response approaching full attainment. In developing the James River basin allocations under the Bay TMDL, the vast majority of the spring and summer season 3-year periods came into full attainment at the established nitrogen and phosphorus allocations of 23.5 million pounds of nitrogen per year and 2.35 million pounds of phosphorus per year (see Section 6.2.3 and Appendix O). EPA considered 1 percent nonattainment of the applicable segment and season-specific chlorophyll *a* criteria in attainment for only a limited number of segment/season/3-year period combinations given the evidence, though limited, of reduced sensitivity when approaching full attainment of the criteria values.

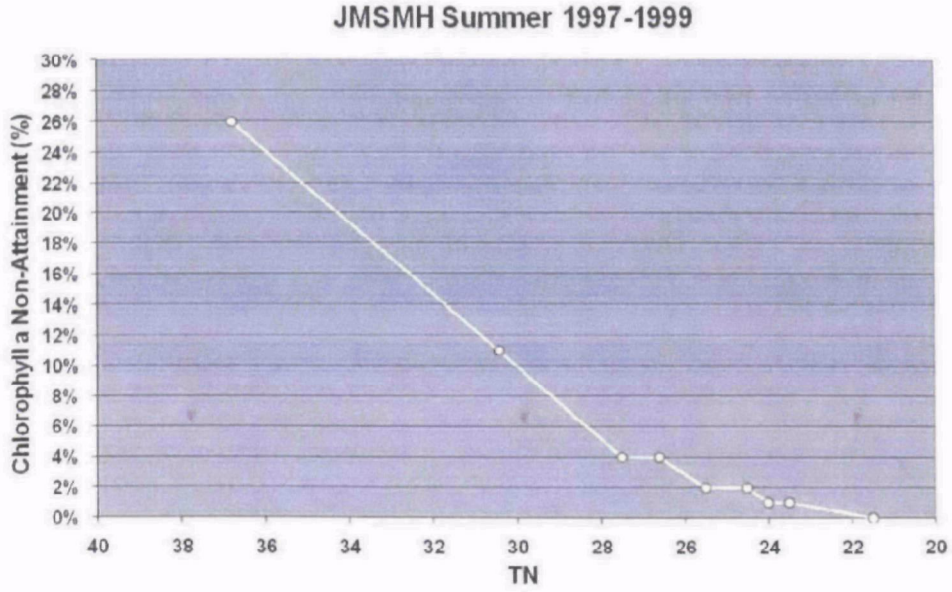


Figure I-14. Example of the middle James River segment's summer chlorophyll *a* criteria nonattainment results from a wide range of TN and TP loading Chesapeake Bay Water Quality Model scenarios.

Application in Development of the Bay TMDL

DO Criteria

Because such findings have been observed in a wide variety of different segments across all three designated uses—open-water, deep-water, and deep-channel—and confirmed through an independent analysis, DO criteria nonattainment percentages rounded to 1 percent were considered in attainment for that Bay segment's designated use for purposes of developing the Bay TMDL. For those designated use-segments for which a jurisdiction has adopted a restoration variance that sets attainment at a percentage of the non-allowable criteria exceedances, the 1 percent nonattainment described above does not apply to assessment of the restoration variance percentage. For example, Maryland's designated use-segment CB4MH deep water has a restoration variance of 7 percent. Chesapeake Bay Water Quality Model-based criteria attainment assessment results showing 8 percent nonattainment would still be considered in nonattainment.

Chlorophyll a and Water Clarity/SAV Criteria

In the case of the chlorophyll *a* criteria assessments, EPA considered nonattainment percentages rounded to 1 percent in attainment only for a select set of segment/season/3-year period combinations given the more limited evidence of reduced sensitivity when approaching full attainment of the criteria values compared with DO. Only one Bay segment had unique circumstances that supported EPA's considering water clarity/SAV criteria nonattainment percentages rounded to 1 percent to be in attainment.

References

USEPA (U.S. Environmental Protection Agency). 2003. Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries. EPA 903-R-03-002. Region 3 Chesapeake Bay Program Office, Annapolis, MD.

Appendix J
Key Chesapeake Bay TMDL Reference and Management Modeling Scenarios: Definitions and Descriptions

1985 Scenario

The 1985 scenario uses the estimated 1985 land uses, NPS loadings, animal numbers, atmospheric deposition, and point source loads. This scenario estimates the highest loads of nitrogen, phosphorus, and sediment to the Bay in recent time (using a constant 1991-2000 hydrology). The Phase 5.3 Chesapeake Bay Watershed Model simulated nitrogen, phosphorus, and sediment loads for this scenario are listed in Tables J-2, J-4, and J-6, respectively.

2009 Scenario

The 2009 scenario uses the estimated 2009 land uses, NPS loadings, animal numbers, atmospheric deposition, and point source loads as well as the best management practices tracked and reported by the seven watershed jurisdictions through 2009. The 2009 year was chosen as the baseline for the TMDL, as it was the most recent year for which complete implementation data (BMPs, waster loads, etc.) was available during the Bay TMDL development process. Phase 5.3 Chesapeake Bay Watershed Model simulated nitrogen, phosphorus and sediment loads for this scenario are listed in Tables J-2, J-4, and J-6, respectively.

Tributary Strategy Scenario

The Tributary Strategy scenario estimates the nitrogen, phosphorus, and sediment loads through model simulations of full implementation of the seven jurisdictions' 2004-2005 tributary strategies throughout the Chesapeake Bay watershed. This scenario included an accounting for all the tributary strategy BMPs on a 2010 land use, and the 2010 estimated permitted loads for all the significant and non-significant wastewater dischargers, as described in Table J-1. Adjustments to the jurisdictions' tributary strategies developed in 2004 and 2005 to reflect changes in State laws or policies (e.g., permitting of significant wastewater discharge facilities) since development of the initial set of jurisdictional tributary strategies were also included in this scenario's input decks. Atmospheric deposition inputs were from the Community Multi-scale Air Quality Model's 12 km grid with an estimated 2010 deposition and included simulations of the State Implementation Plans to reach the 2010 Air Quality Standards. Phase 5.3 Chesapeake Bay Watershed Model simulated nitrogen, phosphorus, and sediment loads for this scenario are listed in Tables J-2, J-4, and J-6, respectively.

Table J-1. Wastewater discharge facilities and combined sewer overflows (CSO) assumptions for the Tributary Strategy, Everything by Everyone Everywhere (E3) and the 2010 No Action scenarios

Scenario		Tributary Strategy	E3	2010 No Action
Definition		Latest jurisdiction tributary strategy	Level of Technology Everywhere Tier 4 Level	No management action. Secondary Treatment at the same level everywhere with tributary strategy flows
Concentration	Significant Municipal Plants	Latest jurisdiction tributary strategy BOD=5 mg/l, DO=5 mg/l and TSS=5 mg/l	TN=3 and TP=0.1 BOD=3 mg/l, DO=6 mg/l and TSS=5 mg/l	TN=18 mg/l and TP =3 mg/l BOD=30 mg/l, DO=4.5 mg/l and TSS=15 mg/l
	Significant Industrial Plants	Latest jurisdiction tributary strategy BOD=5 mg/l, DO=5 mg/l and TSS=5 mg/l	TN=3 and TP=0.1 or tributary strategy level if less for industrial facilities BOD=3 mg/l, DO=6 mg/l and TSS=5 mg/l	Highest Loads on record, or tributary strategy loads if greater BOD=30 mg/l, DO=4.5 mg/l and TSS=15 mg/l
	Non-significant Municipal Plants	2006 data or more recently submitted non-significant facility data BOD=30 mg/l, DO=4.5 mg/l and TSS=25 or 45 mg/l	TN=8 mg/L and TP=2 mg/L for municipal plants Current level adjusted by the same rates used for sig industrial plants BOD =5 mg/l, DO=5 mg/l and TSS= 8 mg/l	TN=18 mg/l and TP =3 mg/l BOD=30 mg/l, DO=4.5 mg/l and TSS=15 mg/l
	Non-significant Industrial Plants	Tetra Tech estimated non-significant industrial data BOD=30 mg/l, DO=4.5 mg/l and TSS=25 or 45 mg/l	Tetra Tech estimated non-significant industrial data adjusted by the percentage of equivalent reduction from No-Action (18 mg/l TN, 3mg/l TP) to E3 (3 mg/l TN, 0.1 mg/l TP) BOD =5 mg/l, DO=5 mg/l and TSS= 8 mg/l	Tetra Tech estimated non-significant industrial data. BOD=30 mg/l, DO=4.5 mg/l and TSS=25 or 45 mg/l
Flow		Tributary strategy flows for significant facilities. 2006 data or more recently submitted data for non-significant facilities	Same as tributary strategy scenario	Same as tributary strategy scenario
CSO		Long Term Control Plan--full implementation	100% CSO overflow reduction	2003 Estimates

Notes: E3 - everyone, everything, everywhere, TN - total nitrogen, TP - total phosphorus, BOD - biological oxygen demand, DO - dissolved oxygen, TSS - total suspended solids, CSO- combined sewer overflow

1985 No Action Scenario

The No Action scenario estimates nitrogen, phosphorus, and sediment loads under the conditions of minimal to no pollution reduction controls on sources and nonpoint sources using a 1985 land use and human and agricultural animal populations. Major widespread management practices that would not already be in place such as nutrient management and conservation tillage were eliminated in this scenario. Wastewater treatment/discharging facilities were set at primary treatment with no nutrient removal and with no phosphate detergent ban. Atmospheric deposition loads were set to 1985 levels of emissions and controls. Phase 5.3 Chesapeake Bay Watershed Model simulated nitrogen, phosphorus and sediment loads for this scenario are listed in Tables J-2, J-4, and J-6, respectively.

The No Action scenario is used with the E3 scenario to define "controllable" loads, the difference between No Action and E3 loads. No Action and E3 scenario conditions can be determined for historic years (beginning 1985), current year, or projected future (through 2030) by changing the underlying land use, associated pollutant loadings and population estimates. All past practices, programs, and treatment upgrades that currently exist are credited toward the needed reductions from the No Action "baseline".

1985 No Action Wastewater Treatment/Discharging Facilities

- No Action Significant municipal wastewater treatment facilities
  - Flow = Tributary Strategy flows where most are at design flows
  - Nitrogen effluent concentration = 18 mg/l TN
  - Phosphorus effluent concentration = 6 mg/l TP
  - BOD = 30 mg/l, DO = 4.5 mg/l and TSS = 15 mg/l
- No Action Significant industrial dischargers
  - Flow = Tributary Strategy flows where most are at design flows
  - Highest Loads on record or Tributary Strategy loads if greater
  - BOD = 30 mg/l, DO = 4.5 mg/l and TSS = 15 mg/l
- No Action Nonsignificant municipal wastewater treatment facilities
  - Flow = Tributary Strategy flows
  - Nitrogen effluent concentration = 18 mg/l TN
  - Phosphorus effluent concentration = 6 mg/l TP
  - BOD = 30 mg/l, DO = 4.5 mg/l and TSS = 15 mg/l

1985 No Action Combined Sewer Overflows

- Flow = current base condition flow
- Nitrogen effluent concentration = 18 mg/l TN
- Phosphorus effluent concentration = 6 mg/l TP
- BOD = 200 mg/l, DO = 4.5 mg/l and TSS = 45 mg/l.

1985 No Action On-site Waste Treatment Systems

There are no nitrogen and phosphorus control practices and programs in the No Action scenario throughout the Chesapeake Bay watershed for on-site waste treatment systems.

1985 No Action Atmospheric Deposition

The 2020 CMAQ Scenario is used for atmospheric deposition in both the E3 and No-Action scenarios in determining the "controllable" load (see Appendix L). This approach allows for the agreed to Bay TMDL air reductions to be already considered in the nitrogen load reductions needed to achieve the Bay water quality standards.

1985 No Action Urban Practices

There are no nitrogen, phosphorus, and sediment control practices and programs in the No Action scenario throughout the Chesapeake Bay watershed for the urban sector.

1985 No Action Agricultural Practices

There are no nitrogen, phosphorus, and sediment control practices and programs in the No Action scenario throughout the Chesapeake Bay watershed for agricultural lands and operations.

1985 No Action Forestry Practices

There are no nitrogen, phosphorus, and sediment control practices and programs in the No Action scenario throughout the Chesapeake Bay watershed on forest lands where there could be environmental impacts from timber harvesting and dirt and gravel roads.

2010 No Action Scenario

This scenario estimates nutrient and sediment loads under the conditions of minimal to no pollution reduction controls on point sources and nonpoint sources using a 2010 land use and population. Major widespread management practices such as nutrient management and conservation tillage were eliminated in this scenario. Wastewater treatment facilities were set at primary treatment (no nutrient removal) with no phosphate detergent ban. Atmospheric deposition loads were set to 1985 levels of emissions and controls. See the above description of the 1985 No Action Scenario for further details. Phase 5.3 Chesapeake Bay Watershed Model simulated nitrogen, phosphorus, and sediment loads for this scenario are listed in Tables J-2, J-4, and J-6, respectively.

Everyone, Everything, Everywhere (E3) Scenario

The E3 Scenario is an estimate of the application of management actions to the fullest possible extent practicable (this is not Limit of Technology). The E3 scenario is a "what-if" scenario of watershed conditions with the theoretical maximum practicable levels of managed controls on all pollutant load sources. There are no cost and few physical limitations to implementing BMPs for point and nonpoint sources in the E3 scenario. This scenario is used with the No Action scenario

to define "controllable" loads, the difference between No Action and E3 loads. Phase 5.3 Chesapeake Bay Watershed Model simulated nitrogen, phosphorus, and sediment loads for this scenario are listed in Tables J-2, J-4, and J-6, respectively.

"Controllable" loads are considered when allocating the target loads needed to meet water quality standards to different regions of the Chesapeake Bay watershed. Target cap allocations also take into consideration the relative impacts of load reductions from regions throughout the watershed on water quality standards. Differences between No Action and E3 scenario loads provide equity among regions of the Chesapeake Bay watershed in that the assumptions for point source controls and nonpoint source practice and program implementation levels for each scenario are spatially universal. Differences among regions occur because of more "inherent" differences in, for example, animal and human populations, the number and types of point source facilities, agricultural land uses and areas, urban land areas, atmospheric deposition, etc.

Generally, E3 implementation levels and their associated reductions in nitrogen, phosphorus, and sediment could not be achieved for many practices, programs, and control technologies when considering physical limitations and required participation levels. E3 includes most technologies, practices and programs that have been reported by jurisdictions as part of annual model assessments, Tributary Strategies, and two-year milestones.

For most non-point source BMPs, it was assumed that the load from every available acre of the relevant land area was being controlled by a suite of existing or innovative practices. In addition, management programs converted land uses from those with high yielding nitrogen, phosphorus, and sediment loads to those with lower. E3 does not include the entire suite of practices, but rather, fully implements only those practices that have been estimated to produce greater reductions than alternative practices that could be applied to the same land base.

The current definition of E3 includes a greater number of types of practices than historic E3 scenarios. E3 load reductions could be exceeded through greater effectiveness of practices and technologies in the future because of, for example, employment of new technologies and greater efforts on operation and maintenance. For point sources, nutrient control technologies are assumed to apply to all dischargers.

E3 Wastewater Discharging Facilities

- E3 Significant municipal wastewater treatment facilities
  - Flow = Tributary Strategy flows where most are at design flows
  - Nitrogen effluent concentration = 3 mg/l TN
  - Phosphorus effluent concentration = 0.1 mg/l TP
  - BOD = 3 mg/l, DO = 6 mg/l and TSS = 5 mg/l
- E3 Significant industrial dischargers
  - Flow = Tributary Strategy flows where most are at design flows
  - Nitrogen effluent concentration = 3 mg/l TN or Tributary Strategy concentration if less
  - Phosphorus effluent concentration = 0.1 mg/l TP or Tributary Strategy concentration if less
  - BOD = 3 mg/l, DO = 6 mg/l and TSS = 5 mg/l

- E3 Non-significant municipal wastewater treatment facilities
  - Flow = Design or 2006 flow if design is not available
  - Nitrogen effluent concentration = 8 mg/l TN or Tributary Strategy concentration if less
  - Phosphorus effluent concentration = 2 mg/l TP or Tributary Strategy concentration if less
  - BOD = 5 mg/l, DO = 5 mg/l and TSS = 8 mg/l
- E3 Nonsignificant industrial wastewater treatment facilities
  - Applies the percentage of equivalent reduction from No Action (18 mg/l TN, 3mg/l TP) to E3 (3 mg/l TN, 0.1 mg/l TP) to the 2010 load estimates.

E3 Combined Sewer Overflows

- 100% overflow reduction through storage and treatment, separation or other practices. Storage and treatment is assumed in current model scenarios.

E3 On-site Wastewater Treatment Systems

- E3 Septic system connections
  - 10% of septic systems retired and connected to wastewater treatment facilities.
- E3 Septic denitrification and maintenance
  - Remaining septic systems after connections employ denitrification technologies and are maintained through regular pumping to achieve a 55% TN load reduction at the edge-of-septic-field.
  - Septic systems are maintained by a responsible management entity or in perpetuity through a maintenance contract.

E3 Atmospheric Deposition

- E3 atmospheric deposition uses the Chesapeake Bay Program's air scenario that shows the maximum reductions in deposition – a projection to 2020 called the Maximum Feasible Scenario (see Appendix L).
- The Chesapeake Bay Program's Water Quality Goal Implementation Team decided to use the same atmospheric deposition for both the E3 and No Action scenarios in the allocation methodology.
- The 2020 Maximum Feasible Scenario represents 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 – such as the proposed 0.070 ppm ozone standard of January 2010.
- Emissions projections for the 2020 E3 scenario assume the following:
  - National/regional and available State Implementation Plans (SIP) for NOx reductions – with 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.
  - Electric Generating Units (EGU):
    - CAIR second phase in place, in coordination with earlier NOx SIP call.

    - NOx Budget Trading Program (NBP).
    - Regional Haze Rule and guidelines for Best Available retrofit Technology (BART) for reducing regional haze.
    - Clean Air Mercury Rule (CAMR) in place.
  - 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.
    - Solid Waste Rules – Hospital/Medical Waste Incinerator Regulations
  - On-Road mobile sources:
    - On-Road Light Duty Mobile Sources – Tier 2 vehicle emissions standards and the Gasoline Sulfur Program which affects SUV's, pickups and vans which are subject to same national emission standards as cars.
    - On-Road Heavy Duty Diesel Rule – Tier 4: New emission standards on diesel engines starting with the 2010 model year for NOx, plus increased penetration of diesel retrofits and continuous inspection and maintenance using remote onboard diagnostic systems.
  - Clean Air Non-Road Diesel Rule:
    - Off-road diesel engine vehicle rule, reduced NOx emissions from marine vessels in coastal shipping lanes, 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).
  - Area (nonpoint area) sources: switching to natural gas and low sulfur fuel.

- E3 Agricultural Ammonia Emissions Reductions
  - Assumes rapid incorporation of fertilizers in soils at the time of application, litter treatment, bio-filters on housing ventilation systems, and covers on animal waste storage or treatment facilities.
  - The overall benefit of reduced emissions from confined animal housing and waste storage as well as lower emissions from fertilized soils is a 15% reduction of ammonia deposition.

E3 Urban Practices

- E3 Forest conservation & urban growth reduction
  - All projected loss of forest from development is retained or planted in forest.
- E3 Riparian forest buffers on urban
  - 10% of pervious riparian areas without natural vegetation (forests and wetlands) associated with urban lands are buffered as forest for each modeled hydrologic segment in the Chesapeake Bay watershed.
  - The area of un-buffered riparian land is determined using the best available data: 1) 1:24K National Hydrography Dataset; and 2) 2001 land cover.

- E3 Tree planting on urban
  - Forest conservation and urban riparian forest buffers account for tree plantings in the urban sector.
- E3 Stormwater Management
  - Regions with karst topography (low permeability) and Coastal Plain Lowlands (high groundwater)
    - 50% of areas – impervious cover reduction.
    - 30% of area – filtering practices designed to reduce TN by 40%, TP by 60% and SED by 80% from a pre-BMP condition.
    - 20% of area – infiltration practices designed to reduce TN by 85%, TP by 85% and sediment by 95% from a pre-BMP condition.
  - Ultra-urban regions – defined as high- and medium-intensity land cover
    - 50% of areas – impervious cover reductions, e.g. cisterns and collections systems to capture rainwater for reuse.
    - 30% of area – filtering practices, e.g., sand filters, bio-retention, and dry wells.
    - 20% of area – infiltration practices, e.g., infiltration trenches and basins.
  - Other urban/suburban regions
    - 10% of areas - impervious cover reduction.
    - 30% of area – filtering practices, e.g. sand filters, bio-retention.
    - 60% of area – infiltration practices.
- E3 Erosion & sediment controls
  - Controls of the runoff from all bare-construction land use areas are assumed to be at a level so that the construction loads are equal to the nutrient and sediment edge-of-stream loads from pervious urban under E3 conditions.
- E3 Nutrient management on urban
  - All pervious urban acres are under nutrient management.
- E3 Controls on extractive (active and abandoned mines)
  - Controls of the runoff from all extractive land use areas are assumed to be to a degree so that the loads are equal to the nutrient and sediment edge-of-stream loads from pervious urban under E3 conditions.

E3 Agricultural Practices

- E3 Conservation tillage
  - All row crops are conservation-tilled.
- E3 Enhanced nutrient management applications
  - All cropland is under enhanced nutrient management – the hybrid of reduced application rate and decision agriculture.
  - Long-term, adaptive management approach with continuous improvement.

- E3 Riparian forest buffers on agriculture
  - Riparian areas without natural vegetation (forests and wetlands) associated with agricultural lands are buffered as forest.
  - This equates to 15% of cropland and 10% of pasture land including the pasture stream corridor for each modeled hydrologic segment in the Chesapeake Bay watershed.
  - The area of un-buffered riparian land is determined using the best available data: 1) 1:24K National Hydrography Dataset; and 2) 2001 land cover.
  - Current implementation of riparian grass buffers is considered converted to riparian forest buffers.
- E3 Wetland restoration
  - 5% of available agricultural acres in crops and grazed for each modeled hydrologic segment in the Chesapeake Bay watershed.
- E3 Carbon sequestration / alternative crops
  - 5% of the available row crop acres for each modeled hydrologic segment in the Chesapeake Bay watershed.
  - Program is replacement of row crops with long-term grasses that serve as a carbon bank.
- E3 Agricultural land retirement
  - Retirement of highly erodible land is considered in the E3 practices of riparian forest buffers, wetland restoration, and carbon sequestration practices which typically have equal or greater environmental benefits.
- E3 Tree planting on agriculture
  - Tree planting is considered in the E3 practice of riparian forest buffers which typically have equal or greater environmental benefits.
- E3 Conservation Plans (non-nutrient management)
  - Conservation Plans are fully implemented on all agricultural land (row crops, hay, alfalfa, and pasture).
- E3 Cover crops and commodity cover crops
  - Early-planting rye cover crops with drilled seeding on all relevant row crops.
  - The watershed-wide average of 81% of row crops are not associated with small-grain production is applied to each modeled hydrologic segment in the Chesapeake Bay watershed.
  - Early-planting wheat commodity cover crops with drilled seeding on remaining row crops (associated with small-grain production).
    - The watershed-wide average of 19% of row crops associated with small-grain production is applied to each modeled hydrologic segment in the Chesapeake Bay watershed.
- E3 Pasture Management
  - Stream Access Control with Fencing – Exclusion fencing is assumed to protect the stream corridor area designated as the degraded landuse and the area between the

stream bank and fence is converted to (and is part of) the agricultural forest buffer determination.
  - Prescribed grazing – All upland pasture area is assumed to be under prescribed grazing.
  - Dairy Precision Feeding and Forage Management (also listed under E3 Dairy Precision Feeding) – All dairy heifers have reduced nutrient concentrations in excreted manure of TN = 24% and TP = 28% from a pre-feed management condition.
    - Management approaches may include increased productivity and use of on-farm grass forage.
  - Horse pasture management benefits are the same as those for fencing and prescribed grazing practices for livestock in general.

- E3 Animal waste management/runoff control
  - Controls of runoff of manure nutrients from the production area of animal feeding operations is assumed to be at a level so that loads are equal to the nutrient and sediment edge-of-stream loads associated with hay that does not receive fertilizer applications.
  - Other practices typically associated with animal waste management and runoff control, that may affect runoff from the production area, are addressed separately in the E3 scenario. These include Poultry and Swine Phytase, Dairy Precision Feeding, Manure Transport, and Ammonia Emissions Reductions.

- E3 Poultry phytase
  - The phosphorus content in the manure of all poultry is reduced by 32% from a pre-feed management condition.

- E3 Swine phytase
  - The phosphorus content in excreted manure of all swine is reduced from a pre-feed management condition by 17%.

- E3 Dairy Precision Feeding
  - All dairy heifers have reduced nutrient concentrations in excreted manure of TN = 24% and TP = 28% from a pre-feed management condition.

- E3 Ammonia emissions reductions
  - Also under E3 Atmospheric Deposition – Agricultural Ammonia Emissions Reductions
  - Assumes rapid incorporation of fertilizers in soils at the time of application, litter treatment, bio-filters on housing ventilation systems, and covers on animal waste storage or treatment facilities.
  - The overall benefit of reduced emissions from confined animal housing and waste storage as well as lower emissions from fertilized soils is a 15% reduction of ammonia deposition.

- E3 Nursery Management
  - All nursery operations are managed through a number of practices to protect water quality including properly addressing nutrient management and incorporating erosion and sedimentation controls.

- Controls are to a degree so that runoff from nursery areas is equal to the nitrogen, phosphorus, and sediment edge-of-stream loads from hay that does not receive fertilizer applications.

E3 Forest Harvest Practices

- E3 Forest harvesting practices
  - Controls of runoff from the disturbed area of timber harvest operations is assumed to be at a level so that the nitrogen, phosphorus, and sediment loads are equal to edge-of-stream loads associated with the forest/woody landuse.
  - It's assumed these BMPs, designed to minimize the environmental impacts from timber harvesting (such as road building and cutting/thinning operations), are properly installed on all harvested lands with no measurable increase in nitrogen, phosphorus, and sediment discharge.

All Forest with Current Air Scenario

This scenario uses an all forest land use and estimated atmospheric deposition loads for the 1991 – 2000 period, and represents estimated loads with maximum reductions on the land including the elimination of fertilizer, point source, and manure loads. However, this scenario has loads greater than a pristine scenario which would have reduced input atmospheric deposition loads by about an order of magnitude. Phase 5.3 Chesapeake Bay Watershed Model simulated nitrogen, phosphorus and sediment loads for this scenario are listed in Tables J-3, J-5, and J-7, respectively.

Base Calibration Scenario

The Base Calibration Scenario is used in data correction procedures and represents the calibration of the time series of land uses, loads, and hydrology over the ten year simulation period (1991-2001) used for TMDL scenarios. Phase 5.3 Chesapeake Bay Watershed Model simulated nitrogen, phosphorus and sediment loads for this scenario are listed in Tables J-2, J-4, and J-6, respectively.

Allocation Scenario

The Allocation Scenario characterizes the nitrogen, phosphorus and sediment loads necessary to achieve the Bay jurisdictions' Chesapeake Bay water quality standards. This scenario, ultimately replaced by the final Bay TMDL allocations listed in Section 9, is provided for documentation purposes. The Phase 5.3 Chesapeake Bay Watershed Model simulated nitrogen, phosphorus and sediment loads for this scenario are listed in Table J-8.

190/12.7 Loading Scenario

This scenario of 190 million pounds nitrogen and 12.7 million pounds phosphorus delivered to the Bay is one of several scoping scenarios that were run to explore the region of nutrient loads that were close to achieving all water quality standards in the Chesapeake. Phase 5.3 Chesapeake

Bay Watershed Model simulated nitrogen, phosphorus, and sediment loads for this scenario are listed in Tables J-3, J-5, and J-7, respectively.

179/12 Loading Scenario

This scenario of 179 million pounds nitrogen and 12 million pounds phosphorus delivered to the Bay is one of several scoping scenarios that were run to explore the region of nutrient loads that were close to achieving all water quality standards in the Chesapeake Bay. Phase 5.3 Chesapeake Bay Watershed Model simulated nitrogen, phosphorus and sediment loads for this scenario are listed in Tables J-3, J-5 and J-7, respectively.

170/11.3 Loading Scenario

This scenario of 170 million pounds nitrogen and 11.3 million pounds phosphorus delivered to the Bay is one of several scoping scenarios that were run to explore the region of nutrient loads that were close to achieving all water quality standards in the Chesapeake Bay. Phase 5.3 Chesapeake Bay Watershed Model simulated nitrogen, phosphorus, and sediment loads for this scenario are listed in Tables J-3, J-5, and J-7, respectively.

James Level of Effort Potomac Scenario

This scenario was one of several scoping scenarios examining achievement of the tidal James River's chlorophyll *a* water quality standards. The 190/12.7 Loading Scenario was used as a base for this scenario and all other basins but the James River basin received the nitrogen and phosphorus loadings that were allocated as part of the 190/12.7 Loading Scenario. In the James River basin, the nitrogen and phosphorus loads were equivalent to the same level of effort as Virginia's portion of the Potomac for the 190/12.7 Loading Scenario. Phase 5.3 Chesapeake Bay Watershed Model simulated nitrogen, phosphorus, and sediment loads for this scenario are listed in Tables J-3, J-5, and J-7, respectively.

James ½ Level of Effort Potomac Scenario

This scenario was one of several scoping scenarios examining achievement of the tidal James River's chlorophyll *a* water quality standards. The 190/12.7 Loading Scenario was used as a base for this scenario and all other basins but the James received the nitrogen and phosphorus loadings that were allocated as part of the 190/12.7 Loading Scenario. In the James River basin, the nitrogen and phosphorus loads are equivalent to the level of effort ***half way*** between Virginia's portion of the Potomac River basin and the James River basin for the 190/12.7 Loading Scenario. Phase 5.3 Chesapeake Bay Watershed Model simulated nitrogen, phosphorus and sediment loads for this scenario are listed in Tables J-3, J-5 and J-7, respectively.

Please note that in some cases the scenario loads reported in this Appendix may differ slightly from loads reported in other documentation, such as in the stoplight plots in Appendix M. This is because the scenario loads in this Appendix have the latest updated input load information but the stoplight plots in Appendix M contain scenarios that were dated and in some cases corrected with new information. For example, the scoping scenarios of the 190/12.7 Loading Scenario,

179/12 Loading Scenario, and 170/11 Loading Scenario were developed with appropriate factors of an early Tributary Strategy Scenario which has been updated since the stoplight assessments were run.

Table J-2. Delivered Total Nitrogen Loads (millions lbs/year) by State Basin and Scenario

Scenario		1985	Base Calibration	2009	2010 No-Action	Tributary Strategy	2010 E3
Eastern Shore (EAS)							
	DE	4.59	4.77	4.15	4.98	3.16	2.22
	MD	16.55	16.35	12.42	17.70	9.84	7.18
	PA	0.57	0.54	0.44	0.49	0.31	0.20
	VA	2.15	2.20	2.00	2.41	1.03	0.79
James River Basin (JAM)							
	VA	42.47	36.82	31.52	49.11	27.51	16.45
	WV	0.02	0.02	0.02	0.02	0.02	0.02
Potomac River Basin (POT)							
	DC	6.22	5.41	2.86	9.78	2.26	1.47
	MD	29.56	26.96	18.77	32.96	16.10	11.42
	PA	7.23	6.95	6.23	6.69	4.24	3.50
	VA	30.14	28.36	20.31	33.53	16.38	13.31
	WV	8.08	7.79	5.91	6.37	4.78	3.61
Rappahannock River Basin (RAP)							
	VA	8.92	8.35	6.94	9.33	5.62	4.39
Susquehanna River Basin (SUS)							
	MD	2.29	2.02	1.54	1.75	1.26	0.87
	NY	16.87	15.02	10.95	11.03	9.56	6.39
	PA	127.49	118.86	101.65	119.29	71.09	56.89
Western Shore (WES)							
	MD	27.00	17.75	14.00	36.64	9.84	5.99
	PA	0.04	0.04	0.03	0.04	0.01	0.01
Patuxent River Basin (PAT)							
	MD	4.16	3.86	3.09	6.01	2.78	2.03
York River Basin (YOR)							
	VA	7.60	7.37	6.44	8.49	5.09	3.83
Totals(millions lbs/year)							
State	DC	6.22	5.41	2.86	9.78	2.26	1.47
	DE	4.59	4.77	4.15	4.98	3.16	2.22
	MD	79.56	66.95	49.81	95.05	39.82	27.49
	NY	16.87	15.02	10.95	11.03	9.56	6.39
	PA	135.34	126.39	108.35	126.51	75.66	60.59
	VA	91.27	83.10	67.21	102.86	55.65	38.78
	WV	8.11	7.81	5.93	6.39	4.80	3.63
Basin	EAS	23.85	23.85	19.01	25.58	14.34	10.39
	JAM	42.49	36.84	31.54	49.12	27.53	16.47
	POT	81.23	75.47	54.07	89.33	43.76	33.31
	RAP	8.92	8.35	6.94	9.33	5.62	4.39
	SUS	146.65	135.90	114.14	132.07	81.92	64.15
	WES	27.04	17.79	14.03	36.68	9.85	6.00
	PAT	4.16	3.86	3.09	6.01	2.78	2.03
	YOR	7.60	7.37	6.44	8.49	5.09	3.83
Chesapeake Bay Total(millions lbs/year)							
Total		341.95	309.44	249.26	356.61	190.90	140.57

Table J-3. Delivered Total Nitrogen Loads (millions lbs/year) by State Basin and Scenario

		190/12.7	179/12	170/11.3	James L.O.E. 1/2 Potomac	James L.O.E. Potomac	All Forest
Eastern Shore							
	DE	3.14	2.85	2.57	3.14	3.14	0.58
	MD	9.76	8.88	8.00	9.76	9.76	2.65
	PA	0.31	0.28	0.25	0.31	0.31	0.09
	VA	1.02	0.93	0.84	1.02	1.02	0.22
James River Basin							
	VA	26.55	25.99	25.43	23.47	21.51	7.26
	WV	0.02	0.02	0.02	0.02	0.02	0.01
Potomac River Basin							
	DC	2.31	2.21	2.10	2.31	2.31	0.06
	MD	16.48	15.72	14.96	16.48	16.48	4.66
	PA	4.34	4.14	3.94	4.34	4.34	1.03
	VA	16.77	16.00	15.23	16.77	16.77	5.22
	WV	4.89	4.67	4.44	4.89	4.89	1.84
Rappahannock River Basin							
	VA	5.87	5.54	5.22	5.87	5.87	2.20
Susquehanna River Basin							
	MD	1.25	1.17	1.09	1.25	1.25	0.50
	NY	9.44	8.85	8.27	9.44	9.44	2.88
	PA	70.20	65.87	61.54	70.20	70.20	23.52
Western Shore							
	MD	9.45	9.08	8.71	9.45	9.45	2.29
	PA	0.01	0.01	0.01	0.01	0.01	0.00
Patuxent River Basin							
	MD	2.77	2.63	2.49	2.77	2.77	0.88
York River Basin							
	VA	5.37	5.10	4.83	5.37	5.37	1.85
Totals(millions lbs/year)							
State	DC	2.31	2.21	2.10	2.31	2.31	0.06
	DE	3.14	2.85	2.57	3.14	3.14	0.58
	MD	39.70	37.48	35.26	39.70	39.70	10.98
	NY	9.44	8.85	8.27	9.44	9.44	2.88
	PA	74.86	70.30	65.74	74.86	74.86	24.63
	VA	55.58	53.56	51.54	52.51	50.55	16.74
	WV	4.91	4.69	4.46	4.91	4.91	1.85
Basin	EAS	14.23	12.94	11.66	14.23	14.23	3.54
	JAM	26.57	26.01	25.45	23.49	21.53	7.27
	POT	44.79	42.73	40.67	44.79	44.79	12.80
	RAP	5.87	5.54	5.22	5.87	5.87	2.20
	SUS	80.88	75.89	70.90	80.88	80.88	26.90
	WES	9.46	9.09	8.72	9.46	9.46	2.30
	PAT	2.77	2.63	2.49	2.77	2.77	0.88
	YOR	5.37	5.10	4.83	5.37	5.37	1.85
Chesapeake Bay Total(millions lbs/year)							
		189.94	179.94	169.95	186.86	184.90	57.72

Table J-4. Delivered Total Phosphorus Loads (millions lbs/year) by State Basin and Scenario

		1985	Base Calibration	2009	2010 No-Action	Tributary Strategy	2010 E3
Eastern Shore							
	DE	0.37	0.38	0.32	0.45	0.27	0.19
	MD	1.70	1.59	1.17	2.00	1.04	0.83
	PA	0.02	0.02	0.02	0.02	0.01	0.01
	VA	0.26	0.25	0.19	0.30	0.13	0.12
James River Basin							
	VA	6.47	4.32	3.25	7.52	3.28	1.55
	WV	0.01	0.01	0.01	0.01	0.01	0.01
Potomac River Basin							
	DC	0.10	0.10	0.09	1.58	0.11	0.05
	MD	1.48	1.24	1.01	3.56	1.03	0.63
	PA	0.57	0.54	0.54	0.61	0.38	0.33
	VA	2.18	2.09	2.01	4.97	1.70	0.98
	WV	0.85	0.91	0.82	0.92	0.54	0.37
Rappahannock River Basin							
	VA	1.29	1.24	1.08	1.65	0.94	0.60
Susquehanna River Basin							
	MD	0.09	0.07	0.06	0.07	0.06	0.04
	NY	1.07	0.98	0.80	0.97	0.65	0.43
	PA	4.48	3.79	3.41	5.25	2.65	1.76
Western Shore							
	MD	1.62	0.87	0.77	3.63	0.68	0.25
	PA	0.00	0.00	0.00	0.00	0.00	0.00
Patuxent River Basin							
	MD	0.48	0.36	0.29	0.83	0.29	0.13
York River Basin							
	VA	1.02	0.76	0.62	1.16	0.59	0.35
Totals(millions lbs/year)							
State	DC	0.10	0.10	0.09	1.58	0.11	0.05
	DE	0.37	0.38	0.32	0.45	0.27	0.19
	MD	5.37	4.13	3.31	10.10	3.10	1.88
	NY	1.07	0.98	0.80	0.97	0.65	0.43
	PA	5.07	4.36	3.97	5.89	3.04	2.10
	VA	11.24	8.67	7.15	15.60	6.64	3.60
	WV	0.86	0.93	0.83	0.93	0.55	0.38
Basin	EAS	2.36	2.23	1.70	2.77	1.45	1.15
	JAM	6.49	4.34	3.26	7.53	3.29	1.55
	POT	5.19	4.90	4.46	11.64	3.76	2.36
	RAP	1.29	1.24	1.08	1.65	0.94	0.60
	SUS	5.64	4.84	4.27	6.29	3.36	2.24
	WES	1.62	0.87	0.77	3.63	0.68	0.25
	PAT	0.48	0.36	0.29	0.83	0.29	0.13
	YOR	1.02	0.76	0.62	1.16	0.59	0.35
Chesapeake Bay Total(millions lbs/year)							
		24.10	19.54	16.46	35.51	14.36	8.63

Table J-5. Delivered Total Phosphorus Loads (millions lbs/year) by State Basin and Scenario

		190/12.7	179/12	170/11.3	James L.O.E. 1/2 Potomac	James L.O.E. Potomac	All Forest
Eastern Shore(EAS)							
	DE	0.29	0.27	0.25	0.29	0.29	0.05
	MD	1.10	1.02	0.94	1.10	1.10	0.22
	PA	0.01	0.01	0.01	0.01	0.01	0.00
	VA	0.14	0.13	0.12	0.14	0.14	0.02
James River Basin(JAM)							
	VA	2.67	2.57	2.47	2.34	2.21	0.90
	WV	0.01	0.01	0.01	0.01	0.01	0.01
Potomac River Basin(POT)							
	DC	0.10	0.09	0.09	0.10	0.10	0.00
	MD	0.95	0.90	0.85	0.95	0.95	0.25
	PA	0.35	0.33	0.31	0.35	0.35	0.13
	VA	1.56	1.48	1.39	1.56	1.56	0.40
	WV	0.50	0.47	0.45	0.50	0.50	0.27
Rappahannock River Basin(RAP)							
	VA	0.91	0.85	0.78	0.91	0.91	0.30
Susquehanna River Basin(SUS)							
	MD	0.05	0.05	0.04	0.05	0.05	0.01
	NY	0.56	0.53	0.51	0.56	0.56	0.31
	PA	2.28	2.17	2.06	2.28	2.28	1.04
Western Shore(WES)							
	MD	0.45	0.42	0.40	0.45	0.45	0.15
	PA	0.00	0.00	0.00	0.00	0.00	0.00
Patuxent River Basin(PAT)							
	MD	0.21	0.20	0.18	0.21	0.21	0.07
York River Basin(YOR)							
	VA	0.54	0.51	0.48	0.54	0.54	0.21
Totals(millions lbs/year)							
State	DC	0.10	0.09	0.09	0.10	0.10	0.00
	DE	0.29	0.27	0.25	0.29	0.29	0.05
	MD	2.75	2.58	2.41	2.75	2.75	0.71
	NY	0.56	0.53	0.51	0.56	0.56	0.31
	PA	2.64	2.52	2.39	2.64	2.64	1.17
	VA	5.82	5.53	5.24	5.48	5.36	1.84
	WV	0.51	0.48	0.45	0.51	0.51	0.28
Basin	EAS	1.53	1.42	1.31	1.53	1.53	0.30
	JAM	2.68	2.58	2.47	2.35	2.22	0.91
	POT	3.46	3.27	3.09	3.46	3.46	1.06
	RAP	0.91	0.85	0.78	0.91	0.91	0.30
	SUS	2.89	2.75	2.62	2.89	2.89	1.36
	WES	0.45	0.42	0.40	0.45	0.45	0.15
	PAT	0.21	0.20	0.18	0.21	0.21	0.07
	YOR	0.54	0.51	0.48	0.54	0.54	0.21
Chesapeake Bay Total(millions lbs/year)							
		12.67	12.00	11.33	12.33	12.20	4.36

Table J-6. Delivered Total Suspended Solids Loads (millions lbs/year) by State Basin and Scenario

		1985	Base Calibration	2009	2010 No-Action	Tributary Strategy	2010 E3
Eastern Shore							
	DE	76.68	76.96	64.78	93.67	54.75	31.13
	MD	260.20	243.41	185.80	294.98	156.99	126.05
	PA	38.73	37.04	31.66	40.47	20.12	19.52
	VA	22.16	20.21	16.38	21.99	10.30	8.83
James River Basin							
	VA	1562.90	1473.21	1247.04	1506.04	1004.70	691.16
	WV	29.45	28.81	28.52	28.59	18.21	14.62
Potomac River Basin							
	DC	22.54	29.86	32.00	100.95	10.31	4.12
	MD	923.43	866.58	781.47	1036.36	665.62	471.50
	PA	323.32	303.02	309.61	391.39	226.28	225.46
	VA	1296.91	1204.65	1092.77	1346.84	823.32	607.61
	WV	426.22	384.14	349.86	418.46	230.02	166.15
Rappahannock River Basin							
	VA	890.56	840.71	754.27	852.79	688.86	634.32
Susquehanna River Basin							
	MD	106.49	96.35	73.29	100.82	63.55	53.72
	NY	400.98	336.60	337.27	344.28	310.74	212.05
	PA	2718.95	2386.77	2286.39	2899.89	1756.33	1589.07
Western Shore							
	MD	311.80	266.86	239.00	325.15	204.99	105.10
	PA	0.93	0.89	0.77	1.11	0.49	0.56
Patuxent River Basin							
	MD	182.30	171.33	114.46	158.87	103.34	60.57
York River Basin							
	VA	208.88	179.78	145.18	201.47	114.12	83.19
Totals(millions lbs/year)							
State	DC	22.54	29.86	32.00	100.95	10.31	4.12
	DE	76.68	76.96	64.78	93.67	54.75	31.13
	MD	1784.21	1644.53	1394.02	1916.18	1194.48	816.94
	NY	400.98	336.60	337.27	344.28	310.74	212.05
	PA	3081.93	2727.72	2628.42	3332.86	2003.23	1834.60
	VA	3981.40	3718.57	3255.65	3929.11	2641.31	2025.11
	WV	455.67	412.96	378.38	447.04	248.23	180.77
Basin	EAS	397.76	377.62	298.62	451.11	242.17	185.53
	JAM	1592.34	1502.02	1275.56	1534.62	1022.91	705.78
	POT	2992.42	2788.26	2565.72	3293.99	1955.55	1474.84
	RAP	890.56	840.71	754.27	852.79	688.86	634.32
	SUS	3226.43	2819.72	2696.94	3345.00	2130.62	1854.84
	WES	312.73	267.75	239.76	326.26	205.48	105.65
	PAT	182.30	171.33	114.46	158.87	103.34	60.57
	YOR	208.88	179.78	145.18	201.47	114.12	83.19
Chesapeake Bay Total(millions lbs/year)							
		9803.41	8947.19	8090.52	10164.10	6463.06	5104.72

Table J-7. Delivered Total Suspended Solids Loads (millions lbs/year) by State Basin and Scenario

		190/12.7	179/12	170/11.3	James L.O.E. 1/2 Potomac	James L.O.E. Potomac	All Forest
Eastern Shore(EAS)							
	DE	59.35	53.25	47.15	59.35	59.35	43.17
	MD	170.16	152.68	135.20	170.16	170.16	51.17
	PA	21.81	19.57	17.33	21.81	21.81	7.11
	VA	11.17	10.02	8.87	11.17	11.17	2.63
James River Basin(JAM)							
	VA	893.92	875.04	856.15	833.04	809.93	388.49
	WV	16.20	15.86	15.52	15.10	14.68	11.68
Potomac River Basin(POT)							
	DC	9.73	9.36	9.00	9.73	9.73	2.44
	MD	627.64	604.39	581.13	627.64	627.64	263.33
	PA	213.37	205.46	197.56	213.37	213.37	99.70
	VA	776.35	747.58	718.82	776.35	776.35	274.89
	WV	216.90	208.86	200.83	216.90	216.90	120.38
Rappahannock River Basin(RAP)							
	VA	678.31	657.13	635.96	678.31	678.31	506.66
Susquehanna River Basin(SUS)							
	MD	59.65	58.51	57.37	59.65	59.65	24.85
	NY	291.65	286.08	280.51	291.65	291.65	186.12
	PA	1648.48	1616.97	1585.46	1648.48	1648.48	1044.88
Western Shore(WES)							
	MD	150.73	144.46	138.20	150.73	150.73	84.11
	PA	0.36	0.35	0.33	0.36	0.36	0.06
Patuxent River Basin(PAT)							
	MD	81.84	78.75	75.67	81.84	81.84	64.89
York River Basin(YOR)							
	VA	105.98	101.56	97.13	105.98	105.98	61.29
Totals(millions lbs/year)							
State	DC	9.73	9.36	9.00	9.73	9.73	2.44
	DE	59.35	53.25	47.15	59.35	59.35	43.17
	MD	1090.01	1038.79	987.56	1090.01	1090.01	488.34
	NY	291.65	286.08	280.51	291.65	291.65	186.12
	PA	1884.03	1842.36	1800.68	1884.03	1884.03	1151.75
	VA	2465.72	2391.33	2316.94	2404.84	2381.73	1233.96
	WV	233.10	224.72	216.34	231.99	231.58	132.06
Basin	EAS	262.48	235.52	208.55	262.48	262.48	104.08
	JAM	910.12	890.90	871.67	848.14	824.61	400.16
	POT	1843.98	1775.66	1707.35	1843.98	1843.98	760.74
	RAP	678.31	657.13	635.96	678.31	678.31	506.66
	SUS	1999.78	1961.56	1923.33	1999.78	1999.78	1255.85
	WES	151.09	144.81	138.53	151.09	151.09	84.17
	PAT	81.84	78.75	75.67	81.84	81.84	64.89
	YOR	105.98	101.56	97.13	105.98	105.98	61.29
Chesapeake Bay Total(millions lbs/year)							
		6033.58	5845.89	5658.19	5971.60	5948.07	3237.84

Table J-8. Delivered Total Allocation Scenario Loads (millions lbs/year) by State Basin

		Allocation Scenario (Nitrogen)	Allocation Scenario (Phosphorus)	Allocation Scenario (TSS) (range)
Eastern Shore(EAS)				
	DE	2.95	0.26	58-64
	MD	9.71	1.09	166-182
	PA	0.28	0.01	21-23
	VA	1.21	0.16	11-12
James River Basin(JAM)				
	VA	23.48	2.34	837-920
	WV	0.02	0.01	15-17
Potomac River Basin(POT)				
	DC	2.32	0.12	10-11
	MD	15.70	0.90	654-719
	PA	4.72	0.42	221-243
	VA	17.46	1.47	810-891
	WV	4.67	0.74	226-248
Rappahannock River Basin(RAP)				
	VA	5.84	0.90	681-750
Susquehanna River Basin(SUS)				
	MD	1.08	0.05	60-66
	NY	8.23	0.52	293-322
	PA	71.74	2.31	1660-1826
Western Shore(WES)				
	MD	9.74	0.46	155-170
	PA	0.02	0.001	0.37-0.41
Patuxent River Basin(PAT)				
	MD	2.85	0.21	82-90
York River Basin(YOR)				
	VA	5.41	0.54	107-118
Totals(millions lbs/year)				
State	DC	2.32	0.12	10-11
	DE	2.95	0.26	58-64
	MD	39.09	2.72	1,116-1,228
	NY	8.23	0.52	293-322
	PA	76.77	2.74	1,903-2,093
	VA	53.40	5.41	2,446-2,691
	WV	4.68	0.75	241-265
Basin	EAS	14.15	1.53	256 -281
	JAM	23.50	2.35	852-937
	POT	44.88	3.66	1,920-2,113
	RAP	5.84	0.90	681-750
	SUS	81.06	2.88	2,013-2,214
	WES	9.76	0.46	155-171
	PAT	2.85	0.21	82-90
	YOR	5.41	0.54	107-118
Bay Total(millions lbs/yr)				
		187.44	12.52	6,066-6,673

Appendix K.
Allocation Methodology to Relate Relative Impact to Needed Controls

Introduction

The nutrient allocation procedures agreed to by five of the seven Bay watershed partners and followed by EPA are described in Section 6.4 of the main document. The reader should be familiar with Section 6.4 before reading this appendix. The goal of this appendix is to expand the options that were considered before selecting the final procedures and to provide rationale for the final decisions. Unless otherwise noted, the information presented in this appendix is based on the Phase 5.3 Chesapeake Bay Watershed Model and is the same information that was used to inform the decisions in the spring and summer of 2009 using the Phase 5.2 Chesapeake Bay Watershed Model, which had known limitations. Many of the values given in this appendix will be different from the final version as these decisions were not revisited with Phase 5.3 Bay Watershed Model.

Relative Effectiveness Options

Section 6.3.1 of the main document is a discussion of the relative effectiveness of major basins in improving dissolved oxygen in the critical areas of the tidal waters of the Chesapeake.

Relative effectiveness is a combination of riverine effectiveness, also known as a delivery factor, which is expressed as

- pounds of reduction reaching tidal waters/pounds of reduction to the local river and estuarine effectiveness, which is expressed as
- improvement in dissolved oxygen/pounds of reduction reaching tidal waters Multiplying the two together gives
- improvement in dissolved oxygen/pounds of reduction to the local river

Riverine Effectiveness Options

No options were considered in calculating riverine delivery factors. The principles of calculating delivery factors in the Chesapeake Bay Program watershed models are long-standing and have been approved several times by Chesapeake Bay Program workgroups and subcommittees. These principles were also reviewed in the Chesapeake Bay Program's Scientific and Technical Advisory Committee sponsored independent scientific peer reviews of the Phase 5 Chesapeake Bay Watershed Model in 2007 and 2009. Nitrogen delivery factors are calculated for each river segment. Nitrogen levels are lowered naturally in river systems through denitrification, providing a long-run removal of nitrogen. Phosphorus and sediment do not undergo a similar process to denitrification and do not have long-run removal mechanisms other than delivery through the river system and burial. Burial is offset by scour, both of which are episodic in nature. That does not hold true in reservoir systems, where burial is much more significant and is not offset by scour to a great degree. Because of the lack of spatially and temporally detailed phosphorus and sediment data that would be needed to precisely calibrate scour and burial on the segment scale, the calculation of delivery factors for phosphorus and sediment is closed around reservoirs rather

than segment by segment. That is, all segments upstream of a reservoir or an entrance to the tidal system and downstream of other reservoirs receive the same riverine delivery factor.

Geographic Grouping of Estuarine Effectiveness

The estuarine effectiveness is calculated by comparing the dissolved oxygen simulated in the Bay of the calibration run to the dissolved oxygen simulated in the Bay when a given watershed area has reduced loads relative to the calibration loads. The effectiveness for that given area is then calculated by dividing the improvement in dissolved oxygen by the reduction delivered loads. A choice has to be made regarding the geographic areas to test.

Each area along the estuary would theoretically have a different estuarine effectiveness, but there are limitations to what can be effectively calculated. If the area tested has a low total load and, therefore, a small change in going to a reduced load, the estuarine model might not be able to resolve the change in dissolved oxygen. Tested areas must be aggregated up to a reasonably large load to be able to record the change. Also, the estuarine model takes a few days to complete a run, and it would be time-prohibitive to make 100 or so more runs.

There is no difference in estuarine effectiveness between loads in the same nontidal watershed. Loads from areas just west of Washington, DC, would have the same estuarine effectiveness as loads from West Virginia because they enter the tidal waters at the same point, although they would have different overall effectiveness scores because of the differences in their riverine effectiveness. Therefore, the head of tide of large river systems is a natural place to define a discrete watershed. The estuarine portion of major river systems like the Potomac and Rappahannock would have significantly different effects on the critical area for dissolved oxygen and also have large enough loads to resolve these differences, so those areas are another reasonable place to lump geographically. The Eastern Shore is not amenable to simple rules like this because there are no large nontidal river systems connected to large estuarine river systems. There are, however significant differences in estuarine effectiveness between the northernmost and southernmost portions of the Eastern Shore. The Eastern Shore was therefore divided in to four sections.

The final geographic breakout, as a balance between the desire to calculate a different effectiveness where a distinction exists and the limiting factors of computer run time and the ability of the estuarine model to resolve the oxygen effect of small differences in loading are

Susquehanna	Rapp Above Fall Line	Upper East Shore
West Shore	Rapp Below Fall Line	Middle East Shore
Patuxent Above Fall Line	York Above Fall Line	Lower East Shore
Patuxent Below Fall Line	York Below Fall Line	East Shore VA
Potomac Above Fall Line	James Above Fall Line	
Potomac Below Fall Line	James Below Fall Line	

To be clear, the allocation calculations are split between those geographic areas within jurisdictions, resulting in 30 different spatial units. The allocations, however, are expressed on the jurisdiction and major river basin scale. That is, there is a calculation of Maryland Potomac above and below the fall line, but the allocation is expressed only as Maryland Potomac.

Choice of the Critical Designated Uses and Segments for Calculating Relative Effectiveness

To estimate the estuarine effectiveness, the change in dissolved oxygen must be calculated for a relevant area of the Chesapeake Bay. The most persistent areas of dissolved oxygen violations are in the mainstem of the Chesapeake Bay from roughly the Bay Bridge between Annapolis and Kent Island, Maryland, south to the mouth of the Potomac River and also the lower tidal Potomac River. The deep-water and deep-channel designated uses are impaired at a higher rate than the open-water designates use and also better integrators of baywide rather than local loads.

The deep-water and deep-channel designated uses of CB3MH, CB4MH, and CB5MH and the deep-water designated use of POTMH_MD were selected as the most appropriate grouping to use in calculating estuarine relative effectiveness for the following reasons:

1. These segments and designated uses had high levels of impairment
2. They are centrally located
3. They represent a large group of segments and a large volume of the Bay
4. Deep-water and deep-channel designated uses are good geographic integrators

Further tests of other combinations showed that the estuarine effectiveness was not particularly sensitive to the addition or subtraction of any given designated use.

Metric for Relative Effectiveness

To estimate the change in dissolved oxygen an appropriate metric of dissolved oxygen must be calculated that is sensitive to load changes across a wide array of segments, designated uses, and impairment levels and is relevant to the assessment of dissolved oxygen criteria. Three metrics were investigated:

1. Percent nonattainment.
2. Average dissolved oxygen during the summer assessment period
3. 25th percentile (quartile) of dissolved oxygen during the summer assessment period

Three criteria were applied in determining which of these make the best metric

1. Relevance to attainment of dissolved oxygen standards
2. Broad applicability to designated uses and water quality segments
3. Linearity of response—does the first pound have the same effect as the last?

Percent nonattainment is clearly the most relevant metric to standards attainment, although other measures of dissolved oxygen are certainly also relevant. The quartile is more relevant than the average in that EPA is estimating increases in the lower values of oxygen.

Percent nonattainment is applicable only to areas that are not in attainment in the calibration and do not come into attainment when simulating a reduction in any single basin, which is a considerable limitation. Average dissolved oxygen is not an appropriate measure for many open-water segments. An impaired open-water segment might have average dissolved oxygen near saturation but experience large swings between super saturation and low oxygen. A load reduction might not change the average but improve the water quality by reducing the variability

of oxygen levels and the frequency of low values. The quartile is applicable to all segments and all designated uses.

Linearity of response is a crucial component. If a metric responded much more to the first pound of reduction than to the last, smaller basins would be estimated to have a greater pound-for-pound influence than larger basins. To determine the linearity of the response to the three candidate metrics, a run was made with the Susquehanna at half the level of reduction normally used to calculate estuarine effectiveness. In general, across multiple segments and designated uses, the response for all three metrics was mostly linear. There was not a significant difference between the metrics on this count.

The average was judged to be not suitable because of its limited applicability. The percent nonattainment was judged to be slightly more relevant than the quartile, but the quartile was selected as the appropriate metric because of its universal applicability.

Level of Effort Options

Section 6.3 of the main document describes the expression of level of effort as between the two extreme scenarios of No Action scenario and E3. Selection of those two scenarios is an expression of the third principle under Section 6.3 that all previous reductions are credited toward achieving the allocations.

Atmospheric Deposition

The atmospheric deposition options and rationale for choosing the air allocation is documented in Section 6.4.1. The method of incorporation is to hold atmospheric deposition constant through the bookend scenarios of No Action and E3, and through all the prospective management scenarios unless specific actions are called for in state plans that go beyond the federal levels. One example of states going beyond the federal level is that the E3 has atmospheric deposition set to a level that incorporates reduced agricultural emissions and other possible state actions. That allows the jurisdictions to be responsible strictly for the reductions that they can control and not for federal actions on atmospheric deposition.

Scenario Options

The E3 scenario was selected as the appropriate lower end of loading rather than other candidate scenarios such as the Current Programs, Maximum Feasible, or All Forest. Current Programs could be used as the lower end and an assessment made of how far efforts had to increase beyond current programs, but doing so would violate the expression of equity described above because jurisdictions that had already achieved significant reductions would have to do proportionately more than jurisdictions that have not. Maximum Feasible would be a similar expression as E3 and would meet the equity provision, but it was judged to be much more subjective and, therefore, inferior to E3 as a metric. The All Forest scenario would be an expression of anthropogenic, rather than controllable loads. The All Forest was used in the 2003 goal setting. Basing the allocation method on E3 recognizes that various sources have different possible levels of reduction. An allocation based on anthropogenic load could require levels of reduction beyond E3. For example, if an allocation required all loads to go 60 percent of the way toward All

Forest, certain theoretical land uses that can achieve only a 50 percent reduction at E3 would not be able to achieve the allocations, while wastewater treatment plants would be able to achieve a much larger than 60 percent reduction from No Action. Those distortions would increase at smaller scales as sources become more dominant locally.

The No Action scenario was chosen as the upper end to follow the principle of accounting for previous reductions. Using a starting point that incorporated management practices or higher levels of treatment would give a disadvantage to jurisdictions that had implemented the actions.

Allocation Method Options

Section 6.3.1 describes the method used to relate relative effectiveness to reduction effort. With that basic outline there is an infinite number of ways to define the allocation and still meet water quality standards. The major decisions to be made are the number of lines that represent different source categories and the shapes of those lines. The options were discussed in the Chesapeake Bay Program's Water Quality Goal Implementation Team (WQGIT) and the Principals' Staff Committee, and agreement was reached between EPA and five of the seven jurisdictional partners.

Number of Allocation Lines

During the allocation process, the WQGIT recognized that different source categories had different abilities to make progress toward an E3 level of implementation. Figure K-1 is a plot of implementation progress through 2009 plotted on the same vertical axis as the allocation charts, percent of E3 from No Action.

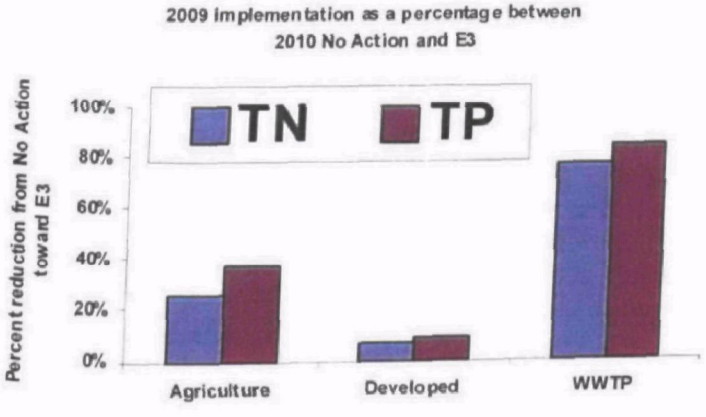


Figure K-1. 2009 implementation by sector.

The 2009 implementation represents the choices that the jurisdictions have made to date, presumably taking into account the same types of criteria that will be used to make decisions on restoration spending in the future.

There is a clear separation between the sources in that jurisdictions have chosen to set wastewater treatment plants at a level closer to E3, relative to No Action, than either agriculture

or developed land. There is also a separation between agriculture and developed land, but it is not as large as the separation between wastewater treatment plants and all other sources. With that information, the decision was made to use two lines, one for wastewater treatment plants and one or all other sources.

Shape of the Allocation Lines

Several allocation line shapes were discussed with the three main shapes being

1. Straight: This is the most straightforward expression of the allocation principle stated under section 6.3 that areas with a greater pound for pound effect on water quality should do more.
2. Hockey Stick: It was recognized that a natural maximum existed for some sources, particularly with waste water treatment where a given technology could reach a concentration that could be expressed as a percentage from No Action to E3. A hockey stick line has a maximum for watershed areas in the range of relative effectiveness and slopes down for lower levels of relative effectiveness.
3. Z-curve: Similar to the hockey stick but also recognizing that a natural minimum also might exist. Again, related to wastewater treatment plants, a given technology producing a known concentration can be seen as a minimum technology that should be implemented.

As reported in more detail in Section 6.3.3 the wastewater line was set first in a hockey stick shape such that the upper 50 percent of the relative effectiveness values were at a maximum attainment percentage, according to a given concentration and the rest sloped off to a minimum value also based on a concentration. The straight line for all other sources was set such that a zero relative effectiveness would have a 20 percent lower value on the percent controllable axis than the area with the maximum relative effectiveness value. The intercept for all other sources was set such that the water quality standards were attained. Figure K-2, which is also Figure 6-7 in the main document, is the implementation of this method for nitrogen.

To make the above decision, the partnership was presented with several options for constructing the lines. Basin-jurisdiction loads were calculated for each option.

Table K-1 is a sample of options that were explored using the Phase 5.2 Chesapeake Bay Watershed Model. Several more options were generated before the final decision was made.

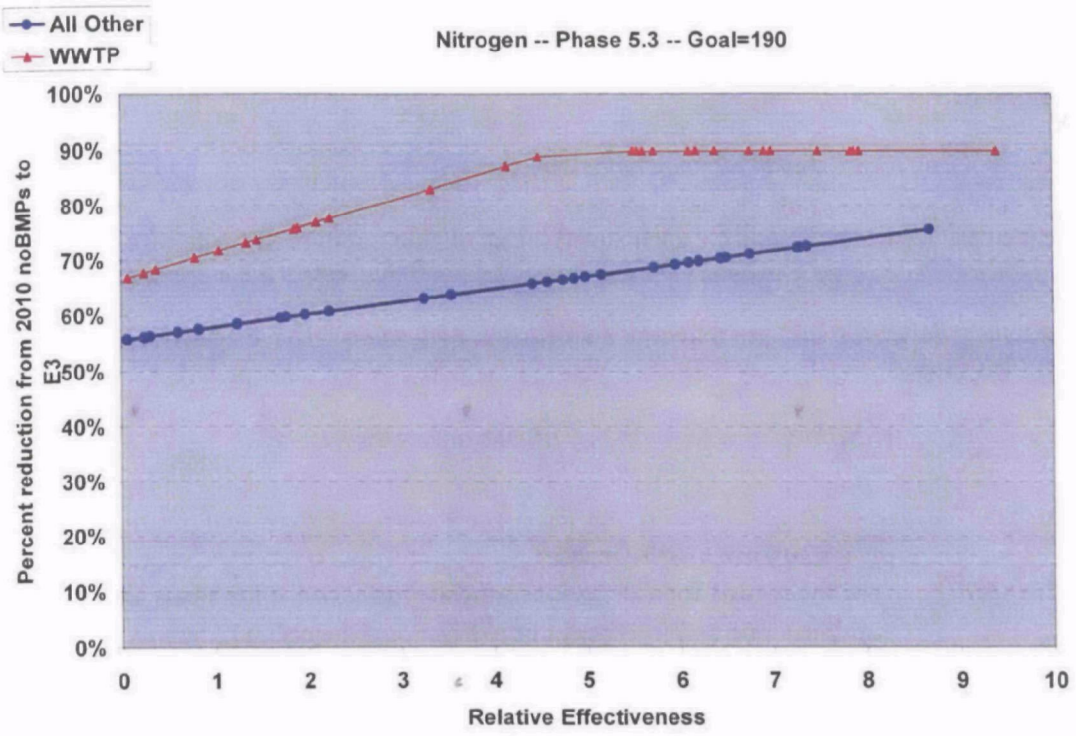


Figure K-2. Allocation methodology example showing the hockey stick and straight line reductions approaches, respectively, to wastewater (red line) and all other sources (blue line).

Table K-1: Initial options presented to the Chesapeake Bay Program's Water Quality Goal Implementation Team on September 30, 2009

Lines	2	2	2	2	2				
WWTP rule	3-8 mg/l	3-8 mg/l	3-8 mg/l HS	3-8 mg/l HS	3-8 mg/l Z				
Other Load Rule	20%	10%	20%	10%	20%	Largest			
DO goal	200	200	200	200	200	Difference	2010 Noact	E3 load	TS load
DC Potm	2.82	2.82	2.37	2.37	2.37	16%	9.68	1.53	2.12
DE Esh	5.12	5.21	5.25	5.34	5.21	4%	9.28	3.45	6.43
MD Esh	12.54	12.76	12.81	13.03	12.70	4%	23.94	8.25	13.84
MD Patux	3.26	3.25	3.15	3.13	3.27	4%	6.57	2.15	3.17
MD Potm	14.73	14.52	14.10	13.89	14.29	6%	30.31	9.65	14.66
MD Susq	0.81	0.83	0.83	0.85	0.82	4%	1.35	0.61	0.97
MD Wsh	10.18	10.15	10.15	10.11	10.12	1%	36.50	6.15	9.49
NY Susq	10.54	10.41	10.54	10.41	10.55	1%	16.36	7.78	8.68
PA Potm	4.76	4.58	4.83	4.65	4.83	5%	7.08	3.12	4.31
PA Susq	67.96	68.59	68.81	69.44	68.37	2%	121.19	49.23	68.86
VA Esh	1.60	1.59	1.61	1.61	1.60	1%	3.25	0.88	1.67
VA James	28.84	28.14	28.49	27.78	29.58	6%	52.63	15.80	28.85
VA Potm	16.85	16.47	16.09	15.72	16.50	7%	33.05	10.72	15.81
VA Rap	6.54	6.37	6.49	6.32	6.60	4%	10.61	4.33	6.49
VA York	6.55	6.32	6.53	6.30	6.72	6%	10.54	4.05	6.48
WV Potm	5.65	5.44	5.71	5.50	5.73	5%	8.32	3.76	5.69
Total	**198.77**	**197.46**	**197.76**	**196.45**	**199.27**	1%	**380.66**	**131.45**	**197.53**

Calculation of Equivalent Allocation Options

For any given level of water quality, an infinite number of lines can be drawn on the allocation plots like Figure K-2. To calculate an equivalent line to an existing line, it is necessary to meet the condition of

$$\sum(DeliveredLoad)\times(EstuarineDelivery)=C$$

or the sum of all delivered loads for each state/basin/fall-line combination times its estuarine delivery factor must equal a constant for the family of lines that meets the same water quality.

Expanding the delivered load term to create an equation between relative effectiveness and delivered load gives

$$\sum(E3_i+(NoBMP_i-E3_i)(1-mX_i-b))EstuarineDelivery_i=C$$

where

X_i	is the relative effectiveness
$E3_i$ and $NoBMP_i$	are the loads for that state/basin/fall-line/sector for the two scenarios
m and b	are the slope and intercept of the line and the only unknowns

Given a slope or an intercept, the above equation can be solved numerically for the other parameter of the line. This equation was implemented in MS Excel for multiple lines with enforced maximum and minimum to accommodate the decisions above.

Appendix L.
Setting the Chesapeake Bay Atmospheric Nitrogen Deposition Allocations

Atmospheric Deposition Nitrogen Inputs Compared to Other Nitrogen Sources

Atmospheric deposition of nitrogen is the highest nitrogen input load in the Chesapeake watershed (Figure L-1). Other nutrient input loads are fertilizer, manures, point sources, and septic systems. Over the 1985 to 2005 Chesapeake Bay model simulation period, the Chesapeake watershed average atmospheric deposition loads of nitrogen have been declining, particularly those of oxidized nitrogen.

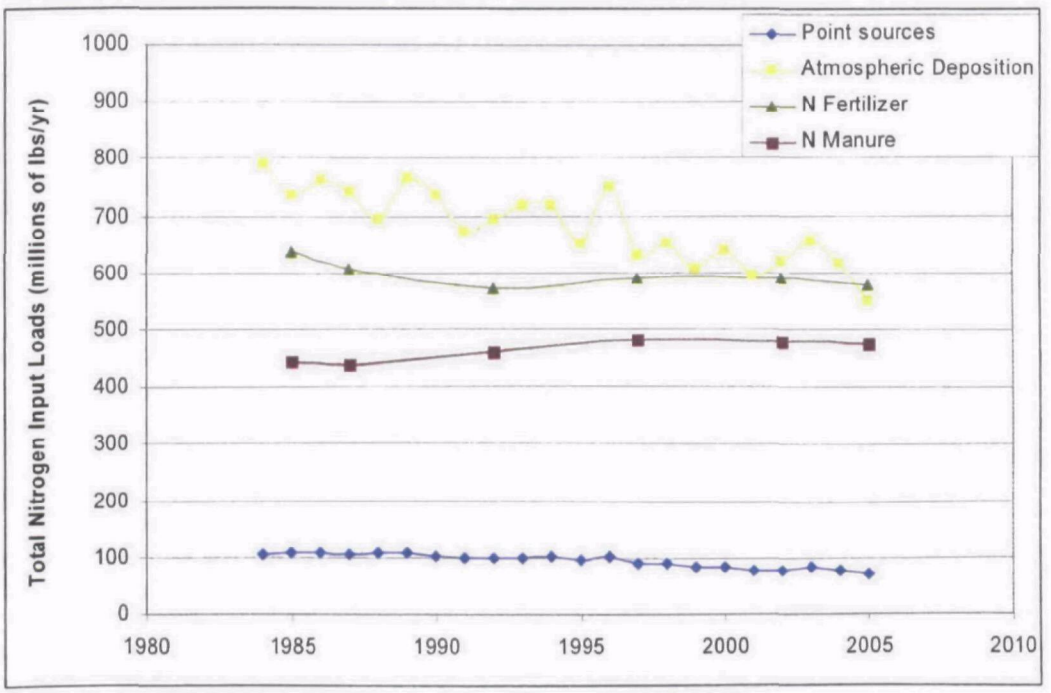


Figure L-1. 20-year (1985–2005) time series of atmospheric, fertilizer, manure, and wastewater treatment plant nitrogen input loads to the Chesapeake Bay Water Quality and Sediment Transport Model.

Atmospheric Deposition Inputs

Atmospheric loads of nitrogen are from chemical species of oxidized nitrogen, also called NOx, and from reduced forms of nitrogen deposition, also called ammonia (NH3). Oxidized forms of nitrogen deposition originate from conditions of high heat and pressure and are formed from eutrophically inert diatomic atmospheric nitrogen. The principle sources of NOx are air emissions from industrial-sized boilers such as electric power plants and internal combustion engines in cars, trucks, locomotives, airplanes, and the like.

Reduced nitrogen, or ammonia, is responsible for approximately one-third of the total nitrogen emissions that eventually end up as loads to the Bay. Ammonia sources are predominately agricultural, and ammonia is released into the air by volatilization of ammonia from manures and emissions from ammonia based fertilizers. Minor sources include mobile sources, slip ammonia released as a by-product of emission controls on NOx at power plants and industrial processes.

Two types of deposition are differentiated and both are tracked through the Chesapeake models and atmospheric deposition monitoring networks as input daily. The first is wet deposition, which occurs during precipitation events and contributes only to nitrogen loads during days of rain or snow. The other is dry deposition, which occurs continuously and is input at a constant rate daily into the Bay Watershed and Bay Water Quality models.

Because the Bay Watershed and Bay Water Quality models are mass balance models, all sources of nutrient inputs to the tidal Bay have to be accounted for including phosphorus and organic forms of nutrients. For phosphorus and organic nutrients, the models estimate loads to open water only, on the assumption that all phosphorus and organic nutrients are derived from aeolian or wind processes that result in no net change in organic nitrogen on terrestrial surfaces but result in a net gain when deposited on water surfaces.

Organic nitrogen is represented as wet fall only, i.e., dissolved organic nitrogen (DON). The magnitude of dry fall organic nitrogen is not well characterized in the literature, but the latest Community Multiscale Air Quality (CMAQ) model simulations with updated chemical mechanisms do include peroxyacyl nitrates (PAN, $CH_3COOONO_2$) and an organic nitrate group (NTR). The NTR represents several organic nitrates that are produced from ozone photochemistry. Both of these species are relatively small in magnitude and both are biologically labile. Therefore, the dryfall PAN and NTR are lumped into the oxidized nitrogen atmospheric deposition dryfall inputs. Table L-5 shows the estimated atmospheric deposition loads to the Bay's tidal surface waters of the different nutrient species.

Air sources contribute about a third of the total nitrogen loads delivered to the Chesapeake Bay by depositing directly onto the Bay's tidal surface waters and onto the surrounding Bay watershed. Direct nitrogen atmospheric deposition to the Bay's tidal surface waters is estimated to be 6 to 8 percent of the total (air and non-air) nitrogen load delivered to the Bay. The atmospheric nitrogen deposited onto the watershed and subsequently transported to the Bay is estimated to account for 25 to 28 percent of the total nitrogen loadings to the Bay.

Atmospheric Deposition Input Trends

Between 1985 and 2005, the simulation period of the Phase 5.3 Bay Watershed Model, atmospheric deposition loads of nitrate have tended to decrease overall in the Chesapeake Bay watershed. Over that 20-year period, nitrate loads have decreased by about 30 percent (Figure L-2); however, considerable variability exists across the Bay watershed, with the greatest reductions occurring in the northern and western portions. In Figure L-2, the average annual concentration is used as an adjustment to smooth out the high and low rainfall years, which bring different amounts of deposition load to the Bay watershed, primarily from the volume of precipitation. Use of the dissolved inorganic nitrogen (DIN), nitrate (NO_3), and ammonia (NH_3) concentrations provides a reasonable estimate of the trend in atmospheric deposition.

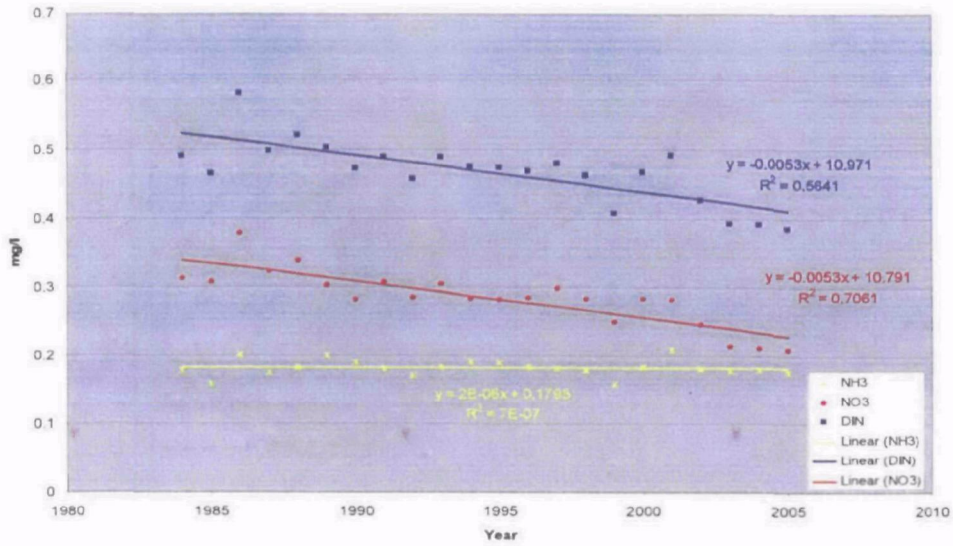


Figure L-2. Trend of estimated average NO_3, NH_3 and DIN deposition concentrations input to the Phase 5.3 Chesapeake Bay Watershed Model.

Much of the reduction has been due to point source air emission reductions, particularly from electric generating units (EGUs) as shown in Figure L-3. More rapid declines in air emissions are expected between 2008 to 2010 as the Clean Air Transport Rule (previously the Clean Air Interstate Rule [CAIR]) controls on power plant emissions and the air quality standards for ozone and particulate matter come into enforcement deadlines by 2010 (Figure L-3). Further reductions are expected with the reduced ozone air quality standard announced in August 2010. Reductions from mobile sources are another large contributor to the downward trend. Reductions from mobile sources will continue past the year 2020 as large off-road diesel and marine diesel fleets are replaced.

Table L-1 shows the estimated portion of deposited NO_x loads on the Chesapeake Bay watershed from four sectors including EGUs, mobile sources, industry, and all other sources. From 1990 to 2010, considerable reductions have been made in the electrical generation sector. In addition, both on road and off-road mobile sources have ongoing fleet turnover and replacement, which is putting cleaner spark and diesel engines in service; that is expected to continue beyond 2020. Note that some NOx sources like mobile sources seem to increase in percentage relative to other sources like EGUs. Both sources are actually decreasing and the total projected deposition load in 2020 is less than 1990, however, EGU emission reductions are relatively more than mobile reductions.

Average ammonia atmospheric deposition loads over the Chesapeake Bay watershed have followed the trend in overall manure loads in the watershed and have remained steady over the 1985 to 2005 simulation period (Figure L-2). Ammonia deposition is very site specific and strongly influenced by local emissions. Local and regional trends in manure, such as the rise of poultry animal units in the Eastern Shore and Shenandoah, and dairy's diminishment in the northern portions of the watershed in the late 1980s, affect regional ammonia deposition in the Bay watershed.

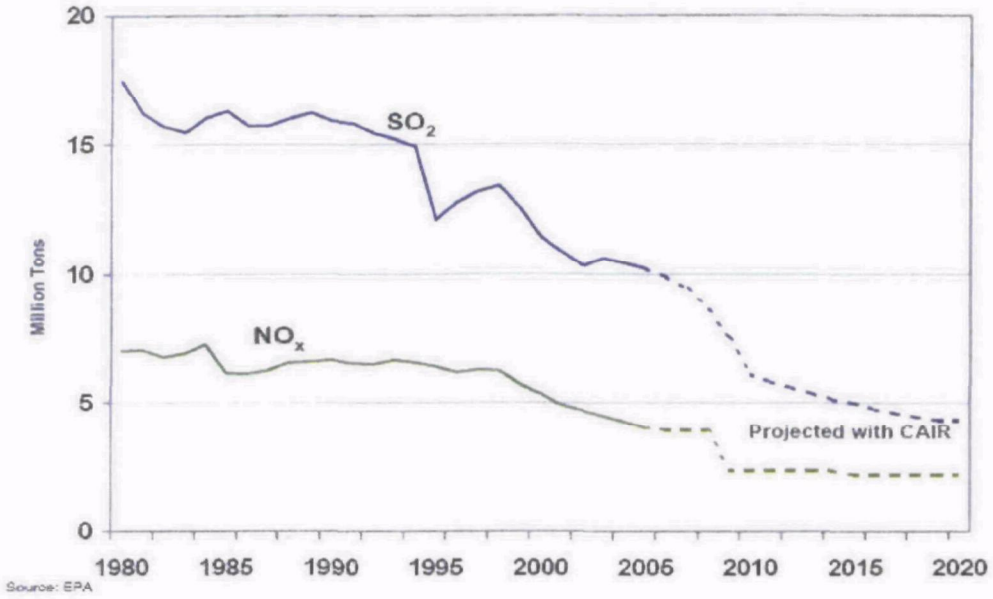


Figure L-3. Estimated nationwide emissions of NOx and SO_2 from EGUs since 1980 and estimated emissions to 2020.

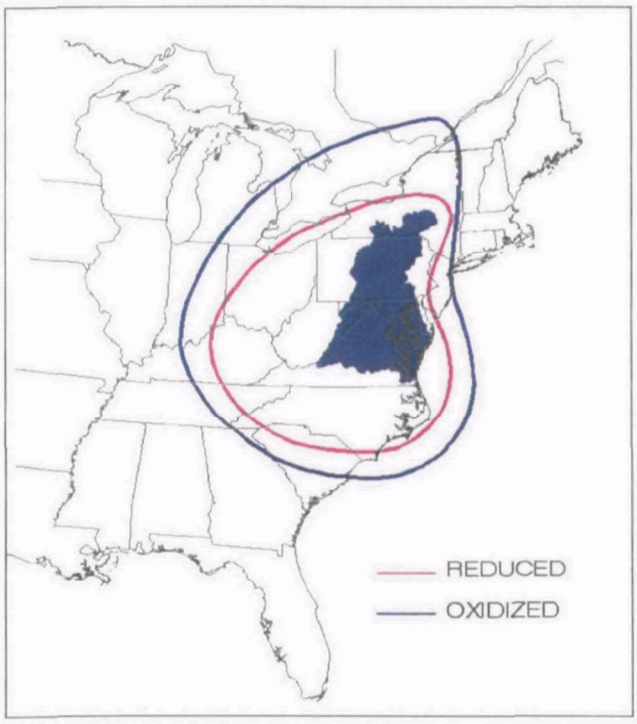
Table L-1. Estimated portion of atmospherically deposited NOx loads on the Chesapeake watershed from four sectors including EGUs, mobile sources, industry, and all other sources in 1990 and projected out to 2020

Sectors	1990	2020 (Preliminary)
Power Plants (EGUs)	40%	17%
Mobile Sources (on-road)	30%	32%
Industry	8%	20%
Other (off-road construction; residential & commercial)	21%	31%

The Bay's NOx airshed—the area where emission sources that contribute the most airborne nitrates to the Bay originate—is about 570,000 square miles, or seven times the size of the Bay's watershed. The ammonia airshed is slightly smaller (Figure L-4). Close to 50 percent of the NOx deposition to the Bay is from air emission sources located in the seven Bay watershed jurisdictions. Another 25 percent of the atmospheric deposition load to the Chesapeake Bay watershed is from the remaining area in the airshed and the remaining 25 percent of deposition is from the area outside the airshed. The ammonia airshed is similar to the NOx airshed, but slightly smaller (Figure L-4).

CBP Airshed Model

The Chesapeake Bay Airshed Model is a combination of a regression model of wet deposition (Grimm and Lynch 2005) and a continental-scale air quality model of North America called the CMAQ for estimates of dry deposition (Dennis et al. 2007; Hameedi et al. 2007). The Bay Airshed Model is represented in Figure L-5.



Source: Chesapeake Bay Program Office

Figure L-4. The oxidized nitrogen airshed (blue line) is the principle area of NO_X emissions that contribute nitrogen deposition to the Chesapeake Bay and its watershed. The reduced nitrogen airshed (red line) of ammonia deposition is slightly smaller.

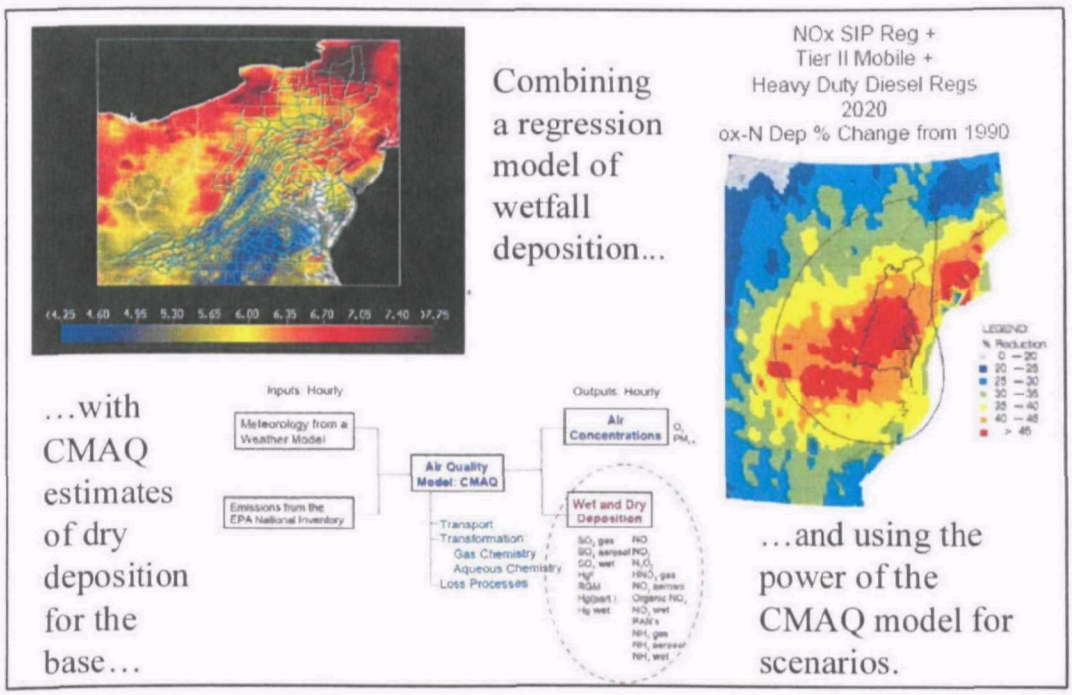


Figure L-5. The Chesapeake Bay Airshed Model is a combination of a regression model of wet deposition and the Community Multi-scale Air Quality Model of dry deposition.

The regression and deterministic airshed models that provide atmospheric deposition input estimates, have gone through a series of refinements with increasingly sophisticated models of both applied over time (Linker et al. 2000; Grimm and Lynch 2000, 2005; Lynch and Grimm 2003). The amount and timing of the wet atmospheric deposition input in the Phase 5.3 Bay Watershed Model is hourly, and is related to the timing and amount of hourly rainfall in the Phase 5.3 Bay Watershed Model precipitation input data. The dry deposition estimates are monthly constants that are input daily and are based on the CMAQ model (Dennis et al. 2007; Hameedi et al. 2007).

Wet Deposition Regression Model

Wet deposition is simulated using a regression model developed by Grimm and Lynch (2000, 2005; Lynch and Grimm 2003). The regression model provides hourly wet deposition loads to each land segment on the basis of each land segment's rainfall. The regression model uses 29 National Atmospheric Deposition Program (NADP) monitoring stations and 6 AIRMoN stations to form a regression of wetfall deposition in the entire Chesapeake Bay watershed over the entire simulation period (Figure L-6).

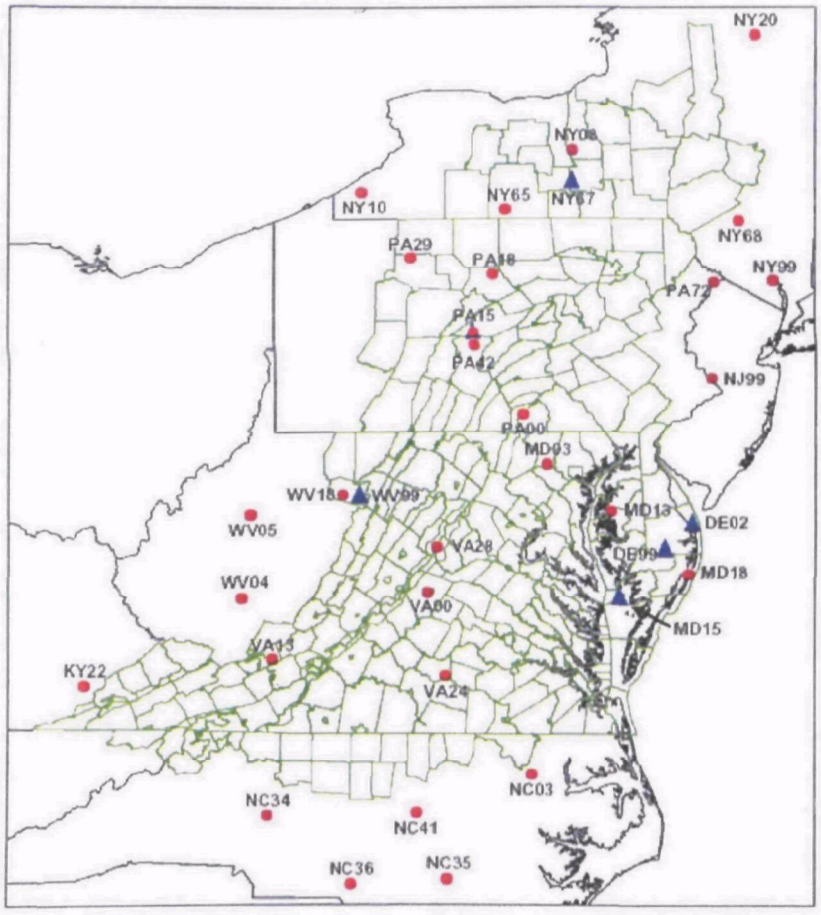


Figure L-6. Atmospheric deposition monitoring stations used in developing the wet deposition regression model.

To improve the accuracy of the regression estimates over previous regression analyses (Linker et al. 2000) a number of improvements in the sampling and representation of spatial and temporal patterns of land use activities and intensities and of emission levels were made. Also, detailed meteorological data were assimilated into the regression model to identify contributing emission source areas and to estimate the impact of the contributions on daily deposition rates on a per-event basis.

This version of the regression model included nine additional NADP/NTN sites in the regression estimates (DE99, MD07, MD08, MD15, MD99, PA47, VA10, VA27, VA98, and VA99) that were placed in operation in and around the Chesapeake Bay watershed since 2001, providing a comprehensive representation of agricultural influences.

Refinements also involved developing a more accurate and comprehensive representation of the spatial and temporal distribution and intensity of livestock production and other agricultural activities across the Bay watershed. An improved accounting of livestock production activities was achieved by combining county- and watershed unit-specific livestock production statistics with high-resolution (30 meters) land use data from the USGS's National Land Cover Database (NLCD). Estimates of local ammonia emissions from fertilizers and manure applications to croplands were also assimilated into the model using EPA inventories and high resolution NLCD to identify likely cropland areas. Last, localized estimates for NH_3 and NO_x emissions for the Phase 5 Chesapeake Bay Watershed Model domain and surrounding states were developed by combining facility and county-specific emissions reports from the EPA's National Emissions Inventory (NEI) database with the NLCD classifications.

For each day of rain, wetfall atmospheric deposition is estimated by the regression that has the general form

$$\text{Log10}(c) = b_o + b_1\text{log10}(ppt) + \sum b_{2s}\text{season} + b_3v_3 + \ldots + b_nv_n + e$$

where

- c = daily wet-fall ionic concentration (mg/L)
- b_o = intercept
- ppt = daily precipitation volume (inches)
- b_1 = coefficient for precipitation term
- season = vector of 5 binary indicator variables encoding the 6 bi-monthly seasons
- b_{2s} = vector of 5 coefficients for season terms
- $v_3 \ldots V_n$ = additional predictors selected through stepwise regression
  - National Land Cover Data (NLCD)
    - Within proximities of 0.8, 1.6, 3.2, 8.0, and 16.1 km of each NADP/NTN site: open water, forested, residential, industrial/transportation, croplands, and vegetated wetlands
  - Local emission levels of ammonia and nitrous oxides from EPA National Emission Trends (NET)
    - County emission totals 1985-2005
    - County containing each NADP/NTN monitoring site and for the nearest three counties
- $b_3 \ldots b_n$ = coefficients corresponding to $v_3 \ldots V_n$

The daily precipitation nitrate and ammonium concentration models were developed using a linear least-squares regression approach and single-event precipitation chemistry data from the 29 NADP/NTN sites and six AIRMoN stations in Figure L-6. The most significant variables in both models included precipitation volume, the number of days since the last event, seasonality, latitude, and the proportion of land within 8 km covered by forests or devoted to transportation and industry. (Local and regional ammonia and nitrogen oxides emissions were not as well correlated as land cover.) The abilities of these variables to predict wet deposition arise primarily from their relationship to either (1) the spatial and temporal distribution of emissions of ammonium and nitrate precursors from sources within or upwind of the Bay watershed; or (2) the chronology and characteristics of precipitation events. Modeled concentrations compared very well with event chemistry data collected at six NADP/AIRMoN sites within the Chesapeake Bay watershed. Wet deposition estimates were also consistent with observed deposition at selected sites.

Volume, duration, and frequency of precipitation events have obvious roles in determining wet deposition rates. However, these parameters alone do not completely describe all of the characteristics of a precipitation event. In particular the intersection of a precipitation event and a volume of air with a particular history is also important in determining wet deposition flux, so the interactions between storm trajectories and emission sources were also incorporated into the wet deposition regression model.

Using metrological data from the National Center for Environmental Prediction's North American Regional Reanalysis (NARR), components were added to daily ammonium and nitrate wet deposition models that predict the rate at which emissions from area and point sources are emitted, dispersed, and transported to specific deposition locations. Surface and upper-level vertical and horizontal air movement data from the NARR allowed estimates of the extent to which emissions were transported and mixed into surface and upper-level atmospheric layers; and, thereby, enabled construction more realistic multilevel air mass trajectories with which to predict the movement of emissions from multiple source locations to deposition points of interest.

Dry Deposition - Community Multi-scale Air Quality Model (CMAQ)

The CMAQ Model is a fully developed air simulation of North American (Dennis et al. 2007; Hameedi et al. 2007). The CMAQ model simulates atmospheric deposition to the Chesapeake Bay watershed (indirect deposition) and tidal Bay (direct deposition) for every hour of every day for the representative year. A variety of input files are needed that contain information pertaining to the modeling domain which is all North America. Those include hourly emissions estimates and meteorological data in every grid cell and a set of pollutant concentrations to initialize the model and to specify concentrations along the modeling domain boundaries. The initial and boundary concentrations were obtained from output of a global chemistry model.

The CMAQ model simulation period is for one year, 2002, because 2002 is characterized as an average precipitation year and, therefore, an average deposition year. The 2002 CMAQ simulation year was used to provide the monthly dry deposition estimate for all years of the 1985 to 2005 Phase 5.3 Bay Watershed Model simulation. Phase 5.3 Bay Watershed Model dry deposition input estimates are derived from the CMAQ model as monthly average inputs expressed as a daily load.

An adjustment for the 20-year trend in atmospheric deposition loads was applied by using the trend developed in the wet deposition regression model, and assuming the dry deposition trend to be the same as the wet in the separate nitrate and ammonia estimates. Figure L-7 shows the 12-km grid used to provide better resolution of the Phase 5 Chesapeake Bay Watershed Model's atmospheric deposition loads. The improved spatial resolution of direct atmospheric deposition of loads to tidal surface waters and the atmospheric deposition of loads to the watershed adjacent to tidal waters from metropolitan and mobile sources was an important improvement (STAC 2007).

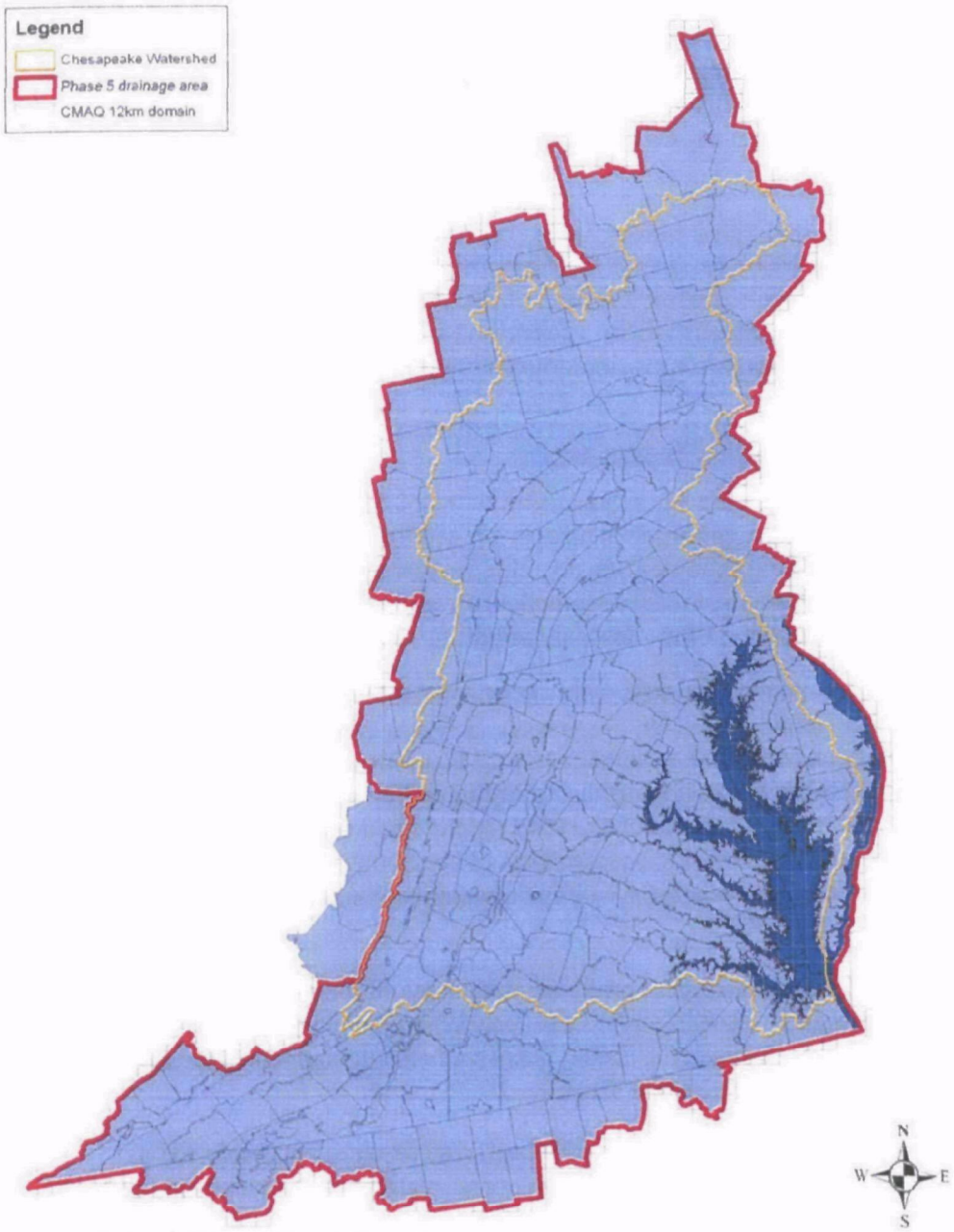


Figure L-7. The CMAQ model's 12-km grid over the Phase 5 Chesapeake Bay Watershed Model domain.

Organic Nitrogen Deposition

The Phase 5.3 Bay Watershed Model accounts for estimated loads of atmospheric organic nitrogen to the open water land use on the assumption that all organic nitrogen is derived from aeolian or wind processes that result in no net change in organic nitrogen on terrestrial surfaces but do result in a net gain when deposited on water surfaces. Organic nitrogen is represented as wet fall only, i.e., DON. The magnitude of dry fall organic nitrogen is unknown.

Dryfall Organic Nitrogen Deposition

The dryfall organic nitrogen is likely to be sorbed onto large and small particles or even to be particles themselves, like pollen. Such dryfall organic carbon species can be involved in long-range transport, such as the pollens and organic nitrates found on the dust coming over from Africa, but EPA does not have a good estimate of the fraction of the dry deposition that these particles compose.

Also, the latest CMAQ simulations with updated chemical mechanisms include peroxyacyl nitrates (PAN, $CH_3COOONO_2$) and an NTR. The NTR represents several organic nitrates that are produced from ozone photochemistry. Both of these species are relatively small in magnitude, and both are biologically labile. Therefore, the dryfall PAN and NTR are lumped into the oxidized nitrogen atmospheric deposition dryfall inputs.

Wetfall Organic Nitrogen Deposition

In the 1992 Phase 2 version of the Chesapeake Bay Watershed Model, organic nitrogen was assumed to be about 670 micrograms per liter (µg/L) (as nitrogen) based on data summarized by Smullen et al. (1982). The data showed considerable seasonal variability. The organic nitrogen load was constant in all watershed model segments. An equivalent annual load was used in the tributary model with application of the seasonal variability suggested by Smullen et al. (1982).

Organic nitrogen measurements from Bermuda are calculated at about 100 µg/L (as nitrogen) (Knap et al. 1986). Moper and Zita (1987) reported an average DON concentration from the western Atlantic and Gulf of Mexico of about 100 µg/L (as nitrogen). That is consistent with the reported range from the North Sea and northeast Atlantic of between 90 µg/L to 120 µg/L (Scudlark and Church 1993). Scudlark et al. (1996) reported an annual volume-weighted average DON concentration in the mid-Atlantic coastal areas to be about 130 µg/L (as nitrogen). Measurements in this study are consistent with the interannual variation (maximum in spring) reported by Smullen et al. (1982).

A later study identified methodological problems with some of the previous studies and suggests the wet deposition of organic nitrogen in the Chesapeake watershed would be closer to 50 µg/L on an annual average basis (Keene et al. 2002). This study also documented the highest concentrations of organic nitrogen in the spring.

On the basis of Keene et al. (2002), a value of 50 µg/L (as nitrogen) was selected as representative of an average annual wet deposition concentration to the watershed and tidal waters with the seasonal loading pattern suggested by Smullen (1982) and Scudlark et al. (1996). That applies an average concentration of 40 µg/L from July to March in rainfall and an average

concentration of 80 µg/L from April to June. The load of organic nitrogen would depend on the precipitation in a particular land segment, but assuming 40 inches of precipitation, the load would be on the order of 0.4 lb/ac-yr.

Total Atmospheric Deposition Inputs of Nitrogen from Wet and Dry Deposition

The annual rate of total atmospheric deposition to Phase 5 land segments is shown in Figure L-8 and Table L-2.

Table L-2. Annual average atmospheric deposition of reduced DIN, oxidized DIN and total DIN on land segments in the entire Phase 5.3 Chesapeake Bay watershed model

Land Segment	NH4	NO3	Total DIN
A10001	2.50	3.21	**5.71**
A10003	1.68	2.87	**4.55**
A10005	5.62	4.55	**10.16**
A11001	0.24	0.44	**0.68**
A24001	0.41	1.37	**1.78**
A24003	1.02	2.99	**4.01**
A24005	2.02	4.42	**6.44**
A24009	0.40	1.29	**1.69**
A24011	1.60	1.64	**3.25**
C51071	0.17	0.53	**0.69**
C51165	0.45	0.28	**0.72**
Total	**264.07**	**556.59**	**820.66**

Organic and Inorganic Phosphorus Deposition

The Phase 5.3 Bay Watershed Model accounts for estimated loads of atmospheric organic and inorganic phosphorus to the open water land use on the assumption that, like organic nitrogen, the load is derived from aeolian or wind processes that result in no net change in organic nitrogen on terrestrial surfaces but do result in a net gain when deposited on water surfaces. Following Smullen (1982), annual loads of organic and inorganic phosphorus are set at 47 µg/L and 16 µg/L, respectively. Seasonally, those loads are treated in the same way as organic nitrogen, assuming that organic phosphorus will follow a pattern similar to organic nitrogen and that an aeolian source of inorganic phosphorus might well increase during the bare ground of spring agricultural practices. Accordingly, organic and inorganic phosphorus concentrations are set at 74 µg/L and 25 µg/L, respectively, from April to June, and at half those concentrations for the other nine months of the year.

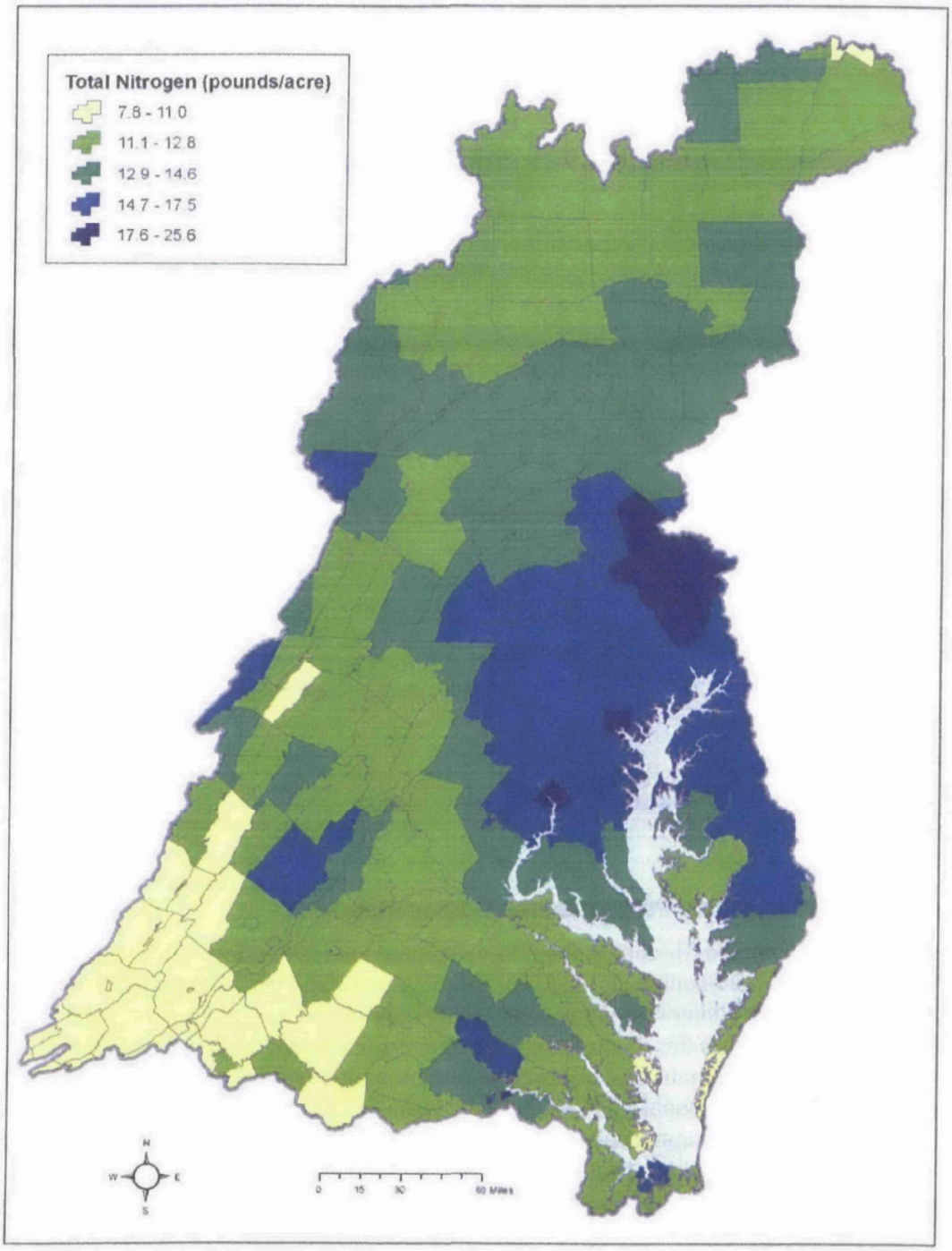


Figure L-8. Annual average DIN atmospheric deposition on land segments in the entire Phase 5.3 Chesapeake Bay Watershed Model domain.

CMAQ Airshed 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 scenarios reflect emissions reductions from national control programs for both stationary and mobile sources, including the CAIR, the Tier-2 Vehicle Rule, the Nonroad Engine Rule, the Heavy-Duty Diesel Engine Rule, and the Locomotive/Marine Engine Rule. Although CAIR has been remanded to EPA, it will remain in place pending a rulemaking to replace it. It is 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 Bay watershed model scenario using one of the CMAQ model air scenarios below, a monthly factor is determined by the CMAQ model by comparing the CMAQ model's 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 the Phase 5.3 Bay Watershed Model over the 1991 to 2000 scenario years.

CMAQ 2010 Scenario

The 2010 Scenario represents emission reductions from 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 that were fully phased in by the 2006 model year and will begin to show an impact in 2010. For EGUs the 2010 controls assume that the NOx SIP call, NOx Budget Trading Program, 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.

CMAQ 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 from regulations implemented through the Clean Air Act authority to meet National Ambient Air Quality standards for criteria pollutants in 2020. Those include:

- On-Road mobile sources: For on-road light duty mobile sources, this includes Tier 2 vehicle emissions standards and the Gasoline Sulfur Program that affects SUVs pickups, and vans, which are now subject to same national emission standards as cars.
- On-Road Heavy Duty Diesel Rule – Tier 4: New emission standards on diesel engines starting with the 2010 model year for NOx, plus some diesel engine retrofits.

- Clean Air Non-Road Diesel Rule: 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).
- EGUs: CAIR second phase in place (in coordination with earlier NOx SIP call); Regional Haze Rule and guidelines for BART for reducing regional haze; CAMR all in place.
- Non-EGUs: Solid Waste Rules (Hospital/Medical Waste Incinerator Regulations).

CMAQ 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 to meet a more stringent ozone standard. The more stringent standard is due to a reconsideration of the national ambient air quality standards for ozone that were promulgated in 2008 along with a review of the secondary national ambient air quality standards for oxides of nitrogen and sulfur. The new ozone standard was proposed in 2010 of between 0.070 ppm and 0.060 ppm. EPA now expects that the ozone standards will be final by the end of July 2011. The 2020 Maximum Feasible Scenario was designed to meet a 0.070 ppm ozone standard, which is less than the 0.075 ppm ozone standard in place since 2008.

Incremental control measures for five 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.

The 2020 Maximum Feasible Scenario also includes a reduction of ammonia deposition of 15 percent from estimated ammonia emission programs in the Bay watershed jurisdictions. Estimates of up to about 30 percent ammonia emission reductions from manures can be achieved through rapid incorporation of manures in to soils at the time of application, biofilters on poultry houses, and other management practices (Mark Dubin 2009, personal communication). From a state and sector analysis of NOx emissions and deposition, an estimated 50 percent of emissions from Bay states becomes deposition to the Chesapeake Bay watershed, along with a further 50 percent of the ammonia deposition load coming from outside the Bay watershed. Assuming that only 50 percent of the emissions are from watershed sources, a 30 percent reduction of emissions results in an estimated 15 percent decrease in wet and dry ammonia deposition for the Maximum

Feasible Scenario from ammonia emission control management practices in the Bay watershed jurisdictions.

CMAQ 2030 Scenario

The 2030 scenario is in some areas a further decrease in emissions beyond the 2020 Maximum Feasible Scenario due to continuing fleet replacement of heavy diesels, off road diesels, and mobile sources of all types. These emission decreases are offset by continued growth in the Chesapeake Bay 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.
- Marine Vessels: Further reductions in NOx emissions from marine vessels in coastal shipping lanes.

Atmospheric Deposition Loads to the Watershed and Tidal Bay

Nitrogen loads atmospherically deposited to the Chesapeake Bay watershed by jurisdiction and by nitrogen species of wet and dry deposition for key scenarios are tabulated in Table L-3. Table L-4 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 Chesapeake Bay Watershed Model.

All the scenarios in Table L-4 use the 2002 scenario as a base year. The point sources, human and animal populations, septic system loads and so on, are the same 2002 levels in all these scenarios. Only the atmospheric deposition changes. The 1985 CMAQ scenario uses the trend of atmospheric deposition described in Figure L-2, and the same trend was used for the 2002 atmospheric deposition in the 2002 scenario. The scenarios of 2010, 2020, 2020 Maximum Feasible, and 2030 used estimated atmospheric deposition loads from the CMAQ model.

Atmospheric Deposition of Nitrogen to the Tidal Chesapeake Bay

The regression and CMAQ models provide estimates of direct atmospheric deposition to the Bay's tidal surface waters. Table L-5 lists the estimates of direct atmospheric deposition to the Bay's tidal surfaces for seven key scenarios.

Two key factors in the relative increase in the estimated reduced nitrogen deposition over time are the downward pressure on oxidized nitrogen emissions and the lack of controls on ammonia emissions. It is notable that changes in atmospheric chemistry of SO_X and NO_X in the seven key

Table L-3. Atmospheric deposition loads of nitrogen (millions of pounds as nitrogen) to the Chesapeake watershed for key scenarios by jurisdiction

	STATE							Chesapeake
Total Nitrogen	**DE**	**DC**	**MD**	**NY**	**PA**	**WV**	**VA**	**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

Source: Phase 5.2-August 2009 Version of the Chesapeake Bay Watershed Model
Note: This table does not include the 15 percent decrease in wet and dry ammonia deposition for the Maximum Feasible scenario due to ammonia emission.

scenarios also affect ammonia dry deposition. In the scenarios with decreased SO_X and NO_X emissions, the dry deposition of ammonia increases, even though the total nitrogen deposition is decreasing. The interplay of how decreased SO_X and NO_X emissions affect an increase of NH_3 dry deposition is seen in Figure L-9.

Table L-4. Total nitrogen delivered to the Bay (millions pounds per year) from the nine major river basins under different key CMAQ atmospheric deposition scenarios.

Basins	CMAQ Atmo. Deposition 1985 Scenario	CMAQ Atmo. Deposition 2002 Scenario	CMAQ Atmo. Deposition 2010 Scenario	CMAQ Atmo. Deposition 2020 Scenario	CMAQ Atmo. Deposition 2020 Maximum Feasible Scenario	CMAQ Atmo. Deposition 2030 Scenario
Susquehanna	160.4	148.1	141.4	138.7	137.6	139.3
West Shore	15.7	15.3	15.07	15.0	14.9	15.0
Potomac	77.0	72.2	69.4	68.3	67.9	68.6
Patuxent	4.8	4.5	4.4	4.3	4.3	4.3
Rappahannock	11.0	9.8	10.0	9.8	9.8	9.8
James	37.9	36.7	35.6	35.2	35.	35.1
York	9.3	8.9	8.6	8.4	8.4	8.4
East Shore MD-DE	31.6	29.8	29.2	29.2	29.1	29.7
East Shore VA	3.0	2.9	2.8	2.8	2.8	2.8
Total	350.7	328.1	316.5	311.7	309.7	313.0

Note: All the scenarios were applied to a 2002 Base condition of land use, BMPs, and point source discharges in order to show the relative effect of changing atmospheric deposition.

Table L-5. Direct atmospheric deposition loads of nitrogen (millions of pounds as nitrogen) to Chesapeake Bay's tidal surface waters for seven key scenarios

Scenario	Wet NOx Deposition	Dry NOx Deposition	Wet NH3 Deposition	Dry NH3 Deposition	Total Inorganic Nitrogen Deposition	Wet Organic Nitrogen Deposition	Total Nitrogen Deposition	Wet PO4 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	1.31
2002 Scenario	4.81	10.04	3.57	2.12	20.54	1.05	21.59	0.33	0.98	1.31
2010 Scenario	3.27	6.85	3.49	2.76	16.37	1.05	17.42	0.33	0.98	1.31
2020 Scenario	2.56	5.11	3.72	3.24	14.63	1.05	15.68	0.33	0.98	1.31
2020 Maximum Feasible Scenario	2.30	4.48	3.64	3.41	13.83	1.05	14.88	0.33	0.98	1.31
2020 Max Feas w/ 15% NH4 Drop	2.30	4.48	3.09	2.90	12.77	1.05	13.82	0.33	0.98	1.31
2030 Scenario	2.22	4.30	3.96	4.08	14.56	1.05	15.61	0.33	0.98	1.31

Note: This table includes two entries for the Maximum Feasible Scenario. The 2020 Max Fes w/15% NH4 Drop scenario includes the 15% decrease in wet and dry ammonia deposition for the Maximum Feasible Scenario due to ammonia emission control management practices in the Bay watershed jurisdictions described in CMAQ 2020 Maximum Feasible Scenario; the 2020 Maximum Feasible Scenario does not.

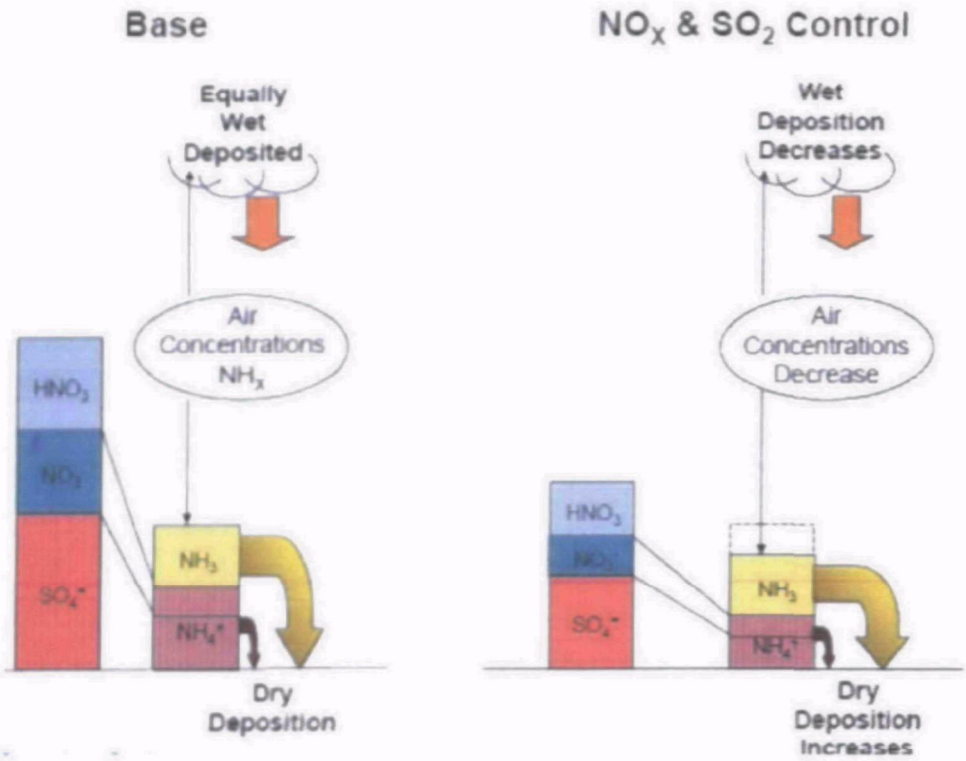


Figure L-9. Decreased SO_x and NO_x emissions cause increased NH_3 dry deposition.

How the percentage of ammonia, or reduced atmospheric deposition, to total nitrogen deposition is changing can be seen in Table L-5. For the 1985 Scenario, the percent ammonia deposition compared to the total DIN deposition was estimated to be 21 percent. For the 2010 and 2030 scenarios, the percentage of ammonia deposition to the tidal Chesapeake was estimated to increase to 38 percent for the 2010 scenario and 55 percent for the 2030 scenario. The respective estimated ammonia deposition on the watershed for these same three scenarios—1985, 2010, and 2030—are 24 percent, 44 percent, and 64 percent.

Atmospheric Deposition of Nitrogen to the Coastal Ocean

The CMAQ Model allows us to estimate atmospheric deposition loads to the coastal ocean at the mouth of the Chesapeake Bay, which contributes to the coastal ocean nutrient budgets made by others (Fennel et al. 2006; Howarth et al. 1995; Howarth 1998). The estimated distribution of 2001 atmospheric deposition loads to North America and adjacent coastal ocean is shown in Figure L-10. Howarth (1998) reported that atmospheric deposition loads are roughly equivalent to watershed loads in the northeast United States (Maine to Virginia). Howarth (1998) estimated that the watershed inputs of nitrogen to the northeast coastal waters to be 0.27 teragram. Inputs from direct atmospheric deposition to coastal waters are 0.21 teragram, and inputs from deep ocean upwelling are 1.54 teragrams, for a total input to the coastal ocean of 2.02 teragrams (Howarth 1998).

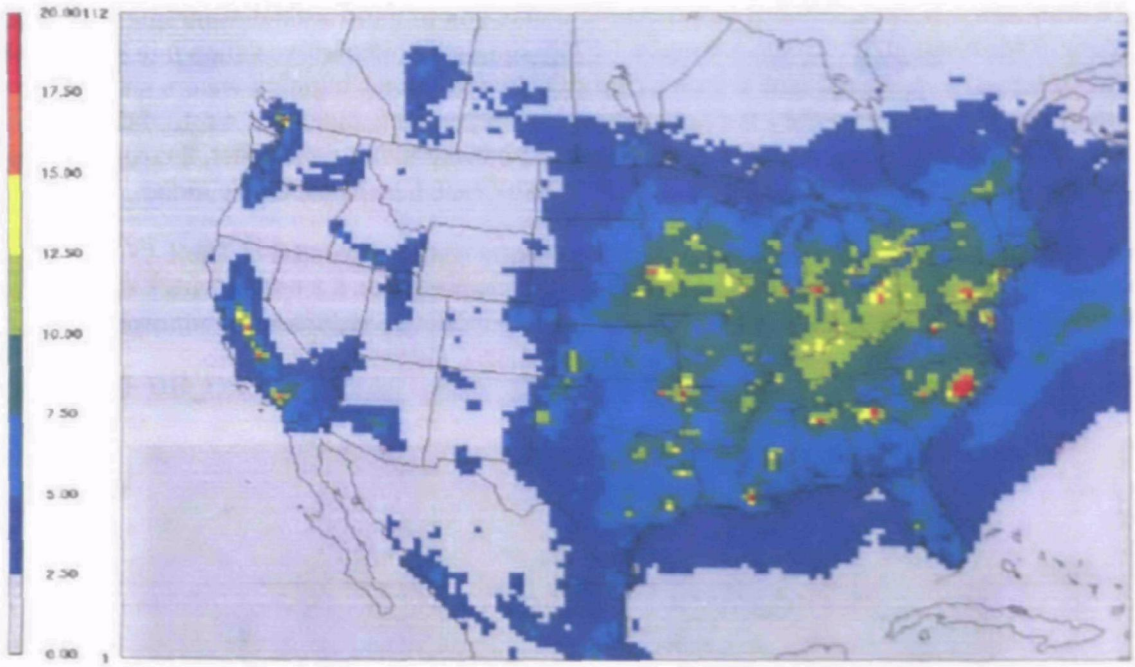


Figure L-10. Estimated 2001 annual total deposition of nitrogen (kg-N/ha) to North America and adjacent coastal ocean based on outputs from the CMAQ Air Quality Model, 36 km x 36 km grid.

That has implications for the fixed-ocean boundary condition used in the Chesapeake Bay Water Quality Sediment Transport Model. Atmospheric deposition total nitrogen loads to the coastal ocean are estimated to be about 6.63 kg/ha in the Base Case 2002 scenario (Table L-6). That correlates to 43.8 million kilograms of total nitrogen deposition to a region of the ocean that can exchange waters with the Chesapeake (Table L-6). In the case of the 2020 Maximum Feasible scenario, the nitrogen atmospheric deposition to the same region is estimated to be 29.4 million pounds, a reduction of 32 percent. If that same reduction is extrapolated to the coastal ocean, the direct atmospheric inputs to the coastal ocean would decrease to 0.14 teragram. Assuming the watershed loads discharged to the ocean and the deep upwelling pelagic loads are constant, that would give a combined watershed, direct deposition, and uncontrollable deep upwelling load of 1.95 teragrams, a decrease of 3 percent relative to the estimated current ocean boundary condition. Table L-6 lists the estimated reductions of the ocean boundary for the five key CMAQ scenarios.

Table L-6. Atmospheric deposition loads of nitrogen (kg per hectare) to the coastal water area shown in Figure L-11 for key scenarios

Scenario	Dry deposition	Wet deposition	Total deposition
Base 2002 Scenario	3.32	3.31	6.63
2010 Scenario	2.59	2.68	5.27
2020 Scenario	2.26	2.49	4.75
2020 Maximum Feasible	2.10	2.35	4.45
2030 Scenario	2.13	2.40	4.53

To determine CMAQ estimates of atmospheric deposition to the coastal ocean region affecting nitrogen loads through the ocean boundary EPA assigned boundaries as shown in Figure L-11 that correspond to the proximate region of the coastal ocean exchanging waters with the Chesapeake Bay. The 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 Bay mouth.

Estimated atmospheric deposition loads to the coastal waters are listed in Table L- 7 for key scenarios. The loads to the coastal ocean in kilograms per hectare for the CMAQ Base 2002 scenario are shown in Figure L-12. Table L-8 lists the relative reduction of atmospheric deposition of nitrogen in coastal waters versus the Base Calibration scenario.

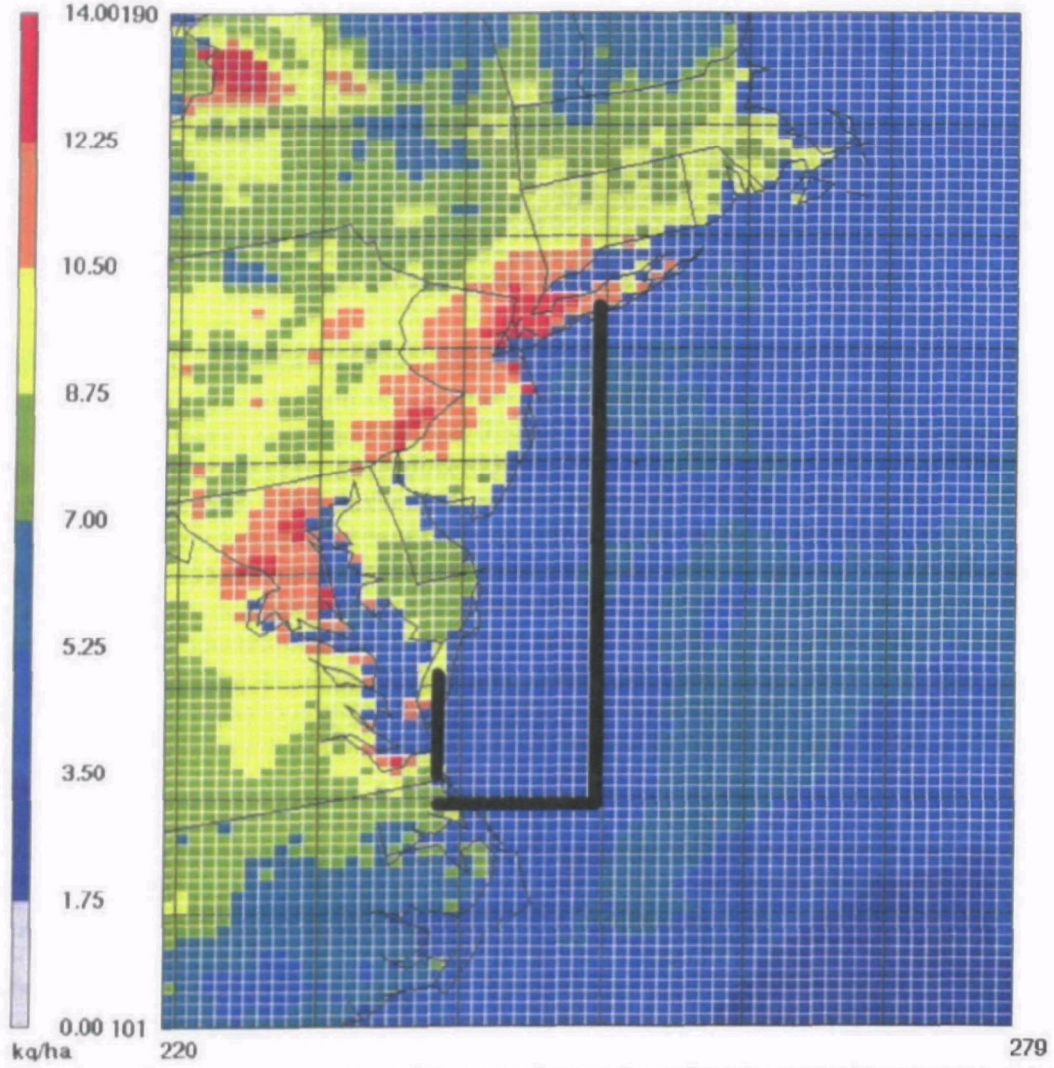


Figure L-11. Boundaries of the coastal ocean region used to adjust the ocean boundary conditions in the Chesapeake Bay WQSTM.

Table L-7. Total atmospheric deposition loads of nitrogen (millions of kg) to coastal waters for key scenarios

Scenario	Dry deposition	Wet deposition	Total deposition
Base 2002 Scenario	21.90	21.89	43.80
2010 Scenario	17.12	17.71	34.82
2020 Scenario	14.94	16.45	31.39
2020 Maximum Feasible	13.87	15.50	29.37
2030 Scenario	14.06	15.88	29.95

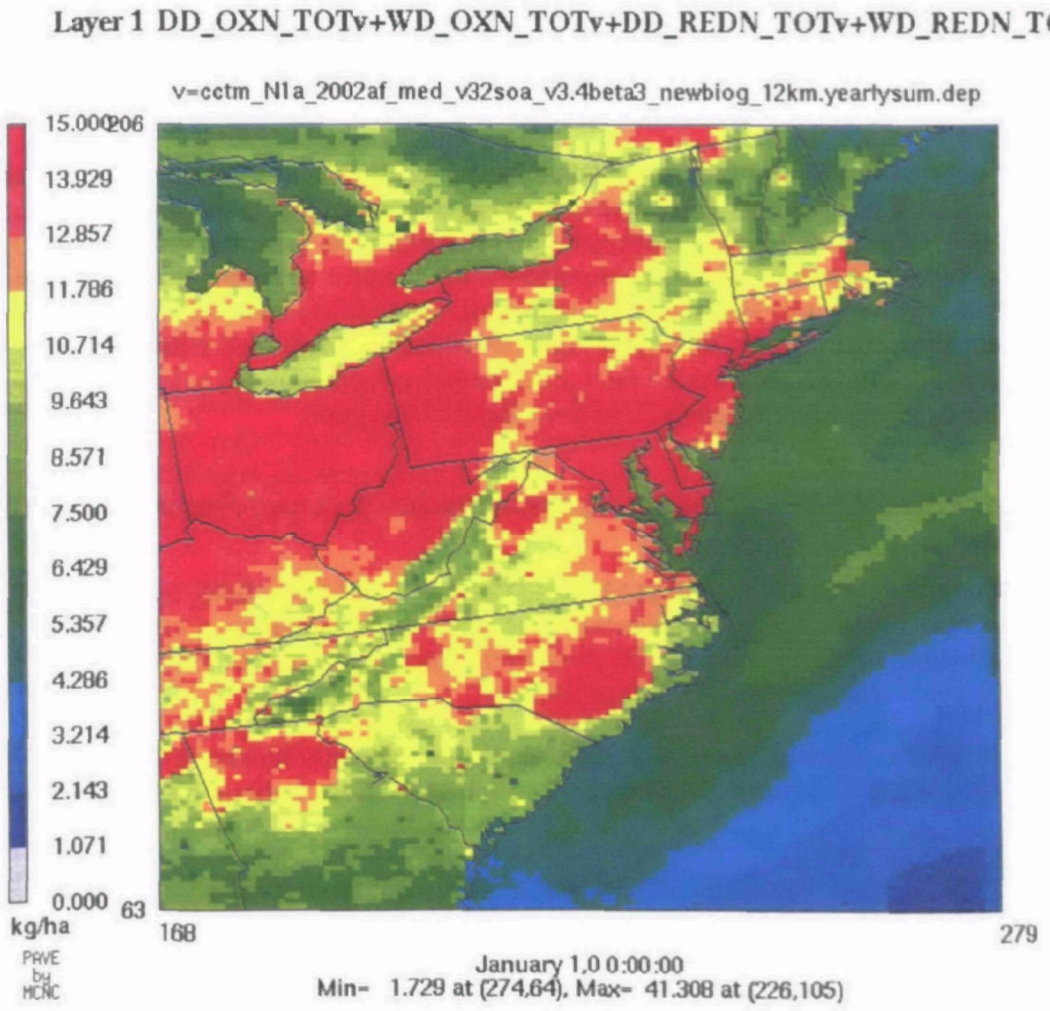


Figure L-12. Nitrogen atmospheric deposition loads (kg/ha) to the coastal ocean region for the Base 2002 scenario.

Table L-8. Adjustment of the ocean boundary load for all nitrogen species for key CMAQ Model scenarios' deposition to coastal waters adjacent to the Chesapeake Bay mouth

Scenario	% Reduction of ocean boundary
Base 2002 Scenario	0%
2010 Scenario	2.1%
2020 Scenario	2.9%
2020 Maximum Feasible	3.5%
2030 Scenario	3.3%

Adjustment of Ocean Boundary Concentrations in the WQSTM from Reductions in Atmospheric Deposition to Coastal Waters and Internal Bay Load Changes

Ocean boundary concentrations of the Bay Water Quality and Sediment Transport Model state-variables are set based on monthly observations at the Bay mouth water quality monitoring stations. The exchange of materials at the Bay mouth/ocean boundary follows the two layer flows of the estuary. Net outflow occurs predominantly at the upper and southern boundaries with the ebb tides, while net inflow occurs predominantly at the lower and northern boundaries. The ocean boundary values govern the inflowing flux of ocean nutrients and sediment to the Bay. Specifically, adjustments are made to the ocean boundary conditions to adjust for changes in loads in the Chesapeake and for changes in atmospheric deposition.

Adjustment of Nutrient Boundary Conditions Due to Load Reductions in the Chesapeake

Previous versions of the Bay Water Quality Model (8k grid version) found that a 90 percent reduction in nitrogen load from the watershed produced a 10 percent reduction in inflowing nitrogen concentration at the Bay mouth. Likewise, a 90 percent phosphorus load reduction produced a 5 percent reduction in inflowing phosphorus.

Accordingly, for each load reduction scenario, the percent reduction (or increase) of total nitrogen and total phosphorus loads in the entire Bay versus the Base Calibration scenario is calculated

TN reduction = 100 × (TN Base Calibration scenario – TN scenario) / TN Base Calibration scenario

TP reduction = 100 × (TP Base Calibration scenario – TP scenario) / TP Base Calibration scenario

EPA further calculates the following factors:

TN Factor = 1 – 0.1 × TN reduction/90

TP Factor = 1 – 0.05 × TP reduction/90

EPA then uses the TN factor and TP factor to multiply the Base Calibration ocean boundary concentrations of all the nitrogen and phosphorus nutrient species in each boundary cell, with the only exception of the cells in the southern boundary, because the southern Bay cells have predominantly outflows. No adjustments are made to ocean boundary sediment because it responds do different dynamics, and the source of the ocean input is primarily from courser particles entrained in the southbound long-shore current.

Adjustment of Nutrient Boundary Conditions from Atmospheric Deposition Load Reductions in the Coastal Shelf

If a load reduction scenario involves reducing nitrogen load from the atmosphere, a further adjustment in the boundary conditions is done. A reduction of nitrogen atmospheric deposition on the coastal ocean adjacent to the Chesapeake Bay causes reductions of nitrogen concentrations in the shelf waters and thereby, reduction to inputs of nitrogen to the Bay.

For example, with the 2020 Clean-Air scenario, the reduction of atmospheric deposition of nitrogen versus the Base Calibration scenario in the shelf waters is 0.029 (Table L-8). In that case, the ocean boundary TN factor is further reduced by the third term on the right-hand side of the following equation:

$$\text{TN Factor} = 1 - 0.1 \times \text{TN reduction}/90 - 0.029 \times 26/32$$

In the above formula, the 0.029 is multiplied with a ratio of 26 to 32. That is based on the average salinity at the boundary to be 26 ppt, and the average salinity of shelf waters to be 32 ppt. The ratio of 26 to 32 represents the ratio of the incoming ocean water over the sum of the incoming water and the freshwater going out the boundary (i.e., the mixing water at the boundary).

Allocation of Atmospheric Deposition of Nitrogen to Tidal Waters

In determining the allowable loading from air deposition, EPA separated the nitrogen deposition into two discreet parcels: (1) deposition occurring on the land and non-tidal waters which is subsequently transported to the Bay, also called indirect deposition; and (2) atmospheric deposition occurring directly onto the Bay's tidal surface waters also called direct deposition (Figure L-13).

The deposition on the land becomes part of the allocated load to the jurisdictions because the air deposition on the land becomes mixed with the nitrogen loadings from the land based sources and, therefore, becomes indistinguishable from land based sources. Furthermore, once the nitrogen is deposited on the land, it would be managed and controlled along with other sources of nitrogen that are present on that parcel of land. That is also called the referenced allocation as Clean Air Act mandates nationwide reductions, as estimated in the CMAQ 2020 scenario, are required to reduce the air deposition to the watershed and are assumed to be in place as the Bay watershed jurisdictions finalize and implement their Watershed Implementation Plans to reduce nitrogen loads further with land-based Best Management Practices (BMPs). In contrast, the nitrogen deposition directly to the Bay's tidal surface waters is a direct loading with no land-based management controls and, therefore, needs to be linked directly back to the air sources and air controls as EPA's allocation of atmospheric nitrogen deposition.

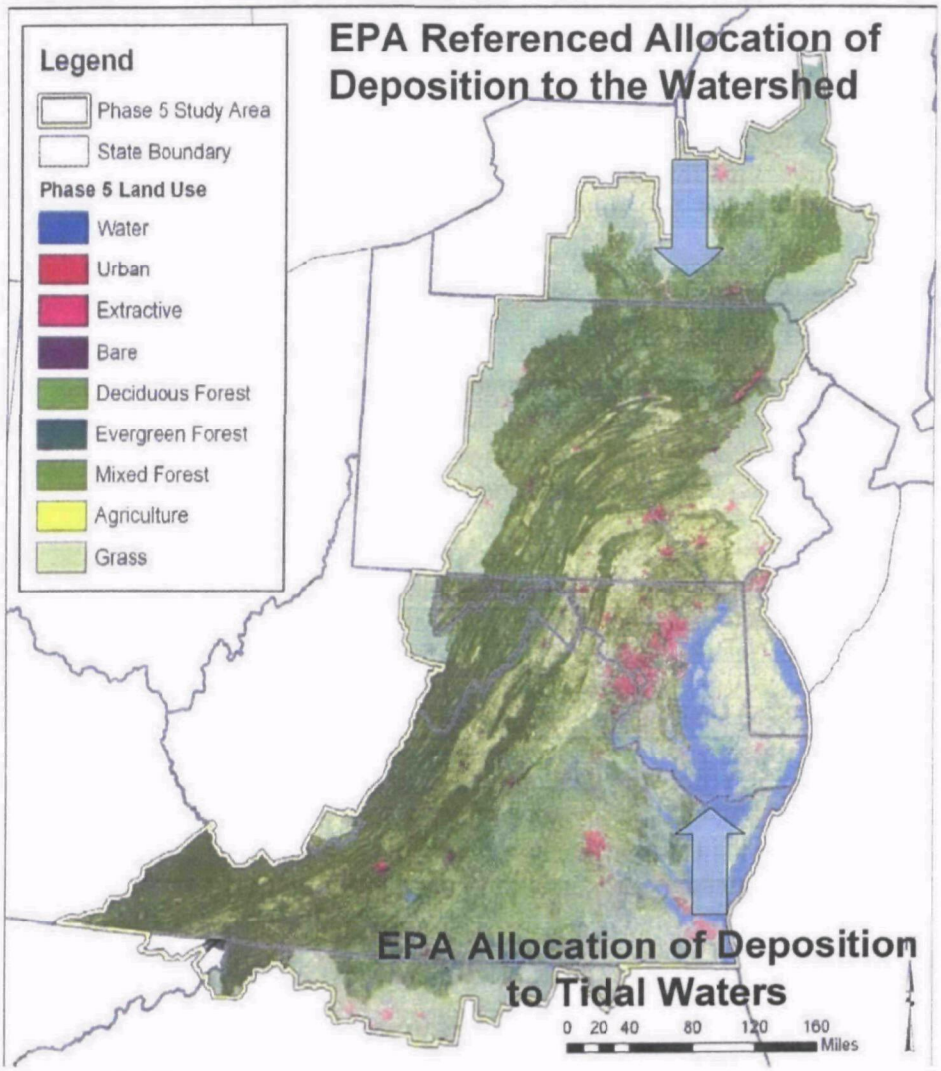


Figure L-13. EPA's reference allocation of nitrogen atmospheric deposition to the Bay watershed and the allocation of nitrogen atmospheric deposition direct to Bay's tidal surface waters.

EPA included an explicit basinwide nitrogen allocation, which was determined to be 15.7 million pounds of atmospheric deposition loads direct to Chesapeake Bay and tidal tributary surface waters. Activities associated with implementation of federal Clean Air Act regulations by EPA and the jurisdictions through 2020 will ensure achievement of this allocation. This nitrogen atmospheric deposition allocation is already accounted for within the jurisdiction and major river basin nitrogen allocations. Any additional nitrogen reductions realized through more stringent air pollution controls at the jurisdictional level, beyond federal requirements to meet air quality standards, may be credited to the individual jurisdictions through future revisions to the jurisdictions' Watershed Implementation Plans, 2-year milestones, and the Chesapeake Bay TMDL tracking and accounting framework.

In determining the amount of air controls to be used as a basis for the air allocation, EPA relied on current laws and regulations under the Clean Air Act. These requirements, together with national air modeling analysis, provided the resulting allocated load to air from direct deposition to the tidal waters of the Bay and its tidal tributaries.

The air allocation 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. The air allocation scenario includes:

- The CAMR.
- The BART used for reducing regional haze, and the off-road diesel and heavy duty diesel regulations.
- On-Road mobile sources: For On-Road Light Duty Mobile Sources this includes Tier 2 vehicle emissions standards and the Gasoline Sulfur Program, which affects SUVs pickups, and vans, which are now subject to same national emission standards as cars.
- On-Road Heavy Duty Diesel Rule – Tier 4: New emission standards on diesel engines starting with the 2010 model year for NOx, plus some diesel engine retrofits.
- Clean Air Non-Road Diesel Rule: Off-road diesel engine vehicle rule, commercial marine diesels, and locomotive diesels (phased in by 2014) require controls on new engines.
- EGUs: CAIR second phase in place (in coordination with earlier NOx SIP call).
- Non-EGUs: Solid Waste Rules (Hospital and Medical Waste Incinerator Regulations).

The controls described above were modeled using the national air models (CMAQ) and the amount of deposition direct to the Chesapeake Bay's tidal surface waters was determined. On the basis of the air allocation scenario as described above, the nitrogen deposition direct to tidal surface waters is 15.7 million pounds per year. Therefore, the air allocation for the Chesapeake Bay TMDL is 15.7 million pounds per year of nitrogen.

EPA anticipates that the loading cap of 15.7 million pounds of atmospheric deposition loads direct to Chesapeake Bay and tidal tributary surface waters will be achieved through implementation of federal Clean Air Act regulations by EPA and the states through 2020. Projected reductions in atmospheric deposition loads to the surrounding watershed over this same period are already accounted for within the individual jurisdiction and major river basin nitrogen load allocations. Any additional nitrogen reductions realized through more stringent air pollution controls at the jurisdiction level, beyond minimum federal requirements, as for example in ammonia deposition reductions, may be credited to the individual jurisdictions through future revisions to the jurisdictions' Watershed Implementation Plans, 2-year milestones and the Bay TMDL tracking and accounting framework.

Crediting the States with Additional Air Controls

As mentioned above, it is possible, that individual or statewide air emission reductions, beyond those used to derive the air deposition allocation may be achieved by a state. In this case, for the purpose of evaluating the 2-year milestone progress, the state can be credited with the reductions that would result for its portion of the Chesapeake Bay watershed. EPA will use the following

steps to determine, with the state, the amount of nitrogen credit to apply to air emission controls that go beyond the air allocation scenario described above.

1) Determine whether the emission source for which the state is seeking credit already assessed credit for reductions in the State's State Implementation Plan (SIP) for achieving the State's air quality standards)

All of the Chesapeake Bay Watershed states are in nonattainment of current air quality standards. When new air quality standards for ozone are complete in July 2011, the gap between current air quality conditions and air quality standard achievement is expected to grow. Since the Chesapeake Bay Program tracks the SIP management actions in an ongoing series of scenarios designed to track expanded SIP implementation in the watershed and credit these additional air reductions in the two-year milestones, the inclusion of air emissions reductions that are already captured in the SIP will double count the reduction. Examples of air reductions that are not in the SIPs are reductions in any ammonia emissions and reductions in NOx emissions that are not needed for air quality standard achievement.

2) Determine whether the emission reduction is a state-wide emission or point source

Currently only a state-wide source emission reduction can be applied in the Phase I Watershed Implementation Plans. As modeling capacity to handle air to water trading develops, the capability to handle the specificity of latitude and longitude of point source emissions that are being reduced will be applied in the Chesapeake models.

3) Determine if the emission controls will impact NOx and/or NH_3 emission

There are situations in some air management actions where, for example, a NOx point source emission is reduced, which in turn reduces the ammonia slip emissions (ammonia slip occurs with NOx control technologies). States might be provided additional credit if both are reduced.

4) Determine the annual average emission reduction

Estimates are needed of the emission reduction on an annual average basis, and whether the emission reduction occurs year round or is seasonal. Estimates of current emissions, which serve as a baseline for the reduction, are also needed.

It should be noted that the reduction in nitrogen loads to the Bay can be orders of magnitude less than the actual reduction in air emissions. Operationally, the emission reductions could be discounted by the following:

1. Discounting the mass of NO_2 measured in air programs to the "as N" units used in water programs and in the WIP
2. Discounting for what is deposited within the State from the emissions reduced based on a CMAQ State and sector analysis (also, the reduced deposition in other States will be calculated if operationally possible)
3. Discounting for estimated attenuation from the land
4. Discounting for estimated attenuation in the rivers.

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Appendix M.
Chesapeake Bay Water Quality/Sediment Transport Model Management Scenario Criteria Attainment Assessment Results and 2008 303(d) List Assessment Results

This appendix presents the Chesapeake Bay water quality criteria attainment assessment results of various Chesapeake Bay Water Quality and Sediment Transport Model (Bay Water Quality Model) management scenarios in the stoplight format used by the U.S. Environmental Protection Agency and its partner jurisdictions in developing the Chesapeake Bay TMDL. The stoplight spreadsheets summarize the percentage of space and time exceeding the four Bay jurisdictions' water quality criteria for each of the 92 Chesapeake Bay segments. The spreadsheets are produced from an assessment of Bay Water Quality Model outputs and Bay water quality monitoring data as described in Sections 6.2.4 and 6.4.4. The spreadsheets were used to evaluate whether a management scenario met all applicable criteria across all designated use-segments. Green highlighted percentages represent attainment of the applicable water quality standards. Red highlighted percentages represent a violation or an exceedance of applicable water quality standards. The assessment results provided in this appendix are in three spreadsheets:

- Appendix M-1: Chesapeake Bay Dissolved Oxygen Criteria Attainment Assessment Results (AppendixM1_DO_Stoplight.xls)
- Appendix M-2: Chesapeake Bay Chlorophyll *a* Criteria Attainment Assessment Results (AppendixM2_Chlor_Stoplight.xls)
- Appendix M-3: Chesapeake Bay SAV/Water Clarity Criteria Attainment Assessment Results (AppendixM3_SAV-Clarity_Stoplight.xls)

The loading values in appendices M-1 and M-2 were derived in one of two ways. Loading values for the 1985 Scenario, 2009 Scenario, Tributary Strategy, and E3 2010 Scenario were derived from explicit management scenarios and described further in Appendix J. Loading values for the remaining scenarios were calculated as ratios of existing management scenarios to achieve particular basinwide loading targets.

This appendix also contains the Chesapeake Bay segments 2008 303(d) list assessment results spreadsheet.

Interpreting the Spreadsheets

Appendix M-1: Chesapeake Bay Dissolved Oxygen Criteria Attainment Assessment Results

The dissolved oxygen water quality criteria stoplight plots describe the degree of nonattainment (as percent of volume and time) of dissolved oxygen water quality criteria for each Chesapeake Bay segment by designated use criteria. The dissolved oxygen criteria attainment assessment results are based on assessing the open-water 30-day mean, deep-water 30-day mean, and deep-channel instantaneous minimum criteria during the June 1 through September 30 summer period (see Table 3-4 in Section 3.1.2). The green highlighted percentages represent attainment of the applicable dissolved oxygen criterion. The red highlighted percentages represent nonattainment of dissolved oxygen criterion. The rows show the percent nonattainment by Bay segment. The

columns show the percent nonattainment by the respective Bay Water Quality Model scenario and are listed from left to right in descending order of loading values for total nitrogen (TN), total phosphorous (TP), and total suspended solids (TSS). The Bay Water Quality scenarios are grouped by 3-year water quality model assessment windows and are ordered chronologically. The Bay Water Quality Model scenarios marked with an asterisk (*) had loading values derived from the key management scenario spreadsheets (see Appendix J). All other scenarios' loading values were calculated as ratios of existing management scenarios to achieve particular basinwide loading targets. The critical period for the Chesapeake Bay TMDL was selected as 1993–1995 for assessment of the dissolved oxygen criteria (see Section 6.2.1).

Appendix M-2: Chesapeake Bay Chlorophyll a Criteria Attainment Assessment Results

The chlorophyll *a* water quality criteria stoplight plots show the percent nonattainment of chlorophyll *a* (CL) criteria by two periods: CL Spring Seasonal (March 1 through May 31) and CL Summer Seasonal (July 1 through September 30). The green highlighted percentages represent attainment of chlorophyll *a* criteria. The red highlighted percentages represent nonattainment of chlorophyll *a* criteria. The rows show percent nonattainment by Bay segment. The columns show the percent attainment by Bay Water Quality Model scenario and are listed from left to right in descending order by loading values for TN and TP. The Bay Water Quality Model scenarios are grouped by 3-year water quality model assessment windows and are ordered chronologically. For the allocation scenarios specific to the James River Basin, loading values were calculated as ratios of existing management scenarios to achieve particular loading targets. Analyses failed to identify a critical period for the chlorophyll *a* water quality criteria, so all 3-year periods had equal weight in the Bay TMDL assessment (see Section 6.2.1).

Appendix M-3: Chesapeake Bay SAV/Water Clarity Criteria Attainment Assessment Results

The submerged aquatic vegetation (SAV)/water clarity stoplight spreadsheets describe the degree of nonattainment (as percent of SAV acreage + water clarity acres—see Section 6.4.4 and Appendix P) of SAV/water clarity criteria for each of the Bay segments assigned a shallow-water bay grass designated use. The green highlighted percentages represent the percent nonattainment of SAV/water clarity criteria. The red highlighted percentages represent the percent nonattainment of SAV/water clarity criteria. The rows show the percent nonattainment by Bay segment. The columns show the percent nonattainment by Bay Water Quality Model scenario and are listed from left to right in descending order of loading values for TN, TP, and TSS.

The Bay Water Quality scenarios are grouped by 3-year water quality model assessment windows and are ordered chronologically. The Bay Water Quality Model scenarios marked with an asterisk (*) had loading values derived from the key management scenario spreadsheets (see Appendix J). All other scenarios' loading values were calculated as ratios of existing management scenarios to achieve particular basinwide loading targets. The critical period for the Chesapeake Bay TMDL was selected as 1993–1995 for assessment of the SAV/water clarity criteria (see Section 6.4.1).

Appendix M-4: Chesapeake Bay Segments 2008 303(d) List Assessment Results

The following are short descriptions of the information/data in each column in the Appendix M-4 Chesapeake Bay segments 2008 303(d) list assessment results spreadsheet (AppendixM4_Bay_Segments_2008_303d.xls). Green means the criterion/designated use was attained; red means the criterion/designated use was not attained; and yellow means insufficient data for criterion assessment or no published criteria assessment protocol. The key to each lettered column of information and data are as follows:

A: Chesapeake Bay segment

B: Jurisdiction

C: Designated used: MSN-migratory spawning and nursery; SWSAV-shallow-water bay grass, OW- open water; DW-deep-water; DC-deep-channel

D: Season for criteria application: Summer-June 1 through September 30; Rest of year (ROY)-October 1 through May 31

E: 30-day mean dissolved oxygen criterion with the value being the applicable criterion

F: 7-day mean dissolved oxygen criterion with the value being the applicable criterion

G: 1-day mean dissolved oxygen criterion with the value being the applicable criterion

H: Instantaneous minimum dissolved oxygen criterion with the value being the applicable criterion

I: Temperature based dissolved oxygen criterion protective of shortnose sturgeon (species listed as endangered)

J: Numerical chlorophyll *a* criteria assessment results

K: SAV restoration acreage criteria assessment results with the value being the applicable SAV restoration acreage

L: Water clarity acreage assessment results

M: Combined SAV restoration acreage + water clarity acreage assessment results

N: Water clarity criteria assessment results

O: Description of criteria attainment assessment results by designated use-segment

P: 303(d) listing category

Q: Benthic community impairment status

Appendix N.
Resolution of Segments Failing to Attain the Jurisdictions' Water Quality Standards

Segments failing to attain the Dissolved Oxygen Standards

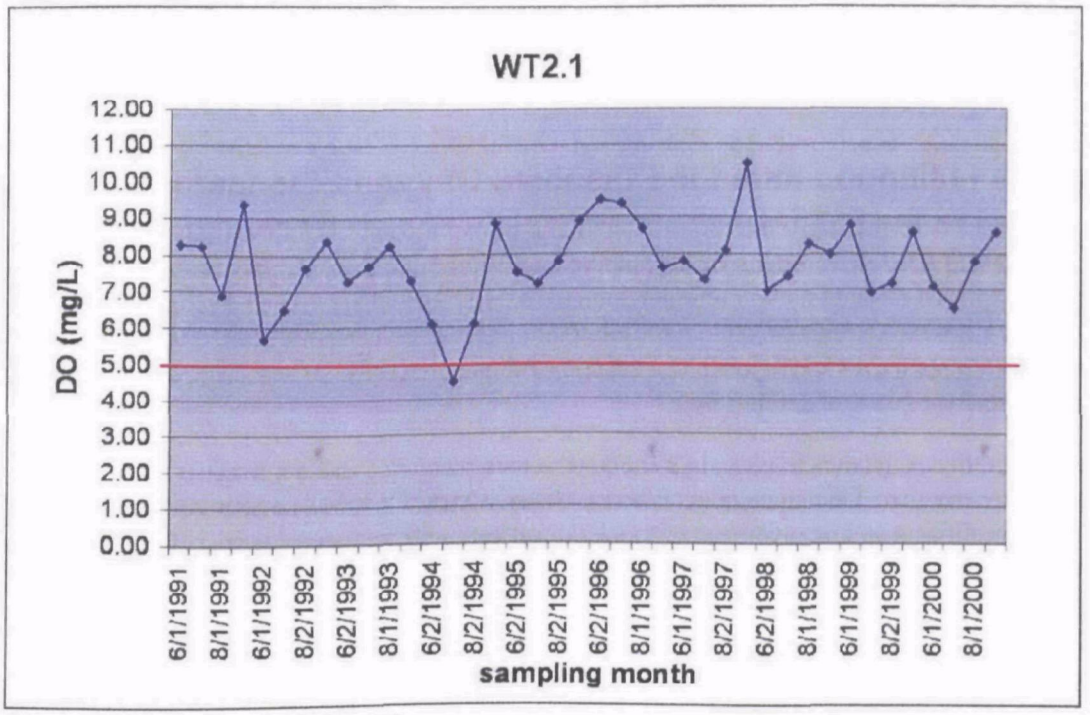
In the process of determining the target nitrogen and phosphorous load allocations, it was observed that in a limited number of Chesapeake Bay segments, poor dissolved oxygen (DO) conditions appeared to persist even under scenarios of dramatically reduced nitrogen and phosphorous loads. A series of systematic diagnostic analyses were conducted to determine the drivers of such persistent violations. The findings of those analyses, summarized in Section 6.4.4, are described in more detail here.

The most important analyses to explain the anomalous results in these segments were to determine whether the Chesapeake Bay Water Quality Model (WQM) effectively simulated historical conditions and improvement in those conditions with reduced loads. If the WQM was determined to be non responsive in the affected Bay segments, additional lines of evidence were explored to determine whether the apparent nonattainment represented an area of real concern, or whether those segments could reasonably be expected to show sufficient improvement to attain water quality standards (WQS) given the nitrogen and phosphorous load reductions. Each Bay segment was evaluated to determine the following:

1. Whether violations of the DO criteria were isolated or widespread
2. Whether the Chesapeake Bay WQM effectively simulated historical conditions and improvement in those conditions with reduced loads
3. Whether nearby Bay segments also exhibited persistent or widespread hypoxia (low to minimal DO levels)

Gunpowder River

The DO criteria nonattainment in the tidal Gunpowder River (GUNOH) was driven by two converging factors. First, the historical water quality DO monitoring data for this location show that the water in the Gunpowder River is generally well-oxygenated in the summertime, with only a single instance of hypoxia observed (July 1994) over the course of 10 consecutive summers from 1991 to 2000 that violated the open-water criterion of 5.0 milligrams per liter (mg/L) (red line in Figure N-1). Recall that the assessment process includes overlaying the improvement in water quality predicted by the model onto the observed water quality from the hydrologic period. For that reason, anomalous observed water quality measures can be critical to the assessment results.



Source: http://www.chesapeakebay.net

Figure N-1. Measurements taken in summer months (June–September) at water quality monitoring station WT2.1 in the Gunpowder River 1991–2000.

Second, the Bay WQM's simulations for this location, which ranged from about 8 to 10 mg/L, were only moderately higher than the average historical summertime conditions. However the Bay WQM did not simulate conditions below 8 mg/L in this region. Because no simulated hypoxia existed, there was no example of simulated improvement in DO concentrations with reduced nitrogen and phosphorous inputs for this region. With summertime DO concentrations at or above 8 mg/L, the Bay WQM generally simulated a minimal increase in DO concentrations in response to reduced nitrogen and phosphorous loads. That is in clear contrast to the Bay WQM's performance when hypoxic conditions are simulated under calibration (i.e., historical) conditions—for an example from the middle of the Chesapeake Bay, see Figure N-2. That figure is an example of a regression plot showing WQM performance consistent with historical observations. The pink symbols and line represent DO concentrations from the calibration scenario; the blue symbols and line represent DO concentrations under reduced nitrogen and phosphorous loads of the E3 Scenario. The range of DO concentrations in the calibration scenario spans the range of historical observations. Greater increase in DO concentrations is observed with reduced loads when the initial (calibration) concentrations are low. In those cases, the Bay WQM's predictions are consistent with empirical findings, namely, that hypoxic conditions will improve with reduced loads to a greater degree than will initially high DO concentrations.

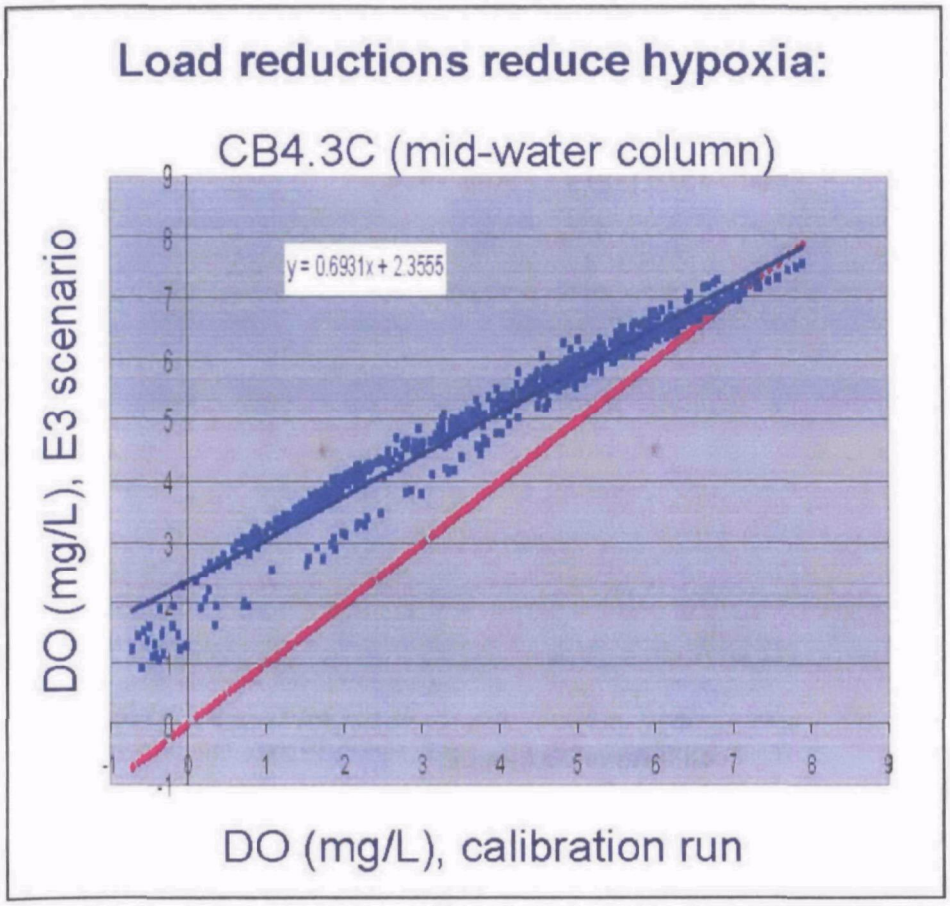


Figure N-2. Example of a regression plot showing Bay WQM performance consistent with historical water quality monitoring DO observations in the lower central Chesapeake Bay segment CB4MH at station CB4.3C.

The regression equation that is used to scenario-modify DO concentrations (for a description of the scenario-modification procedure, see Section 6.2.2) is generated from a comparison of DO concentrations simulated in the calibration scenario with those simulated in a management scenario such as E3. When little change is observed in DO concentrations between the two scenarios, the resulting regression equation reflects it (Figure N-3). When simulated DO concentrations are consistently at or above 8 mg/L in the calibration scenario, the Bay WQM generally does not show dramatic improvements in concentrations with reduced pollutant loads. Furthermore, when the resulting regression equation is applied to a DO concentration well outside the range of the simulated data, it can cause a *DO response* that does not accurately reflect the information provided by the Bay WQM.

In the case of Gunpowder River monitoring station WT2.1 for July 1994, the Bay WQM-simulated DO concentrations fell between about 8 and 10 mg/L for the calibration scenario as well as the numerous reduced loading *management* scenarios. In Figure N-3, the pink symbols and line represent the calibration scenario DO concentrations; the light blue symbols and black line show the change in DO concentrations from the calibration to the E3 scenario. The red arrows show the predicted change in an initial DO concentration of 4.5 mg/L. In that case, a

historical observation of 4.5 mg/L was scenario-modified to a concentration of 4.4 mg/L for the E3 scenario.

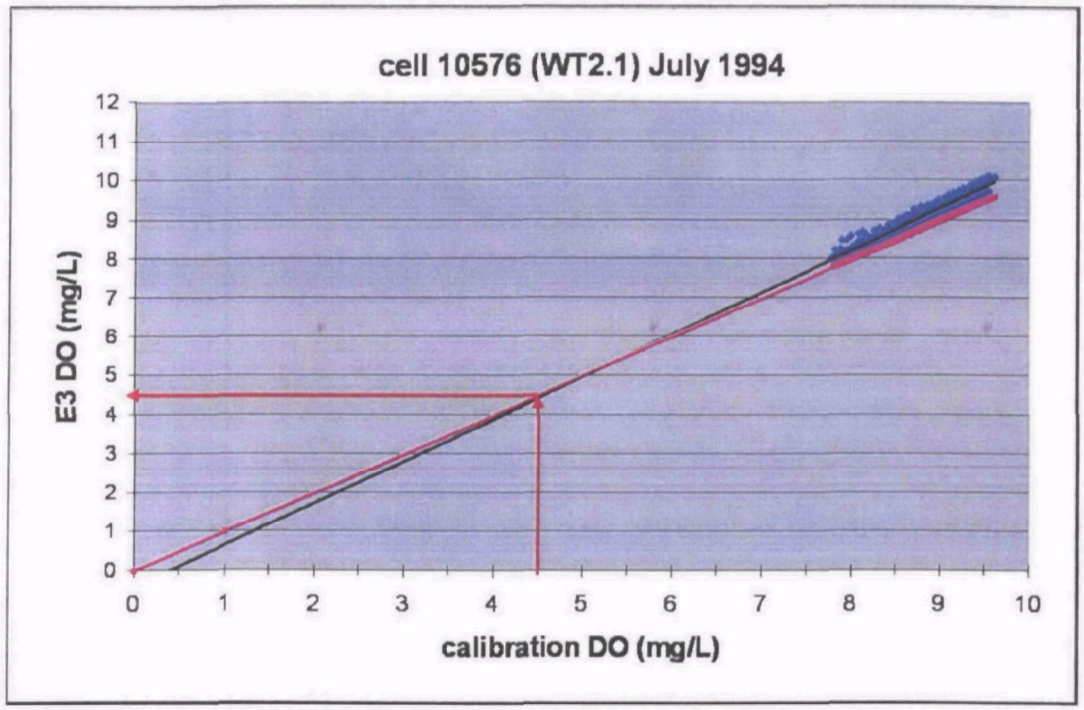


Figure N-3. Bay WQM scenario DO concentrations and regression for station WT2.1 in the Gunpowder River.

As is shown here, even at the *E3* scenario (for a description of management scenarios, see Appendix J) only a slight increase in DO concentrations is observed across the range of simulated concentrations. Typically, a greater response—in the form of higher DO concentrations—is observed when the initial (i.e., calibration) DO concentrations are low (i.e., less than 5 mg/L). In such a case, when the linear regression representing the relationship between the calibration and E3 DO concentrations is extrapolated far below the range of simulated conditions, the result suggests that under E3 conditions, hypoxia could actually get worse rather than better. That prediction is not an accurate representation of model simulations; rather it is the effect of extrapolating the regression equation well outside the range of the simulations from which it was generated. Such was the case for July 1994, when a historical observation of 4.5 mg/L was scenario-modified to a concentration of 4.4 mg/L under the dramatically reduced load conditions of the E3 scenario.

Examination of nearby segments—the Bush River (BSHOH), the upper Chesapeake Bay (CB2OH), and the Middle River (MIDOH)—showed attainment of DO WQS under historical loading conditions and under all load reduction scenarios (Figure N-4).

Cbseg	'91 -'00 Base Scenario 309TN, 19.5TP, 8950TSS '93-'95 DO Open Water Summer Monthly	2009 Scenario 248TN, 16.6TP, 8110TSS '93-'95 DO Open Water Summer Monthly	Target Load Option A 200TN, 15TP, 6390TSS '93-'95 DO Open Water Summer Monthly	Tributary Stategy 191TN 14.4TP, 6462 TSS '93-'95 DO Open Water Summer Monthly	190/13 Loading Scenario 190TN, 13TP, 6123TSS '93-'95 DO Open Water Summer Monthly	190 Loading Scenario 190TN 12.6TP, 6030TSS '93-'95 DO Open Water Summer Monthly	179 Loading Scenario 179TN 12.0TP, 5510TSS '93-'95 DO Open Water Summer Monthly	170 Loading Scenario 170TN 11.3TP, 5650TSS '93-'95 DO Open Water Summer Monthly	E3 2010 Scenario 141TN 8.5TP, 5060TSS '93-'95 DO Open Water Summer Monthly
BSHOH	0%	0%	0%	0%	0%	0%	0%	0%	0%
CB2OH	0%	0%	0%	0%	0%	0%	0%	0%	0%
MIDOH	0%	0%	0%	0%	0%	0%	0%	0%	0%
GUNOH	5%	5%	5%	5%	5%	5%	5%	5%	5%

Figure N-4. Open-water DO criteria attainment *stoplight plot* of the Gunpowder River segment GUNOH and nearby segments.

In summary, the incidence of hypoxia in the tidal Gunpowder River was isolated. In that single, isolated case, the Bay WQM was unable to provide information on the magnitude of expected improvement in DO conditions with reduced nitrogen and phosphorous loads in the region. Examination of nearby segments showed consistent attainment of DO WQS under historical (Base) and reduced loading scenarios. Therefore, it is reasonable to expect that the open-water designated use of GUNOH will attain DO WQS under the basinwide target allocation of 190 million pounds per year total nitrogen (TN) and 12.7 million pounds per year total phosphorus (TP).

Manokin River

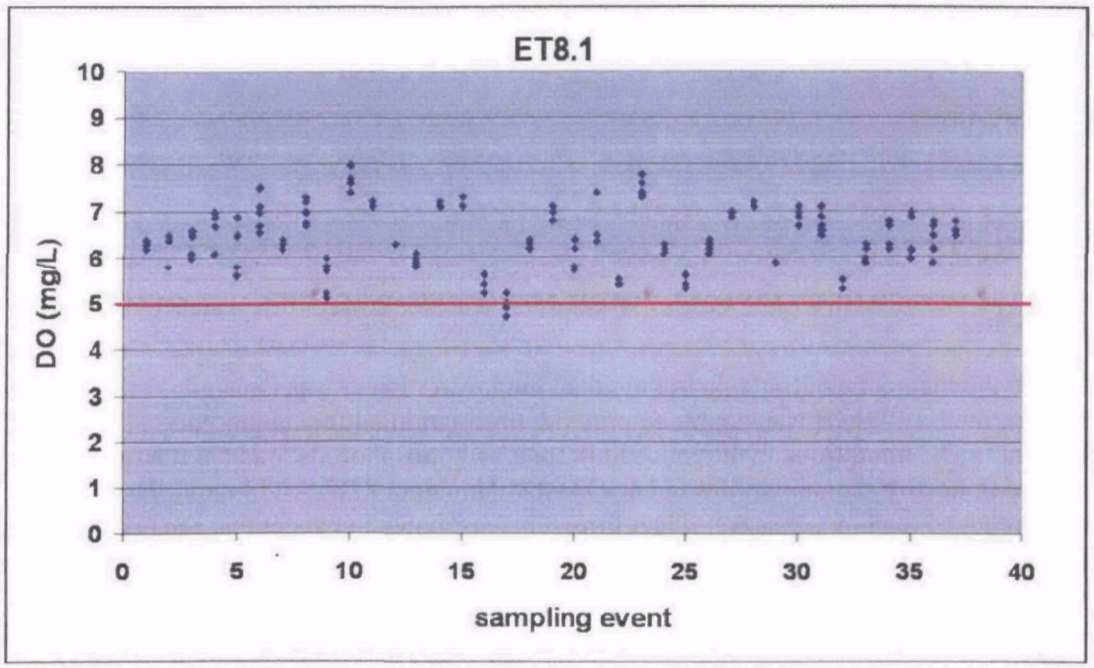
In the Manokin River (MANMH), violations of the segment's open-water DO WQS for the years 1991–2000 were limited to three measurements, ranging from 4.7 to 4.9 mg/L, taken during one sampling event in July 1995 (Figure N-5).

The isolated, marginal violations of the DO WQS under historical conditions were scenario-modified to greater nonattainment under simulated load reductions. At the same time, adjacent and nearby segments—Tangier Sound (TANMH), Big Annemessex River (BIGMH), and the lower Pocomoke River (POCMH)—all attained their respective DO WQS under historical conditions and reduced loading scenarios (Figure N-6).

Further examination of the performance of the Bay WQM in the vicinity of water quality monitoring station ET8.1 (MANMH's single tidal monitoring station) showed lower—rather than higher—DO concentrations under reduced loading scenarios (Figure N-7).

The grid location that represents the Manokin River's single monitoring station is shallow and directly adjacent to the land. The highlighted cell (cell 6705) in Figure N-8 coincides with the location of long-term fixed station ET8.1. In such cases, the Bay WQM often struggles to integrate the multiple, interacting drivers of a parameter such as DO. Further investigation showed that chlorophyll *a* concentrations in cell 6705 decreased to zero (or less) at the E3 scenario (data not shown). If chlorophyll *a* concentrations had *increased* in concert with lower DO concentrations, a temporal anomaly in pollutant loads to cell 6705 or its vicinity would have

been suspected. However, the combination of nonexistent chlorophyll *a* concentrations and low DO concentrations observed here indicates that the WQM struggled to integrate the effect of reduced loads on the feedbacks among multiple drivers of DO concentrations.



Source: http://www.chesapeakebay.net

Figure N-5. Summertime DO observations (dark blue symbols) at water quality monitoring station ET8.1 in the Manokin River 1991–2000.

Cbseg	"91 -'00 Base Scenario 309TN, 19.5TP, 8950TSS '93-'95 DO Open Water Summer Monthly	2009 Scenario 248TN, 16.6TP, 8110TSS '93-'95 DO Open Water Summer Monthly	Target Load Option A 200TN, 15TP, 6390TSS '93-'95 DO Open Water Summer Monthly	Tributary Stategy 191TN 14.4TP, 6462 TSS '93-'95 DO Open Water Summer Monthly	190/13 Loading Scenario 190TN, 13TP, 6123TSS '93-'95 DO Open Water Summer Monthly	190 Loading Scenario 190TN 12.6TP, 6030TSS '93-'95 DO Open Water Summer Monthly	179 Loading Scenario 179TN 12.0TP, 5510TSS '93-'95 DO Open Water Summer Monthly	170 Loading Scenario 170TN 11.3TP, 5650TSS '93-'95 DO Open Water Summer Monthly	E3 2010 Scenario 141TN 8.5TP, 5060TSS '93-'95 DO Open Water Summer Monthly
MANMH	1%	5%	5%	5%	5%	5%	5%	5%	5%
TANMH	0%	0%	0%	0%	0%	0%	0%	0%	0%
BIGMH	0%	0%	0%	0%	0%	0%	0%	0%	0%
POCMH	0%	0%	0%	0%	0%	0%	0%	0%	0%

Figure N-6. Open-water DO criteria attainment *stoplight plot* of the Manokin River segment MANMH and nearby segments.

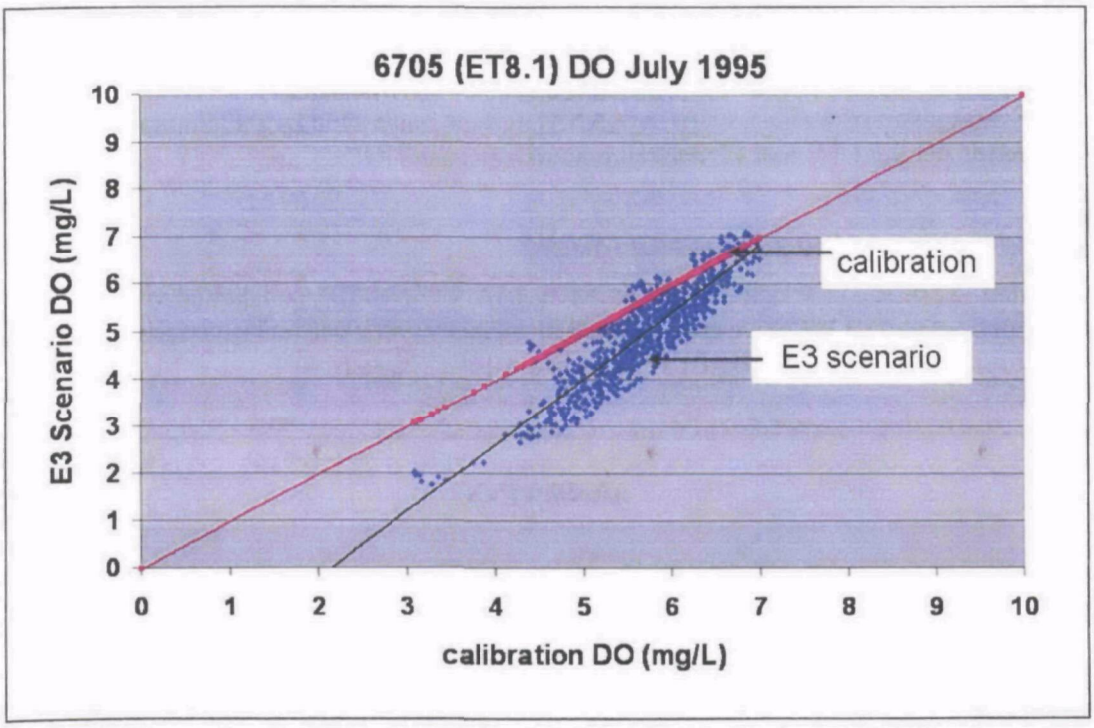


Figure N-7. Regression plot for the Bay WQM cell (6705) corresponding to the MANMH water quality monitoring station (ET8.1).

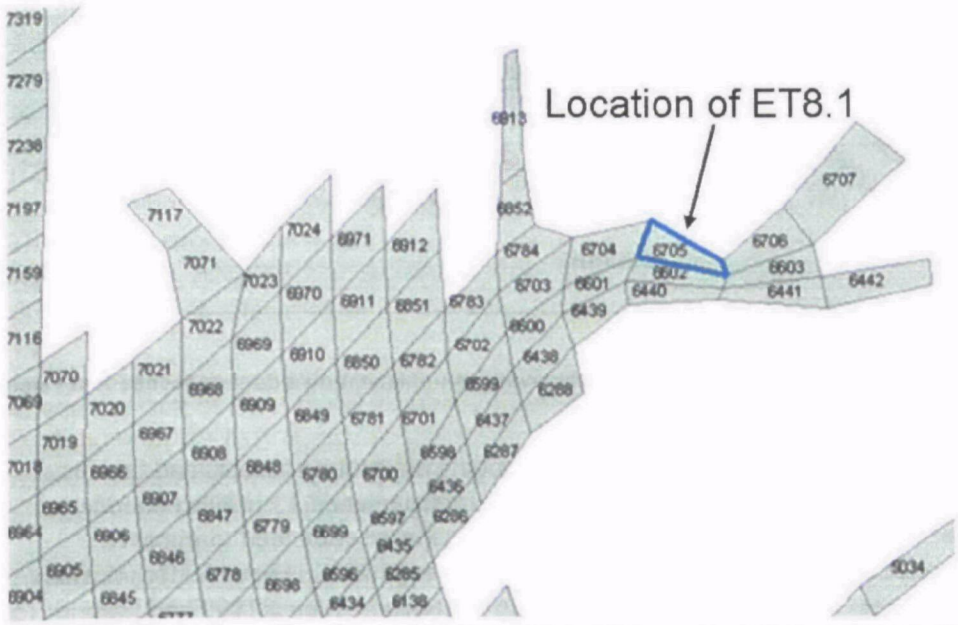
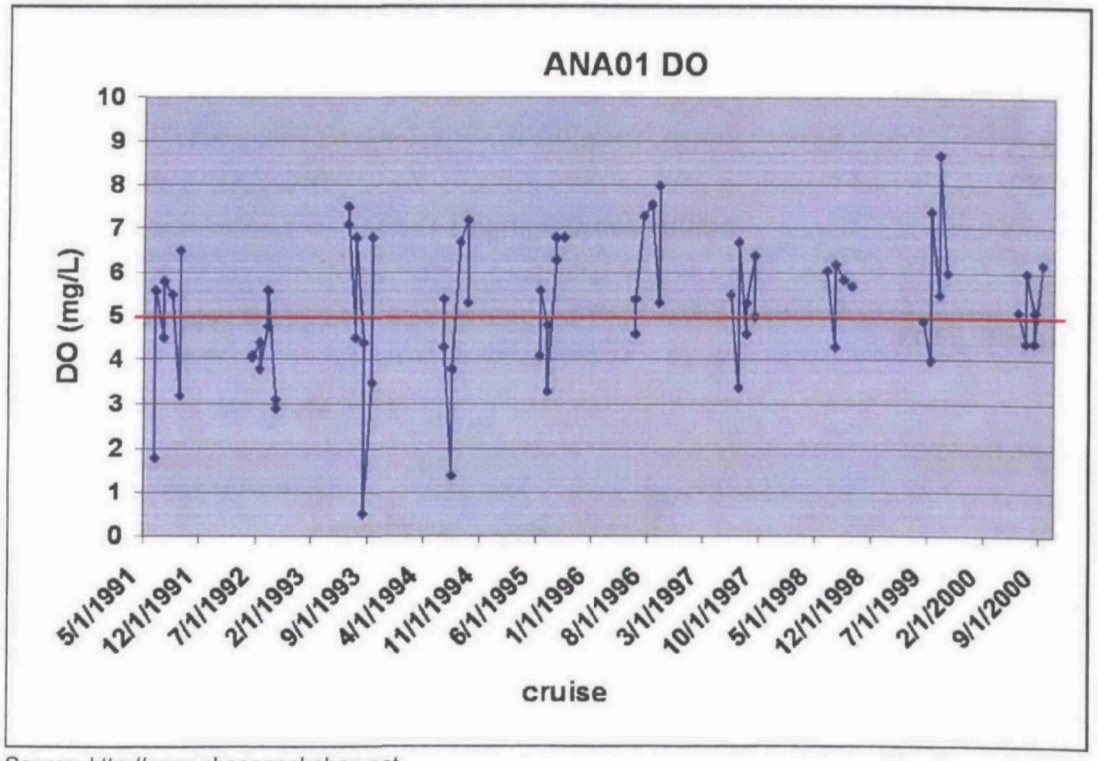


Figure N-8. Chesapeake Bay WQM grid for the Manokin River and a portion of Tangier Bay.

Given the isolated nature of DO criteria violations in MANMH under historical conditions, the poor performance of the WQM, and the unimpaired nature of adjacent waterbodies under historical conditions and simulated reduced loadings, EPA concludes that it is reasonable to expect full attainment of the DO WQS in MANMH at the basinwide target allocation of 190 million pounds per year TN and 12.7 million pounds per year TP.

Maryland Portion of the Anacostia River

In the Maryland portion of the tidal Anacostia River (ANATF_MD), substantial violations of the segment's open-water DO WQS were observed historically, with particularly serious violations occurring at station ANA01 in August 1993 and July 1994 (Figure N-9).



Source: http://www.chesapeakebay.net

Figure N-9. Summertime water quality DO monitoring observations at Maryland's tidal Anacostia River water quality monitoring station ANA01 1991–2000.

Table N-1 shows the modeled DO violations under a model calibration scenario and under a lower loading scenario of 179 million pounds per year of nitrogen and 12 million pounds per year of phosphorus. The majority of the historical violations were estimated to improve substantially or even reach full attainment with further load reductions. However, for the two months during the critical period with the most serious violations—August 1993 and July 1994—no improvement in DO WQS nonattainment percentage was predicted (Table N-1).

Table N-1. Monthly open-water DO criteria nonattainment percentages for ANATF_MD in the 1993–1995 critical period

year	month	violation rate	
		calibration	179 TN, 12TP
1993	6	0.0%	0.0%
1993	7	20.3%	10.1%
1993	8	100.0%	100.0%
1993	9	53.6%	11.6%
1994	6	79.7%	0.0%
1994	7	100.0%	100.0%
1994	8	20.3%	0.0%
1994	9	20.3%	0.0%
1995	6	100.0%	0.0%
1995	7	100.0%	0.0%
1995	8	0.0%	0.0%
1995	9	0.0%	0.0%

For those months, EPA Chesapeake Bay Program Office (CBPO) analysts compared Bay WQM simulated DO concentration with historical water quality monitoring observations. For July 1994, model simulated DO concentrations at Bay WQM grid cell 6443—the location coincident with monitoring station ANA01—ranged from 7.2 to 13.0 mg/L. In contrast, monitoring observations for the same month ranged from 1.0 to 3.8 mg/L. Similar results were found for the month of August 1993, when Bay WQM-simulated DO concentrations for cell 6443 ranged from 7.5 to 15.5 mg/L while historical observations at the same location (ANA01) ranged from 0.5 to 4.4 mg/L. Because the Bay WQM did not simulate severe hypoxia in the region for those summer months, it was not able to provide a sufficient estimate of the magnitude of DO response to be expected with nitrogen and phosphorous load reductions.

CBPO analysts also considered the attainment status of the two downstream segments closest to ANATF_MD: the District of Columbia's portion of the Anacostia River (ANATF_DC) and the District's portion of the tidal Potomac River (POTTF_DC) (Figure N-10). Unlike segment ANATF_MD, ANATF_DC and POTTF_DC both attained their respective DO WQS at the target basinwide allocation of 190 million pounds per year TN and 12.7 million pounds per year TP.

Given the lack of Bay WQM fit in this segment and the Bay WQM-projected DO WQS attainment of the two segments immediately downstream, EPA concludes that it is reasonable to expect attainment of the DO WQS in Maryland's tidal Anacostia River at the basinwide target allocation of 190 million pounds per year TN and 12.7 million pounds per year TP.

In addition, EPA approved in June 2008, a established by Maryland and the District of Columbia. The TMDL will address any localized water quality impairments.

Cbseg	1985 Scenario 342TN, 24.1TP, 9790TSS '93-'95 DO Open Water Summer Monthly	'91 -'00 Base Scenario 309TN, 19.5TP, 8950TSS '93-'95 DO Open Water Summer Monthly	2009 Scenario 248TN, 16.6TP, 8110TSS '93-'95 DO Open Water Summer Monthly	Target Load Option A 200TN, 15TP, 6390TSS '93-'95 DO Open Water Summer Monthly	Tributary Stategy 191TN 14.4TP, 6462 TSS '93-'95 DO Open Water Summer Monthly	190/13 Loading Scenario 190TN, 13TP, 6123TSS '93-'95 DO Open Water Summer Monthly	190 Loading Scenario 190TN 12.6TP, 6030TSS '93-'95 DO Open Water Summer Monthly
DCATF	38%	28%	10%	14%	1%	2%	1%
DCPTF	10%	1%	0%	0%	0%	0%	0%
MDATF	34%	39%	19%	18%	12%	12%	12%

Figure N-10. Open-water DO criteria nonattainment in ANANTF_MD MDATF and nearby Bay segments. TN, TP, and total suspended sediment loads (TSS) are in million pounds per year.

West Branch Elizabeth River

Violations of the DO WQS were not uncommon in the Western Branch of the Elizabeth River (WBEMH), particularly in the early half of the 1991–2000 decade. Violations of the 5.0 mg/L open-water DO criterion (red line in Figure N-11) were common during summer months, particularly at depths below 0.5 meter.

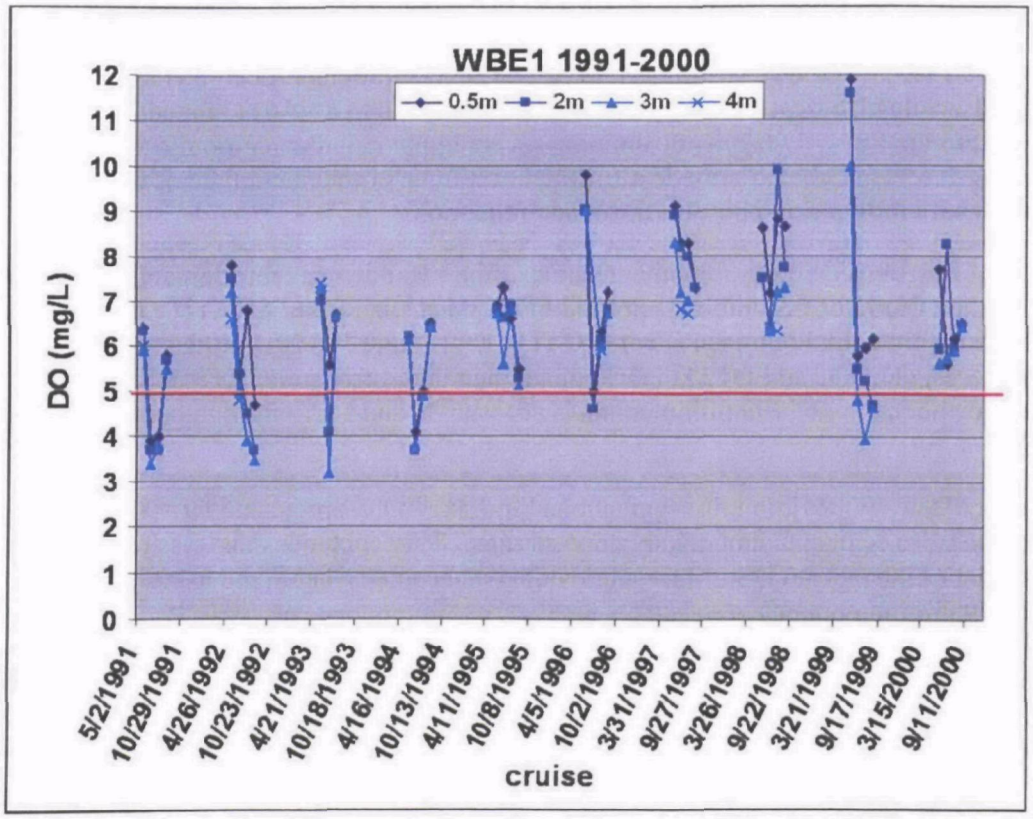


Figure N-11. Summertime DO concentrations observed at water quality monitoring station WBE1 in segment WBEMH 1991–2000.

Some of the violations improved with model-simulated load reductions such as those represented in Table N-2; however, for two months in particular—July 1993 and July 1994—no improvement in monthly violation rate was observed under scenario-modified conditions.

Table N-2. Monthly open-water DO criteria nonattainment percentages for water quality monitoring station WBE1 in the 1993–1995 critical period

		violation rate	
year	month	calibration	179TN, 12TP
1993	6	0.0%	0.0%
1993	7	45.9%	45.9%
1993	8	0.0%	0.0%
1994	6	0.0%	0.0%
1994	7	100.0%	100.0%
1994	8	49.2%	0.0%
1994	9	0.0%	0.0%
1995	6	0.0%	0.0%
1995	7	0.0%	0.0%
1995	8	0.0%	0.0%
1995	9	0.0%	0.0%

Further investigation of model performance in WBEMH showed that the Bay WQM failed to simulate the range of DO concentrations observed at WBE1 for either of these months. While the Bay WQM consistently simulated concentrations greater than 7 mg/L for the Bay WQM cell at station WBE1, monitoring observations for the same month and year were below 5.0 mg/L. In Figure N-12, the pink symbols represent DO concentrations for the calibration scenario; blue symbols and line represent DO concentrations and linear regression for the 179 TN, 12 TP load reduction scenario. Dark blue symbols represent DO observations for July 1994 at depths ranging from 0.5 to 3 meters.

As described for previous segments, when the range of Bay WQM simulations falls in this range, the model fails to provide an estimate of improvement in hypoxic conditions with load reductions.

When Bay WQM simulations do not span the range of hypoxic conditions observed, additional lines of evidence such as the attainment of nearby segments are considered in determining the necessity for further load reductions. In the case of WBEMH, adjacent and nearby segments attained their respective open-water DO WQS at or before the basinwide target nitrogen and phosphorous allocations (Figure N-13).

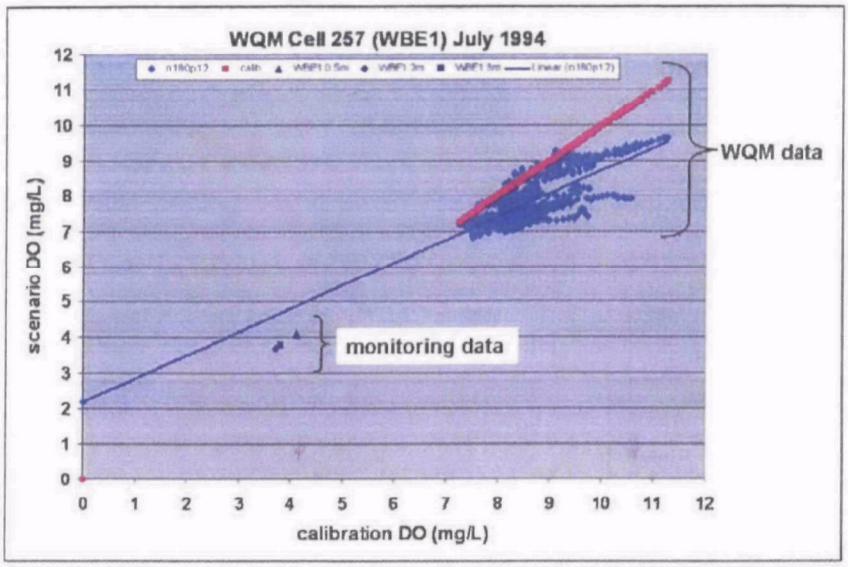


Figure N-12. Chesapeake Bay WQM simulations at WQM cell 257 and observations at water quality monitoring station WBE1 for July 1994.

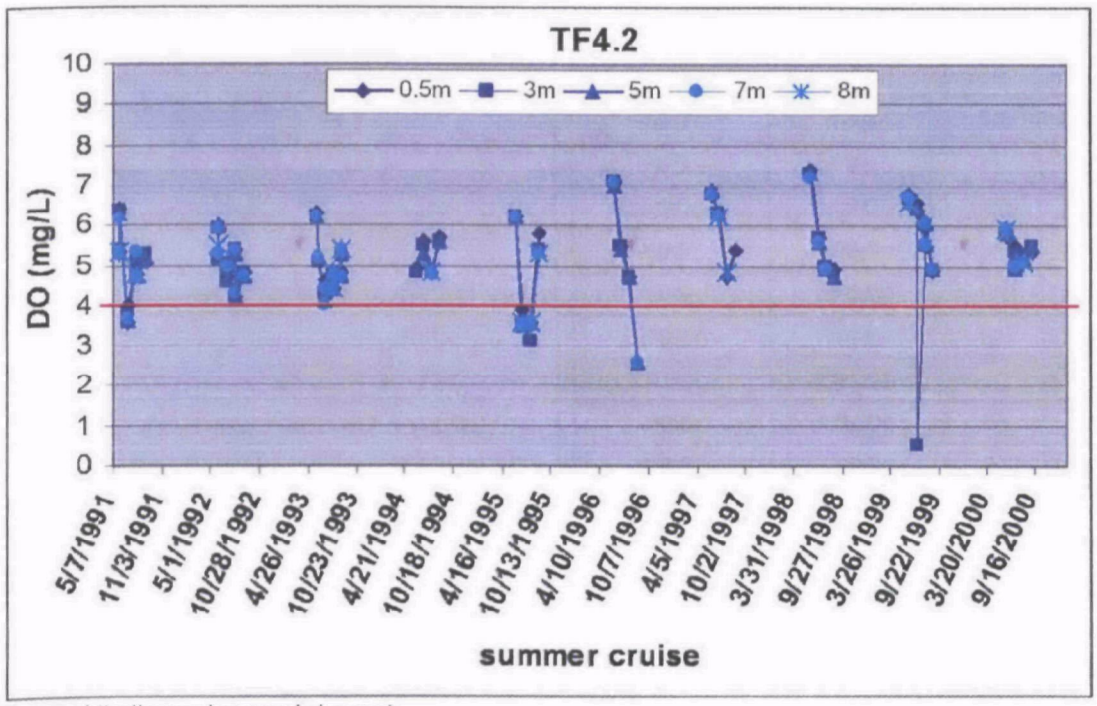
Cbseg	'91 -'00 Base Scenario 309TN, 19.5TP, 8950TSS '93-'95 DO Open Water Summer Monthly	2009 Scenario 248TN, 16.6TP, 8110TSS '93-'95 DO Open Water Summer Monthly	Target Load Option A 200TN, 15TP, 6390TSS '93-'95 DO Open Water Summer Monthly	Tributary Stategy 191TN 14.4TP, 6462 TSS '93-'05 DO Open Water Summer Monthly	190/13 Loading Scenario 190TN, 13TP, 6123TSS '93-'95 DO Open Water Summer Monthly	190 Loading Scenario 190TN 12.6TP, 6030TSS '93-'95 DO Open Water Summer Monthly	179 Loading Scenario 179TN 12.0TP, 5510TSS '93-'95 DO Open Water Summer Monthly	170 Loading Scenario 170TN 11.3TP, 5650TSS '93-'05 DO Open Water Summer Monthly	E3 2010 Scenario 141TN 8.5TP, 5060TSS '93-'95 DO Open Water Summer Monthly
ELIPH	4%	0%	0%	0%	0%	0%	0%	0%	0%
JMSPH	0%	0%	0%	0%	0%	0%	0%	0%	0%
EBEMH	23%	18%	5%	0%	0%	0%	0%	0%	0%
JMSMH	0%	0%	0%	0%	0%	0%	0%	0%	0%
SBEMH	35%	16%	8%	0%	0%	0%	0%	0%	0%
WBEMH	11%	15%	8%	8%	8%	8%	8%	8%	0%

Figure N-13. Attainment of the open-water DO WQS for WBEMH and nearby Bay segments under progressively stringent load reduction scenarios.

While the periodic occurrence of hypoxia in the Western Branch of the Elizabeth River remains a matter of concern, in this case the WQM provided no information on the magnitude of response in DO concentrations to be expected with load reductions. Considering the attainment of DO WQS observed in adjacent segments well before the target basinwide allocation, EPA concludes that it is reasonable to expect attainment of the DO WQS in Western Branch of the Elizabeth River at the basinwide target allocation of 190 million pounds per year TN and 12.7 million pounds per year TP.

Upper Pamunkey River

DO concentrations at station TF4.2 in the upper Pamunkey River (PMKTF) occasionally violated this segment's open-water DO criterion of 4.0 mg/L (Figure N-14). Violations during the 1993–1995 critical period were moderate and limited to the summer of 1995.



Source: http://www.chesapeakebay.net

Figure N-14. Summertime monitored DO concentrations (mg/L) at station TF4.2 in segment PMKTF.

A closer look at DO violations occurring in July and August of 1995 (Table N-3) showed that while DO concentrations in August improved sufficiently to attain WQS with simulated load reductions, no improvement was observed in the July 1995 violation rate.

Investigation of the Bay WQM-derived regression for July 1995 revealed that as with other small tidal tributaries discussed in this section, simulated DO concentrations for the calibration scenario did not match historical observations for the same month and location in the upper Pamunkey River. In Figure N-15, DO concentrations for the 190 TN, 12.7 TP load reduction scenario (blue symbols and linear regression line) showed little or no improvement compared with those of the calibration scenario (pink symbols). DO concentrations for both scenarios were greater than those observed at station TF4.2.

It is also worth noting that the observed violations were only marginally lower than the 4.0 mg/L criterion. Furthermore, the two segments immediately downstream from PMKTF—the lower Pamunkey River (PMKOH) and the mesohaline York River (YRKMH)—attained their respective open-water DO WQS at or before the target load allocation (Figure N-16).

Table N-3. Monthly open-water DO criteria nonattainment percentages for water quality monitoring station TF4.2 in segment PMKTF in the summer months of 1993-1995 critical period

year	month	violation rate	
		calibration	190 TN, 12.7 TP
1993	6	0.0%	0.0%
1993	7	0.0%	0.0%
1993	8	0.0%	0.0%
1993	9	0.0%	0.0%
1994	6	0.0%	0.0%
1994	7	0.0%	0.0%
1994	8	0.0%	0.0%
1994	9	0.0%	0.0%
1995	6	0.0%	0.0%
1995	7	100.0%	100.0%
1995	8	100.0%	0.0%
1995	9	0.0%	0.0%

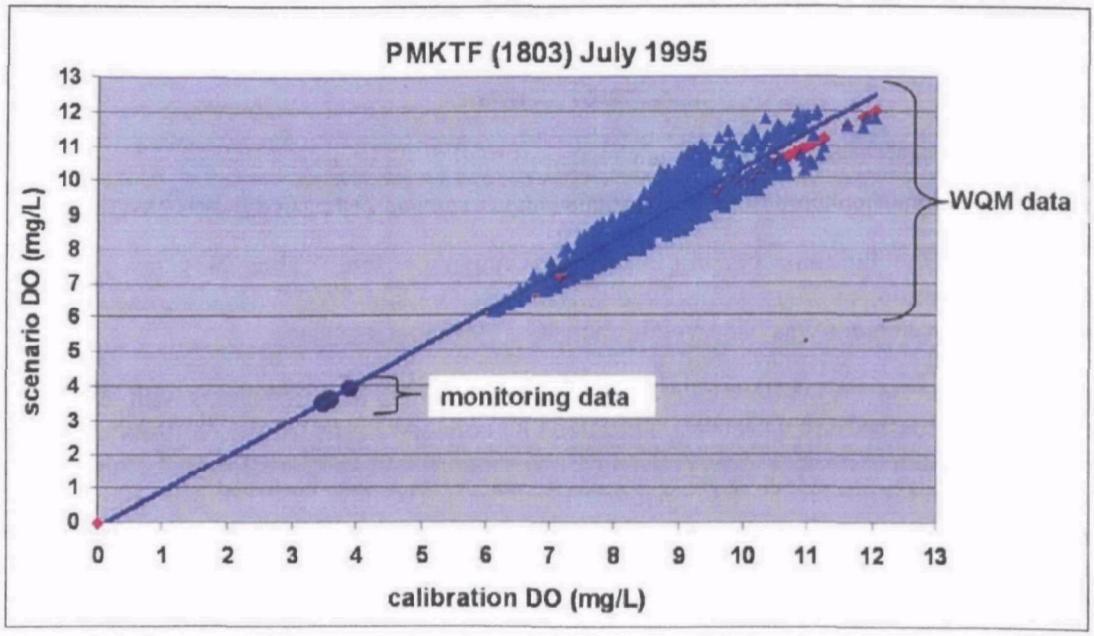


Figure N-15. Simulated DO concentrations for cell 1803, the Bay WQM grid cell coincident with monitoring station TF4.2 in segment PMKTF.

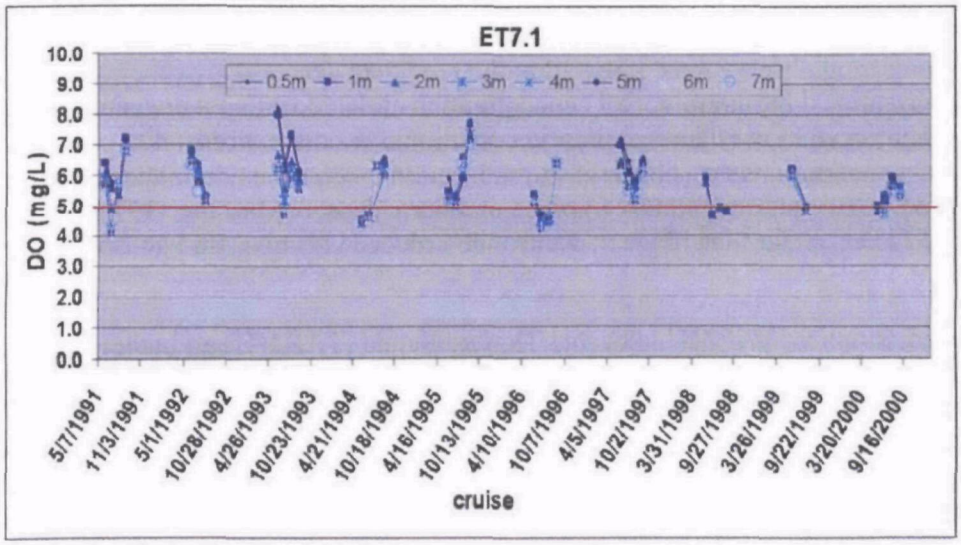
Cbseg	'91 -'00 Base Scenario 309TN, 19.5TP, 8950TSS '93-'95 DO Open Water Summer Monthly	2009 Scenario 248TN, 16.6TP, 8110TSS '93-'95 DO Open Water Summer Monthly	Target Load Option A 200TN, 15TP, 6390TSS '93-'95 DO Open Water Summer Monthly	Tributary Stategy 191TN 14.4TP, 6462 TSS '93-'95 DO Open Water Summer Monthly	190/13 Loading Scenario 190TN, 13TP, 6123TSS '93-'95 DO Open Water Summer Monthly	190 Loading Scenario 190TN 12.6TP, 6030TSS '93-'95 DO Open Water Summer Monthly	179 Loading Scenario 179TN 12.0TP, 5510TSS '93-'95 DO Open Water Summer Monthly	170 Loading Scenario 170TN 11.3TP, 5650TSS '93-'95 DO Open Water Summer Monthly	E3 2010 Scenario 141TN 8.5TP, 5060TSS '93-'95 DO Open Water Summer Monthly
PMKOH	1%	0%	0%	0%	0%	0%	0%	0%	0%
PMKTF	11%	5%	5%	5%	5%	5%	5%	2%	1%
YRKMH	24%	3%	3%	1%	1%	1%	1%	0%	0%

Figure N-16. Attainment of the open-water DO WQS for PMKTF and nearby Bay segments under progressively stringent load reduction scenarios.

Given the mismatch between historical water quality monitoring observations and the Bay WQM simulations in the segment, the complete lack of response in DO concentrations with simulated load reductions, the moderate nature of violations observed in PMKTF for the critical period, and the attainment of the two nearest downstream segments at or before the target basinwide allocation, EPA concludes that it is reasonable to expect attainment of the DO WQS in upper Pamunkey River at the basinwide target allocation of 190 million pounds per year TN and 12.7 million pounds per year TP.

Wicomico River

Moderate excursions below the open-water criterion for Wicomico (WICMH) of 5.0 mg/L were not uncommon in summer months (Figure N-17) between 1991–2000; however, few were extensive enough to cause high percentages of WQS nonattainment. For the 1993–1995 critical period, two months—June and July 1994—had extensive violations of the DO criterion.



Source: http://www.chesapeakebay.net

Figure N-17. DO concentrations observed at station ET7.1 (WICMH) in the summers months 1991–2000.

While the historical violations present in July 1994 were resolved under scenario-modified conditions of the target basinwide allocation (190 TN, 12.7 TP Loading Scenario), DO concentrations in June 1994 showed no improvement in violation rate, even under the extensive load reductions of the E3 Scenario (Table N-4).

Table N-4. Monthly open-water DO criteria nonattainment percentages for water quality monitoring station ET7.1 in segment WICMH in the summer months of 1993–1995 critical period.

WICMH		violation rate		
year	month	calibration	190TN, 12.7TP	E3
1993	6	0.0%	0.0%	0.0%
1993	7	5.5%	0.0%	1.9%
1993	8	0.0%	0.0%	0.0%
1993	9	0.0%	0.0%	0.0%
1994	6	100.0%	100.0%	100.0%
1994	7	100.0%	0.0%	0.0%
1994	8	0.0%	0.0%	0.0%
1994	9	0.0%	0.0%	0.0%
1995	6	0.0%	0.0%	0.0%
1995	7	0.0%	0.0%	0.0%
1995	8	0.0%	0.0%	0.0%
1995	9	0.0%	0.0%	0.0%

Further investigation of the conditions causing the persistent violation revealed that DO concentrations simulated by the Bay WQM's Calibration Scenario for grid cell 7658 are higher than those observed at station ET7.1 for June 1994. In Figure N-18, the DO concentrations observed at station ET7.1 (dark blue symbols) are shown for June 1994. The E3 linear regression falls below those monitoring observations, illustrating the predicted decrease in scenario-modified DO concentrations. Furthermore, DO concentrations in the location were generally similar to (or sometimes even lower than) calibration conditions. In other words, no improvement in DO concentrations was observed at the location when even dramatically reduced loads were simulated. As a result, the mildly hypoxic conditions observed in June 1994 were scenario-modified to lower, rather than higher, values with reduced nitrogen and phosphorous loads.

In contrast with predictions for WICMH, adjacent Tangier Sound (TANMH) and other nearby segments attained DO WQS at or before the target basinwide load allocation (Figure N-19).

As with other segments described herein, the Bay WQM effectively simulated neither the observed historical conditions nor the expected improvement in those conditions with reduced nitrogen and phosphorous loads in this small, shallow region of the Wicomico River. Given the moderate nature of the observed violations the unimpaired condition of adjacent and nearby segments and the considerable level of effort already required of this river basin with the current

target load allocation, EPA considers that it is reasonable to expect WICMH to attain WQS at the target load allocations.

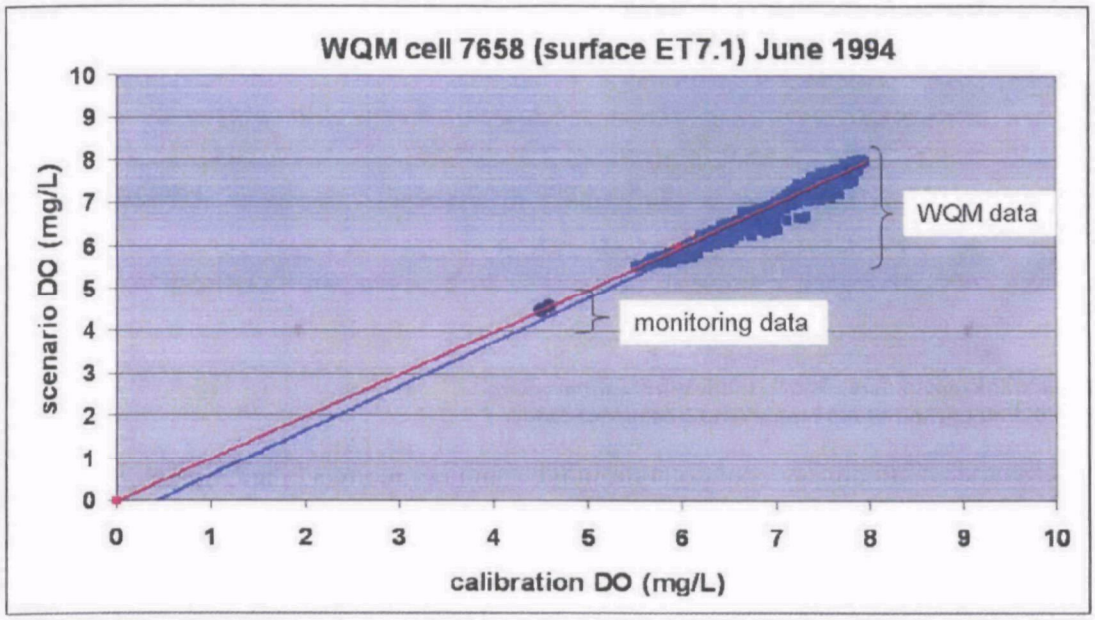


Figure N-18. Simulated DO concentrations for the Calibration Scenario (pink symbols with 1:1 linear regression line) compared to those for the E3 Scenario (blue symbols and blue linear regression line).

Cbseg	1985 Scenario 342TN, 24.1TP, 9790TSS '93-'95 DO Open Water Summer Monthly	'91-'00 Base Scenario 309TN, 19.5TP, 8950TSS '93-'95 DO Open Water Summer Monthly	2009 Scenario 248TN, 16.6TP, 8110TSS '93-'95 DO Open Water Summer Monthly	Target Load Option A 200TN, 15TP, 6390TSS '93-'95 DO Open Water Summer Monthly	Tributary Stategy 191TN 14.4TP, 6462 TSS '93-'95 DO Open Water Summer Monthly	190/13 Loading Scenario 190TN, 13TP, 6123TSS '93-'95 DO Open Water Summer Monthly	190 Loading Scenario 190TN 12.6TP, 6030TSS '93-'95 DO Open Water Summer Monthly	179 Loading Scenario 179TN 12.0TP, 5510TSS '93-'95 DO Open Water Summer Monthly	170 Loading Scenario 170TN 11.3TP, 5650TSS '93-'95 DO Open Water Summer Monthly	E3 2010 Scenario 141TN 8.5TP, 5060TSS '93-'95 DO Open Water Summer Monthly
FSBMH	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
NANMH	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%
TANMH	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
WICMH	11%	11%	11%	15%	5%	5%	5%	5%	5%	5%

Figure N-19. Attainment of the open-water DO WQS for WICMH and nearby Bay segments under progressively stringent load reduction scenarios.

Magothy River

The Magothy River (MAGMH) is a small, shallow tidal tributary adjacent to the upper-central Chesapeake Bay segment CB3MH. The Magothy River is represented by one long-term fixed monitoring station, WT6.1. The narrow, embayment-like nature of the Magothy River is evident in the portion of the Bay WQM grid that represents it; the entire tributary is represented by only five WQM cells. The grid cell representing station WT6.1 highlighted in Figure N-20.

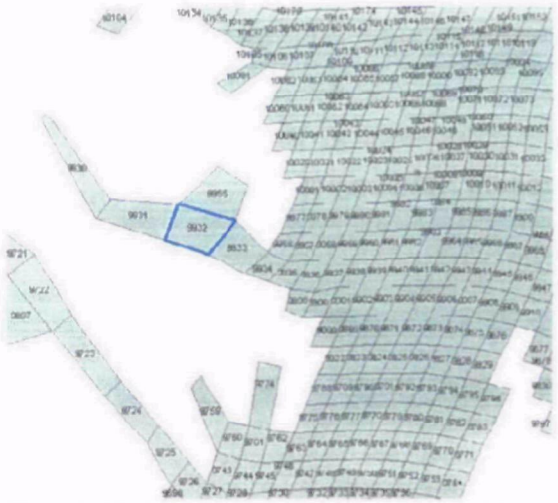
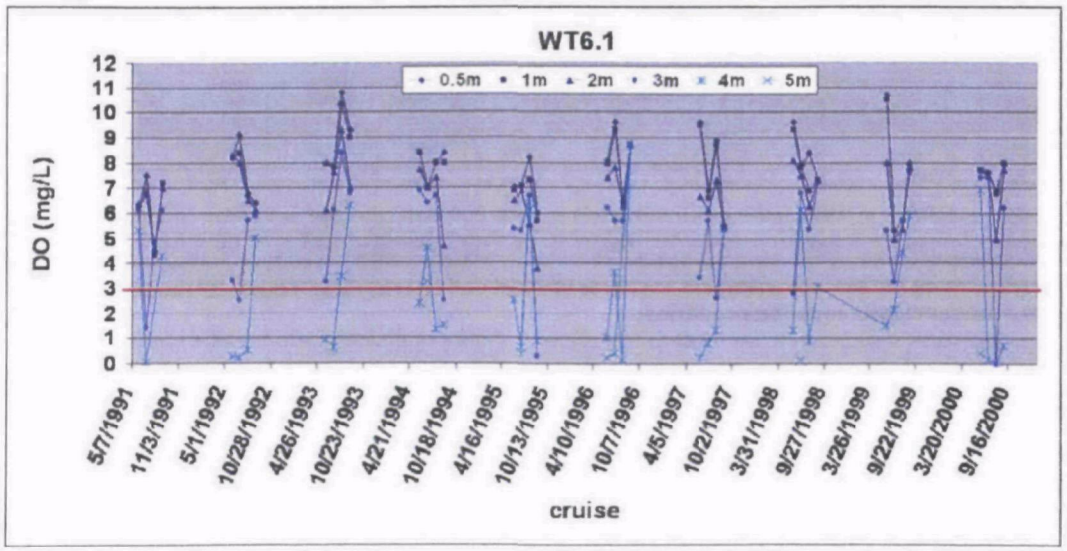


Figure N-20. Chesapeake Bay WQM grid for the Magothy River and the adjoining portion of the mainstem Chesapeake Bay.

Severely hypoxic conditions are common during the summer months in the Magothy River (Figure N-21). Low DO concentrations are often exacerbated by water column stratification, which prevents the vertical mixing that would otherwise re-oxygenate bottom waters. Concentrations often fell below the deep-water criterion of 3.0 mg/L (red line), particularly at depths greater than 2 to 3 meters (Figure N-21). The documented presence of an upper pycnocline boundary in the Magothy River recently led EPA and Maryland to recommend adding a Summer Deep Water designated use to the Magothy River (USEPA 2010). However, even when the deep-water criterion of 3.0 mg/L is applied to stratified bottom waters, nonattainment of the DO WQS persists with simulated load reductions at the level of the target basinwide allocation (see Figure N-23).



Source: http://www.chesapeakebay.net

Figure N-21. DO concentrations observed at station WT6.1 in segment MAGMH during summer months 1991–2000.

Further investigation of the persistent nonattainment of DO WQS observed in MAGMH showed that while violations occurring in some summer months improved with load reductions, hypoxic conditions in other months improved to a much lesser degree or not at all (Table N-5). In particular, violations of the DO criterion that occurred in September 1994 showed no improvement, even when loads were reduced to the 179 TN, 12 TP level.

Table N-5: Summer monthly violation rates for MAGMH during the 1993–1995 critical assessment period

MAGMH		violation rate	
year	month	observed	179 TN 12 TP
1993	6	44.9%	0.0%
1994	9	44.9%	44.9%
1995	7	100.0%	0.0%
1995	8	0.0%	0.0%
1995	9	100.0%	44.9%

The performance of the Bay WQM in the location of the MAGMH monitoring station was examined. As illustrated in Figure N-22, simulated DO concentrations in the WQM cell representing the bottom depths at station WT6.1 were consistently higher than 5.0 mg/L for September 1994. However, historical measurements for the lower depths at station WT6.1 showed concentrations less than 3.0 mg/L. In Figure N-22, the Calibration Scenario (pink symbols and regression line) is compared with the 179 TN, 12.0 TP Loading Scenario (light blue symbols and linear regression). Historical observations (dark blue circles) fall well outside the range of simulations. As described previously, the failure of the Bay WQM to simulate hypoxic conditions affects its ability to predict the magnitude of improvement that will occur in DO concentrations when nitrogen and phosphorous loads are reduced.

The inability of the Bay WQM to simulate the hypoxic conditions observed during summer months in the Magothy River reduces its ability to predict the magnitude of improvement in DO concentrations that can be expected as nitrogen and phosphorous loads are reduced. However, the Bay WQM much more effectively simulates historical conditions and, therefore, predicted improvements, in nearby deeper, wider regions of the Chesapeake Bay. Thus, the predicted attainment of WQS in the deep-water designated use of CB3MH, well before the target basinwide load allocation (see Figure N-23), can help to inform expectations of attainment for the Magothy River.

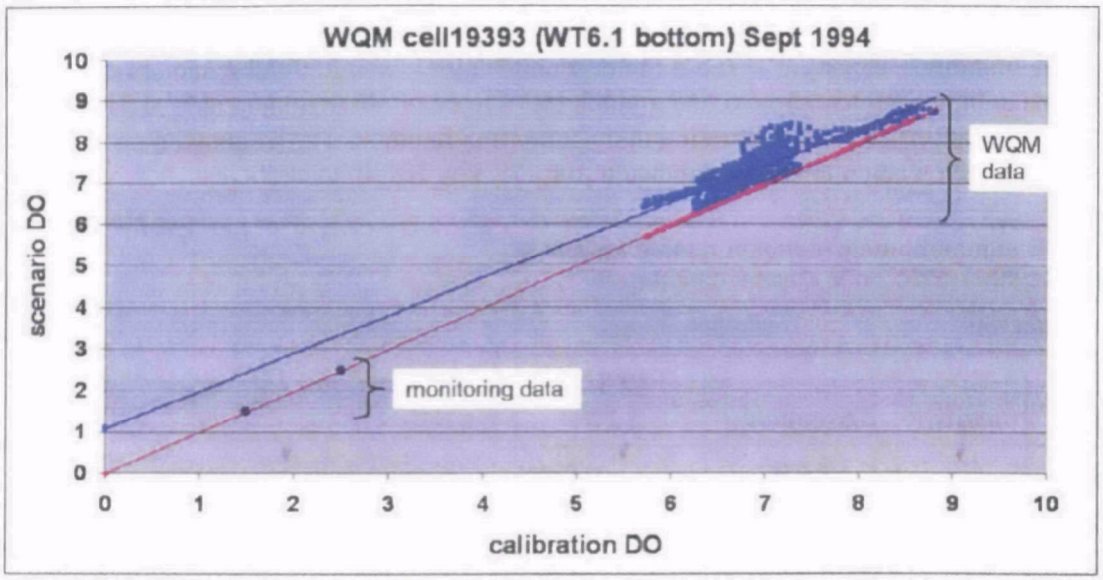


Figure N-22. Simulated DO concentrations in grid cell 19393 of the Bay WQM for September 1994.

Cbseg	1985 Scenario 342TN, 24.1TP, 9790TSS '93-'95 DO Deep Water	'91-'00 Base Scenario 309TN, 19.5TP, 8950TSS '93-'95 DO Deep Water	2009 Scenario 248TN, 16.6TP, 8110TSS '93-'95 DO Deep Water	Target Load Option A 200TN, 15TP, 6390TSS '93-'95 DO Deep Water	Tributary Strategy 191TN 14.4TP, 6462 TSS '93-'95 DO Deep Water	190/13 Loading Scenario 190TN, 13TP, 6123TSS '93-'95 DO Deep Water	190 Loading Scenario 190TN 12.5TP, 6030TSS '93-'95 DO Deep Water	179 Loading Scenario 179TN 12.0TP, 5510TSS '93-'95 DO Deep Water	170 Loading Scenario 170TN 11.3TP, 5650TSS '93-'95 DO Deep Water	E3 2010 Scenario 141TN 8.5TP, 5060TSS '93-'95 DO Deep Water
CB3MH	3%	2%	0%	0%	0%	0%	0%	0%	0%	0%
MAGMH	35%	35%	35%	16%	16%	16%	3%	3%	1%	1%

Figure N-23. Predicted attainment of DO WQS for the summer deep-water designated use in CB3MH and MAGMH.

While the severely hypoxic conditions commonly observed in the Magothy River during the summer months remain a matter of concern, EPA lacks data to effectively predict the recovery of the Magothy River in those months when the Bay water quality fails to simulate historical conditions. However, given attainment of adjacent deep-waters of CB3MH, and the extensive load reductions already required of the Magothy River basin for the target basinwide allocation of 190 million pounds per year TN and 12.7 million pounds per year TP, EPA anticipates that the MAGMH deep-water designated use will attain WQS when the target load allocation is achieved.

Resolution of Segments Failing to Attain the SAV/Water Clarity Criteria

After assessing attainment of the combined submerged aquatic vegetation (SAV)/water clarity criteria on the basis of Bay Water Quality/Sediment Transport Model outputs for the nitrogen and phosphorous Allocation Scenario (190 TN/12.7 TP), four Bay segments were initially found to be in nonattainment of the SAV/water clarity criteria.

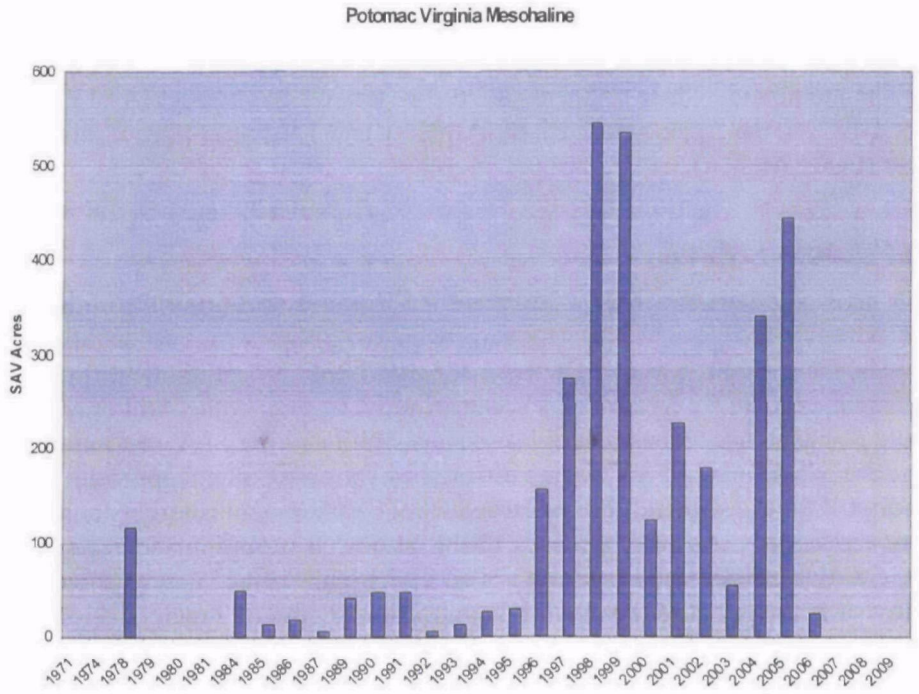
On the basis of recent observed SAV acre or allowance of 1 percent nonattainment of the water clarity criteria (see Section 6.6.2 and Appendix I), the four remaining segments were judged to actually be currently in attainment. Those segments are the Mattawoman Creek (MATTF), the Gunpowder River (GUNOH), the Appomattox River (APPTF), and Virginia's portion of the lower Potomac River (POTMH_VA).

Virginia Middle Potomac River

The SAV restoration acreage criterion is for 4,250 acres for Virginia's portion of the middle Potomac River (POTMH_VA) (Figure N-24). At the nitrogen and phosphorous Allocation Scenario loading levels, the segment was at 10 percent nonattainment. Nonattainment was persistent and was estimated to be 9 percent at E3 Scenario and 6 percent at the All Forest Scenario nitrogen and phosphorous and sediment load levels. With its high SAV restoration acreage criterion and the low levels of SAV acres estimated by the assessment approach described in Appendix P for the segment, the estimated level of attainment is largely achieved through water clarity acres only. As a consequence of the high SAV restoration acreage criterion, the calculated water clarity acreage-based criterion is also very high—10,625 acres. However, the available shallow-water area out to the maximum application depth of 2 meters is less than the water clarity acres criterion for this segment.

The observed SAV record shows overall improvement in SAV coverage in recent years. Because the 1993–1995 SAV coverage was close to its lowest recorded acreage, EPA used the recent observed SAV area (2004–2005) in the SAV/water clarity criteria assessment procedure described in Appendix P. Starting with this SAV acreage, more consistent with recent years of observed SAV acreage (Figure N-25), Virginia's portion of the lower Potomac River achieved its SAV/water clarity WQS at the sediment allocation levels.

Figure N-24. The location of the different embayments of Virginia's portion of the lower Potomac River (above left) and its representation of the Nomini Bay region of the segment by the Chesapeake Bay WQM (above right).



Source: http://www.vims.edu/bio/sav

Figure N-25. Observed SAV acres in Virginia' lower Potomac River segment.

Mattawoman Tidal Fresh—MATTF

Initially, the Mattawoman Creek (Figure N-26) appeared to be in nonattainment of its SAV/water clarity standards on the basis of Bay WQM simulation of the nitrogen and phosphorous Allocation Scenario loading levels. Subsequently, a fuller analysis that included the recent SAV monitoring data found that the Mattawoman Creek segment had 877 acres of observed SAV in 2008, and 866 acres in 2009 (Figure N-27). Both recent years of observed SAV exceeded the 792 acres SAV restoration acreage criterion. From the recent observed SAV data and the upward trend of SAV expected with continued nitrogen and phosphorous and sediment reduction in the Mattawoman Creek, those other lines of evidence supported the finding that the sediment allocations for this segment will achieve the SAV standards.

Figure N-26. The location of Mattawoman Creek in the upper Potomac River (above left) and the Chesapeake Bay WQM representation of Mattawoman Creek (above right).

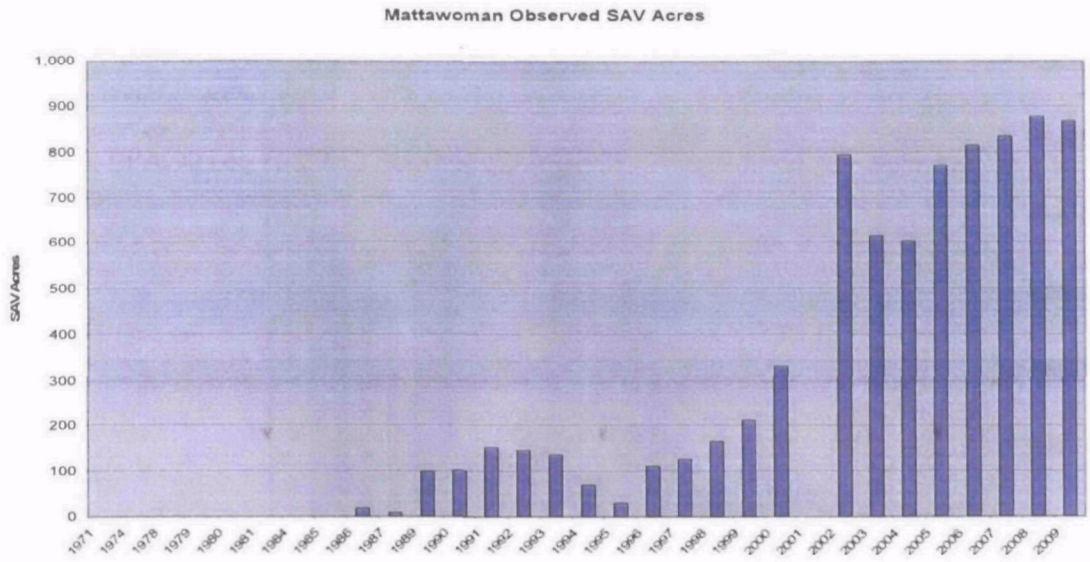


Figure N-27. The observed SAV data for Mattawoman Creek from 1971 to 2009.

Gunpowder River

Initially, the Gunpowder River (GUNOH) (Figure N-28) appeared to be in nonattainment of its SAV/water clarity standards according to the Bay WQM simulation of the nitrogen and phosphorous Allocation Scenario loading levels. Subsequent analysis found that the Gunpowder River segment had essentially reached its SAV restoration acreage criterion of 2,432 acres in recent years (2000, 2004) and found a generally increasing trend of SAV expansion as nitrogen and phosphorous and sediment loads continue to decrease toward the allocation scenario loads (Figure N-29). Consequently, that other line of evidence supports the finding that further sediment reductions beyond the phosphorus-based sediment loads within the nitrogen and phosphorous Allocation Scenario would be unwarranted.

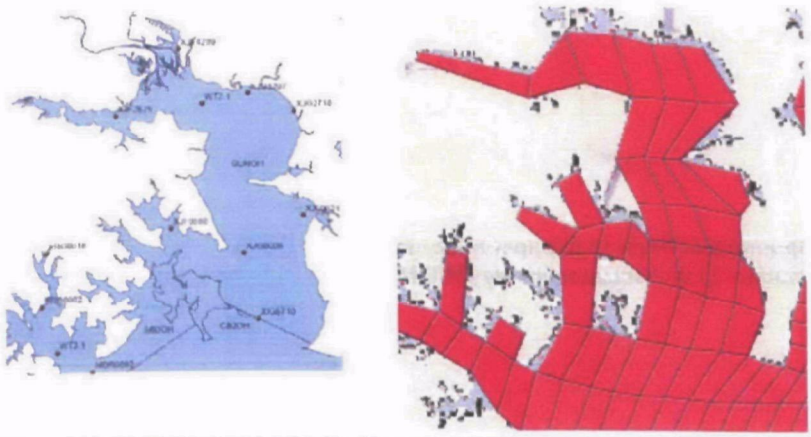


Figure N-28. The location of the Gunpowder River (above left) and the Chesapeake Bay WQM representation of Gunpowder River (above right).

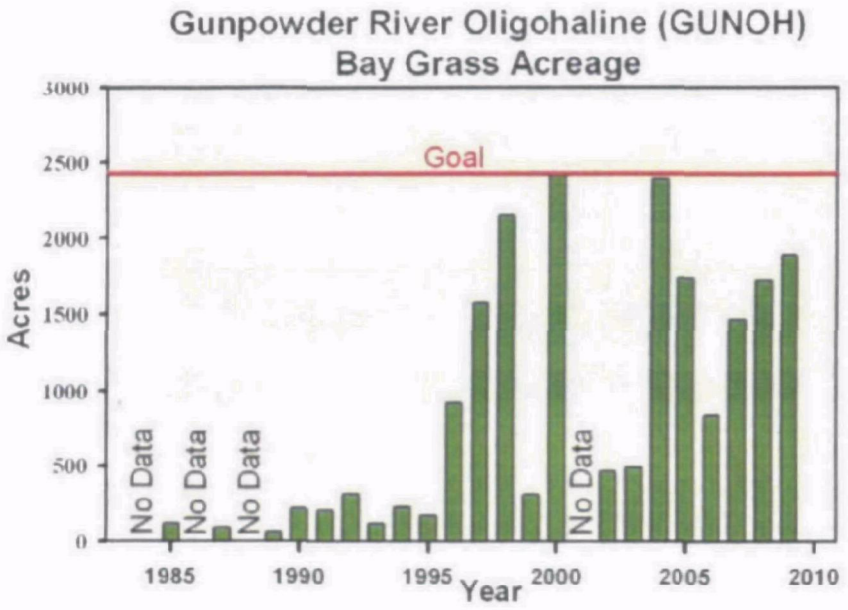


Figure N-29. The observed SAV data for the Gunpowder River from 1985 to 2009.

Appomattox River

In the Appomattox River (Figure N-30), the SAV restoration acreage criterion is 379 acres, although no SAV has been observed from 1978 to present. A persistent, low-level nonattainment (1 percent), which is based on attainment of the water clarity criteria only, is estimated at the Sediment Allocation Scenario loading level. Allowance of 1 percent persistent nonattainment of the water clarity criteria moves the segment into attainment.

Figure N-30. The location of the Appomattox River in the upper tidal James River (above left) and its representation by the Chesapeake Bay WQM (above right).

References

USEPA (U.S. Environmental Protection Agency). 2010. *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries: 2010 Technical Support for Criteria Assessment Protocols Addendum.* May 2010. EPA 903-R-10-002. CBP/TRS 301-10. U.S. Environmental Protection Agency, Region 3 Chesapeake Bay Program Office, Annapolis, MD.

Appendix O.
Setting the Chlorophyll *a* Criteria-Based Nutrient Allocations for the James River Watershed

The initial Draft Target Load Allocation of 190 million pounds per year (mpy) total nitrogen (TN) and 12.7 mpy total phosphorus (TP) was determined on the basis of attainment of Chesapeake Bay basinwide numeric dissolved oxygen standards. At that loading level, an assessment of predicted chlorophyll *a* concentrations showed nonattainment of Virginia's numeric chlorophyll *a* water quality standard (WQS) in the James River for several 3-year assessment periods, in multiple segments and in both spring and summer seasons (see Figure O-1). The narrative rationale for Virginia's numeric chlorophyll *a* criteria (see Table O-1) is described in EPA's 2003 *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll* a *for the Chesapeake Bay and Its Tidal Tributaries* (USEPA 2003a).

Cbseg	190 Loading Scenario 190TN, 12.7TP, 6030TSS '91-'93 CL Spring Seasonal	190 Loading Scenario 190TN, 12.7TP, 6030TSS '92-'94 CL Spring Seasonal	190 Loading Scenario 190TN, 12.7TP, 6030TSS '93-'95 CL Spring Seasonal	190 Loading Scenario 190TN, 12.7TP, 6030TSS '94-'96 CL Spring Seasonal	190 Loading Scenario 190TN, 12.7TP, 6030TSS '95-'97 CL Spring Seasonal	190 Loading Scenario 190TN, 12.7TP, 6030TSS '96-'98 CL Spring Seasonal	190 Loading Scenario 190TN, 12.7TP, 6030TSS '97-'99 CL Spring Seasonal	190 Loading Scenario 190TN, 12.7TP, 6030TSS '98-'00 CL Spring Seasonal
JMSTFL	0%	0%	2%	2%	2%	0%	0%	0%
JMSTFU	0%	0%	0%	0%	0%	0%	0%	0%
JMSOH	0%	0%	0%	4%	4%	4%	0%	5%
JMSMH	3%	1%	0%	0%	0%	0%	0%	0%
JMSPH	0%	0%	0%	0%	0%	0%	0%	0%
Cbseg	**CL Summer Seasonal**	**CL Summer Seasonal**	**CL Summer Seasonal**	**CL Summer Seasonal**	**CL Summer Seasonal**	**CL Summer Seasonal**	**CL Summer Seasonal**	**CL Summer Seasonal**
JMSTFL	0%	0%	0%	0%	5%	15%	15%	8%
JMSTFU	0%	0%	0%	0%	0%	0%	0%	0%
JMSOH	0%	0%	0%	0%	0%	0%	0%	0%
JMSMH	0%	0%	0%	0%	0%	0%	15%	14%
JMSPH	0%	0%	0%	0%	0%	0%	11%	11%

For this scenario, the James River Basin allocation is 26.6 mpy TN and 2.7 mpy TP. Failure to attain WQS is shown in red text as percent nonattainment.

Figure O-1. Attainment of numeric chlorophyll *a* WQS in the James River at the draft Target Load Chesapeake Bay basinwide allocation of 190 mpy TN and 12.7 mpy TP.

Table O-1. James River numeric chlorophyll *a* criteria

Segment	Seasonal mean criterion (µg/L) spring/summer
JMSTFU	10/15
JMSTFL	15/23
JMSOH	15/22
JMSMH	12/10
JMSPH	12/10

µg/L = micrograms per liter

To identify the level of load reductions necessary to achieve chlorophyll *a* WQS in the James River, the EPA Chesapeake Bay Program's (CBP's) modeling and monitoring teams investigated the underlying drivers of those remaining instances of nonattainment.

Determining Chlorophyll *a* attainment for spring in the Tidal Fresh James River

First, the drivers of nonattainment in the lower tidal fresh James during the spring for the three assessment periods spanning 1993–1997 were examined. For all three assessment periods, failure to attain the WQS at draft target loading levels was driven by conditions and estimated levels of improvement in the spring of 1995 at stations TF5.5 and TF5.5A, where chlorophyll *a* concentrations exceeding the seasonal mean chlorophyll *a* criterion of 15 µg/L were observed.

Stations TF5.5 and TF5.5A are marked with black dots and circled in red.

Figure O-2. James Tidal Fresh Lower (JMSTFL) segment of the James River, with long-term fixed monitoring stations shown.

CBP analysts next investigated whether the estuarine Water Quality Sediment Transport Model (WQSTM) was sufficiently calibrated to observed conditions in that region of the James River. A comparison of observed values at station TF5.5 with those generated by the WQSTM during its calibration run demonstrated that the WQSTM simulated the range of surface chlorophyll *a* conditions experienced in the region in 1995 (Figure O-3).

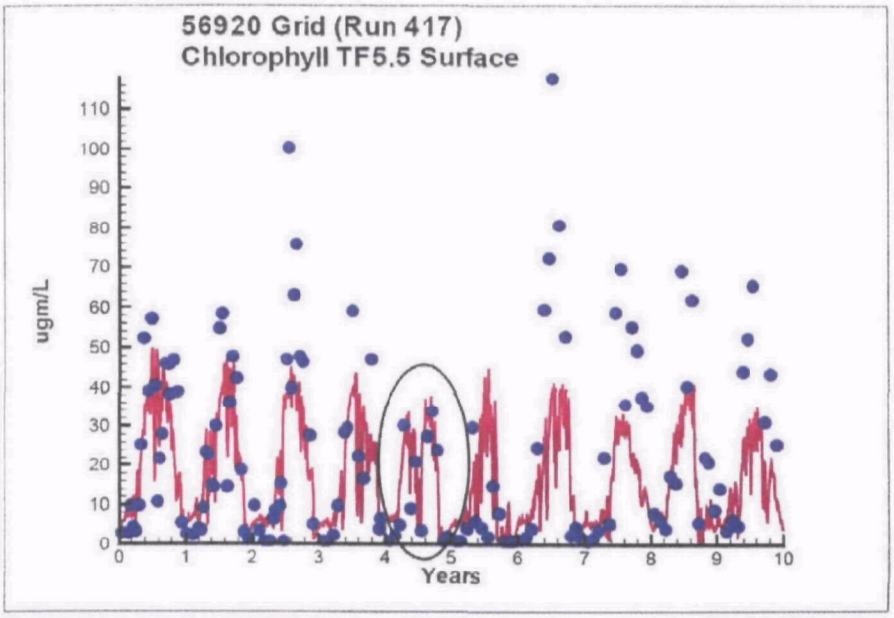


Figure O-3. Plot comparing WQSTM-simulated surface chlorophyll *a* values (red line) with historical observations (blue dots). For the year 1995 (circled in black), simulated values captured the range of observed conditions.

Furthermore, a comparison of the WQSTM's response to load reductions in the region showed a consistent response in the form of a reduction of undesirable surface chlorophyll *a* levels (i.e., those exceeding the seasonal mean criterion) when loads were reduced (see Table O-2). From those lines of evidence, it was determined that this instance of nonattainment represented a best available estimate of remaining nonattainment in the JMSTFL for the spring seasons of 1993–1995, 1994–1996, and 1995–1997 periods. Those periods reached attainment of WQS with the *170 TN, 11.3TP Loading Scenario*, for which James River Basin loads were 25.5 mpy TN and 2.5 mpy TP. At that loading level, some individual surface chlorophyll *a* values exceeded the seasonal mean criterion, but the average seasonal degree of criteria violation fell within the allowable exceedance of 1 percent.

Table O-2. Observed and scenario-modified chlorophyll *a* concentrations (µg/L) at stations TF5.5 (a) and TF5.5A (b) in the spring of 1995. The 26.6 TN, 2.7 TP loading level represents James River Basin load reductions for the global 190 TN, 12.7 TP loading.

(a)

TF5.5			
Month	observed	26.6 TN 2.7 TP	25.5 TN 2.5 TP
March 1995	5.1	5.5	5.6
April 1995	30.2	18.8	17.7
May 1995	9.1	7.7	7.2

(b)

TF5.5A			
Month	observed	26.6 TN 2.7 TP	25.5 TN 2.5 TP
March 1995	48.7	29.7	26.8
April 1995	38.8	21.8	20.3
May 1995	7.7	9.6	9.2

Verification of the violations described above, and determination of their resolution at the James River-specific loading level of 25.5 mpy TN and 2.5 mpy TP, enabled EPA CBP analysts to confirm a minimum required reduction scenario for James River to this loading level.

Determining the remaining Chlorophyll *a* attainment in the James River

Remaining violations at the 25.5 mpy TN/2.5 mpy TP loading level (170 Loading Scenario) were investigated. To determine the maximum necessary additional loading reductions, analysts focused on the greatest remaining levels of nonattainment—those occurring for the summer season in JMSTFL, JMSMH, and JMSPH (see Figure O-4).

Cbseg	170 Loading Scenario 25.5 TN, 2.5TP '91-'93	170 Loading Scenario 25.5 TN, 2.5TP '92-'94	170 Loading Scenario 25.5 TN, 2.5TP '93-'95	170 Loading Scenario 25.5 TN, 2.5TP '94-'96	170 Loading Scenario 25.5 TN, 2.5TP '95-'97	170 Loading Scenario 25.5 TN, 2.5TP '96-'98	170 Loading Scenario 25.5 TN, 2.5TP '97-'99	170 Loading Scenario 25.5 TN, 2.5TP '98-'00
	CL Spring Seasonal	CL Spring Seasonal	CL Spring Seasonal	CL Spring Seasonal	CL Spring Seasonal	CL Spring Seasonal	CL Spring Seasonal	CL Spring Seasonal
JMSTFL	0%	0%	1%	1%	1%	0%	0%	0%
JMSTFU	0%	0%	0%	0%	0%	0%	0%	0%
JMSOH	0%	0%	0%	2%	2%	2%	0%	2%
JMSMH	2%	0%	0%	0%	0%	0%	0%	0%
JMSPH	0%	0%	0%	0%	0%	0%	0%	0%
Cbseg	CL Summer Seasonal	CL Summer Seasonal	CL Summer Seasonal	CL Summer Seasonal	CL Summer Seasonal	CL Summer Seasonal	CL Summer Seasonal	CL Summer Seasonal
JMSTFL	0%	0%	0%	0%	4%	11%	11%	4%
JMSTFU	0%	0%	0%	0%	0%	0%	0%	0%
JMSOH	0%	0%	0%	0%	0%	0%	0%	0%
JMSMH	0%	0%	0%	0%	0%	0%	12%	12%
JMSPH	0%	0%	0%	0%	0%	0%	9%	9%

For this scenario, the James River Basin allocation is 25.5 mpy TN and 2.5 mpy TP.
Failure to attain WQS is shown in red text as percent nonattainment.

Figure O-4. Attainment of numeric chlorophyll *a* WQS in the James River at the Chesapeake Bay basinwide loading level of 170 mpy TN and 11.3 mpy TP.

Using the same systematic procedure employed for the JMSTFL violations described above, the 12 percent nonattainment observed for JMSMH in the summers of 1997–1999 and 1998–2000 was examined. The primary driver of the nonattainment was traced to conditions occurring at James River monitoring stations LE5.2 and LE5.3 in September 1999. Examination of observed and scenario-modified data for the summer of 1999 in the region of LE5.2 and LE5.3 showed that individual historical observations did in some cases exceed the summer seasonal mean criterion of 10 µg/L for JMSMH. But more importantly, the regression equations used to scenario-modify chlorophyll *a* concentrations (for details on the scenario-modification procedure, see Section 6.4) at the stations in September 1999 were generating *higher* chlorophyll *a* concentrations with reduced loads rather than lower concentrations.

A comparison of the WQSTM simulation against observed values at LE5.3 showed that the WQSTM simulated the range of surface chlorophyll *a* conditions observed in 1999 (see Figure O-5). For the year 1999 (circled in black), simulated values captured the range of observed conditions.

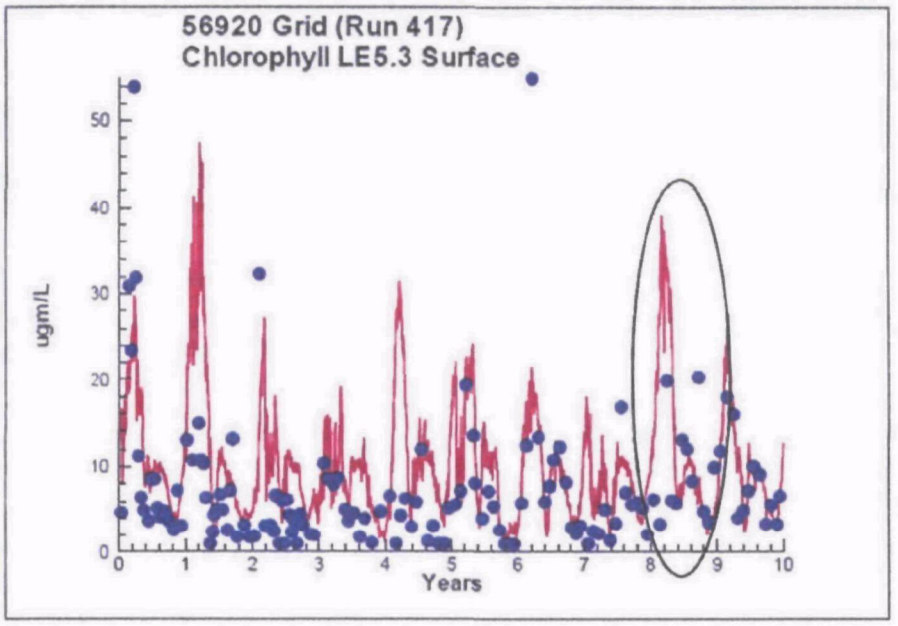


Figure O-5. Plot comparing WQSTM-simulated surface chlorophyll *a* values (red line) with historical observations (blue dots).

A closer look at simulated surface conditions at LE5.2 and LE5.3 in the summer of 1999 showed that from June through early September, simulated chlorophyll *a* concentrations were within the range or moderately lower than observed surface chlorophyll *a* values and that chlorophyll *a* concentrations consistently declined when loads were reduced. However, an anomaly occurred in some driver of the model simulation that caused poor scenario performance in the latter half of September 1999 at LE5.2 (see Figure O-6) and, to a lesser degree, LE5.3 (not shown). Specifically, chlorophyll *a* concentrations suddenly increased in all scenarios, and concentrations for the load reduction scenarios increased to even higher levels than for the calibration scenario.

For most of the summer, load reduction scenarios such as the 179 TN/12.0 TP loading scenario (light blue symbols and line, *180 TN*) and the E3 scenario (dark blue symbols and line, *E3*) simulated consistently reduced surface chlorophyll *a* concentrations relative to the calibration scenario (pink symbols and line, *calib*). After September 15, load reduction scenarios generated higher chlorophyll *a* concentrations than the calibration scenario. As a result, regression equations used to scenario-modify chlorophyll *a* observations from September 1999 generated higher chlorophyll *a* concentrations under reduced loading scenarios.

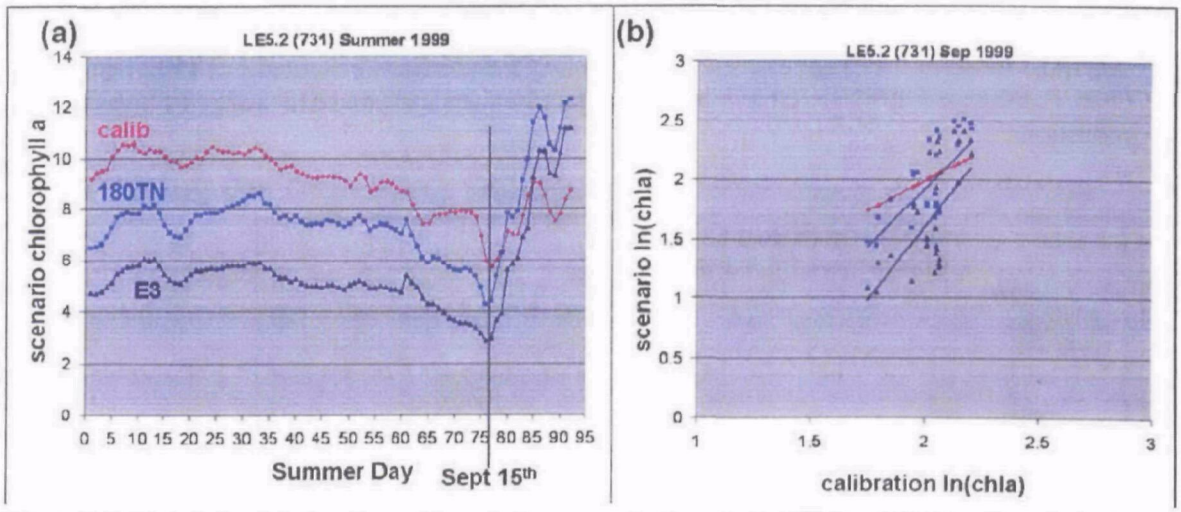


Figure O-6. Plot of simulated surface chlorophyll *a* concentrations for WQSTM cell 731 (location of station LE5.2) during the summer of 1999 (a), and resulting regression plot for September 1999 LE5.2 chlorophyll *a* (b).

The effect of that anomaly was to generate flawed regression equations for the September period which caused chlorophyll *a* observations to be scenario-modified to higher rather than lower concentrations under reduced-load scenarios (see Table O-3).

Table O-3. Observed, scenario-modified (190 TN), and refined scenario-modifed chlorophyll *a* concentrations at LE5.2 in summer 1999

LE5.2	chlorophyll *a* (µg/L)		
Month	Observed	190 TN	190 TN, refined
July 1999	11.1	8.94	8.94
August 1999	6.19	5.34	5.34
September 1999	14.0	23.7	10.8

When the anomalous data generated after September 15 were removed from the analysis, the resulting regression equations better reflected the information provided by the WQSTM with regard to predicted improvements in chlorophyll *a* concentrations with reduced pollutant loads. Using the *refined regression* for September 1999, the percent nonattainment of 12 percent for JMSMH in the summer 1997–1999 and 1998–2000 summer periods shown in Figure O-5 declined to only 2 percent at the 170 Loading Scenario level of 25.5 mpy TN and 2.5 mpy TP for the James River Basin.

As with the violations described for JMSTFL above, the newly verified nonattainment levels were used to identify further load reductions required to achieve attainment of summer seasonal WQS in JMSMH. Scenarios were generated with progressively more stringent load reductions. Attainment of summer seasonal chlorophyll *a* WQS was achieved in JMSMH for the 1997–1999 and 1998–2000 assessment periods at the 23.5 TN, 2.35 TP loading level for the James River Basin (see Figure O-7).

Cbseg	23.5 TN 2.35 TP '91-'93 CL Spring Seasonal	23.5 TN 2.35 TP '92-'94 CL Spring Seasonal	23.5 TN 2.35 TP '93-'95 CL Spring Seasonal	23.5 TN 2.35 TP '94-'96 CL Spring Seasonal	23.5 TN 2.35 TP '95-'97 CL Spring Seasonal	23.5 TN 2.35 TP '96-'98 CL Spring Seasonal	23.5 TN 2.35 TP '97-'99 CL Spring Seasonal	23.5 TN 2.35 TP '98-'00 CL Spring Seasonal
JMSTFL	0%	0%	0%	0%	0%	0%	0%	0%
JMSTFU	0%	0%	0%	0%	0%	0%	0%	0%
JMSOH	0%	0%	0%	0%	0%	0%	0%	0%
JMSMH	1%	0%	0%	0%	0%	0%	0%	0%
JMSPH	0%	0%	0%	0%	0%	0%	0%	0%
Cbseg	CL Summer Seasonal	CL Summer Seasonal	CL Summer Seasonal	CL Summer Seasonal	CL Summer Seasonal	CL Summer Seasonal	CL Summer Seasonal	CL Summer Seasonal
JMSTFL	0%	0%	0%	0%	2%	6%	6%	2%
JMSTFU	0%	0%	0%	0%	0%	0%	0%	0%
JMSOH	0%	0%	0%	0%	0%	0%	0%	0%
JMSMH	0%	0%	0%	0%	0%	0%	1%	1%
JMSPH	0%	0%	0%	0%	0%	0%	9%	9%

Figure O-7. Attainment stoplight plot of James River chlorophyll *a* WQS for the 23.5 TN, 2.35 TP load reduction scenario. Highlighted fields show attainment in JMSMH for summers 1997–1999 and 1998–2000.

At that load reduction level, two blocks of nonattainment remained: JMSTFL summer for the assessment periods 1995–1997 through 1998–2000, and JMSPH summer for the assessment periods 1997–1999 and 1998–2000.

Summer nonattainment in JMSPH for assessment periods 1997–1999 and 1998–2000 was traced to conditions at station LE5.4W in the summer of 1999. Chlorophyll *a* concentrations in that region consistently exceeded the summer seasonal mean criterion for JMSPH of 10 µg/L (see Table O-4).

Table O-4. Observed and scenario-modified chlorophyll *a* concentrations at LE5.5-W in the summer of 1999

LE5.5W	chlorophyll *a* (µg/L)		
Month	Observed	26.6 TN, 2.7 TP	25.5 TN/2.5 TP
July 1999 cruise 1	14.7	11.9	11.3
July 1999 cruise 2	22.7	19.3	18.3
Aug 1999 cruise 1	12.9	9.98	9.48
Aug 1999 cruise 2	14.2	11.0	10.4
September 1999	39.2	15.5	14.0

When historical observations fall well outside the range of concentrations simulated by the water quality model, the WQSTM's ability to estimate the predicted magnitude of response to reduced loads is compromised. Some of the concentrations observed at LE5.5W in the summer of 1999 were within the range of the WQSTM simulations. However, the September 1999 observation of 39.2 µg/L was well outside the range of simulated conditions, reducing confidence in estimates of expected improvement in chlorophyll *a* concentrations. While concern remains regarding such clear violations of chlorophyll *a* WQS, insufficient information exists to justify further load

reductions from estimates of remaining nonattainment for JMSPH in the 1997–1999 and 1998–2000 assessment periods.

The case of remaining summer nonattainment in JMSTFL is similar to that of JMSPH but even more pronounced. Remaining nonattainment could be traced back to summer conditions in 1997 and 1998, when surface chlorophyll *a* concentrations regularly exceeded the summer seasonal mean criterion of 23 µg/L. In Figure O-3, summer observations ranging from about 50 to more than 100 µg/L can be seen to far exceed the WQSTM's simulated average summer conditions for the region. Similarly, conditions at station TF5.5A ranged from 75.6 to 113 µg/L in the summer of 1997. Such bloom conditions exceed the range of simulated conditions to such a degree that it is difficult to predict the expected magnitude of improvement with load reductions. Therefore, insufficient information exists to justify further load reductions on the basis of estimates of remaining nonattainment for JMSTFL in those summer assessment periods.

Using the information gained from the analyses described above, the chlorophyll *a*-based nutrient load allocations for the James River Basin were set at 23.5 mpy TN and 2.35 mpy TP. At that load allocation, verified events of nonattainment in JMSTFL for the spring seasons of 1993–1995, 1994–1996, and 1995–1997, as well as verified events of nonattainment in JMSMH for the summer seasons of 1997–1999 and 1998–2000, were resolved. Regions with remaining instances of nonattainment (i.e., JMSTFL and JMSPH summer seasonal conditions) will be closely monitored in coming years to ensure that the allocated load reductions result in the conditions necessary to achieve attainment of chlorophyll *a* WQS.

Appendix P. Setting the Water Clarity/SAV Criteria-Based Sediment Allocations

Appendix P is comprised of the following written appendix coupled with a spreadsheet (Appendix P SAV Coverage 1971- 2009 Spreadsheet.xls) that shows observed SAV for Bay segments in 1971-2009. The observed SAV areas from 102 segments are aggregated into SAV areas for the 8 tidal basins for each year.

Appendix P.
Setting the SAV/Water Clarity Criteria Based Sediment Allocations

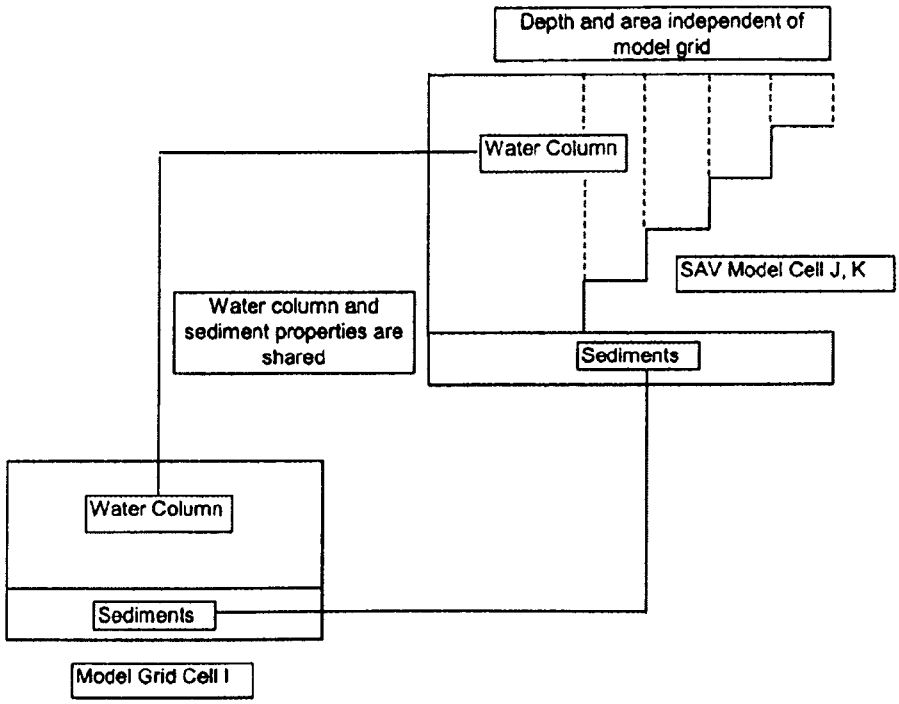
Introduction

The scale of the Chesapeake Bay Program partnership's models extend from the extreme of the continental scale of the Community Multiscale Air Quality Bay Airshed Model and watershed-wide scale of the Phase 5.3 Bay Watershed Model to the other extreme of the narrow ribbon of shallow water adjacent to the Bay's more than 11,000 miles of tidal shoreline. The ribbon of shallow water of 2 meters or less in depth is the region where the jurisdictions' submerged aquatic vegetation (SAV)/water clarity criteria are applied to assess protection of the shallow-water bay grass designated use. This region of a convoluted shoreline is spatially and temporally more heterogeneous than the rest of the Chesapeake Bay Water Quality and Sediment Transport Model (WQSTM) domain covering the open and contiguous waters of the Chesapeake. Episodic loads from shoreline erosion, resuspension, and watershed inputs all transit this narrow band of land and water interface.

The challenge of assessing SAV and water clarity criteria at these scales has only recently been taken up by the Chesapeake Bay Program partnerships in the past 5 years. Monitoring, modeling and research in these shallow-water systems is in its relative infancy compared to the more mature environmental science surrounding dissolved oxygen in eutrophic estuarine ecosystems. In addition, while moving toward these finer scales, the retention of system-wide representation of loading sources, boundary conditions must be preserved.

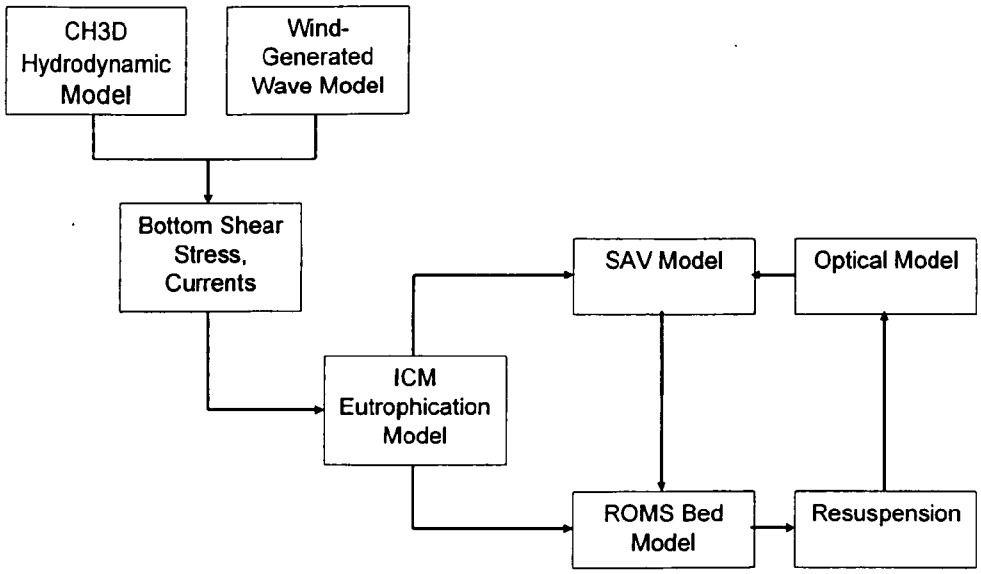
Key Model Refinements in Simulating Water Clarity-SAV

The Bay Water Quality Model used in setting the 2003 Chesapeake Bay nutrient and sediment allocations (Cerco and Noel 2004; Linker et al. 2000; Cerco et al. 2004) was refined to include full sediment transport of four classes of inert particulates approximating the settling and transport behavior of sand, silt, clay, and a sediment fraction of slowly settling clay. The resulting Chesapeake Bay WQSTM was capable of resolving turbidity maximum zones in the Bay and appropriately setting the boundary conditions for the shallow water region of the SAV/water clarity criteria. Resuspension of sediment was generated by currents, both tidal and residual, and by waves. Additional refinements included high resolution at half-meter depths of the shallow-water SAV growth areas (Figure P-1), an advanced optics model of underwater light attenuation, improvements to the SAV simulation, and refinements to shoreline erosion. Those model refinements and additions are shown schematically in Figure P-2.



Source: Cerco et al. 2010

Figure P-1. A schematic of the half-meter depths of the SAV sub-grid unit cells mapped to the WQSTM grid cell, which provides light attenuation and other model state variables the SAV growth cell.

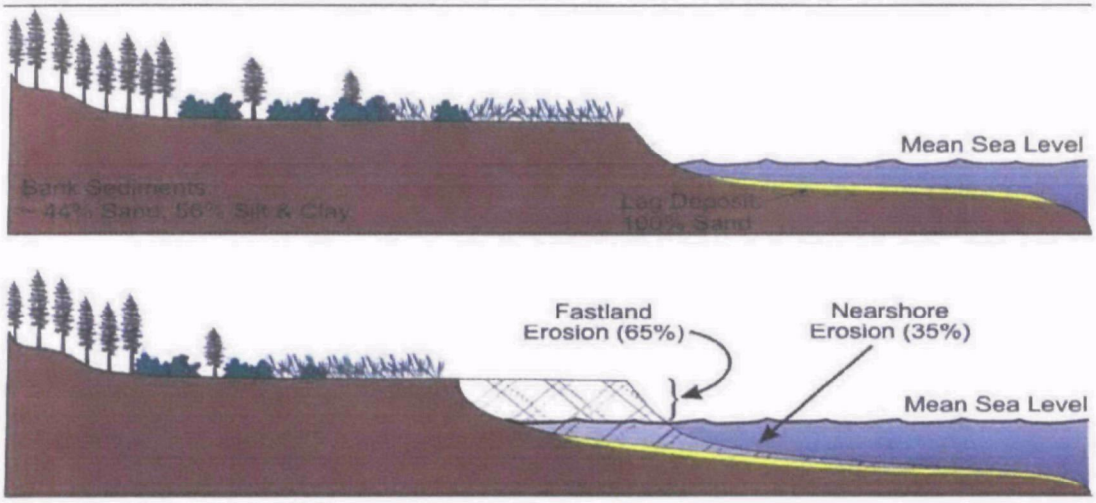


Source: Cerco et al. 2010

Figure P-2. A schematic of the WQSTM refinements applied for the simulation of the SAV/water clarity water quality standard.

Refinements to Shore Erosion Estimates

Consistent temporal and spatial data for erosion rates, bank heights, shoreline protection, and sediment type were needed for the entire Chesapeake Bay to better estimate the role of shoreline erosion in the overall sediment budget (Hennessee et al. 2006; Hardaway et al. 1992). The refined shoreline sediment load estimates included both bank load (e.g., fastland erosion) and nearshore erosion (Figure P-3). Spatially explicit erosion rates by *reach* that allowed for variance with bank height, shoreline orientation, and sediment composition were calculated. Best estimates of the actual shoreline lengths were used, including reduced erosion rates for enclosed minor inlets where reduced wave and current erosion would be expected. The different shoreline loading estimates were then incorporated into the appropriate WQSTM cells.



Source: Hopkins and Halka 2007

Figure P-3. Example of fastland and nearshore components of the shoreline sediment loads.

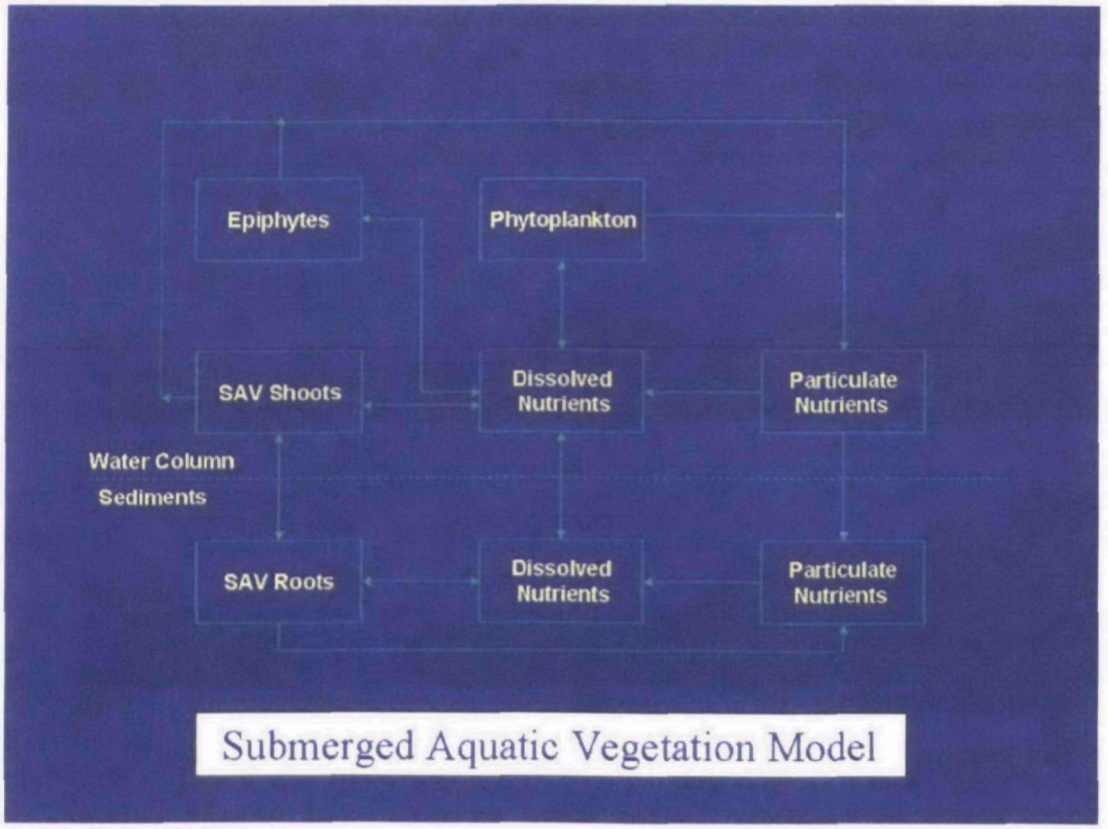
For unprotected shorelines the shoreline erosion computation was as follows:

- Eroded Fastland Volume = Shoreline Length × Elevation × Erosion Rate/Day
- Total Eroded (Fastland + Nearshore) = Fastland Mass / 0.65
- Eroded Silt/Clay Mass = Total Eroded Volume × Bulk Density × Silt Clay %
- Different silt/clay proportions for bank and marsh sources (Applied to Maryland portion tidal shoreline only)
- Different silt/clay proportions for north and south banks of each major river (Applied to Virginia tidal shoreline only)

For protected shorelines everywhere, the assumption was that fastland erosion was eliminated, but that nearshore erosion continued. Nearshore erosion was estimated for protected shorelines by using adjacent or nearby unprotected shoreline.

Simulating SAV

The unit SAV simulation computes SAV density (mass / unit area) as a function of irradiance and nutrients for SAV shoot and roots as shown in Figure P-4. Irradiance and epiphytes are calculated separately, and the SAV model fully interacts with water column and bed sediments (see Figure P-4).



Source: Cerco 2009

Figure P-4. The Chesapeake Bay WQSTM's SAV unit model.

The current simulation of SAV considers light to be the sole determinant of SAV abundance, but other factors such as composition of bottom substrate, SAV community structure, and seed bank availability are significant. Those factors are not explicitly simulated in the WQSTM but are accounted for via an empirical *probability of success.*

The probability function was empirically set to best represent SAV biomass under current nutrient loads and adjusted to improve the probability of SAV growth under conditions that are more representative of mid-1900s Chesapeake nutrient loads (Hagy et al. 2004). The use of the empirically set probability function for SAV allowed appropriate SAV levels to best simulate water clarity, which was solely used to assess the water clarity criteria. Moving forward, in the next generation of the Bay Model, the probability function will be replaced with salient first principal forcing functions.

Process of Assessing the Water Clarity-SAV Criteria

Three methods are used to assess attainment of the Bay jurisdictions' SAV/water clarity water quality standards. Any one of the following three methods can be used to determine whether the SAV and water clarity goal is achieved. The SAV/water clarity criteria assessment applied to the Bay WQSTM scenario output is always on the combined SAV and water clarity criteria assessment method.

Using only acres of SAV coverage: A segment attains the goal if the SAV acreage of single best year in the segment is met in the preceding 3 years (including the current year) (USEPA 2003).

Using only water clarity acres: A segment attains the goal if the single best year water clarity acreage in the preceding 3 years exceeds 2.5 times the SAV restoration acreage. The water clarity acres for a year are assessed on the basis of the arithmetic mean of monthly water clarity in the criteria months that meets the water clarity criteria (see Section 3.1.4, Table 3-5 of the TMDL Report) (USEPA 2007).

Using combined SAV and water clarity achievement: This method considers both the achieved SAV acreage and water clarity acre in a segment. In the assessment, the water clarity acre can be converted to an SAV-equivalent acre by dividing the water clarity acre by 2.5, which will be credited along with the SAV coverage estimated by regression model.

Estimating SAV/Water Clarity in a WQSTM Loading Scenario

In the combined SAV and water clarity assessment, both the SAV acres and water clarity acres need to be estimated in load-reduction scenarios. The light extinction coefficient, *Ke*, is the metric used to measure water clarity. The Ke in a load-reduction scenario is estimated using the Chesapeake Bay WQSTM. The SAV area in a load reduction scenario is estimated from a regression model.

Ke Assessment by the WQSTM

The simulated Ke in the WQSTM is based on the amounts of simulated clay, silt, sand, organic particulates, and dissolved organic matters in a model cell. Because the simulated Ke is an imperfect representation of the observed Ke, a data-correction method is used to obtain an adjusted scenario Ke in each shallow cell for the target loading scenario. While several more sophisticated data correction methods were tried, a simple proportional adjustment of the shallow-water Ke to the nearest observed water quality monitoring station was found to provide the best shallow-water data correction as determined by independent, shallow-water monitoring sites.

The shallow-water bay grass designated-use habitat is considered the are located between the 2-meter depth contour and the adjacent shoreline. A segment consists of Bay WQSTM cells. Because of inconsistency between the model cell boundary and the 2-meter contour area, EPA remapped and extended the model cells to cover tidal water up to the shoreline, and subdivided the area into 0–0.5 meters, 0.5–1.0 meters, 1.0–1.5 meters, and 1.5–2.0 meter depths. For each half-meter contour area, EPA applies corresponding Ke criteria (see Section 3, Table 3-5). Note

that the areas of defined no-growth zone are excluded from the cell segment area in the assessment.

Credit of SAV Area Based on Observed SAV Area

The projected SAV acreage in a target scenario is based on a regression of observed SAV in the Bay segments which, together, compose the major tributaries and the nutrient and sediment loads from each corresponding land basin (i.e., the major subwatershed) of the Chesapeake Bay watershed, which provides loads to the collective set of segments (Table P-1).

Through the Baywide SAV aerial survey, the partners have access to annual SAV distribution and abundance data for almost every year in the past 30 years. The attached Excel file, Appendix P SAV Coverage 1971-2009 Spreadsheet.xls, shows observed SAV for Bay segments in 1971-2009. The observed SAV areas from 102 segments are aggregated into SAV areas for the 8 tidal basins for each year.

Total nitrogen (TN), total phosphorus (TP), and total suspended sediment (TSS) loads from the 8 major basins are estimated from the Phase 5.3 Chesapeake Bay Watershed Model's progress scenarios under years 1985, 1987, 1992, 1998, 2002, 2005, 2007, and 2009 management conditions.

Linear regression of SAV versus load of TN or TP or TSS, respectively, is conducted for each basin, yields

$$SAV = m\,\text{Load} + b$$

where, coefficient m is the slope and b is the intercept from the linear regression. The results are presented in Table P-1.

For individual basins, we use the regression of SAV with Load component TN or TP or TSS, which has the highest R2 of regression.

The Bay TMDL's critical period of 1993–1995 is our reference for the TMDL. The load in the reference year for each basin can be estimated from Bay Watershed Model calibration, and the corresponding SAV is known from the observation. They also have the relationship

$$SAV_ref = m\,Load_ref + b.$$

A projected SAV of the basin in a load reduction scenario is calculated as follows:

$$Proj_SAV = m\,Proj_load + b$$

Therefore, $Proj_SAV - SAV_ref = m\,(Proj_load - Load_ref)$.

We can calculate the ratio

$$Rate = Proj_SAV / SAV_ref = (Proj_SAV - SAV_ref) / SAV_ref + 1 = m\,(Proj_load - Load_ref) / SAV_ref + 1 = (m\,(Proj_load - Load_ref) + SAV_ref) / SAV_ref$$

Thus, the projected SAV of this basin for the target loading scenario can also be estimated by

$$Proj_SAV = Rate \times SAV_ref.$$

EPA assumes that the rate calculated from a major river basin is applicable to individual Bay segments contained within that basin. That rate is then used to calculate projected SAV in the reference hydrology year for each Bay segment within that basin:

$$Proj_SAV\ (seg) = Rate \times SAV_ref\ (seg).$$

The projected SAV in segments is then used for SAV credit in the assessment.

Table P-1. Results of linear regression of SAV versus TN, TP, and TSS loads for 8 major basins

Basin	Component	R2	Slope	Intercept
Susquehanna	TN	0.8983	-4.16E+02	6.43E+04
Susquehanna	TS	0.8049	-2.77E+01	9.11E+04
Susquehanna	TP	0.6847	-8.54E+03	5.12E+04
Potomac	TN	0.9068	-2.85E+02	2.82E+04
Potomac	TS	0.8769	-2.13E+01	6.83E+04
Potomac	TP	0.8449	-1.28E+04	7.04E+04
York	TN	0.0468	1.09E+03	1.79E+03
York	TS	0.8948	-8.81E+01	2.65E+04
York	TP	0.7539	-9.38E+03	1.79E+04
Eastern Shore	TN	0.1615	-1.87E+03	7.69E+04
Eastern Shore	TS	0.5769	-2.29E+02	1.20E+05
Eastern Shore	TP	0.3518	-2.18E+04	8.09E+04
Rappahannock	TN	0.5900	-6.93E+02	6.57E+03
Rappahannock	TS	0.5425	-8.42E+00	7.88E+03
Rappahannock	TP	0.6609	-5.44E+03	7.68E+03
James	TN	0.9624	-8.54E+00	3.81E+02
James	TS	0.8763	-3.59E-01	5.89E+02
James	TP	0.7467	-3.27E+01	2.21E+02
MD Western Shore	TN	0.5437	-2.35E+02	6.11E+03
MD Western Shore	TS	0.7106	-4.79E+01	1.49E+04
MD Western Shore	TP	0.5361	-3.50E+03	5.17E+03
Patuxent	TN	0.5940	-2.02E+02	9.31E+02
Patuxent	TS	0.5693	-3.66E+00	7.66E+02
Patuxent	TP	0.3253	-1.38E+03	6.89E+02

Assessing Attainment of the SAV/Water Clarity Standard

Before the assessment, EPA converted the SAV restoration goal acreage (see Section 3.1.4, Table 3-6 of the TMDL Report) with a factor of 2.5 to establish the water clarity acre for each Bay segment.

For individual months, EPA compared the monthly average Ke in a cell at four depth-interval areas (0–0.5, 0.5–1.0, 1.0–1.5, and 1.5–2.0) with the applicable water clarity criterion for the four

application depths (i.e., 0.5, 1.0, 1.5, and 2.0), respectively. If it meets the criterion for that depth, the area is accounted. Adding the area achieving the water clarity criterion for each depth of all cells in the segment, yields the total area achieving the water clarity criterion for the month. Averaging (using arithmetic mean) the monthly achieving areas in the criteria months (i.e., SAV growing seasons—see Section 3.1.4, Table 3.5 of the TMDL Report) produces the water clarity acres for that year for each segment. If the water clarity acre is smaller than the SAV area, EPA uses 2.5 of the assessed SAV area as the total water clarity acre from the combined SAV/water clarity assessment in the year. If the water clarity acre is greater than the SAV area, EPA credits 1.5 of the assessed SAV area, into the total water clarity acre of this year for this combined SAV water clarity assessment.

Finally, the water clarity acre in single best year of the 3 consecutive assessment years (i.e., 1993–1995 hydrology years) is regarded as the achieved water clarity acreage. If the achieved water clarity acre was greater than the water clarity acre goal (i.e., 2.5 times SAV acre goal), the combined SAV/water clarity criteria were projected to be achieved in this segment under model loading scenario. Otherwise, i.e., the achieved water clarity acre is less than the water clarity acre goal, a percent violation is calculated as follows:

100 × (water clarity acre goal – water clarity acre) ÷ water clarity acre goal.

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Appendix Q. Detailed Annual Chesapeake Bay TMDL WLAs and LAs

Appendix Q is an allocation spreadsheet (Appendix Q_Annual TMDLs_final.xls) that contains components of the Chesapeake Bay TMDLs that were developed for total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) (sediment). Detailed source allocations of successful TMDL scenarios are provided as wasteload allocations (WLAs) for individual and aggregate point sources and load allocations (LAs) for specific nonpoint source sectors. The TMDL components and supporting information are presented in tabular format in separate pages of the allocation spreadsheet. Each page is formatted so that the user may select from one of the pull-down menus in the table header to view specific details regarding a particular stream or pollutant source. Appendix Q is comprised of the following tables:

- Introduction – The Introduction provides a description of each of the tables included in the allocation spreadsheet.
- Watershed Map and Major Basins – This table presents a listing of the 92 impaired segments with the corresponding Jurisdiction, CB Segment Name, and Major Basin. Additionally, two figures are provided showing the location of the 92 impaired segments and also the location of the major river basins in the Chesapeake Bay watershed.
- Annual TMDLs_92 Segments – This table contains the components of the TMDL equation for the 92 impaired segments for TN, TP, and TSS, in average annual terms. Nitrogen and phosphorus have an implicit margin of safety (MOS) while sediment has both an implicit and explicit MOS.
- Annual Individual WLAs – This table contains individual WLAs for the 478 significant point sources permitted to discharge throughout the Chesapeake Bay watershed as well as 10 MS4 point sources permitted to discharge in Virginia. Individual WLAs are presented as edge of stream (EOS) and delivered load for each of the 92 impaired segments by NPDES permit number for TN, TP, and TSS.
- Annual Aggregate WLAs – This table contains aggregate WLAs for specific permitted sectors that discharge throughout the Chesapeake Bay watershed. Aggregate WLAs are presented as delivered load for each of the 92 impaired segments by NPDES permit number for TN, TP, and TSS. Additionally, aggregate WLAs are presented as EOS load for wastewater aggregates for each of the 92 impaired segments by NPDES permit number for TN, TP, and TSS.
- Annual Land Based LAs – This table contains detailed Land Based LAs for specific nonpoint source sectors: agriculture, forest, nontidal atmospheric deposition, onsite septic, and urban. Land Based LAs are presented as delivered load for each of the 92 impaired segments by jurisdiction and by nonpoint source sector for TN, TP, and TSS.
- NPDES Permit Inventory – This table contains the NPDES permit inventory for all permits addressed in the Chesapeake Bay TMDL. Each permit is listed by jurisdiction, facility name, NPDES permit number, significant or nonsignificant, discharge type, SIC Code, SIC Description, Location by County, Receiving Water, Major Model River Basin, Bay Segment, Land River Segment, Number Land River Segment, WIP defined flow, latitude, and longitude.
- NPDES Permit Inventory Notes – This table provides notes containing additional information for certain permits listed in the NPDES Permit Inventory tab.

Appendix R. Chesapeake Bay TMDL Daily WLAs and LAs

Appendix R is an allocation spreadsheet (Appendix R_Daily TMDLs_final.xls) that contains components of the Chesapeake Bay TMDLs that were developed for total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) (sediment). Detailed source allocations of successful TMDL scenarios are provided as wasteload allocations (WLAs) for individual and aggregate point sources and load allocations (LAs) for specific nonpoint source sectors. The TMDL components and supporting information are presented in tabular format in separate pages of the allocation spreadsheet. Each page is formatted so that the user may select from one of the pull-down menus in the table header to view specific details regarding a particular stream or pollutant source. Appendix R is comprised of the following tables:

- Introduction – The Introduction provides a description of each of the tables included in the allocation spreadsheet.
- Watershed Map and Major Basins – This table presents a listing of the 92 impaired segments with the corresponding Jurisdiction, CB Segment Name, and Major Basin. Additionally, two figures are provided showing the location of the 92 impaired segments and also the location of the major river basins in the Chesapeake Bay watershed.
- Daily TMDLs_92 Segments – This table contains the components of the TMDL equation for the 92 impaired segments for TN, TP, and TSS, in daily loads. Nitrogen and phosphorus have an implicit margin of safety (MOS) while sediment has both an implicit and explicit MOS.
- Daily Individual WLAs – This table contains daily individual WLAs for the 478 significant point sources permitted to discharge throughout the Chesapeake Bay watershed as well as 10 MS4 point sources permitted to discharge in Virginia. Individual WLAs are presented as edge of stream (EOS) and delivered load for each of the 92 impaired segments by NPDES permit number for TN, TP, and TSS.
- Daily Aggregate WLAs – This table contains daily aggregate WLAs for specific permitted sectors that discharge throughout the Chesapeake Bay watershed. Aggregate WLAs are presented as delivered load for each of the 92 impaired segments by NPDES permit number for TN, TP, and TSS. Additionally, aggregate WLAs are presented as EOS load for wastewater aggregates for each of the 92 impaired segments by NPDES permit number for TN, TP, and TSS.
- Daily Land Based LAs – This table contains daily Land Based LAs for specific nonpoint source sectors: agriculture, forest, nontidal atmospheric deposition, onsite septic, and urban. Land Based LAs are presented as delivered load for each of the 92 impaired segments by jurisdiction and by nonpoint source sector for TN, TP, and TSS.
- NPDES Permit Inventory – This table contains the NPDES permit inventory for all permits addressed in the Chesapeake Bay TMDL. Each permit is listed by jurisdiction, facility name, NPDES permit number, significant or nonsignificant, discharge type, SIC Code, SIC Description, Location by County, Receiving Water, Major Model River Basin, Bay Segment, Land River Segment, Number Land River Segment, WIP defined flow, latitude, and longitude.
- NPDES Permit Inventory Notes – This table provides notes containing additional information for certain permits listed in the NPDES Permit Inventory tab.

Appendix S.
Offsetting New or Increased Loadings of Nitrogen, Phosphorus, and Sediment to the Chesapeake Bay Watershed

As an assumption of the Chesapeake Bay total maximum daily load (TMDL), U.S. Environmental Protection Agency (EPA) expects Chesapeake Bay jurisdictions to account for and manage new or increased loadings of nitrogen, phosphorus, and sediment.

As explained in Section 10.1, where the TMDL does not provide a specific allocation to accommodate new or increased loadings of nitrogen, phosphorus, or sediment, a jurisdiction may accommodate such new or increased loadings only through a mechanism allowing for quantifiable and accountable offsets of the new or increased load in an amount necessary to implement the TMDL and applicable water quality standards (WQS) in the Chesapeake Bay and its tidal tributaries.

Therefore, the Chesapeake Bay TMDL assumes and EPA expects that the jurisdictions will accommodate any new or increased loadings of nitrogen, phosphorus, or sediment that lack a specific allocation in the TMDL with appropriate offsets supported by credible and transparent offset programs subject to EPA and independent oversight. This appendix provides details of common elements from which EPA expects the jurisdictions to develop and implement offset programs.

Source Documents

The common elements are based on, and consistent with, the following documents provided or made available to the jurisdictions:

National Guidance

- *Water Quality Trading Policy*, EPA, 2003 (http://www.epa.gov/owow/watershed/trading/finalpolicy2003.pdf).
- *Water Quality Trading Toolkit for NPDES Permit Writers*, EPA, 2007 (http://www.epa.gov/owow/watershed/trading/WQTToolkit.html).

Regional/Chesapeake Bay Specific Documents

- *Expectations Letter*, EPA Region 3 to Principals' Staff Committee, Nov. 4, 2009 (http://www.epa.gov/reg3wapd/pdf/pdf_chesbay/tmdl_implementation_letter_110409.pdf).
- *Federal Actions Letter*, EPA Region 3 to Chesapeake Bay jurisdictions, Dec. 29, 2009 (http://www.epa.gov/region3/chesapeake/bay_letter_1209.pdf).
- *A Guide for EPA's Evaluation of Phase I Watershed Implementation Plans*, EPA Region 3, Apr. 2, 2010 (http://archive.chesapeakebay.net/pubs/Guide_for_EPA_WIP_Evaluation_4-2-10.pdf).

- *Strategy for Protecting and Restoring the Chesapeake Bay Watershed*, Federal Leadership Committee, May 12, 2010 (http://executiveorder.chesapeakebay.net/category/Reports-Documents.aspx).

Definitions

The terms used in this appendix are to be interpreted consistently with the above-listed source documents, unless specifically defined below.

1. *Offset.* For purposes of the Chesapeake Bay TMDL, means (n.) a reduction in the loading of a pollutant of concern from a source or sources that is used to compensate for the loading of the pollutant of concern from a different point or nonpoint source in a manner consistent with meeting WQS; or (v.) compensating for the loading of a pollutant of concern from a point or nonpoint source with a reduction in the loading from a different source or sources, in a manner consistent with meeting WQS.
2. *Credit.* For purposes of the Chesapeake Bay TMDL, means a measured unit of nitrogen, phosphorus, or sediment pollutant reduction per unit of time at a location designated and standardized by the jurisdiction that can be generated, sold, or traded as part of an offset.
3. *Offsets Baseline.* For purposes of the Chesapeake Bay TMDL, means the amount of pollutant loading allowed by wasteload allocation (WLA) or load allocation (LA) that applies to individual credit generators in the absence of offsets. Sources generating credits are expected to first achieve their applicable offset baselines before credits may be generated.
4. *New or Increased Loading* of nitrogen, phosphorus or sediment. For purposes of the Chesapeake Bay TMDL means, for a point or nonpoint sources meeting its Chesapeake Bay TMDL WLA or LA as of the date of establishment or modification of the Chesapeake Bay TMDL, any nitrogen, phosphorus, or sediment loading from the point or nonpoint source in an amount greater than reflected by WLAs or LAs in the Chesapeake Bay TMDL; for a point or nonpoint sources not meeting its Chesapeake Bay TMDL WLA or LA as of the date of establishment or modification of the Chesapeake Bay TMDL, any nitrogen, phosphorus, or sediment loading from the point or nonpoint source in an amount greater than reflected by WLAs or LAs in the Chesapeake Bay TMDL, after the point in time the source begins meeting its WLA or LA.

Common Elements

As an assumption of the Chesapeake Bay TMDL, EPA expects that offset credits will be generated under programs that are consistent with the common elements described below. Those common elements are not presented here as regulatory requirements. However, EPA believes that in the aggregate, they will help to ensure that offsets are achieved through reliable pollution controls and that the goals of the Bay TMDL are met. EPA recognizes the value that consistent offset programs will have in promoting effective regional implementation of the TMDL.

1. *Authority.* That legal authority exists to authorize the new or increased loading of nitrogen, phosphorus, and sediment on the basis of offsetting reductions from another point or nonpoint source and to implement, monitor, and enforce such offsets.

2. *Offsets Baseline (for credit generators).* That any point or nonpoint source generating a credit has implemented practices or met any reductions necessary to be consistent with the Chesapeake Bay TMDL allocations:
    (a) For point sources generating credits, the TMDL assumes that the offsets baseline is the water quality-based effluent limit (WQBEL) included in that discharger's permit consistent with the applicable WLA in the TMDL. For some point sources, the baseline will be a numeric limitation; for others, it will be a suite of BMPs determined to be protective of WQS.
    (b) For nonpoint sources generating credits, baseline options should be consistent with the TMDL LA for the appropriate sector and may be further defined in terms of load, geographic scale, minimum practices, schedule of implementation and/or time needed to facilitate improved environmental compliance with WQS.
3. *Minimum Controls (for credit users).* That any point or nonpoint source using a credit has implemented certain minimum controls:
    (a) For point sources using credits, that the discharger using a credit will meet on-site any relevant minimum technology-based standards or secondary treatment standards.
    (b) For nonpoint sources using credits, that the source has met all federal, state, and local requirements applicable to nonpoint sources.
4. *Eligibility.* Inclusion in the basis and record for any offset, any additional criteria the jurisdiction will use to determine when a point source or nonpoint source may generate credits. Inclusion of a statement defining the eligibility requirements for and acceptable roles of aggregators or third parties in generation, sale, and purchase of offsets on behalf of others.
5. *Credit Calculation and Verification:* Ensuring that credits are quantified using appropriate metrics and are routinely verified to ensure that they are producing expected reductions, including the following:
    (a) Appropriately quantifying pollutant loading credits generated and ensuring that offsets acquired reflect load reductions equivalent to or greater than the new or increased loadings being offset, including the following:
        i. Accounting for the equivalency of pollutants to compensate for changes in pollutant form, e.g., total nitrogen versus dissolved nitrogen;
        ii. Accounting for uncertainty of source reductions due to factors such as practice efficiencies related to the use of BMPs, a lack of required monitoring or reporting compared to other sources, and/or the lack of regulation of the source by federal, state and/or local regulations;
        iii. Accounting for any distance between the generating and acquiring sources that could affect water quality including the potential for

water chemistry variations and other delivery factors that could cause pollutant attenuation;

iv. Accounting rules for inclusion of practices implemented through public cost-share incentives; and

v. Accounting for degradation in the effectiveness of a practice over the projected term of the practice.

(b) Validating that proposed activities to create reductions (e.g., treatment or BMP installation) are expected to generate the credits offered for offsets, including identifying the metrics and data used to quantify the offset/credit generated and the period for credits.

(c) Verifying that the credit was and continues to be generated, via monitoring, inspection, reporting, or some other mechanism, including articulating the frequency of on-site or other monitoring and the entity responsible for conducting monitoring or inspections.

(d) Articulating whether third parties may verify and certify credits and offsets within and between jurisdictions.

6. *Safeguards.* Inclusion in the basis and record for any offset, safeguards to ensure that the entire delivered load is accounted for and that water quality will be protected, such as the following:

(a) Prohibiting the use of offsets where such use would cause or contribute to exceedances of WQS, TMDLs, WLAs or LAs in affected receiving waters, locally or elsewhere;

(b) Restricting the use or generation of offsets by an unpermitted point source or a source that is not in compliance with its NPDES permit or a jurisdiction equivalent, or other federal or state law or regulation;

(c) Protecting affected communities from disproportionate harm arising from offsets; and

(d) Ensuring temporal consistency between the period when a credit or offset is generated and when it is used. As provided for in EPA's *Water Quality Trading Toolkit*, "credits should not be used before the time frame in which they are generated." That includes any credits expected to be generated under a contract between a new discharger and a generating source, or credits generated under an in-lieu fee program in which the jurisdiction uses discharger paid fees to achieve loadings reductions beyond baseline. For NPDES dischargers, credits should be created and used within the periods that are used to determine compliance with effluent limitations. The permitting authority may have discretion to determine the appropriate averaging period for WQBELs, depending on the pollutants of concern and other watershed specific factors. The permitting authority should decide whether and when a credit expires.

7. *Certification and Enforceability.* Designating the process to be used and the institutional entity responsible for credit/offset program operation and certification, and ensuring the enforceability of Clean Water Act discharge permits and offset transactions, including the following:
    (a) Requiring that any offsets, along with the enforceable WQBELs based on the applicable WLA (e.g., zero for new dischargers), will be included and recorded in the NPDES permit.
    (b) Estimating annually the increased pollutant loading from nonpoint sources and discharges from point sources that will not be permitted, acquiring offsets needed to fully offset such increases, and recording those offsets in an appropriate instrument.
    (c) Determining whether offsets may occur without reopening or modifying a NPDES permit to incorporate the offset transaction.
    (d) Ensuring that transactions can be enforced by the jurisdiction. Articulating how transactions can otherwise be protected by the jurisdiction, for example through a credit reserve insurance account, if failure by the offset generator occurs.
    (e) Determining whether a civilly enforceable agreement exists between an offset generator and an offset user.
    (f) Ensuring that an NPDES permittee remains accountable for meeting the WQBEL(s) in its permit, for example through a standard condition in all NPDES permits within a jurisdiction.
8. *Accountability and Tracking.* Developing accountability and tracking system(s) that are holistic and focused on performance outcomes while providing maximum transparency, operational efficiency, and accessibility to all interested parties. Such system(s) should demonstrate the following:
    (a) An appropriate offset baseline is used to generate credits.
    (b) The offset is quantified and verified according to standards established by the jurisdiction.
    (c) The offset or credit is sold to no more than one purchaser at a time.
    (d) The nutrient delivery equivalency of the offset generated and the offset consumed both in terms of the equivalency of pollutants and appropriate attenuation.
    (e) The locations(s) of the offset, including where the offset or credit is generated.
    (f) Authentication of ownership.
    (g) The NPDES permit number or other identification of the purchaser of the offset or credit.
    (h) Documentation of agreements between parties to the offset transaction.

(i) Whether sufficient offsets will be acquired over the period of the new or increased loading.

(j) Compliance status of NPDES parties.

(k) The results of monitoring and verification for each offset.

(l) Time frames for regular review and evaluation of the offset program.

9. *Nutrient-impaired Segments.* In addition to the safeguards in 6 above, ensuring that offsets in nutrient-impaired water segments

   (a) Result in progress toward attainment of WQS in the impaired segment;

   (b) Do not result in exceedances of WQS in the purchaser's impaired segment; and

   (c) Do not increase delivery loads in downstream impaired segments, do not violate WQS in any intermediary segments, and do not violate local WQS.

10. *Credit Banking.* Appropriate roles and operating practices of credit banks should be specified. It is recommended that credit banking on a basin or interstate basis be authorized subject to meeting the elements noted above. Expectations concerning necessary costs and reasonable expenses of banks that acquire and sell credits should be described.

The Chesapeake Bay jurisdictions also can consider whether to use the additional offset program features discussed in Section 10.1.3 to build their offset programs for new or increased loadings of nitrogen, phosphorus, and sediment. Those include net improvement offsets, aggregated programmatic credits, and a reserve-offset hybrid.

In developing and implementing their offset programs, EPA encourages jurisdictions to consult with EPA to facilitate alignment with the Clean Water Act and the Chesapeake Bay TMDL. EPA intends to fulfill its various oversight responsibilities of these offset programs by conducting periodic audits and evaluations as detailed in Section 10.1.4. Where questions or concerns arise, EPA will use its oversight authorities to ensure that offsets and offset programs are fully consistent with the Clean Water Act and its implementing regulations.

Appendix T.
Sediments behind the Susquehanna Dams Technical Documentation

Assessment of the Susquehanna River Reservoir Trapping Capacity and the Potential Effect on the Chesapeake Bay

Prepared for: United States Environmental Protection Agency
Prepared by: Tetra Tech, Inc., 10306 Eaton Place, Suite 340, Fairfax, VA 22030

Introduction

In developing the Chesapeake Bay Total Maximum Daily Load (TMDL), EPA must account for a vast array of dynamics that affect the loadings to the Chesapeake Bay and how to appropriately assign load allocations to each state. A large influencing factor in sediment and nutrient loads to the Chesapeake Bay are the dams along the lower Susquehanna River, which retain large quantities of sediment in their reservoirs. The three major dams along the lower Susquehanna River are the Safe Harbor Dam, Holtwood Dam, and the Conowingo Dam. This document looks at the dams' effects on the pollutant loads to the Chesapeake Bay and how those loads will change when the dams no longer function to trap sediment.

Sediment Trapping and Storage Capacity

Annually, the reservoir system traps approximately 70 percent of the sediment passing through the system (Langland and Hainly 1997). The trapping capacity is the ability of a reservoir to continue storing sediment before reaching an equilibrium, after which the amount of sediment flowing into the reservoir equals the amount leaving the reservoir, and the stored volume of sediment is relatively static. The sediment storage capacity is the actual maximum amount of sediment that can be stored in a reservoir when it is at equilibrium.

Safe Harbor Dam (Lake Clarke) and Holtwood Dam (Lake Aldred)

Lake Clarke and Lake Aldred have no remaining sediment trapping capacity. The two lakes have been in long-term equilibrium for 50 years or more.

Conowingo Dam and Reservoir

The Conowingo Reservoir is divided into three parts: upper, middle and lower. The upper and middle portions of the reservoir are in long-term equilibrium. Other than temporary increases in sediment storage due to scour events, there is no remaining storage capacity (Langland 2009a).

The lower part of the reservoir is the final 4 miles from just above Broad Creek to the Conowingo Dam. Between 1996 and 2008, 12,000,000 tons of sediment were deposited in the Conowingo Reservoir, primarily in the lower part (Langland 2009a). The total amount of sediment stored in the lower part of the reservoir was 103,000,000 tons by 2008 (Langland 2009a). The lower part of the Conowingo Reservoir is the only section of the entire three-

reservoir system that has not reached long-term sediment storage equilibrium. Some trapping capacity remains in this portion of the reservoir.

Expected Time Remaining until Sediment Storage Capacity Is Reached

The sediment storage capacity of Conowingo Reservoir has been decreasing since 1929, except during temporary scour events, such as the one during the *Big Melt* in January 2006 (Langland 2009a). The average reservoir sediment-deposition rate from 1959 to 2008 was 2,000,000 tons per year (Langland 2009). The long-term trapping efficiency of the Conowingo Reservoir has remained relatively stable at around 55 percent for the last 30 years (Michael Langland, USGS, personal communication, November 4, 2009).

According to the U.S. Geological Survey's (USGS's) most recent study, 20,000 acre-feet of sediment storage remain in the Conowingo Reservoir from Hennery Island to the dam; this translates to 30,000,000 tons of sediment (Langland 2009a). Given the rate of transport is 3,000,000 tons per year, and the rate of deposition is 2,000,000 tons per year, if there are no major scouring events in the Conowingo Reservoir and the sediment input does not change, the remaining capacity will be filled in 15–20 years (Langland 2009a). Once the sediment storage capacity is reached, sediment loads transported downstream past the reservoir will approach the loads transported from upstream (Langland 2009a).

However, because Langland notes that the time until the reservoir reaches capacity is affected by three factors—sediment transport into the reservoir, scour removal events, and sediment trapping efficiency—the time until steady state conditions are reached could be extended to 25–30 years (Langland 2009b). That assumes sediment transport decreases from 3.2 to 2.5 million tons/year, statistically expected scour events occur, and the long-term trapping efficiency remains at 55 percent (Langland 2009b).

It should be noted that the sediment trapping efficiency of the reservoir is highly variable, depending on rainfall. During drought conditions, the trapping efficiency can increase to 85 percent, and during wet periods, the trapping efficiency can fall to 40 percent (Michael Langland, USGS, personal communication January 15, 2010).

Effects on Chesapeake Bay Once Sediment Storage Capacity is Reached

As of 1997 the Susquehanna River contributed roughly 50 percent of the fresh water discharge to the Chesapeake Bay and about 66 percent of the annual nitrogen load, 40 percent of the phosphorus load, and 25 percent of the suspended sediment load from non-tidal parts of the Bay (Langland and Hainly 1997).

According to USGS water quality sampling in 1985–1989, pollutant loads in the Susquehanna River increase substantially below Harrisburg, Pennsylvania: total nitrogen increased 42 percent, total phosphorus increased 49 percent, and total suspended sediment increased 50 percent compared to loads at Harrisburg (Reed et al. 1997). The increased load is a result of more urbanized areas, agrochemical fertilizers and manure, and fewer forested areas (Reed et al.

1997). A significant percentage of those pollutant loads are captured by sediment deposition behind the dams, primarily the Conowingo Dam.

Once the Conowingo Reservoir reaches the sediment trapping capacity, the sediment and nutrient loads delivered to the Chesapeake Bay via the Susquehanna River will equal the load delivered into the reservoir system (Langland and Cronin 2003). Once storage capacity is reached, the nitrogen load will increase by 2 percent; the phosphorus load will increase by 40 percent; and the suspended sediment load will increase by at least 150 percent (Langland and Cronin 2003).

Proposed Activities to Address Sediment Build up Behind the Dam

Dredging

The Susquehanna River Basin Commission Sediment Task Force examined the issue of finding options to address the sediment accumulation behind the Conowingo Dam and concluded that dredging may provide the needed sediment storage capacity behind the dams (SRBC 2002).

In 2009 the U.S. Army Corps of Engineers (USACE) Baltimore District received funds to conduct a study of sediment management in the Conowingo Reservoir. The investigation could be developed as a Sediment Management Plan, to prioritize areas for work and make recommendations to implement sediment reduction options (Compton 2009). The study approach outlined by the USACE is conceptual, and the final components will be determined with input from the cost-share sponsor. The USACE has not yet found a cost-share partner for this feasibility study (Anna Compton, USACE Baltimore District, personal communication, December 22, 2009).

Conowingo Hydroelectric Project Relicensing Process

The Conowingo Hydroelectric Project is undergoing relicensing. On February 4, 2010 FERC (Federal Energy Regulatory Commission) accepted Exelon's Revised Study Plan, including the requested study *Sediment Introduction and Transport (Sediment and Nutrient Loading)* which will address "the effects of the Conowingo Project and its operation on upstream sediment and nutrient accumulation, sediment transport past the project, and sediment deposition and distribution upstream and downstream of the projects" (Exelon Corporation 2009). Specific tasks include a review of existing information regarding sediment and nutrient storage capacity, accumulation rates, scouring events, and such, in the Conowingo Reservoir; an analysis of the effects of project operations on habitat and substrate below the dam; and a review of watershed-based management efforts and load reduction successes. Exelon noted that the "estimated cost in 1995 dollars of dredging to simply keep up with annual sediment inflow (estimated to be 2.3 million cubic yards per year at the time) was $28 million per year. Using Means Cost Indices the comparable 2009 cost would be $48.44 million.

Cost Comparison of Dredging and Other Nutrient and Sediment Reduction Strategies

Comparisons with cost estimates for dredging Baltimore Harbor and Channels from the *Dredged Material Management Plan and Final Tiered Environmental Impact Statement* (Weston Solutions 2005) reveal that dredging costs are highly variable, and, to a large extent, depend on

the selected destination and use of the dredged materials. Costs can be as little as $12/yd^3$ for artificial island creation or beach nourishment and as much as $69/yd^3$ if dredged materials are taken to a confined disposal facility (Weston Solutions 2005). The sediment management feasibility study proposed by the USACE, and awaiting a cost-share sponsor, is likely the best mechanism to determine the true cost of dredging the Conowingo Reservoir.

Cost-Effective Strategies for the Bay (Chesapeake Bay Commission 2004) outlines the six most cost-effective practices to reduce nutrient and sediment loading to the Chesapeake Bay. Table T-1 summarizes the six selected practices and their estimated costs and compares them to the estimated costs of dredging the Conowingo Reservoir. Rough estimate calculations of dredging costs at Conowingo were based on the cost assumptions used by Exelon and SRBC and the assumption that 1 yd^3 of sediment weighs 0.945 tons. It is not known, at this time, what is included in Exelon's estimate of the cost to dredge; an assumption was made that the costs include disposal of the dredged materials, and any other associated costs.

Table T-1. Cost-Effective Strategies for Reducing Nitrogen and Sediment Loads to the Bay Compared to Estimated Dredging Costs

Practice	Annual nitrogen reduction at maximum feasible level of implementation	Annual phosphorus reduction at maximum feasible level of implementation	Annual sediment reduction at maximum feasible level of implementation
Wastewater Treatment Plant Upgrades	35 million lbs @ $8.56/lb	3 million lbs @ $74.00/lb	Not applicable
Diet and Feed Adjustments	Under development	0.22 million lbs @ no additional cost (poultry only)	Not applicable
Traditional Nutrient Management	13.6 million lbs @ $1.66/lb	0.8 million lbs @ $28.26/lb	Not applicable
Enhanced Nutrient Management	23.7 million lbs @ $4.41/lb	0.8 million lbs @ $95.79/lb	Not applicable
Conservation Tillage	12.0 million lbs @ $1.57/lb	2.59 million lbs @ no additional cost	1.68 million tons @ no additional cost
Cover Crops	23.3 million lbs @ $3.13/lb	0.44 million lbs @ no additional cost	0.22 million tons @ no additional cost
Rough estimate calculations of dredging costs	Annual nitrogen dredged based on removal equal to annual trapped amount	Annual phosphorus dredged based on removal equal to annual trapped amount	Annual sediment dredged based on removal equal to annual trapped amount
Dredge Conowingo Reservoir	3 million lbs @ $16.42/lb	3.48 million lbs @ $14.15/lb	4,420 million lbs @ $0.01/lb

Source: CBC 2004

Proposal for Addressing the Sediment and Phosphorus Load in the Chesapeake Bay TMDL

EPA's intention is to assume the current trapping capacity will continue through the planning horizon for the TMDL (through 2025). The Conowingo Reservoir is anticipated to reach a steady state in 15 – 30 years, depending on future loading rates, scour events and trapping efficiency. The steady state condition is at the limits of the planning horizon for the TMDLs and, depending on conditions, could be well beyond the planning horizon.

Under these assumptions, the wasteload allocations (WLA) and load allocations (LA) would be based on the current conditions at the dam. This represents a business-as-usual scenario in which the future diminished trapping capacity behind the Conowingo Dam is not considered in developing of the wasteload WLA and LA.

If future monitoring shows the trapping capacity of the dam is reduced, then EPA would consider adjusting the Pennsylvania, Maryland and New York 2-year milestone loads based on the new delivered loads. The adjusted loads would be compared to the 2-year milestone commitments to determine if the states are meeting their target load obligations.

Future increases in sediment and phosphorus downstream of the dam can be minimized by making implementation activities above the dam a management priority. This will decrease the overall loads of sediment and phosphorus, and extend the time until trapping capacity is reached. The states should work together to develop an implementation strategy for the Conowingo Dam and take the opportunity to work with FERC during the relicensing process for Conowingo Dam.

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Appendix U.
Accounting for the Benefits of Filter Feeder Restoration Technical Documentation

Strategies for Allocating Filter Feeder Nutrient Assimilation into the Chesapeake Bay TMDL

Prepared for U.S. Environmental Protection Agency
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Introduction

Filter feeders play an important role in the uptake of nutrients from the Chesapeake Bay and have the potential to significantly improve water quality if present in large numbers. The current goal for the Chesapeake Bay is to increase the native Eastern oyster, *Crassostrea virginica*, population tenfold. A population increase of that magnitude could remove 10 million pounds of nitrogen annually (Cerco and Noel 2005). Menhaden fish, *Brevoortia tyrannus*, are another filter feeding organism in the Chesapeake Bay. This paper explores the options for incorporating the effects of filter feeders into the Chesapeake Bay TMDL and implementation plans. As a way of fostering management and restoration of filter feeders, the U.S. Environmental Protection Agency (EPA) intends to investigate future monitored levels of filter feeder populations and incorporate that into EPA's model-based tracking of State progress in achieving the 2-year milestones.

Current Harvest Situation

The Atlantic States Marine Fisheries Commission (ASMFC) reports that the reduction[1] fishery harvested 85,000 metric tons of menhaden from the Chesapeake Bay in 2008 and 21,150 metric tons from bait landings (ASMFC 2009b). The vast majority of the catch is in the Virginia portion of the Chesapeake Bay using the purse seining method. Purse seining has been banned in the Maryland portion of the Chesapeake Bay for decades, where menhaden are primarily harvested via pound nets.

Addendum IV to Amendment 1 to the Atlantic Menhaden Fishery Management Plan (Chesapeake Bay Reduction Harvest Cap Extension) extends the annual harvest cap established under Addendum III at 109,020 metric tons on reduction fishery harvests from the Chesapeake Bay (ASMFC 2009a). That will extend the cap through 2013. The cap was extended to allow further investigation into the abundance of menhaden in the Chesapeake Bay. There is concern that localized depletion of menhaden in the Bay is occurring. Stock assessments are conducted on a coast-wide basis and not on the Bay individually, so the Bay population is unknown.

According to the National Marine Fisheries Service (NMFS) Annual Commercial Landings Statistics (NMFS 2010), 249,485 pounds of eastern oyster were harvested in Maryland in 2008, and in Virginia, 352,678 pounds of eastern oysters were harvested. Current oyster populations are about 1 percent of the historic population. This is because of a number of factors including,

[1] A reduction fishery takes the harvested fish and processes or "reduces" the fish into non-food products, typically to fish meal and oil.

historical overharvesting, disease, loss of habitat, excess sedimentation from deforestation, agricultural practices, urban development, and natural predation (CBP 2009).

Strategies to Increase Filter Feeder Populations in the Chesapeake Bay

Menhaden Nutrient Assimilation

According to Brush et al. (2009), the Chesapeake Bay larval menhaden appear to feed on zooplankton, then transition to phytoplankton as juveniles and return to higher zooplankton consumption rates as adults (age 1+). Given calculated consumption rates for menhaden, based on age, "adults are unlikely to significantly impact phytoplankton biomass and production on a baywide basis" (Brush et al. 2009). Juvenile consumption of algae is estimated to be a few percent of the daily phytoplankton biomass in the summer and fall, and up to 5 percent and 20 percent of daily productivity in the summer and fall, respectively" (Brush et al. 2009). Menhaden might influence water quality on a smaller scale, such as an individual tributary, Bay segment, or menhaden school (Brush et al. 2009). A menhaden simulation is fully operational in the Water Quality and Sediment Transport Model of the Chesapeake Bay, and the model corroborates the findings of Brush et al. (2009). Although the influence of menhaden on water quality is estimated to be less than that of oyster filter feeders, even a small percentage of nutrient assimilation or chlorophyll reduction in the Chesapeake Bay would ease the pressure in meeting 2-year milestones.

Oyster Nutrient Assimilation

Research shows that 700 to 5,500 pounds of total nitrogen are removed annually per 1,000,000 market-sized oysters harvested from the system. That is a wide range of biomass needed for offsets. Assuming the 2:1 reduction requirement under Virginia's trading program, 3.6–28.5 million oysters would be needed to offset 10,000 pounds of total nitrogen (Stephenson 2008).

Stephenson (2009) estimates the cost of total nitrogen reduction from oyster assimilation at $0–$100 per pound. In comparison, agricultural best management practices (BMPs) costs in Virginia range from $4 to $200 per pound and urban stormwater BMPs can be $25 to more than $1,000 per pound or more (Stephenson 2009).

Oyster Restoration and Preservation

Sanctuaries are already part of the planning process in the Virginia Oyster Restoration Plan and Maryland Priority Restoration Areas. Sanctuary areas could provide spawning areas to increase the population of wild oysters.

The *2009 Maryland Oyster Restoration and Aquaculture Development Plan* would increase sanctuary areas from 9 percent to 24 percent of the remaining quality habitat (36,000 acres) in certain locations: Magothy River, Chester River, the area between Patapsco and Back Rivers, Upper St. Mary's River, Point Lookout, Little Choptank River, Upper Patuxent River, and the area between Hooper Strait and Smith Island.

The *Maryland Oyster Restoration and Aquaculture Development Plan* also outlines 600,000 acres newly available for bottom leasing, including 95,524 acres of formerly off-limits natural oyster bars, and develops Aquaculture Enterprise Zones, which are areas preapproved for leasing (MDNR 2009).

Challenges to Increasing Oyster Populations

A limited amount of bottom is suitable and available as oyster habitat. The *Oyster Management Plan* (CBP 2004) suggests that there are 10,000 to 20,000 acres of restorable habitat in Maryland and about 28,500 acres in Virginia. Even within suitable habitat areas, disease mortality and reduced fecundity are major inhibitors to population expansion.

There is a need to provide greater incentives for aquaculture of native oysters. Oyster aquaculture is limited by the supply of disease-resistant seed oysters. Expansion of aquaculture investment is not likely until more seed is available, which is limited by cost-effective market production from seed (CBP 2004).

Accounting for Filter Feeders in the TMDL

EPA has based the filter feeder component of the TMDL on the current population of filter feeders. Potential future population changes are not accounted for in the TMDL itself. Restoration efforts have been underway for years to increase filter feeder populations with minimal observed population change. The combined factors of disease, lack of suitable substrate and excess nutrients fuel the growth of algae blooms that deplete oxygen in deeper waters and can hinder the development of oysters. Until some of the stressors on the oyster population are alleviated it is not practical to heavily rely on filter feeders to address the water quality issues in the Chesapeake Bay. If future monitoring data indicate changes in the filter feeder population, the 2-year milestone delivered load reductions can be adjusted accordingly. The adjusted loads will be compared to the 2-year milestone commitments to ensure each state is meeting its obligations.

Crediting Filter Feeder Benefits

During the 2-year milestone evaluation of filter feed populations, credits or debits for changes in populations and associated nutrient assimilation can be assigned in one of two ways that EPA is considering.

Under Option A, only the state responsible for the filter feeder changes would obtain a credit/debit towards reaching its 2-year milestones. It would be possible for any state or the District of Columbia to receive credit toward increasing filter feeder populations. Maryland and Virginia can implement their programs directly. Nontidal states and the District of Columbia could provide support to Maryland and Virginia programs to increase filter feeder populations. Maryland and Virginia would have to ensure that any projects funded by other jurisdictions are in addition to activities planned by Maryland or Virginia or both. To eliminate double counting, each project credit must be properly assigned to the jurisdiction paying for the project.

Under Option B, any nutrient credit/debit associated with a change in filter feeder populations would be distributed proportionally across all the states and the District of Columbia, regardless of the jurisdiction responsible for funding or implementing the project.

Under both options, the changes in filter feeder populations would be based on monitoring data. To accurately assign credits to the appropriate jurisdiction and ensure milestones are reached, restoration activities and population increases must be tracked and verified. Regardless of the crediting option chosen, Maryland and Virginia should address filter feeder management in their watershed implementation plans. EPA and the jurisdictions will work together to establish a future strategy for crediting filter feeder benefits.

Other Issues of Concern

While increasing filter feeder populations can provide nutrient assimilation to mitigate the effects of excess nutrients, it is not a method of pollutant source reduction. Because nutrient assimilation can be considered an in-stream treatment technology by some regulators, there is some concern that it might be used in lieu of advanced wastewater treatment technologies (Stephenson 2009). Additionally, filter feeders reduce the pollutant downstream and pollutants are not reduced at or near the source. Reliance on filter feeders to reduce nitrogen downstream could create a problem with meeting local water quality standards in the upstream jurisdictions. Further consideration should be given to address these issues.

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Appendix V. Best Management Practice (BMP) Implementation Rates for Final Scenarios

Appendix V is a spreadsheet (Appendix V - BMP Implementation Rates Assumed within WLAs and LAs_approved.xlsx) that presents the percentage of best management practices (BMPs) that are assumed to be in place in 2009 and within the TMDL WLAs and LAs for sources other than wastewater treatment plants. The 2009 implementation percentages are derived from the Chesapeake Bay Program 2009 progress run and, with the exception of annual practices (i.e., cover crops) that are reported separately each year, represent an accumulation of BMP percent implementation from 1985 through 2009. The Chesapeake Bay jurisdictions report these data annually to EPA.

Appendix V also presents the percentage of BMP implementation that is assumed within the TMDL WLAs and LAs in each jurisdiction. With the exception of BMP implementation percentages for AFO production area practices within West Virginia, which EPA increased as part of its backstop allocation for agriculture, these percentages are based upon jurisdictions final Watershed Implementation Plans (WIP) input deck submissions designed to meet their nitrogen, phosphorus and sediment reduction targets.

Appendix V does not include a table for Maryland because final allocations proposed in Maryland's WIP are derived using the method outlined in Appendix A of Maryland's WIP rather than an input deck that was run through the Chesapeake Bay Program Watershed Model.

The BMP implementation rates are derived from the relative areas where BMPs of different sectors can be applied. The comparison of the 2009 and WIP BMP percent implementation rates are provided to demonstrate the assumptions of the wasteload and load allocations in the TMDL.

The BMP percent implementation are divided into three categories:

1. Agricultural Practices
Nutrient management practices (Decision Agriculture, Enhanced Nutrient Management, and Nutrient Management) combined represents the percent area in some form of nutrient management on available crops. There is a separate percentage for nutrient management on pasture. Other pasture BMPs are combined for the total coverage on pasture and nutrient management pasture land uses. Other agriculture and animal agriculture BMP implementation percentages are compared against the calculated available acres or animals for each BMP individually.

2. Urban/Suburban Practices
Urban/Suburban stormwater management BMPs are combined for a total coverage of the total acreage. Other Urban and septic BMP implementation percentages are compared to the relative acreage or systems available for each BMP individually.

3. Resource Practices
Resource BMP implementation percentages are compared to the available land in the appropriate modeled land uses for each BMP individually.

Appendix W. Response to Comments

Appendix W is not included in this document as it totals over 3,000 pages. A separate hard copy of the full Response to Comments is available in the EPA Region III office in Philadelphia. An electronic copy of the Response to Comments is available on the Chesapeake Bay TMDL website.

Appendix X.
Staged Implementation Approach for Wastewater Treatment Facilities in the Virginia James River Basin

With the exception of one portion of the tidal Potomac River, the tidal James River is unique throughout the Chesapeake Bay watershed in that ten chlorophyll-*a* water quality criteria (5 segments*2 seasons) are applicable to protect local and tidal water quality conditions. In the July 1, 2010 allocation of nutrients, EPA determined that attainment of these numeric chlorophyll a criteria would require achievement of much lower levels of nutrients than previously expected.

Specifically, in the July 2010 letter, EPA determined allocations for the James River in the amounts of 23.48 million pounds per year of total nitrogen and 2.34 million pounds per year of total phosphorus. To achieve the dissolved oxygen and water clarity criteria, EPA had previously calculated that the levels of 26.8 million pounds per year of total nitrogen and 2.69 million pounds per year of total phosphorus would be sufficient. [See TMDL Appendix O - *Setting the Chlorophyll a Criteria-Based Nutrient Allocations for the James River Watershed*] Those higher levels (to achieve DO) are roughly equivalent to the 2003 James River cap load allocation of 26.4 million pounds per year of total nitrogen and 3.41 million pounds per year of total phosphorus. (Secretary Tayloe Murphy, 2003).

Up until the July 2010 allocation, Virginia had been working to implement past strategies to meet the previous, higher 2003 cap load allocations of total nitrogen and total phosphorus for the James. To achieve total nitrogen and total phosphorus allocations sufficient to comply with the current chlorophyll-*a* criteria, absent significant reductions from other pollution sectors, it is estimated that every significant municipal and industrial wastewater treatment facility in the river basin (39 facilities) would have to install nutrient removal technologies at or below limit of technology levels. In addition, due to the geographic location of the James River (southernmost river in the Bay watershed), Bay circulation patterns, and strong tidal flushing from the Atlantic Ocean, total nitrogen, total phosphorus and sediment loadings from the James River have a relatively small impact on water quality in the mainstem Bay. For these reasons, a staged implementation approach has been developed for implementing necessary nutrient reduction controls at wastewater facilities in the James River Basin to achieve the wasteload allocations of the Chesapeake Bay TMDL. As part of that staged implementation approach, EPA is establishing in this TMDL the wasteload allocations (WLA) for significant facilities in the James River as aggregate WLAs for total nitrogen and total phosphorus (Table 9-4 in Section 9 of the TMDL Report).

Total nitrogen and total phosphorus allocations from the tributary strategy for the James River sufficient to attain the dissolved oxygen criteria for the James River and Chesapeake Bay do not concurrently provide for the attainment of the James River Chlorophyll *a* criteria. Therefore, it is necessary in the TMDL to allocate more stringent total nitrogen and total phosphorus reductions in the James River than previously expected to attain the Chlorophyll *a* criteria (an additional 3 million pounds per year and 0.3 million pounds per year respectively). To facilitate that staged implementation approach, in this TMDL, EPA is establishing the more stringent wasteload allocations (WLA) for significant facilities in the James River as aggregate WLAs for total nitrogen and total phosphorus (Table 9-4 in Section 9 of the TMDL Report). The key components of the implementation strategy include:

- Near-term (2011-2017) interim effluent limits and controls under the Watershed General Permit for individual facilities implementing current and planned facility upgrades, including sixteen upgrade projects at POTWs, to achieve those portions of the wasteload allocations for total nitrogen and total phosphorus reductions that are based on the DO standards attainment, plus reductions of an additional 1.6 million pounds of total nitrogen and 200,000 pounds of total phosphorus.
- Achievement of 60% of the TMDLs overall total nitrogen and total phosphorus allocations by 2017 and 100% of the wastewater treatment plant component by no later than January 1, 2023.
- Near-term *aggregate* Chlorophyll-*a*-based effluent limits for total nitrogen and total phosphorus that apply under the Watershed General Permit to all 39 significant wastewater facilities to achieve the remaining 40% of the load reductions needed to meet the applicable aggregate wasteload allocations and the applicable Chlorophyll-*a* criteria with compliance as soon as possible pursuant to 40 CFR 122.47. Existing information suggests that compliance with this aggregate limit may not be possible until after 2017, but not later than January 1, 2023.
- Sufficient time for the Commonwealth of Virginia to perform an engineering/cost optimization study to establish which of the 39 facilities under the Watershed General Permit, and in what order, will need to upgrade treatment to meet the aggregate Chlorophyll-a-based limits.
- Establishment in 2017 of *facility-specific* effluent limits necessary to achieve reductions of an additional 1.0 million pounds per year of TN and 250,000 pounds per year of TP by January 1, 2022, and *facility-specific* TN and TP wasteload allocations, to inform the permit requirements of the 2018 Watershed General Permit reissuance, for each of the 39 significant WWTPs as stringent as necessary to achieve the remaining load reductions needed to meet the applicable Chlorophyll-*a* criteria. Also continue the enforceable aggregate Chlorophyll-*a*-based effluent limits for TN and TP that apply to all 39 facilities, with compliance required as soon as possible after 2017, based on present information, and not later than January 1, 2023.
- Establishment in 2018 of *facility-specific* effluent limits for TN and TP based on the facility WLAs established in 2017, as stringent as necessary to achieve the applicable Chlorophyll-*a* water quality criteria, and facility-specific compliance schedules requiring compliance with the effluent limitations for TN and TP limits as soon as possible, but not later than January 1, 2023
- EPA expects Virginia (and Virginia has committed) to reissue the Watershed General Permit and fact sheet in 2012, 2017 and 2018 to include all elements of the staged implementation approach, including any schedule of interim milestones pursuant to 40 CFR 122.47. To guide issuance of adequate permits in the James River, EPA is including the description of the projected schedule of the staged implementation approach in the Chesapeake Bay TMDL as assumptions and requirements of the applicable James River wasteload allocations. Federal law and regulation require that water quality-based effluent limits in permits must be derived from and comply with the applicable water quality standards and be consistent with the assumptions and requirements of TMDL wasteload allocations. 40 C.F.R. 122.44(d)(1)(vii)(A)&(B).