Maryland
Department of
the Environment

TMDL Approaches for Chloride and Temperature Impairments

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Greg Busch, P.E.
MDE TMDL Development Program
gregory.busch@maryland.gov

TMDL Objectives

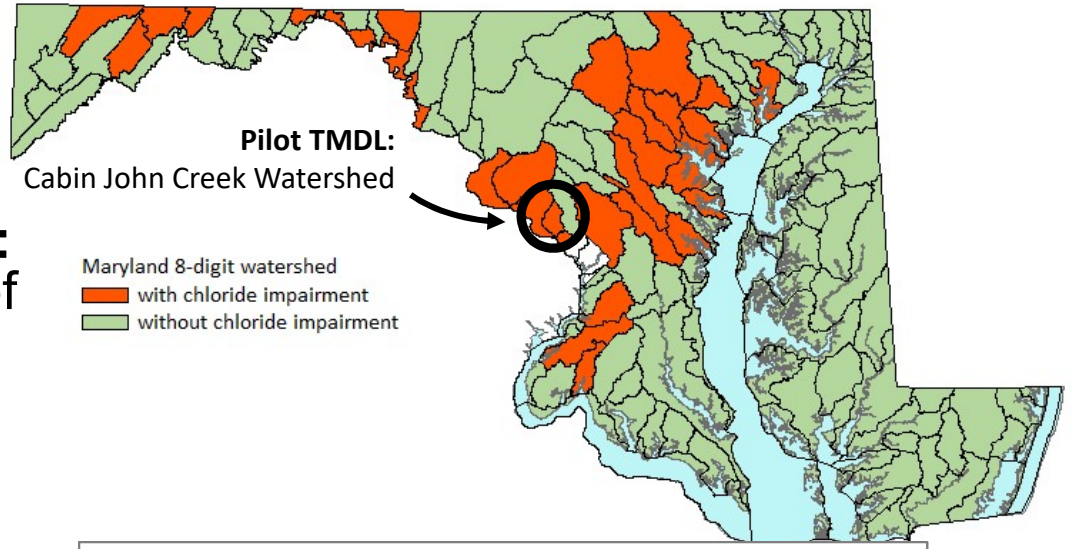
- Build TMDLs with an eye toward implementation and impact
  - Link the TMDL reduction with:
    - implementation efforts
    - water quality response
- Use of high resolution data
  - To better inform implementation efforts
  - To provide a better characterization of the watershed and sources
  - Take advantage of continuous water quality measurements

Upcoming TMDL Pollutants

- Chloride
- High temperature
- Sulfate

Chloride Listings

- **Water Quality Impairments:**
  - 27 eight-digit watersheds
  - Dating back to 2010
- **Designated Use not met:** Growth and propagation of fish, aquatic life & wildlife
- **Cause:** Biological Stressor ID: Inorganic pollutants, including chloride



Chloride-impaired watersheds based off of Maryland's Draft 2016 Integrated Report of Surface Water Quality

http://mde.maryland.gov/programs/Water/TMDL/Integrated303dReports/Pages/2016IR.aspx

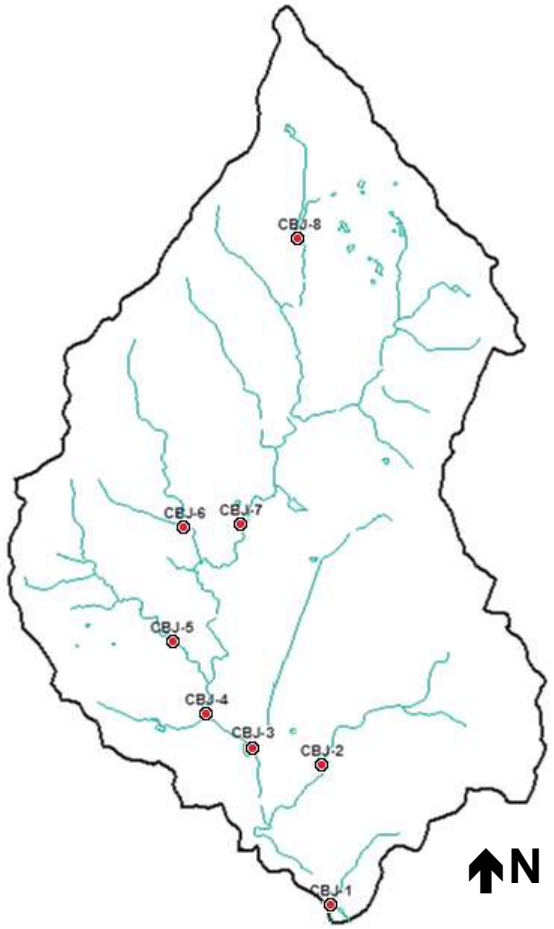
Chloride Endpoint

- Numeric targets
  - 1-hour acute chloride concentration
  - 4-day chronic chloride concentration
  - Specific to Maryland based on native species
- Aquatic life goal
  - No impairment of in-stream aquatic life and wildlife
  - Complicated by multiple stressors

Chloride Monitoring

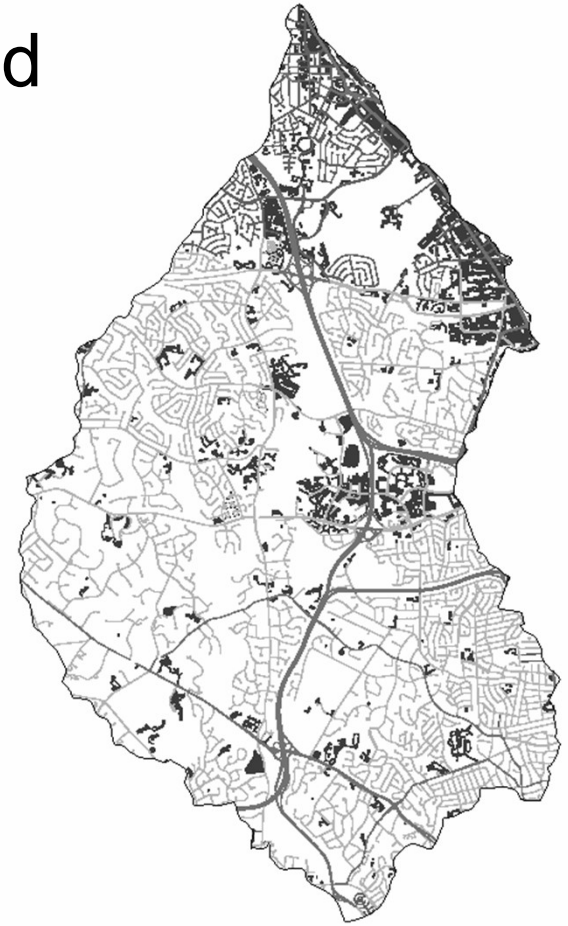
Cabin John Creek watershed

- 8 stations in watershed
  - 2 years of data
    - 2015 & 2016
  - Continuous
    - conductivity monitoring
    - 15- and 30-minute intervals
  - Discrete
    - Ion matrices
    - Monthly
    - Winter storm events



Other Data

- Administrative records of road salt application
  - State, county and city governments
  - tons/year per applicator
  - Applied proportionally to watershed
- Road network data
  - From high-resolution data provided by the Chesapeake Conservancy



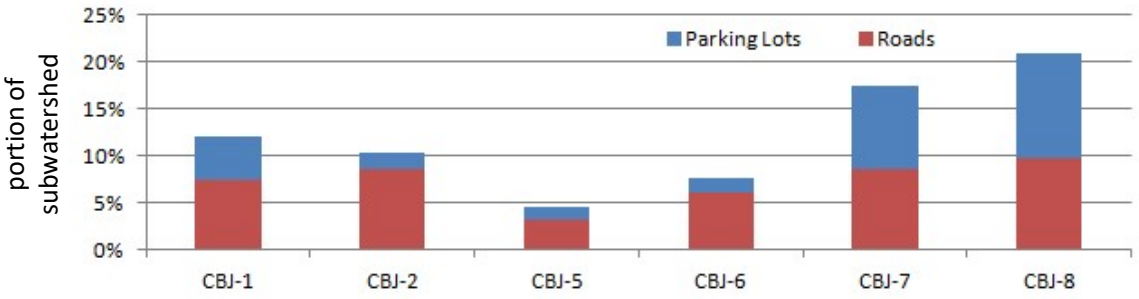
TMDL data analysis

Winter 2016 in-stream conductivity and road salt application in the Cabin John watershed

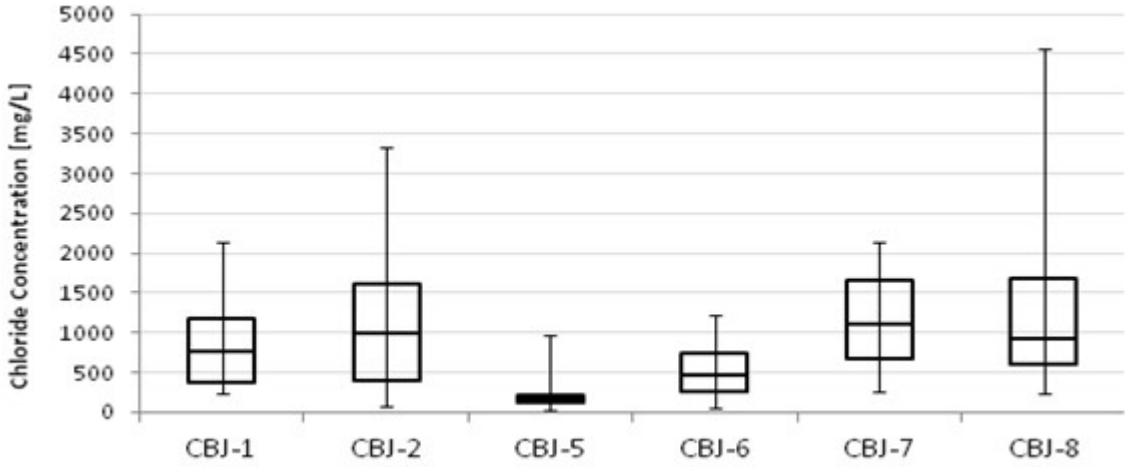
January 2016
US Blizzard

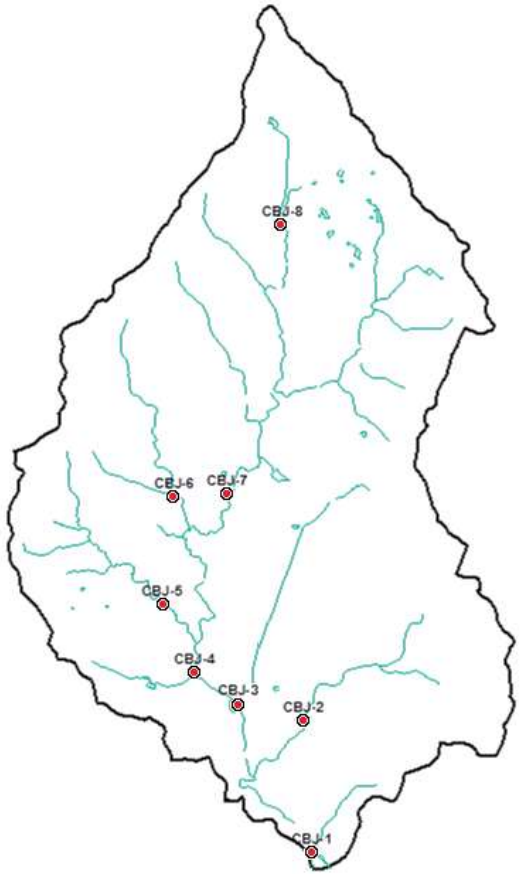
TMDL data analysis

Roads and parking lots in monitoring station drainage



Observed in-stream chloride concentrations





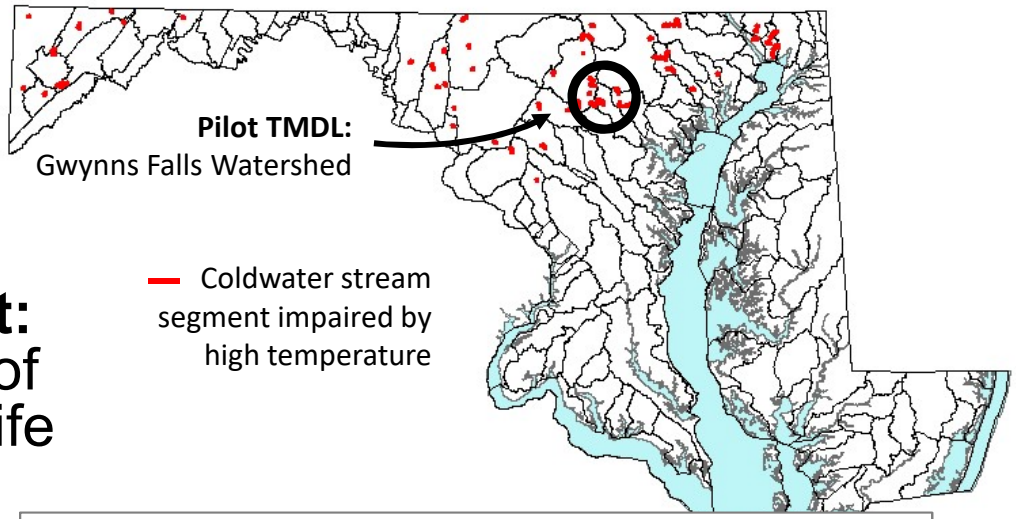
Chloride Results

- Simple modeling approach: *mass = flow x concentration*
  - Able to relate road salt application to in-stream observations via mass balance
    - The mass of chloride observed in stream due to winter storms was between 50% and 100% of the estimated chloride applied as road salt
  - Able to relate variations in chloride presence to difference in land use

- Define a logical process for verification once implementation occurs
  - Confirm the impact of changes to road salt application with in-stream measurements

Temperature Listings

- **Water Quality Impairments:**
  - 71 stream segments
  - Dating back to 2014
  - Non-tidal cold water (Use Class III) streams
- **Designated Use not met:** Growth and propagation of fish, aquatic life and wildlife
- **Cause:** Temperature measurements exceed criteria



Temperature-impaired stream segments based off of Maryland's Draft 2016 Integrated Report of Surface Water Quality

Temperature Endpoints

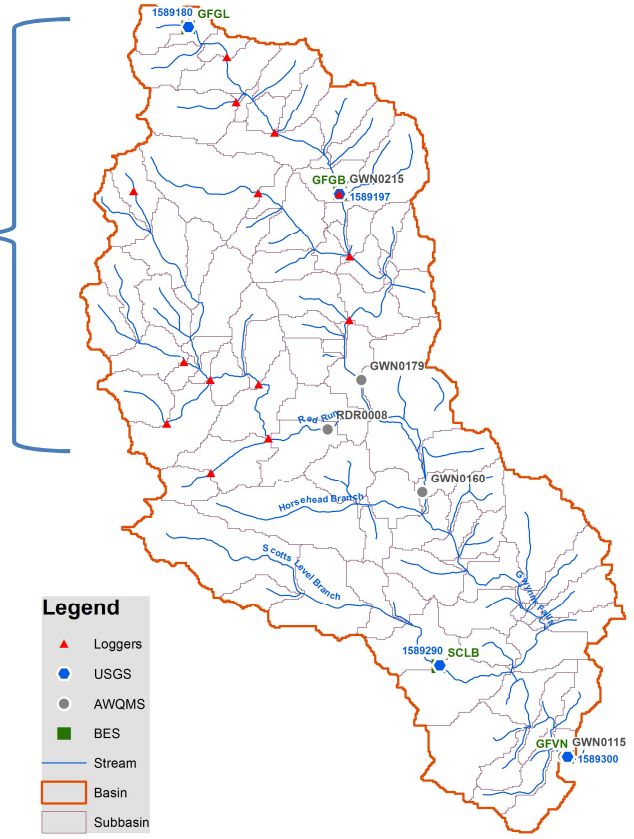
- June 1 to August 31 in-stream temperature
  - 90^{th}-percentile value ≤ 20 ˚C
  - Maximum value < 23.8˚C
- Additional implementation considerations
  - Presence of trout species:
    - young-of-year (YOY) AND
    - multiple year classes (MYC)
  - Presence of multiple coldwater obligates
    - 3 trout and 2 stonefly species
- Based off of Maryland's *Temperature Assessment Methodology for Use III(-P) Streams in Maryland*

http://mde.maryland.gov/programs/Water/TMDL/Integrated303dReports/Documents/Assessment_Methodologies/Temp_AM_UCIII_2015.pdf

Temperature Monitoring

- Monitoring
  - Summers
    - 2016 & 2017
  - 13 stations in watershed
    - Continuous
    - April to October

Coldwater Streams



Temperature monitoring stations in the Gwynns Falls watershed

Modeling

Potential Approaches

- SWAT
  - Stream temperature *(Ficklin et al.)*
  - Reach-specific K parameter
    - Proxy for factors like shading and differing geometry
- HSPF
  - SHADE Module *(Chen et al.)*

$$T_{w.\text{local}} = \frac{(T_{\text{snow}}\,\text{sub\_snow}) + (T_{\text{gw}}\,\text{sub\_gw}) + (\lambda T_{\text{air.lag}})(\text{sub\_surq} + \text{sub\_latq})}{\text{sub\_wyld}} \quad (2)$$

$$Tw_{\text{initial}} = \frac{T_{w.\text{upstream}}(Q_{\text{outlet}} - \text{sub\_wyld}) + T_{w.\text{local}}\,\text{sub\_wyld}}{Q_{\text{outlet}}} \quad (3)$$

$$T_w = Tw_{\text{initial}} + (T_{\text{air}} - T_{\text{initial}})K(TT) \quad \text{if} \quad T_{\text{air}} > 0 \quad (4)$$

$$T_w = Tw_{\text{initial}} + [(T_{\text{air}} + \varepsilon) - Tw_{\text{initial}}]K(TT) \quad \text{if} \quad T_{\text{air}} \le 0 \quad (5)$$

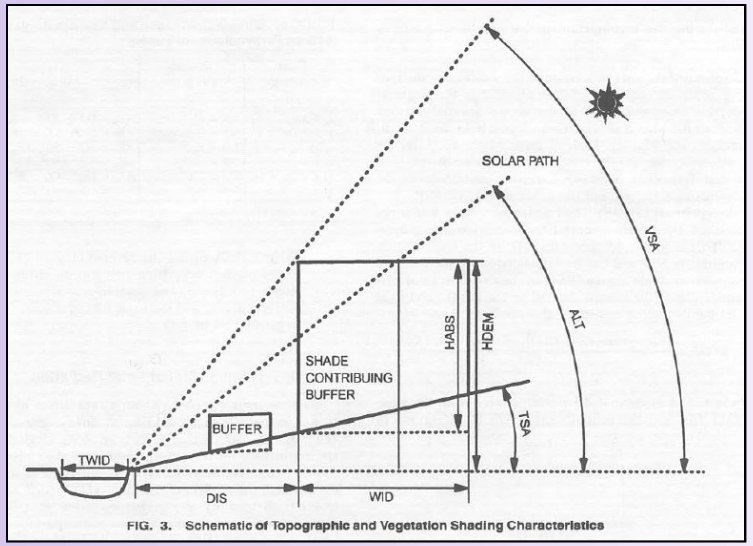
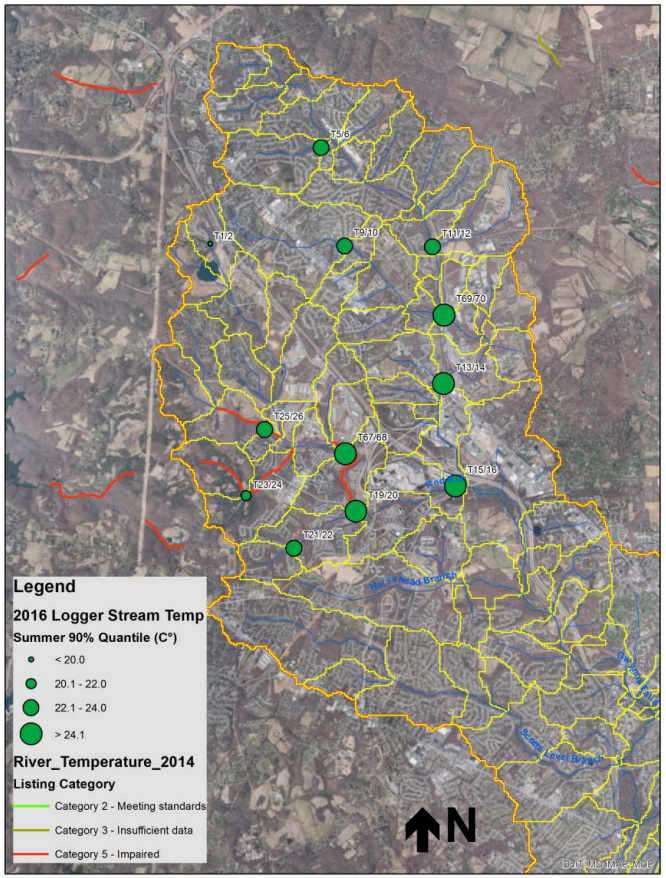


FIG. 3. Schematic of Topographic and Vegetation Shading Characteristics

Ficklin, D. L., Y. Luo, I. T. Stewart, and E. P. Maurer (2012), Development and application of a hydroclimatological stream temperature model within the Soil and Water Assessment Tool, Water Resour. Res., 48, W01511, doi:10.1029/2011WR011256.
Chen, Y. D., S. C. McCutcheon, D. J. Norton, and W. L. Nutter (1998), Stream Temperature Simulation of Forested Riparian Areas: I. Watershed-Scale Model Development, Journal of Environmental Engineering, Journal of Environmental Engineering [J. Environ. Eng.], vol. 124, no. 4, pp. 304-315, Apr 1998, doi: 10.1061/(ASCE)0733-9372(1998)124:4(304)

Temperature Data Analysis

- **Goal:** Assess the relationship between higher 90th-percentile temperatures and:
  - Stream order
  - Stream shading
  - Imperviousness
  - Stormwater management facilities
  - Stream geometry



Results of summer 2016 temperature monitoring in the Gwynns Falls watershed

Temperature Results

So far …

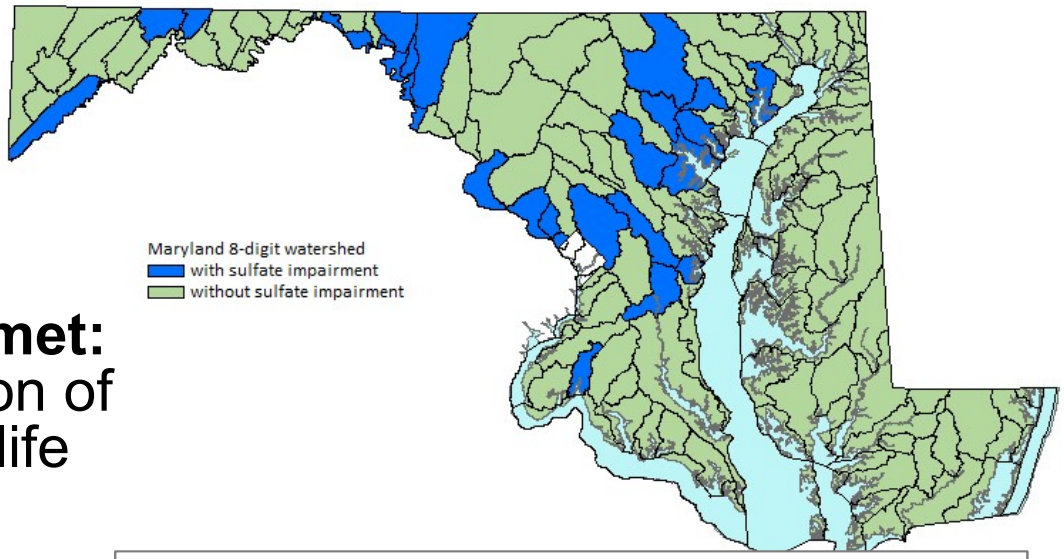
- Strong predictive model of stream temperature

Soon …

- Try to relate this to anthropogenic disturbances
- Express TMDL in thermal units but provide analysis of implementation activities by subwatershed
- Provide implementers with modeling tools used for TMDL development

Sulfate Listings

- **Water Quality Impairments:**
  - 22 eight-digit watersheds
  - Dating back to 2010
- **Designated Use not met:** Growth and propagation of fish, aquatic life & wildlife
- **Cause:** Biological Stressor ID: Inorganic pollutants, including sulfate



Temperature-impaired stream segments based off of Maryland's Draft 2016 Integrated Report of Surface Water Quality

Conclusions

- Every TMDL pollutant presents its own set of challenges
- Careful thought should be given at the outset to how the TMDL structure can promote the right sort of implementation
  - What actions will need to be undertaken?
  - How can we verify that they're working?
- Future TMDLs
  - Segue from data-rich pilot approach to less data-intensive methods
  - Use lessons learned from early TMDLs. For example …
    - Can chloride concentration be reliably estimated from road salt application?
    - Can temperature be estimated off of % impervious and riparian shading?
  - Use water quality data as an external validation