Potomac PCB TMDL

Modeling Approach and Current Status

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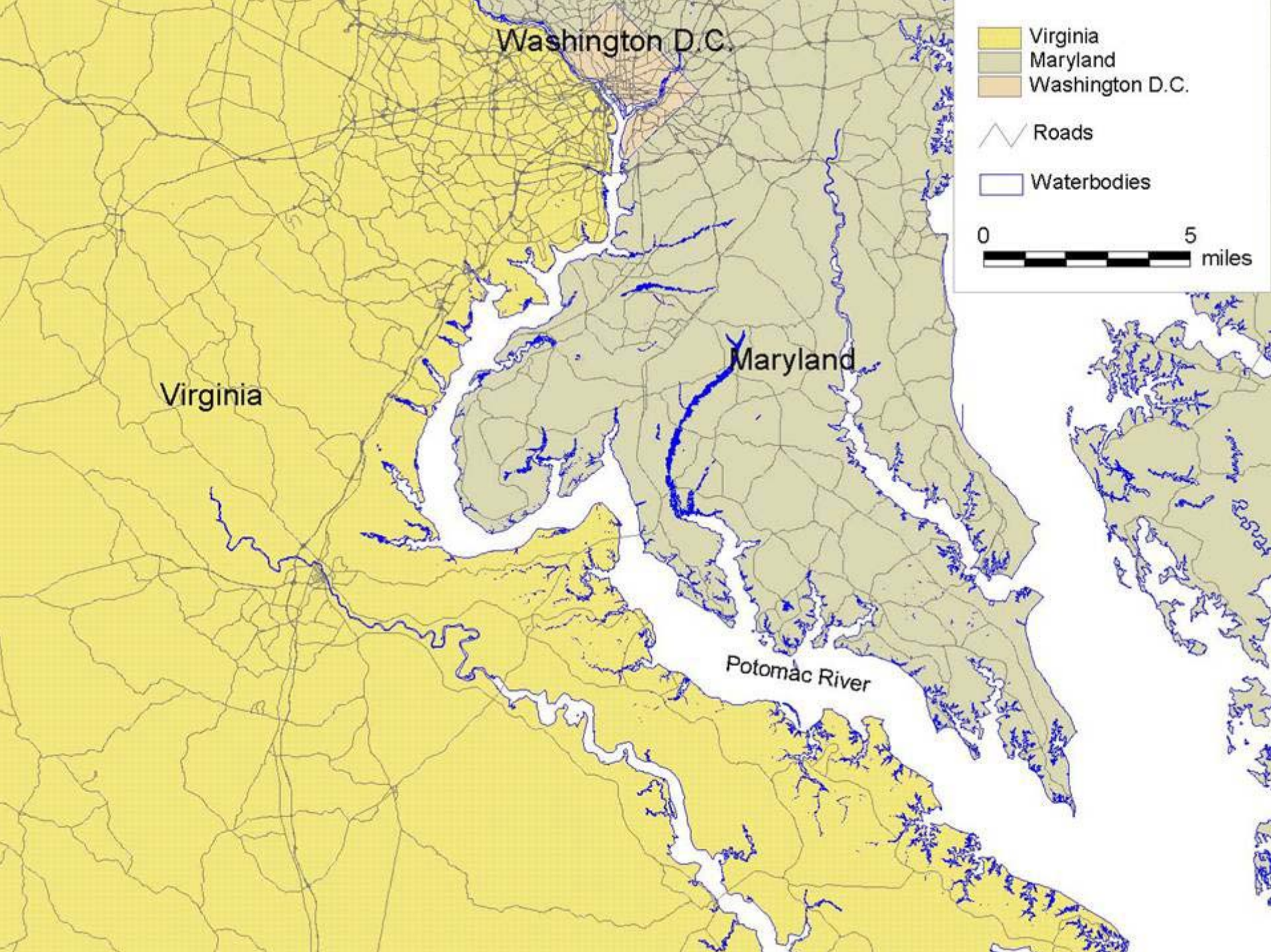
Limno-Tech, Inc.

Technical Advisory Committee Meeting
Metropolitan Washington Council of Governments
Washington, DC

January 23, 2006

Presentation Outline

- Background
- Modeling Approach
- Current Model Status
- Next Modeling Steps
- Outstanding Modeling Issues
- Data Requirements and Gaps
- Recommendations
- Illustrative Model Results


Washington D.C.
Virginia
Maryland
Washington D.C.
Roads
Waterbodies
0
5
miles
Maryland
Virginia
Potomac River

Challenges

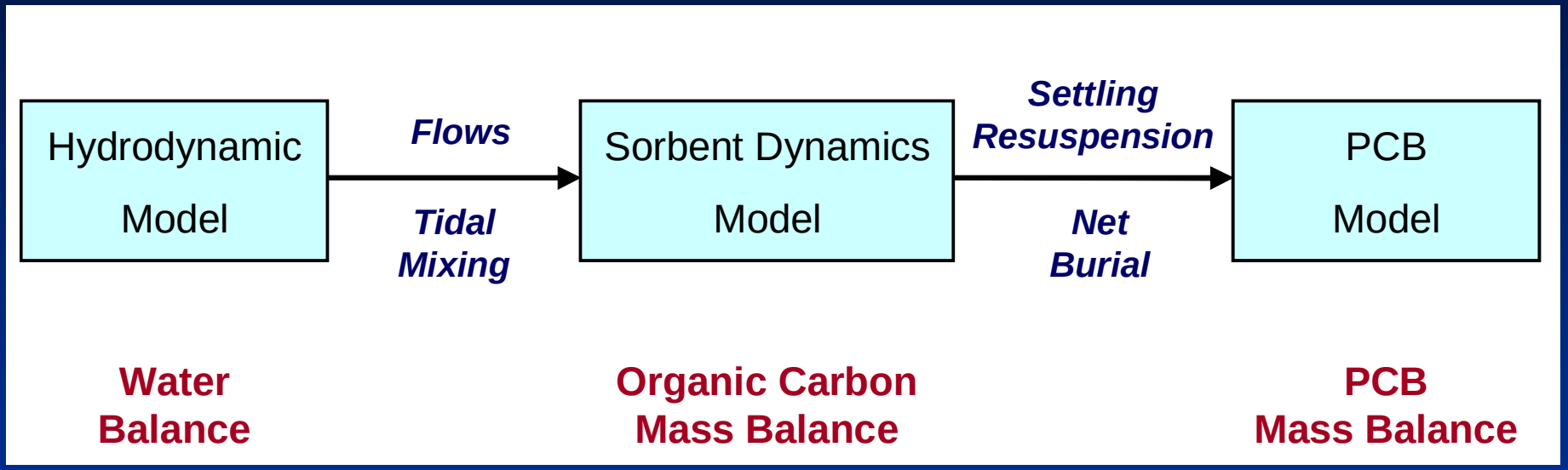
- Complexity of system
  - Tidal
  - Multiple PCB sources
    - Ongoing sources from watershed
    - Atmospheric sources
    - Legacy contamination in sediments
  - Different PCB water quality standards
    - DC, Maryland and Virginia
- PCB data limitations
  - Water column
  - Loadings
- Ambitious schedule
  - Court mandates
  - Administrative agreements

Project Schedule

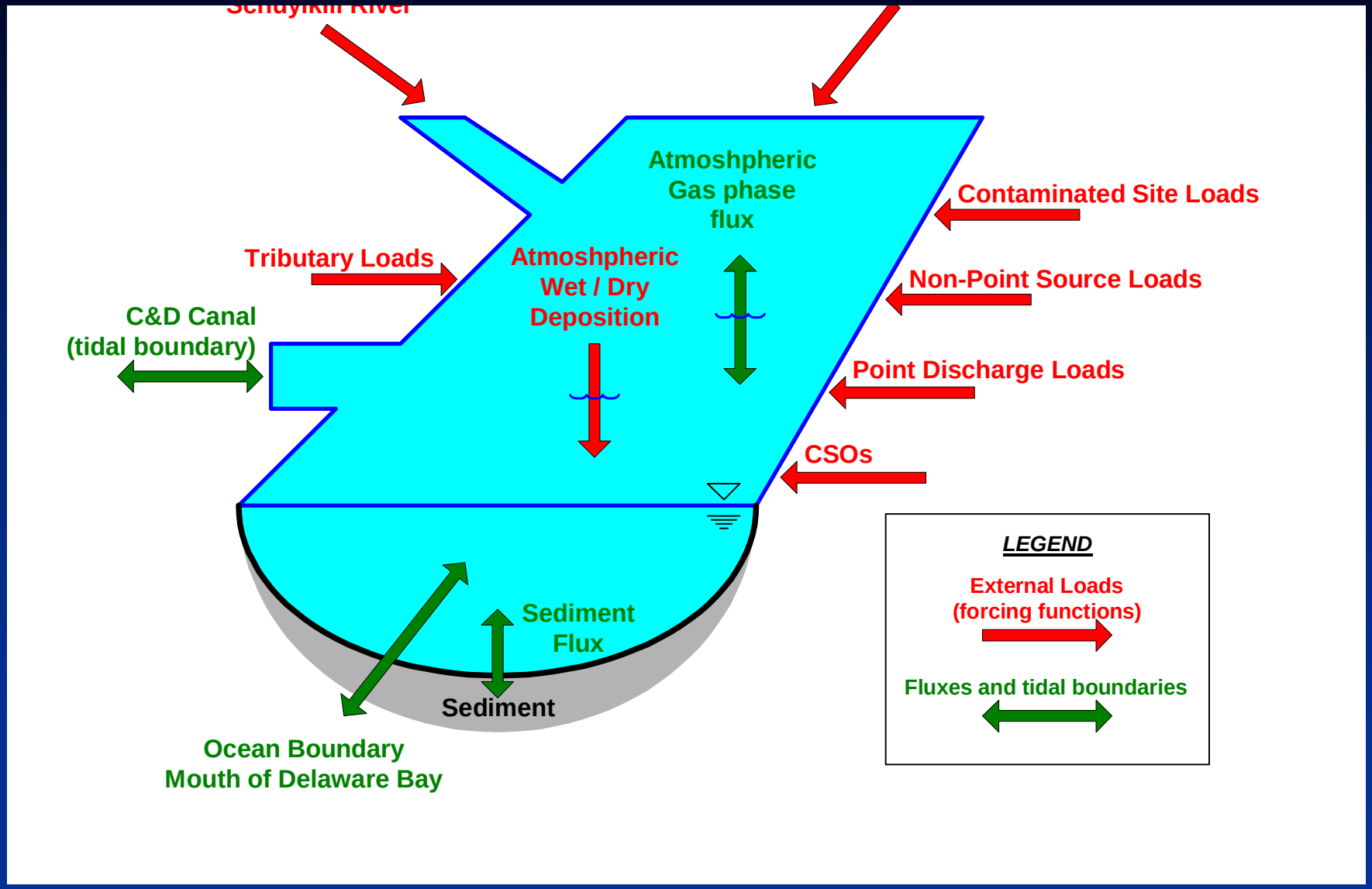
July 8, 2005	Draft Work Plan
September 30, 2005	Report on Modeling Approach Report on Data Availability and Data Gaps
February 23, 2006	Hydrodynamic/Salinity Model Calibration Draft Report
September 30, 2006	PCB Model Calibration Draft Report
March 31, 2007	Draft TMDL
September 30, 2007	Final Approval of TMDL

Modeling Approach

Integrated Modeling Framework



Example Mass Balance Approach
Delaware River Estuary



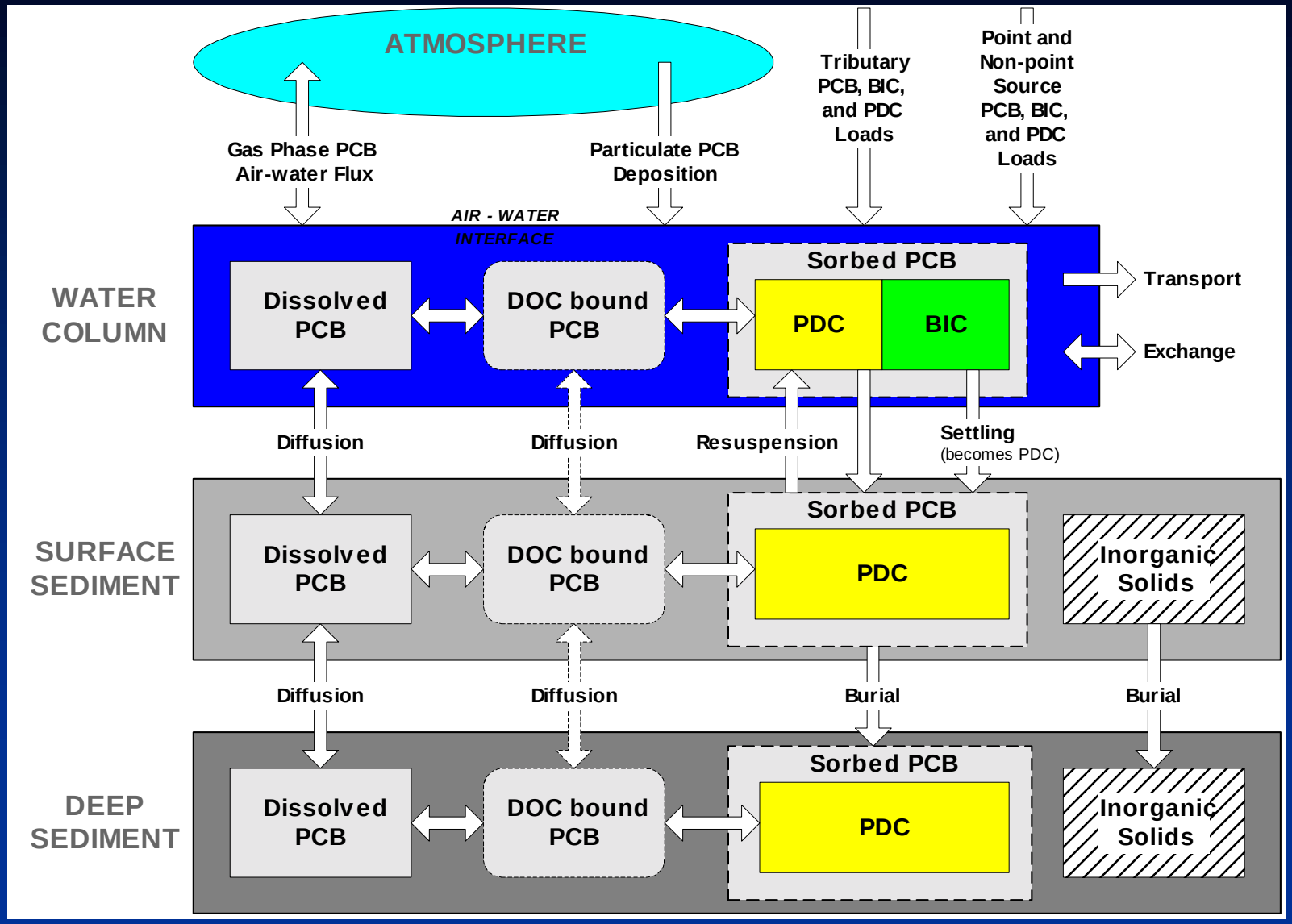
Options Considered

- PCB Model Framework
  - Water Quality Analysis Simulation Program (WASP7)
  - PCB Water Quality Model for Delaware Estuary (WASP5/DELPCB)
- Hydrodynamic Model Framework
  - DYNHYD5
  - Environmental Fluid Dynamics Code (EFDC)
  - Chesapeake Bay Environmental Model Package (CBEMP)

Key Features

- Hydrodynamics (DYNHYD5)
  - Builds upon CBEMP, TAM/WASP and DEM models
  - 1D branched spatial grid
  - Represents main channel, Anacostia and Virginia embayments
  - Daily forcing for freshwater inflows
  - Hourly forcing for downstream tidal heights
- PCB Mass Balance (WASP5)
  - PCBs follow the organic carbon
  - Builds upon Delaware River Estuary PCB TMDL model
  - 1:1 spatial mapping between DYNHYD5 and WASP5
  - 2D horizontal spatial grid
  - 250 spatial grid cells

DELPCB Model Framework



Advantages of DYNHYD5/WASP5

- Proven successful in Delaware River Estuary
- Approved by expert panel of independent scientists
- Accepted by EPA Regions 2 and 3 for development of Stage 1 PCB TMDL
- Existing linkage between DYNHD5 and WASP5/DELPCB
- Model code available and transferable to Potomac River Estuary
- Most technically defensible approach achievable by September 2006

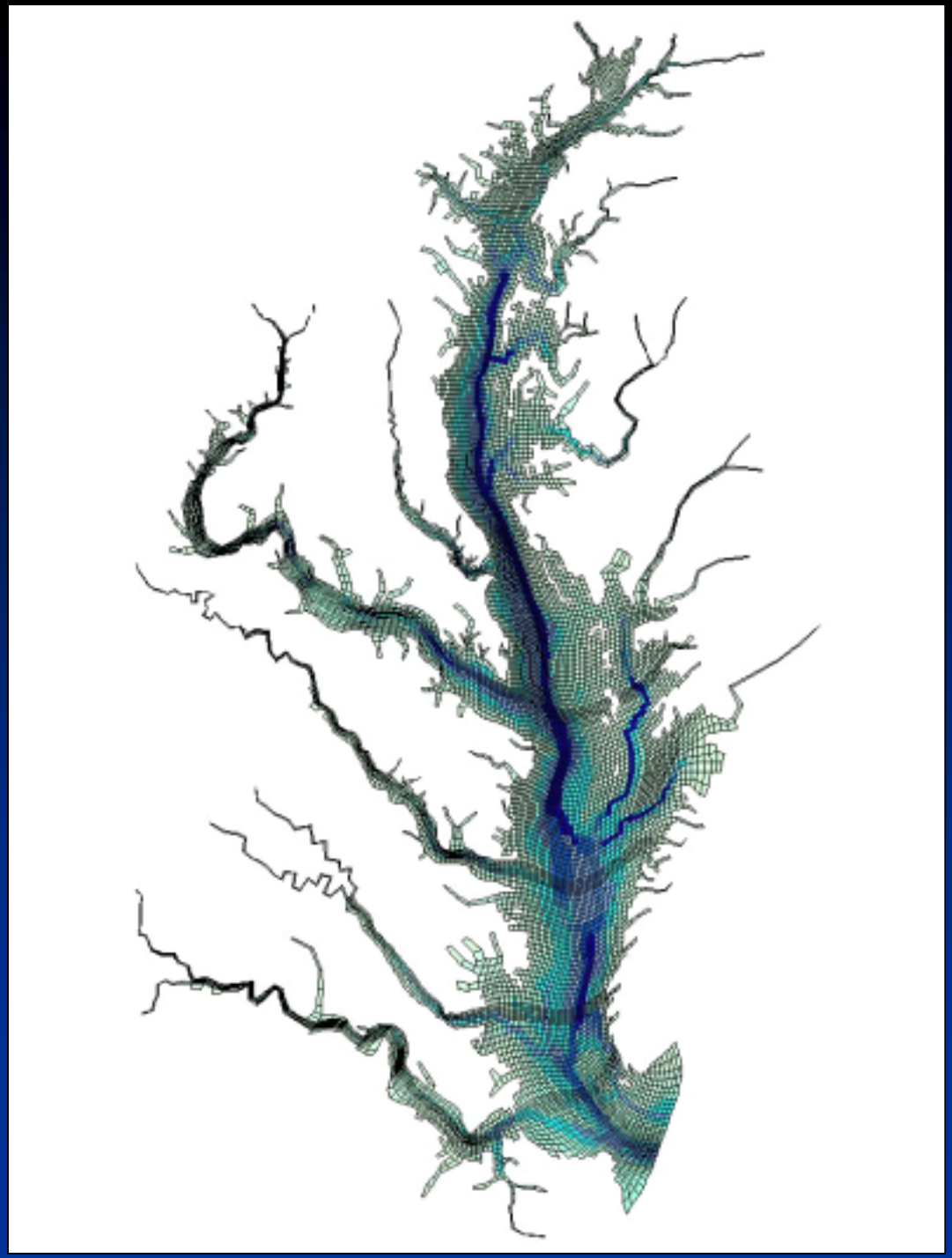
Principal Model Limitations

Does Not Represent ….

- Lateral spatial gradients within main channel and/or within embayments, tributaries and coves
- Potential differences in sediment-water exchanges between the main channel and nearshore areas
- Complex physical processes in the vicinity of the estuarine turbidity maximum
- Vertical stratification in the lower estuary
- Sediment transport or suspended solids mass balance

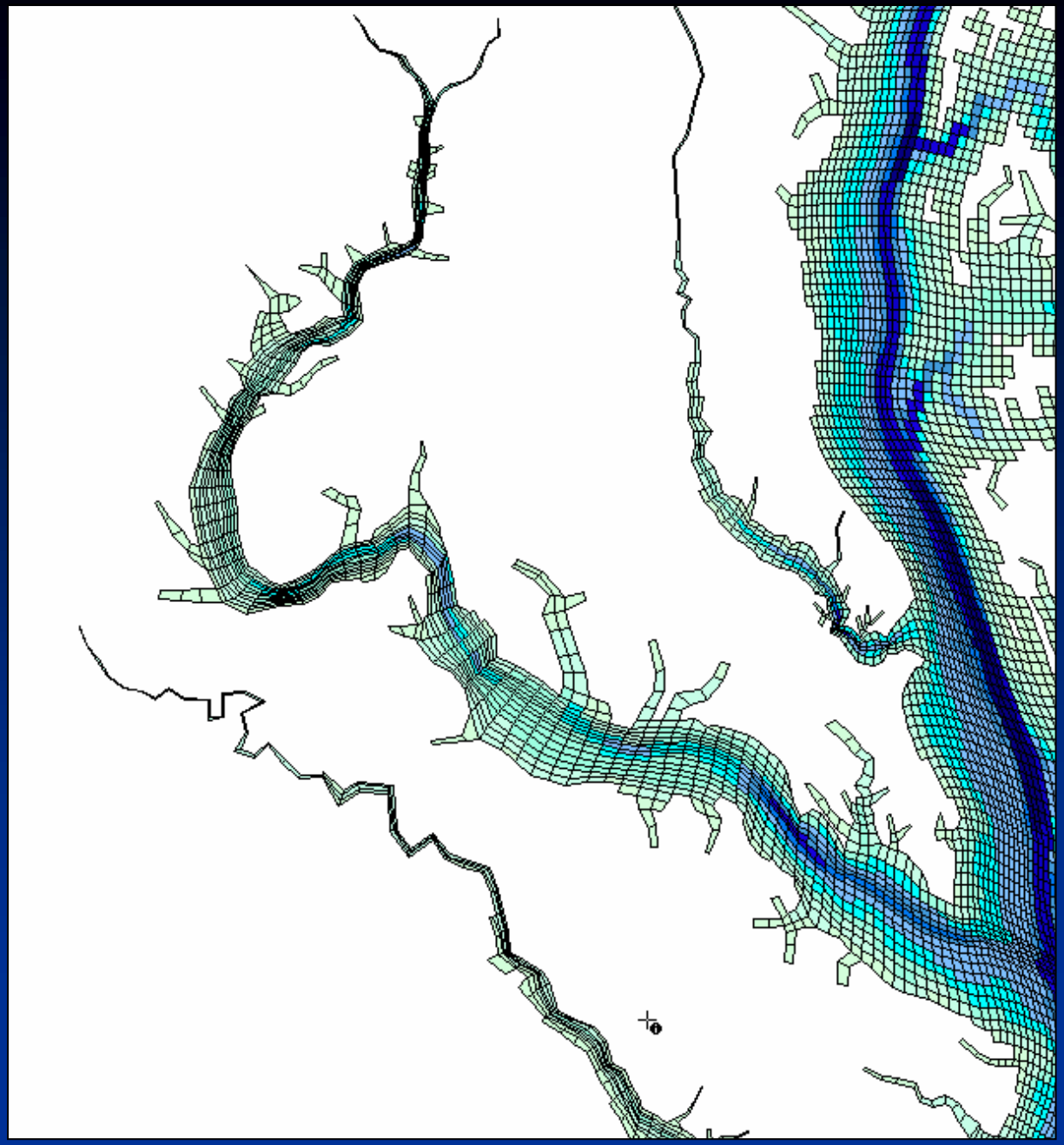
Model Grid Development

- Chesapeake Bay Model (57K grid)
  - Mainstem Potomac
  - Middle and lower estuary
- TAM/WASP Model
  - Anacostia
- Dynamic Estuary Model (DEM)
  - Washington Ship Channel
- VIMS Virginia Embayment Models
  - Virginia embayments



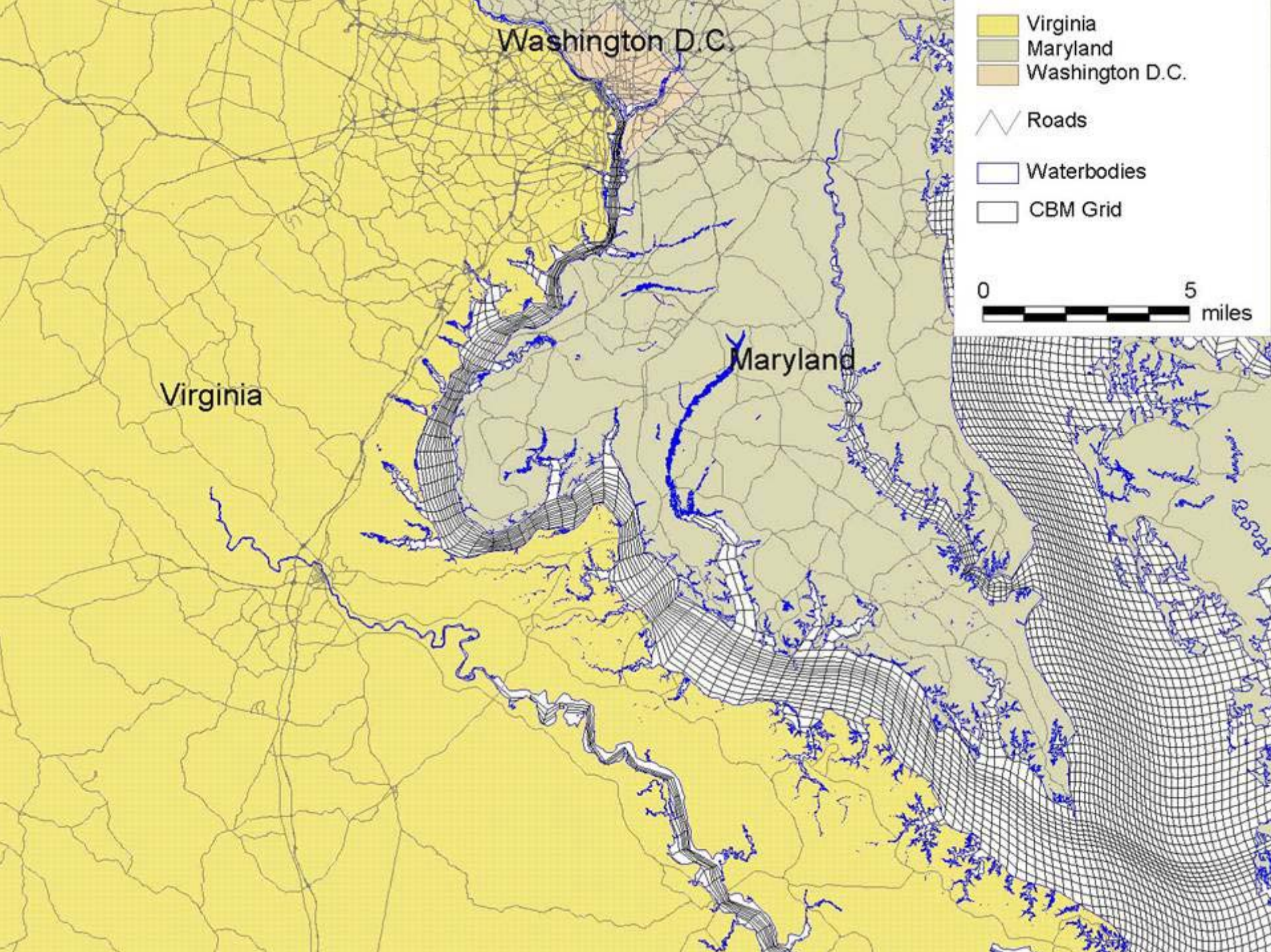
Spatial Grid

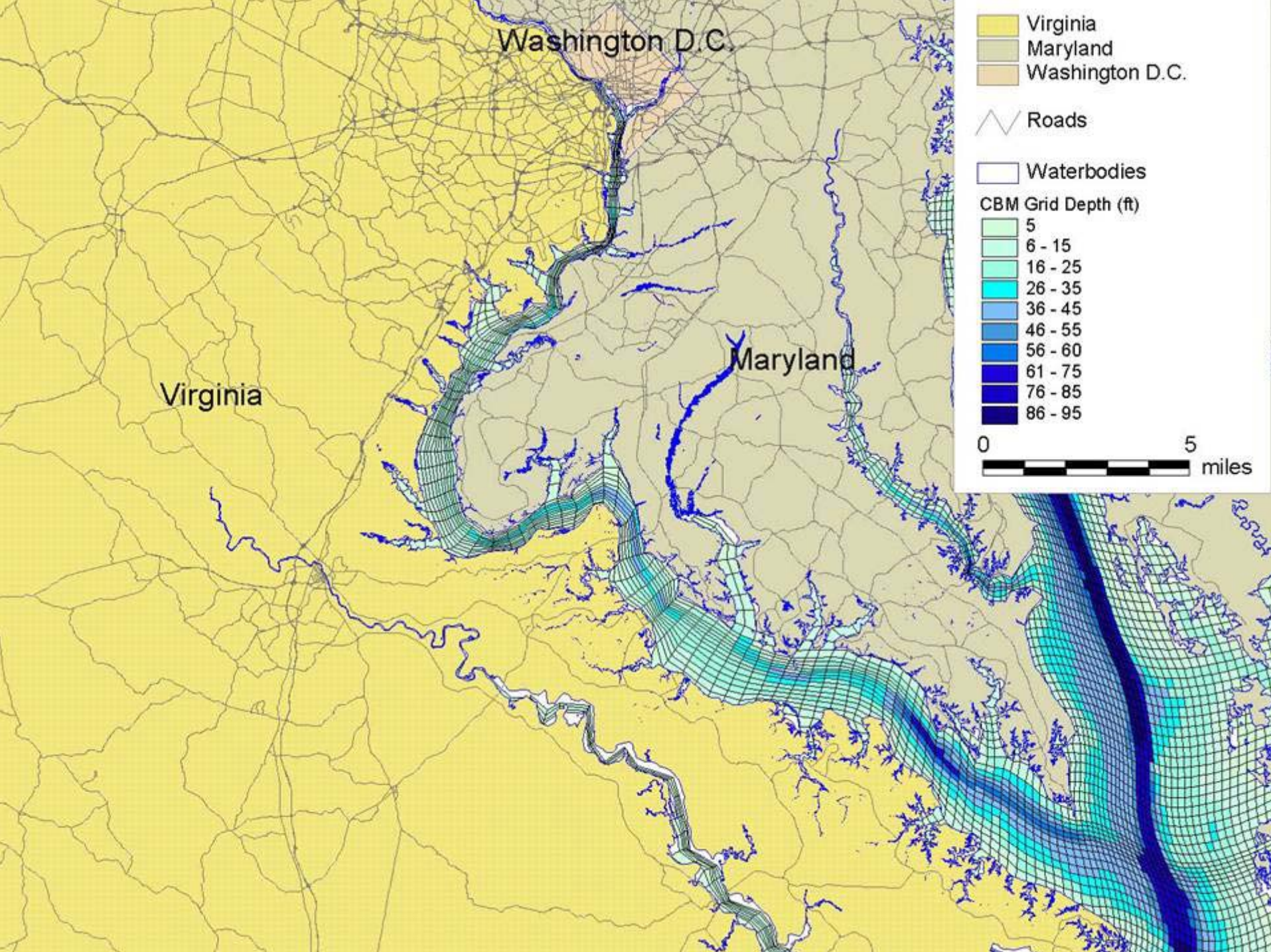
57K Bay Model

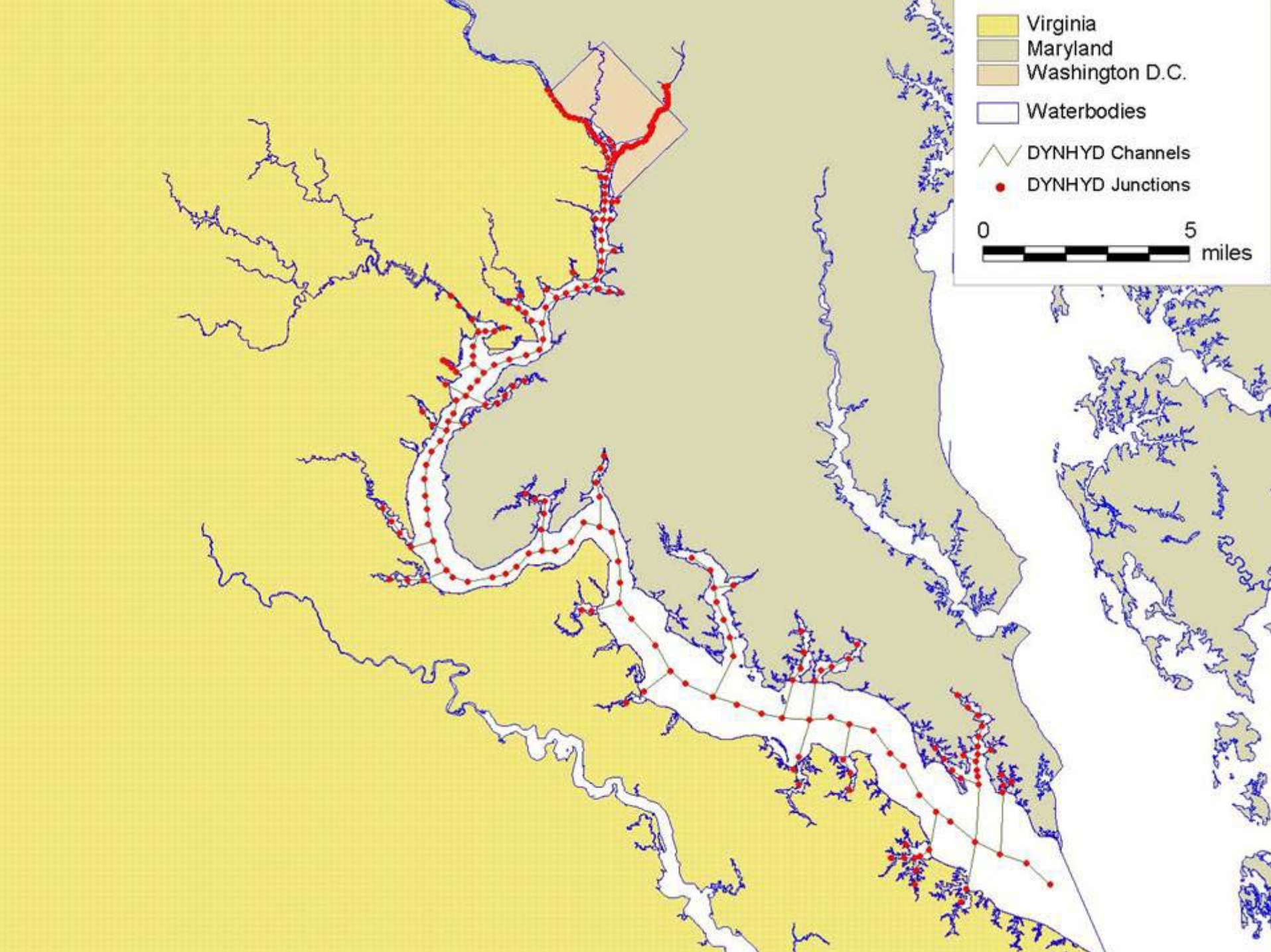


Potomac Portion

57K Bay Model


Washington D.C.
Virginia
Maryland
Virginia
Maryland
Washington D.C.
Roads
Waterbodies
CBM Grid
0
5
miles


Washington D.C.
Virginia
Maryland
Virginia
Maryland
Washington D.C.
Roads
Waterbodies
CBM Grid Depth (ft)
5
6 - 15
16 - 25
26 - 35
36 - 45
46 - 55
56 - 60
61 - 75
76 - 85
86 - 95
0
5
miles


Virginia
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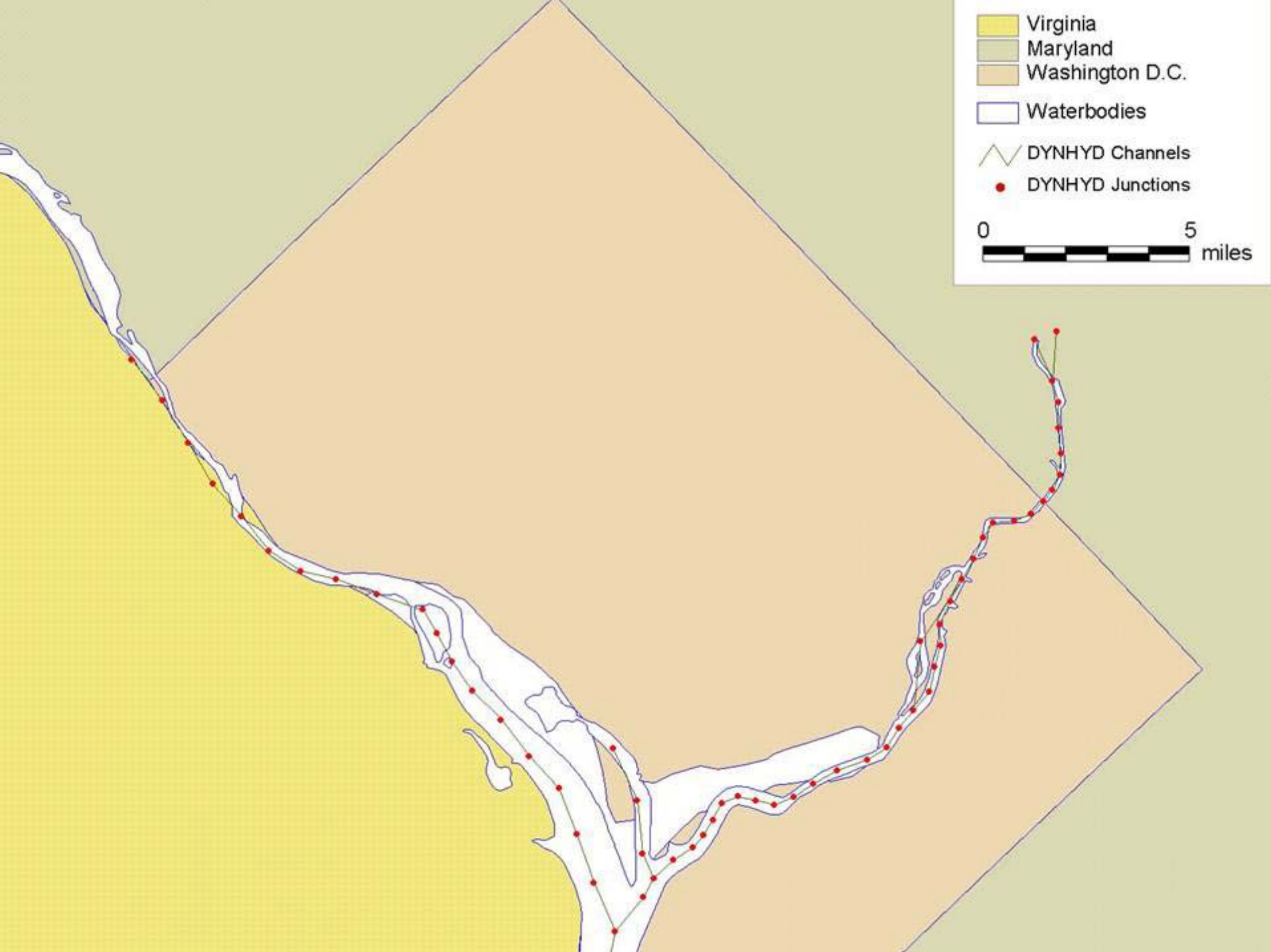
Waterbodies
DYNHYD Channels
DYNHYD Junctions
0
5
miles


Virginia
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Waterbodies
DYNHYD Channels
DYNHYD Junctions
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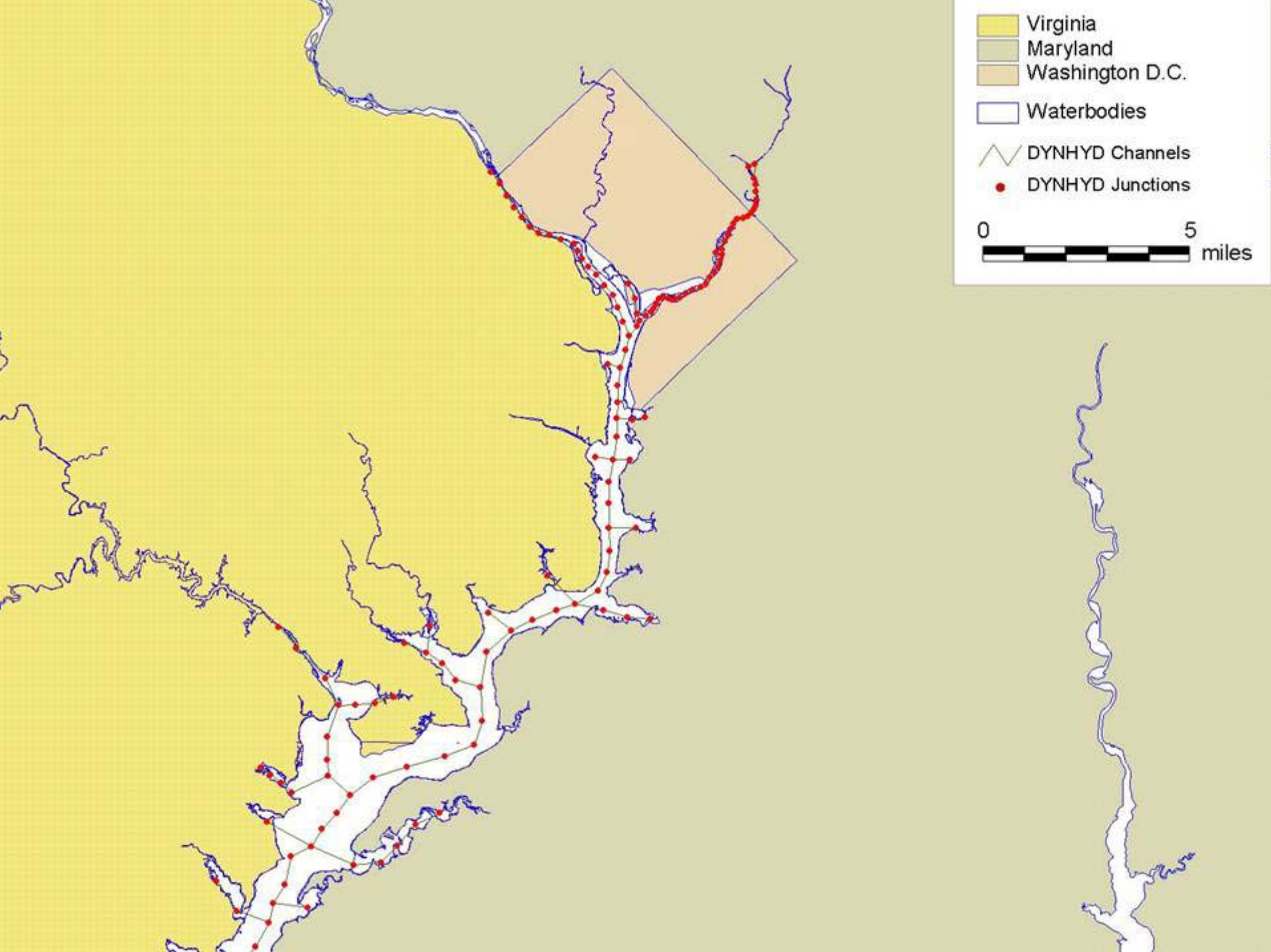
Virginia
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Waterbodies
DYNHYD Channels
DYNHYD Junctions
0
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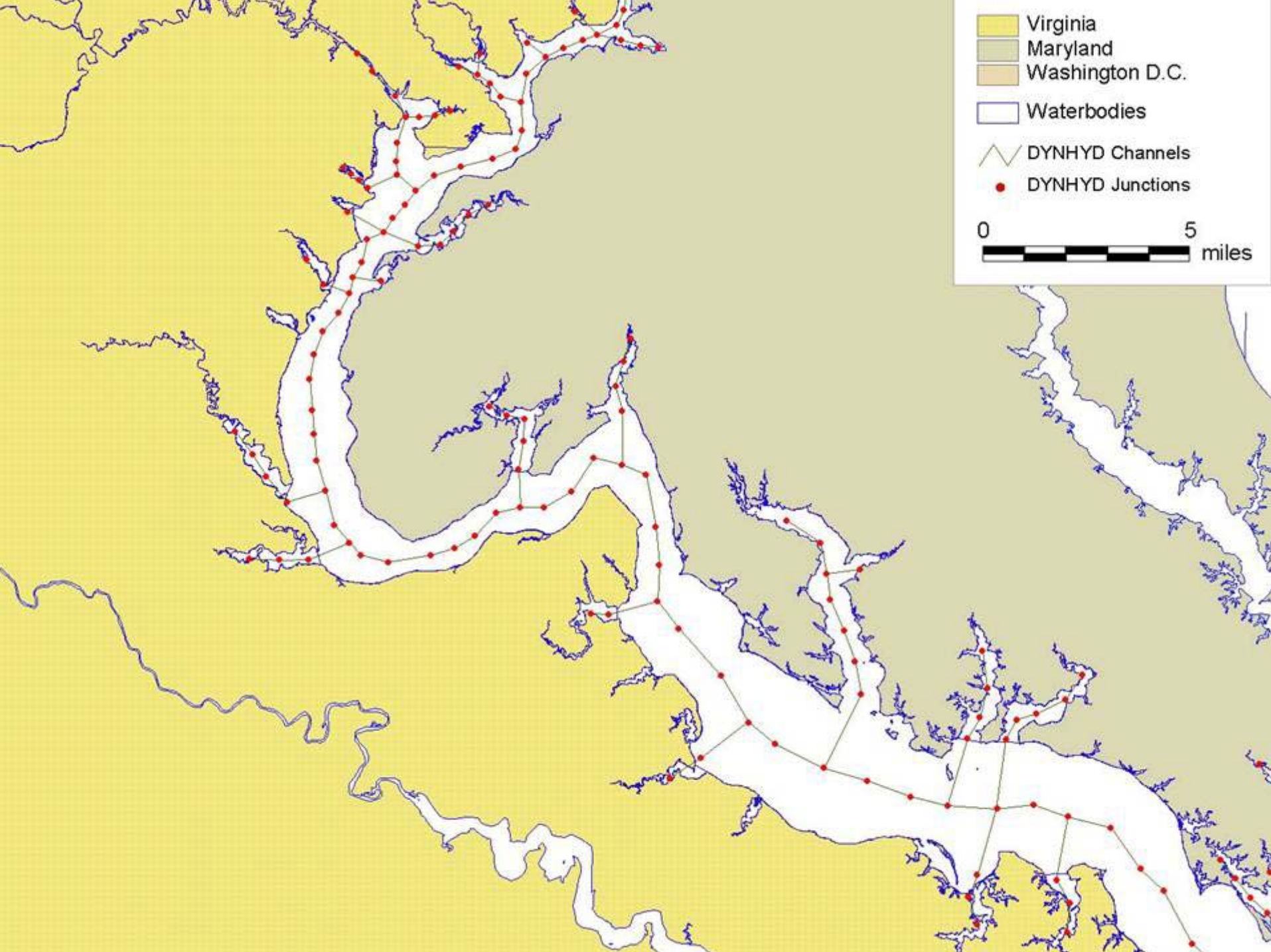
miles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Waterbodies
DYNHYD Channels
DYNHYD Junctions
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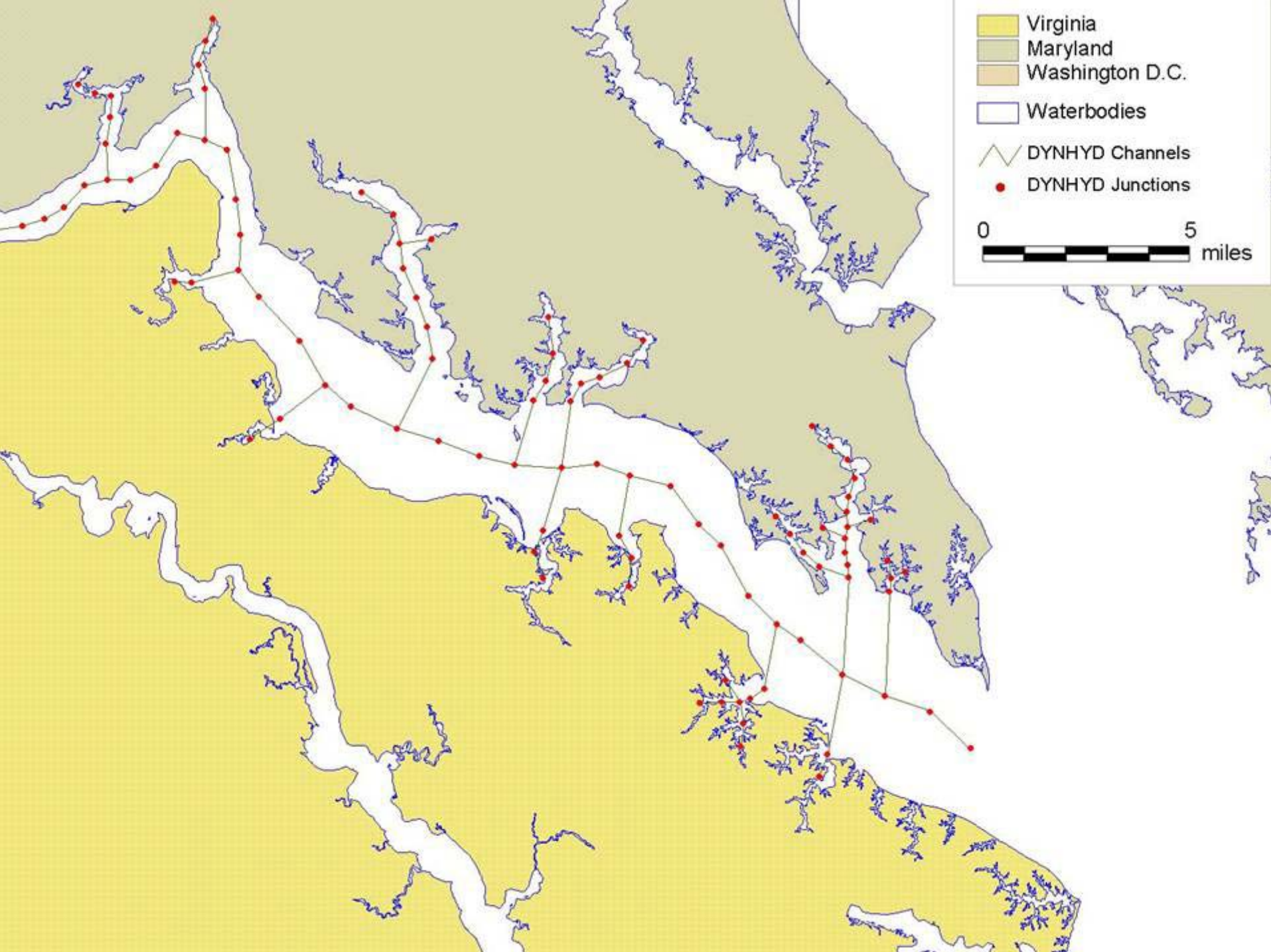
miles


Virginia
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Waterbodies
DYNHYD Channels
DYNHYD Junctions
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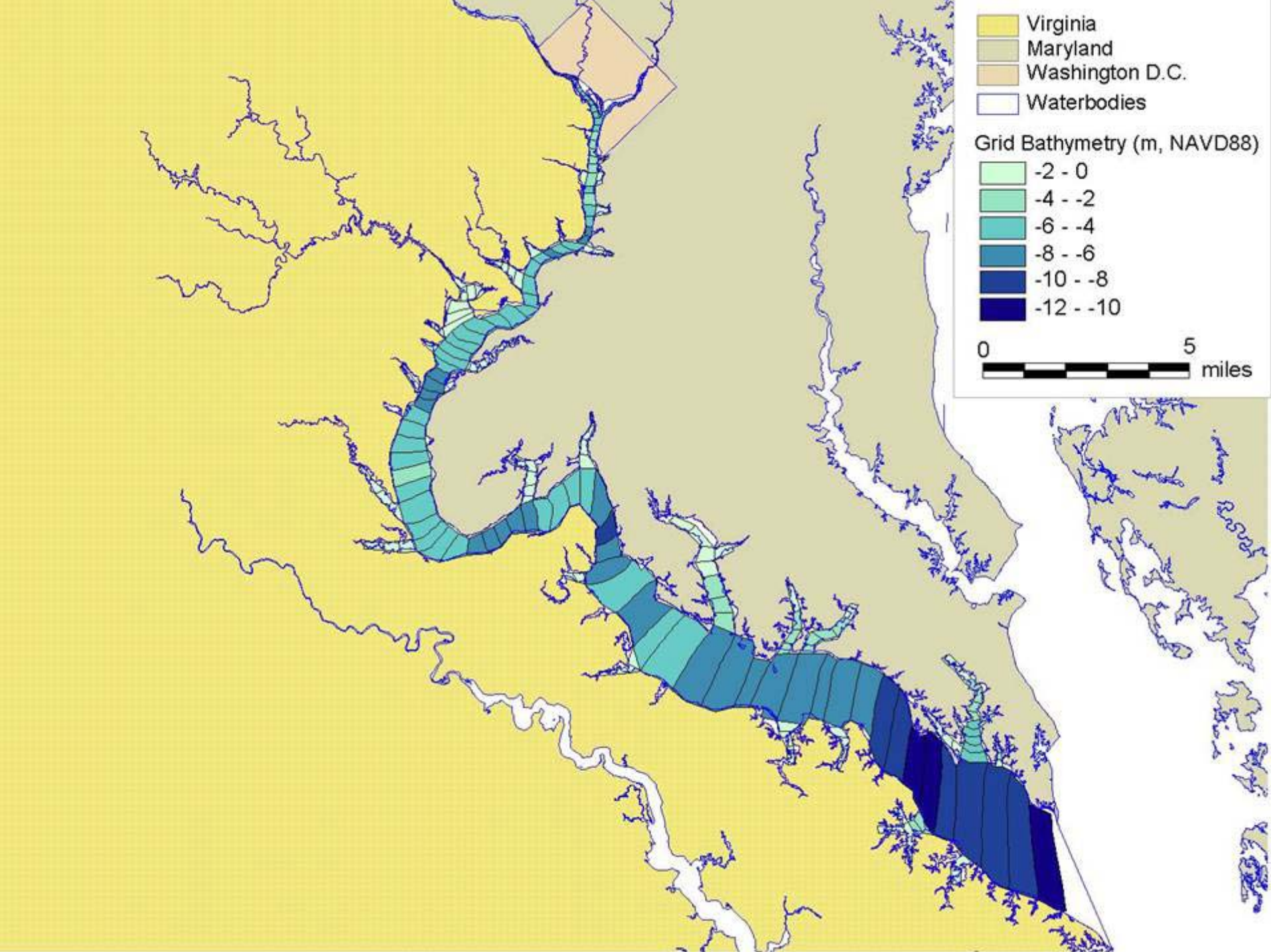
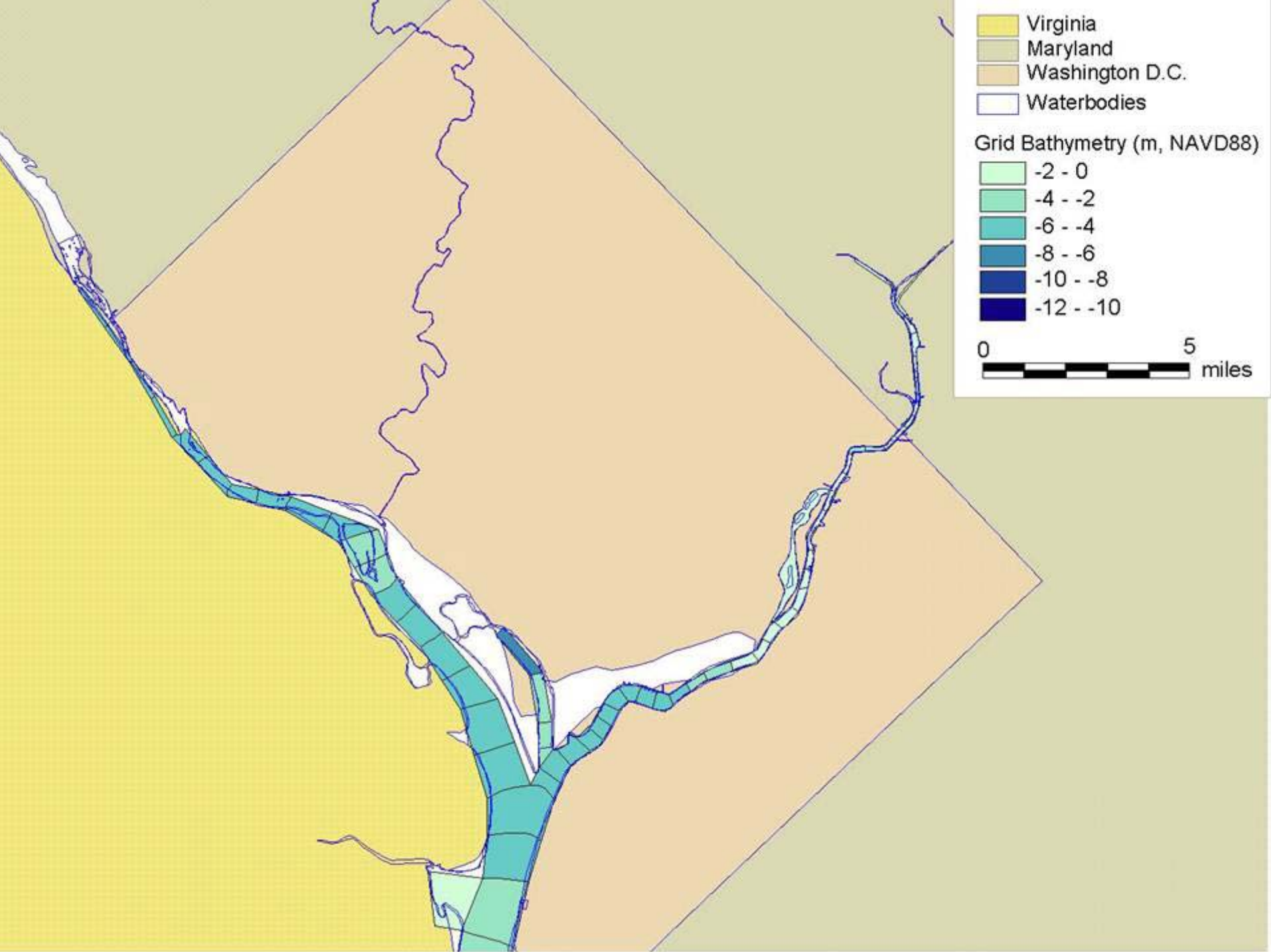
miles


Virginia
Maryland
Washington D.C.
Waterbodies
Grid Bathymetry (m, NAVD88)
-2 - 0
-4 - -2
-6 - -4
-8 - -6
-10 - -8
-12 - -10
0
5
miles


Virginia
Maryland
Washington D.C.
Waterbodies
Grid Bathymetry (m, NAVD88)
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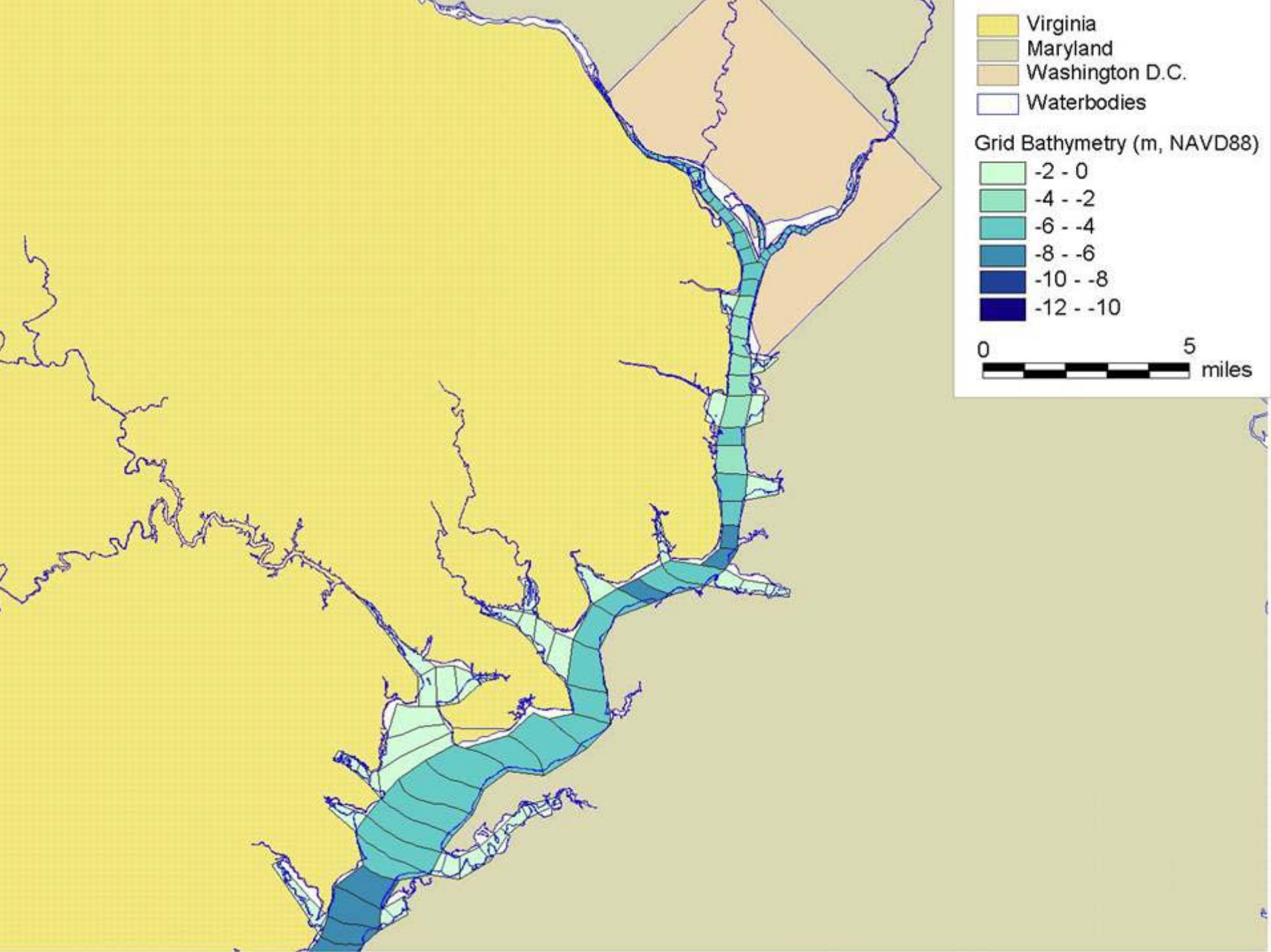
-4 - -2
-6 - -4
-8 - -6
-10 - -8
-12 - -10
0
5
miles


Virginia
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Washington D.C.
Waterbodies
Grid Bathymetry (m, NAVD88)
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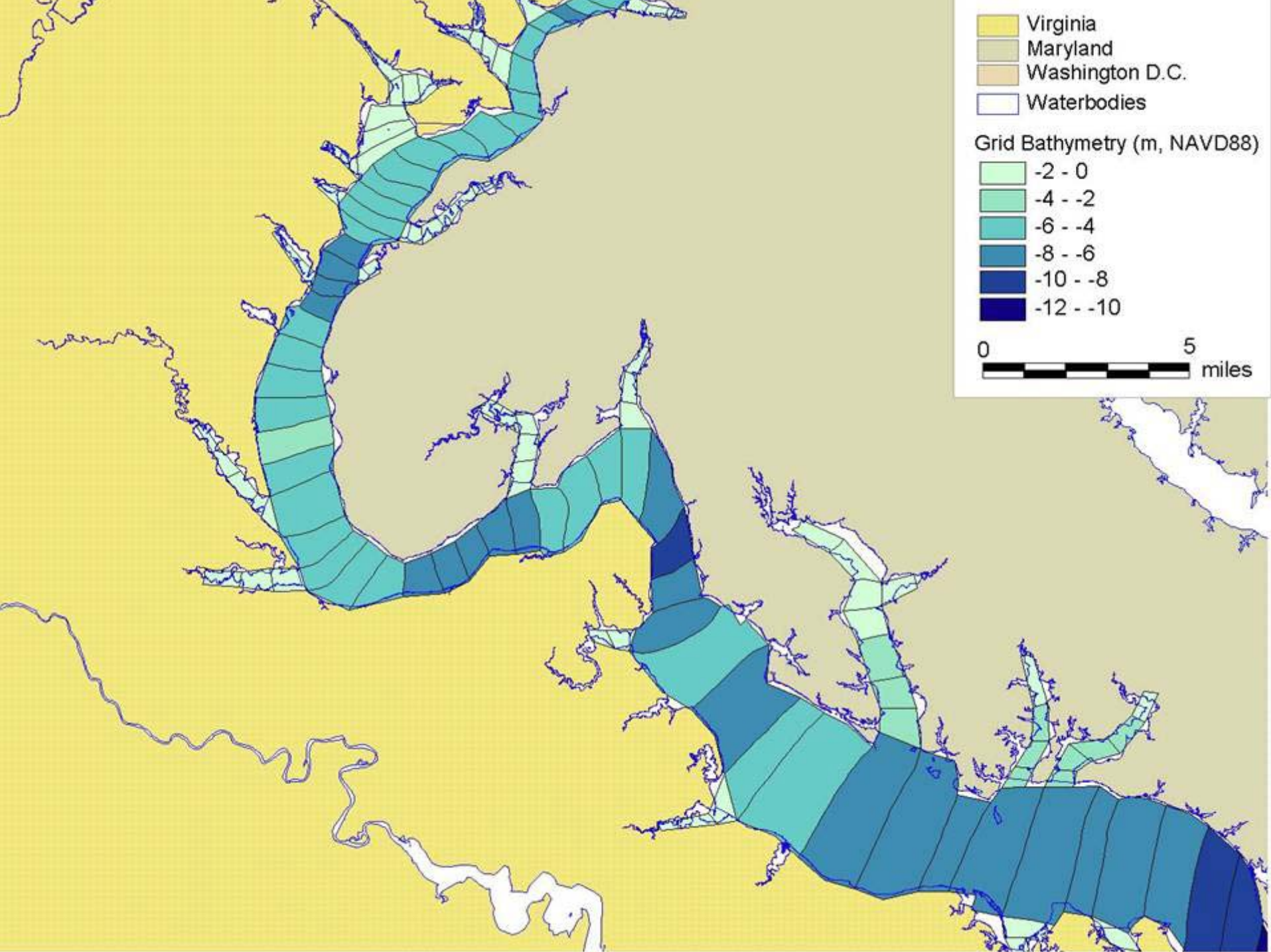
-4 - -2
-6 - -4
-8 - -6
-10 - -8
-12 - -10
0
5
miles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Maryland
Washington D.C.
Waterbodies
Grid Bathymetry (m, NAVD88)
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-4 - -2
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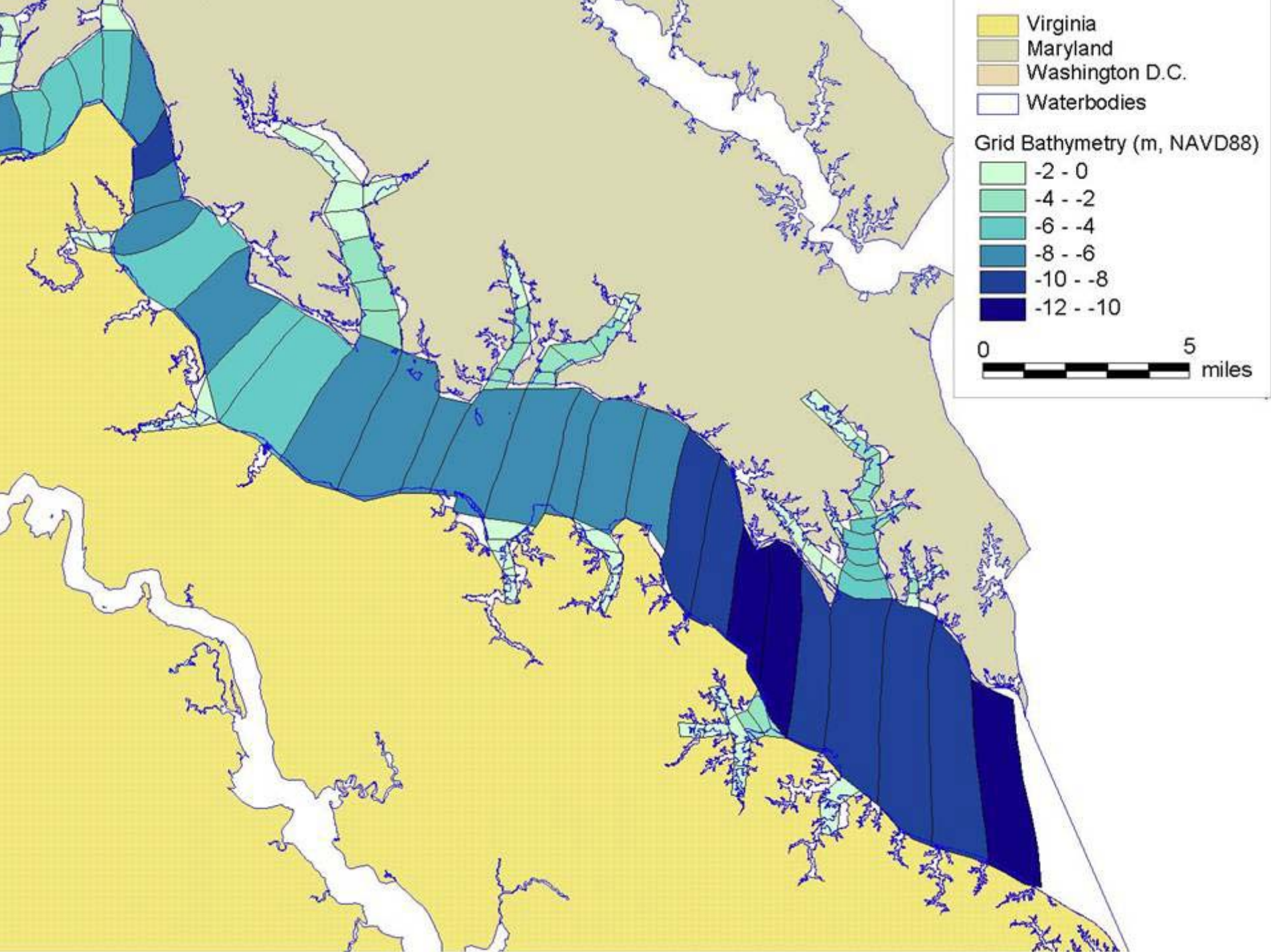
-8 - -6
-10 - -8
-12 - -10
0
5
miles


Virginia
Maryland
Washington D.C.
Waterbodies
Grid Bathymetry (m, NAVD88)
-2 - 0
-4 - -2
-6 - -4
-8 - -6
-10 - -8
-12 - -10
0
5
miles

Calibration Periods and Run Times

- Calibration Periods
  - 1994-1996 (Hydrodynamics and Salinity)
  - 2004-2005 (PCBs)
- DYNHYD5 Hydrodynamic Model
  - 5 second time step
  - 6 hours run time
- WASP5 Salinity Model
  - 1 minute time step
  - 30 minutes run time
- WASP5 PCB Model
  - 1 minute time step
  - 3 hour run time (estimated)

Current Model Status

- Grid development finalized
- Model code operational
- Numerical solution stable
- Model conserves mass
- Preliminary results
  - Flow
  - Water surface elevation
  - Velocity
  - Depth
  - Salinity

Next Modeling Steps

- Finalize freshwater inflows
- Finalize downstream boundary conditions
- Calibrate to water surface elevation and velocity
- Calibrate to salinity
  - Mass balance check
- Conduct diagnostic, sensitivity and uncertainty analyses
- Prepare interim draft report
  - February 23, 2006
- Develop inputs and calibration data for PCB model

Outstanding Modeling Issues

- Representation of PCBs
  - Which homolog group(s)?
- Linking model results to water quality standards
  - PCB concentrations?
    - Different WQS for DC, Maryland and Virginia
  - Fish tissue residues?
    - BAF and/or BSAF
- Long-term hindcast/consistency check for PCB model
  - Loadings?
  - Ambient data?
    - Surficial sediment concentrations
    - Dated sediment cores
    - Fish tissue residues

Data Assessment

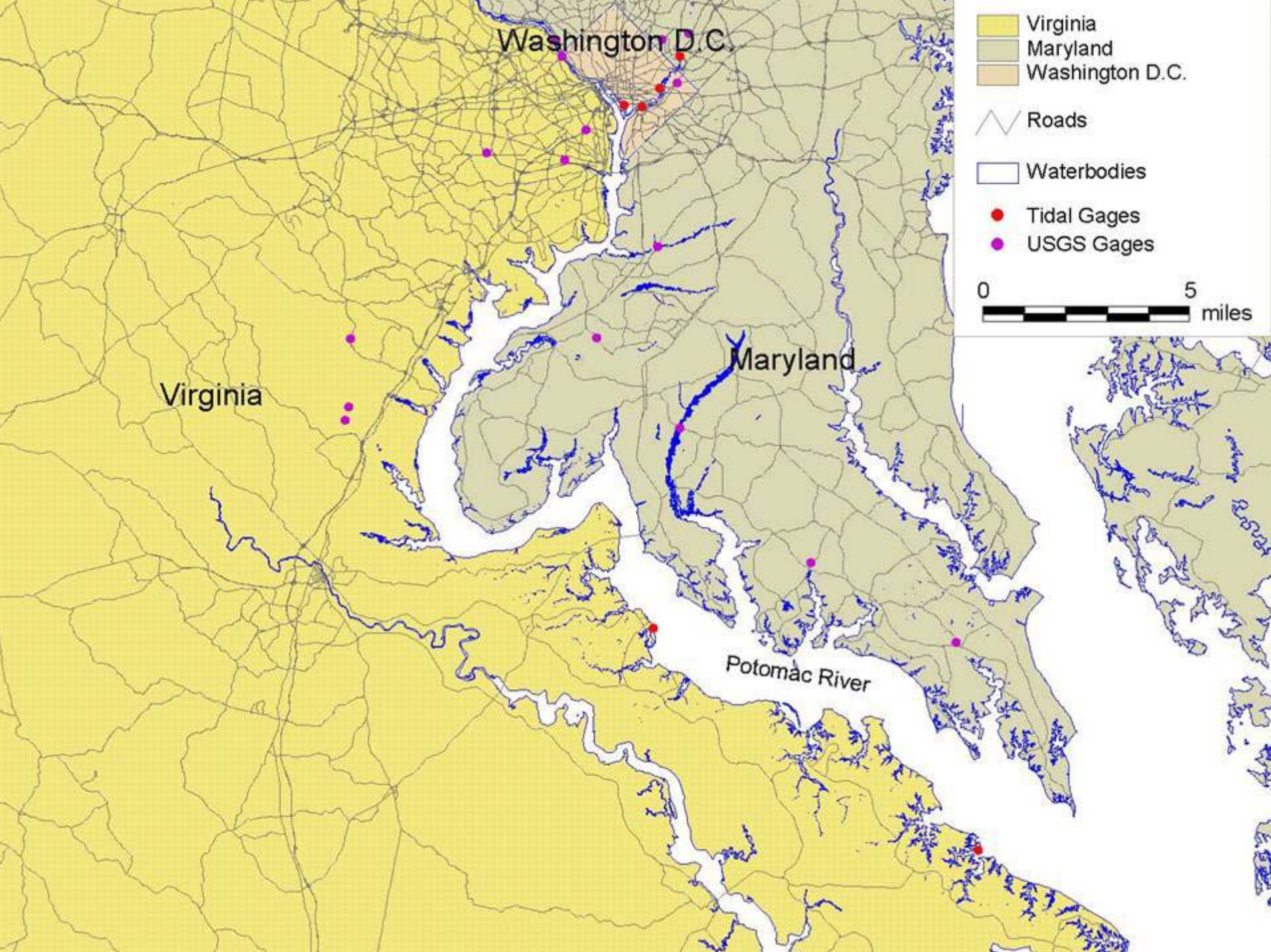
Based on data available as of August, 2005

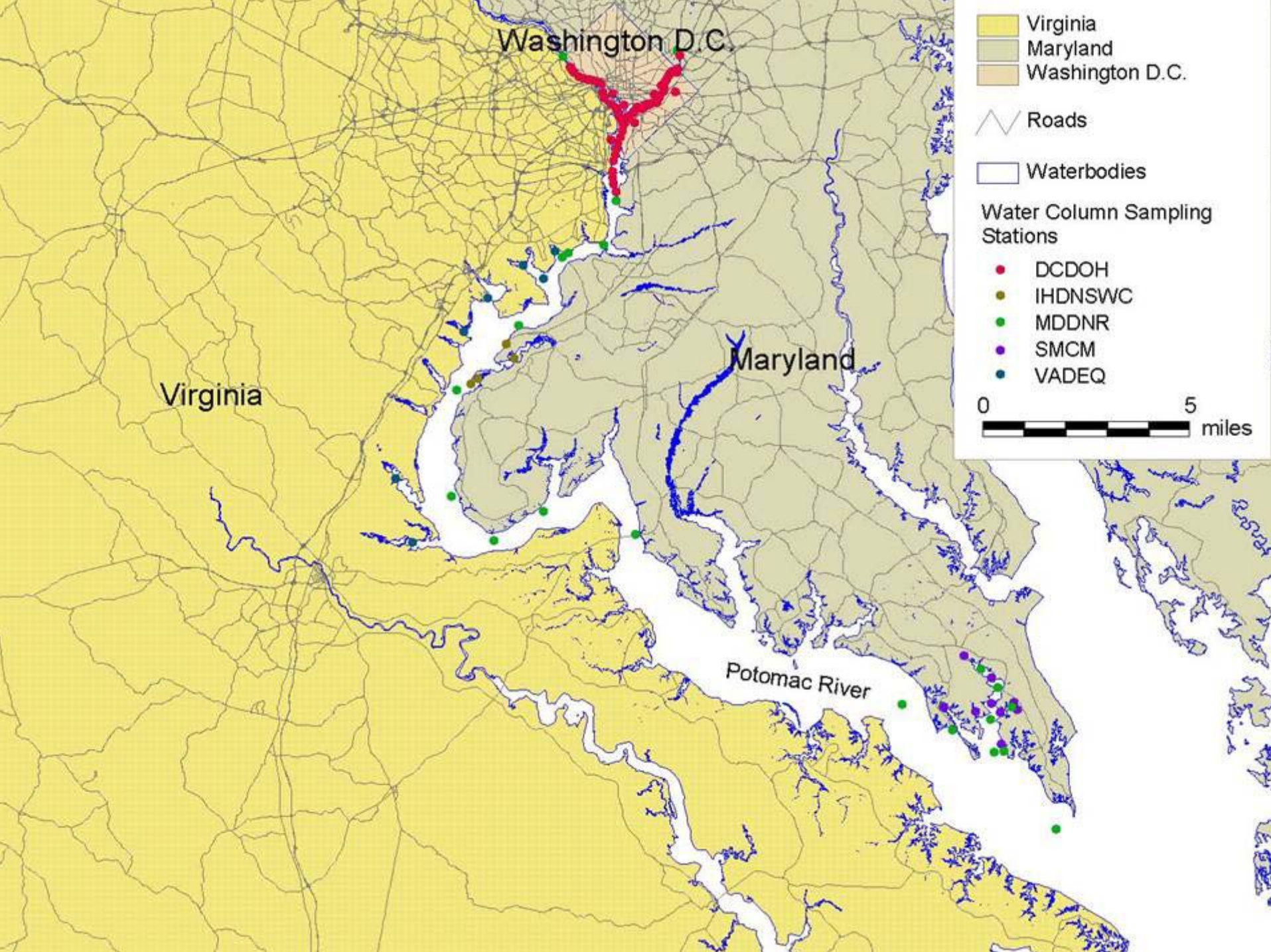
Summary of Required Data

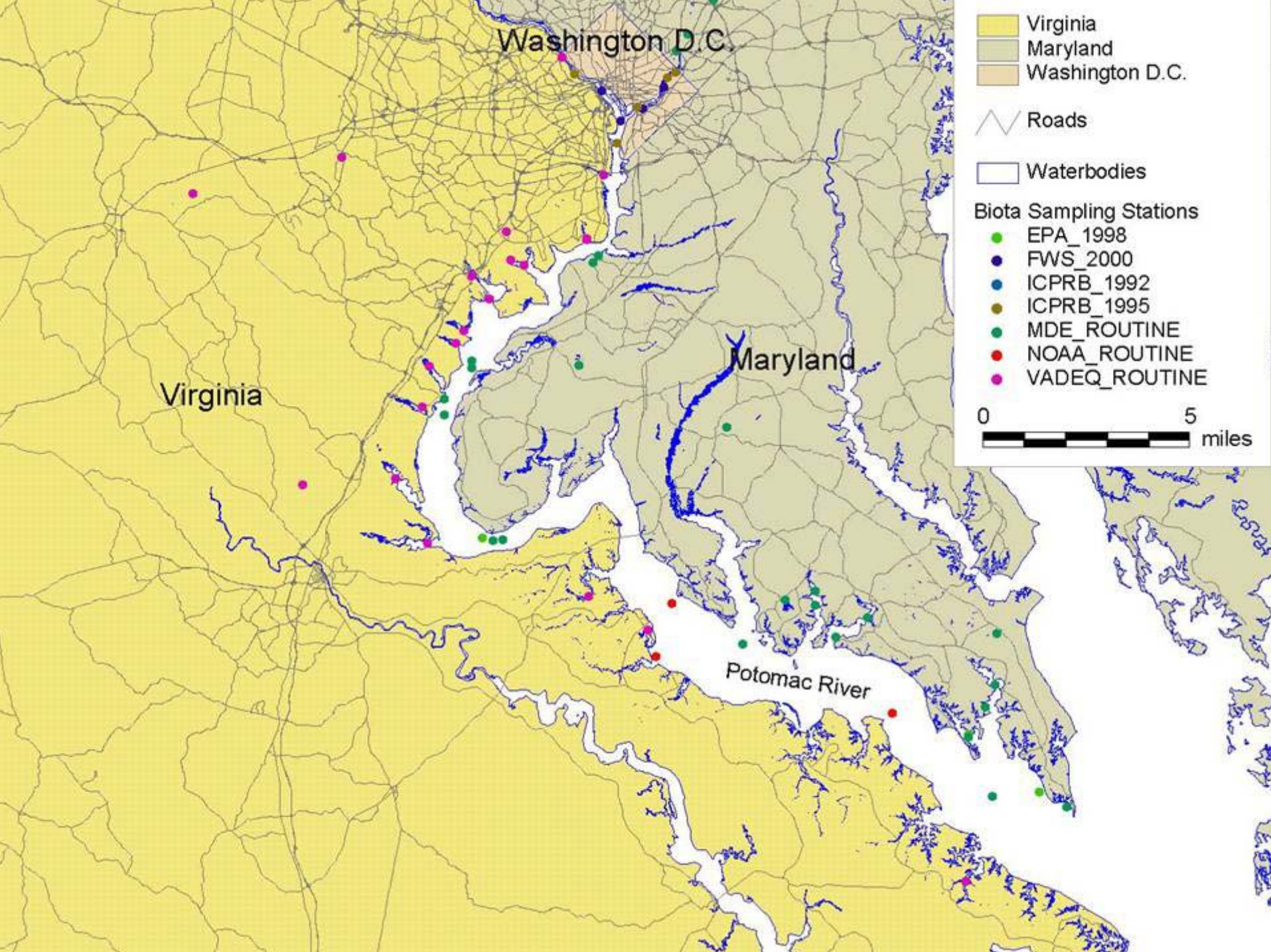
- Bathymetry data
- Meteorological data
  - Wind speed, air temperature, rainfall
- Hydrodynamic data
  - Freshwater inflows
  - Water surface elevation
  - Current velocity
  - Salinity
- Sorbent and PCB mass loadings
- Ambient data for water column, sediments and biota

AMBIENT DATA REQUIREMENTS AND GAPS

PARAMETER	WATER	SEDIMENT	BIOTA	ATMOSPHERE
Freshwater inflows	Yes	n/a	n/a	n/a
Water surface elevation (tidal heights)	Yes	n/a	n/a	n/a
Current velocity	Yes	n/a	n/a	n/a
Precipitation	n/a	n/a	n/a	Yes
Wind velocity	Yes	n/a	n/a	Yes
Temperature	Yes	n/a	n/a	Yes
Salinity	Yes	n/a	n/a	n/a
Total suspended solids (TSS)	Yes	n/a	n/a	n/a
Organic carbon (TOC, POC, DOC, lipid)	Yes	Yes[1]	Yes	n/a
Chlorophyll *a*	Yes	n/a	n/a	n/a
Algal primary production	Yes[2]	n/a	Yes	n/a
PCBs (total, particulate, dissolved, gas phase)	No	Yes	n/a	Yes[3]
Grain size	n/a	No[4]	n/a	n/a
Particle density	n/a	No[4]	n/a	n/a
Porosity	n/a	No[4]	n/a	n/a
Bulk density	n/a	No[4]	n/a	n/a
Sediment oxygen demand (SOD)	n/a	Yes[2]	n/a	n/a
Net sediment burial rate	n/a	No	n/a	n/a

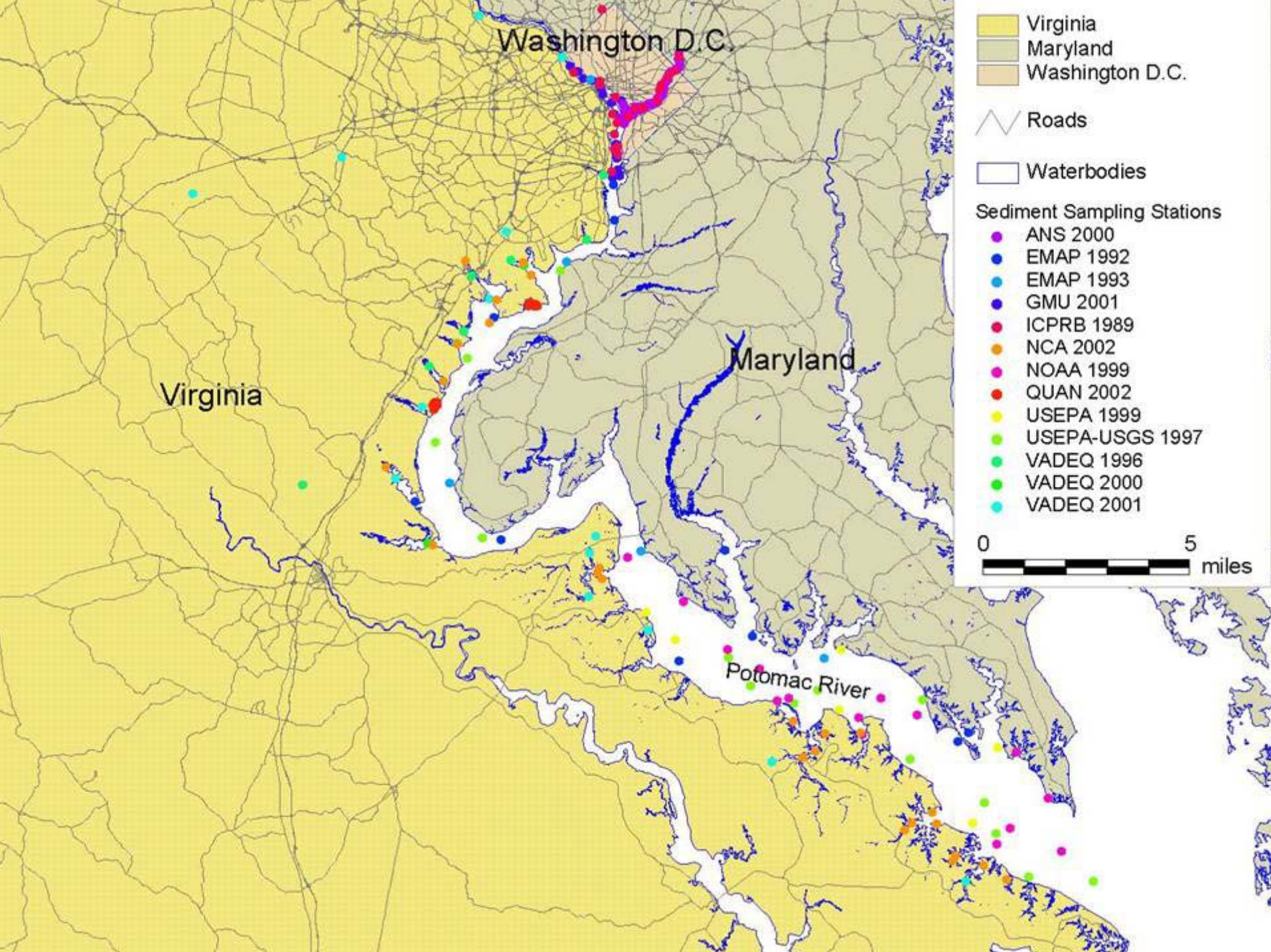

Washington D.C.
Virginia
Maryland
Washington D.C.
Roads
Waterbodies
Tidal Gages
USGS Gages
0
5
miles
Maryland
Virginia
Potomac River


Washington D.C.
Virginia
Maryland
Potomac River
Virginia
Maryland
Washington D.C.
Roads
Waterbodies
Water Column Sampling Stations
DCDOH
IHDNSWC
MDDNR
SMCM
VADEQ
0
5
miles


Washington D.C.
Virginia
Maryland
Potomac River
Virginia
Maryland
Washington D.C.
Roads
Waterbodies
Biota Sampling Stations
EPA_1998
FWS_2000
ICPRB_1992
ICPRB_1995
MDE_ROUTINE
NOAA_ROUTINE
VADEQ_ROUTINE
0
5
miles

AVAILABLE SEDIMENT DATA SETS

AGENCY	SOURCE	SAMPLING YEAR(S)	PARAMETERS	SPATIAL COVERAGE
ICPRB	CBP toxics database	1989	PCB congeners	DC receiving waters
USEPA Environmental Monitoring and Assessment Program (EMAP)	CBP toxics database	1992 – 1993	PCB congeners, and Total PCB (1993 only)	Potomac River Estuary
Virginia Department of Environmental Quality (VADEQ)	Mark Richards	1996, 2000, 2001, 2002		Virginia tributaries
USEPA and USGS	CBP toxics database	1997	PCB congeners	Potomac River Estuary
NOAA	CBP toxics database	1999	PCB congeners and Total PCB	Potomac River Estuary
USEPA	CBP toxics database	1999	PCB congeners	Potomac River Estuary
George Mason University	Greg Foster	2000 – 2001	PCB congeners, Total PCB, and TOC	Potomac River – Chain Bridge to Blue Plains
Academy of Natural Sciences, Patrick Center for Environmental Research (ANS-PCER)	David Velinsky	2000	PCB congeners, Total PCB, and TOC	Anacostia River and a few nearby Potomac River sites
MCCDC, Quantico	Kristein Stein	2002	PCB congeners and Total PCB	Quantico Embayment


Washington D.C.
Virginia
Maryland
Potomac River
Virginia
Maryland
Washington D.C.
Roads
Waterbodies
Sediment Sampling Stations
ANS 2000
EMAP 1992
EMAP 1993
GMU 2001
ICPRB 1989
NCA 2002
NOAA 1999
QUAN 2002
USEPA 1999
USEPA-USGS 1997
VADEQ 1996
VADEQ 2000
VADEQ 2001
0
5
miles

Principal Loading Sources

- Potomac and Anacostia fall lines
- Tributaries
- Point sources
- CSOs
- MS4s
- Direct non-point source runoff
- Algal primary production (organic carbon)
- Marsh areas (organic carbon)
- Shoreline bank erosion (solids)
- Contaminated sites
- Atmospheric (wet/dry deposition; gas phase PCB)

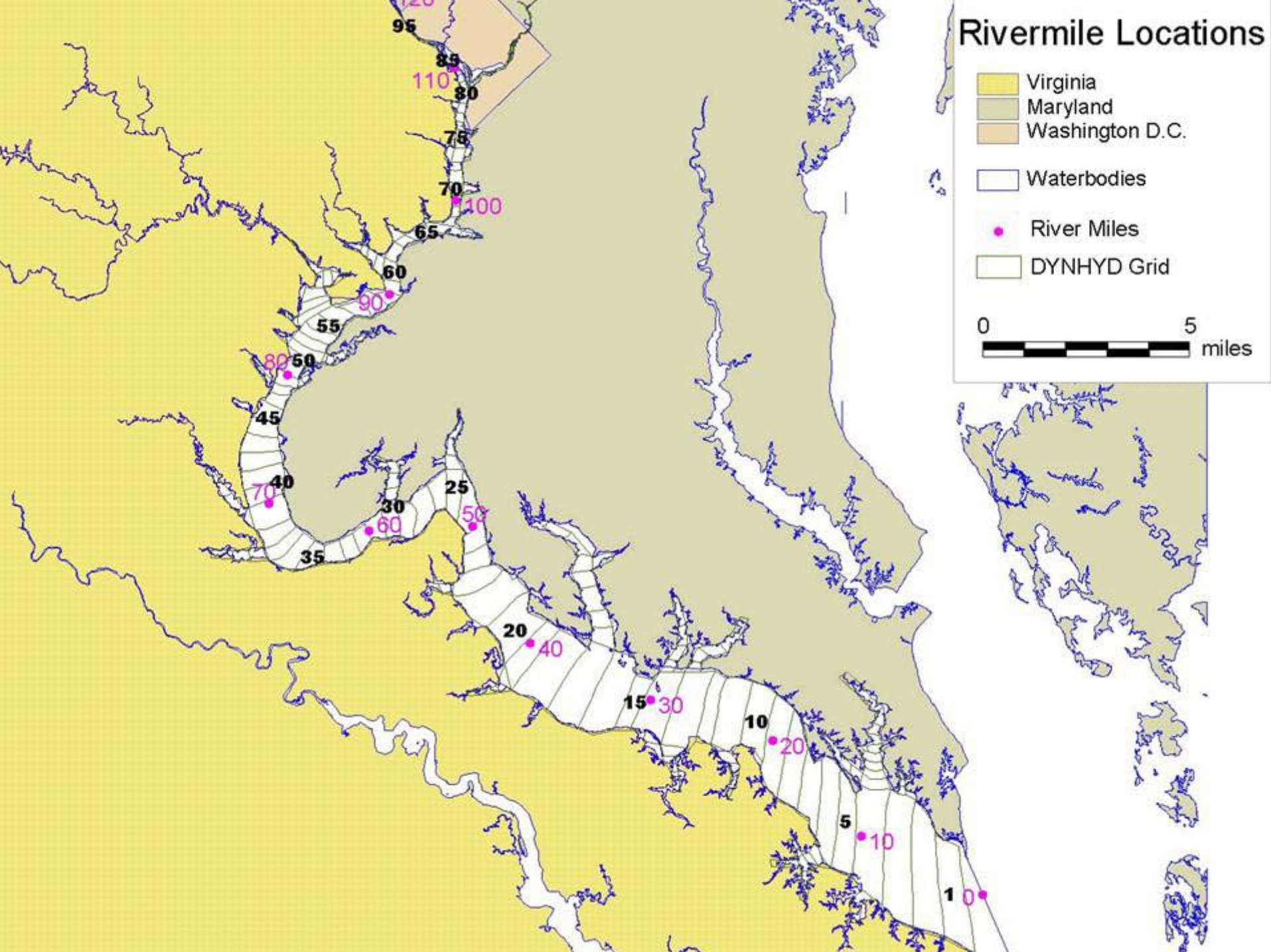
LOADING REQUIREMENTS FOR PCB TMDL MODEL

Available Information from Chesapeake Bay Program

SOURCE	FLOW	MASS LOADINGS		
		TSS	Organic Carbon	PCBs
Potomac Fall Line	WSM5	WSM5	WSM5 (tentative)	N
Anacostia NW Branch	WSM5	WSM5	WSM5 (tentative)	N
Anacostia NE Branch	WSM5	WSM5	WSM5 (tentative)	N
Tributaries (WSM5 Loading Points)	WSM5	WSM5	WSM5 (tentative)	N
Point Sources	Data	Data	Data	N
CSOs	Data (Blue Plains only)	Data (Blue Plains only)	Data (Blue Plains only)	N
MS4s	N	N	N	N
Direct NPS Runoff	WSM5	WSM5	WSM5 (tentative)	N
Algal Primary Production	N/A	N/A	CBEMP	N/A
Marsh Areas	N/A	N/A	Data	N/A
Shoreline Bank Erosion	N/A	Data	Data	N/A
Contaminated Sites	N	N	N	N
Atm Wet/Dry Deposition	N/A	N/A	N/A	N
Atm Gas Phase	N/A	N/A	N/A	N

Recommendations
Monitoring and Loadings

- Conduct PCB Monitoring
  - Potomac and Anacostia fall lines
  - Water column downstream of fall lines
  - Major point sources
  - CSOs
  - MS4s
- Use Model Results from Chesapeake Bay Program
  - Phase 5 Watershed Model (WSM5)
    - Freshwater inflows
    - Mass loadings
  - Bay Water Quality Model (CBEMP)
    - Stage height, salinity, water temperature
    - Algal primary productivity


Rivermile Locations
Virginia
Maryland
Washington D.C.
Waterbodies
River Miles
DYNHYD Grid
0
5
miles
95
85
110
80
75
70
100
65
60
90
55
80
50
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70
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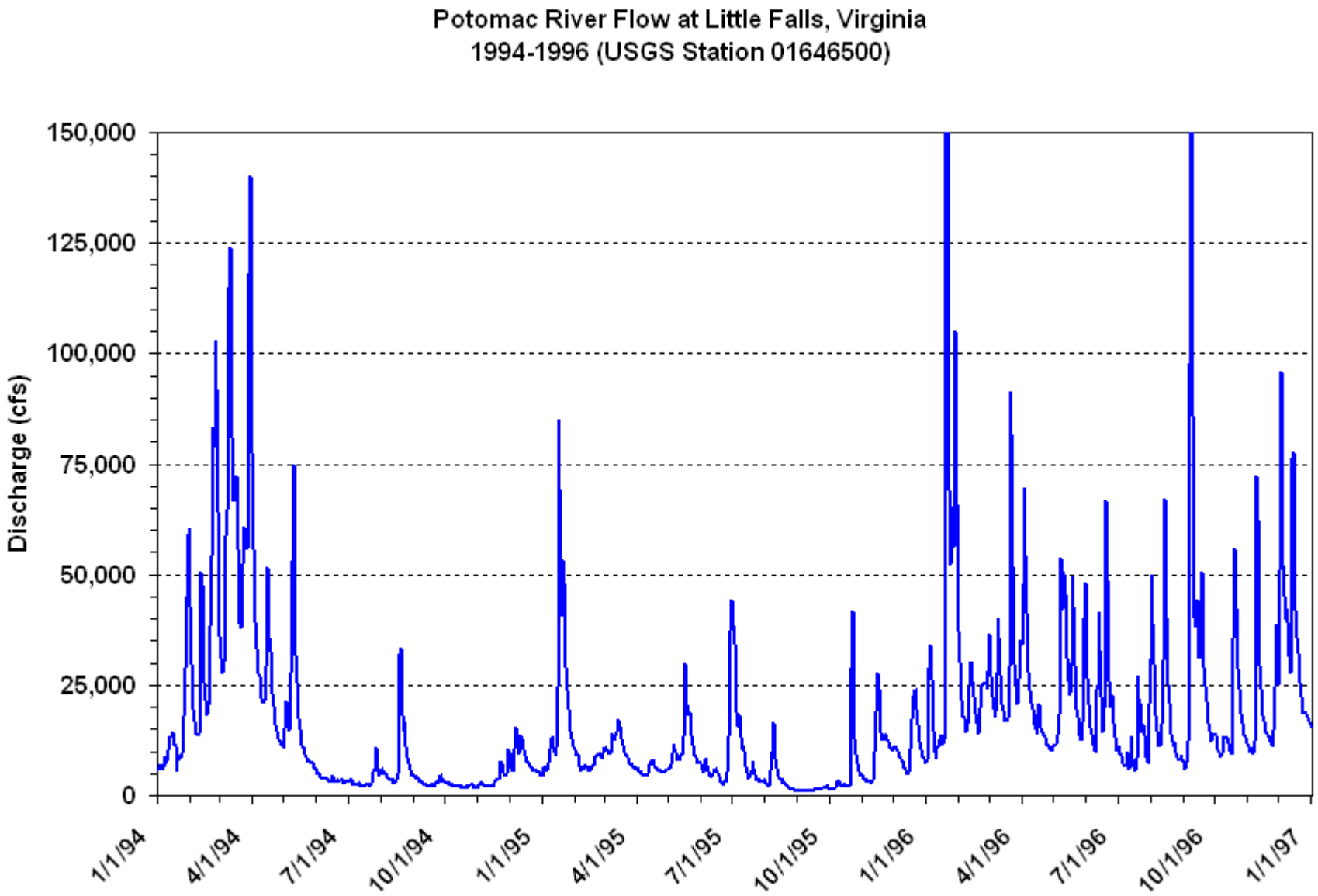
Potomac River Flow at Little Falls, Virginia
1994-1996 (USGS Station 01646500)
Discharge (cfs)
150,000
125,000
100,000
75,000
50,000
25,000
0
1/1/94
4/1/94
7/1/94
10/1/94
1/1/95
4/1/95
7/1/95
10/1/95
1/1/96
4/1/96
7/1/96
10/1/96
1/1/97